7. EFFECTS OF ALTERNATIVES SELECTED FOR DETAILED ANALYSIS

7.1 INTRODUCTION

This chapter presents the hydrologic; water quality; sedimentation, erosion, and ice processes; economic; and environmental effects of a set of five alternatives to the current Water Control Plan (CWCP). The Corps would like to receive feedback from the Tribes, States, other Federal agencies, stakeholders, and other interested parties on this set of alternatives and their impacts as it moves through the process of determining what the future Water Control Plan should be for the Mainstem Reservoir System.

This chapter identifies the effects of the CWCP and five other alternatives. One alternative includes three basic plan components that were changed from those making up the CWCP. These changed components include unbalanced storage among the three upper and largest lakes in the Mainstem Reservoir System, increased drought conservation measures like those included in the Missouri River Basin Association (MRBA) alternative (see Chapters 4 and 5), and a Fort Peck spring rise approximately every third year (when conditions allow). Because the most dominant factor in this alternative is the modified drought conservation measures, this plan is referred to as the Modified Conservation Plan (MCP). The other four alternatives include changes to releases from Gavins Point Dam—increased spring releases (a spring rise) and lower summer flows. Because these four alternatives have modified Gavins Point Dam releases, they are called the Gavins Point options, or GP options. Their specific naming convention has six characters: GP followed by two numerals representing the amount of the spring rise in thousand cubic feet per second (kcfs), followed by two numerals representing the amount of the summer low-flow release from Gavins Point Dam. For example, the **GP1528** option includes a **15**-kcfs spring rise release above that normally required for full service to navigation (modeled as running from mid-May to mid-June), followed by a minimum service flat release (modeled as **28.5** kcfs) that ends on September 1. Similarly, the **GP2021** option has a **20**-kcfs spring rise followed by a 25-kcfs release to mid-July when the release drops to a low of **21**-kcfs until mid-August when it returns to 25 kcfs until September 1. Of the GP options, the GP1528 option has the lowest spring rise and the highest summer flows compared to the CWCP. The other two options included in this chapter are GP1521 and GP2028. These two options are included to provide a perspective of what would happen if the summer low-flow release were further reduced without changing the spring rise (GP1521) and if the spring rise were further increased without changing the summer low-flow release (GP2028). Table 7.1-1 shows the features of the alternatives.

This chapter includes two sets of numbers on the figures with the bar plot of the average annual values of the various environmental resource, economic use, or historic properties values. The values for the six alternatives are presented on the right side of the bar. In addition to these values, the values for the submitted alternatives discussed in Chapter 5 are also presented on the left side of the bar, as they were in Chapter 5. This allows the readers and those that submitted alternatives to see side by side the impacts of a submitted alternative versus those considered in more detail in Chapter 7.

A much different approach is taken in this chapter for the comparison of the effects of the alternatives evaluated in detail. First, the effects of changing from the CWCP to the MCP are identified relative to the effects of the CWCP. Second, the effects of changing from the MCP to the GP1528 option are identified relative to the effects of the MCP. This is done to demonstrate what might happen to the various economic uses and environmental resources as the smaller (of those in the GP options) Gavins Point Dam release changes are added to the MCP. Finally, the effects of the other three GP options are compared to the relative effects of the GP1528 option. This comparison identifies what could happen if the greater Gavins Point Dam changes were made assuming that the GP1528 option was implemented before the other three.

Table 7.1-1. Alternatives selected for detailed analysis in the RDEIS.

Feature	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Adaptive Management	Yes	Yes	Yes	Yes	Yes	Yes
Drought Conservation Measures	CWCP	>CWCP	>CWCP	>CWCP	>CWCP	>CWCP
Unbalancing of Upper Three Lakes	No	Yes	Yes	Yes	Yes	Yes
Fort Peck Flow Modification	No	Yes	Yes	Yes	Yes	Yes
Gavins Point Release Changes:						
Spring Rise	No	No	15 kcfs	20 kcfs	15 kcfs	20 kcfs
Summer Flow	34.5 kcfs	34.5 kcfs	28.5 kcfs	25/21 kcfs	25/21 kcfs	28.5 kcfs

The analyses identify the relative effects of changing to the other options under an iterative process such as the adaptive management process. The effects are presented in a variety of ways from average annual data to annual data. In some cases, more detailed data is presented to provide the reader with data that more closely match the areas of concern that have been expressed throughout the Study process in general, and more specifically during the preparation of this FEIS.

The comparative process presented in this chapter will allow the reader to more completely understand the effects of individual plan components. The reader is encouraged to place more emphasis on the relative difference in values among the alternatives than on the absolute value for each alternative. The modeling techniques used in the Study were developed to measure the effects of changing the CWCP and not to forecast the future. Many factors that will influence future economic and environmental performance were not modeled.

Each section of this chapter includes one or more tables that include data broken down by river reaches. In some instances, the data for the individual reaches do not add up to the total value included in the table. This occurs because the numbers were rounded off after the totals were computed.

As was done in Chapter 5, data specific to many of the basin Tribes are presented. This effort was incorporated into this chapter as the Corps strives to better fulfill its Trust responsibilities to the American Indian Tribes in the Missouri River basin.

Finally, this chapter has several more sections than Chapter 5. These additional sections include discussions of the cumulative effects of operating under the alternatives selected for detailed analysis, a depletion analysis (analysis of operations with less water than currently available) of five of the alternatives (all except the GP 1521 option), and a final section presenting the results of analyses of two changes that could be made to two or more of the GP options as part of the Annual Operating Plan (AOP) process. Besides these specific additional sections, the results of additional analyses are included under several sections, including the wildlife habitat, hydropower, and Mississippi River sections that were not included in the corresponding sections of Chapter 5. These additional analyses were for lake tern and plover habitat, a discussion of the relative importance of riverine and lake tern and plover habitat, hydropower revenue and consumer rate analyses, capacity and energy at risk during the low-flow period analyses, and three environmental analyses and a dredging analysis for the Middle Mississippi River.

7.2 MAINSTEM RESERVOIR SYSTEM HYDROLOGY

This section of Chapter 7 focuses on the hydrologic variation that will result from the operation of the Mainstem Reservoir System under the MCP and the four GP options (GP1528, GP2021, GP2028, and GP1521) designed to address Gavins Point Dam release changes for the three listed species provided protection under the ESA. Total storage, individual lake elevations, and river flows in all of the reaches will vary as drought conservation increases under the MCP, increased spring release are made from Fort Peck Dam, and the magnitude of the spring rise and summer low flows vary under the GP options.

7.2.1 Mainstem Reservoir System Storage and Lake Elevations

In the hydrologic modeling process, lake levels and total system storage are two hydrologic features important to those whose livelihoods and responsibilities are associated with one or more of the mainstem lakes. Table 7.2-1 displays the minimum system storage levels and minimum lake levels for the upper three lakes for the CWCP, the MCP, and the four GP options. Minimum levels are presented for each of the three major droughts experienced during the 100-year period of record as well as for the period of actual historic operation from 1967 to 1997. The system storage represents the minimum daily total of the combined volume of the six mainstem lakes during each drought period: the 1930 to 1941 drought, the 1954 to 1961 drought, and the 1987 to 1993 drought. Minimum daily lake levels for the upper three lakes (Fort Peck Lake, Lake Sakakawea, and Lake Oahe) during each drought period are also presented. Minimum lake elevations for the other three mainstem lakes (Lake Sharpe, Lake Francis Case, and Lewis and Clark Lake) are not provided. These lakes are much smaller than the upper three, representing only 12 percent of the total storage, and their operation, and therefore, their lake levels, do not vary significantly with the different alternatives.

The minimum system storage levels modeled during the three droughts under the MCP and all four GP options are higher than those under the CWCP. One of the objectives of the MCP and the GP options was to retain water in the system lakes during times of drought.

The MCP consists of the same conservation measures as the MRBA alternative discussed in Chapter 5, but it also includes a spring rise downstream from Fort Peck Dam. The MCP results in a minimum system storage of approximately 27.2 million acre-feet (MAF) during the 1930 to 1941 drought, the same as the MRBA alternative. The GP options are similar to the MCP, but include a spring rise below Gavins Point Dam and a lower summer release. These options result in slightly lower minimum system storages than the MCP during the 1930 to 1941 drought, ranging from 26.4 MAF for the GP1528 option to 25.7 MAF for the GP2021 option. Although there is little variation among the GP options, the two with the lowest summer flows (GP2021 and GP1521) result in slightly lower minimum storage levels during the 1930 to1941 drought because their lower summer flows allow for a longer navigation season (navigation season length was based on minimum storage level of about 43 MAF in the 1987 to 1993 drought). As a result, they end the navigation season with less total storage and this loss is carried over to the early part of the following year prior to the start of the spring runoff.

Table 7.2-1. Minimum system storage (MAF) and lake levels for the upper three lakes (feet).

Alternative	System Storage		Fort Peck Lake		Lake Sakakawea		Lake Oahe	
	Date	MAF	Date	Level (feet)	Date	Level (feet)	Date	Level (feet)
1930-1942 Drought								
CWCP	Sep-41	18.7	Jun-41	2,157	Feb-37	1,773	May-41	1,537
MCP	Feb-40	27.2	Mar-40	2,181	Mar-40	1,793	Feb-40	1,559
GP1528	Mar-41	26.4	Mar-41	2,179	Mar-41	1,791	Feb-41	1,558
GP2021	Feb-41	25.7	Mar-41	2,178	Feb-41	1,790	Feb-40	1,556
GP1521	Feb-41	25.8	Mar-41	2,178	Oct-40	1,790	Feb-40	1,556
GP2028	Mar-41	26.1	Mar-41	2,178	Mar-41	1,790	Feb-41	1,557
1954-1962 Drought								
CWCP	Dec-61	40.1	Mar-62	2,206	Feb-62	1,813	Aug-61	1,586
MCP	Dec-61	42.1	Mar-62	2,209	Feb-62	1,817	Aug-55	1,588
GP1528	Dec-61	45.5	Mar-62	2,215	Feb-62	1,821	Aug-55	1,587
GP2021	Dec-61	44.6	Aug-61	2,213	Feb-62	1,820	Aug-55	1,588
GP1521	Dec-61	44.7	Aug-61	2,213	Feb-62	1,820	Aug-55	1,588
GP2028	Dec-61	45.5	Mar-62	2,215	Feb-62	1,821	Aug-55	1,587
1987-1993 Drought								
CWCP	Jan-93	40.2	Apr-91	2,206	Mar-93	1,813	Aug-90	1,585
MCP	Jan-93	42.7	Mar-93	2,209	Feb-91	1,817	Aug-90	1,586
GP1528	Jan-93	43.3	Mar-93	2,206	Mar-93	1,818	Aug-92	1,588
GP2021	Jan-93	43.4	Mar-93	2,206	Mar-93	1,819	Aug-92	1,590
GP1521	Jan-93	43.3	Mar-93	2,206	Mar-93	1,819	Aug-92	1,590
GP2028	Jan-93	43.3	Mar-93	2,206	Mar-93	1,818	Aug-92	1,588
Historic Minimums								
1967-1997	Jan-91	40.8	Apr-91	2,209	May-91	1,815	Nov-89	1,581

During the less severe droughts, 1954 to 1961 and 1987 to 1993, the MCP and the four GP options again result in higher system storages than the CWCP due to the higher drought conservation measures. The minimum system storage under the MCP is 2.0 MAF higher than the CWCP in the 1954 to 1961 drought, and 2.5 MAF higher in the 1987 to 1993 drought. The GP options are higher yet, ranging from 2.5 to 3.4 MAF higher than the MCP during the 1954 to 1961 drought and 0.6 to 0.7 MAF higher than the MCP in the 1987 to 1993 drought. The GP options with the lowest summer releases result in the lowest minimum system storage during the 1954 to 1961 drought, as in the 1930 to 1941 drought. During the 1987 to 1993 drought, minimum system storages are essentially the same for all GP options.

Comparing the MCP and the four GP options to the actual historic operation during the period of record (which only includes the 1987 to 1993 drought), all of the alternatives result in a higher minimum system storage than actually occurred during the latest drought.

Variations in the lake elevations of the upper three lakes are similar to the total system storage because the storage in the three lakes makes up nearly 90 percent of the total system storage. However, there are minor variations due to the unique operating objectives of the individual lakes, such as unbalancing and the Fort Peck Dam spring rise, which can affect the timing and distribution of storage in the system. In general, all of the alternatives result in higher lake levels than the CWCP during the three drought periods. This is because the alternatives have increased drought conservation measures.

The MCP provides significantly higher minimum lake levels than the CWCP for the upper three lakes during the 1930 to 1941 drought. Increases in minimum lake levels are 24, 20, and 32 feet, respectively, for Fort Peck Lake, Lake Sakakawea, and Lake Oahe. For the lesser droughts—1954 to 1961 and 1987 to 1993—the MCP again provides higher minimum lake levels than the CWCP for the upper three lakes, but on a much smaller scale. At Fort Peck Lake, the minimum lake level is 3 feet higher under the MCP than the CWCP for both droughts; Lake Sakakawea is 4 feet higher under the

MCP than the CWCP for both droughts; and Lake Oahe is 2 feet higher during the 1954 to 1961 drought and 1 foot higher during the 1987 to 1993 drought.

The four GP options have nearly identical minimum pool elevations for the upper three lakes during the three drought periods, with variations between the GP options generally limited to 1 to 2 feet. In the 1930 to 1941 drought, the GP options result in minimum lake levels at all three lakes that are slightly below the MCP. The GP options are 1 to 2 feet lower than the MCP at Fort Peck Lake, 2 to 3 feet lower than the MCP at Lake Sakakawea, and 1 to 3 feet lower at Lake Oahe.

During the two lesser droughts, the four GP options result in minimum lake levels that range from 6 feet above to 3 feet below the MCP. During the drought of 1954 to 1961 the GP options result in a minimum pool 4 to 6 feet higher than the MCP at Fort Peck Lake, and 3 to 4 feet higher at Lake Sakakawea. However, Lake Oahe's minimum level during the 1954 to 1961 drought is as much as 1 foot lower with the GP options than with the MCP.

During the 1987 to 1993 drought, minimum Fort Peck Lake levels are 3 feet lower under the four GP options than under the MCP, essentially equivalent to the CWCP. Lake Sakakawea is 1 to 2 feet higher with the GP options than the MCP during the 1987 to 1993 drought, and Lake Oahe is 2 to 4 feet higher with the GP options.

In summary, all of the alternatives result in generally higher minimum system storage and lake levels during the three drought periods than under the CWCP. The MCP results in the highest minimum storage and lake levels during the 1930 to 1941 drought, but is generally equivalent to or lower than the GP options during the lesser droughts. The differences among the GP options are generally small, ranging from 0 to 2 feet. These minor differences in the GP options can be attributed to changes in timing and distribution of releases from Gavins Point Dam that result in minor differences in minimum system storages and lake elevations.

7.2.2 Fort Peck Dam Release

A spring rise out of Fort Peck Dam for the benefit of native fish species is included in all of the alternatives to the CWCP discussed in this chapter. Although all of the alternatives include the spring rise below Fort Peck Dam, there are minor differences due to the timing associated with the different Gavins Point Dam release patterns. The modeling results for the various alternatives are presented on Figures 7.2-1 through 7.2-3 as a derivative of a flow duration-type analysis. The modeling results for the various alternatives are presented on Figures 7.2-1 through 7.2-3 as flow duration plots. Duration plots are used in this case because the flows vary considerably from year to year, making it difficult to see relative differences among the alternatives. Increased releases of 23 kcfs for 3 weeks from Fort Peck Dam in the mid-May through June timeframe approximately every third year were recommended as a starting point in the USFWS 2000 BiOp. Although the USFWS goal was to release 23 kcfs for 3 weeks, some benefit is derived even if the goal is not fully met; therefore, a release of 18 kcfs is also discussed in the analysis model results.

Figure 7.2-1 compares the MCP and the GP1528 option—both of which have a spring rise below Fort Peck Dam—to the CWCP, which does not have a Fort Peck spring rise. The MCP is effective at providing a spring rise of 23 kcfs for 2 weeks about 20 percent of the time. The GP1528 option, the lowest spring rise and highest summer flows, is slightly more effective than the MCP at providing a spring rise of 23 kcfs for about 2 weeks, meeting that goal about 23 percent of the time. Both the MCP and the GP1528 options provide a 18 kcfs spring rise about 30 percent of the time.

Figure 7.2-2 compares the GP1528 and GP2021 options. Although the differences between the two options are minor, GP1528 is slightly better than GP2021 in providing a spring rise from Fort Peck Dam. GP1528 provides the 23 kcfs spring rise for 14 days, an additional 2 percent of the years compared to GP2021.

Figure 7.2-3 compares GP1528 with the GP1521 and GP2028 options. Again, GP1528 increases the percent of years where the spring rise is achieved 2 to 3 percent of the years compared to the other options.

In summary, the GP1528 option provides a 23 kcfs spring rise in the greatest percent of years when compared to the other alternatives.

7.2.3 Lake Sakakawea Elevations

The State of North Dakota indicated that it has water quality concerns at Lake Sakakawea when the pool is drawn down below elevation 1,825 feet.

This elevation appears to be a critical elevation for coldwater habitat in the lake by the State based on observations made during the 1987 to 1993 drought. A loss of smelt occurred in Lake Sakakawea the summer the lake was below this elevation when the lake turned over, mixing the colder, deeper water with the warmer water at the surface of the lake. To facilitate the water quality analysis for Lake Sakakawea, Figures 7.2-4 through 7.2-6 were developed to compare the number of days that Lake Sakakawea was below elevation 1,825 feet during the three historic drought periods in the Missouri River basin under the various operating scenarios.

For background purposes, the carryover-multiple use zone under the CWCP extends from elevation 1,775 to 1,837.5 feet. The actual historic minimum pool level at Lake Sakakawea during the 1987 to 1993 drought was 1,815.0 feet.

As simulated using the Daily Routing Model (DRM), Lake Sakakawea is drawn down below 1,825 feet for a period of many years under all of the operating alternatives during the drought of 1930 to 1941. As shown in Figure 7.2-4, Lake Sakakawea was drawn down the longest under the CWCP, nearly 12 consecutive years during the 1930 to 1941 drought. The MCP, with its increased drought conservation measures, results in fewer days below 1,825 feet in the early years of the drought, from 1931 to 1933, and also allows for a quicker recovery at the end of the drought than the CWCP. GP1528 is similar to the MCP in the early years of the 1930 to 1941 drought, but recovers even quicker than the MCP at the end of the drought. Only the GP2021 option is shown on Figure 7.2-4. The other GP option with minimum service summer low flows, GP2028, has a low lake level nearly identical to the GP1528 option and, therefore, is not shown in Figure 7.2-4. The remaining two GP options, GP1521 and GP2021, are similar to GP1528 in the early years of the 1930 to 1941 drought, but recover slower than either the GP1528 option or the MCP at the end of the drought. The primary difference between the GP options is whether or not navigation is supported during particular years of the drought. GP1528 and GP2028 do not support navigation during 1942, which results in retention of water in the upper lakes. This allows Lake Sakakawea to recover a little quicker than with the GP1521 and GP2021 options.

Figure 7.2-5, representing the1954 to 1961 drought, shows considerably more difference among the CWCP, the MCP, and the GP options. During the 1954 to 1961 drought, the MCP is considerably better than the CWCP because of its additional conservation measures, but still results in Lake Sakakawea dropping below 1,825 for at least a short period of time each year between 1957 and 1962. In contrast, all of the GP options reduce the time spent below 1,825 feet during the 1954 to 1961 drought to a short duration in 1961 and 1962. There is essentially no difference among the GP options.

During the 1987 to 1993 drought, as shown in Figure 7.2-6, the MCP results in Lake Sakakawea spending less time below 1,825 than the CWCP. The results for the GP1528 and GP2028 options are identical to each other and, with the exception of 1989, result in fewer days below 1,825 feet than the MCP. The GP2021 and GP1521 options also are identical, and are consistently lower than the other two GP options. The volume and timing of releases to support navigation account for the primary difference in the durations that Lake Sakakawea is below 1,825 feet for the GP options.

In summary, the MCP results in Lake Sakakawea spending less time below 1,825 feet than the CWCP. The GP options reduce the duration spent below 1,825 feet even further than the MCP.

7.2.4 Bismarck Flow Duration

A flow duration-type analysis was done using the DRM results at Bismarck. In the analysis, the number of days during the April to June timeframe when flows at Bismarck exceed 55 kcfs were totaled for each year in the 100-year period of record. A duration-type analysis was also performed. Flood damages in the Bismarck area begin when flows exceed the 55 to 60 kcfs range. Figures 7.2-7 through 7.2-9 compare the results of the analysis for the CWCP and MCP alternatives and the four GP options: GP1528, GP2021, GP1521, and GP2028.

As shown in Figure 7.2-7, the MCP alternative results in slightly more days with flows above 55 kcfs at Bismarck in the April to June timeframe than the CWCP. Except in rare events, the increase in the number of days is small, in the range of 2 to 3 additional days per year. The GP1528 option has fewer days above 55 kcfs than the MCP alternative, and the duration curve is nearly identical to the CWCP.

Figure 7.2-8 compares the GP1528 and GP2021 options. Although the GP2021 option has a higher spring rise (20 kcfs rather than 15 kcfs), there is very little difference between the flow duration curves at Bismarck. This is further reinforced by Figure 7.2-9, which shows essentially no difference in the flow duration at Bismarck for the GP1528, GP1521, and GP2028 options.

In summary, the GP options result in essentially no increase in the time flows at Bismarck exceed 55 kcfs over the CWCP, and the MCP results in only a slight increase over the CWCP.

7.2.5 Gavins Point Dam Release

The six alternatives discussed in this chapter have widely varying Gavins Point Dam releases, depending on the existence and magnitude of the spring rise and summer low flows that differentiate the alternatives. Neither the CWCP nor the MCP have a spring rise or low summer flows, although the MCP has more conservation measures than the CWCP. These conservation measures reduce service to navigation during times of drought. The four GP options are differentiated by the magnitude of the spring rises and summer low flows. The GP1521 and GP1528 options have a 15-kcfs spring rise out of Gavins Point Dam, while the GP2021 and GP2028 options have a 20-kcfs spring rise. Likewise, the GP1521 and GP2021 options have low summer flows of 21 to 25 kcfs from late June through the end of August, whereas the GP1528 and GP2028 options have a minimum service flat release of 28.5 kcfs during that time frame. The differences among the alternatives described in the following paragraphs can also be used to describe flow changes downstream from Fort Randall Dam.

The varying Gavins Point Dam releases are directly observable in the release duration plots developed for each month (January -December) using average monthly Gavins Point Dam releases for the period of record. The results are presented on 12 monthly figures each displaying the CWCP, the MCP, and the GP1528 and GP2021 options. Figures 7.2-10 through 7.2-21 allow a month-by-month comparison of the alternatives. The discussion here, however, is limited to pointing out the major differences among the plans.

Between January and March, Figures 7.2-10 through 7.2-12, the duration curves for the various alternatives are, for the most part, quite similar in the range and frequency of the Gavins Point Dam release. In particular, the MCP has slightly higher releases than the CWCP between January and March. The GP options have a slightly different shape in the months of January and February than the MCP, but the overall differences are minor.

In April, a significant dichotomy in the duration curves becomes apparent (Figure 7.2-13). The MCP is nearly identical to the CWCP, but the GP options require higher releases during April in wet years because of the release restrictions imposed later in the summer. These alternatives indicate much higher April releases, up to 10 kcfs, than the MCP, which does not include a spring rise out of Gavins Point Dam. The GP option with minimum service summer flow, GP1528, has a duration curve significantly higher than the MCP. This duration curve is, however, slightly lower than the GP option with the more restricted summer flows, GP2021.

The effects of the spring rise, which was modeled from mid-May through mid-June, are most evident in the duration curves for May (Figure 7.2-14). The CWCP and the MCP have nearly identical release duration curves that are significantly lower than the GP options. The GP option with the 15-kcfs spring rise, GP1528, ranges from several kcfs higher than the MCP to as much as 15 kcfs higher. The 20-kcfs spring rise option, GP2021, results in the highest releases, generally about 5 kcfs higher than the 15-kcfs spring rise option.

In June, the Gavins Point Dam release duration curves for the CWCP and the MCP are very similar once again. Furthermore, because the GP options have high Gavins Point Dam releases during the first half of June and low releases during the second half of the month, the average monthly flows depicted in Figure 7.2-15, are generally in the same range as the MCP. If June flows had been subdivided between the first and second halves of the month, the results would have been similar to those of May and July, respectively.

In July and August, Gavins Point Dam releases for the CWCP and the MCP are the highest, followed by the GP option with minimum service flows from late June through the end of August. The GP option with the 25/21/25 low summer flows, GP2021, has the lowest Gavins Point Dam releases.

After the low summer flows in the GP options, Gavins Point Dam releases are increased in order to evacuate the remaining excess water in the system storage between September and November (Figures 7.2-18 through 7.2-20). Release duration curves for the GP options are significantly higher than the

CWCP and the MCP curves. The November release duration curve also indicates the shortened navigation season required in 35 to 40 percent of the years under the MCP and the GP1528 option.

December's duration curves for the CWCP, the MCP, and the GP options (Figure 7.2-21) are once again quite similar, although there is some variation in the Gavins Point Dam release at the end of the navigation season. The minimum winter release, 12 kcfs, is consistent across the range of alternatives.

7.2.6 Nebraska City Flow Duration

Along the Lower River below the Mainstem Reservoir System, the magnitude, timing, and duration of high flows may affect landowners through direct flooding, high groundwater, and/or interior drainage flooding. Because the duration of high flows is a significant factor, the modeling results for the various alternatives are presented on Figures 7.2-22 through 7.2-24 as a derivative of a flow duration-type analysis. In the analysis, the number of days during the April to July timeframe when flows at Nebraska City exceed 55 kcfs was totaled for each year in the 100-year period of record, and a duration-type analysis was performed. Landowners in the Nebraska City area begin to experience interior drainage problems when flows in the Missouri River approach 55 kcfs. Figures 7.2-22 through 7.2-24 compare the results of the analysis for the CWCP, the MCP, and the four GP options. Because the flows at Nebraska City are highly influenced by the Gavins Point Dam releases, the differences among the alternatives follow a similar pattern.

Figure 7.2-22 shows that, while the MCP duration curve is nearly identical to that of the CWCP, the GP1528 option with its spring rise results in more days with flows above the 55 kcfs level during the period of April through July. Likewise, Figure 7.2-23, comparing the GP1528 and GP2021 options, shows that, for the most part, as the magnitude of the spring rise increases, the frequency and duration of flows above 55 kcfs at Nebraska City also increases. This is also indicated on Figure 7.2-24 where the GP2028 option results in the most days above 55 kcfs at Nebraska City.

In summary, although there is very little difference between the CWCP and the MCP flow duration at Nebraska City, the GP options result in an increase in the percent of time that 55 kcfs is exceeded.

7.2.7 Boonville Flow Duration

A similar analysis was performed for flows at Boonville, Missouri. Figures 7.2-25 through 7.2-27 show a duration-type analysis of the number of days during the May through June time frame that flows at the Boonville gage exceed 90 kcfs. Long duration, high flows on the Lower River can restrict releases from tributary lakes. Releases from the Kansas River tributaries begin to be restricted when flows at Waverly, Missouri are greater than 90 kcfs. Waverly is not a control point in the DRM; however, Boonville is the next downstream control point.

For the May through June period, Figure 7.2-25, comparing the CWCP to the MCP and the GP1528 option, shows essentially no difference between the flow duration curves for the CWCP and the MCP. The flow duration curve at Boonville for the GP1528 option is slightly higher than the MCP, averaging several additional days with flows above 90 kcfs at Boonville.

Figures 7.2-26 and 7.2-27, comparing the four GP options, show a very slight increase in the number of days with flows above 90 kcfs for the GP options with the highest spring rises: GP2028 and GP2021.

In summary, the spring rise from Gavins Point Dam provided by the GP options results in a very minor increase in the number of days during the May to June timeframe that the flows at Boonville are in excess of 90 kcfs.

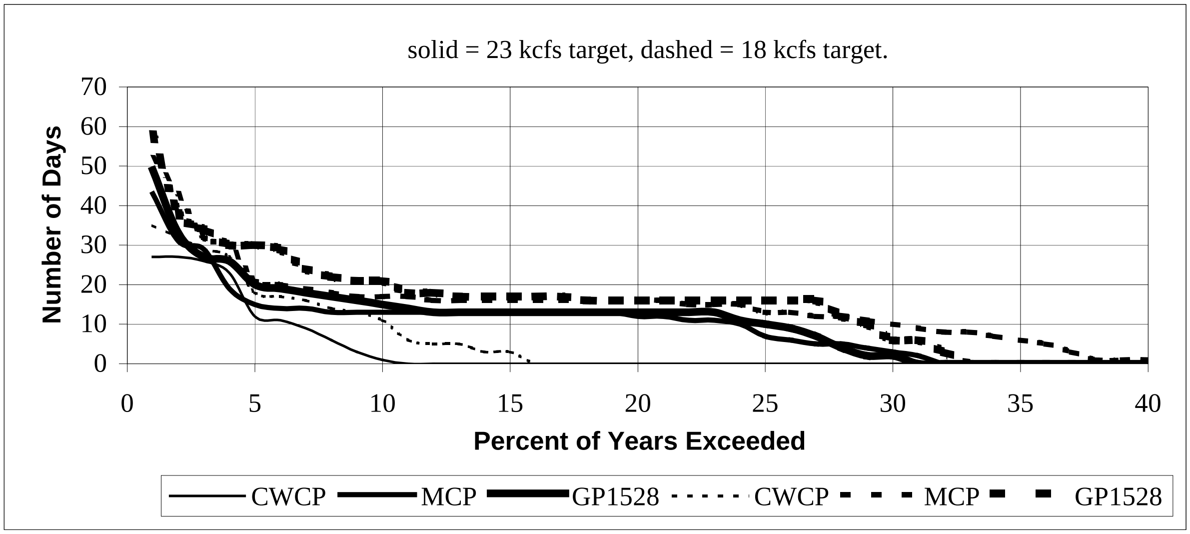

Figure 7.2-1. Number of days in May/June that Fort Peck Dam releases exceed target for CWCP, MCP, and GP1528.

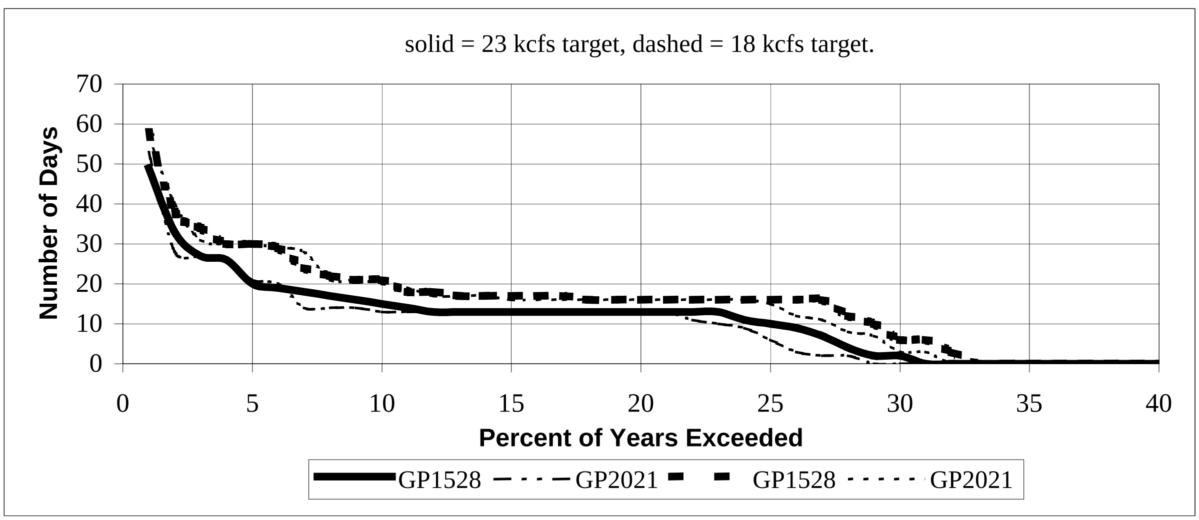

Figure 7.2-2. Number of days in May/June that Fort Peck Dam releases exceed target for GP1528 and GP2021.

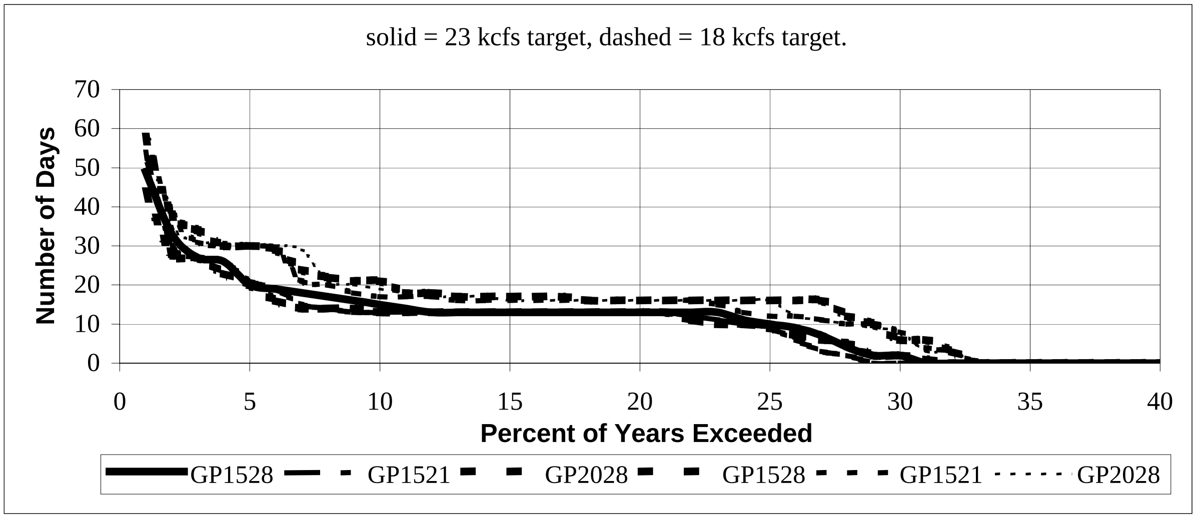

Figure 7.2-3. Number of days in May/June that Fort Peck Dam releases exceed target for GP1528, GP1521, and GP2028.

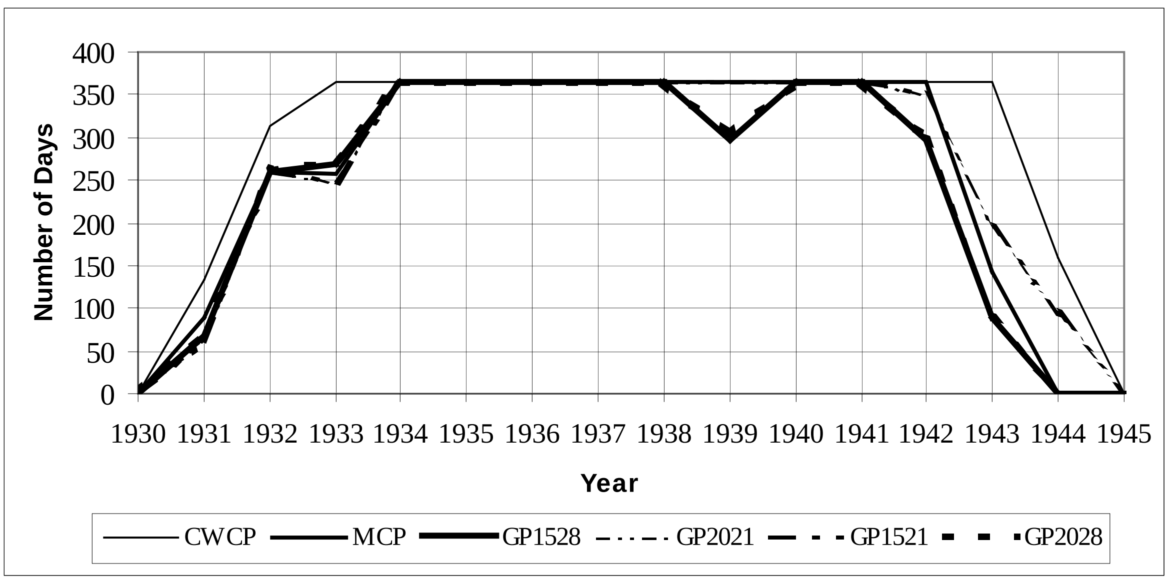

Figure 7.2-4. Number of days per year Lake Sakakawea is below elevation 1,825 feet: 1930 to 1941 drought.

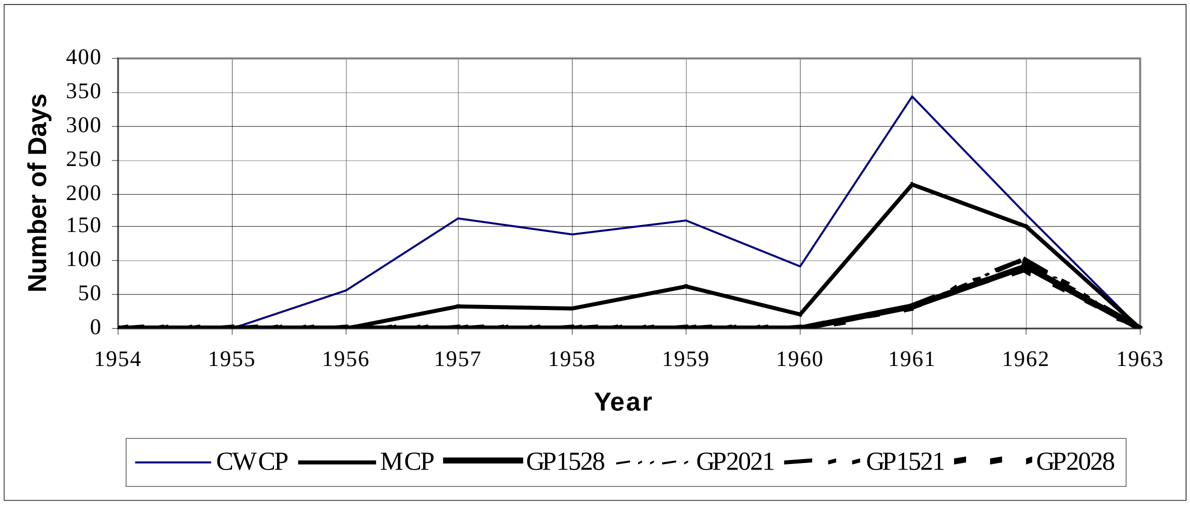

Figure 7.2-5. Number of days per year Lake Sakakawea is below elevation 1,825 feet: 1954 to 1961 drought.

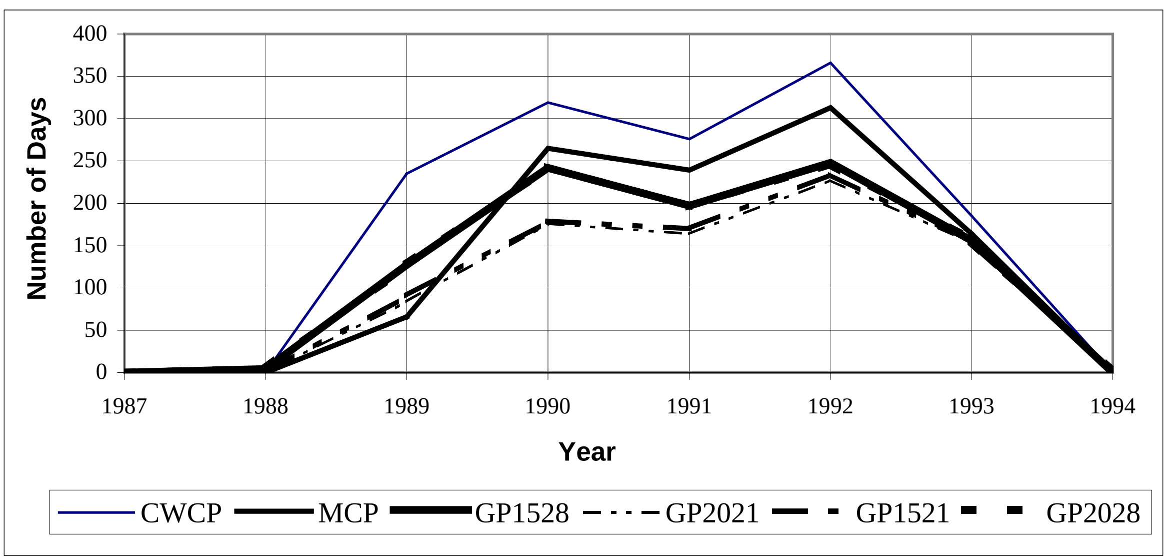

Figure 7.2-6. Number of days per year Lake Sakakawea is below elevation 1,825 feet: 1987 to 1993 drought.

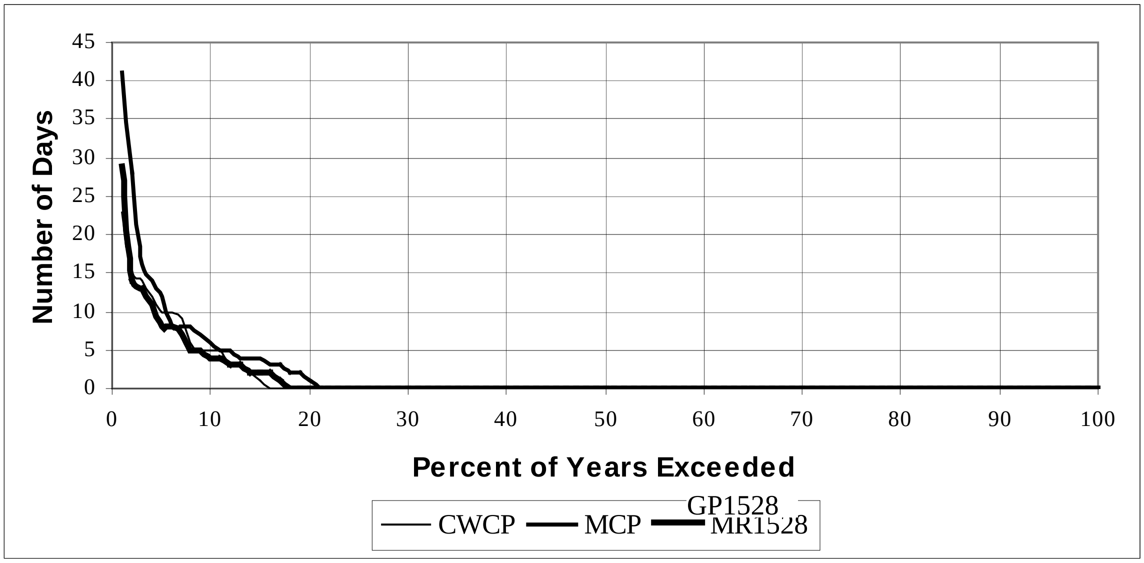

Figure 7.2-7. Missouri River at Bismarck: Number of days flows exceed 55 kcfs, April to June for CWCP, MCP, and GP1528.

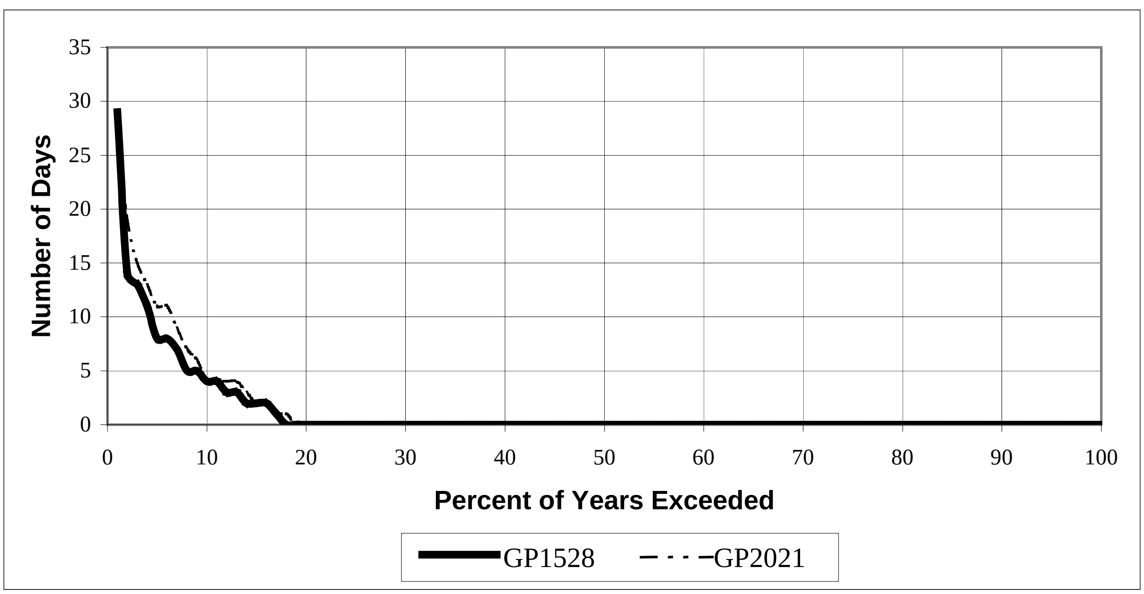

Figure 7.2-8. Missouri River at Bismarck: Number of days flows exceed 55 kcfs, April to June for GP1528 and GP2021.

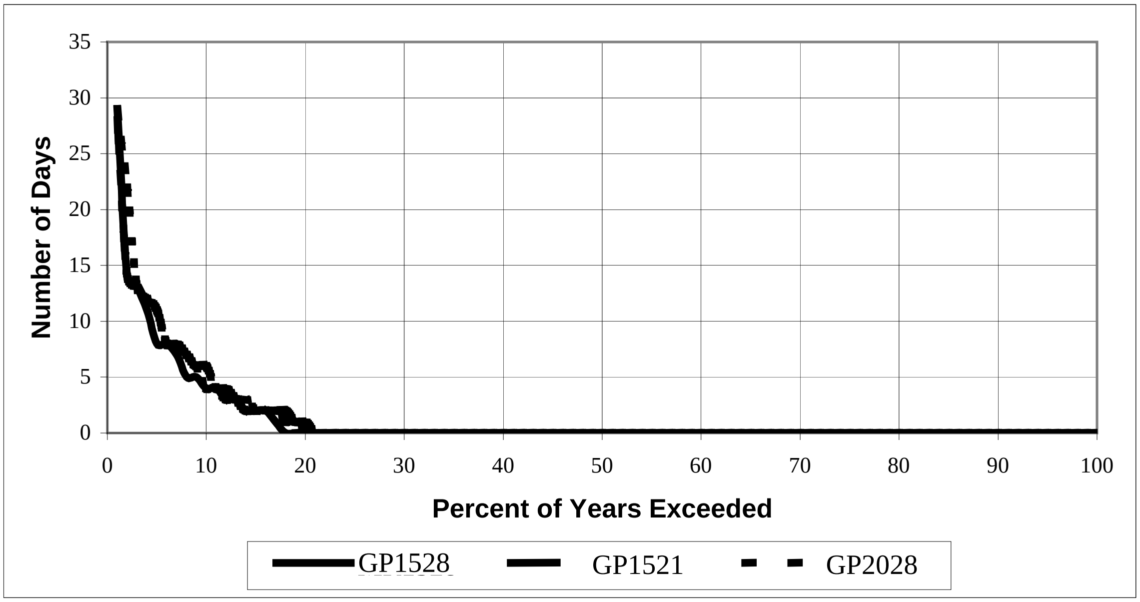

Figure 7.2-9. Missouri River at Bismarck: Number of days flows exceed 55 kcfs, April to June for GP1528, GP1521, and GP2028.

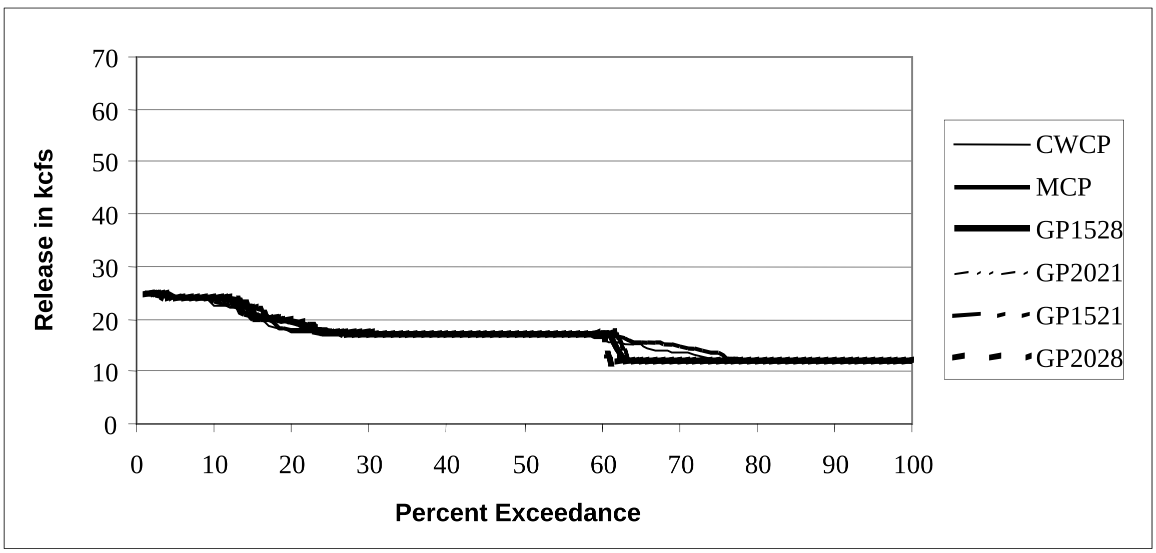

Figure 7.2-10. Gavins Point Dam release duration, January.

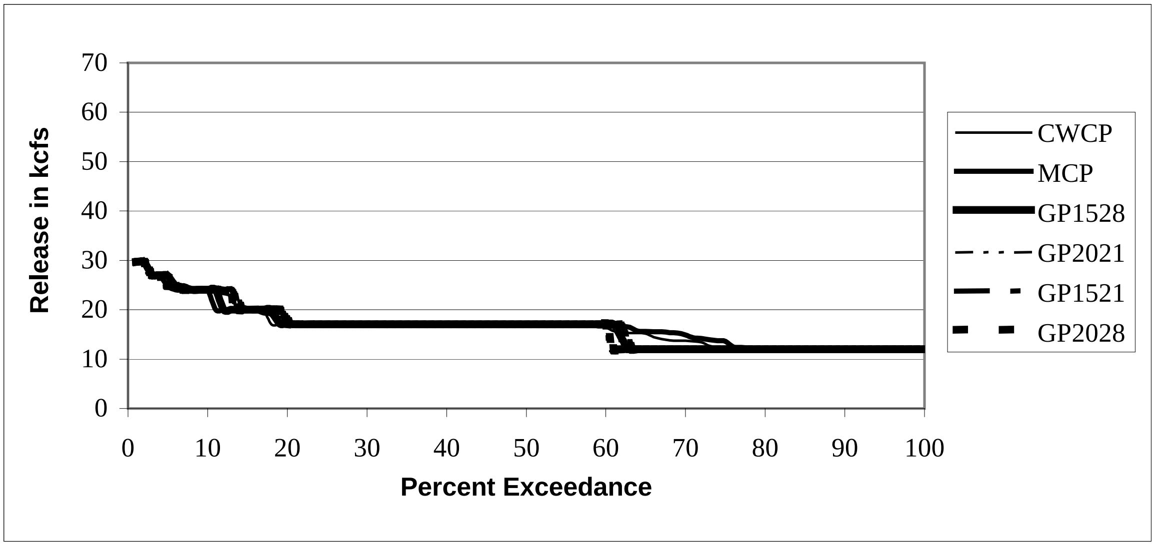

Figure 7.2-11. Gavins Point Dam release duration, February.

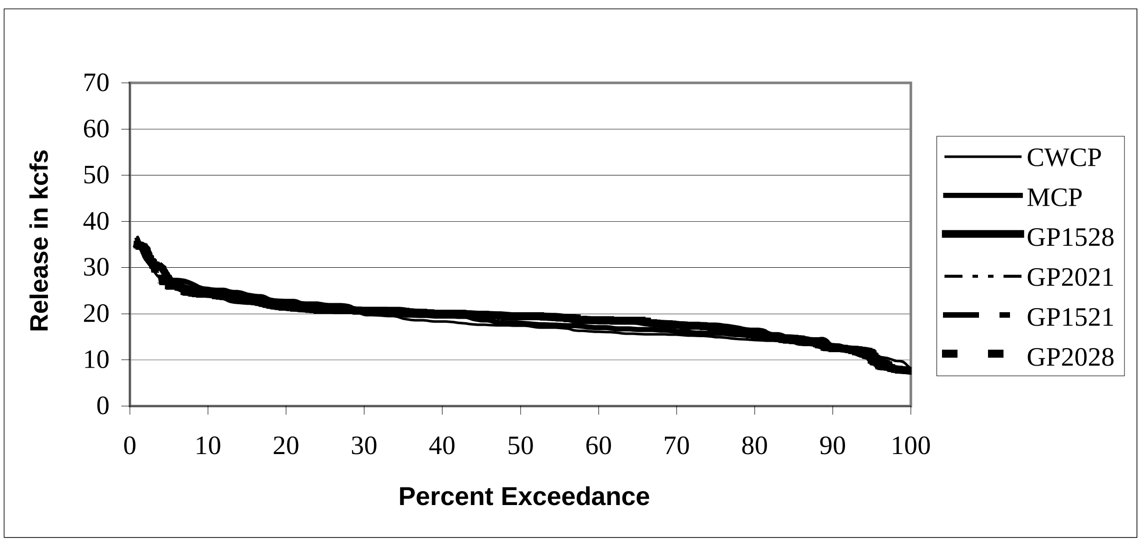

Figure 7.2-12. Gavins Point Dam release duration, March.

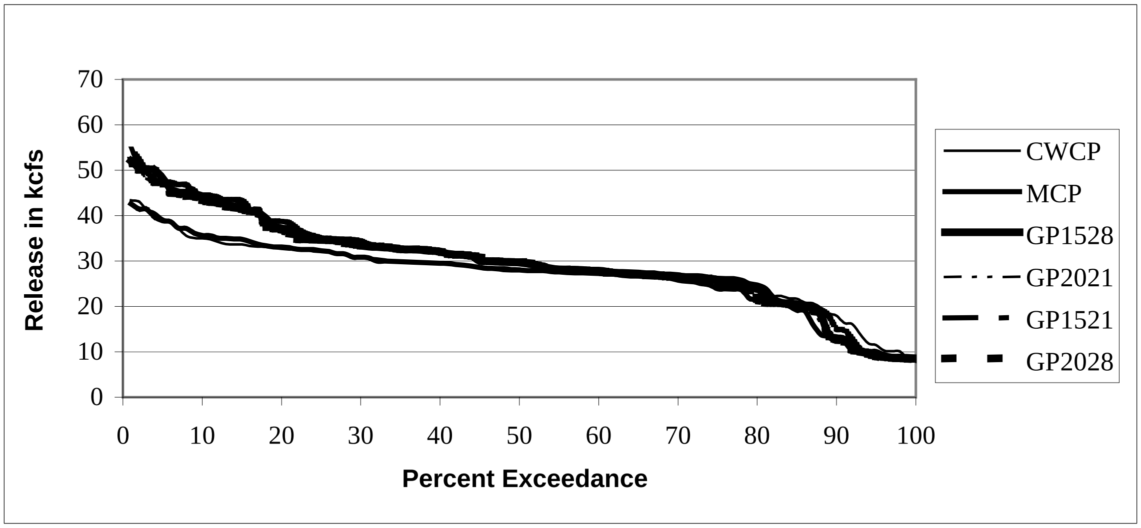

Figure 7.2-13. Gavins Point Dam release duration, April.

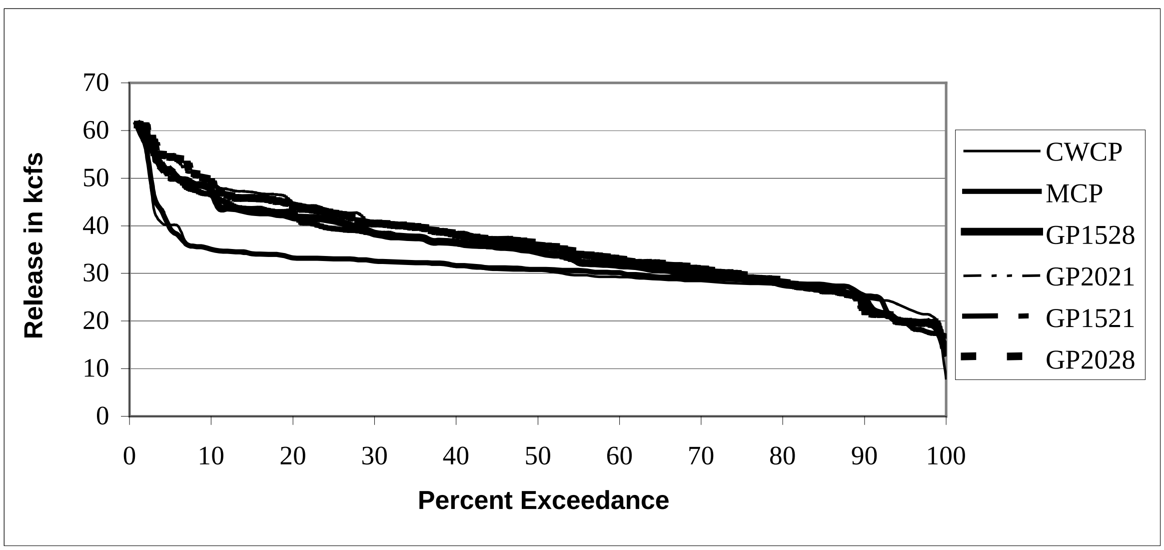

Figure 7.2-14. Gavins Point Dam release duration, May.

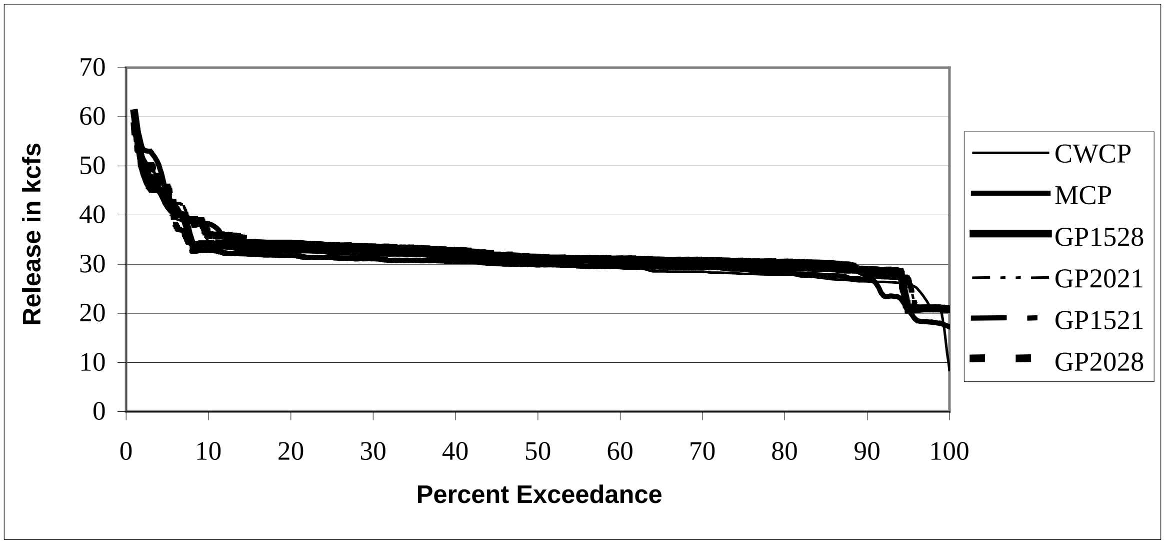

Figure 7.2-15. Gavins Point Dam release duration, June.

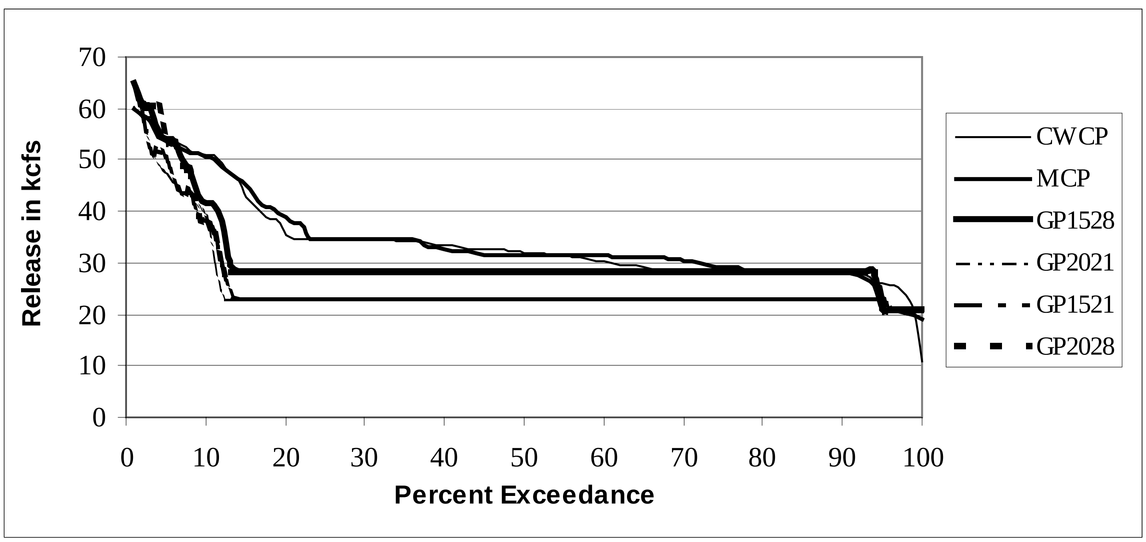

Figure 7.2-16. Gavins Point Dam release duration, July.

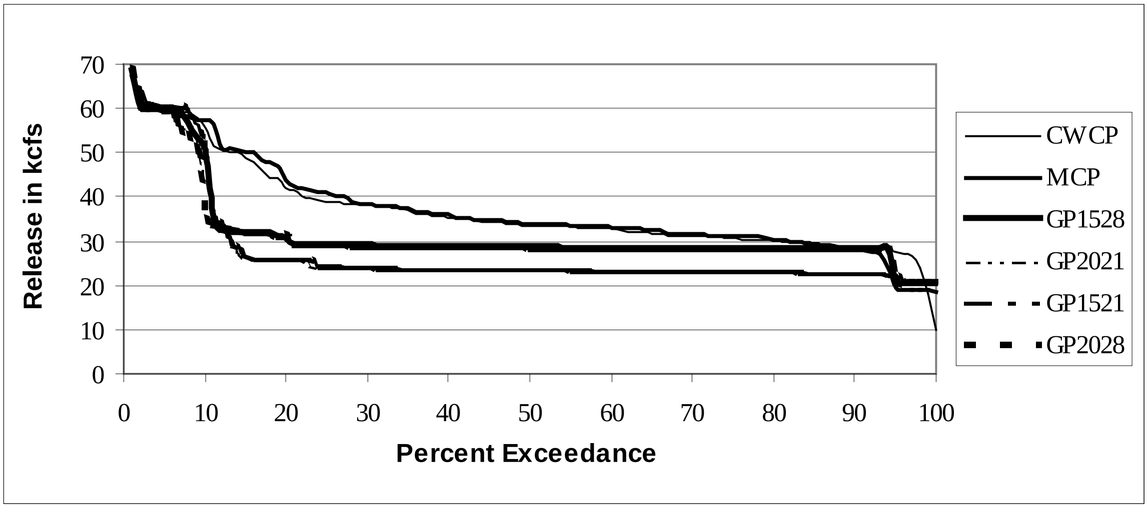

Figure 7.2-17. Gavins Point Dam release duration, August.

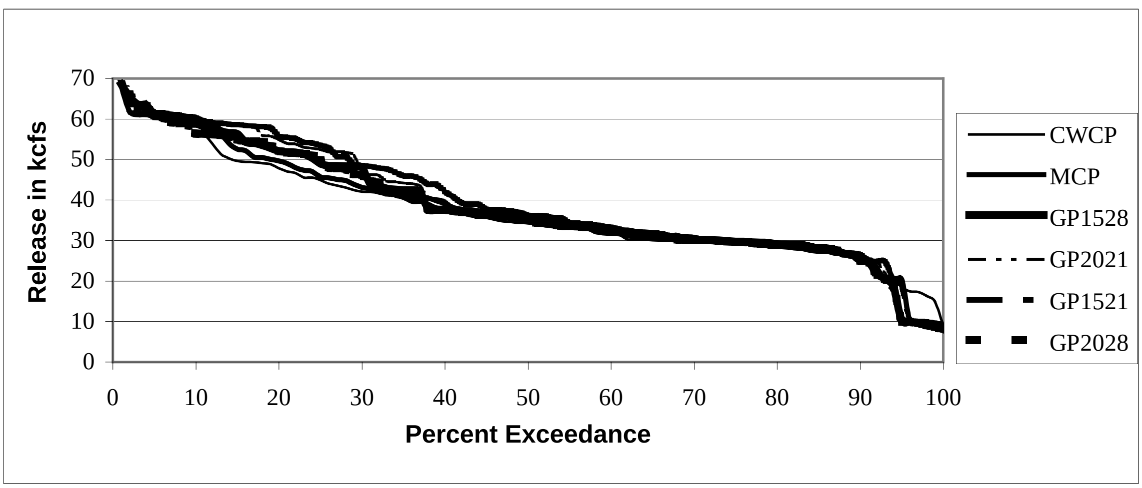

Figure 7.2-18. Gavins Point Dam release duration, September.

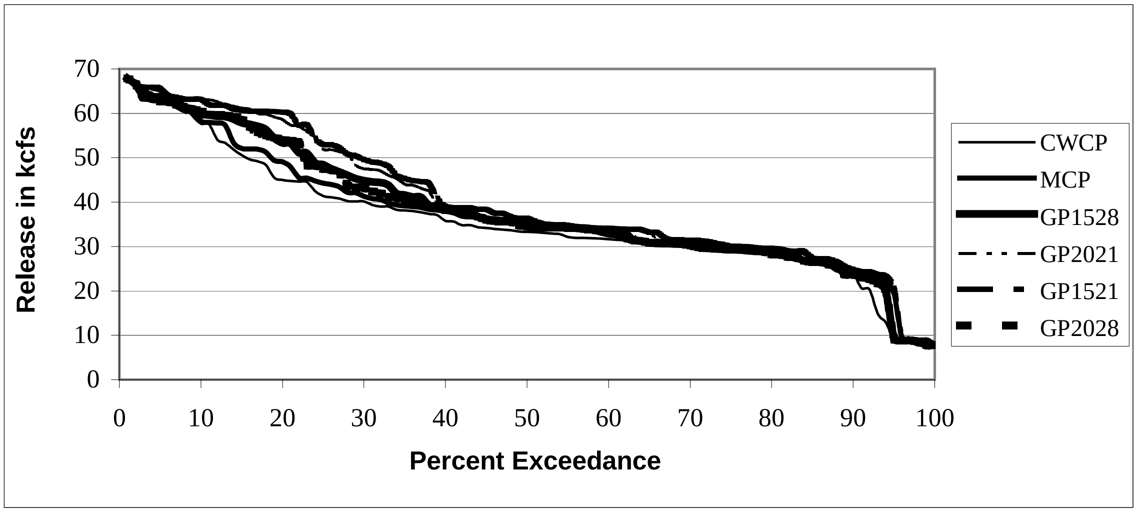

Figure 7.2-19. Gavins Point Dam release duration, October.

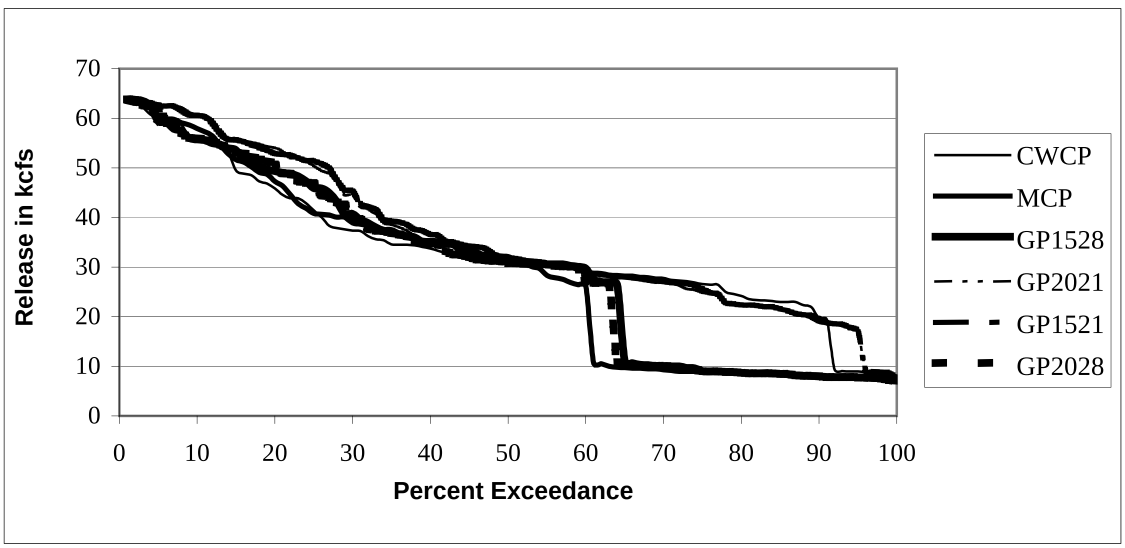

Figure 7.2-20. Gavins Point Dam release duration, November.

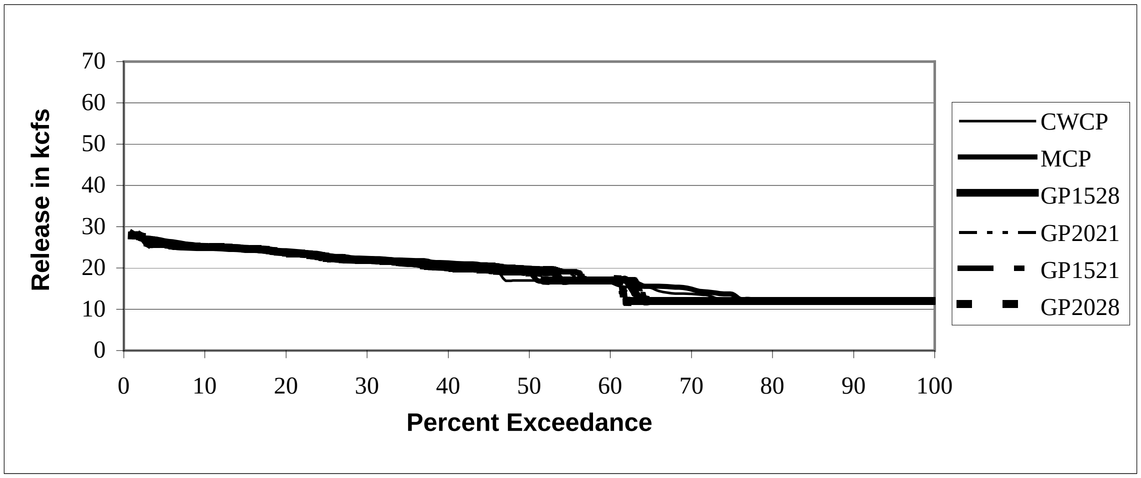

Figure 7.2-21. Gavins Point Dam release duration, December.

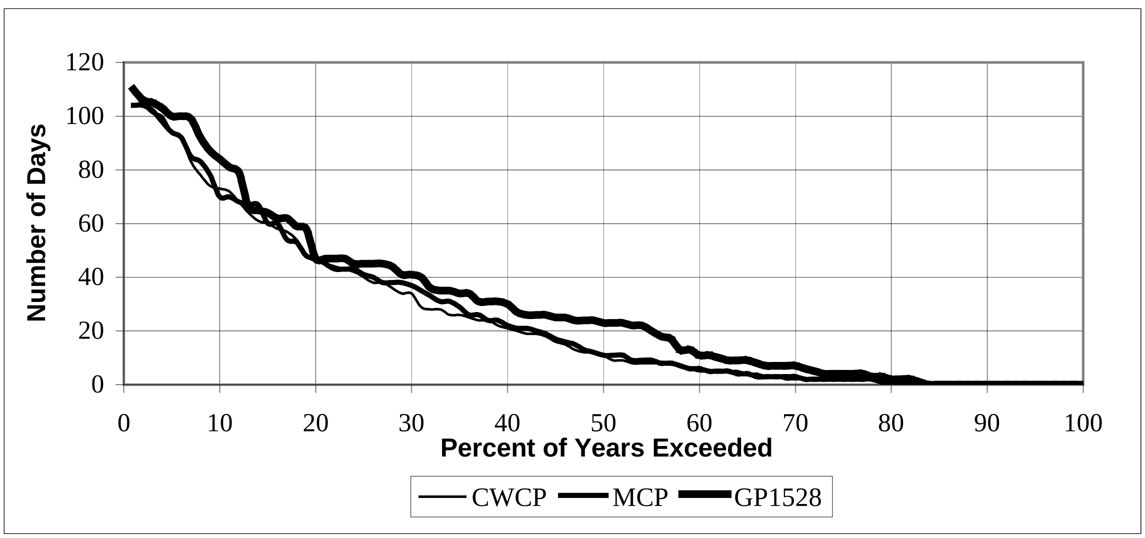

Figure 7.2-22. Missouri River at Nebraska City: Number of days flows exceed 55 kcfs, April to July for CWCP, MCP, and GP1528.

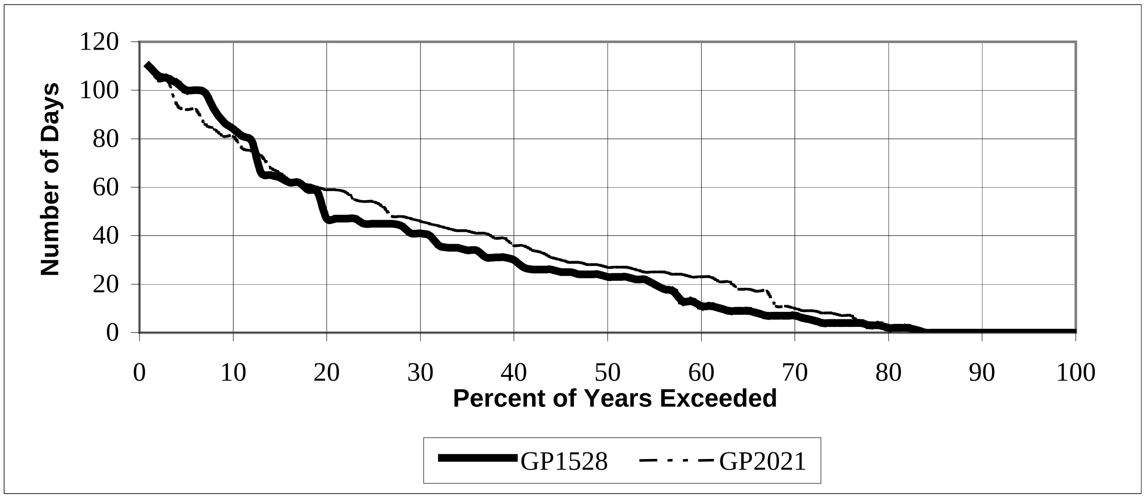

Figure 7.2-23. Missouri River at Nebraska City: Number of days flows exceed 55 kcfs, April to July for GP1528 and GP2021.

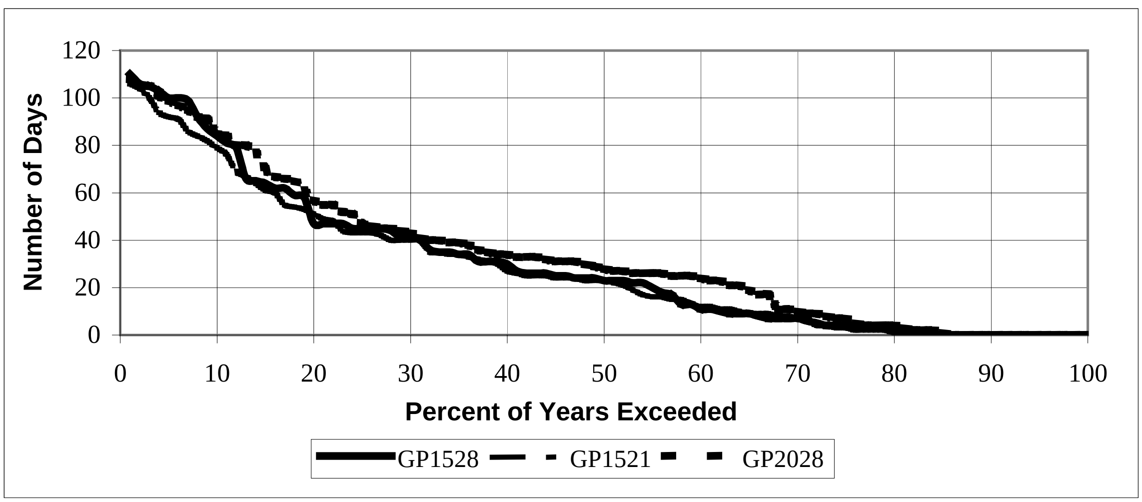

Figure 7.2-24. Missouri River at Nebraska City: Number of days flows exceed 55 kcfs, April to July for GP1528, GP1521, and GP2028.

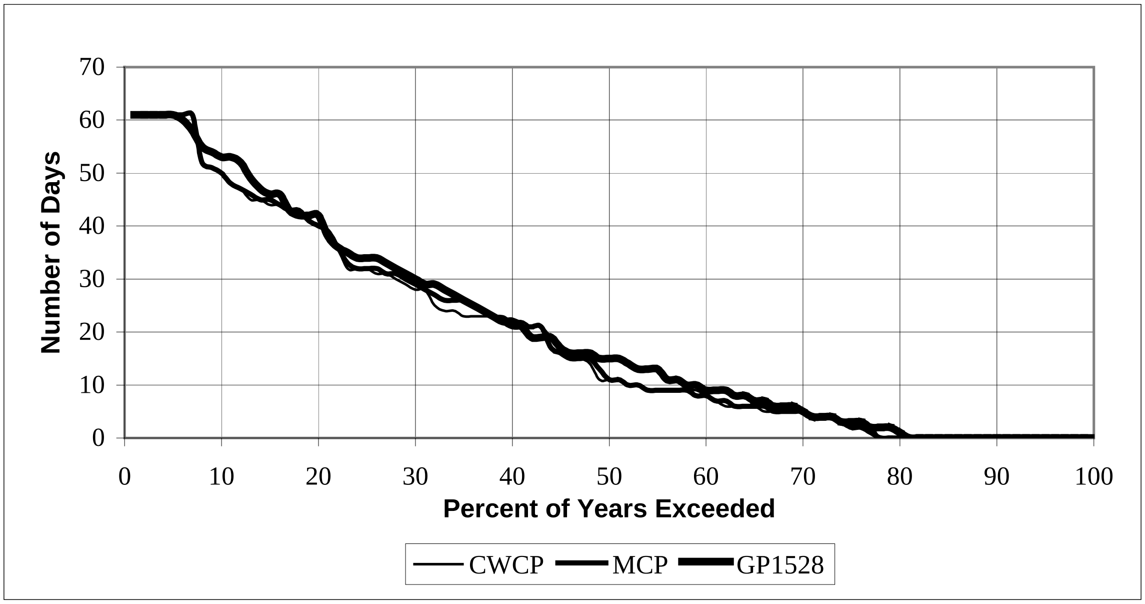

Figure 7.2-25. Missouri River at Boonville: Number of days flows exceed 90 kcfs, May to June for CWCP, MCP, and GP1528.

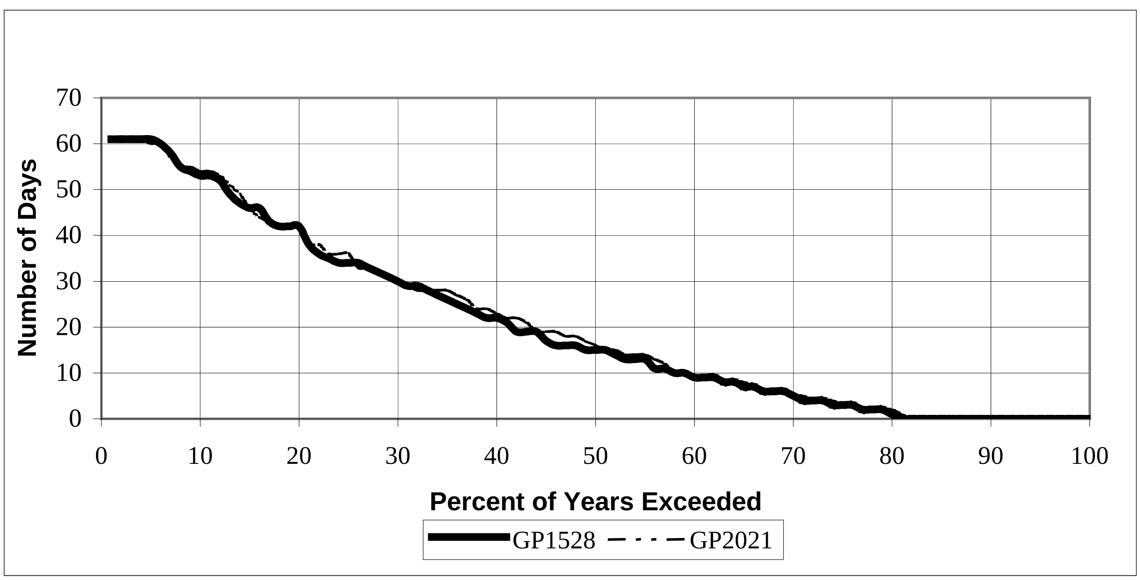

Figure 7.2-26. Missouri River at Boonville: Number of days flows exceed 90 kcfs, May to June for GP1528 and GP2021.

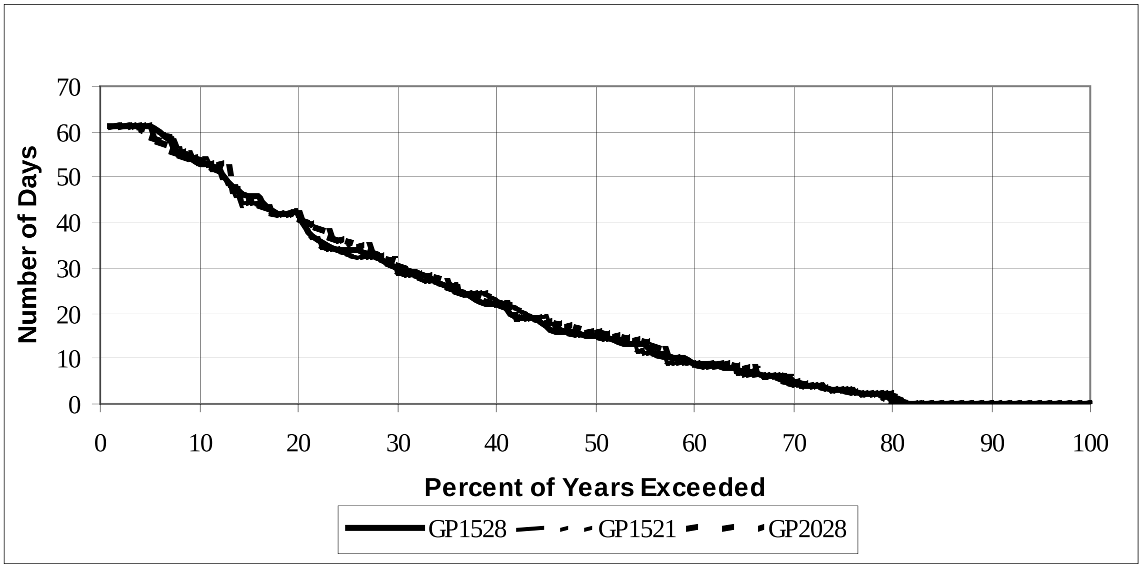

Figure 7.2-27. Missouri River at Boonville: Number of days flows exceed 90 kcfs, May to June for GP1528, GP1521, and GP2028.

7.3 SEDIMENTATION, EROSION, AND ICE PROCESSES

The amount of water in storage in the Mainstem Reservoir System lakes impacts sedimentation (deposition) patterns and shoreline erosion within and upstream from the individual lakes. Those with property along the river have expressed concerns over the years that differences in releases from the lakes impact the downstream riverbed and bankline erosion and ice processes. This section discusses in qualitative terms the relative effects of the alternatives on these processes. For additional technical analysis, please consult two technical reports on this subject: Aggradation, Degradation, and Water Quality Conditions (Corps, 1994f) and Cumulative Erosion Impacts Analysis (Corps, 1998h).

7.3.1 Sedimentation and Erosion

Mainstem Reservoir System operations have the potential to have a noticeable impact on sedimentation and erosion processes in extreme, short-lived situations. For example, the extreme high releases from Garrison Dam and subsequent flows past Bismarck in the late summer of 1997 resulted in considerable erosion in the Bismarck reach of the river. Obviously, if erosion increases in one location, deposition must increase in another location, in this case, the headwaters of Lake Oahe. Storage losses due to sedimentation will continue at historic rates irrespective of how the Mainstem Reservoir System is operated. Although releases caused erosion, the more dominant factor affecting erosion was the extremely high water volumes (twice normal levels) flowing into the Mainstem Reservoir System in 1997.

In 1995, the Corps initiated an analysis to quantify the potential effects of flows on erosion as part of the Missouri River Master Water Control Manual Review and Update (Study). This analysis examined the data that the Corps has acquired over the last 4 to 5 decades on erosion in four reaches. These reaches are located between Fort Peck Lake and Lake Sakakawea, between Lake Sakakawea and Lake Oahe, between Lake Francis Case and Lewis and Clark Lake, and downstream from Lewis and Clark Lake. Although not addressed specifically in the analysis, the Fort Peck Reservation and the Yankton Reservation are directly related to these reaches. The conclusions of this analysis are summarized in Table 7.3-1. Sedimentation and erosion impacts for all of the alternatives are not addressed specific to individual Reservations, but rather to the reaches as a whole. The most relative conclusions of the erosion analysis are those comparing the CWCP with the past preferred alternative of the 1994 DEIS. Basically, the analysis found no relationship among the annual hydrograph and channel features affected by sediment erosion and deposition. Based on this statement, there appears to be little merit in further discussing the effects of the alternatives on the sediment erosion and deposition processes.

7.3.2 Ice Processes

Ice formation and movement are problems to contend with during the 3 winter months. All of the alternatives have the same minimum flow criteria downstream from Gavins Point Dam (12 kcfs average in winter months). Minimum flows are, therefore, not expected to be a problem among the alternatives. Higher flows tend to create more problems with ice, especially when the flows are transitioning from a lower flow to a higher flow.

Transitioning is a problem in two situations. The first is when ice initially forms but does not completely cross the channel. The movement of pieces of ice in the channel can be impeded, which allows the ice to agglomerate and form an ice bridge across the channel that may restrict flows. Flooding can also be a problem if an ice bridge is too restrictive and does not break up. The second transitioning problem occurs once the ice has completely covered the channel. In such cases, the ice-covered channel may have a limited capacity that prevents an increase of flows. Differences among the alternatives that affect these two transitioning situations are not anticipated.

Table 7.3-1. Erosion study conclusions on erosion and deposition of channel features, additional stabilization, and operational changes.

Feature	Downstream of Fort Peck Lake	Downstream of Lake Sakakawea	Downstream of Lake Francis Case	Downstream of Lewis & Clark Lake
Bank Erosion	Rate of bank erosion in all of the reaches is declining with time. Trends are indicating that not all the banks are stable. Eroded material is entrained into the alluvial processes to build sandbars and channel border fills, but eroded material no longer builds high bank land.			
Bed Erosion	Approaching equilibrium	Approaching equilibrium	Still in adjustment phase	Factors from both ends of reach keep this reach most active.
Turbidity	Not analyzed	No correlation with flow	Not analyzed	No correlation with flow
Island Size	Not related to flow	Indirectly related	Directly related	Directly related
Sand Bar Size	Not related to flow	Indirectly related	Directly related	Directly related
Chutes/Border Fills	Discussion of these features was limited to changes with time and other channel feature changes and not related to flow.			
Downstream Lake Storage Losses	10 percent from the banks	6 percent from the banks 7 percent from the bed	20 percent from the banks	No downstream lake
Comparison of the CWCP Versus the Past Preferred Alternative of the DEIS	The average channel velocities of the two plans are essentially identical; therefore, no significant difference in bank and channel bed erosion is expected even though annual variations in the hydrographs are significant. Annual sediment yields will be about the same. There should be no impact on the turbidity in the water. There should be no significant impact on islands, sandbars, and chutes.			

7.4 WATER QUALITY

7.4.1 Water Quality in the Lakes of the Mainstem Reservoir System

An impact analysis was conducted for the CWCP, the MCP, and the four GP options to determine potential impacts to mainstem lake water quality. Based on this analysis, the water quality assessment for the alternatives discussed in this chapter is presented in Table 7.4-1. The table provides a detailed description of the potential water quality impacts under the CWCP, the qualitative effects of the MCP and the four GP options, the rationale for the conclusion regarding the potential effects, and non-operational impact reduction activities. The qualitative effects of the five alternatives are presented in a progressive manner: effects of a change from the CWCP to the MCP, effects of a change from the MCP to the GP1528 option, and effects of a change from the GP1528 option to the other GP options.

Compared to the CWCP, the MCP improves water quality in the mainstem lakes. The increase in water conservation during droughts within the mainstem lakes reduces the fluctuations in lake level and volume. This additional water storage increases aquatic coldwater habitat and aids in the lakes' ability to avoid eutrophic conditions.

Water quality in the mainstem lakes improves under the GP1528 option, the GP option with the lowest spring rise and the highest summer flows. Under this option, the lower summer release causes the lakes to be held at slightly higher levels through the mid-summer and fall timeframe, which slightly improves and protects coldwater fish habitat in the months when coldwater habitat may be lowest. There is also greater protection against developing eutrophic conditions by having more water in storage to dilute nutrient loading from tributaries.

To provide a perspective for how water quality could change in the future if changes are made under the GP1528 option, the following describes the lake water quality changes for the other GP options relative to the GP1528 option, the GP option with the lowest spring rise and the highest summer flows. The GP2021 option has a lower summer release, the 25/21-kcfs split summer release, from Gavins Point Dam. This improves lake water quality over the GP1528 option by another, slightly greater, increase in lake levels in the latter half of the summer and fall months. This water quality improvement occurs within the three upper lakes in the Mainstem Reservoir System. With the same summer flow of the 25/21-kcfs split from Gavins Point Dam, a slight water quality improvement over the GP1528 option is obtained through slightly higher lake levels. With a change in only the spring rise amount from 15 kcfs to 20 kcfs, as with the GP2028 option, no additional improvement in water quality is expected in the mainstem lakes over the GP1528 option.

7.4.2 Water Quality in the River Reaches of the Missouri River

An impact analysis was conducted for the CWCP, the MCP, and the four GP options to determine potential water quality impacts to the river reaches downstream of the mainstem dams. Based on this analysis, the water quality assessment for the alternatives discussed in this chapter is presented in Table 7.4-2. This table provides a detailed description of the potential water quality impacts under the CWCP, the qualitative effects of the MCP and the four GP options, the rationale for the potential conclusion regarding the effect, and non-operational impact reduction activities. Again, the effects will be presented in a progressive manner, as they were for the lake water quality.

Compared to the CWCP, the MCP improves water quality conditions downstream of Fort Peck Dam. The MCP has a release, via the spillway, that will be used to move warmer water from the surface of the lake into the Missouri River. This spillway water mixes with the powerplant's colder water to increase the water temperature downstream from the spillway. The spillway and powerplant releases meet about 6 miles downstream from the dam.

Table 7.4-1. Water quality effects of the alternatives on the Missouri River mainstem lakes.[1/] Page 1 of 3

Potential Impact	Description	Lake	Incr. Effects CWCP-MCP-GP1528-others MCP	GP1528	GP2021	GP1521	GP2028	Rationale for Effect	Impact Reduction
Arsenic concentrations may increase in water column, exceeding Tribal and State water quality standard for domestic drinking water and aquatic life.	Arsenic from the Missouri River basin (natural background and nonpoint sources) becomes adsorbed onto solids entering and being deposited in the lake. The wave action erodes and agitates the lake sediments during low lake levels, potentially causing elevated dissolved arsenic concentrations in the water column. Elevated arsenic concentrations during low lake elevations and drought conditions may affect domestic water usage (requiring additional treatment prior to domestic use) and cause chronic effects to aquatic life in lakes.	All	NC	NC	NC	NC	NC	Adverse effects are greatest during droughts when lakes are drawn down and bottom sediments are exposed to erosive effects of waves on the lakes. The alternatives generally have lower or higher lake levels than the CWCP during droughts and, no matter what the alternative is, the lake levels will expose sediments containing adsorbed arsenic.	Sediments with arsenic are already deposited in the lakes from background, point and nonpoint sources. Accumulation of additional arsenic in the top layers of deposited sediments can be reduced if the arsenic can be stopped at the source. Domestic water systems should test for arsenic, metals, and other pollutants to ensure water supplies are protective of human health.
There may be an increase in exposure of fish to sediment containing mercury, pesticides, and other toxic pollutants that will accumulate in fish tissue.	Consumption advisories have been issued for fish caught in the Missouri River mainstem lakes in Montana, North Dakota, South Dakota, and Nebraska. Montana suggests limiting the consumption of walleye, northern pike, lake trout, and Chinook salmon due to elevated levels of mercury. In North Dakota, all species and size of fish tested were found to contain mercury. Elevated levels of PCBs and dieldrin in channel catfish taken from the river were found in Nebraska.	All	NC	NC	NC	NC	NC	The lakes receive sediment, metals, nutrients, pesticides, and other pollutants from upstream watershed areas. Lakes are sediment sinks that contain adsorbed metals and pollutants that can be in high concentrations. Chemical dynamics between the sediment and water column will continue to expose aquatic life to metals and pollutants. The flow regimes of the alternatives relative to the CWCP will have no effect on the overall exposure and biological uptake of these pollutants by fish in the lakes.	The EPA should work with Tribes, States, and other entities to establish an integrated monitoring program to assess increased bioaccumulation of toxic pollutants in lakes. As part of the Missouri River adaptive management process, bioaccumulation of metals and pesticides should be addressed based upon reliable water quality and fish monitoring data. Action needs to be taken in the watershed to reduce point and nonpoint sources of pollutants that bioaccumulate in fish tissue.

Table 7.4-1. Water quality effects of the alternatives on the Missouri River mainstem lakes. [1/] Page 2 of 3

Potential Impact	Description	Lake	Incr. Effects CWCP-MCP-GP1528-others MCP	GP1528	GP2021	GP1521	GP2028	Rationale for Effect	Impact Reduction
Severe fluctuations in lake elevations in Fort Peck Lake, Lake Sakakawea, and Lake Oahe may affect the size and quality of coldwater fish habitat.	Reduction in coldwater habitat in lower portions of lakes occurs in Fort Peck Lake, Lake Oahe, and Lake Sakakawea. The low lake volume in combination with warmwater temperatures can decrease the dissolved oxygen concentrations below State water quality standards. The hypolimnion during summer stratification conditions can offer limited habitat area for coldwater fish species that require dissolved oxygen greater that 5 mg/L and a water temperatures less than 10°C.	FPL, SAK, OAHE	+	+	+	+	NC	The (+) for the MCP means a positive impact to the Missouri River relative to the CWCP. Aquatic habitat models indicate an improvement in coldwater fish habitat due to increased drought conservation measures (see Section 7.7.2). The (+) for GP1528 reflects additional improvement in aquatic habitat relative to the MCP by additional conservation measures due to the lower summer flows. The (+) for the GP2021 and GP1521 options indicates even greater annual summer conservation measures with Gavins Point Dam releases. NC for the remaining option GP2028 means there is no additional improvement to the lake fluctuations relative to option GP1528.	As part of the Missouri River adaptive management process, the Corps, Tribes, States, and EPA should evaluate the relationship between coldwater habitat and water quality to lake elevations based upon reliable water quality monitoring data.
Low lake levels contribute to the development of eutrophic conditions (nutrient enrichment) in the lakes.	Nutrient concentrations in lakes may increase due to reduced lake volumes in extended droughts that provide less dilution to nutrient loads under normal conditions. This reduced level condition would provide less dilution to nutrient loads. Nutrient and metal releases from anoxic conditions may occur. The decomposition of organic matter may decrease available dissolved oxygen concentrations in the hypolimnetic region of the lake. Blue green algae blooms can also cause aesthetic and water quality problems.	All	+	+	+	+	NC	The (+) for the MCP means a positive impact to the Missouri River relative to the CWCP. Additional conservation initially increases the volume of water in the lakes and slows down the severe drops in lake elevations in the drought periods. The (+) for GP1528 reflects additional annual summer conservation, and higher lake levels and more lake volumes to dilute nutrient loading. Additional conservation with the lowest summer release from Gavins Point Dam for the GP2021 and GP1521 options indicates a (+) change for the GP1528 option. NC for GP2028 means there is no additional improvement towards reducing lake eutrophication relative to the GP1528 option.	Reduce nutrient loading from point and nonpoint sources within the watersheds. Under the adaptive management strategy, the Corps Tribes, States, and EPA should review potential water quality concerns referencing water quality monitoring data specific to eutrophic conditions.

Table 7.4-1. Water quality effects of the alternatives on the Missouri River mainstem lakes. [1/]

			Incr. Effects CWCP-MCP-GP1528-others						
Potential Impact	**Description**	**Lake**	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**	**Rationale for Effect**	**Impact Reduction**
Missouri River flows will transport and deposit large amounts of sediment, causing more problems in achieving narrative sediment standards.	Narrative water quality standards for sediment (siltation) are being exceeded in lakes (Sharpe, Oahe, Francis Case and Lewis and Clark Lakes). Siltation and sediment accumulation that is affecting the designated uses is the reason for lake impairment.	SRP, LFC, OAHE, LC	NC	NC	NC	NC	NC	Sediment erosion, transport, and deposition are normal processes when operating dams systems. The dam system developed on the Missouri River has resulted in less total suspended solid loading throughout the river system than under natural conditions. The total amount of sediment loading will not be affected by the alternatives' spring and summer flow regimes in the river. High sediment loading into lakes comes from tributaries within watersheds with highly erodible soils. Tributaries with high sediment loading into the mainstem lakes include the Bad River (Lake Sharpe), the White River (Francis Case Lake), the Niobrara River (Lewis and Clark Lake), and the Cheyenne River Arm (Lake Oahe).	Control sediment loading through source control in the watersheds. Implement nonpoint and stormwater control practices such as the Section 319 Project on the Bad River. Erosion control studies that involve both structural controls and best management practices are needed to reduce high sediment loading.

1/ Legend for abbreviations used in table:
- (+) means positive improvement to the environment
- NC means no change
- (-) means negative impact to environment
- All - All lakes in Missouri River Mainstem System
- FPL - Fort Peck Lake
- SAK - Lake Sakakawea
- OAHE - Lake Oahe
- SRP - Lake Sharpe
- LFC - Lake Francis Case Lake
- LC - Lewis and Clark Lake

Table 7.4-2. Water quality effects of the alternatives on the river segments of the Missouri River.[1/]

Potential Impact	Description	River Reach	Incr. Effects CWCP-MCP-GP1528-others					Rationale for Effect	Impact Reduction
			MCP	GP1528	GP2021	GP1521	GP2028		
Water discharged from dams causes channel alterations via bank and channel cuts that affect aquatic life habitat.	Dam discharges are considered to be aggressive since they are not in equilibrium with the receiving water sediment conditions, causing sediment erosion downstream. Erosion of river banks and channels near the dam discharge location can also be influenced by discharge velocity, channel morphology, and soil erosion potential. Erosion scours the river bed, which impacts benthic aquatic life and lowers the elevation of the river bed. The lowering of the river bed elevation in turn lowers the local groundwater table, which affects vegetation and side channels.	Downstream of Fort Peck Dam	NC	NC	NC	NC	NC	No change is expected relative to the CWCP. Analyses of the erosion potential among the alternatives have determined that there will be no net effect on the erosion process downstream from Fort Peck Dam.. Similarly, no net effect is anticipated across from the spillway compared to what may have occurred had the releases been made solely from the powerhouses 6 miles upstream.	Pilot testing will be performed by the Corps to assess potential erosion problems using the spillway for thermal mixing downstream. Portions of the stream bank areas being eroded by the high velocity spillway discharges may be stabilized using best management practices for erosion control.
Releases of cold water at Fort Peck, Garrison, and Oahe Dams may affect downstream habitat by not meeting thermal water quality standards.	Discharge water from dams introduces cold hypolimnetic water downstream. Coldwater releases into designated warmwater habitats have negatively affected aquatic life downstream until temperature equilibrium conditions are restored.	Downstream of Fort Peck Dam	+	NC	NC	NC	NC	The (+) for the MCP means a positive impact to the aquatic environment. The MCP has a dam release that will be used to discharge warmer water from the lake into the Missouri River via the spillway. Mixing with water released from the powerhouse will increase water temperatures downstream. The NC means that the other options also contain this spillway release activity and there is no change relative to the MCP.	Construction of a selective withdrawal structure through which releases could be taken from optimum lake depths will improve thermal problems downstream. Use of spillway discharge from Fort Peck Dam will allow mixing of the warmer surface water with the cold bottom release water in order to comply with and maintain thermal standards. The TMDL study being performed by the State of Montana, EPA, and the Fort Peck Tribe will review and assess alternatives to achieve water quality standards below Fort Peck Dam.
	North and South Dakota have not identified that coldwater releases from Garrison and Oahe contribute to water quality problems.	Downstream of Garrison and Oahe Dams	NC	NC	NC	NC	NC	Garrison and Oahe Dam releases are not significantly affected by the alternatives.	N/A

Table 7.4-2. Water quality effects of the alternatives on the river segments of the Missouri River.[1/]

Potential Impact	Description	River Reach	Incr. Effects CWCP-MCP-GP1528-others MCP	GP1528	GP2021	GP1521	GP2028	Rationale for Effect	Impact Reduction
Flow regime changes from Gavins Point Dam will affect downstream NPDES permits for thermal discharges.	Lower flow conditions, especially during summer and drought conditions, may affect critical low-flow assumptions (7Q10) in permits. Change in flow regimes may cause temperature violations for powerplants using water for once-through cooling. Reduced flows in the Missouri River could cause some river segments to not meet thermal water quality standards.	Downstream of Gavins Point Dam to the Mississippi River	NC	NC	-	-	NC	Relative to the CWCP, the MCP will have no change. Downstream discharges from Gavins Point Dam are similar. GP1528 has a lower summer discharge that the MCP, but not enough to impact downstream thermal conditions. The (-) for GP2021 and GP1521 reflects a more reduced summer flow (21 kcfs) than the MCP and GP1528. Downstream thermal impacts may occur for flows less than 25 kcfs at Gavins Point Dam. GP2028 has summer releases similar to GP1528 and no change is expected.	States will enforce NPDES permit conditions for thermal discharges. Renewed NPDES permits may need to be changed due to the change in flow regimes from Gavins Point Dam. Powerplants may need to consider using cooling ponds or towers to reduce thermal discharges into the river. Powerplants may have to reduce power generation capabilities when discharges at Gavins Point Dam are 21 kcfs. EPA is studying thermal discharges and verifying mixing zone calculation assumptions on the Missouri River.
Flow regime changes from Gavins Point Dam will affect downstream NPDES permits for industrial and Publicly Owned Treatment Works (POTW) dischargers.	Low summer flow conditions and drought conditions, may affect critical low-flow assumptions and calculations in NPDES permits. Flows used to determine chronic effluent discharge limits (7Q10) and acute discharge limits (1Q10) may change. With less dilution available, water quality-based NPDES permit limits may have to be reduced.	Downstream of Gavins Point Dam to the Mississippi River	NC	NC	NC	NC	NC	NC means that there will be no change relative to the CWCP. Studies have indicated that above 9 kcfs adequate flows exist for NPDES 7Q10 flows. Historically, flows below 9 kcfs at Gavins Point Dam occurred during the drought years. No water quality problems associated with NPDES permits or water quality impacts were reported to the Corps.	N/A
Changing flow regimes will affect waters designated as outstanding water resources (Tier III Anti-degradation)	Low-flow conditions may affect Missouri River segments designated as "outstanding waters" in Nebraska and Iowa due to sediment erosion and deposition and elevated pollutant concentrations. According to the Clean Water Act, the water quality of outstanding waters must be maintained and protected. No water quality degradation can occur.	Iowa-Missouri state line to Big Sioux confluence, and Nebraska from Nebraska-South Dakota state line to Niobrara River and from Niobrara River to Big Sioux River	NC	NC	NC	NC	NC	The alternatives have a spring flow ranging from 34.5 to 54.5 kcfs and a summer flow range of 21 to 34.5 kcfs. These flows are well within the range of flows that have occurred under the CWCP. No water quality degradation has occurred in these outstanding water resources under the CWCP. No change in the condition of outstanding water resources is expected.	No water quality impacts expected. The Missouri River adaptive management process should be used to ensure that designated high quality water resources will not be negatively affected.

Table 7.4-2. Water quality effects of the alternatives on the river segments of the Missouri River.[1/] Page 3 of 4

Potential Impact	Description	River Reach	Incr. Effects CWCP-MCP-GP1528-others					Rationale for Effect	Impact Reduction
			MCP	GP1528	GP2021	GP1521	GP2028		
Low-flow conditions may make portions of the river unsuitable for domestic drinking water uses.	Low-flow conditions of the Missouri River may provide less dilution to tributary loading of pollutants. Higher concentrations of pollutants may be realized in isolated stream reaches, exceeding domestic drinking water standards.	Downstream of Gavins Point Dam to Mississippi River	NC	NC	NC	NC	NC	Low-flow studies performed by the Corps conclude that the critical flow from Gavins Point Dam that will affect drinking water quality is 9 kcfs. Alternative flows are well above this critical flow value. No change in water quality is expected.	No water quality concerns expected. The Missouri River adaptive management process should be used to assess the river water quality and operational changes necessary to ensure that impairment to drinking water resources will not occur in the Missouri River.
Low-flow conditions may cause portions of the river to exceed water quality standards for recreation and aquatic life uses.	During low-flow conditions, less dilution may be available to the river to reduce pollutant concentrations in the Missouri River. Pollutant loading may be from tributaries, overland runoff, stormwater drainage from urban areas, combined sewer overflows, and wastewater by-passing. Water quality criteria for aquatic life (chronic) and recreation standards may be exceeded, especially near tributaries and urban areas. Metal, nutrient, pathogen, and basic water quality criteria may be exceeded periodically.	Downstream of Gavins Point Dam to the Mississippi River	NC	-	-	-	NC	Reductions in summer flows are most critical. The MCP flows are the same as the CWCP; therefore, no change is expected. GP1528 has a lower summer flow than the MCP, thus providing less dilution to downstream pollutant sources. There is a lack of available information to determine the critical summer releases from Gavins Point Dam that could cause an aquatic life criteria to be exceeded below flows of 25 kcfs. It seems possible that lower Missouri River flows in combination with lower tributary flows could create conditions that cause aquatic life criteria to be temporarily exceeded. GP2021 and GP1521 have lower summer flows than GP1528 and have a higher potential of causing aquatic life criteria to be exceeded. GP2028 and GP1528 summer flows are similar and no change is expected. During the last drought, no water quality problems were reported to the Corps.	The Missouri River adaptive management process should review monitoring data collected on the Missouri River to determine if water quality problems occur during low summer flow and drought conditions. Water quality studies to address this critical flow issue should be designed and executed by the Tribes, States, EPA, and the Corps. Modeling studies can be performed to estimate critical flow in order to maintain water quality standards. Modeling studies need to be verified by water quality monitoring and analysis.

Table 7.4-2. Water quality effects of the alternatives on the river segments of the Missouri River.[1/]

Potential Impact	Description	River Reach	Incr. Effects CWCP-MCP-GP1528-others					Rationale for Effect	Impact Reduction
			MCP	GP1528	GP2021	GP1521	GP2028		
Pollutant loading from the Missouri River basin into the Mississippi River contributes to the Gulf of Mexico's hypoxia condition.	Nonpoint sources such as nutrients, pesticides, metals, and sediment from the Missouri River basin are discharged into the Missouri River. The combination of the nutrient and organic chemical loading from both the Mississippi River and Missouri River basins cause extremely poor water quality conditions in the Gulf of Mexico (low dissolved oxygen, eutrophic conditions, and toxic metal concentrations).	Confluence with the Mississippi River to the Gulf of Mexico	NC	NC	NC	NC	NC	The alternatives will have no effect on the hypoxic conditions in the Gulf of Mexico. Essentially, the same amount of water and mass loading of chemical constituents will be released at Gavin Point Dam on an annual basis relative to the CWCP.	Nonpoint source pollution needs to be controlled at the source within watersheds. Best management practices need to be implemented to control pollutant runoff into surface waters.
Releases from dams may exceed the National standard of 110% saturation for total dissolved gases.	Waters being discharged from dams can become aerated to the extent that supersaturation of gases, especially nitrogen, can occur. States have not listed total dissolved gases as a cause of water quality impairment.	Immediately downstream of Fort Peck and Gavins Point Dams	-	-	NC	NC	NC	It is possible that aeration will occur during spring rise discharges over spillways, which can lead to high total dissolved gases. The CWCP has fewer operational spillway discharges. The (-) for the MCP means that spillway discharges that will occur at Fort Peck Dam have the potential of increasing total dissolved gas concentrations. In relation to the MCP, GP1528 will have spillway discharges from both Fort Peck Dam and Gavins Point Dam. High concentrations of dissolved gases are harmful to fish; therefore, a negative (-) impact is shown. The GP2021, GP1521, and GP2028 options have the same spillway discharge activity as GP1528; therefore, no change is expected.	As part of the Missouri River adaptive management process, the Corps should monitor dissolved gas concentrations during spillway discharge conditions. No water quality problems have been observed by the Corps from spillway discharges at Gavins Point Dam.

1/ Legend for abbreviations used in table:
NC means no change relative to the CWCP
(+) means positive change or improved impact to environment
(-) means negative impact to environment

Negative effects on water quality downstream of Fort Peck Dam under this alternative may include an increase in the total dissolved gas concentration in the water as the spillway releases enter the river downstream of the spillway.

Water quality in the Missouri River decreases under the GP1528 option, the GP option with the lowest spring rise and the highest summer flows, when the 15-kcfs spring rise and the minimum navigation service flat release at Gavins Point Dam are added to the MCP.

Under the GP1528 option, the summer flows at Gavins Point Dam are lower than the MCP flows. This provides less downstream dilution of point and nonpoint pollutants. This lack of dilution may periodically affect aquatic life and recreational use water quality. The GP1528 option includes spillway discharges from both Fort Peck Dam and Gavins Point Dam during the spring rise releases. This leads to the possibility of exceeding the National standard for total dissolved gas concentrations.

To provide a perspective for how water quality could change in the future if changes are made to the GP1528 option, the following describes the downstream reach water quality changes relative to the GP1528 option. The GP2021 option has the 20-kcfs spring rise above full service navigation and 25/21-kcfs split summer release from Gavins Point Dam. The reduced summer release discharge relative to that of the GP1528 option causes less dilution of pollutants entering the river. Summer low-flow conditions may negatively affect aquatic life and recreational uses due to a loss of pollutant dilution and may require reduced powerplant thermal discharges to the river. The effects of a change to the GP1521 option are similar because the summer low flows are similar under both GP options. With a change in only the spring rise amount from 15 kcfs to 20 kcfs, as with the GP2028 option, no change in water quality is expected in the Missouri River relative to the GP1528 option.

7.4.3 Water Quality for Tribal Reservations

There are numerous beneficial uses for the Missouri River designated by the Tribes, EPA, and the States. These designated uses include coldwater and warmwater aquatic life, domestic drinking water, recreation, agriculture, and industrial uses. Tribes have reserved water rights to the Missouri River and are actively involved with managing their water resources.

Compared to the CWCP, the MCP with its spring rise provides some improvement to water quality in the Fort Peck reach in some years. The MCP provides an increase in conservation within the upper three mainstem lakes that reduces the fluctuations in lake levels and volume. The MCP provides no change to water quality in the Lower River compared to the CWCP.

The four GP options (GP1528, GP2021, GP1521, and GP2028) have the same drought conservation measures as the MCP; however, they have spring rise and lower summer flows than the MCP. They also have Fort Peck Dam spring rise releases. These four options have implications on water quality for both the lakes and river reaches that are adjacent to Tribal Reservations along the Mainstem Reservoir System and the Lower River. The four GP options have different impacts to individual Reservations, depending upon the location within the Missouri River. The lower summer releases from Gavins Point Dam cause more water to be retained in the lakes during the mid-summer through fall period. The drought conservation measures are most beneficial for Reservations that are adjacent to the major lakes (Fort Peck Lake, Lake Sakakawea, and Lake Oahe).

The Missouri River downstream from Fort Peck Dam and adjacent to Fort Peck Reservation is designated for the following uses: domestic drinking water, recreation, agriculture, and industry. The two Missouri River water quality issues related to Fort Peck Reservation are coldwater releases and erosion of sediment into the river. The MCP and the four GP options have a spring rise discharge from Fort Peck Dam. Water released from the dam is mixed with warmer water released from the spillway, raising the downstream water temperature for the native river fish. Local residents are concerned about increased erosion in the spring, but the Corps' studies indicate that long-term erosion should be similar for alternatives with or without the spring rise.

Water quality concerns for Fort Berthold Reservation are dependent upon the conditions of Lake Sakakawea. Lake Sakakawea water quality concerns include suspension of metals, uptake of these metals by fish, nutrient loading leading to eutrophication, and loss of coldwater habitat for some lake fish species. The MCP and the four GP options have increased drought conservation measures and lower releases from the system during the summer. Limiting the decline of the lake level in droughts through increased drought conservation maintains greater amounts of coldwater habitat and provides greater volumes of water in the lakes to dilute nutrient loads and reduce eutrophication. The lower summer releases from Gavins Point Dam also slightly reduce the drawdown of the lake in non-drought periods, which should also slightly reduce these water quality concerns. Neither the MCP nor the four GP options limit the suspension of metals into the water column and the accumulation of metals and other toxic elements in fish tissue in Lake Sakakawea.

Standing Rock Reservation and Cheyenne River Reservation are located on Lake Oahe. This lake shares the same water quality issues as Lake Sakakawea. The MCP and the four GP options improve the water quality conditions by increased water conservation during droughts. The eutrophication and coldwater habitat effects are reduced during droughts under these alternatives. Lake Oahe is also held at slightly higher level from the mid-summer through the fall, which should also slightly help these water quality concerns in non-drought periods. None of the alternatives limits the suspension of metals into the water column and the accumulation of metals and other toxic elements in fish tissue in Lake Oahe.

Lower Brule Reservation and Crow Creek Reservation are located on Lake Sharpe. Water quality concerns within this lake include metals, nutrient loading, and accumulated sediment. The MCP and the four GP options provide no water quality changes to this area because water levels on Lake Sharpe are controlled at a relatively consistent level under the CWCP, the MCP, and the GP options. Tributaries into Lake Sharpe are the major source of metals, sediments, and nutrients coming from both point and nonpoint sources.

Yankton Reservation is located primarily on Lake Francis Case. This lake has water quality concerns including bioaccumulation of metals in fish tissue, accumulated sediment, nutrient loading leading to potential eutrophication, and siltation. The MCP and the four GP options have no water quality effects on Lake Francis Case because the lake is maintained at comparable elevations for the CWCP, the MCP, and the GP options. Tributaries carrying high sediment, nutrient, and metal loads from highly erodible watersheds heavily influence the water quality of Lake Francis Case.

Ponca Tribal Lands and Santee Reservation are located adjacent to the headwaters of Lewis and Clark Lake. Water quality concerns include bioaccumulation of metals in fish tissue, accumulated sediment, and nutrient loading. No differences in lake levels are expected among the CWCP, the MCP, and the four GP options; therefore, no differences in the water quality issues are expected. Tributaries carrying high sediment, nutrient, and metal loads from highly erodible watersheds heavily influence the water quality of Lewis and Clark Lake.

There are several Reservations located on the Missouri River downstream from Sioux City, including Winnebago, Omaha, Iowa, and Sac and Fox Reservations. The water quality issues in this river reach include National Pollutant Discharge Elimination System (NPDES) permit discharge requirements, thermal discharges, designation of the reach adjacent to Omaha Reservation and Winnebago Reservation by the State of Iowa as an outstanding water resource, drinking water degradation, and water quality standards for recreation and aquatic life issues. The alternatives with lower summer flows, the four GP options, may adversely affect all of these issues, especially the GP1521 and GP2021 options with their lowest summer release of 21 kcfs from mid-July to mid-August.

7.5 WETLAND AND RIPARIAN HABITAT

This section focuses on the differences in the impacts of the CWCP, the MCP, and the four GP options on wetland and riparian habitat along the Mainstem Reservoir System and in seven Tribal Reservations areas. Analysis of the changes in these two habitat types is based on the inventory of habitat at 42 representative sites along the Mainstem Reservoir System and the Lower River. Vegetation changes in these sites respond to water surface elevations adjacent to and in the 42 sites.

Because the total acreage is constant and is composed of wetland vegetation types, riparian vegetation types, and water, an increase in wetland vegetation generally results in a decrease in riparian vegetation. A complete inventory of wetland and riparian habitat found along the Missouri River is contained in a technical report, Environmental Studies–Wetland and Riparian Habitat (Corps, 1994o; Corps, 1994p).

7.5.1 Wetland Habitat

Table 7.5-1 presents the total and reach breakdown of the average annual wetland habitat for the CWCP, the MCP, and the four GP options during the full 100-year period of analysis at the 42 sites analyzed. The total data are also presented in graphic form in Figure 7.5-1. The CWCP provides 156,100 acres of habitat on an average annual basis. This total acreage at the sites analyzed is distributed among the lake deltas (22.5 percent), Upper River sites (28.3 percent), and Lower River sites (49.2 percent). The MCP and the four GP options shown in Table 7.5-1 provide between 0.8 and 1.5 percent more total annual wetland habitat than the CWCP. Compared to the CWCP, the MCP and the four GP options would decrease wetland habitat in the lake deltas and increase wetland habitat in the Upper and Lower Rivers.

Figure 7.5-1 graphically shows that there are three separate groupings of total average annual wetland habitat values. The CWCP has the lowest total wetland habitat value at 156,100 acres. The MCP and the GP1528 option, the GP option with the lowest spring rise and the highest summer flows, are closely grouped together between 157,400 and 157,500 acres, and the three remaining GP options are more closely aligned between 158,400 and 158,500 acres. Both of these groupings differ by only 100 acres. The CWCP has 1,300 acres less wetland habitat than the bottom end of the range for the MCP and the four GP options, providing the least amount of total annual wetland habitat. The CWCP provides the least amount of wetland habitat within the Upper and Lower Rivers, but the most wetland habitat within the lake deltas. Figure 7.5-1 also shows the values for the submitted alternatives discussed in Chapter 5 to provide perspective as to how the GP options perform relative to the submitted alternatives. The GP1528 option provides total wetland habitat amounts that are closest to both the MODC and FWS30 alternatives. These two submitted alternatives are similar to the GP options in that intrasystem regulation among the upper three lakes is unbalanced, all have a Fort Peck spring rise, and conservation in the upper three lakes is increased to the same level. The FWS30 alternative has a

Table 7.5-1. Average annual wetland habitat (thousands of acres).1/

	1898 to 1997			
Alternative	**Total**	**Lake Deltas**	**Upper River**	**Lower River**
CWCP	**156.1**	35.1	44.2	76.8
MCP	**157.4**	33.1	47.2	77.1
GP1528	**157.5**	30.5	47.5	79.6
GP2021	**158.4**	32.6	47.5	78.3
GP1521	**158.5**	32.4	46.7	79.3
GP2028	**158.4**	30.8	47.8	79.9

1/ Based on 42 representative sites.

30-kcfs spring rise and a split navigation season while the MODC alternative has neither of these features but extends the full service navigation flat release (34.5 kcfs) to mid-September.

Both the CWCP and the MCP have no additional spring rise, and the summer release at Gavins Point Dam is flat (34.5 kcfs). The primary differences between these two alternatives are that the intrasystem regulation among the upper three lakes is unbalanced and drought conservation is greater for the MCP. These two differences result in a 0.8 percent increase in total wetland vegetation acres along the Mainstem Reservoir System and Lower River. Compared to the CWCP, there is a 5.7 percent reduction in wetland habitat in the lake deltas and a 6.8 percent increase in wetland habitat along the Upper River. Only a 0.4 percent increase in wetland habitat would occur along the Lower River.

The GP1528 option has a 15-kcfs spring rise unless downstream flood control constraints are exceeded. The summer release under this option is flat (28.5 kcfs) from Gavins Point Dam and represents a 6-kcfs decrease in summer release when compared to the MCP. The total increase in wetland habitat under the GP1528 option is 0.1 percent over the MCP. The greatest change in wetland habitat occurs under the GP1528 option in the lake deltas, where wetland habitat would decline by 7.9 percent. Compared to the remaining three GP options, this represents the greatest decrease in wetland habitat within this reach. The GP1528 option increases wetland habitat over the MCP by 0.6 and 3.2 percent along the Upper and Lower Rivers, respectively.

The GP2021, GP1521, and GP2028 options described below provide perspective for how habitat could change in the future if changes are made from the GP1528 option, the GP option with the lowest spring rise and the highest summer flows. The GP2021 option has a 20-kcfs spring rise that occurs once every 3 years on average and a summer release that is split between 25 and 21 kcfs from Gavins Point Dam. This change from the GP1528 option results in a 0.6 percent increase in total annual wetland habitat. The GP2021 option increases wetland habitat over the GP1528 option within the lake deltas by 6.9 percent but decreases this wetland habitat by 1.6 percent in the Lower River. Compared to the GP1528 option, there is no change in the amount of wetland habitat within the Upper River under the GP2021 option.

The GP1521 option has a 15-kcfs spring rise and a split 25/21-kcfs low summer flow from Gavins Point Dam. Since this option has a greater water savings measure during the summer, subsequent fall and April releases may be higher than the GP1528 option in wetter years. Under the GP1521 option, total annual wetland habitat increases by 0.6 percent. The GP1521 option increases wetland habitat within the lake deltas by 6.2 percent, while the Upper and Lower Rivers experiences 1.7 and 0.4 percent decreases in wetland habitat, respectively.

The GP2028 option has a 20-kcfs spring rise and a flat summer release of 28.5 kcfs that represents the minimum summer low flow for continued navigation service. Compared to the GP1528 option, this option increases the total annual wetland habitat by 0.6 percent. The greatest amount of variation from GP1528 under the GP2028 option occurs within the lake deltas, where wetland habitat increases by 1.0 percent. Wetland habitat increases occur in the Upper River (0.6 percent) and Lower River (0.4 percent) as well.

The annual values of total wetland vegetation acres for the CWCP, the MCP, and the four GP options are shown on Figures 7.5-2 through 7.5-4. All of the alternatives discussed in this chapter tend to respond to changes made during the 100-year period of analysis in a similar fashion. The average acreage of wetland habitat for the 42 sites throughout this period ranges between 150,000 and about 175,000 acres. During the early 1940s, there is a 2- to 3-year period when wetland habitat acreage is at its lowest (about 100,000 acres). Of the alternatives analyzed, the MCP and the GP2021 and GP1521 options show slightly higher wetland acres during this period. There is no set pattern in the rest of the 100-year period.

A change from the CWCP to the MCP improved wetland habitat in the 1909 to 1956 period. Changing from the MCP to the GP1528 option resulted in losses over much of that period, but provides larger wetland habitat acreages in primarily the 1964 to 1987 period. A switch to the other three GP options generally improves wetland habitat over the GP1528 option from about 1940 through the early 1990s. To conclusively identify the cause of the changes is not possible. Increased conservation and unbalancing the storage among the three upper lakes are primary causes, but the amount of the spring rise and the summer low flow are also factors.

Wetland Habitat For 10 Tribal Reservations

Table 7.5-2 presents the average annual wetland habitat under the alternatives for 10 Tribal Reservations during the full period from 1898 to 1997. The Reservations analyzed include those along the lake deltas (Standing Rock, Cheyenne River, and Santee Reservations and Ponca Tribal Lands), the Upper River (Fort Peck and Yankton Reservations), and the Lower River (Winnebago, Omaha, Iowa, and Sac and Fox Reservations).

Total wetland habitat associated with the analyzed sites adjacent to these Reservations equals 27,910 acres. The MCP is the only alternative that increases this wetland habitat (0.1 percent) over the CWCP. The four GP options decrease total wetland habitat: the GP1528 option by 4.4 percent, the GP2021 option by 3.7 percent, the GP1521 option by 3.5 percent, and the GP2028 option by 2.9 percent. The GP1528 option has an added 15-kcfs spring rise and reduces total wetland habitat associated with the Reservations the most. The GP2028 option, with its added 20-kcfs spring rise, reduces total wetland habitat the least. Both of these options have a minimum summer service level that is 6 kcfs less than the CWCP. These net changes from the CWCP result from a combination of positive and negative changes for individual Reservations.

The MCP is the only alternative that results in an increase in wetland habitat over the CWCP within Fort Peck Reservation (3.4 percent). The GP2028 and GP1521 options both reduce wetland habitat within Fort Peck Reservation by 6.5 and 7.8 percent, respectively. The third largest reduction in wetland habitat occurs under the GP2021 option (13.9 percent), and the GP1528 option shows the largest total percent reduction in wetland habitat of the four GP options (14.1 percent).

Within Standing Rock Reservation, the GP2021 option increases wetland habitat by 2.1 percent over the CWCP. All of the remaining alternatives discussed in this chapter decrease wetland habitat within this Reservation. The MCP reduces wetland habitat by 9.8 percent, while the GP1521 option decreases wetland habitat by 39.9 percent. Compared to the CWCP, the GP2028 and GP1528 options show the greatest reduction in wetland habitat within Standing Rock Reservation (59.4 and 61.5 percent, respectively).

Within Cheyenne River Reservation, the MCP and three of the GP options decrease wetland habitat from the CWCP, while the GP1521 option provides a 6.8 percent increase in wetland habitat. The GP2028 and GP1528 options reduce wetland habitat within Cheyenne River Reservation by the least amount (6.8 and 9.5 percent, respectively). The GP2021 option and the MCP reduce wetland habitat by the greatest amount (13.5 and 18.9 percent, respectively). The Cheyenne River Reservation has expressed concerns regarding the types of plant species that grow around the rim of Lake Oahe. Some of these species are considered noxious weeds, and the Reservation has to undertake measures to limit their spread and growth. The Tribe has expressed a specific concern that the unbalancing of the water stored in the upper three lakes may further encourage growth of these species.

The MCP and the four GP options provide an increase in wetland habitat over the CWCP within the Yankton Reservation. The GP2028, GP1528, and GP2021 options provide the greatest increases at 5.8, 5.3, and 5.1 percent, respectively. Lesser increases occur under both the GP1521 option (3.4 percent) and the MCP (1.2 percent).

Compared to the CWCP, the MCP and the four GP options decrease wetland habitat within Ponca Tribal Lands and Santee Reservation. The least amount of

Table 7.5-2. Average annual wetland habitat (thousands of acres) for 10 Tribal Reservations.[1/]

	1898 to 1997					
Reservation	**CWCP**	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Peck	4.75	4.91	4.08	4.09	4.38	4.44
Standing Rock	1.43	1.29	0.55	1.46	0.86	0.58
Cheyenne River	0.74	0.60	0.67	0.64	0.79	0.69
Yankton	4.14	4.19	4.36	4.35	4.28	4.38
Ponca and Santee	8.62	8.54	8.60	8.09	8.14	8.58
Winnebago and Omaha	4.31	4.43	4.23	4.18	4.31	4.23
Iowa and Sac and Fox	3.92	3.98	4.19	4.08	4.17	4.20
Total	**27.91**	**27.94**	**26.68**	**26.89**	**26.93**	**27.10**

1/ Based on appropriate representative sites.

wetland habitat reduction occurs under the GP1528 option (0.2 percent), followed by the GP2028 option (0.5 percent) and the MCP (0.9 percent). The greatest reductions in wetland habitat occur under the GP1521 option (5.6 percent) and the GP2021 option (6.1 percent).

Under the GP1521 option, there is no change in wetland habitat from the CWCP within Winnebago and Omaha Reservations. The MCP increases wetland habitat by 2.8 percent, while the remaining three GP options decrease wetland habitat. The least amount of wetland habitat reduction occurs under the GP1528 and GP2028 options; both of these options decrease wetland habitat by 1.9 percent. The greatest reduction in wetland habitat occurs under the GP2021 option (3.0 percent).

Compared to the CWCP, the MCP and the four GP options increase wetland habitat adjacent to the Iowa Reservation and the Sac and Fox Reservation. The GP2028 option increases wetland habitat the most (7.1 percent), while the GP1528 and GP1521 options provide lesser increases (6.9 and 6.4 percent, respectively). Of the four GP options, wetland habitat increases least under the GP2021 option (4.1 percent); however, the MCP provides the smallest percent increase in wetland habitat over the CWCP (1.5 percent).

7.5.2 Riparian Habitat

As discussed earlier, riparian habitat should vary indirectly with the values presented for the wetland habitat. The methodology for the analysis of riparian and wetland habitat changes is based on field surveys of existing wetland sites. All of the sites have vegetation types that could be classified as either wetland or riparian, and the methodology identified changes in the vegetation types with changes in water levels at the wetland sites. As water levels decline, wetland vegetation types are likely to be replaced with riparian vegetation types, and vice versa. The methodology does not identify expansion or contraction of the size of each site except for the conversion of vegetation to open water at extremely high water levels. This leads to the general conclusion that if there is an increase in wetland habitat there will be a corresponding decrease in riparian habitat.

Table 7.5-3 presents the total and reach breakdown of the average annual riparian habitat in the 42 representative sites for the CWCP, the MCP, and the four GP options during the full period from 1898 to 1997. These data are also presented in graphic form in Figure 7.5-5. The CWCP provides 108,100 acres of riparian habitat on an annual basis. This total acreage at the sites analyzed is distributed among the lake deltas (11.1 percent), Upper River sites (38.8 percent), and Lower River sites (50.1 percent). Compared to the CWCP, the MCP and the GP1528 option decrease total riparian habitat by 2.1 and 4.4 percent, respectively (see Table 7.5-3). Two of the three remaining GP options increase total riparian habitat by between 0.3 and 0.6 percent compared to the GP1528 option, while the third option decreases total riparian habitat by 0.8 percent.

Figure 7.5-5 graphically shows that there are three separate groupings of total average annual riparian habitat values. The CWCP has the highest total riparian habitat value at 108,100 acres. The next grouping includes only the MCP, which provides 2,300 acres (2.1 percent) less riparian habitat than the CWCP. The four GP options constitute the third grouping. Of the GP options, GP1521 reduces riparian habitat by the least amount (4,200 acres, or 3.9 percent less than the CWCP). The GP2028 option, the bottom end of the range of options, shows the greatest reduction in total riparian habitat (5,600 acres, or 5.2 percent less than the CWCP). Also shown in Figure 7.5-5 are the values for the submitted alternatives discussed in Chapter 5. As mentioned above, they are included to provide some perspective as to how the GP options perform relative to the submitted alternatives. The GP1528 option provides total riparian habitat amounts that are closest to the BIOP, FWS30, and ARNRC alternatives, which all have a spring rise followed by lower summer flows than the CWCP.

Both the CWCP and the MCP have no additional spring rise, and the summer service level release at Gavins Point Dam is flat at full service to navigation (modeled at 34.5 kcfs). The CWCP has a balanced intrasystem regulation among the upper three lakes, whereas the MCP is unbalanced, with greater conservation during the drought periods.

Also, the MCP's summer release remains higher throughout much of the drought periods than the CWCP. This results in a decrease in total riparian habitat of 2.1 percent compared to the CWCP. The greatest decrease in riparian habitat occurs in the Upper River (4.1 percent less riparian habitat

Table 7.5-3. Average annual riparian habitat (thousands of acres).[1/]

	1898 to 1997			
Alternative	**Total**	**Lake Deltas**	**Upper River**	**Lower River**
CWCP	**108.1**	12.0	41.9	54.1
MCP	**105.8**	11.7	40.2	53.8
GP1528	**103.3**	11.7	39.8	51.8
GP2021	**103.6**	11.4	39.9	52.3
GP1521	**103.9**	11.3	40.2	52.4
GP2028	**102.5**	11.7	39.5	51.3

1/ Based on 42 representative sites.

than the CWCP), while lesser amounts of riparian habitat decreases occur in the lake deltas (2.5 percent less) and Lower River (0.6 percent less).

The GP1528 option, the GP option with the lowest spring rise and the highest summer flows, with a 15-kcfs spring rise and flat summer release (28.5 kcfs) from Gavins Point Dam added to the MCP, provides 2.4 percent less total riparian habitat than the MCP. Under the GP1528 option, the greatest reduction in riparian habitat (3.7 percent) occurs in the Lower River. In addition, the GP1528 option decreases riparian habitat by 1.0 percent in the Upper River, although there are no change in riparian habitat from the MCP in the lake deltas.

The following discussion on the GP2021, GP1521, and GP2028 options provides some perspective for how riparian habitat could change relative to the GP1528 option. Most notable is that the remaining three options all show an inverse relationship between riparian and wetland habitats within the lake deltas, Upper River, and Lower River. For example, when riparian habitat is increased under a particular scenario, the corresponding wetland value decreases (see Section 7.5.1).

The changes from the GP1528 option, under the GP2021 option, include a 20-kcfs spring rise that occurs once every 3 years on average and a split summer release from Gavins Point Dam. This change results in a 0.3 percent increase in total annual riparian habitat within the Mainstem Reservoir System and Lower River. The GP2021 option decreases riparian habitat compared to the GP1528 option within the lake deltas by 2.6 percent, but increases this habitat by 0.3 and 1.0 percent in the Upper and Lower Rivers, respectively. The GP1521 option has a 15-kcfs spring rise, a split summer flow from Gavins Point Dam, and greater water savings measures during the summer. Under the GP1521 option, the total annual riparian habitat increases by 0.6 percent compared to the GP1528 option. The GP1521 option decreases riparian habitat within the lake deltas by 3.4 percent, while the Upper and Lower Rivers experience a 1.0 and 1.2 percent increase in riparian habitat, respectively. These values are higher than those associated with the GP2021 option, which indicates that a lower spring flow combined with a split summer flow provide more area for the establishment of riparian habitat.

The GP2028 option has a 20-kcfs spring rise and a flat summer release, representing the minimum navigation service summer low flow. Compared to the GP1528 option, this option decreases the total annual riparian habitat by 0.8 percent. There is no variation from the GP1528 option within the lake deltas. Riparian habitat declines in the Upper River (0.8 percent) and Lower River (1.0 percent).

The annual values of riparian vegetation acres for the CWCP, the MCP, and the four GP options are shown on Figures 7.5-6 through 7.5-8. Generally, the CWCP, the MCP, and the four GP options show a similar response to changes. The most significant increase in riparian habitat begins about 1940 and lasts for 3 years before there is a general downward trend in habitat. This is opposite from the results discussed for wetland habitat where, during this 3-year period, there is a significant decrease in wetland habitat. The GP1528 option reaches slightly higher amounts of riparian habitat during this 3-year period. Between 1913 and 1922, the GP2021 option shows slightly higher amounts of riparian habitat than the other options, whereas the CWCP tends to show higher riparian acres from about 1934 to 1976.

Riparian Habitat for 10 Tribal Reservations

Table 7.5-4 presents the average annual riparian habitat for those sites analyzed adjacent to the Reservations under the alternatives for 10 Tribal Reservations during the full period from 1898 to 1997. The Reservations analyzed include the lake delta Reservations (Standing Rock, Cheyenne, River, and Santee Reservations and Ponca Tribal Lands), the Upper River Reservations (Fort Peck and Yankton Reservations), and the Lower River Reservations (Winnebago, Omaha, Iowa, and Sac and Fox Reservations).

With the CWCP, total riparian habitat associated with these Reservations equals 20,120 acres. The MCP and the four GP options decrease total riparian habitat from that of the CWCP: the MCP by 0.5 percent, the GP1528 option by 2.0 percent, the GP2021 option by 3.9 percent, the GP1521 option by 2.9 percent, and the GP2028 option by 3.2 percent. The GP2021 option reduces total riparian habitat the most, and the MCP reduces total riparian habitat the least. Generally, Fort Peck Reservation has the most riparian habitat while Cheyenne River Reservation has the least amount of riparian habitat. As a result, the smallest and largest percentage differences from the CWCP occur within these respective Reservations. The Fort Peck Reservation has expressed its concern regarding the lack of cottonwood regeneration and has considered planting this species of trees to ensure an adequate population of these trees in the future.

Within Fort Peck Reservation, the MCP and the four GP options decrease riparian habitat from the CWCP by the same amount (0.2 percent). This is the only Reservation where this type of result would occur.

Compared to the CWCP, the greatest increase in riparian habitat within Standing Rock Reservation occurs under the GP1528 option (4.6 percent). Lesser increases occur under both the MCP (2.3 percent) and the GP2028 option (1.2 percent). The GP2021 option decrease riparian habitat the least (8.7 percent) and the GP1521 option reduce riparian habitat the most within Standing Rock Reservation (13.9 percent). Regeneration of cottonwoods is also a concern on this Reservation and at other locations along the lakes within the Mainstem Reservoir System. At times there are stands of cottonwoods that start to grow; however, higher lake levels cause these trees to die and suspend the regeneration process.

Within Cheyenne River Reservation, the MCP and the four GP options decrease riparian habitat from the CWCP. The MCP decrease riparian habitat by 11.1 percent. The greatest reduction in riparian habitat occur under the four GP options. The GP2021 option result in a 22.2 percent reduction in riparian habitat. Both the GP1521 and GP2028 options reduce riparian habitat by the same amount (27.8 percent), while the GP1528 option result in the largest decrease in riparian habitat from the CWCP (33.3 percent).

Within Yankton Reservation, the MCP and the four GP options decrease riparian habitat from the amount under the CWCP. The GP1521 option result in the least amount of riparian habitat reduction (0.9 percent), and the MCP reduces riparian habitat by 1.8 percent. The GP1528, GP2021, and GP2028 options all result in greater riparian habitat reductions from the amount under the CWCP (3.7, 4.1, and 4.6 percent, respectively).

The GP2021 and GP1521 options provide an increase in riparian habitat over the CWCP on Ponca Tribal Lands and Santee Reservation. Both of these options increase habitat over the CWCP by the same amount

Table 7.5-4. Average annual riparian habitat (thousands of acres) for 10 Tribal Reservations.[1/]

	1898 to 1997					
Reservation	**CWCP**	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Peck	5.55	5.54	5.54	5.54	5.54	5.54
Standing Rock	1.73	1.77	1.81	1.58	1.49	1.75
Cheyenne River	0.18	0.16	0.12	0.14	0.13	0.13
Yankton	2.18	2.14	2.10	2.09	2.16	2.08
Ponca and Santee	0.66	0.63	0.65	0.69	0.69	0.65
Winnebago and Omaha	4.85	4.83	4.75	4.49	4.70	4.55
Iowa and Sac and Fox	4.97	4.94	4.75	4.81	4.82	4.78
Total	**20.12**	**20.01**	**19.72**	**19.34**	**19.53**	**19.48**

1/ Based on appropriate representative sites.

(4.5 percent). Both the GP1528 and GP2028 options result in a 1.5 percent reduction in riparian habitat from the CWCP, and the MCP reduces riparian habitat the most (4.5 percent).

Within Winnebago Reservation and Omaha Reservation, the MCP and the four GP options decrease riparian habitat. The MCP results in the least amount of riparian habitat reduction (0.4 percent). The GP1528 and GP1521 options reduce riparian habitat by 2.1 and 3.1 percent, respectively. The greatest reductions in riparian habitat occur under the GP2028 option (6.2 percent) and the GP2021 option (7.4 percent).

The MCP and all of the GP options reduce riparian habitat from the CWCP within Iowa and Sac and Fox Reservations. The MCP results in the least amount of riparian habitat reduction (0.6 percent). Three of the four GP options, the GP1521, GP2021, and the GP2028 options, reduce riparian habitat by 3.0, 3.2, and 3.8 percent, respectively, while the GP1528 option, the GP option with the lowest spring rise and the highest summer flows, reduces riparian habitat the most (4.4 percent).

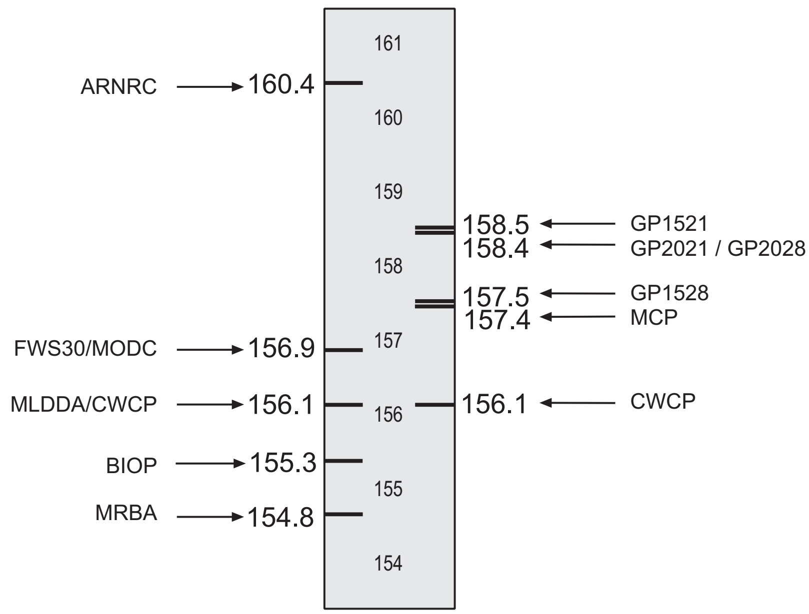

Figure 7.5-1. Average annual wetland habitat (thousands of acres) for the submitted alternatives and the alternatives.

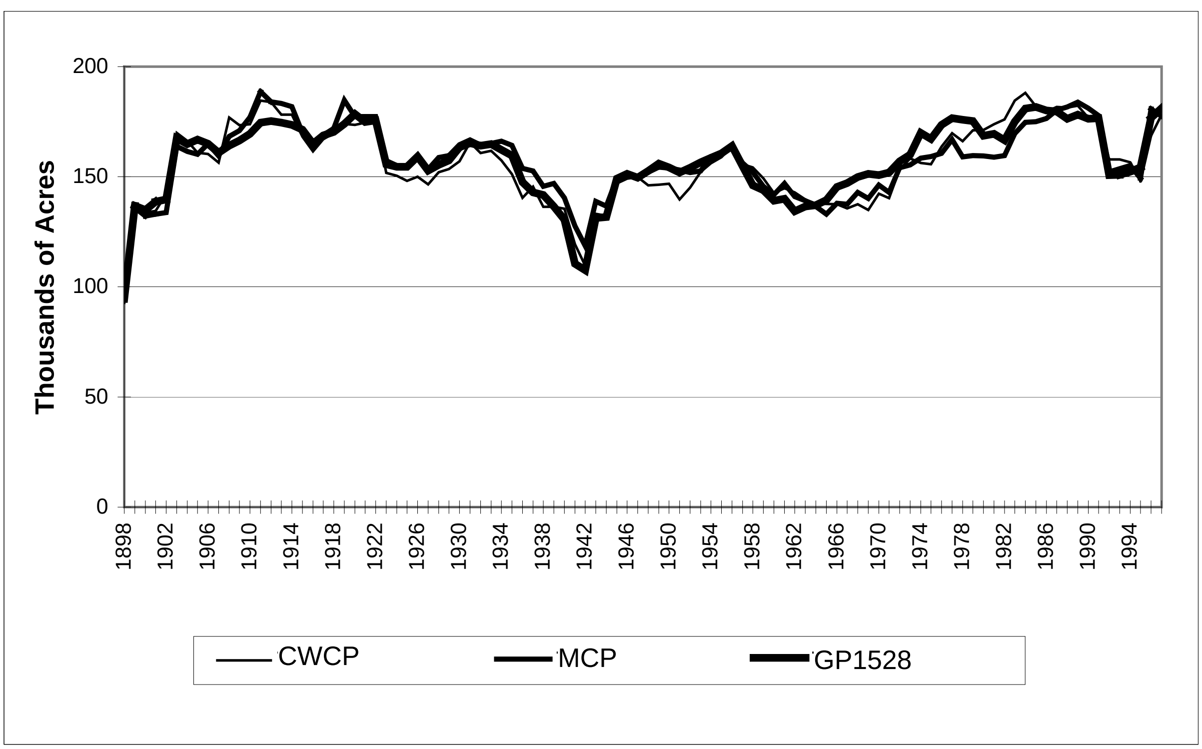

Figure 7.5-2. Annual wetland vegetation acres for CWCP, MCP, and GP1528.

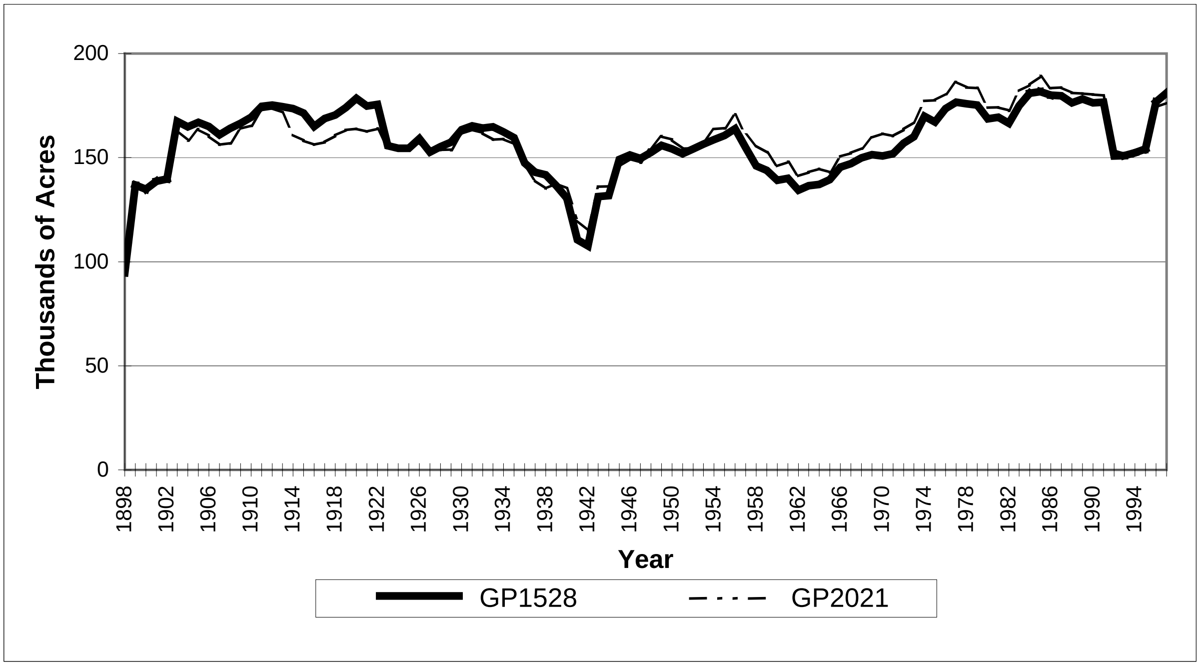

Figure 7.5-3. Annual wetland vegetation acres for GP1528 and GP2021.

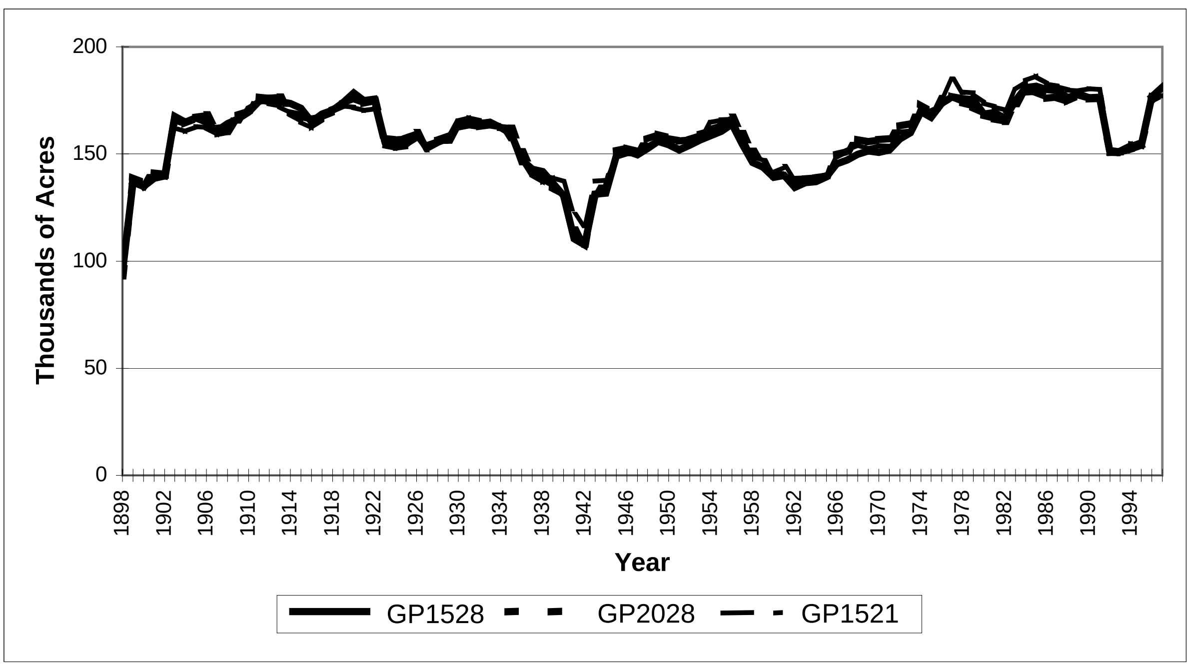

Figure 7.5-4. Annual wetland vegetation acres for GP1528, GP2028, and GP1521.

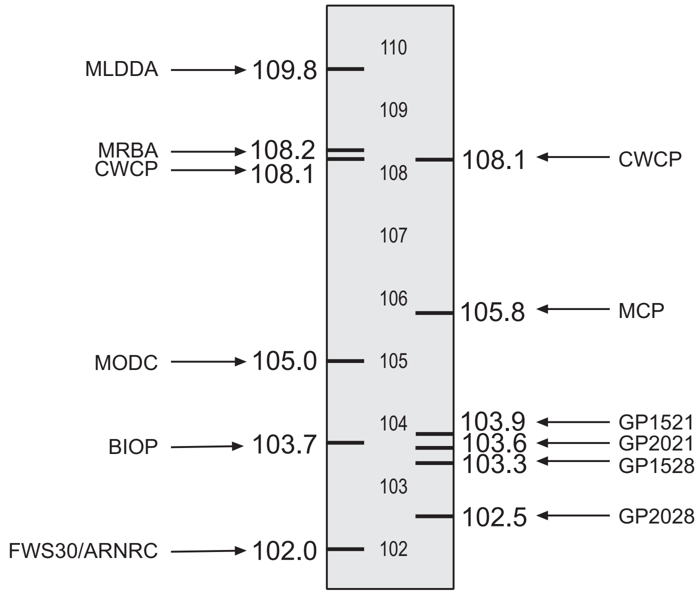

Figure 7.5-5. Annual riparian habitat (thousands of acres) for the submitted alternatives and the alternatives.

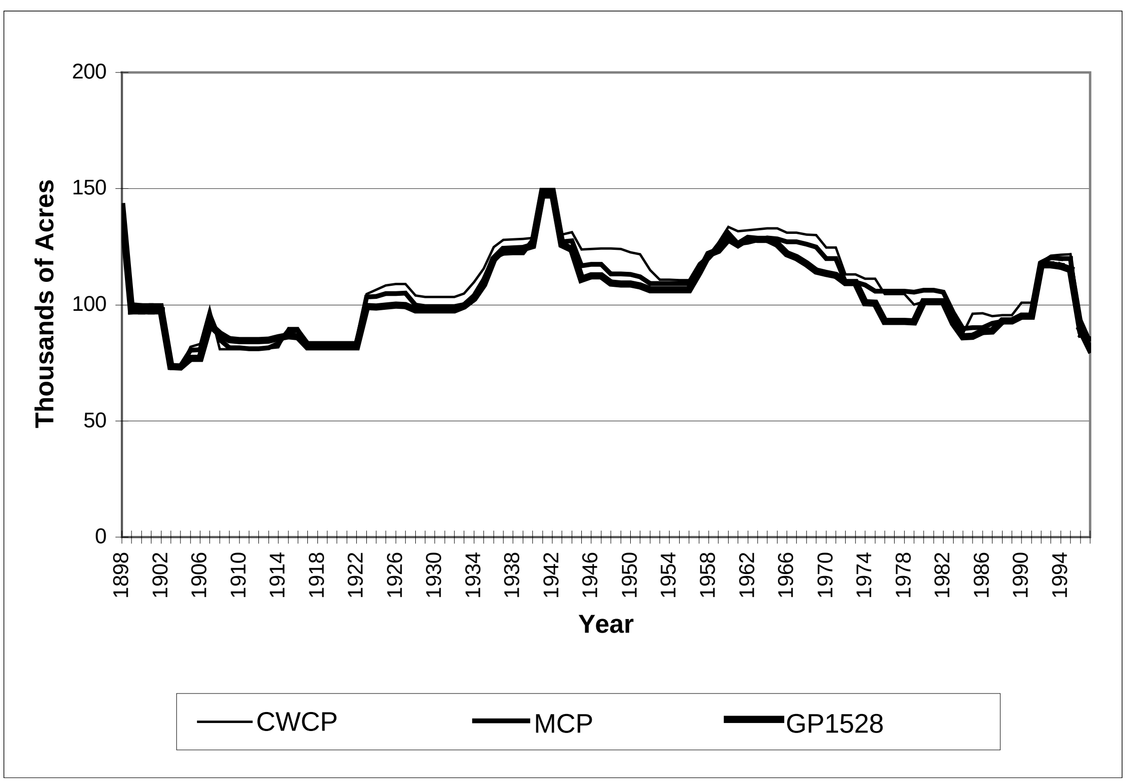

Figure 7.5-6. Annual riparian vegetation acres for CWCP, MCP, and GP1528.

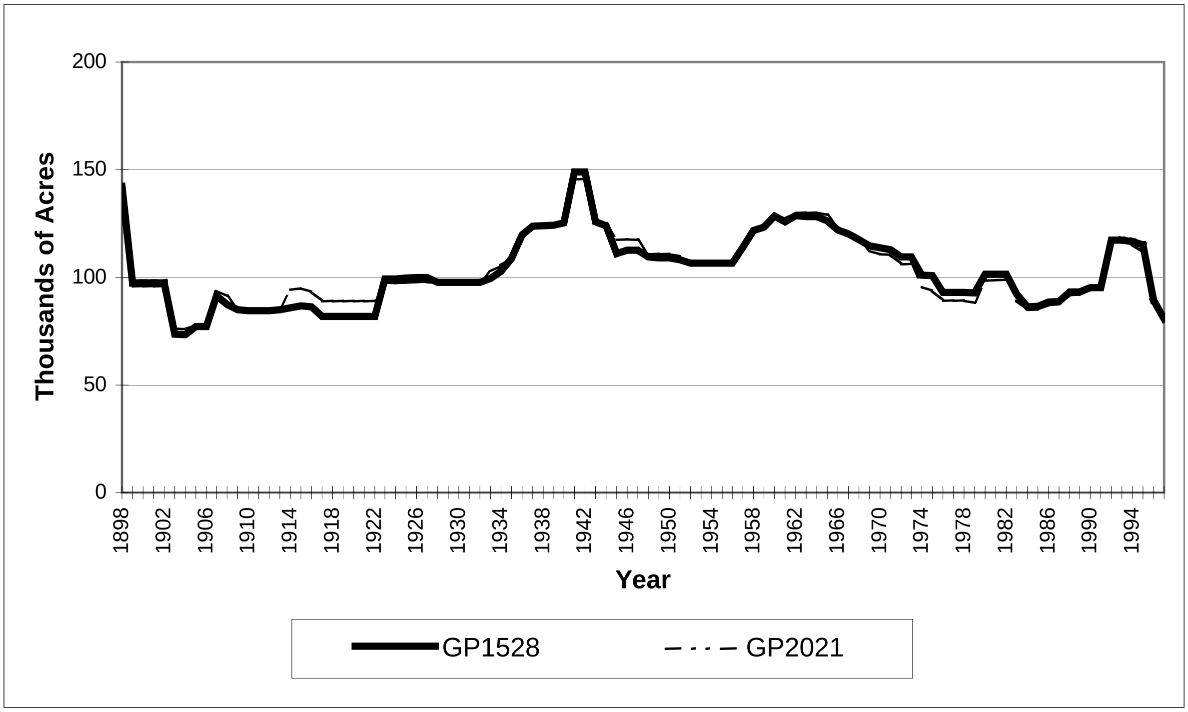

Figure 7.5-7. Annual riparian vegetation acres for GP1528 and GP2021.

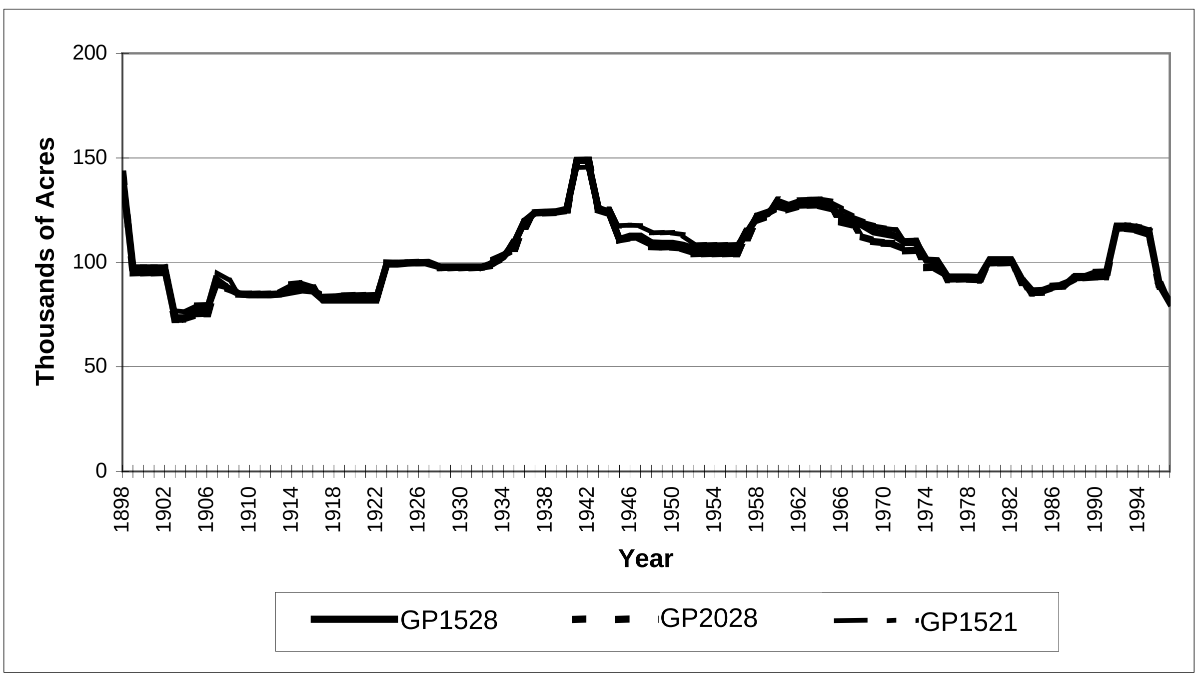

Figure 7.5-8. Annual riparian vegetation acres for GP1528, GP2028, and GP1521.

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7.6 WILDLIFE RESOURCES

Diverse species of wildlife depend on the Missouri River floodplain habitats. The endangered interior least tern and threatened piping plover nest on exposed sandbars and are consequently directly affected by river flows. Periodic high flows are required to remove encroaching vegetation; however, during and following the nesting season, stable or declining flows are needed to avoid nest flooding and the stranding of immature birds on the lower parts of sandbars and islands. These birds also nest on bare sand exposed when the lakes drop during droughts.

Effects on other wildlife species were not individually modeled. Changes in the wetland and riparian habitat values should provide some insight into the effects of a change from the CWCP to one of the other alternatives.

Two tern and plover models were developed to compute changes in the amount of suitable habitat for these two species. The riverine model has been used since early in the Study, and another model for computing changes in suitable habitat on two of the mainstem lakes was developed after receiving pubic input during the comment period on the RDEIS.

7.6.1 Riverine Tern and Plover Habitat

The riverine tern and plover model simulates the vegetation encroachment and removal process as river flows and associated stages rise and fall in four river reaches. These reaches are downstream from Fort Peck, Garrison, Fort Randall, and Gavins Point Dams. The baseline habitat acreage was that acreage existing in the early 1990s in these four reaches. Unfortunately, the model does not simulate the geomorphic process of island and sandbar building that takes place at very high flows with a relatively long duration, such as occurred in 1997. Not enough is currently known about this geomorphic process to incorporate it into the model at this time. Habitat acreages presented are, therefore, representative values useful for comparing alternatives and do not represent absolute acreages provided by the alternatives. A more comprehensive discussion of least tern and piping plover populations and habitat along the Missouri River is contained in Environmental Studies—Least Tern and Piping Plover (Corps, 1994q) and in the Supplemental Biological Assessment included as Appendix C to this FEIS. Uncertainties associated with the tern and plover habitat model are described in Section 6.5.6.

An analysis of the number of acres of relatively clear island and sandbar habitat was conducted for each alternative as part of the modeling effort to determine potential impacts to the terns and plovers on the four modeled river reaches. Based on this analysis, the average annual available habitat for terns and plovers for the alternatives discussed in this chapter are presented in Table 7.6-1 and shown in Figure 7.6-1. The table provides data on the individual reaches, as well as the values for the total average annual habitat for the full period of

Table 7.6-1. Average annual riverine tern and plover habitat downstream of mainstem dams (acres).[1/]

	1898 to 1997				
Alternative	**Total**	**Fort Peck**	**Garrison**	**Fort Randall**	**Gavins Point**
CWCP	**220.5**	50.3	97.9	32.7	39.5
MCP	**315.6**	81.3	152.1	38.7	43.4
GP1528	**356.4**	28.7	205.0	52.4	70.3
GP2021	**384.7**	35.4	207.8	64.6	76.9
GP1521	**370.0**	36.0	193.5	66.4	74.0
GP2028	**353.1**	27.4	201.5	53.3	70.9

1/ These habitat values are based on river flow impacts to the amount of habitat that existed in the four reaches in the 1991 and 1992 timeframe, which may be representative of minimal habitat values.

analysis from 1898 to 1997. Two factors need to be considered as the data are reviewed. First, the reach downstream from Garrison Dam has almost half of the total habitat of the four reaches with the habitat. Second, the reach downstream from Gavins Point Dam has provided the greatest number of fledged birds in recent years even though it has approximately 60 percent less habitat than the reach downstream from Garrison Dam.

The CWCP provides 220.5 acres of riverine tern and plover habitat on an annual basis. This total acreage along the four downstream reaches analyzed is distributed among the Fort Peck reach (22.8 percent), Garrison reach (44.4 percent), Fort Randall reach (14.8 percent), and Gavins Point reach (18.0 percent). The MCP provides an additional 95.1 acres (a 43.1 percent increase) of tern and plover habitat over the CWCP. An even greater amount of habitat is provided by the four options that constitute the range of changes added to the MCP to form the four GP options. These changes provide between 60.1 and 74.5 percent more total annual tern and plover habitat than the CWCP. Compared to the CWCP, the MCP increases habitat and the four GP options reduce habitat within the Fort Peck reach. Historically, the Fort Peck reach has been less productive than the other reaches; therefore, the loss in this reach is outweighed by the gains in other more productive reaches. Both the MCP and the four GP options increase this habitat downstream of Garrison, Fort Randall, and Gavins Point Dams.

Figure 7.6-1 graphically shows that there are four separate groupings of average annual riverine habitat values. At 220.5 acres, the lowest value is for the CWCP. The next grouping includes only the MCP, which provides 43.1 percent more habitat. The third grouping constitutes the four GP options. One of the two Gavins Point Dam release components, the summer low-flow component, provides a pattern within this cluster. The low-flow 25/21 split season options (those ending with a 21 in the six-character option name) provide more habitat than the minimum navigation service flat release option (those ending with a 28 as the last two characters). Inclusion of the minimum service option increases habitat by 60.1 to 61.6 percent, and the 25/21 split option increases habitat by 67.8 to 74.5 percent over that provided by the CWCP. The fourth grouping includes one alternative referred to as the ROR, or Run-of-River, alternative. It has been added to Figure 7.6-1 to show how much habitat would be provided if there was no control of the inflows into the Missouri River. Total average annual habitat increases dramatically to 584.7 acres, 165.2 percent over that provided by the CWCP, if flows are uncontrolled.

Figure 7.6-1 includes the values for the submitted alternatives addressed in Chapter 5 to provide some perspective as to how the GP options perform relative to the submitted alternatives. The GP options provide habitat similar to that provided by the two alternatives submitted by the USFWS for consideration: the BIOP and FWS30 alternatives. Because these two options include the 25/21 low-flow option, the habitat that would be provided is essentially the same as that provided by the corresponding GP options. This supports the general relationship that tern and plover habitat would generally increase as the summer flow decreases with all other factors held relatively constant.

Under the MCP, tern and plover riverine habitat increases within all reaches downstream of the mainstem dams. An unbalanced intrasystem regulation among the upper three lakes, with greater conservation during the drought periods and higher service levels for summer releases throughout these drought periods, increases total tern and plover habitat 43.1 percent over the CWCP. Downstream of Fort Peck Dam, the MCP yields 61.6 percent more clear island sand bar habitat for terns and plovers than the CWCP. Compared to the CWCP, the MCP yields 55.4, 18.3, and 9.9 percent more tern and plover habitat downstream of the Garrison, Fort Randall, and Gavins Point Dams, respectively.

Tern and plover habitat increases under the GP1528 option, the GP option with the lowest spring rise and the highest summer flows, when the 15-thousand cubic feet per second (kcfs) spring rise and the minimum navigation service flat release at Gavins Point Dam are added to the MCP. Total habitat increases by an additional 12.9 percent over that provided by the MCP. Decreasing the summer flow from 34.5 kcfs to 28.5 kcfs (representing potential minimum navigation service flat release) is the primary factor affecting changes in habitat. This change results in a 64.7 percent decrease in habitat downstream of Fort Peck Dam compared to the MCP's value and an overall increase in habitat within the remaining downstream locations. Under the GP1528 option, the smallest percent increase in habitat (34.8 percent) occurs downstream of Garrison Dam, while the largest percent increase (62.0 percent) occurs downstream of Gavins Point Dam. Tern and plover habitat increases 35.4 percent over the MCP in the reach downstream of Fort Randall Dam.

To provide a perspective for how riverine habitat could change relative to the GP1528 option, the following paragraphs describe the habitat changes relative to the GP1528 option. The greatest total percent increase in tern and plover habitat (a 7.9 percent increase over that of the GP1528 option) occurs under the GP2021 option. The GP2021 option has the 20-kcfs spring rise and 25/21-kcfs split summer release from Gavins Point Dam. This combination, when added to the MCP, increases habitat by 23.3 percent downstream of Fort Peck Dam, 1.4 percent downstream of Garrison Dam, 23.3 percent downstream from Fort Randall Dam, and 9.4 percent downstream from Gavins Point Dam. In summary, changing both the spring rise and summer low flow at the same time under adaptive management results in positive changes to all four river reaches with tern and plover habitat.

With a change in the summer low flow from minimum service to the 25/21-kcfs split from Gavins Point Dam, as with the GP1521 option, total riverine tern and plover habitat increases an additional 3.8 percent compared to the GP1528 option. Habitat increases in three of the reaches (25.4 percent below Fort Peck Dam, 26.7 percent below Fort Randall Dam, and 5.3 percent below Gavins Point Dam) and decreases by 5.6 percent below Garrison Dam.

With a change in only the spring rise amount from 15 kcfs to 20 kcfs, as with the GP2028 option, total riverine tern and plover habitat decreases by 0.9 percent compared to the GP1528 option. This overall decrease results from decreases downstream from Fort Peck and Garrison Dams (4.5 and 1.7 percent, respectively). Small increases of 1.7 percent and 0.9 percent occur downstream from Fort Randall and Gavins Point Dams, respectively.

The annual values of total riverine tern and plover habitat for the CWCP, the MCP, and the four GP options are shown on Figures 7.6-2 thorough 7.6-4. Tern and plover habitat is highly variable during the entire period of analysis. The years with the greatest increase in habitat, between 1,200 and 1,600 acres, are 1920, 1935, 1953, and the mid- to late 1980s. The alternatives that provide the greatest amount of habitat during these periods include the GP1521, GP1528, and GP2021 options. While the GP1528 option generally creates some of the highest numbers of tern and plover habitat acres during the mid- to late 1980s, the other three options, the GP2021, GP1521, and GP2028 options, produce some of the fewest habitat acres, between zero and 200 acres.

Impacts to Sandbar Creation/Maintenance

Subsequent to the RDEIS, the Corps also examined the impacts of alternatives on creation and maintenance of sandbar habitat for the tern and plover. Sandbars and other alluvial features are created and maintained by the dominant discharge for the reach, or in the case of a regulated sand bed stream, such as the Missouri River, the dominant discharge class. The dominant discharge class is the band of discharges that moves the majority of the bed material load through the reach. To alter the size, density, elevation, etc. of the sandbars requires a shift in the dominant discharge class. To increase the size, density, and barren elevation of the sandbars in the Gavins Point to Ponca reach requires a shift in the dominant discharge class to a higher discharge group. The minimum discharge must be able to overtop a majority of the existing sandbars and must occur for long enough duration to move the majority of the bed material load. Integration of the sediment-discharge rating curve and the flow duration curves for the various alternatives produces the plot shown as Figure 7.6-5. These data indicate that none of the MCP and the GP options cause an upward shift in the dominant discharge class relative to the CWCP and, therefore, would not produce the desired effect.

7.6.2 Lake Tern and Plover Habitat

The Corps received feedback on the RDEIS regarding the lack of an analysis of the habitat that terns and plover, particularly plovers, were using on Lake Sakakawea and Lake Oahe. Historically, more than 98 percent of the tern and plover habitat within the Missouri River has occurred on the two lakes. This situation was discussed with the field biologists who monitor these birds annually to determine if development of such a model could be accomplished. As a result of this inquiry, the Reservoir Habitat Model (RHM) for terns and plovers was developed in 2002. The RHM is a GIS model that combines elevation grids on these two lakes with end-of-month lake water surface elevations to quantify defined habitat type for each year of the 100-year period of record modeled for the Study.

End-of-May elevations were used because the majority of plovers have arrived on Lake Sakakawea and Lake Oahe by this time and have initiated nesting activities. The majority of terns arrive shortly thereafter during the first 2 weeks of June. An inundation elevation was also required for the modeling, and the second largest end-of-month elevation in the previous 12 months was used. This was done to ensure a high probability that areas being classified as inundated had actually been inundated for a sufficient length of time during the previous year to re-establish suitable habitat conditions.

Three-dimensional digital representations of the lake floors were developed from pre-dam (1943 Lake Sakakawea, 1947 Lake Oahe) topographic paper maps. A grid of the river channel bottom at the upstream end of each lake was included in the lake elevation grids. A distance attribute was added to the elevation grid, with the zero distance located at the upstream end of the model area.

Factors that were included in the modeling effort included slope of the exposed bottom (less than 1:10 was acceptable), years post inundation (amount of suitable habitat diminished as years following inundation increased), and distance from the water (100 meters maximum). The amount of suitable habitat included only areas connected to the main body of each lake. For example, a deep pool in a bay with high ground between it and the main lake pool was not included unless the water surface elevation was high enough to top the high ground and fill the pool. The May end-of-month elevation was used to calculate the miles of river that became exposed during each year. The first 4 years of data were not "good data" because the period of post inundation had not been fully engaged until the fifth year. All subsequent years had the factor fully engaged and were, therefore, based on all of the same factors.

Finally, the figures were adjusted to represent 25 percent of the area around each lake. This allowed the modelers to add the values for each lake to better estimate the relative change in potential total habitat. If differing percentages had been used, the one with the greater percentage of habitat included in the analysis would have potentially skewed the results.

Table 7.6-2 presents the average annual lake habitat for Lake Sakakawea and Lake Oahe. The table also includes the combined total habitat value.

The CWCP provides 3,035 acres of tern and plover habitat on an annual basis for the two lakes. Lake Sakakawea has the greater share (59.5 percent) of the total habitat. The MCP provides an additional 133 acres (a 4.4 percent increase) of habitat over the CWCP. An even greater amount of lake habitat is provided by the four GP options. These changes provide 18.6 to 23.9 percent more habitat than the CWCP. Compared to the CWCP, all five alternatives provide more total habitat and more habitat on each lake.

Figure 7.6-6 graphically shows that there are two separate groupings of average annual lake tern and plover habitat. The CWCP and MCP values form one grouping and the four GP options form the other grouping. The spring rises and summer low flows out of Gavins Point Dam appear to be the factors for the differences. Neither one of these factors appears to be the primary one influencing the average annual values on a total basis.

Under the MCP, average annual habitat increases on both lakes. Either the greater drought conservation or the unbalancing of the upper three lakes could be influencing this difference. On Lake Sakakawea, the MCP increases the habitat by only 1.1 percent over that for the CWCP, whereas the habitat increases by 9.2 percent on Lake Oahe.

Lake tern and plover habitat increases on only Lake Sakakawea for a change from the MCP to GP1528, the alternative with the lowest spring rise and the highest summer flows. This increase is 26.4 percent compared to the MCP. A decrease of 3.6 percent results on Lake Oahe.

Both lakes have increased average annual tern and plover habitat when both the spring rise is increased and the summer low flows lowered under the GP2021 option. Lake Sakakawea habitat increases by 1.1 percent compared to the GP1528 option, and Lake Oahe increases by 10.4 percent.

Decreasing only the summer low flows downstream from Gavins Point Dam under the GP1521 option results in a decrease on one lake and an increase on the other. Lake Sakakawea average annual habitat decreases by 2.6 percent compared to the GP1528 option, and Lake Oahe habitat increases by 5.5 percent.

Increasing only the spring rise relative to what it would be under the GP1528 option, as would be done under the GP2028 option, creates a similar response. Lake Sakakawea average annual tern and plover habitat decreases by 2.3 percent relative to

Table 7.6-2. Average annual lake tern and plover habitat on Lake Sakakawea and Lake Oahe (acres).

Alternative	1898 to 1997		
	Total	**Lake Sakakawea**	**Lake Oahe**
CWCP	**3,035**	1,807	1,228
MCP	**3,168**	1,827	1,341
GP1528	**3,601**	2,309	1,292
GP2021	**3,760**	2,334	1,426
GP1521	**3,612**	2,249	1,363
GP2028	**3,602**	2,256	1,346

the GP1528 option, and Lake Oahe habitat increases by 4.2 percent. It is interesting that changing the spring rise or the summer low flows individually results in essentially no change in habitat compared to the GP1528 option; however, changing both at the same time results in more habitat than the GP1528 option.

The annual values for total lake tern and plover habitat are shown on Figures 7.6-7 through 7.6-9.

These figures show that the amount of habitat is very dynamic, ranging from no habitat on the lakes to as much as more than 7,000 acres of habitat in a given year. This is most likely related to the amount of runoff that comes into the Mainstem Reservoir System. In a high runoff year, both lakes would fill into the flood control zones at higher levels than the previous year, resulting in very little if any lake habitat. Conversely, in the early years of a drought, the lake levels are dropping, exposing considerable bare habitat. One can pick out the three major droughts because there is not a noticeable decline in habitat until at least the fourth or fifth year of the drought as the lakes' decline diminishes and enough time has passed that much of the bare habitat is vegetated. Close examination of Figure 7.6-7 shows that the GP1528 option has noticeably higher amounts of habitat in many years than the CWCP or MCP. The other two figures show similar values among the four GP options. The Gavins Point Dam spring rise and lower summer releases are a factor in the amount of habitat on an annual basis. It would take more analysis to determine if most of the increases occur in years with spring rises, which would tend to drop the lakes lower by the end of May as water needs to be moved from the two lakes in preparation for the spring rise out of Gavins Point Dam.

7.6.3 Tern and Plover Habitat for Seven Tribal Reservations

Table 7.6-3 presents the average annual tern and plover habitat under the alternatives for seven Tribal Reservations along two river reaches and the upper two lakes during the full period from 1898 to 1997. The Reservations analyzed include Fort Peck Reservation, located downstream of Fort Peck Dam; Fort Berthold Reservation, located on Lake Sakakawea; Standing Rock Reservation and Cheyenne River Reservation, located on Lake Oahe; and Yankton Reservation, Santee Reservation, and Ponca Tribal Lands, all located downstream of Fort Randall Dam.

Total tern and plover habitat associated with these Reservations is 3,118.1 acres. Changing the conservation measures during droughts, unbalancing the upper three lakes, and adding a spring rise at Fort Peck Dam, as with the MCP, increases total Tribal Reservation tern and plover habitat by 5.4 percent. Adding the 15-kcfs spring rise and a minimum navigation service summer flow instead of the full navigation service flat release under the GP1528 option increases total habitat by 18.1 percent. Increasing the spring rise and decreasing the summer flow under the GP2021 option increases total habitat by 23.8 percent. Decreasing only the summer flow to the 25/21 split under the GP1521 option results in 19.1 percent more acres of habitat than provided by the CWCP. Finally, increasing only the spring rise to 20 kcfs under the GP2028 option results in the greatest decrease in tern and plover habitat associated with the Tribal Reservations, at 18.1 percent compared to the CWCP.

The MCP is the only alternative that increases tern and plover habitat within the Fort Peck Reservation; it creates 61.5 percent more habitat than the CWCP. The four GP options all reduce tern and plover habitat within this Reservation. The

Table 7.6-3. Average annual tern and plover habitat (acres) for seven Tribal Reservations.

	1898 to 1997					
Reservation	**CWCP**	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Peck	50.4	81.3	28.7	35.5	36.5	27.4
Fort Berthold	1,807	1,827	2,309	2,334	2,249	2,256
Standing Rock and Cheyenne River	11,228	1,341	1,292	1,426	1,363	1,346
Yankton, Santee, and Ponca Tribal Lands	32.7	38.7	52.4	64.6	66.5	53.3
Total	**3,118.1**	**3,288.0**	**3,682.1**	**3,860.1**	**3,715.0**	**3,682.7**

GP1521 and GP2021 options, both with the lower summer release from Gavins Point Dam, reduce habitat within the Fort Peck Reservation by lesser amounts, 28.4 and 29.6 percent less than the CWCP, respectively. The options with the greatest percent reduction are the GP1528 (3.0 percent) and the GP2028 (45.7 percent) options.

All of the alternatives increase tern and plover habitat relative to the CWCP on Lake Sakakawea, on which the Fort Berthold Reservation is located. The MCP provides only a 1.1 percent increase. Adding the 15 kcfs spring rise and reducing the summer flows below Gavins Point Dam to minimum service, as would be the case under the GP1528 option, provides an additional 27.8 percent more habitat than the CWCP. The GP2021 option increases the spring rise and further reduces the summer low flows to the 25/21 split, and it provides the greatest increase of tern and plover habitat (29.1) on Lake Sakakawea. Increasing only the spring rise or reducing the summer low flows downstream from Gavins Point Dam (GP2028 and GP1521 options, respectively) provides similar increases in habitat (24.4 and 24.8 percent, respectively).

Changes in lake tern and plover habitat on Lake Oahe, on which the Standing Rock Reservation and Cheyenne River Reservation are located, are greater for the MCP and relatively lower for the GP options than on Lake Sakakawea. A switch to the MCP, with its higher conservation measures and unbalancing of the upper three lakes, increases habitat by 9.2 percent. The GP1528 option increases habitat by only 5.2 percent compared to the CWCP. Providing the highest spring rise and lowest summer flows downstream from Gavins Point Dam results in the greatest amount of lake habitat, an increase of 16.1 percent. Adding either the 20 kcfs spring rise or reducing the Gavins Point Dam release to the 25/21 split increases habitat by 11.0 and 9.6 percent, respectively.

Within Yankton Reservation, Ponca Tribal Lands, and Santee Reservation, the MCP and the four GP options increase tern and plover habitat over the CWCP. The greatest increases occur under the GP1521 option (103.2 percent) and the GP2021 option (97.6 percent). The GP2028 option provides a 62.9 percent increase in tern and plover habitat over the CWCP. Compared to the CWCP, the GP1528 option provides nearly the same amount of tern and plover habitat increase as the GP2028 option (60.2 percent). The MCP provides only an 18.5 percent increase in habitat over the CWCP.

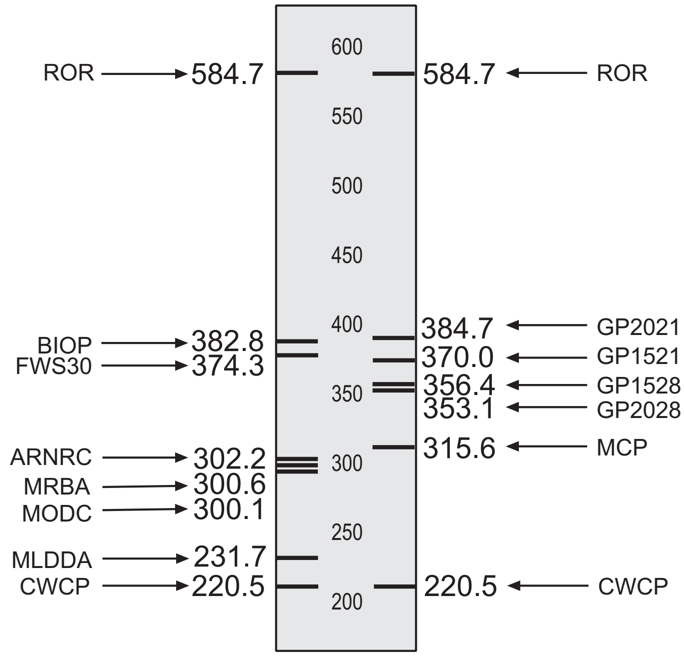

Figure 7.6-1. Average annual riverine tern and plover habitat for the submitted alternatives and the alternatives (acres).

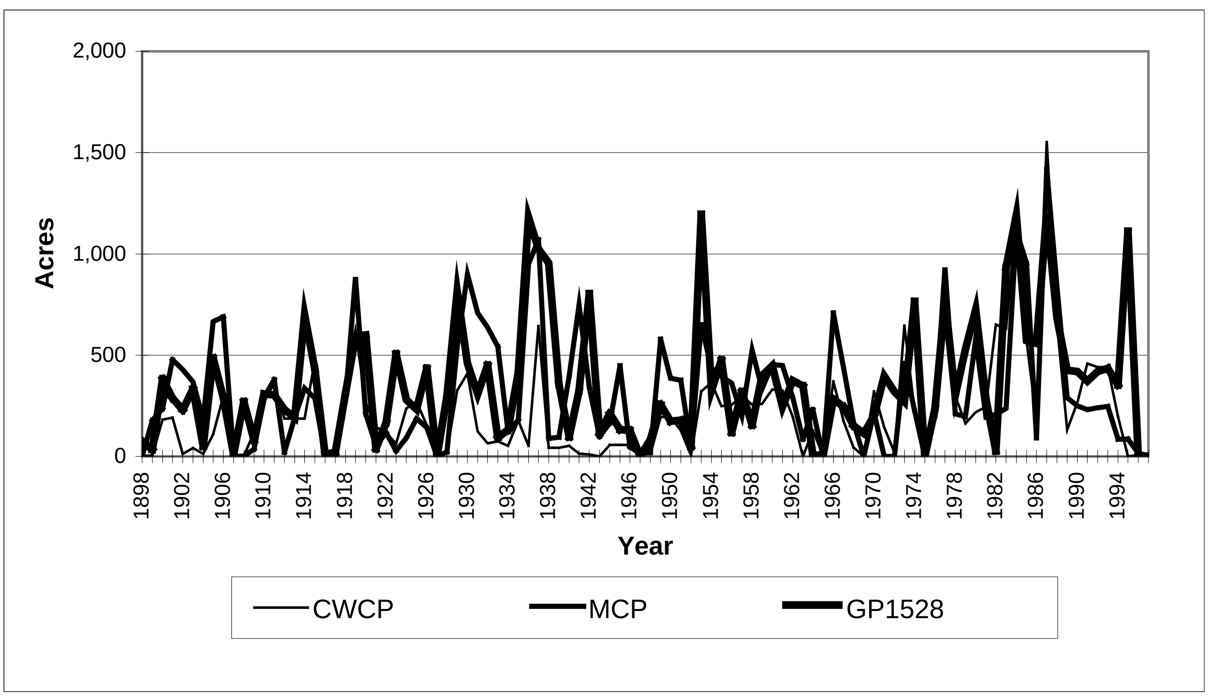

Figure 7.6-2. Annual riverine tern and plover habitat for CWCP, MCP, and GP1528.

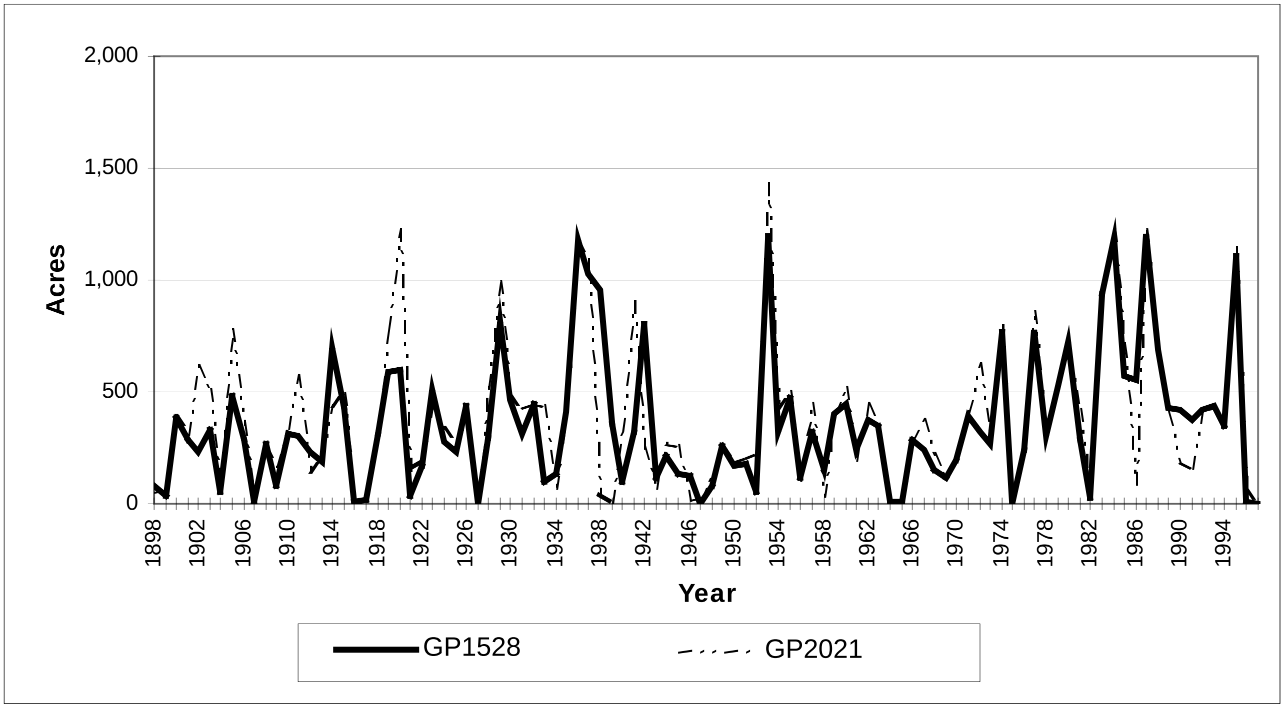

Figure 7.6-3. Annual riverine tern and plover habitat for GP1528 and GP2021.

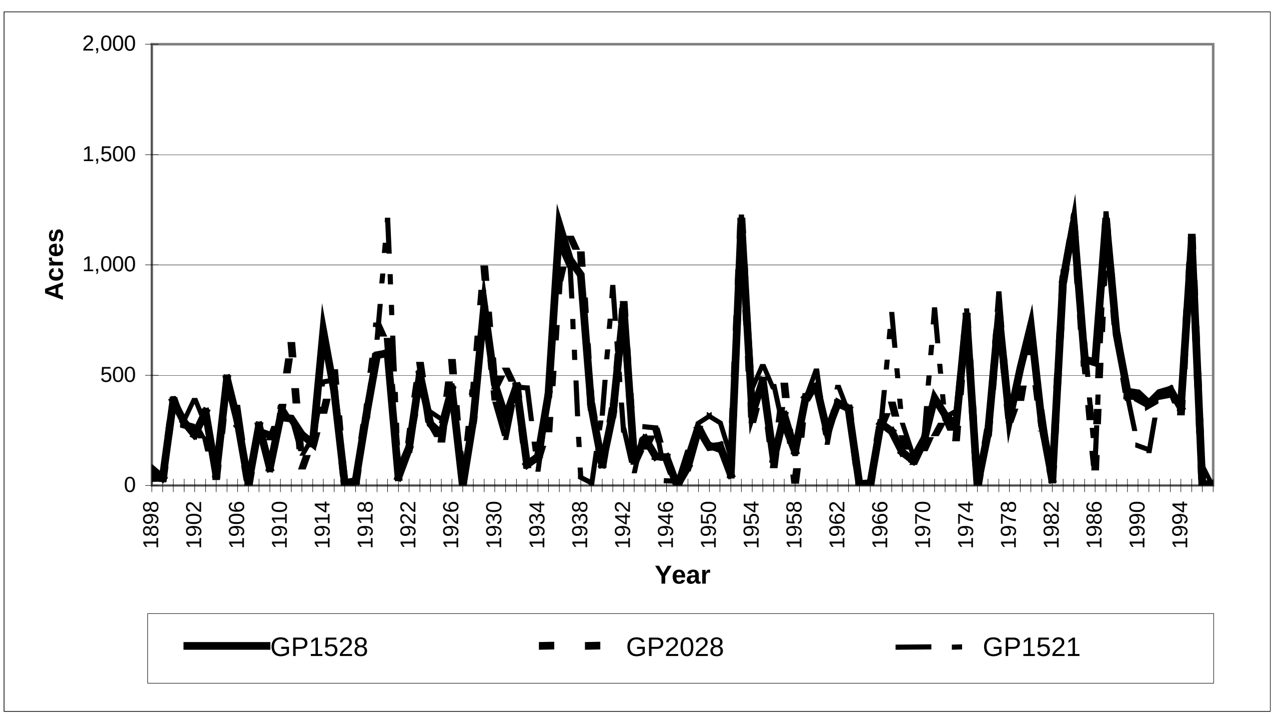

Figure 7.6-4. Annual riverine tern and plover habitat for GP1528, GP2028, and GP1521.

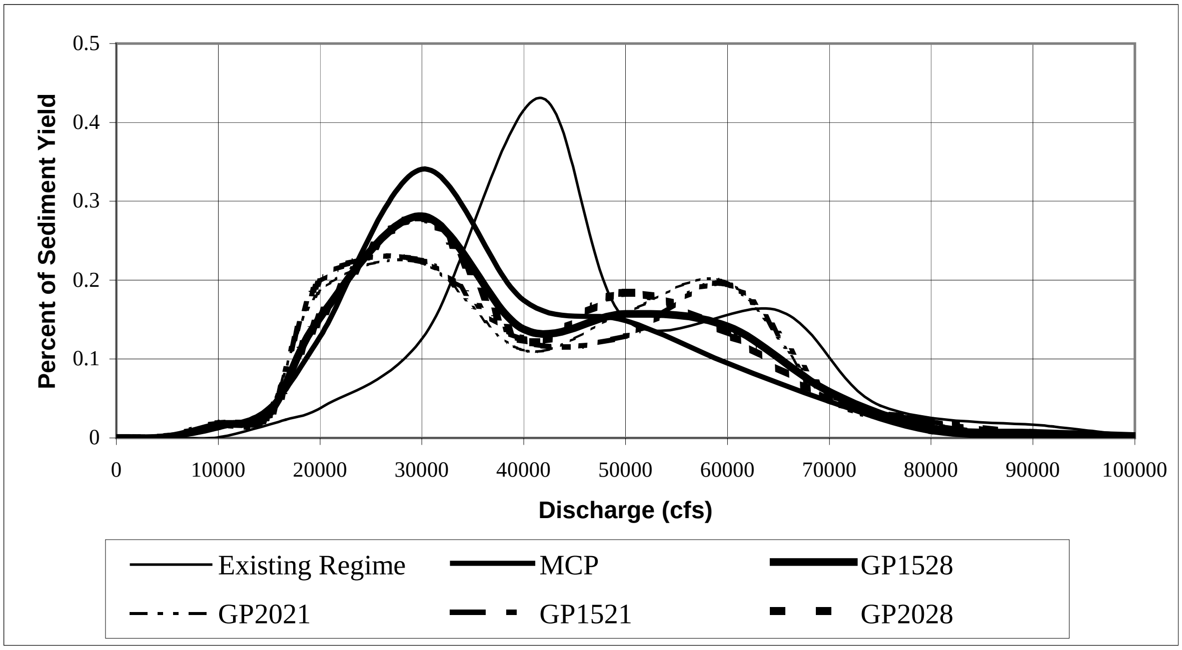

Figure 7.6-5. Missouri River at Sioux City, sediment yield distribution for the alternatives.

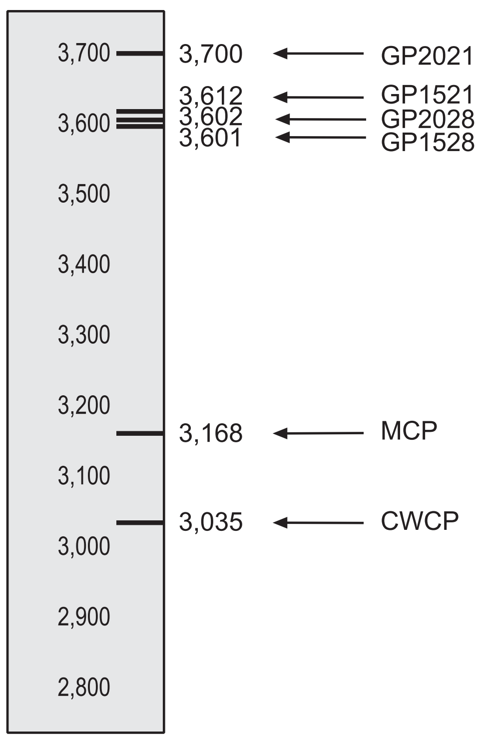

Figure 7.6-6. Average annual lake tern and plover habitat for the alternatives (acres).

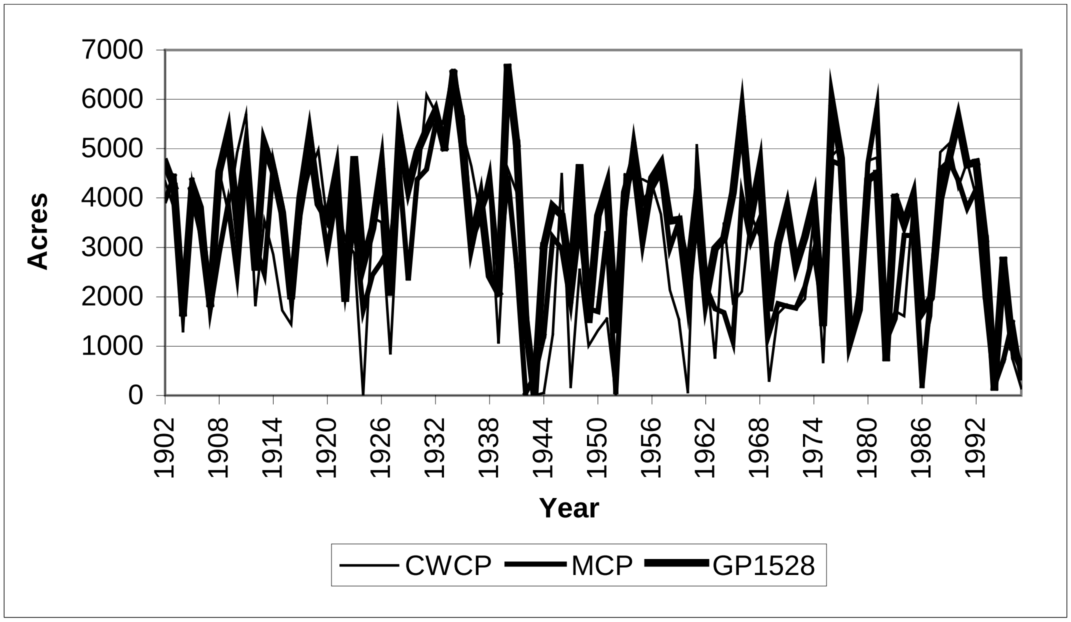

Figure 7.6-7. Annual lake tern and plover habitat for CWCP, MCP, and GP1528.

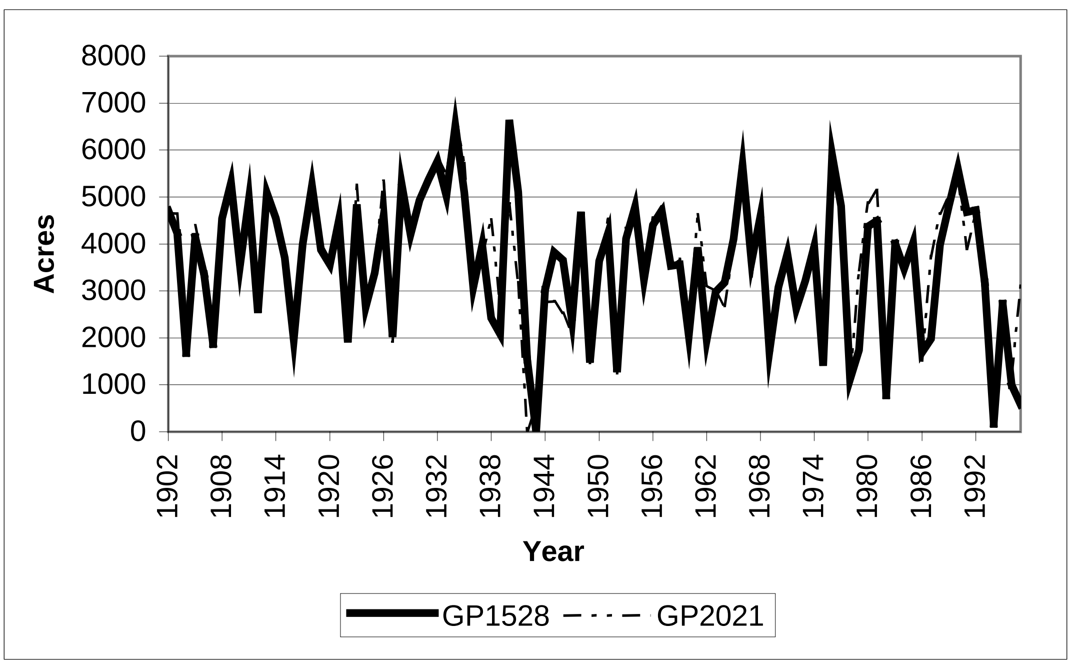

Figure 7.6-8. Annual lake tern and plover habitat for GP1528 and GP2021.

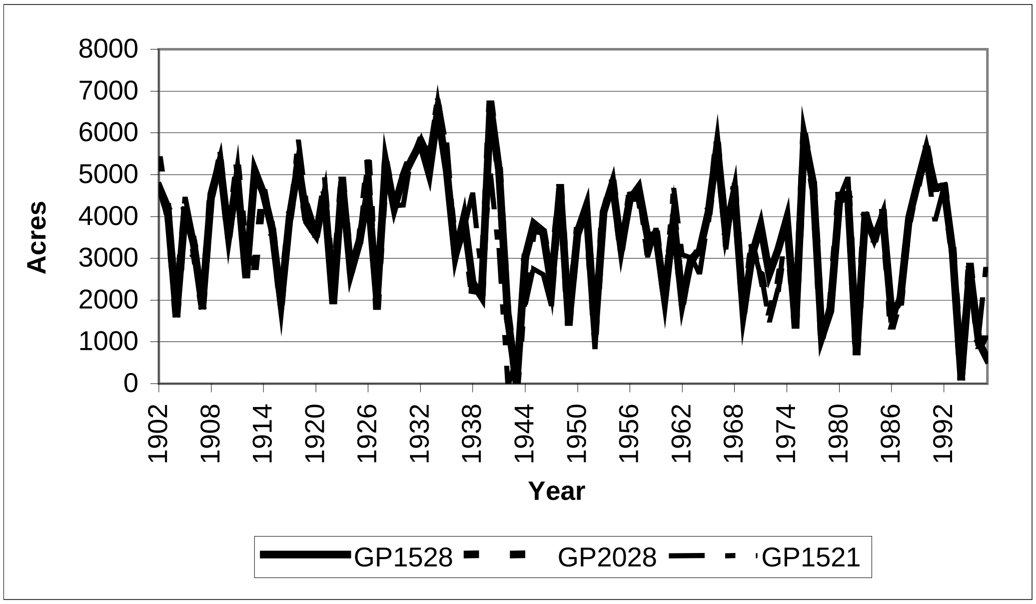

Figure 7.6-9. Annual lake tern and plover habitat for GP1528, GP2028, and GP1521.

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7.7 FISH RESOURCES

The analysis of the effects of the CWCP, the MCP, and the four GP options on fish resources was accomplished using the results of eight models. These models include young fish production in the lakes, coldwater fish habitat in the lakes, coldwater fish habitat in river reaches, warmwater fish habitat in river reaches, physical habitat for native river fish in river reaches, connectivity of the river to low-lying lands along much of the Lower River, spring spawning cue along the Lower River, and shallow water habitat along the Lower River. Several technical reports document the development of these models for assessing lake and riverine fishes, the model assumptions, and the data produced by the model runs (Corps, 1994j; Corps, 1994k; Corps, 1994l; Corps, 1994m; Corps, 1994n). In addition, supplemental information was recently published on riverine fishes (Corps, 1998f; Corps, 1998g). Results derived from the fish models are presented in this section.

7.7.1 Young Fish Production in Mainstem Lakes

The young of year fish production index uses annual hydrologic data to model fish productivity. It was developed through a process of correlating annual catch data for various species to hydrologic variables such as lake levels, inflows, and amount of shore area. For further detail, see Volume 7A: Environmental Studies, from the 1994 Missouri River Master Water Control Manual Review and Update Study (Study). The values presented in the following discussion are useful as an indicator of the relative effects of the different alternatives. For example, if an alternative results in a young of year index value that is 2 percent higher than that of the CWCP, this indicates the potential for a slight increase in annual fish production under that alternative. Table 7.7-1 and Figures 7.7-1 through 7.7-4 present the data from the young fish production model, commonly referred to as the "young-of-year model."

Figure 7.7-1 graphically shows that the CWCP and the MCP are closely grouped together between 2.00 and 2.04 units, a difference of 4 hundredths. The four GP options are more closely related and are grouped between 2.13 and 2.14 units, a difference of only 1 hundredth. This figure also shows the values for the submitted alternatives discussed in Chapter 5 to provide perspective as to how the GP1528 option, the GP option with the lowest spring rise and the highest summer flows, and the other three GP options perform relative to the submitted alternatives. The GP1528 option provides a total average annual young fish production value that is closest to the MODC alternative. The GP1528 option provides only a 2 hundredths (0.9 percent) increase in young fish production values over the MODC alternative.

The average annual total relative index value for the CWCP is 2.00, the lowest among the MCP and the four GP options. The MCP's unbalanced intrasystem regulation and higher drought conservation measures increase the total index value over the CWCP by only 4 hundredths, or 2.0 percent. The Fort Peck spring rise included in the MCP does not appear to affect the total index value. The MRBA alternative is the same as the MCP except for the spring rise (unbalancing apparently already accounts for the increased effect of a spring rise). The GP1528 option's Gavins Point Dam 15-kcfs spring rise and flat 28.5-kcfs summer release increases the total index value for young fish production over the MCP 10 hundredths, or 4.9 percent. Compared to the value for the GP1528 option, the other GP options

Table 7.7-1. Average annual young fish production in the mainstem lakes (relative index).

		1898 to 1997					
Alternative	**Total**	**Fort Peck Lake**	**Lake Sakakawea**	**Lake Oahe**	**Lake Sharpe**	**Lake Francis Case**	**Lewis & Clark Lake**
CWCP	**2.00**	0.55	0.46	0.40	0.23	0.20	0.16
MCP	**2.04**	0.57	0.46	0.41	0.22	0.20	0.18
GP1528	**2.14**	0.54	0.53	0.41	0.23	0.25	0.19
GP2021	**2.13**	0.53	0.53	0.40	0.21	0.27	0.20
GP1521	**2.13**	0.53	0.52	0.39	0.22	0.26	0.20
GP2028	**2.13**	0.53	0.53	0.41	0.22	0.25	0.19

(GP2021, GP1521, and GP2028 options) all show a 1 hundredth, or 0.5 percent, decrease in total index values. This indicates that the various spring rise/summer flow combinations associated with the four GP options (i.e., a 15- or 20- kcfs spring rise combined with a 25/21-kcfs split summer flow or a 20-kcfs spring rise with a 28.5-kcfs flat summer release) would result in similar total relative index values for young fish production.

The MCP is the only alternative that increases young fish production index values over the CWCP within Fort Peck Lake. An unbalanced intrasystem regulation, greater conservation among the three upper lakes during drought periods, and greater conservation measures during the drought periods benefit young fish production within this lake and increase the index value by 2 hundredths, or 3.6 percent, over the CWCP.

Within Lake Sakakawea and Lake Francis Case, the young fish production index value under the MCP does not change from the CWCP. The MCP increases the index value by only 1 hundredth, or 2.5 percent, in Lake Oahe and decreases the young fish production index values by 4.3 percent in Lake Sharpe, compared to the CWCP. Within Lewis and Clark Lake, the MCP increases the index value amount by 2 hundredths, or 12.5 percent, over the CWCP.

The GP1528 option has a 15-kcfs spring rise and a flat 28.5-kcfs summer release from Gavins Point Dam that represents a 6-kcfs decrease in minimum summer service level from the MCP. This results in a decrease in young fish production index values in Fort Peck Lake of 3 hundredths, or 5.3 percent, compared to the MCP. The GP1528 option has the same index value in Lake Oahe as the MCP. Compared to the MCP, the GP1528 option increases the index value in the remaining mainstem lakes. Lake Francis Case and Lake Sakakawea experience the greatest value increases under the GP1528 option (25.0 and 15.2 percent increases, respectively), while Lewis and Clarke Lake and Lake Sharpe experience lesser gains in index values (5.6 and 4.5 percent, respectively).

The GP2021, GP1521, and GP2028 options provide perspective for how young fish production index values could change in the future relative to the GP1528 option. These include changes in the spring rise, total spring flow, and summer flow on the Lower River. The primary difference between the GP2021 and GP1521 options is the spring rise; the GP2021 has a 20-kcfs spring rise, whereas the GP1521 option has a 15-kcfs spring rise. Both options have a summer release that is split between 25 and 21 kcfs from Gavins Point Dam. These changes result in similar increases and decreases in young fish production index values within the mainstem lakes. For example, both options decrease index values in Fort Peck Lake, Lake Oahe, and Lake Sharpe and increase the index value in Lake Francis Case and Lewis and Clark Lake. In Lake Sakakawea the GP2021 option does not change the index value from the GP1528 option, while the GP1521 option results in a value decrease.

When compared to the values for the GP1528 option, both the GP2021 and GP1521 options decrease young fish production index values in Fort Peck Lake by 1 hundredth, or 1.9 percent. In Lake Sakakawea, the index value under the GP2021 option does not change; however, the GP1521 option decreases the value by 1.9 percent. The GP2021 option results in smaller value decreases than the GP1521 option in Lake Oahe (2.4 and 4.9 percent decreases, respectively), while the opposite is true in Lake Sharpe. Here, the GP2021 and GP1521 options reduce young fish production index values by 8.7 and 4.3 percent, respectively. Compared to the remaining options, the GP2021 option has the greatest percent reduction in index value from the GP1528 option within Lake Sharpe. The GP2021 and GP1521 options increase the young fish production index value by 8.0 and 4.0 percent, respectively in Lake Francis Case, and in

Lewis and Clark Lake these two options would result in the same value increase of 1 hundredth, or 5.3 percent higher than the GP1528 option.

The GP2028 option has a 20-kcfs spring rise and a flat summer release of 28.5 kcfs that represents the minimum navigation service, summer low flow. Compared to the GP1528 option, this option decreases (1.9 percent and 4.3 percent, respectively) young fish production index values in two of the mainstem lakes, Fort Peck Lake and Lake Sharpe. The GP2028 option does not result in a change in index values in the remaining four lakes.

The annual values for young fish production in the mainstem lakes for the CWCP, the MCP, and the four GP options are shown on Figures 7.7-2 through 7.7-4. Generally, all of the alternatives discussed in this chapter show similar results during the full period of analysis; relative index values vary between 1 and 3 units. The values for all of the alternatives decrease during the three drought periods and are highly variable from year to year. If the values are sorted based on annual runoff, the general trend is for the index values to increase with increasing annual runoff. There are, however, other factors that cause considerable variability around this trend. These factors likely vary for each lake because the regression equations on which the index values are computed have differing dependent variables on which the equations are based.

7.7.2 Coldwater Fish Habitat in Mainstem Lakes

The minimum coldwater fish habitat volume available from July through October in the upper three Mainstem Reservoir System lakes was estimated for each year of the 100-year simulation period. The following is a comparison of results for the CWCP, the MCP, and the four GP options. Table 7.7-2 and Figure 7.7-5 present the average annual values for the 100-year period of analysis for the upper three lakes. Even though Lake Francis Case was modeled, data for this lake is not included because the average annual values are essentially zero.

The CWCP provides 9.88 MAF of coldwater fish habitat on an annual basis, the lowest amount of the alternatives discussed in this chapter. This total volume at the sites analyzed is distributed among Fort Peck Lake (36.3 percent), Lake Sakakawea (28.3 percent), and Lake Oahe (35.4 percent). As shown in Figure 7.7-5, the CWCP and the MCP group together between 9.88 and 10.18 MAF, a difference of 0.30 MAF. The four GP options are more closely aligned with volumes that range between 10.68 and 10.79 MAF, a difference of only 0.11 MAF. Compared to the CWCP, the GP2021 and GP1521 options have the greatest total volume of average annual coldwater fish habitat in the mainstem lakes. To provide perspective as to how the GP options would perform relative to the submitted alternatives, this figure also illustrates the values for the submitted alternatives discussed in Chapter 5. The GP options provide a total average amount of coldwater fish habitat in the mainstem lakes that is closest to the ARNRC alternative. The ARNRC alternative provides 0.03 MAF (0.3 percent) more coldwater fish habitat than the GP1528 option. Both the GP1528 option and the ARNRC alternative have a 15.0-kcfs spring rise; however, the GP1528 option has a flat, 28.5-kcfs, summer low flow, whereas the ARNRC alternative has a lower summer flow of 18 kcfs. Because less water would be released from the mainstem lakes during the summer months, as with the ARNRC alternative, there would be more coldwater fish habitat available within the lakes.

Within the mainstem lakes, the MCP increases total coldwater fish habitat 3.1 percent, the smallest total percentage increase over the CWCP. Although the CWCP and the MCP have no additional spring rise and have a flat full navigation service level release during the summer at Gavins Point Dam, the MCP has greater conservation in the upper three lakes in the drought periods. These differences from the CWCP result in a habitat increase within Fort Peck Lake (4.2 percent) and Lake Oahe (6.1 percent). Under the MCP, coldwater fish habitat decreases in Lake Sakakawea by 1.8 percent.

A 15-kcfs spring rise and a flat summer release (28.5 kcfs) from Gavins Point Dam, as with the GP1528 option, results in a 6-kcfs decrease in summer navigation service level compared to the MCP. This increases total coldwater fish habitat in the upper three mainstem lakes by 5.4 percent. The GP1528 option creates additional habitat over the MCP in Fort Peck Lake (4.0 percent), Lake Sakakawea (12.0 percent), and Lake Oahe (1.9 percent).

Table 7.7-2. Average annual coldwater fish habitat in the mainstem lakes (MAF).

		1898 to 1997		
Alternative	**Total**	**Fort Peck Lake**	**Lake Sakakawea**	**Lake Oahe**
CWCP	**9.88**	3.59	2.81	3.47
MCP	**10.18**	3.74	2.76	3.68
GP1528	**10.73**	3.89	3.09	3.75
GP2021	**10.76**	3.87	3.08	3.81
GP1521	**10.79**	3.89	3.07	3.83
GP2028	**10.68**	3.85	3.09	3.73

The GP2021, GP1521, and GP2028 options provide some perspective for how coldwater fish habitat in the mainstem lakes could change in the future relative to the GP1528 option, the GP option with the lowest spring rise and the highest summer flows. The GP2021 and GP1521 options' respective 20- and 15- kcfs spring rise and split summer release from Gavins Point Dam result in similar changes in coldwater fish habitat compared to the GP1528 option. Also compared to the GP1528 option, the GP2021 and GP1521 options create 0.3 and 0.6 percent more total coldwater fish habitat, respectively. In Fort Peck Lake, the GP2021 option decreases habitat by 0.5 percent, while the GP1521 option results in a change in habitat from the GP1528 option. In Lake Sakakawea, the GP2021 and GP1521 options decrease habitat by 0.3 and 0.6 percent, respectively, while in Lake Oahe they provide 1.6 and 2.1 percent additional habitat, respectively, than the GP1528 option.

The GP2028 option's 20-kcfs spring rise and flat summer release result in a 0.5 percent decrease in total coldwater fish habitat compared to the GP1528 option. In Fort Peck Lake and Lake Oahe, the GP2028 option decreases coldwater fish habitat by 1.0 and 0.5 percent, respectively. In Lake Sakakawea, there is no variation in the amount of habitat from the GP1528 option.

The annual values of total mainstem lake coldwater fish habitat for the CWCP, the MCP, and the four GP options are shown on Figures 7.7-6 through 7.7-8. The 1930 to 1941 drought period show the least amount of total coldwater fish habitat for all of the alternatives discussed in this chapter. The alternatives that have slightly higher habitat values during this period are the MCP and the GP1528 and GP2028 options. The CWCP shows the least amount of habitat during this period. During the 1954 to 1961 and the 1987 to 1993 drought periods, other reductions of habitat occur, up to 5 MAF; however, they are less severe than that which occurred during the 1930 to 1941 drought period, which reduced habitat below 5 MAF. In addition, the duration for these latter two declines is about 2 to 5 years rather than 10 years. Other than these three periods, annual coldwater fish habitat is fairly stable, between 10 and 15 MAF, during the 100-year period of analysis.

7.7.3 Coldwater Fish Habitat in River Reaches

The number of miles of coldwater fish habitat downstream from Fort Peck and Garrison Dams was computed for the months of April through September. Two factors used to determine the amount of habitat for coldwater fish species were the amount of water released from the upstream dam and its water temperature. Generally, higher lake levels and higher releases result in more miles of coldwater habitat below the dams. Differences in the amount of this habitat for the CWCP, the MCP, and the four GP options are discussed in this section. Annual values were computed and then averaged to compute a single value for each of the two reaches. Table 7.7-3 and Figure 7.7-9 present the combined total value, for the two reaches, and the table presents the value for each reach over the 100-year period of analysis. Before reading the following paragraphs, one additional bit of information is important to understand. The Fort Peck numbers are high for all five alternatives to the CWCP because the coldwater habitat model does not account for the fact that warmer water will go over the spillway at Fort Peck in the years there is a spring rise or very high releases from the dam. The relative differences among the five alternatives should be about the same as presented. The precise number of miles of coldwater fish habitat converted to warmwater fish habitat during the Fort Peck flow modification will depend on the actual climatological and hydrologic conditions, the lake water temperature, and the division of flow between the powerhouse and the spillway. The Fort Peck flow modification will not impact the

Table 7.7-3. Average annual coldwater fish habitat in the river reaches (miles).

Alternative	Total	1898 to 1997	
		Fort Peck	Garrison
CWCP	**183.6**	140.2	43.4
MCP	**186.7**	142.2	44.5
GP1528	**196.4**	151.3	45.0
GP2021	**196.4**	151.8	44.6
GP1521	**196.3**	151.7	44.6
GP2028	**197.4**	152.3	45.1

coldwater trout fishery immediately below the dam because the spillway and powerhouse releases meet 6 miles below the dam.

The CWCP provides 183.6 miles of coldwater fish habitat in two of the river reaches of the Mainstem Reservoir System on an average annual basis. This total volume at the sites analyzed is distributed among the river reaches below Fort Peck Dam (76.4 percent) and Garrison Dam (23.6 percent). Figure 7.7-9 shows that the CWCP and the MCP are aligned between 183.6 and 186.7 miles, a difference of 3.1 miles. The four GP options are more closely grouped together between 196.3 and 197.4 miles, a difference of only 1.1 miles. The CWCP has the least amount of total coldwater fish habitat within the reaches below Fort Peck and Garrison Dams (183.6 miles), while the GP2028 option has the most total habitat (197.4 miles). This figure also depicts the values for the submitted alternatives discussed in Chapter 5, to show how the GP options perform relative to the submitted alternatives. The GP options provide total average annual coldwater fish habitat values that are closest to the FWS30 and BIOP alternatives. These two alternatives are very similar to the four GP options in that they have the same operating features except for different spring rises relative to all of the GP options and different summer low releases from Gavins Point Dam than the GP1528 and GP2028 options.

The CWCP and the MCP are very similar in that they have no spring rise and the same summer flat full navigation service level release at Gavins Point Dam. The MCP's unbalanced intrasystem regulation and higher level of drought conservation creates more total coldwater fish habitat (1.7 percent) in the two river reaches of the Mainstem Reservoir System than the CWCP. It also creates 1.4 and 2.5 percent more habitat below Fort Peck and Garrison Dams, respectively. Compared to the GP options, the increases in habitat under the MCP represent the smallest percent increase over the CWCP.

Compared to the MCP, the GP1528 option increases total coldwater fish habitat within the river reaches by 5.2 percent. Compared to the MCP, the GP1528 option's added 15-kcfs spring rise combined with a reduced (6-kcfs lower) flat summer release increases coldwater fish habitat by 6.4 percent below Fort Peck Dam and by 2.5 percent below Garrison Dam.

The GP2021, GP1521, and GP2028 options provide perspective for how coldwater fish habitat in the river reaches could change in the future relative to the GP1528 option. The GP2021 and GP1521 options result in similar changes in coldwater fish habitat compared to the GP1528 option. Also, compared to the GP1528 option, the GP2021 and GP1521 options both create 0.4 to 0.5 more mile of total coldwater fish habitat below Fort Peck Dam and result in 0.9 percent less habitat below Garrison Dam. Compared to the two other GP options, the GP2028 option is the only one that results in an overall increase in coldwater fish habitat below both Fort Peck Dam (0.7 percent) and Garrison Dam (0.2 percent). Compared to the GP1528 option, the GP2028 option's 20-kcfs spring rise combined with a flat summer release of 28.5 kcfs creates more coldwater fish habitat in the river reaches than the two other GP options.

Figures 7.7-10 through 7.7-12 graphically depict the annual values for total coldwater river fish habitat for the CWCP, the MCP, and the four GP options. Generally, all of the alternatives discussed in this chapter maintain an average 200 miles of habitat during the full period of analysis. Habitat is reduced to between 100 and 150 miles, its lowest amount, during the late 1930s and early 1940s; however, the GP1528 option maintains higher habitat values during this period than the remaining alternatives.

7.7.4 Warmwater Fish Habitat in River Reaches

The number of miles of warmwater river fish habitat downstream from Fort Peck, Garrison, and Fort Randall Dams in each month from April through August was estimated using another fish habitat model. In general, the amount of warmwater habitat is expected to be lower for an alternative that has higher amounts of water in storage. This is the opposite of the effects described for coldwater river fish habitat. The following compares the amount of effects on warmwater river fish habitat of the CWCP, the MCP, and the four GP options. Table 7.7-4 and Figure 7.7-13 present the average annual warmwater river fish habitat for the 100-year period of analysis. The total value is the sum of all three reaches, with the reach downstream from Fort Peck Dam providing more than 60 percent of the habitat.

The numbers for the Fort Peck reach for the alternatives should be generally higher than presented because there is a warmer water release over the spillway at Fort Peck when there is a spring rise or very high releases at Fort Peck Dam. The relative difference among these alternatives should stay about the same, however.

The CWCP provides 52.9 miles of warmwater fish habitat in three of the river reaches of the Mainstem Reservoir System on an annual basis. This total volume for the reaches analyzed is distributed among the river reaches below Fort Peck Dam (62.0 percent), Garrison Dam (11.5 percent), and Fort Randall Dam (26.3 percent). Figure 7.7-13 shows that the four GP options are closely grouped together between 44.6 and 45.3 miles, a difference of only 0.7 mile. The CWCP and the MCP are more aligned between 48.8 and 52.9 miles, a difference of 4.1 miles. While the CWCP provides the most total warmwater fish habitat in the three river reaches of the Mainstem Reservoir System (52.9 miles), both the GP1521 and GP2028 options provide the least amount of habitat (44.6 miles). Figure 7.7-13 also depicts the values for the submitted alternatives discussed in Chapter 5, to show how the GP options perform relative to the submitted alternatives. The GP options provide a total average warmwater fish habitat value that is similar to the FWS30, BIOP, and ARNRC alternatives.

Compared to the CWCP, the MCP is the only alternative that does not change the amount of warmwater fish habitat below Garrison Dam. The four GP options increase habitat in this reach. In addition, these options, including the MCP, provide less warmwater fish habitat than the CWCP below both Fort Peck and Fort Randall Dams. The MCP reduces total warmwater fish habitat by 7.8 percent and the reduction in habitat downstream of Fort Peck and Fort Randall Dams is nearly equal (8.5 and 8.6 percent less habitat, respectively). This reduction of habitat under the MCP represents the smallest percent change from the CWCP of all the alternatives discussed in this chapter.

Compared to the MCP, it appears that a lower, flat summer release from Gavins Point Dam, as with the GP1528 option, the GP option with the lowest spring rise and the highest summer flows, reduces total warmwater fish habitat by 7.2 percent. Below Fort Peck and Fort Randall Dams, the GP1528 option provides 9.7 to 7.9 percent less habitat than the MCP, respectively; however, this option increases habitat below Garrison Dam.

The following discussion on the GP2021, GP1521, and GP2028 options provide perspective for how warmwater fish habitat in the river reaches could change in the future if changes are made to the GP1528 option. A split summer release, as with the GP2021 and GP1521 options, tends to increase warmwater fish habitat downstream of Fort Peck Dam (0.7 and 0.4 percent, respectively) and decrease habitat below Fort Randall Dam (6.8 percent). Compared to the GP1528 option, the GP2021 and GP1521 options do not change the amount of habitat below Garrison Dam. The GP2028 option is the only option that reduces warmwater fish habitat below all three dams. A 20-kcfs spring rise and a flat summer release result in a 1.5 percent total decrease in warmwater fish habitat compared to the GP1528 option. Under the GP2028 option, habitat also is reduced below Fort Peck, Garrison, and Fort Randall Dams by 1.8, 1.5, and 0.9 percent, respectively.

As shown on Figures 7.7-14 through 7.7-16, the availability of warmwater fish habitat is highly variable during the full period of analysis. There is an overall increase in warmwater fish habitat during the 1930 to 1941 drought period, and in the following year or two. Of the fish models analyzed thus far, the warmwater fish habitat model is the only one that has shown an overall benefit in habitat during this period. The CWCP shows a greater benefit during this 13-year period.

Table 7.7-4. Average annual warmwater fish habitat in the river reaches (miles).

		1898 to 1997		
Alternative	**Total**	**Fort Peck**	**Garrison**	**Fort Randall**
CWCP	**52.9**	32.8	6.1	13.9
MCP	**48.8**	30.0	6.1	12.7
GP1528	**45.3**	27.1	6.5	11.7
GP2021	**44.7**	27.3	6.5	10.9
GP1521	**44.6**	27.2	6.4	10.9
GP2028	**44.6**	26.6	6.4	11.6

7.7.5 Physical Habitat for Native River Fish

Native river fish habitat values were computed for the river reaches downstream from four of the dams and for five subreaches on the Lower River downstream from Sioux City. An index value (correlation coefficient) was computed for nine of the months based on how closely the velocity and/or depth distributions for a given river reach match the "natural" flow conditions based on pre-Mainstem Reservoir System channel conditions. In April, May, and June, the habitat value is dependent upon the potential for overbank flooding for each reach. The index value for each month can range from 0 to 1.0, with a value of 1.0 assigned to a perfect match. The values for each of the 12 months are summed to compute an annual index value that can be as high as 12.0 for each reach. A total annual value is computed by combining the values from the nine reaches. Average annual values are the means for the individual and total reaches. This section discusses the physical habitat values for native river fish that were computed for the CWCP, the MCP, and the four GP options. The total and individual reach average annual values are presented in Table 7.7-5 and only the total value is presented in Figure 7.7-17.

As shown in Figure 7.7-17, all of the alternatives discussed in this chapter are closely grouped together between 81.46 and 82.44 units, a difference of about 1.0 unit. The total relative index value for the CWCP is the lowest of the alternatives discussed in this chapter while the GP2028 option has the highest index value. Compared to the CWCP, the GP2028 option provides a 1.2 percent index value increase for total physical habitat for native fish. This figure also shows the values for the submitted alternatives discussed in Chapter 5, to illustrate how the GP options perform relative to the submitted alternatives. The GP options provide total average annual physical habitat index values in the same range as the FWS30 and BIOP alternatives.

Compared to the CWCP, the MCP increases the index value for physical fish habitat within two of the four river reaches (Fort Peck by 0.6 percent and Garrison by 1.0 percent), and within four of the five Lower River subreaches. The index value within the Boonville subreach does not change from the CWCP. Although the MCP increases the index values within these reaches, it provides the smallest percent changes from the CWCP within the Sioux City (0.1 percent), Nebraska City (1.0 percent), St. Joseph (0.9 percent), and Kansas City (0.1 percent) subreaches, and within the Fort Peck reach (0.6 percent). The MCP increases the index value over the CWCP within the Garrison reach, which represents the largest percentage increase over the CWCP of all the alternatives discussed in this chapter. While the MCP's added unbalanced intrasystem regulation and higher drought conservation measures result in an index value increase in the above reaches, these factors result in a decrease of 0.7 and 0.6 percent below Fort Randall and Gavins Point Dams, respectively. Compared to the four GP options, the decrease below Gavins Point Dam under the MCP represents the largest percentage decrease compared to the CWCP.

Compared to the MCP, the GP1528 option increases the index value for physical fish habitat within three of the four Mainstem Reservoir System river reaches (Fort Peck reach by 1.3 percent and the Fort Randall and Gavins Point reaches by 0.8 percent). The river reach below Garrison Dam is the only one that shows an index value decrease (1.8 percent) under this option. A 15-kcfs spring rise and flat summer release (28.5 kcfs) from Gavins Point Dam, as with the GP1528 option, increases index values within all five of the Lower River subreaches downstream from Sioux City. Under this option, the Sioux City subreach

Table 7.7-5. Average annual physical habitat for native river fish in nine river reaches (relative index).

		1898 to 1997								
Alternative	**Total**	**Fort Peck**	**Garrison**	**Fort Randall**	**Gavins Point**	**Sioux City**	**Nebraska City**	**St. Joseph**	**Kansas City**	**Boonville**
CWCP	**81.46**	9.03	7.86	8.56	9.30	10.22	7.98	7.93	10.03	10.55
MCP	**81.64**	9.08	7.94	8.50	9.24	10.23	8.06	8.00	10.04	10.55
GP1528	**82.23**	9.20	7.80	8.57	9.31	10.24	8.23	8.15	10.11	10.62
GP2021	**82.12**	9.19	7.85	8.45	9.34	10.11	8.22	8.19	10.12	10.64
GP1521	**81.91**	9.19	7.84	8.44	9.33	10.07	8.18	8.15	10.09	10.62
GP2028	**82.44**	9.21	7.83	8.57	9.31	10.27	8.27	8.20	10.14	10.63

experiences the lowest percentage increase compared to the MCP (0.1 percent), while the Nebraska City subreach experiences the greatest percent increase (2.1 percent). The St. Joseph, Kansas City, and Boonville subreaches show a 1.9, 0.7, and 0.7 percent increase in index values over the MCP, respectively.

The following discussion on the GP2021, GP1521, and GP2028 options provides perspective for how physical habitat for native river fish could change in the future if changes are made to the GP1528 option. A 5-kcfs difference in the spring rise, where the GP2021 option has a higher spring rise than the GP1521 option, and a split 25/21-kcfs summer release results in a similar change in index values within the four system river reaches. Compared to the GP1528 option, the GP2021 and GP1521 options decrease the index value for physical habitat for native river fish downstream of Fort Peck Dam by 0.1 percent and Fort Randall Dam by 1.4 and 1.5 percent, respectively. The GP2021 option provides slightly greater index value increases below both Garrison Dam (0.6 percent) and Gavins Point Dam (0.3 percent) than the GP1528 option. Compared to the GP1528 option, the GP2021 option increases physical habitat index values in three of the five subreaches downstream from Sioux City: St. Joseph (0.5 percent), Kansas City (0.1 percent), and Boonville (0.2 percent), and decreases the index value in the remaining two subreaches: Sioux City (1.3 percent) and Nebraska City (0.1 percent). The GP1521 option decreases the index value in three of the five subreaches: Sioux City (1.7 percent), Nebraska City (0.6 percent), and Kansas City (0.2 percent), and results in no change in the index value from the GP1528 option in the St. Joseph and Boonville subreaches. The GP2028 option has a 20-kcfs spring rise and a flat summer release of 28.5 kcfs that represents the minimum navigation service, summer low flow. It is apparent that an additional 5 kcfs during the spring rise increases the index values for physical fish habitat in two of the four system river reaches and in all of the five subreaches downstream from Sioux City over the GP1528 option. The GP2028 option increases the index value in the reaches below Fort Peck Dam (0.1 percent) and Garrison Dam (0.4 percent). This option does not result in a change in index values below Fort Randall Dam and Gavins Point Dams. Under this option, the Sioux City, Nebraska City, St. Joseph, Kansas City, and Boonville subreaches all increase index values over the GP1528 option. The improvements to the index values for the three GP options, when compared to the CWCP, are greatest in the Sioux City and St. Joseph reaches.

The annual values of total river fish physical habitat for the alternatives discussed in this chapter are shown on Figures 7.7-18 through 7.7-20. In general, the relative index values remain between 80.0 and 85.0 units during the full period of analysis. During the early-1920s and mid-1950s, the relative index values increase for all alternatives to about 88.0 units, whereas values decrease to about 78.0 units during the early 1900s and mid-to-late 1970s. These latter two periods include some high runoff years from the upper Missouri River basin.

7.7.6 Missouri River Connectivity to Low-Lying Lands during the Spring Rise

As stated in the November 2000 USFWS BiOp, “Floodplain connectivity refers to the seasonal flooding of areas adjacent to the river. The spring flood pulse often provides connectivity between the floodplain to the river. For native river fish like the pallid sturgeon, this floodplain connectivity, especially during May/June, provided spawning areas for forage species, increased phytoplankton production, and redistributed carbon to the river”

(USFWS, 2000). This carbon, in the form of detritus scoured off of the floodplain, settled out in the shallow water areas along the river where the microscopic biota grew. As the pallid sturgeon hatched, the larval fish would float down the river until they were able to float into the shallow water areas. There they would reside during their fragile first months of life.

The physical habitat model discussed in the previous discussion on fish impacts acknowledged this important component for the growth of the young-of-year pallid sturgeon, and requires over-bank flooding to get high index values in April, May, and June. That is the period when organic matter needs to be flushed into the river to provide biota in the shallow water areas with a food source so that the larval pallid sturgeon have adequate food after spawning. Examination of the physical habitat output files for these 3 months shows very low index values, which means that river flows were generally lower than necessary for overbank flooding. To better understand how much floodplain connectivity may be occurring along the Lower River from Sioux City to the mouth, the Corps undertook an analysis. As a first step in the analysis, the Corps estimated the acreage and elevation of the low-lying lands (areas adjacent to oxbow lakes and chutes) that could be inundated by high river flows. The elevations were then converted to river stages for the output nodes of the Daily Routing Model (DRM) hydrologic model to determine when the spring rises were inundating these areas. The months of May and June, the period when the spring rise was modeled in most of the DRM simulation runs, were checked to see how many acres were flooded for a varying number of days for the alternatives being analyzed. All of the alternatives selected for detailed analysis were analyzed with this model of connectivity.

The graphical results of the analyses of connectivity are duration plots of acres inundated versus percent of the time. Duration plots were developed for inundation for at least 2 days up to over 10 days. As the number of days is increased, the amount of acres inundated diminishes, and the curves slide to the lower left on the plots. The duration plot of the 2-day analysis is shown as Figure 7.7-21. This figure shows that the various alternatives provide similar duration plots of connectivity with the number of acres of connectivity for 2 days sometime during May or June increasing as the amount of spring rise increases (GP1521 and GP1528 acres are less than GP2021 and GP2028 acres). This figure also includes the duration plot for the ROR alternative to provide a perspective for how often these low-lying lands would have been inundated for 2 days with no flow control. This flow scenario has considerably higher values across the entire range of the plot from near zero percent to near 100 percent.

Table 7.7-6 presents the total values for the 25th percentile (meaning that 25 percent of the time these acreages will be equaled or exceeded) from Figure 7.7-21 with a breakdown among the reaches making up the total reach from Sioux City to the mouth. The 25th percentile was selected for presentation in the EIS because the alternatives were designed to have spring rises about one-third of the time, and the 25th percentile falls within the range when spring rises may be affecting the amount of connectivity. The total connectivity values are also shown in Figure 7.7-22.

The CWCP provides a total of 3,282 acres of connectivity. The greatest share of this connectivity (39.8 and 23.4 percent) is provided in the Hermann and upstream Boonville reaches. The remaining acres are fairly evenly divided among the five other reaches. The Nebraska City reach has the lowest amount of acres at only 4.1 percent.

Figure 7.7-22 shows the 25th percentile acres of connectivity for the alternatives selected for detailed analysis, the ROR scenario, and the CWCP. The alternatives are clustered into four distinct groups. The lowest group includes the CWCP and the MCP, with a range of only 2 acres. The next group includes the GP options with 15-kcfs spring rises (GP1521 and GP1528), and they have about 100 acres more connectivity than the lowest group. The third group includes the GP options with 20-kcfs spring rises with about 70 acres more than those options with only 15-kcfs spring rises. Finally, the ROR scenario, which has no inflow control (uncontrolled releases from Gavins Point Dam), has the highest value, at 646 acres higher than the CWCP and almost 470 acres more than the higher spring rise GP options.

The MCP has basically the same spring release from Gavins Point Dam as the CWCP; therefore, it has essentially the same connectivity value for the 25th percentile. Two reaches, Sioux City and Nebraska City, increase by 3.0 and 0.7 percent, respectively, and two other reaches, Omaha and Kansas City decrease by of 1.1 and 1.5 percent, respectively.

Table 7.7-6. Connectivity to low-lying lands for 2 days in May and June (acres for the 25th percentile).

River Mile		CWCP	MCP	GP1528	GP2021	GP1521	GP2028
734-648	Sioux City	249	257	316	332	309	334
648-597	Omaha	270	267	295	344	298	351
597-497	Nebraska City	136	137	137	137	137	137
497-374	St Joseph	287	287	287	287	287	287
374-250	Kansas City	265	261	271	272	271	272
250-130	Boonville	768	768	768	768	768	768
130-0	Hermann	1,307	1,307	1,307	1,307	1,307	1,307
Total		**3,282**	**3,284**	**3,380**	**3,446**	**3,377**	**3,456**

The GP1528 option has the lowest spring rise and the highest summer flows, representing the least amount of change from the MCP of the four GP options. This option has a 15-kcfs spring rise. Its 25th percentile value is 2.9 percent higher than the MCP. The greatest share of the increase occurs in the two reaches analyzed that are closest to Gavins Point Dam—Sioux City (23.1 percent increase over the MCP for this reach) and Omaha (10.2 percent increase) reaches. One of the other reaches, the Kansas City reach, has a change of 3.6 percent. The other four reaches have no change.

The GP2021 option has both a Gavins Point Dam spring rise change from 15 to 20 kcfs and a reduced summer release compared to the GP1528 option. A switch to this option with an extra 5 kcfs in the spring increases the 25th percentile connectivity value by 2.0 percent compared to the value for the GP1528 option. The larger increases occur in the Sioux City (5.1 percent) and the Omaha (16.6 percent) reaches. There is some increase in the Kansas City reach, with an increase of 0.5 percent. The other four reaches have no change from the value for the GP1528 option.

The GP1521 option has the same spring rise as the GP1528 option; however, it has the reduced summer release. This option has essentially the same total value as the GP1528 option, which would be expected because the spring rise drives the changes in connectivity. The total connectivity value drops just 0.1 percent for the change from the GP1528 option to the GP1521 option. A decrease of 2.3 percent occurs in the Sioux City reach, and an increase of 1.0 percent occurs in the Omaha reach. The other four reaches have no change in connectivity value with the change to the GP1521 option.

The GP2028 option has a Gavins Point Dam spring rise change from 15 to 20 kcfs, but it has the same summer release as the GP1528 option. A switch to this option from the GP1528 option results in an increase of 2.2 percent in the total connectivity. The primary increases occur in the Sioux City (5.8 percent) and Omaha (19.0 percent) reaches. A minor increase (0.5 percent) occurs in the Kansas City reach. The other three reaches have no change.

The model was not set up to provide year-to-year values for acres of connectivity. If it had, the results would have shown considerable fluctuation throughout the 100-year period of analysis because the forced spring rises from Gavins Point Dam would have increased connectivity in the upstream reaches. The downstream reaches would have also shown considerable year-to-year variability as the flows on the lower reaches fluctuated with tributary inflows in the spring.

In conclusion, the gains in connectivity in the low-lying areas with flow increases via spring rises are relatively minor. In fact, there is effectively no increase in value downstream of the Omaha reach. By adding a spring rise of 15 kcfs, the gain in connectivity is about 100 acres, and the gain is about an additional 70 acres for adding an additional 5 kcfs (for a total spring rise of 20 kcfs). These data indicate that the spring rise included in the alternatives does not provide the gains in connectivity potentially anticipated with increased spring flows.

Another way of looking at the end result of connectivity, the flushing of detritus into the river, is to think about how this type of material gets into the river. Approximately 3,500 acres of low-lying lands would be inundated for 2 days during the May through June timeframe according to the data presented above. This is approximately 5.5 square miles. A small tributary to the Missouri River is likely to be several times larger than 5.5 square miles, and a rainfall event on the drainage area for each tributary flushes detritus into the tributary, which ultimately gets carried into the Missouri River. There are many thousands of acres that drain into the Missouri River, and many of the tributaries carry heavy sediment loads into the river during major rainfall events. These tributaries are, and will continue to be, the main source of detritus to the Missouri River.

7.7.7 Shallow Water Habitat Along the Lower River

In its November 2000 BiOp, the USFWS states that shallow water habitat has value to all life stages of native big river fish and other river organisms. As stated in the introductory remarks of the connectivity analysis discussion, shallow water habitat is especially important during the first few months of the life of the larval pallid sturgeon, an endangered species. The Corps and USFWS agreed during the formal consultation for, and the review of, the BiOp, that 20 to 30 acres of shallow water habitat per mile may provide the habitat necessary for initial recovery of pallid sturgeon. This part of the fish section of the EIS focuses on the amount of shallow water habitat occurring in the Lower River for the CWCP, the MCP, and the four GP options.

The analysis of existing shallow water habitat under the various alternatives was conducted using data obtained for the physical habitat model. As part of the development of that model, cross sections were taken at a representative subreach of seven reaches of the Lower River and hydraulically modeled. These data provided a basis for determining the amount of habitat fitting into a variety of depth and velocity classes for each of the seven reaches (habitat per mile times reach length). Shallow water habitat for the purpose of this analysis is habitat that is up to 5 feet deep with a velocity no greater than 2.5 feet per second. The amount of habitat in each depth and velocity class could be determined based on the amount of flow in each river reach. Using these relationships, the Corps developed a model that would provide duration plots of the acres of habitat per mile in each reach for any timeframe of interest. Generally, the Corps looked at individual months; however, the lowest flows for two of the alternatives occur from mid-July to mid-August. Data were computed for this period for the seven Lower River reaches. Figure 7.7-23 is one of the resulting plots for the CWCP, the MCP, and four GP options. Integration of the area under the duration curve leads to the average daily value per mile for shallow water habitat for each reach. Table 7.7-7 presents these data for all seven subreaches modeled for the CWCP, the MCP, the GP options, and the ROR scenario. Using these acres per mile, the total acreage available in each reach of the Lower River from Gavins Point Dam to the Osage River (RM 130) can be computed. The data for five reaches are presented in Table 7.7-8 on a reach and total basis (data combined using data from two locations for the Sioux City to Omaha reach). Figure 7.7-24 shows the total acres for the five reaches from Sioux City to the Osage River for the CWCP, the MCP, the four GP options, and the ROR scenario (no control of system inflows by the Mainstem Reservoir System). Data are not presented for the reach downstream from Gavins Point Dam because there is already adequate habitat (63.8 acres per mile for the CWCP) in this reach.

The CWCP provides 3,717 acres of shallow water habitat for the five reaches. The greater share of this habitat is provided between the Grand and Osage Rivers in the central part of the State of Missouri: 2,193 acres, or 59.0 percent of the total. The Nebraska City to Kansas City reach provides 25.0 percent of the total, and the other three reaches provide only 16.0 percent of the total, with the Sioux City to Omaha reach providing about half of that.

Table 7.7-7. Expected daily shallow water habitat for representative subreaches from mid-July to mid-August (acres/mile).

Reach	CWCP	MCP	GP1528	GP2021	GP1521	GP2028	ROR
Gavins Point	63.8	63.2	69.2	71.6	71.2	69.8	64.9
Sioux City	2.2	2.3	3.3	5.8	5.8	3.4	3.6
Omaha	1.9	2.0	2.9	5.1	5.1	3.0	3.3
Nebraska City	4.5	4.6	5.0	6.0	6.0	5.0	5.1
St. Joseph	4.8	5.1	5.7	7.9	7.9	5.7	6.2
Kansas City	1.4	1.4	1.6	1.7	1.7	1.6	1.2
Boonville	18.3	18.2	18.9	18.7	18.7	18.9	17.4

Table 7.7-8. Expected daily shallow water habitat available from mid-July to mid-August (acres).

Reach	CWCP	MCP	GP1528	GP2021	GP1521	GP2028	ROR
Sioux City to Omaha	288	304	436	757	754	442	479
Omaha to Nebraska City	144	148	161	191	191	161	165
Nebraska City to Kansas City	929	971	1,088	1,513	1,512	1,090	1,187
Kansas City to Grand River	164	157	189	200	198	188	144
Grand River to Osage River	2,193	2,187	2,263	2,245	2,243	2,266	2,086
Total	**3,717**	**3,767**	**4,137**	**4,906**	**4,899**	**4,147**	**4,061**

Figure 7.7-25 shows that the total acreage varies among the CWCP, the MCP, the four GP options, and the ROR scenario. These can be divided up into three groupings. The lowest grouping has two alternatives, the CWCP and MCP. The range in values is from 3,717 to 3,767, a difference of 50 acres. The two GP options with a minimum navigation service summer flat release, and the ROR scenario are in the second lowest group at between 4,061 to 4,147 acres, a range of 86 acres and about 300 acres more than the top of the lowest group. Next come the two GP options with the 25/21-kcfs split summer release. These two options have values at about 4,900 acres, which is about 1,200 acres more than the lowest group.

The MCP provides a summer flat Gavins Point Dam release essentially the same as the CWCP; therefore, it generally has similar summer flows to the CWCP. As expected, it also has similar total shallow water habitat, at 3,767 acres, as presented in Table 7.7-8. This total represents a 1.3 percent increase in shallow water habitat in the mid-July to mid-August timeframe. There is some variation among the reaches. The three reaches between Sioux City and Kansas City have increased habitat ranging from an increase of 2.9 percent in the middle of the three reaches to an increase of 5.6 percent in the Sioux City to Omaha reach. In contrast, the lower two reaches have decreases of 4.6 and 0.5 percent.

The GP1528 option has the lowest spring rise and the highest summer flows, representing the smallest changes in the spring and summer releases from Gavins Point Dam. This option has a summer flat release of 28.5 kcfs, which is assumed to provide minimum service to navigation. The 4,137 acres represent a 9.8 percent increase in habitat over the MCP. The greatest increase (43.5 percent) in a reach occurs in the Sioux City reach. The other reaches increase by from 3.5 to 20.3 percent over the MCP.

The GP2021 option has summer Gavins Point Dam releases split between 25 and 21 kcfs, with the 21-kcfs release occurring in the mid-July to mid-August timeframe. This alternative has the greatest amount of shallow water habitat at 4,906 acres, which is an increase of 18.6 percent over the GP1528 option. The greatest increases are for the Sioux City to Omaha and the Nebraska City to Kansas City reaches, with increases of 73.5 and 39.0 percent, respectively. The Omaha to Nebraska City and the Kansas City to Grand River reaches have increases of 18.4 and 6.1 percent, respectively.

The GP1521 option also has summer flows in the mid-July to mid-August timeframe that are split between 25 and 21 kcfs; therefore, it has shallow water habitat changes similar to the GP2021 option. The total habitat of 4,899 acres represents an increase of 18.4 percent over the GP1528 option. The four reaches between Sioux City and the Grand River increase, ranging from 5.2 to 72.9 percent. Only the lowest reach decreases (by 0.9 percent).

The GP2028 option has a minimum navigation service release from Gavins Point Dam. This release was modeled as a 28.5-kcfs flat release. This is the same as the GP1528 option; therefore, shallow water habitat is similar to the GP1528 option. Total habitat increases by only 0.2 percent. Four of the reaches have increased values and one, the Kansas City to Grand River reach, has a decreased value. The range in changes is from an increase of 1.3 percent to a decrease of 0.1 percent.

A special effort was made to have the shallow water habitat model create an output file of the average daily habitat values for each year. This data set allowed the creation of Figures 7.7-26 to 7.7-28. The first figure compares the annual values for the CWCP and the MCP. It shows relatively little difference except for noticeable increases during 3 years in the 1930 to 1941 drought and 1 low year in the mid-1960s. The drought years are likely non-navigation years when Gavins Point Dam releases would be targeting an 18-kcfs water supply target in the mid-July to mid-August timeframe. The reason for the noticeable decrease in the mid-1960s resulted from the need to evacuate some extra water from the flood control storage zones. This resulted from the effect of coming out of the 1954 to 1961 drought at a higher storage level, which led to a greater amount of water in storage in a subsequent high inflow year. Going to a minimum service flat release under the GP1528 option (see Figure 7.7-27) increases habitat slightly in a relatively large number of years when compared to the MCP acreage. Finally, further reducing the summer Gavins Point Dam release to 21 kcfs during this mid-summer period results in even more shallow water habitat in most years, as shown in Figure 7.7-28. Results for the GP1521 and GP2028 options were similar to the GP2021 and GP1528 options results described above. The summer low-flow release value provides the changes among the alternatives.

Additional discussion is needed regarding the amount of habitat that exists per mile in the reaches from Sioux City to the Osage River. With the exception of the Grand River to Osage River reach, habitat acreage is well below the minimum of 20 acres per mile that the USFWS recommended in its November 2000 BiOp Reasonable and Prudent Alternative (RPA) for the pallid sturgeon. Even though there are some increases in shallow water habitat (as discussed above and shown in Figures 7.7-24 and 7.7-25), the gains provided by release changes alone are not enough to provide the minimum 20 acres per mile. Because of this, the USFWS included in its BiOp RPA the recommendation for the Corps to construct additional shallow water habitat. If the GP1528 option or the GP2028 option were the selected plan, habitat construction would be reduced by about 400 acres compared to what would be needed for the CWCP or the MCP. If the GP1521 option or the GP2021 option were the selected plan, habitat construction would be further reduced by about 800 acres compared to the other two GP options, or about 1,200 acres less than what would be needed for the CWCP or the MCP. The relatively low acres per mile values indicate that the lower summer releases will not provide the recommended amount of shallow water habitat.

Another shallow water habitat analysis was conducted for the Lower River to better understand the impacts of a change to the MCP and GP options from the CWCP. A number of Missouri River Mitigation and Section 1135 projects have been constructed along the Missouri River Bank Stabilization and Navigation Project. The projects are designed to optimize the habitat values based on the site-specific objectives and the CWCP. Alternative system release patterns will alter the habitat value of these projects. As with other parameters, the impacts of system releases will decrease with distance from Gavins Point Dam. Further, the number, type, and size of the individual projects will also influence the impacts. The shallow water habitat trends for a change from the CWCP for the Missouri River Mitigation and Section 1135 projects are as follows:

- For the Sioux City to Omaha reach, average shallow water habitat acres decrease by 20 and 50 percent, respectively, for the GP1528 and GP2028 options and the GP1521 and GP2021 options compared to the CWCP. The MCP has essentially the same number of acres of shallow water habitat as the CWCP for this reach.
- For the Omaha to Rulo, Nebraska reach, average shallow water habitat acres decrease by 20 percent for the GP1521 and GP2021 options compared to the CWCP. The difference between the CWCP and the minimum service alternatives is negligible. The MCP has essentially the same number of acres of shallow water habitat as the CWCP for this reach.
- For the reach downstream of Rulo, the average shallow water habitat acres decrease by approximately 10 percent for all four GP options compared to the CWCP. The MCP has essentially the same number of acres of shallow water habitat as the CWCP for this reach.

7.7.8 Spawning Cue for the Lower River

The November 2000 USFWS BiOp RPA recommends a spring rise release from Gavins Point Dam to provide, among other biologically important functions, a spawning cue for native river fish, especially the endangered pallid sturgeon. The RPA specifies a modified annual release pattern that has a spring rise above the full navigation service releases of 15 to 20 kcfs. This release is to last for a duration of 2 weeks at its peak and a total of 4 weeks including the period over which the releases are gradually increased and decreased. Discussions between USFWS and Corps staff determined that the spawning cue requirements of the pallid sturgeon are basically unknown at this time.

In an e-mail sent to the Corps on January 22, 2001, the USFWS requested the Corps to conduct some hydrologic analyses. This set of analyses included a spring rise analysis. The USFWS requested, "For gage sites downstream of Gavins Point, document spring rise spawning cues. Rises should be defined as increases of discharge of at least 20 percent above the mean discharge prevailing for the preceding 15 days, during the period May – July. The rise should take place over three days or less" (USFWS, 2001). The November 2000 BiOp did not provide any information on what duration of rise to analyze. This lack of information supported the general understanding between the Corps and USFWS staffs that the required spawning cue is basically unknown at this point in time. Corps staff understood that the aforementioned criteria were hypothetical, and they did not have supporting data, analysis, and documentation of associated spawning success. A discussion of the analysis conducted for evaluating a spawning cue follows.

A model was developed that would access the daily flow data for each DRM node location from Gavins Point Dam to the mouth. A running average of the daily flows for the previous 15 days was conducted using the data starting on May 1 and ending on June 30 of each year. (The likelihood of spawning cues after June 30 is low, so it was not checked.) The flows for May 1, 2, and 3 would be checked to determine if the flows over this 3-day period exceeded the prior 15-day average by at least 20 percent. If the flows on one of the days met the 20 percent increase, the model would continue to check the daily average flow until it dropped to less than 20 percent of the flows for the 15 days prior to May 1. The model would continue day by day to check the prior 15 days, compute an average, and count the number of days the flows continued to be at least 20 percent above that prior 15-day average. This continued up to June 30.

In some years there were some short periods and some longer periods. The model recorded the longest period in terms of days. The longest period was recorded for each year, and when the 100 years of data were analyzed. The 100 annual values were sorted from highest to lowest with the highest value assigned a 1 (for equaled or exceeded 1 percent of the time) and the lowest value was assigned a 100 (for equaled or exceeded 100 percent of the time). A plot of these data is called a duration plot, and Figure 7.7-29 is an example of such a plot for the Sioux City gage. This figure shows the duration plots for the CWCP at all of the gage locations in the DRM simulation output files for the Lower River from Sioux City downstream. A similar plot was completed for the CWCP, the MCP, and the four GP options. Another set of curves was developed for the ROR scenario (no control of inflows to the mainstem of the Missouri River). Sets of curves can be compiled for each gage location using this first set of curves, as shown on Figure 7.7-30. This second set of curves, one for each gage location in the DRM, provides the spawning cues for a full range of days. For example, to determine how often a 20 percent increase in flow occurred for a total of 21 consecutive days, one would go to the point where the 21-day line crosses the duration curves. Next one would slide down and read off the percent of time from the bottom axis of the graph for each curve. In the case of the CWCP curve on the figure, this point is located at 7 percent of the time. Similarly, it is 15 percent of the time for the MCP.

Because the USFWS did not specify a length for the spawning cue, one was selected for analysis based on the spring rise recommended in the November 2000 BiOp RPA. The total rise occurs over a 28-day period. If it takes 3 days to go up 20 percent, there will also be 3 days at the end of the spring rise where the releases will drop below the 20 percent value. This means that the spawning cue lasted 22 days (28 minus 6). Based on this basic consideration, a 3-week, or 21-day, length was evaluated for the spawning cue. Figure 7.7-31 shows a plot of the resulting data for all of the gage locations included in the DRM. The curves shown on this plot would shift upward for shorter lengths of spawning cues, and vice versa.

Figure 7.7-31 shows that the CWCP, the MCP, the four GP options, and the ROR have spawning cues that occur for differing amounts of time. The values are presented in Table 7.7-9. For example, the figure shows that the percent of time increases for the CWCP in a downstream direction, with a 21-day spawning cue occurring 7 percent of the time at Sioux City and a maximum of 38 percent of the time at Hermann. The values for Sioux City vary from alternative to alternative. For example, the MCP raises the value to 15 percent for Sioux City. The GP options further increase the percent value up to 29 percent of the time for the GP1528 and GP1521 options and to as high as 39 percent of the time for the GP2028 option. Generally, for the reaches from Kansas City upstream, the values are higher moving across the figure because the spring rise included in the alternative is higher. Downstream from Kansas City, however, the value for the percent of the time the spawning cue occurs remains relatively constant with the values ranging from 37 to 39 percent. The ROR scenario has more spawning cues because the uncontrolled flows were historically much higher than the modeled spring rises, with the percent values ranging from high on the reaches closest to Sioux City (78 or 79 percent) to the lowest value occurring at Hermann (54 percent).

Figure 7.7-32 shows the same data as in the previous figure and the table, only a different format is used. This may help some readers better see the relationships that are occurring on the river among the array of alternatives. At Sioux City, there is a wide range of percents for the CWCP. Going across the figure in a downstream gage location, the differences among the alternatives diminish and approach the 33 percent line drawn on the plot. This line was drawn because the USFWS specified that the spring rises should happen about one-third of the time. This chart can be interpreted in a couple of ways relative to the 33 percent line. First, by the Kansas City gage location, the spawning cue can be found one-third of the time under the CWCP. In fact it happens one-third of the time for the MCP and the two GP options (with spring rises of 15 and 20 kcfs) shown on the figure. Second, beginning at Kansas City (or as far upstream from the mouth as Kansas City) the spawning cue lasts for 21 days for about one-third of the time, whether or not a spring rise release is made from Gavins Point Dam.

To demonstrate what happens when shorter length spawning cues are used in the analysis, a 14-day and a 7-day spawning cue length were analyzed. As stated earlier, the shorter the spawning cue, the more often it occurs (duration plots shift upward). Figure 7.7-33 shows that this is indeed the case. All of the bars in the graph have shifted upward. The one-third recommendation of the November 2000 BiOp RPA is met by both the GP1528 and GP2021 options at all of the gaging locations with DRM output files. Those locations from Kansas City downstream all have percent values in excess of 35 percent, with some values approaching 50 percent. Figure 7.7-34 shows the results of only a 7-day spawning cue. The lowest value for the MCP and the four GP options is now 29 percent (at Sioux City). The one-third recommendation is met as far upstream as the Nebraska City gage for all four alternatives on the plot.

This brief analysis demonstrates how important it is to have a definitive length for a spawning cue. The MCP comes very close to meeting the one-third requirement for a relatively short spawning cue, and it has a 34.5-kcfs flat release from Gavins Point Dam. This release value is equivalent to a spring rise of about 5 to 6 kcfs in the May timeframe. The Corps' understanding of the primary purpose of the spring rise is to cue the pallid sturgeon to spawn; however, the absolute length and magnitude of the required flow to provide an adequate spawning cue are not known at this time.

The criticality of the spawning cue length is also demonstrated using another analysis that provides more insight into the relationship between spawning cues and shallow water habitat. For the pallid sturgeon to receive the greatest potential for future growth in numbers, the larval fish need to have adequate shallow water habitat following the spawn. Figures 7.7-35 to 7.7-37 show plots of both spawning cue length and shallow water habitat over the period of analysis from 1898 to 1997 for the Sioux City reach. The spawning cue lengths range from zero days up to 61 days, and the shallow water habitat areas range from zero up to 8.7 acres. The spawning cue length is affected by the spring flows, with the higher flows generally resulting in longer cue lengths. Conversely, the shallow water habitat size is affected by the summer flows, with the lower flows resulting in greater amounts of habitat. Because they are driven by different factors, they may not always coincide, as shown in the figures.

Table 7.7-9. Percent of years with a 21-day spawning cue at Lower River gaging stations for CWCP, MCP, GP options, and ROR scenario.

	CWCP	MCP	GP1528	GP2021	GP1521	GP2028	ROR
Gavins Point Dam	18	22	37	39	31	46	78
Sioux City	7	15	29	36	29	39	79
Omaha	7	14	28	34	27	38	79
Nebraska City	10	15	27	33	27	35	68
St Joseph	17	19	23	26	24	28	63
Kansas City	33	35	33	40	36	37	62
Boonville	33	33	31	35	35	34	62
Hermann	38	39	37	38	38	39	54

The Sioux City data were selected for display because of the wider variation between the cue and habitat values, especially for the MCP, shown on Figure 7.7-35.

To assist with the identification of years in which these two values are coincident, an Excel spreadsheet model was developed to identify whether the two are coincident in each year, with the shallow water habitat held constant and the cue length allowed to be variable. Four different cue lengths were run to develop the output for the Sioux City reach. The output file was plotted, and the values for the MCP, the GP1528 option, and the GP2021 option are shown on Figure 7.7-38. This figure shows that the percent of the years increases as the spawning cue length decreases. It also shows that the two factors do not coincide very often for the MCP (5 to 11 percent of the years), but the two GP options increase the percent value considerably. A considerable percentage increase across the range of spawning cue lengths occurs for the GP1528 option, and the GP2021 option adds relatively little more percentage increase across the range of cue lengths. One can also determine the spawning cue length required to have both factors coincide in 33 percent of the years (note 33 percent line on the plot). To have at least 2 acres of shallow water habitat available for the MCP, there are not enough years in which there is even a 5-day spawning cue to meet the 33 percent desirable goal (occurs only in 11 years for the 5-day cue). For the GP1528 option, a spawning cue of no shorter than 9 days has a coincidence rate of 33 percent when at least 2 acres of shallow water habitat are available. Similarly, for the GP2021 option, a spawning cue length of at least 14 days has a coincident rate of 33 percent with at least 2 acres of shallow water habitat. In conclusion, shorter spawning cues of 9 days have to result in successful spawning to have a spawning cue with at least 2 acres of shallow water habitat in 33 percent of the years. This analysis was based on the spawning cue occurring in May or June and the shallow water habitat being measured in the period from mid-July to mid-August.

Similar analyses were done for the Nebraska City and Boonville reaches. The results are shown on Figure 7.7-39 for at least 3 acres per mile of shallow water habitat in the Nebraska City reach and on Figure 7.7-40 for at least 15 acres per mile in the Boonville reach. For the Nebraska City reach, the MCP meets the 33 percent level as long as spawning cues can be as short as 7 days to count as a spawning cue. Similar numbers for cue length are 10 days for the GP1528 option and 16 days for the GP2021 option. For the Boonville reach, the spawning cue requirement needs to be no longer than 8 days for the MCP, 9 days for the GP1528 option, and 12 days for the GP2021 option if there are to be coincidental spawning cues and at least 15 acres of shallow water habitat in the same year for 33 percent of the years. If longer spawning cues are required, smaller habitat requirements are needed. Conversely, if more habitat requirements are needed, an “adequate” spawning cue needs to be shorter.

In conclusion, greater knowledge is required of what constitutes an adequate spawning cue. If the primary reason for having a spring rise is to provide an adequate spawning cue for the pallid sturgeon so this species can recover, better definition of an adequate spawning cue is essential. Without this definition, it is impossible to determine if the water control plan that is implemented at the end of the Study can adequately meet the spawning needs of the pallid sturgeon.

Spring rises occur naturally on the Missouri River downstream from Sioux City; the frequency and magnitude of the spring rises is greatest in the reach from Kansas City to the mouth near St. Louis. These spring rises provide an opportunity to obtain insight as to the required factors for a successful spawning cue. Similarly, test releases from Fort Peck Dam in the spring and natural spring rises on the Yellowstone River could be intensively monitored to obtain similar information on the river flow factors that result in a successful spawning cue.

7.7.9 Fish Resources for Tribal Reservations

Young-of-Year Lake Fish Production

Table 7.7-10 presents the relative index of average annual young fish production for seven Tribal Reservations along the mainstem lakes during the full period from 1898 to 1997, for each of the alternatives discussed in this chapter. The Reservations analyzed include Fort Berthold Reservation on Lake Sakakawea; Standing Rock Reservation and Cheyenne River Reservation, which are on Lake Oahe; Lower Brule Reservation and Crow Creek Reservation on Lake Sharpe; Yankton Reservation on Lake Francis Case; and Santee Reservation on Lewis and Clark Lake. As discussed in Section 7.7.1, the young fish index value is useful as an indicator of the relative effects of the different alternatives.

The total index value for average annual young fish production associated with these Reservations is 1.65 units for the CWCP. The MCP and the four GP options result in a total increase in young fish production values over the CWCP: the MCP by 1.2 percent, the GP1528 option by 12.5 percent, the GP2021 option by 13.7 percent, the GP1521 option by 11.9 percent, and the GP2028 option by 11.8 percent.

Within Fort Berthold Reservation, the MCP does not result in an index value change from the CWCP; however, the four GP options all increase the young fish production index value over the CWCP. The GP1521 option shows a 13.0 percent increase in young fish production index values, while the GP2021, GP1528 and GP2028 options all show a 15.2 percent index value increase.

The GP2021 option does not change the young fish production index value within Standing Rock Reservation and Cheyenne River Reservation. The MCP and the GP1528 and GP2028 options all provide the same increase amount over the CWCP (2.5 percent). The GP1521 option is the only option that actually decreases (by 2.5 percent) young fish production index values within Standing Rock Reservation and the Cheyenne River Reservation.

Within Lower Brule Reservation and Crow Creek Reservation, three of the four GP options (GP1521, GP2021, and GP1528) show an 11.6 percent increase in young fish production index values over the CWCP. The GP2028 option results in a 9.3 percent increase and the MCP shows a 2.3 percent decrease in index values.

Compared to the CWCP, the MCP does not result in an index value change within Yankton Reservation. The greatest index value increase over the CWCP occurs under the GP2021 option (35.0 percent), while the GP1521 option results in a 28.3 percent increase. Both the GP1528 and GP2028 options result in a 25.0 percent increase in young fish production index values within Yankton Reservation. Within Santee Reservation, the two GP options that have a split summer low flow (GP1521 and GP2021) and the two options that have a flat summer release (GP1528 and GP2028) yield the same results. The GP1521 and GP2021 options both provide a 25.0 percent increase in young fish production index values, whereas the GP1528 and GP2028 options both provide an 18.8 percent increase. Under the MCP, the young fish production index value increases 12.5 percent over the CWCP.

Coldwater Fish Habitat in Lakes

Table 7.7-11 presents the average annual volume of coldwater fish habitat for three Tribal Reservations along the mainstem lakes during the full period from 1898 to 1997, for the alternatives discussed in this chapter. The Reservations analyzed include Fort Berthold Reservation on Lake Sakakawea; and Standing Rock Reservation and Cheyenne River Reservation, which are on Lake Oahe.

Under the CWCP, the total volume associated with Fort Berthold Reservation and Standing Rock and Cheyenne River Reservations is 6.28 MAF. Compared to the CWCP, the MCP and the four GP options increase coldwater fish habitat: the MCP by 2.5 percent, the GP1528 option by 8.9 percent, the GP2021 option by 9.7 percent, the GP1521 option by 9.9 percent, and the GP2028 option by 8.6 percent.

Within Fort Berthold Reservation, the two GP options with a flat summer release (GP1528 and GP2028 options) increase coldwater fish habitat 10.0 percent over the CWCP. The GP2021 option provides 9.6 percent additional habitat than the CWCP, and the GP1521 option results in a

Table 7.7-10. Average annual young fish production in the mainstem lakes for seven Tribal Reservations (relative index).

	1898 to 1997					
Reservation	**CWCP**	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Berthold	0.46	0.46	0.53	0.53	0.52	0.53
Standing Rock and Cheyenne River	0.40	0.41	0.41	0.40	0.39	0.41
Lower Brule and Crow Creek	0.43	0.42	0.48	0.48	0.48	0.47
Yankton	0.20	0.20	0.25	0.27	0.26	0.25
Santee	0.16	0.18	0.19	0.20	0.20	0.19
Total	**1.65**	**1.67**	**1.86**	**1.88**	**1.85**	**1.85**

Table 7.7-11. Average annual coldwater fish habitat impact for three Tribal Reservations along the mainstem lakes (MAF).

	1898 to 1997					
Reservation	**CWCP**	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Berthold	2.81	2.76	3.09	3.08	3.07	3.09
Standing Rock and Cheyenne River	3.47	3.68	3.75	3.81	3.83	3.73
Total	**6.28**	**6.44**	**6.84**	**6.89**	**6.90**	**6.82**

9.3 percent increase in habitat. The MCP reduces coldwater fish habitat in the mainstem lakes by 1.8 percent.

The MCP and the four GP options increase coldwater fish habitat over the CWCP in Standing Rock Reservation and Cheyenne River Reservation. The GP1521 option results in the greatest percentage increase over the CWCP (10.4 percent) and the GP2021 option provide the next highest increase (9.8 percent). The GP1528 and GP2028 options result in an 8.1 and 7.5 percent increase in habitat, respectively. The MCP increases coldwater fish habitat over the CWCP by 6.1 percent.

Coldwater Fish Habitat in the River

Table 7.7-12 presents the miles of average annual coldwater habitat for Fort Peck Reservation during the full period from 1898 to 1997, for the alternatives discussed in the chapter. Fort Peck Reservation is located downstream of Fort Peck Dam.

Compared to the CWCP, the MCP and the four GP options all increase total coldwater fish habitat within Fort Peck Reservation. The greatest percentage increase in habitat over the CWCP occurs under the GP2028 option (8.6 percent). The two options that have a split summer low flow, GP1521 and GP2021, increase habitat over the CWCP by 8.2 percent. The GP1528 option increases coldwater fish habitat in Fort Peck Reservation by 7.9 percent, and the least amount of habitat increase over the CWCP occurs under the MCP (1.4 percent).

Warmwater Fish Habitat in the River

Table 7.7-13 presents the miles of average annual warmwater habitat for Tribal Reservations along two river reaches during the full period from 1898 to 1997, for all of the alternatives discussed in this chapter. The Reservations analyzed include Fort Peck Reservation, located downstream of Fort Peck Dam, and Yankton Reservation and Ponca Tribal Lands, located downstream of Fort Randall Dam.

Under the CWCP, total warmwater fish habitat associated with these Reservations is 46.8 miles. Compared to the CWCP, the MCP and the four GP options decrease warmwater fish habitat. The MCP and the GP1528 option reduce total habitat by 8.5 and 17.0 percent, respectively; however, the greatest decreases in total habitat occur under the

Table 7.7-12. Average annual coldwater fish habitat for the Fort Peck Reservation (miles).

Reservation	1898 to 1997					
	CWCP	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Peck	140.2	142.2	151.3	151.8	151.7	152.3

Table 7.7-13. Average annual warmwater fish habitat for Reservations in the reaches downstream from Fort Peck and Fort Randall Dams (miles).

Reservation	1898 to 1997					
	CWCP	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Peck	32.8	30.0	27.1	27.3	27.2	26.6
Yankton and Ponca Tribal Lands	13.9	12.7	11.7	10.9	10.9	11.6
Total	**46.8**	**42.8**	**38.8**	**38.3**	**38.2**	**38.2**

GP2021, GP2028, and GP1521 options where there would be an 18.2, 18.3, and 18.4 percent reduction in habitat, respectively.

Compared to the CWCP, the MCP reduces the least amount of habitat within Fort Peck Reservation (8.5 percent). The GP1528 and GP2021 options reduce habitat within this Reservation by 17.4 and 16.8 percent, while the GP1521 and GP2028 options reduce warmwater fish habitat by 17.0 and 19.0 percent, respectively.

Results are similar for Yankton Reservation and Ponca Tribal Lands, where the MCP reduces the amount of habitat the least (8.6 percent). The GP1528 and GP2028 options reduce habitat by 16.1 and 16.7 percent, respectively, while the GP2021 and GP1521 options both decrease warmwater fish habitat within this Reservation by 21.5 percent.

Physical Habitat for Native Fish

Table 7.7-14 presents the index of average annual physical habitat values for seven Tribal Reservations during the full period from 1898 to 1997, for the alternatives discussed in this chapter. The Reservations analyzed include Fort Peck Reservation, downstream of Fort Peck Dam; Yankton Reservation and Ponca Tribal Lands, which are downstream of Fort Randall Dam; and Winnebago Reservation, Omaha Reservation, Iowa Reservation, and Sac and Fox Reservation, all of which are downstream of Gavins Point Dam.

The index value (correlation coefficient) was computed for nine of the months based on how closely the velocity and/or depth distributions for given tribal lands match the "natural" flow conditions based on pre-Mainstem Reservoir System channel conditions. In April, May and June, the habitat value is dependent on the potential for overbank flooding. The index value for each month can range from 0 to 1.0, with a value of 1.0 assigned to a perfect match. The values for each of the 12 months are summed to compute an annual index value that can be as high as 12.0 for the tribal lands specified. A total annual value is computed by combining the values for the tribal lands and can range up to 48.0.

The total index value for average annual physical habitat associated with these Reservations is 35.74 under the CWCP. The MCP and the four GP options result in an increase in total physical habitat index values over the CWCP: the MCP by 0.2 percent, the GP1528 option by 1.2 percent, the GP2021 option by 0.6 percent, the GP1521 option by 0.3 percent, and the GP2028 option by 1.4 percent.

Within Fort Peck Reservation, the MCP and the four GP options all increase the physical habitat index values for native river fish. The greatest index value increases occur under the GP2028 option (2.0 percent) and the GP1528 option (1.9 percent). Both the GP1521 and GP2021 options result in a 1.8 percent increase, while the MCP only provides a 0.6 percent index value increase.

Within Yankton Reservation and Ponca Tribal Lands, both the GP1528 and GP2028 options result in a 0.1 percent increase in physical habitat index values for native river fish. Index value decreases occur under the MCP (0.7 percent) and the two remaining GP options, the GP2021 option (1.3 percent) and the GP2021 option (1.4 percent).

Within Winnebago Reservation and Omaha Reservation, the two GP options with a split summer low flow both reduce the index value for native river fish physical habitat while the remaining two GP options and the MCP provide an index value increase over the CWCP. The GP2028 and GP1528 options and the MCP all increase the physical habitat for native river fish by 0.5, 0.2, and 0.1 percent, respectively. The GP2021 and GP1521

Table 7.7-14. Average annual physical habitat values for native river fish impact on Reservations (index).

	1898 to 1997					
Reservation	**CWCP**	**MCP**	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Fort Peck	9.03	9.08	9.20	9.19	9.19	9.21
Yankton and Ponca Tribal Lands	8.56	8.50	8.57	8.45	8.44	8.57
Winnebago and Omaha	10.22	10.23	10.24	10.11	10.07	10.27
Iowa and Sac and Fox	7.93	8.00	8.15	8.19	8.15	8.20
Total	**35.74**	**35.81**	**36.16**	**35.94**	**35.85**	**36.25**

options reduce this index value by 1.1 and 1.5 percent, respectively.

The MCP and four GP options would result in a physical habitat index value increase for native river fish within Iowa Reservation and Sac and Fox Reservation. The greatest percentage increases over the CWCP would occur under the GP2028 and GP2021 options, 3.4 and 3.3 percent, respectively. Both the GP1528 and GP1521 options result in a 2.8 percent increase and the MCP provides only a 0.9 percent increase in the index value for physical habitat for native river fish over the CWCP.

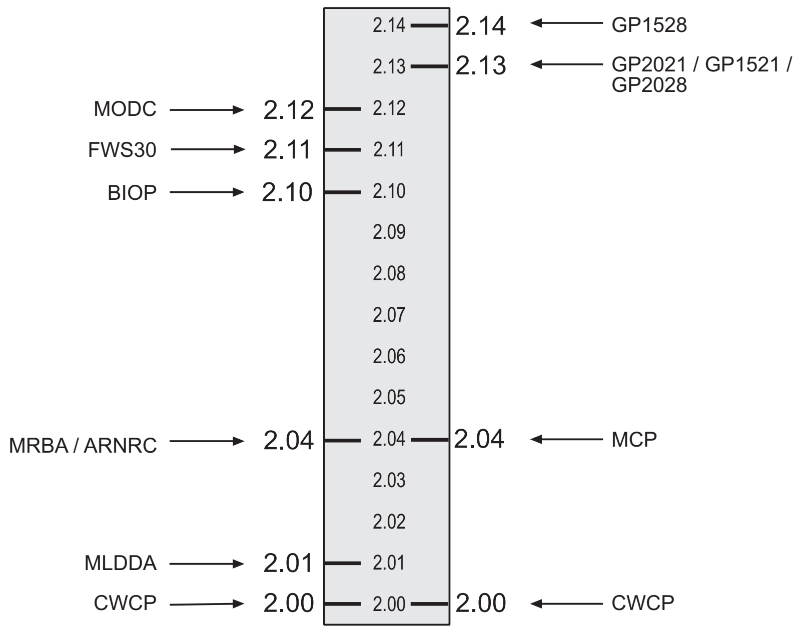

Figure 7.7-1. Average annual young fish production index values for submitted alternatives and the alternatives.

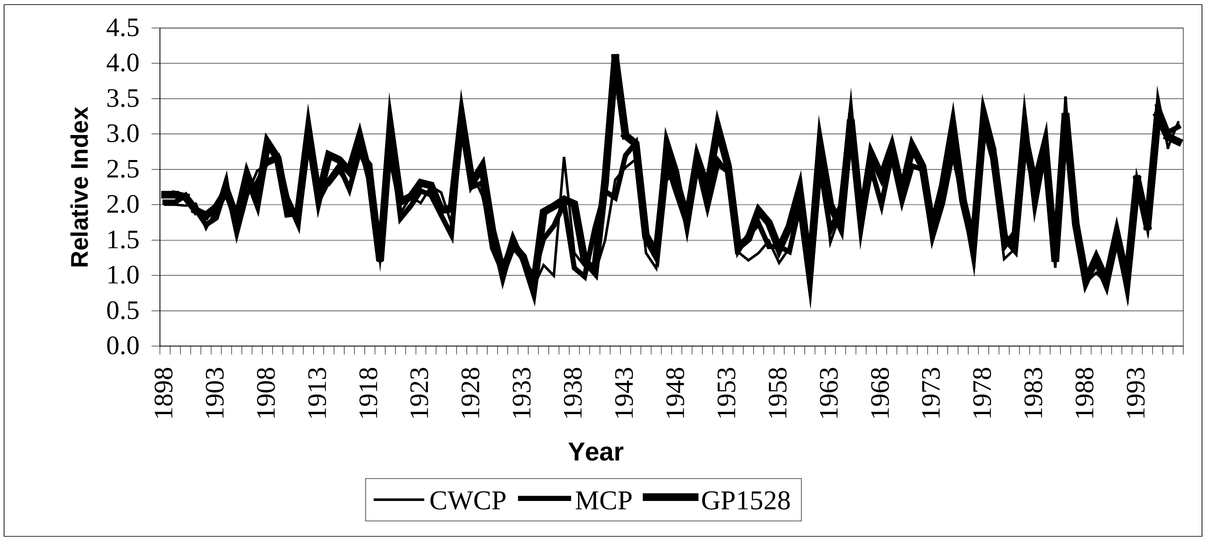

Figure 7.7-2. Annual values for young fish production in the mainstem lakes for CWCP, MCP, and GP1528.

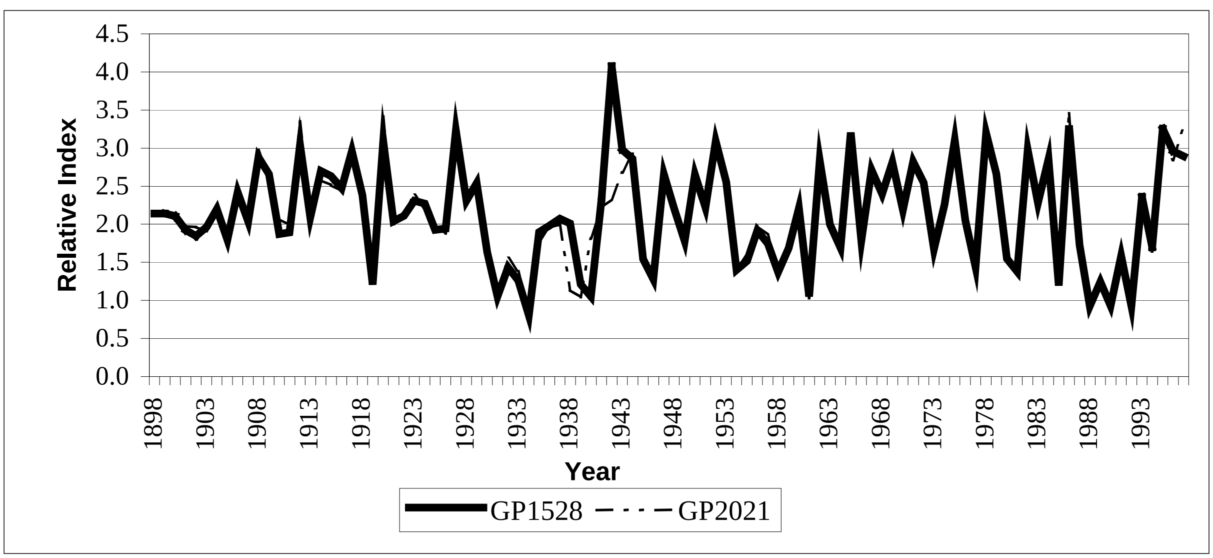

Figure 7.7-3. Annual values for young fish production in the mainstem lakes for GP1528 and GP2021.

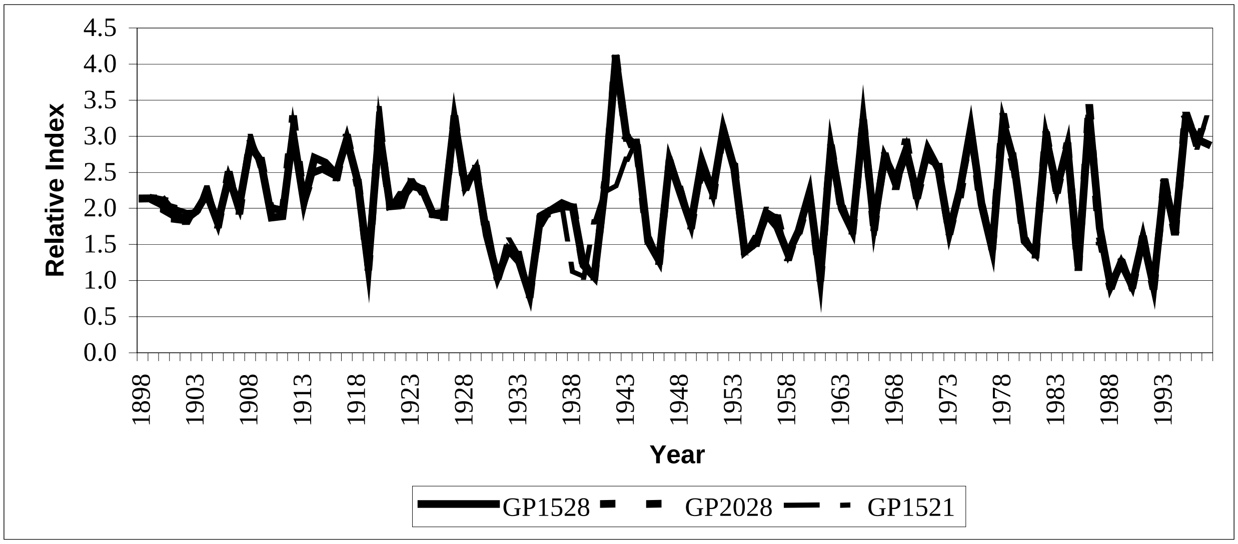

Figure 7.7-4. Annual values for young fish production in the mainstem lakes for GP1528, GP2028, and GP1521.

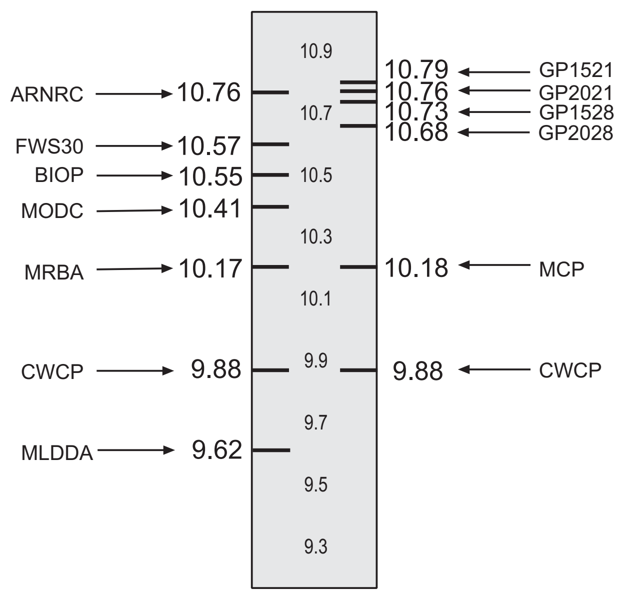

Figure 7.7-5. Average annual coldwater fish habitat in the mainstem lakes for submitted alternatives and the alternatives (MAF).

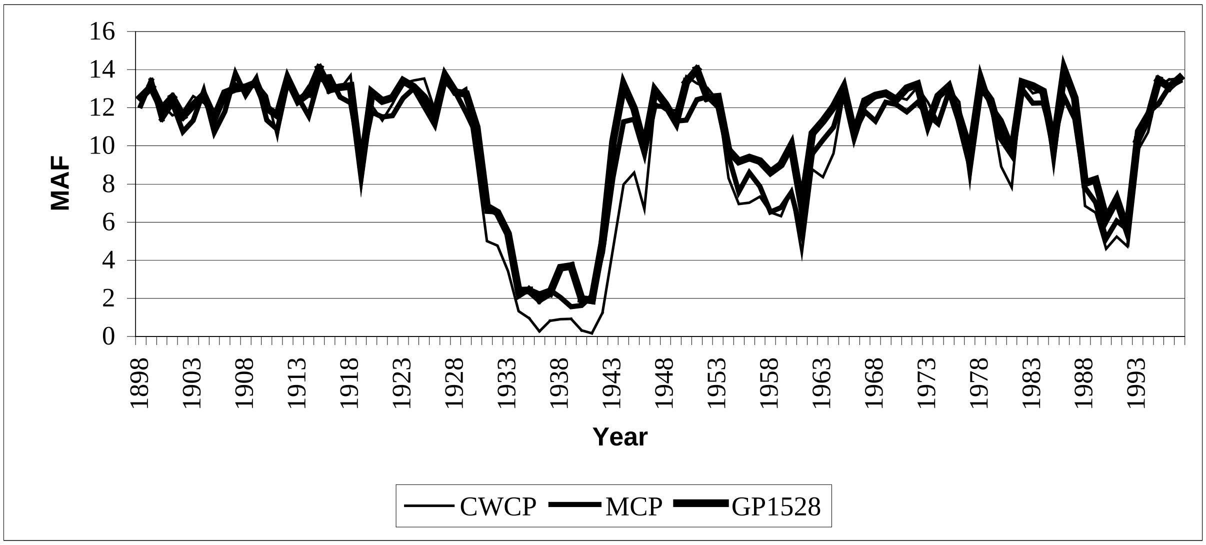

Figure 7.7-6. Annual coldwater fish habitat in the mainstem lakes for CWCP, MCP, and GP1528.

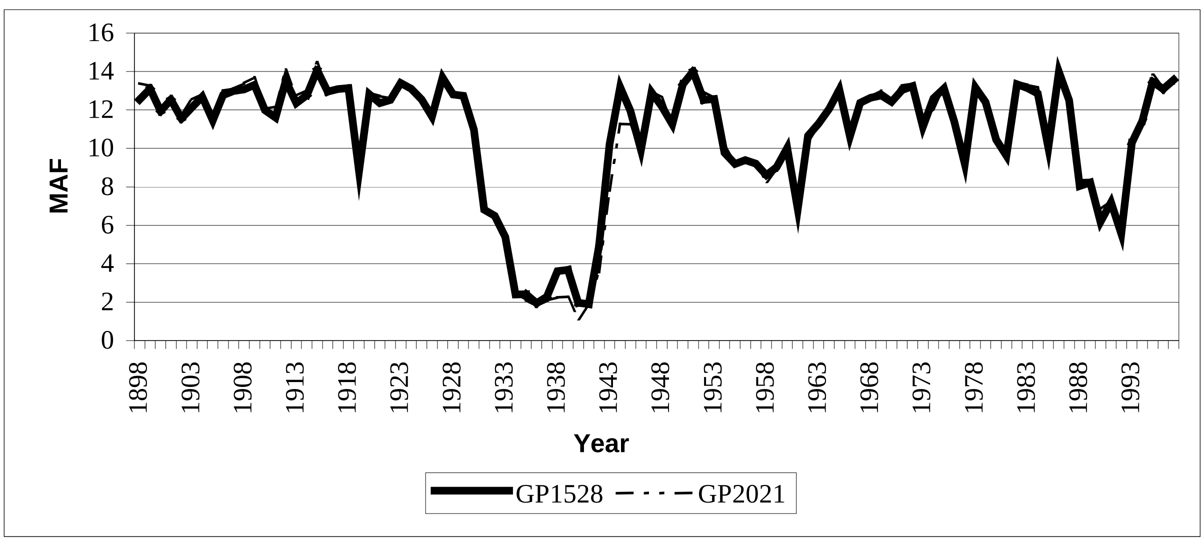

Figure 7.7-7. Annual coldwater fish habitat in the mainstem lakes for GP1528 and GP2021.

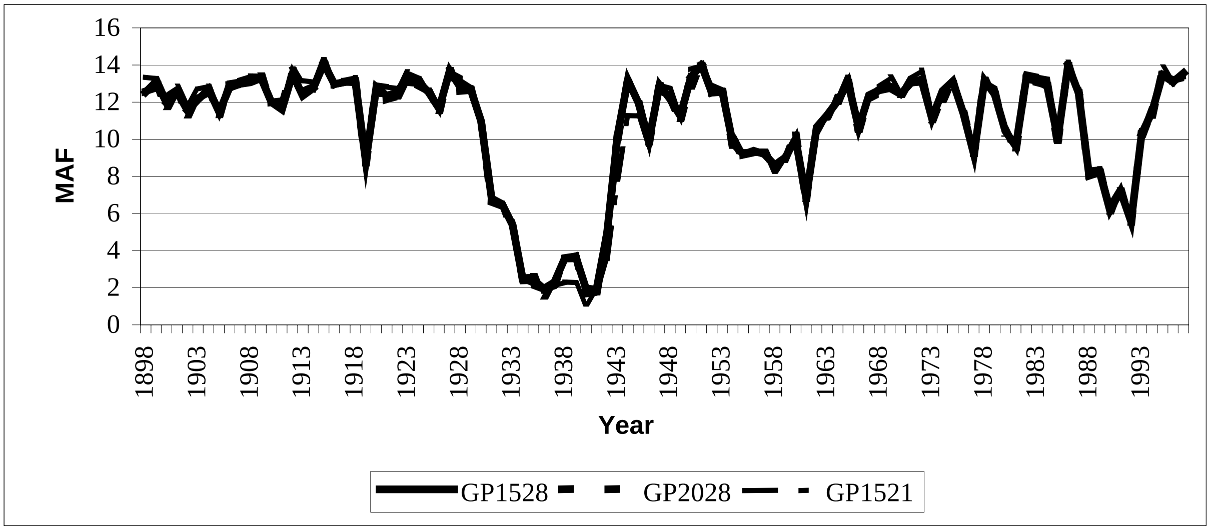

Figure 7.7-8. Annual coldwater fish habitat in the mainstem lakes for GP1528, GP2028, and GP1521.

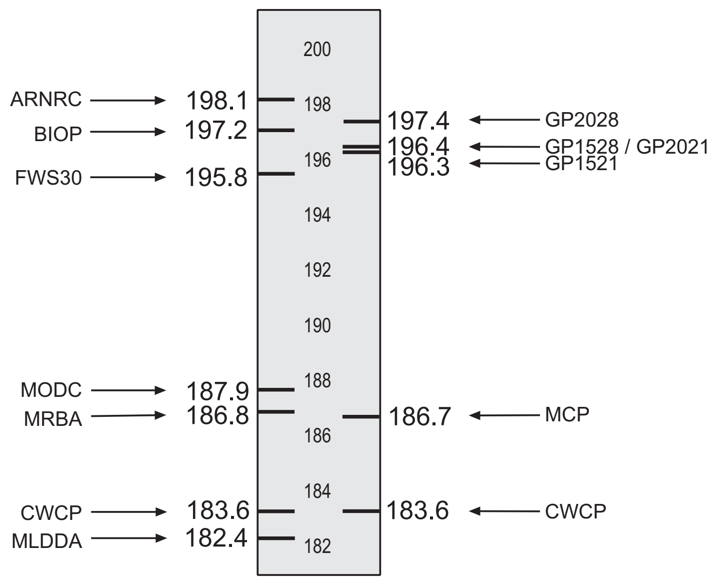

Figure 7.7-9. Average annual coldwater fish habitat in the river reaches for submitted alternatives and the alternatives (miles).

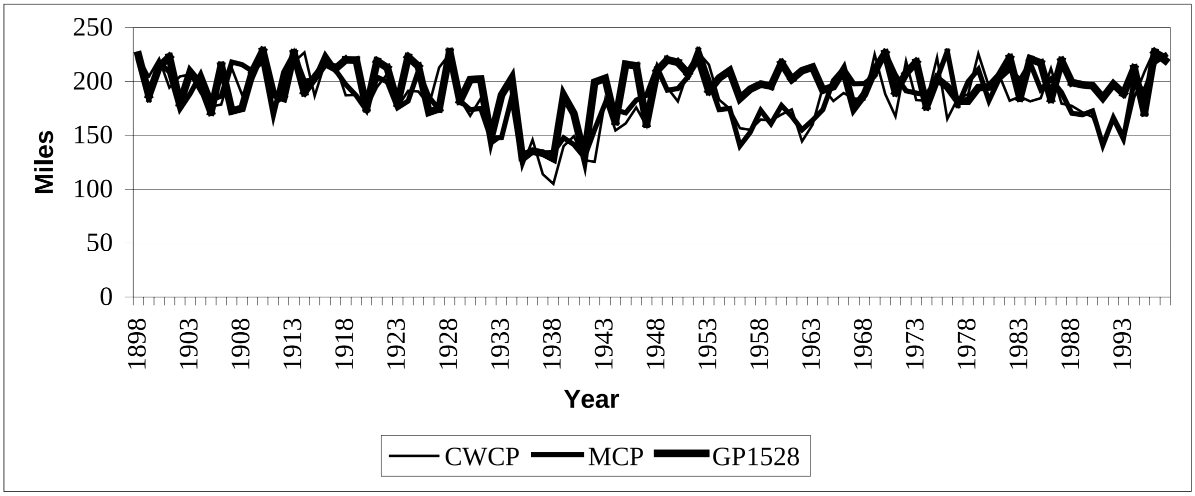

Figure 7.7-10. Annual coldwater fish habitat in the river reaches for CWCP, MCP, and GP1528.

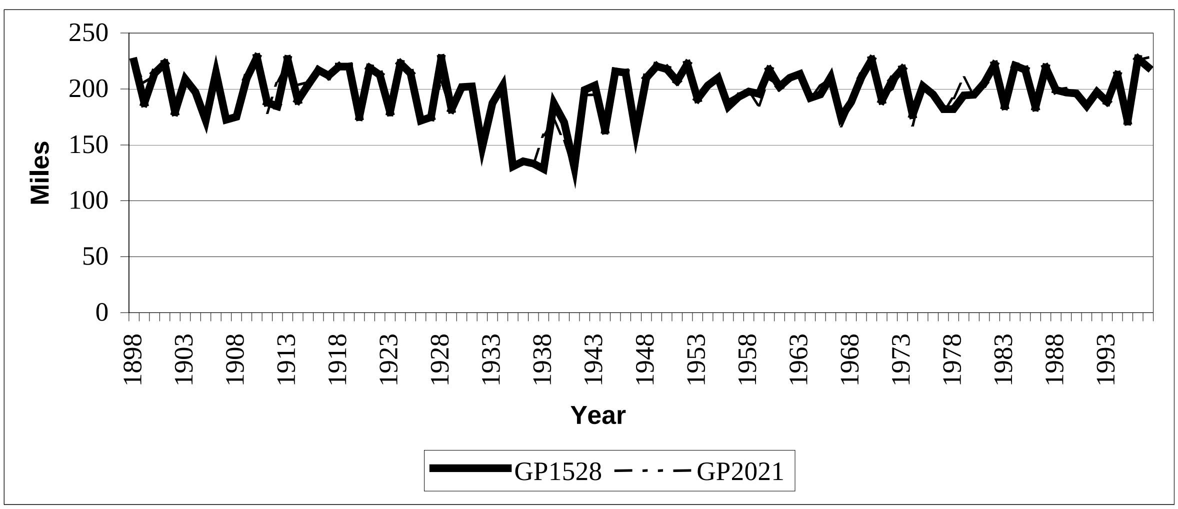

Figure 7.7-11. Annual coldwater fish habitat in the river reaches for GP1528 and GP2021.

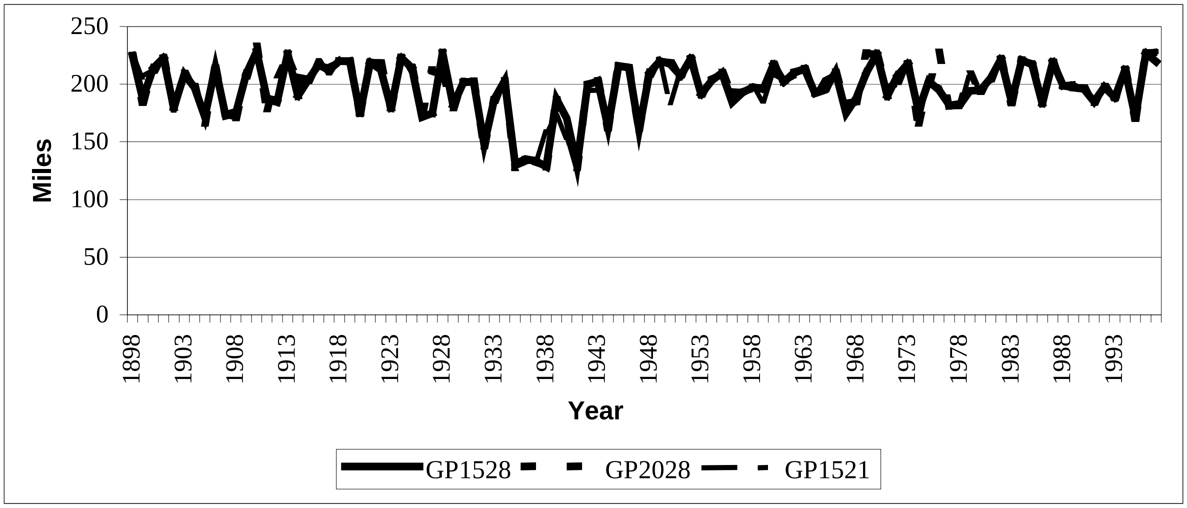

Figure 7.7-12. Annual coldwater fish habitat in the river reaches for GP1528, GP2028, and GP1521.

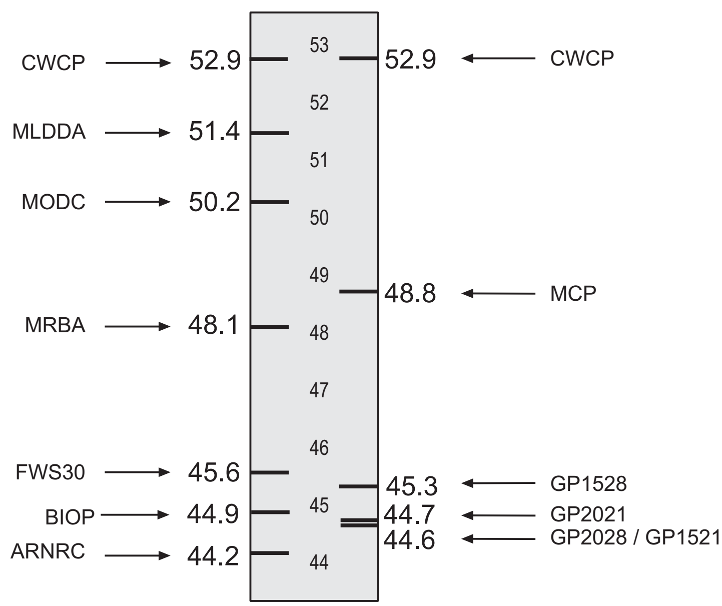

Figure 7.7-13. Average annual warmwater fish habitat in the river reaches for submitted alternatives and the alternatives (miles).

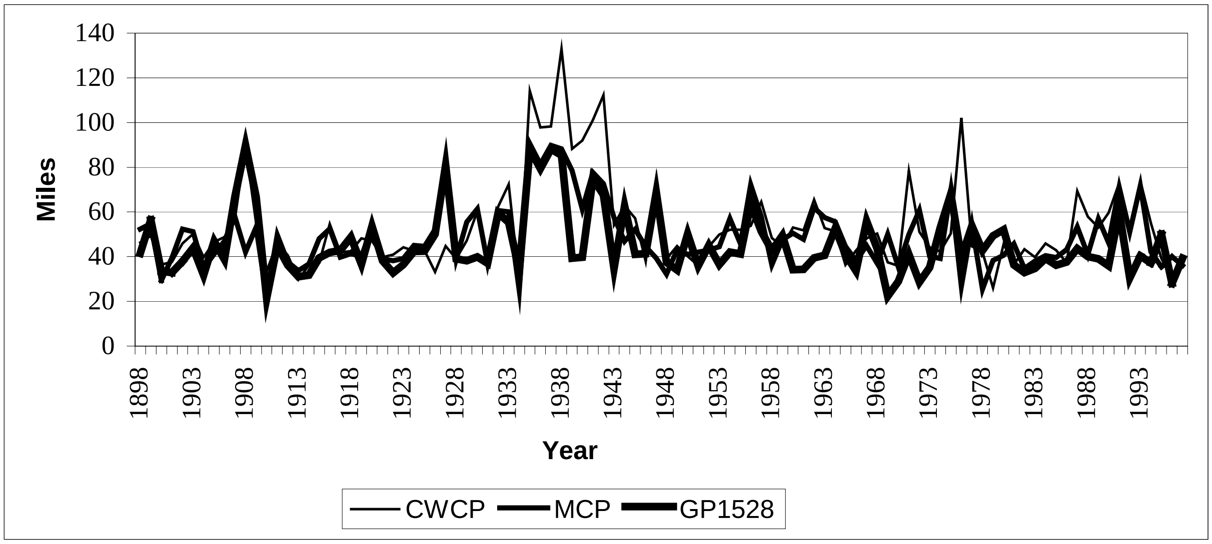

Figure 7.7-14. Annual warmwater fish habitat in the river reaches for CWCP, MCP, and GP1528.

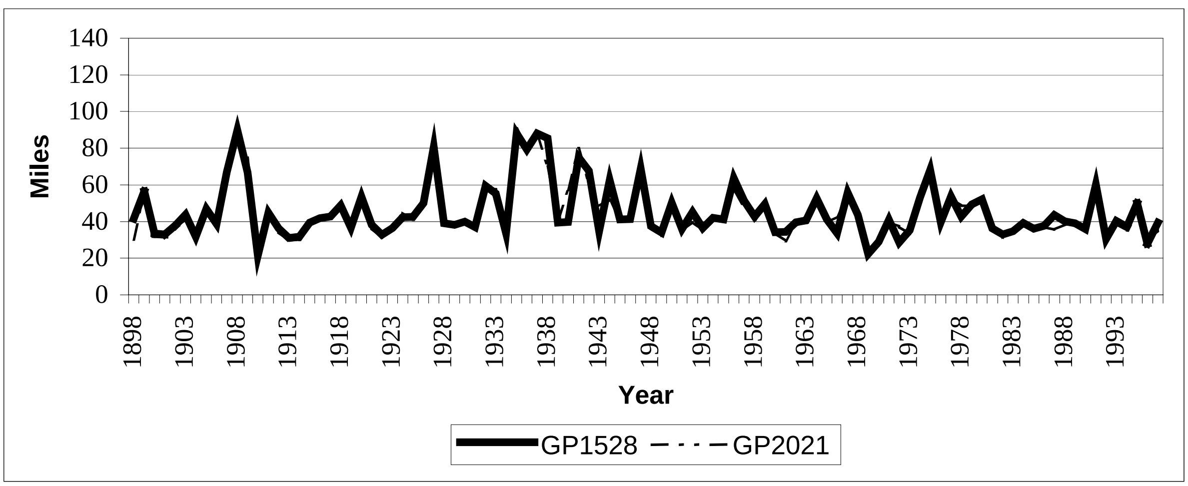

Figure 7.7-15. Annual warmwater fish habitat in the river reaches for GP1528 and GP2021.

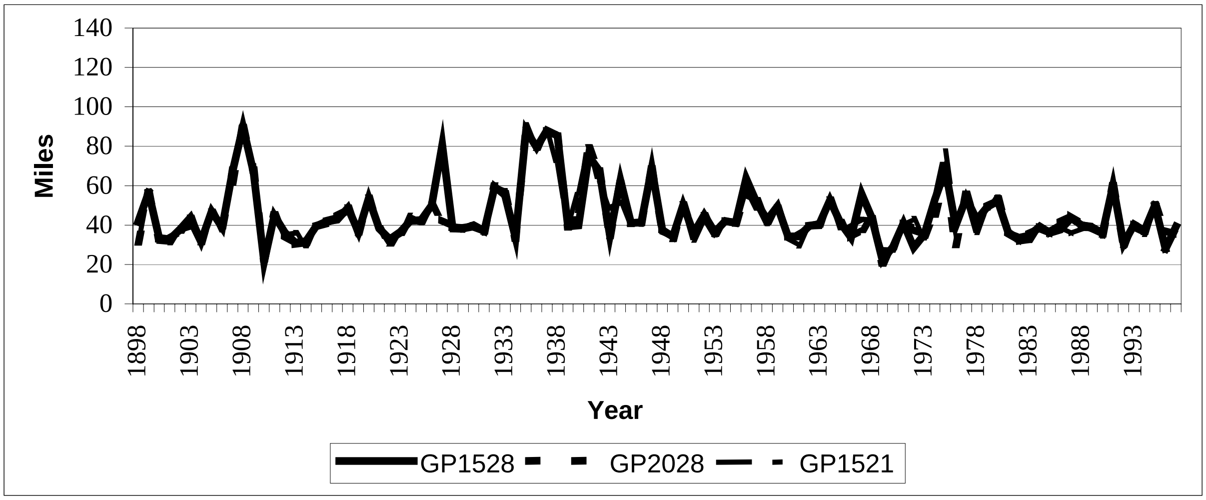

Figure 7.7-16. Annual warmwater fish habitat in the river reaches for GP1528, GP2028, and GP1521.

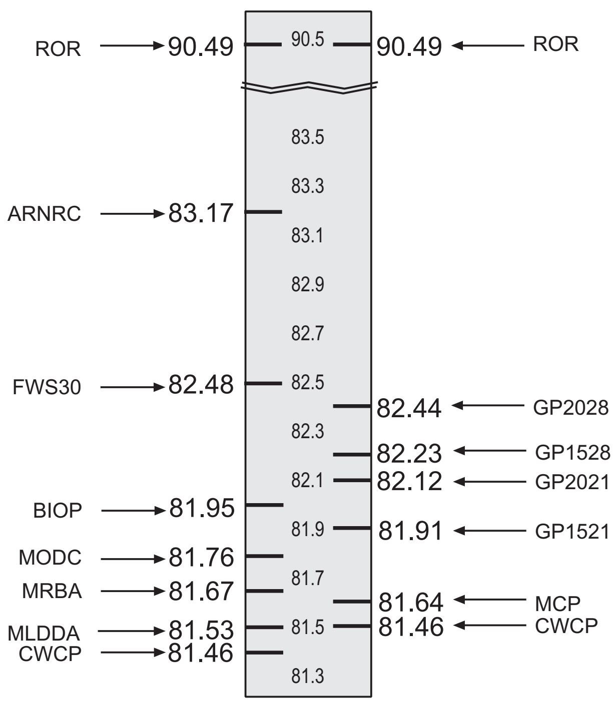

Figure 7.7-17. Average annual native river fish physical habitat index values for submitted alternatives and the alternatives.

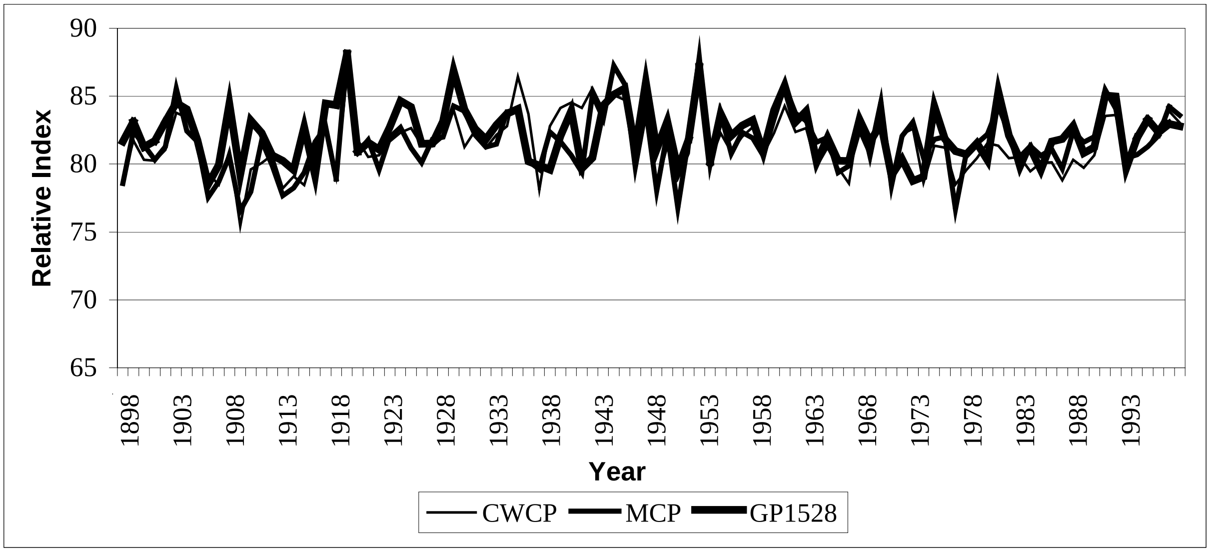

Figure 7.7-18. Annual values for native river fish physical habitat for CWCP, MCP, and GP1528.

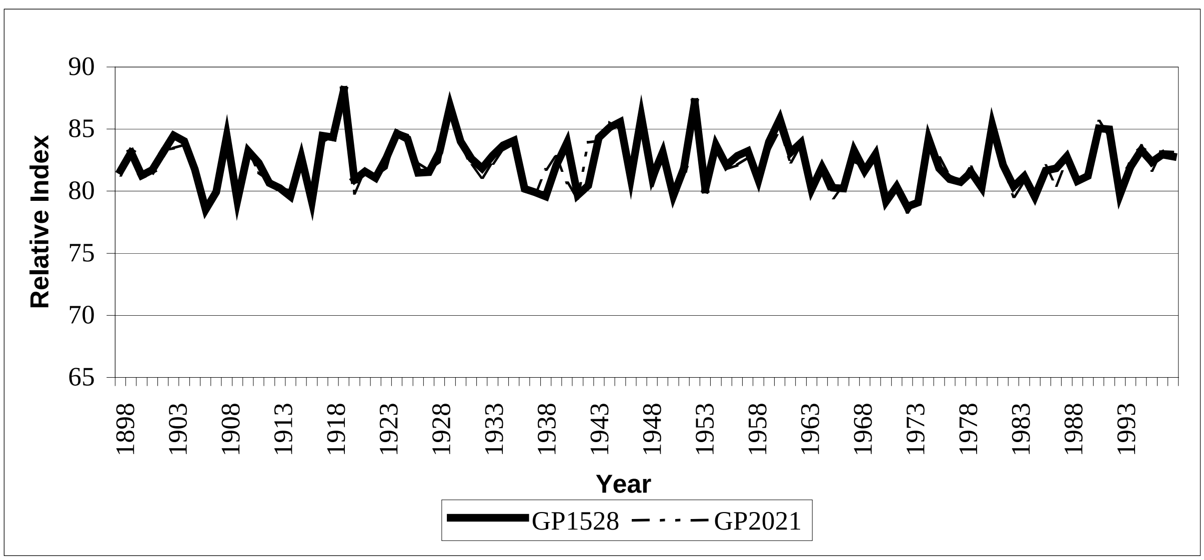

Figure 7.7-19. Annual values for native river fish physical habitat for GP1528 and GP2021.

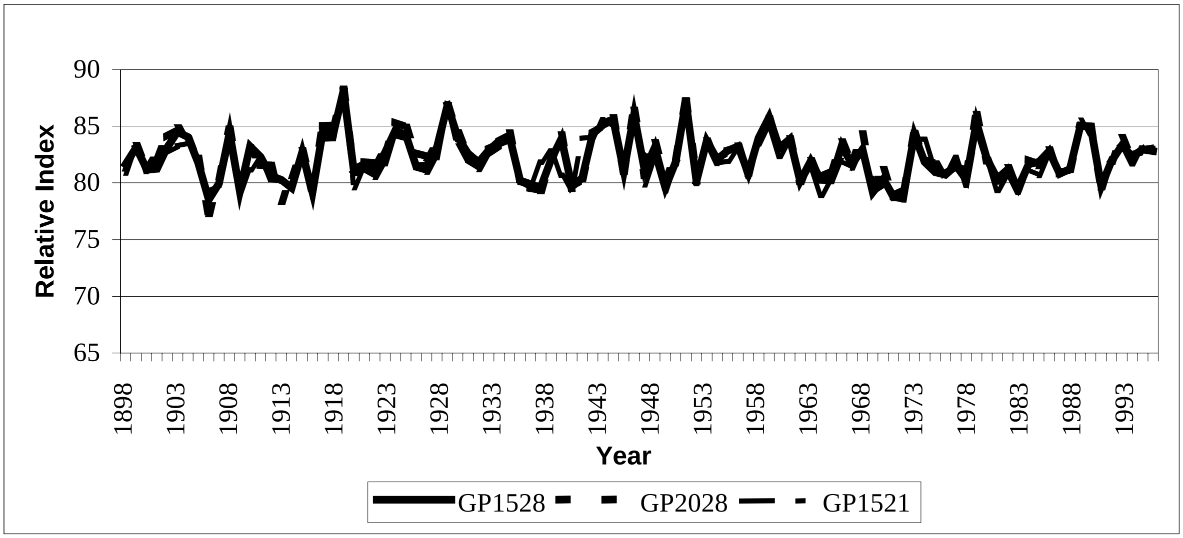

Figure 7.7-20. Annual values for native river fish physical habitat for GP1528, GP2028, and GP1521.

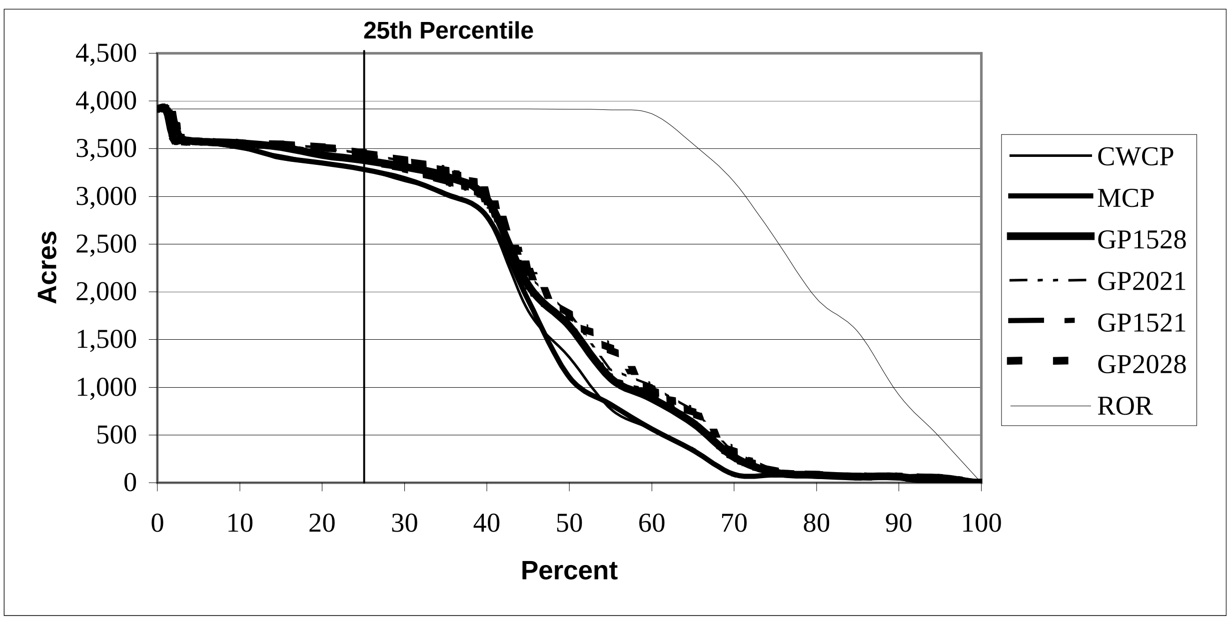

Figure 7.7-21. Acres of connectivity for 2 days during May and June.

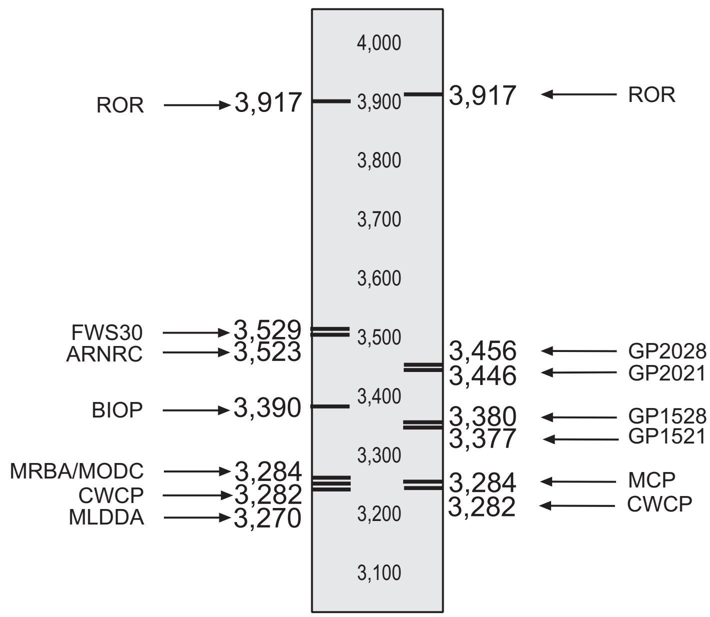

Figure 7.7-22. Acres of connectivity for 2 days in May and June (25th percentile) for the submitted alternatives and the alternatives.

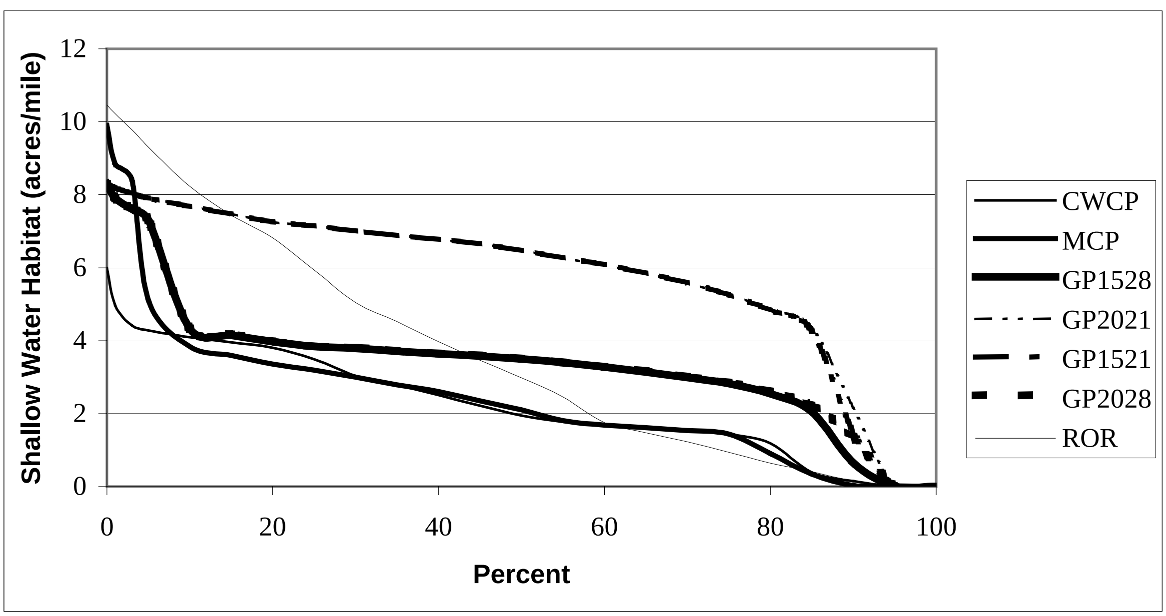

Figure 7.7-23. Duration plot of shallow water habitat (acres/mile) during the mid-July to mid-August period, Sioux City reach.

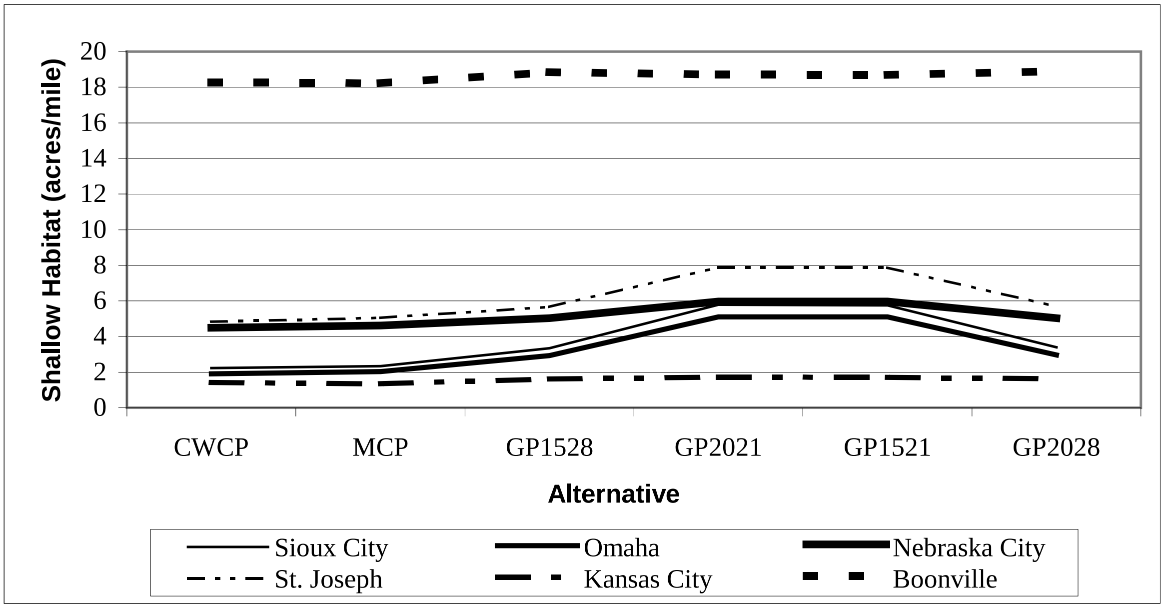

Figure 7.7-24. Expected daily shallow water habitat for river fish.

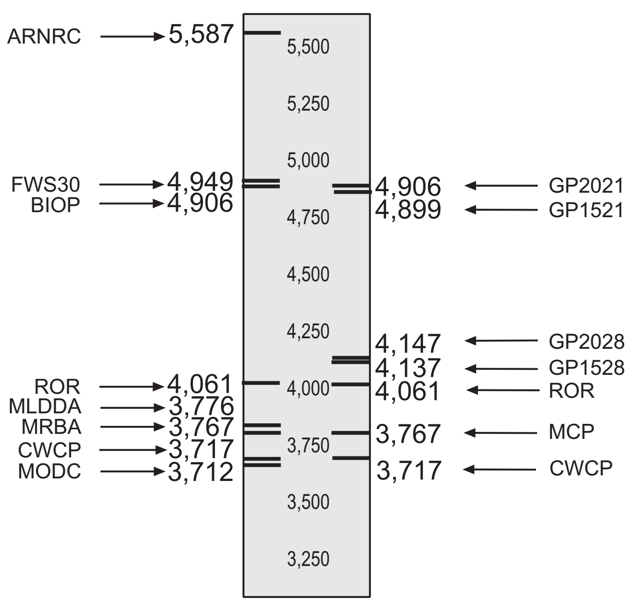

Figure 7.7-25. Shallow water habitat (acres), Sioux City to the Osage River for submitted alternatives and the alternatives.

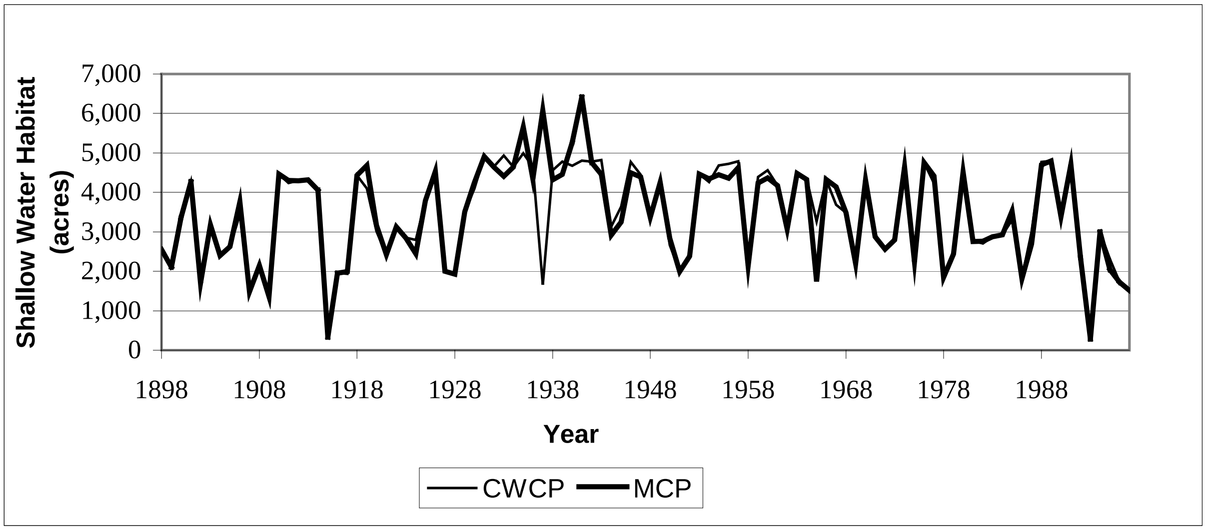

Figure 7.7-26. Annual average daily acres of shallow habitat from Sioux City to the Grand River from mid-July to mid-August for CWCP and MCP.

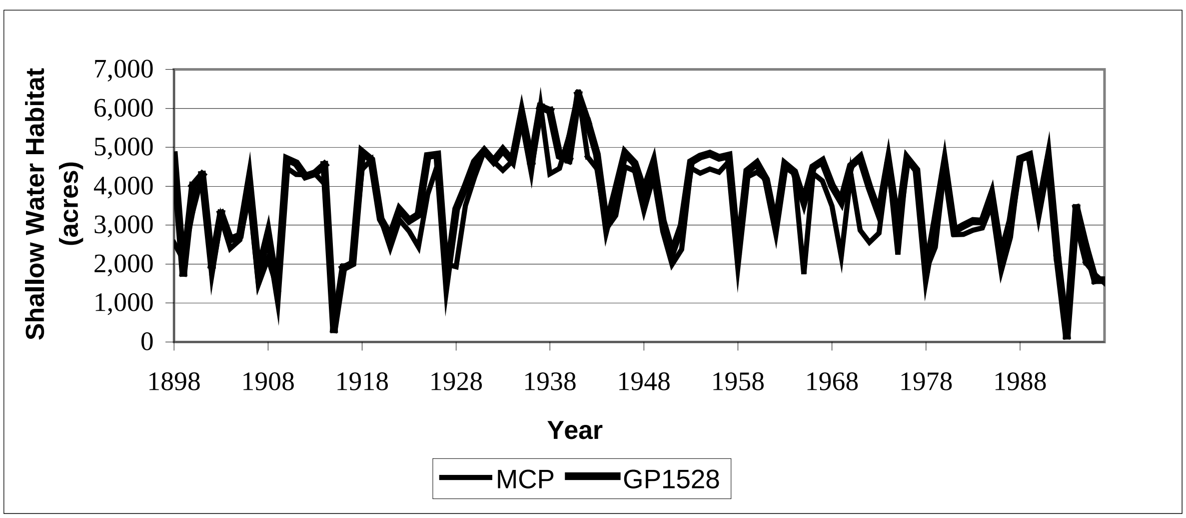

Figure 7.7-27. Annual average daily acres of shallow habitat from Sioux City to the Grand River from mid-July to mid-August for MCP and GP1528.

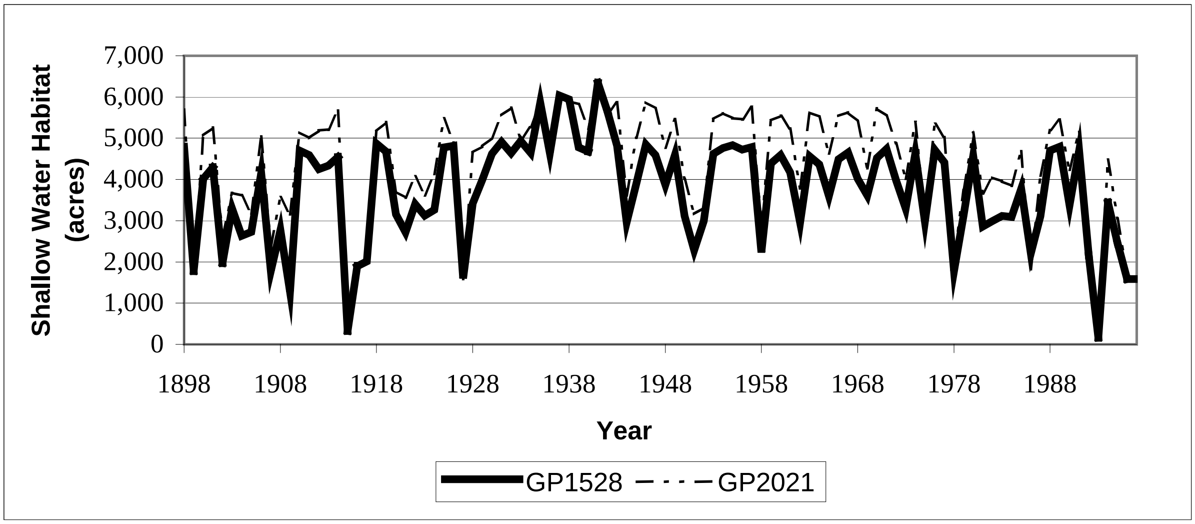

Figure 7.7-28. Annual average daily acres of shallow habitat from Sioux City to the Grand River from mid-July to mid-August for GP1528 and GP2021.

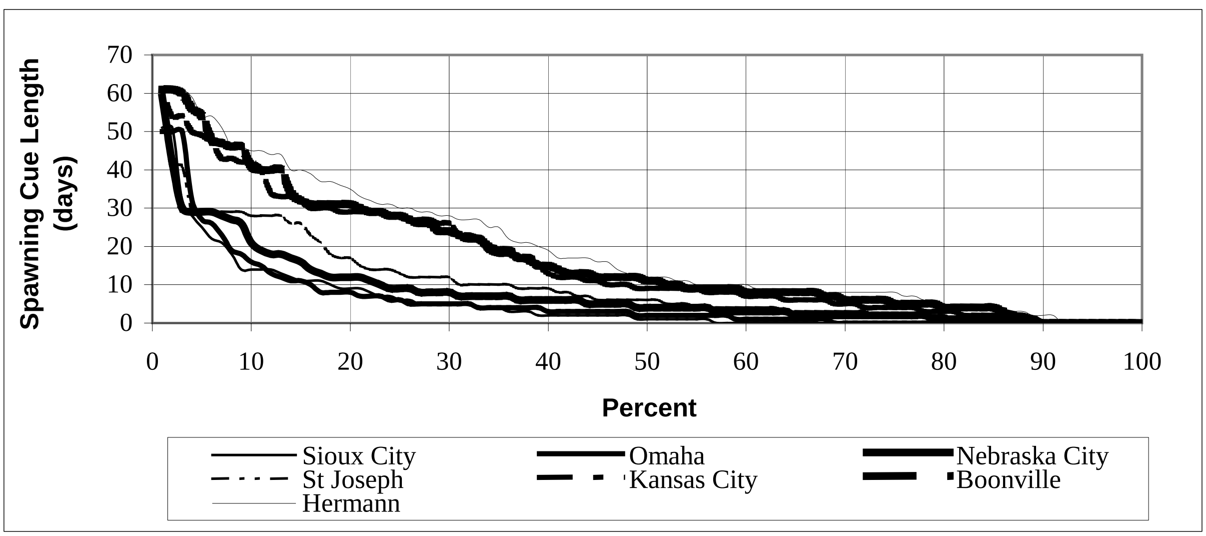

Figure 7.7-29. Duration plot of spawning cue length during May and June for CWCP.

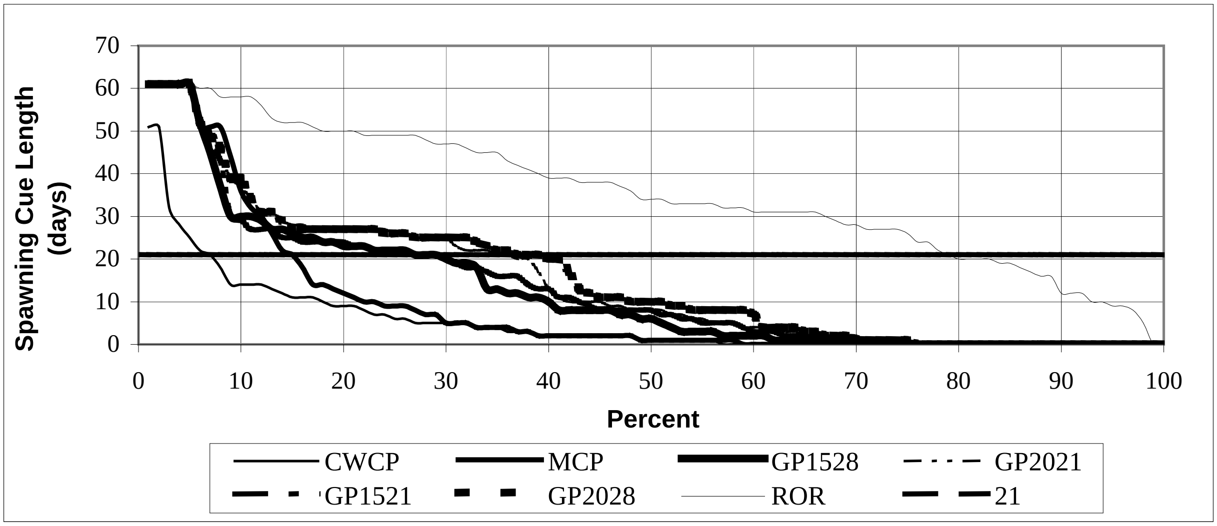

Figure 7.7-30. Duration plot of spawning cue length during May and June at Sioux City for CWCP, MCP, GP options, and ROR scenario.

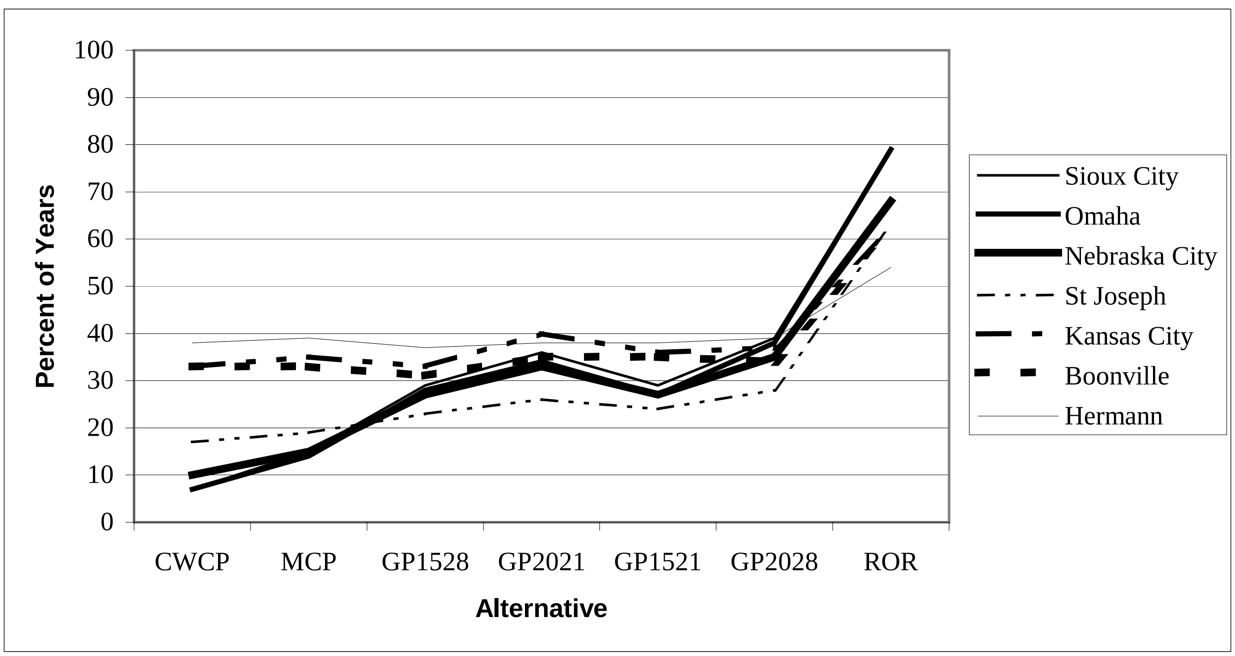

Figure 7.7-31. Percent of years with a 21-day spawning cue at Lower River gaging stations for CWCP, MCP, GP options, and ROR scenario.

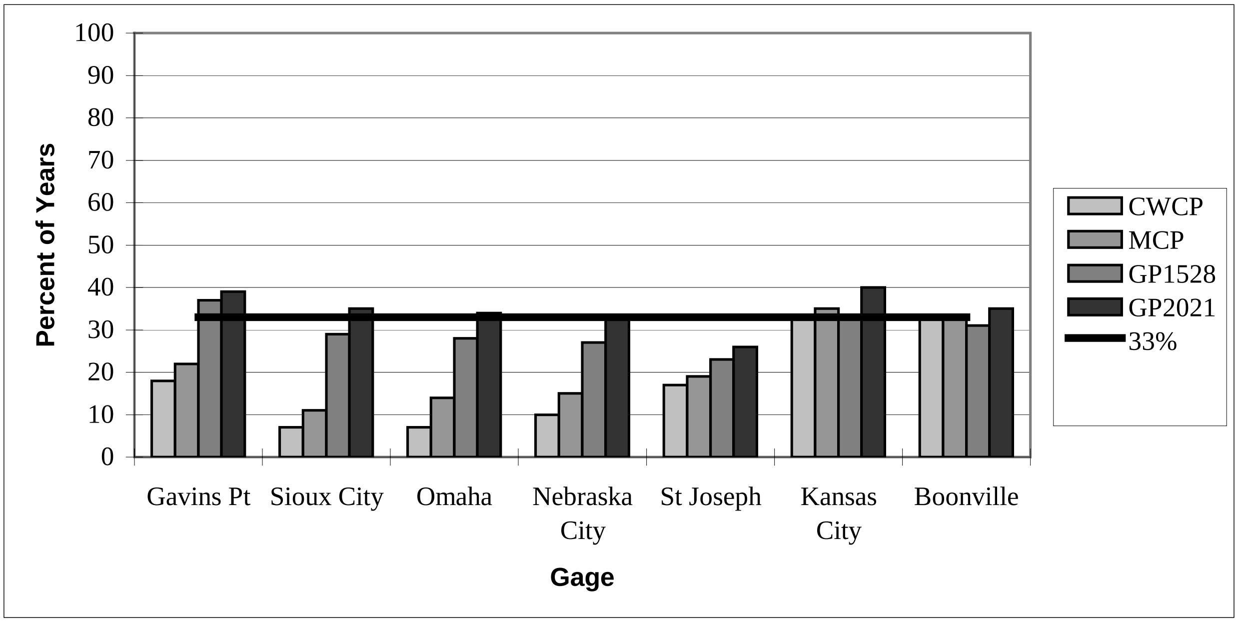

Figure 7.7-32. Percent of years that a 21-day spawning cue is provided.

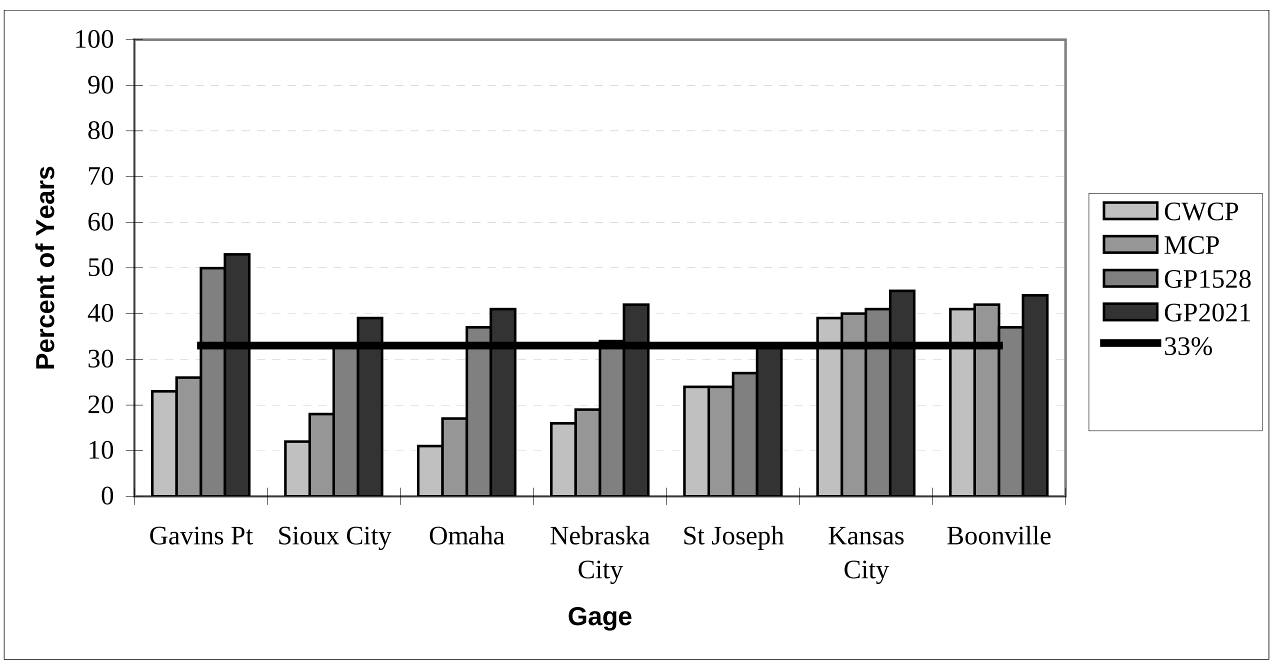

Figure 7.7-33. Percent of years that a 14-day spawning cue is provided.

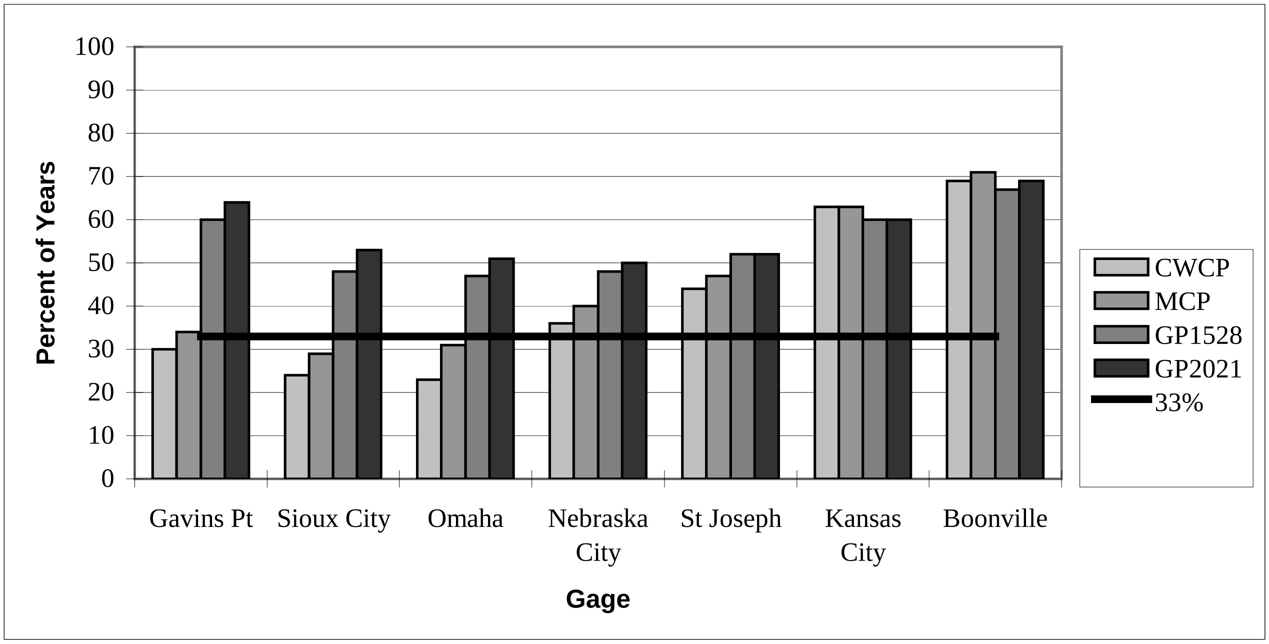

Figure 7.7-34. Percent of years that a 7-day spawning cue is provided.

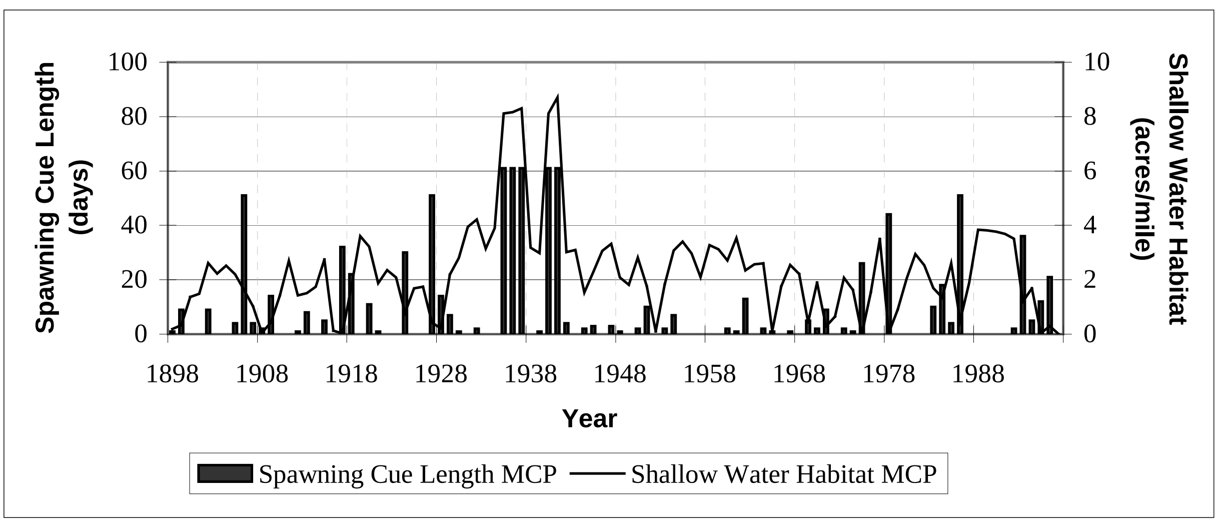

Figure 7.7-35. Annual values for spawning cue length and shallow water habitat at Sioux City for MCP.

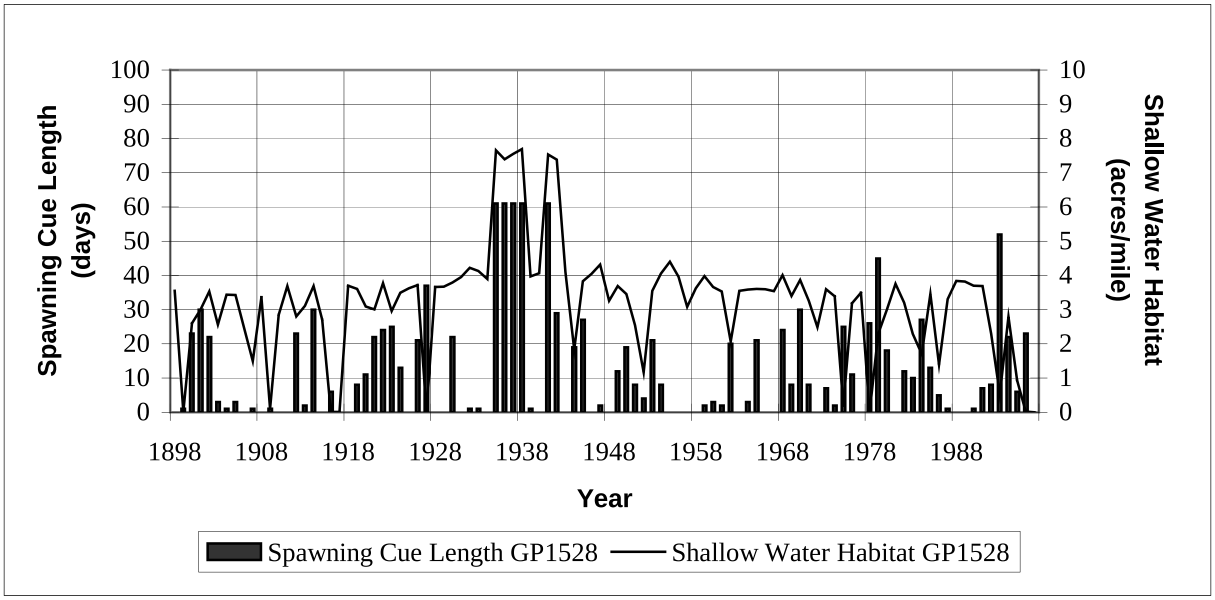

Figure 7.7-36. Annual values for spawning cue length and shallow water habitat at Sioux City for GP1528.

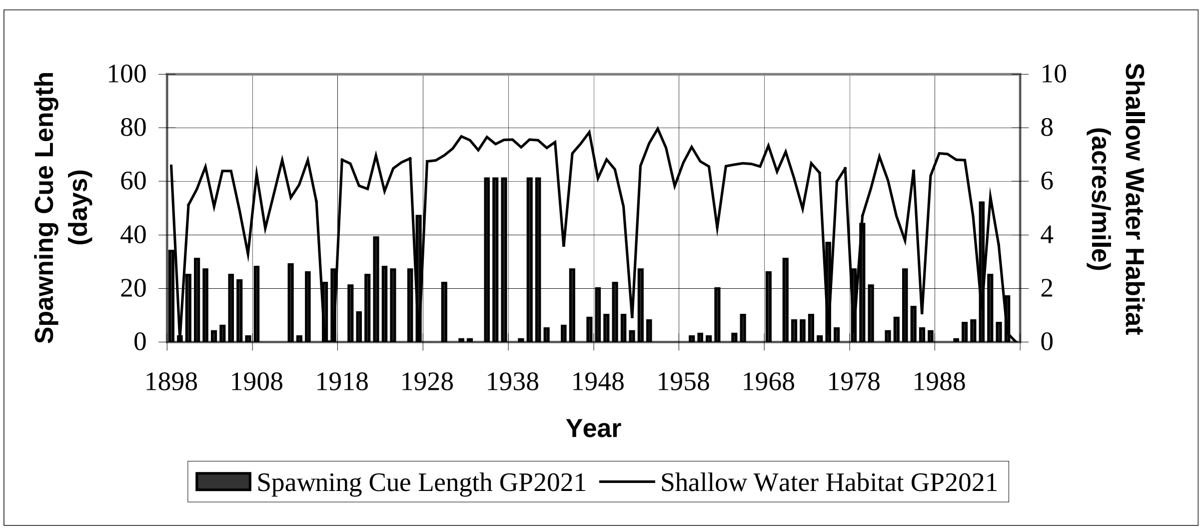

Figure 7.7-37. Annual values for spawning cue length and shallow water habitat at Sioux City for GP2021.

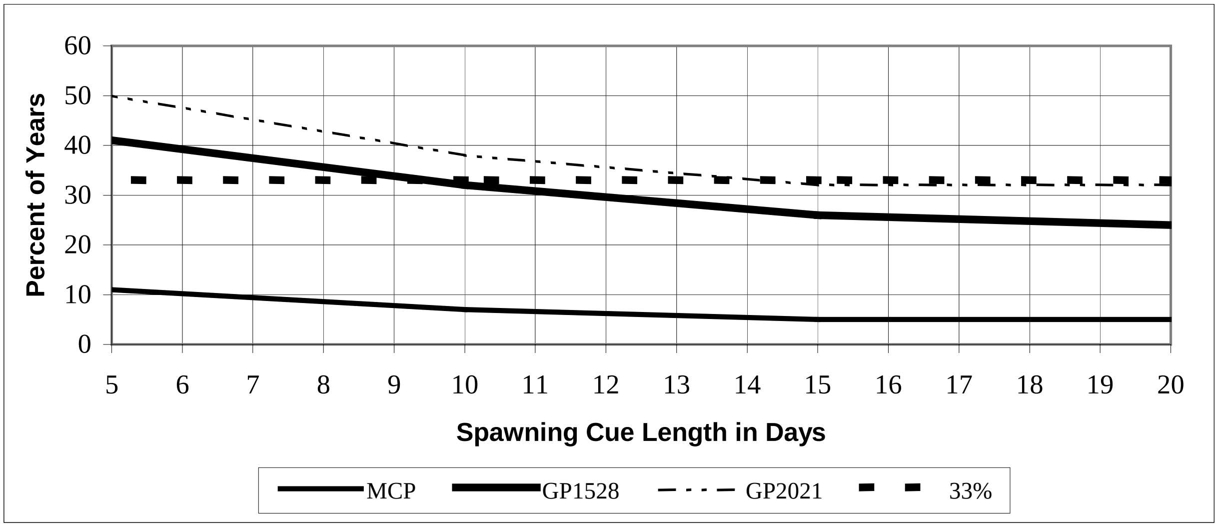

Figure 7.7-38. Percent of years when spawning cue length and shallow water habitat (2 acres/mile) coincide at Sioux City.

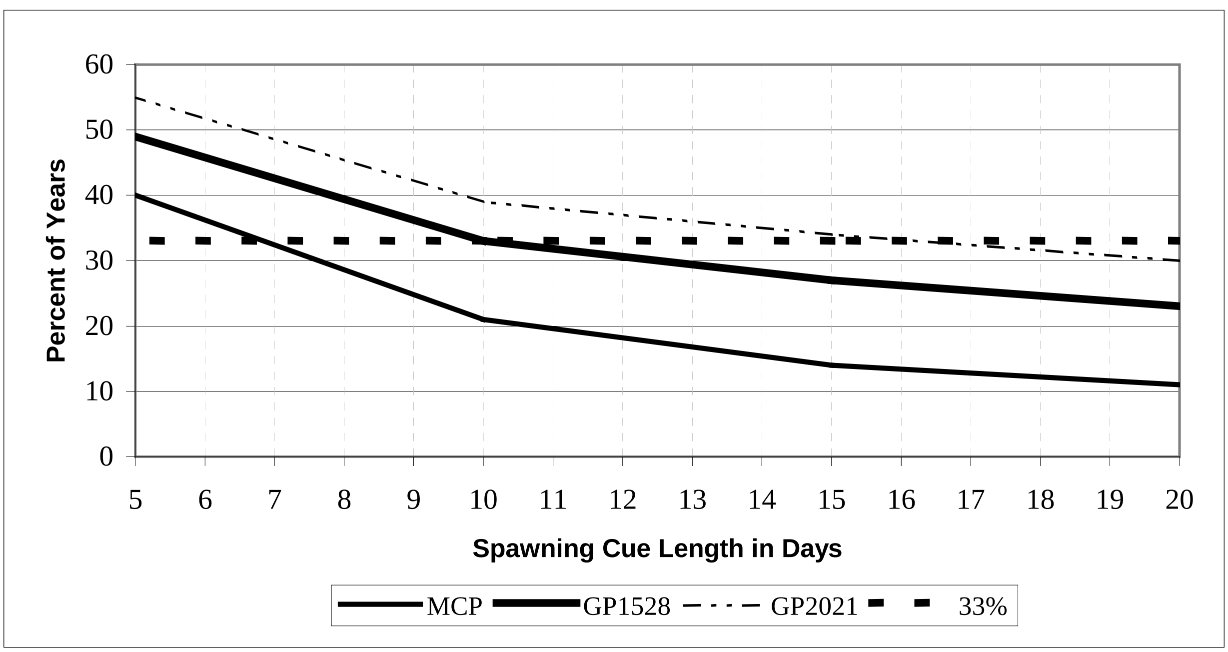

Figure 7.7-39. Percent of years when spawning cue length and shallow water habitat (3 acres/mile) coincide at Nebraska City.

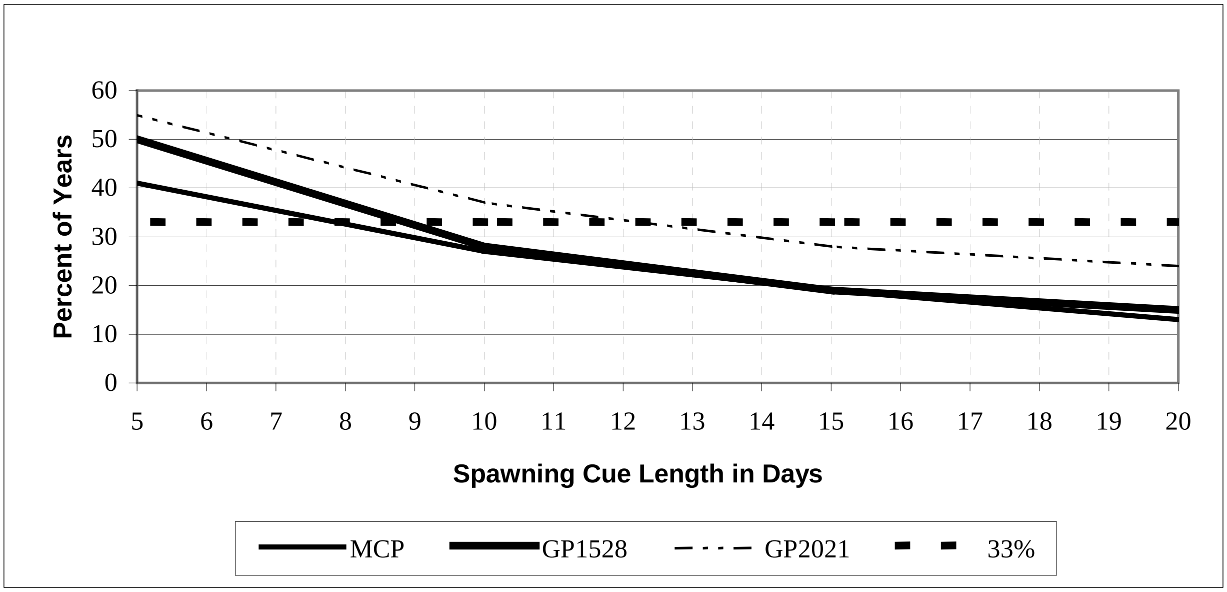

Figure 7.7-40. Percent of years when spawning cue length and shallow water habitat (15 acres/mile) coincide at Boonville.

7.8 FLOOD CONTROL, INTERIOR DRAINAGE, AND GROUNDWATER IMPACTS

The Mainstem Reservoir System dams, in conjunction with other flood control measures, provide flood control benefits to adjacent lands. The dams store upstream inflow and release flows downstream at a controlled rate. The lower controlled releases limit impacts to farmlands and urban areas along the river reaches. The lower river stages facilitate surface water drainage from adjacent lands protected by flood control levees. The lower river stages also allow groundwater levels under adjacent farmlands to drop to levels that do not impact the growth of the crops.

Three separate analyses were developed to quantify potential impacts on flood control, interior drainage, and groundwater. Hypothetically, a major flood event could damage crops that also could be damaged in the same year from inadequate interior drainage or high groundwater levels. The three analyses were conducted independently, and no attempt was made to compute a consolidated damage or benefit to the affected lands. The complexity of the modeling processes limited the interior drainage and groundwater analyses to representative sites. All three analyses covered a different time period: 100 years for flood control, 45 years for interior drainage, and 10 years for groundwater. Again, the complexity of the latter two modeling processes limited the period that could be modeled. Flood control effects were measured in terms of the difference in value (in millions of dollars) of flood control benefits provided by each alternative compared to the Run-of-River (ROR) scenario. The ROR scenario represents natural base inflow with no control placed on the inflow by the dams. Alternatives that include projected lake levels that are higher than the ROR scenario (which has the lake levels held constant at the base of flood control) are reflected by additional damages, or negative benefit values, in the summary tables and figures. The methods applied to get the results presented in this section are described in the Economic Studies—Flood Control, Interior Drainage, Groundwater Technical Report (Corps, 1998d).

7.8.1 Flood Control

Flood control benefits were computed at four mainstem lakes: Fort Peck Lake, Lake Sakakawea, Lake Oahe, and Lake Francis Case. Flood control benefits were also computed for the river reaches downstream from five of the six Mainstem Reservoir System dams, with the Big Bend Dam being the exception. These reaches are Fort Peck Dam downstream, Garrison Dam downstream, Oahe Dam downstream, Fort Randall Dam downstream, and Gavins Point Dam downstream. Besides the reach immediately downstream from Gavins Point Dam, the Lower River was divided into seven other subreaches. These subreaches are the Sioux City, Omaha, Nebraska City, St. Joseph, Kansas City, Boonville, and Hermann subreaches. Total system flood control benefits and the differences among the alternatives are discussed in this section.

Figure 7.8-1 illustrates the total average annual flood control benefits for the alternatives analyzed in this chapter. The alternatives cluster into three groups. The CWCP offers the highest level of flood control benefits. The MCP and the GP2021 option offer the next highest level of flood control benefits. Finally, the GP1521, GP1528, and GP2028 options offer the lowest total average annual flood control benefits of all of the alternatives analyzed.

Figure 7.8-1 also includes the submitted alternatives discussed in Chapter 5 to provide a perspective for how those alternatives compare to the alternatives discussed in this chapter. The MCP and the MRBA alternative have comparable flood control benefits because they are essentially the same alternative with the exception of the inclusion of the Fort Peck spring rise in the MCP. Four submitted alternatives have benefits in the same range as the four GP options: the MODC, BIOP, ARNRC, and FWS30 alternatives. Three of these submitted alternatives also have spring rises with extended low-flow periods in the summer.

Table 7.8-1 summarizes the total and reach flood control benefits for the alternatives analyzed in this chapter. As shown in the table, the CWCP offers the highest level of protection of all of the alternatives.

Total average annual flood control benefits provided by the CWCP are $410.30 million over the 100-year period of analysis. The CWCP has a flat release from Gavins Point Dam in the spring and summer ranging from 34.5 kcfs in non-drought periods to 28.5 kcfs during major droughts. The largest portion of the CWCP flood control benefits is provided to the Sioux City subreach, with $112.51 million or 27.4 percent of the total benefits provided. The reach downstream from Garrison Dam accounts for $72.41 million, or 17.7 percent, of the total protection, and the Omaha and Nebraska City subreaches received 12.0 percent and 10.2 percent of the total benefits, respectively. All other reaches and subreaches individually received less than 10 percent of the total benefit.

When compared to the CWCP, the MCP provides an unbalanced intrasystem regulation among the upper three lakes, conserves greater amounts of water during droughts, and provides higher service levels for summer releases in non-navigation years (increases from 1 year for the CWCP to 5 years for the MCP). This alternative provides $408.04 million over the 100-year period of analysis, slightly reducing the flood control benefits in comparison to the CWCP by $2.26 million, or a decrease of 0.6 percent.

The GP options provide flow changes at Gavins Point Dam that have been recommended by the USFWS in its November 2000 BiOp. These release changes were recommended to ensure that the operation of the Mainstem Reservoir System is more likely to provide for the continued existence of the listed species associated with the Missouri River, or the adverse modification of their habitat. The GP1528 option serves as a potential starting point for comparison of the GP options against the MCP because it represents the least amount of change from the MCP. If this plan were to be implemented in the future, the GP2021, GP1521, and GP2028 options represent the range in changes from the GP1528 option that could be made under adaptive management. Consequently, the comparisons in this section will be based on the percentage change between the GP1528 option and the MCP, and the percentage change in the three options, GP2021, GP1521, and GP2028, from the GP1528 option.

The GP1528 option adds a 15-kcfs spring-rise and a minimum navigation service flat release of 28.5 kcfs at Gavins Point Dam to the MCP. The GP1528 option provides $405.83 million in flood control benefits, a lower benefit than the MCP by $2.21 million, or a decrease of 0.5 percent.

The GP2021 option provides a 20-kcfs spring rise and the 25/21-kcfs split for the summer low-flow

Table 7.8-1. Average annual flood control benefits ($millions).

Reach	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Fort Peck Lake	-0.07	-0.08	-0.06	-0.07	-0.07	-0.06
Fort Peck Dam downstream	2.96	2.93	2.89	2.89	2.87	2.89
Lake Sakakawea	-0.07	-0.10	-0.12	-0.12	-0.12	-0.12
Garrison Dam downstream	72.41	72.19	72.28	72.29	72.25	72.28
Lake Oahe	-0.28	-0.34	-0.38	-0.40	-0.42	-0.37
Oahe Dam downstream	14.75	14.75	14.71	14.67	14.69	14.68
Lake Francis Case	-0.17	-0.19	-0.14	-0.15	-0.13	-0.12
Fort Randall Dam downstream	0.70	0.70	0.70	0.70	0.70	0.70
Gavins Point Dam downstream	15.94	15.95	15.93	15.88	15.87	15.93
Sioux City	112.51	112.10	111.83	112.39	111.81	111.57
Omaha	49.30	49.19	49.18	49.31	49.20	49.24
Nebraska City	41.66	41.17	40.46	41.08	40.81	40.52
St Joseph	36.71	36.47	36.26	36.18	36.27	36.06
Kansas City	37.73	37.16	36.48	37.20	36.77	36.49
Boonville	9.29	9.19	9.10	9.09	9.05	9.07
Hermann	16.93	16.94	16.71	16.77	16.78	16.67
Total	**410.30**	**408.04**	**405.83**	**407.71**	**406.33**	**405.43**

releases from Gavins Point Dam. This option provides $407.71 million in flood control benefits, increasing the benefits by $1.88 million (0.5 percent) over the GP1528 option.

The GP1521 option has the same 15-kcfs spring rise as the GP1528 option, but reduces the summer releases to the 25/21-kcfs split. The level of protection for this option is $406.33 million, which is $0.50 million more than the GP1528 option, or an increase of 0.1 percent.

The GP2028 option includes a higher spring rise of 20 kcfs and the minimum navigation service flat release of 28.5 kcfs. This option provides $405.43 million in flood control benefits, a very slight decrease from the benefit level of the potential starting point (GP1528) of $0.40 million, or a decrease of 0.1 percent Figures 7.8-2 through 7.8-4 graphically illustrate the very slight differences between all alternatives during the 100-year study period. There are no obvious trends for any of the alternatives, other than the greatest benefits tend to occur in the years with the greatest annual runoff. An in-depth analysis found that major differences in flood control benefits in certain years were due to a multitude of differences in the simulation runs; however, not once in the years examined was the major difference due to the Gavins Point spring rise.

Two alternatives were evaluated in detail to determine the primary factors causing the reduction in flood control benefits. These two alternatives are GP2021 and GP2028. Even though the spring rise is one of those factors, it was the sole factor in only 1 year, 1974, when flooding resulted from a major inflow downstream of Kansas City, the most downstream location with a flood control constraint that calls for release cutbacks due to potential downstream flooding. The spring rise was also a secondary factor in 2 or 3 other years, depending on the alternative, in which another factor was the primary reason flood control benefits were reduced. Other factors included a difference in the March timeframe releases (lower summer flows may cause higher early spring releases in some years in the simulation runs), spring evacuation differences in very high runoff years, the transitional flat full navigation service release between the spring rise and lower summer flow, flat releases for the GP options versus spiked releases for the CWCP simulation run, summer and fall evacuation in high runoff years, and drought conservation measures. The MCP and GP options have a minimum release of 3 kcfs less than full service in May and June and in the fall versus a potential for minimum service (-6 kcfs) for the CWCP. Some of these factors have very small release differences; however, the small differences may occur during times of extensive flooding, increasing the total flood damages.

Flood Control for Tribal Reservations

All 13 of the Reservations identified have flood control impacts analyzed for each particular reach that includes the Reservation land. The reach downstream from Fort Peck Dam includes benefits to Fort Peck Reservation. The reach downstream from Fort Randall Dam includes the benefits to Yankton Reservation, Ponca Tribal Lands, and Santee Reservation. The Sioux City reach includes the benefits to both Winnebago and Omaha Reservations, while the St. Joseph reach includes benefits to Sac and Fox and Iowa Reservations.

Table 7.8-2 summarizes the total differences in flood control benefits provided to Reservations by the alternatives analyzed in this chapter. The highest total benefits are provided by the CWCP, with the MCP and the GP2021 option providing the second and third highest levels of benefits. The GP2028 option provides the lowest level of flood control benefits for Reservation lands of all of the alternatives analyzed in this chapter.

The flood control benefits for Fort Peck Reservation are $0.85 million for both the CWCP and the MCP. The GP options provide $0.83 million to Fort Peck Reservation, a decrease of $0.02 million, or 2.4 percent, from the level of the CWCP.

Flood control benefits for Fort Berthold Reservation are highest under the CWCP at $0.03 million in damages per year. Intermediate damages of $0.04 million are provided by the MCP, which represents a 33.3 percent reduction in flood control benefits. The GP options provide a 66.7 percent decrease in flood control benefits from the CWCP.

Table 7.8-2. Average annual flood control benefits ($millions) to Tribal Reservations.

Reservation	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Fort Peck	0.85	0.85	0.83	0.83	0.83	0.83
Fort Berthold	-0.03	-0.04	-0.05	-0.05	-0.05	-0.05
Standing Rock	-0.05	-0.06	-0.06	-0.07	-0.07	-0.06
Cheyenne River	-0.05	-0.06	-0.07	-0.07	-0.08	-0.07
Lower Brule	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Crow Creek	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Yankton and Ponca Tribal Lands	0.12	0.12	0.12	0.12	0.12	0.12
Santee	0.00	0.00	0.00	0.00	0.00	0.00
Winnebago	8.52	8.49	8.47	8.51	8.47	8.45
Omaha	7.96	7.93	7.91	7.95	7.91	7.89
Iowa, Sac and Fox	0.00	0.00	0.00	0.00	0.00	0.00
Total	**17.30**	**17.21**	**17.13**	**17.20**	**17.11**	**17.09**

The benefits provided to Standing Rock Reservation are highest under the CWCP at $0.05 million in damages per year. The MCP provides intermediate damages of $0.06 million per year, a decrease of 20.0 percent relative to those provided by the CWCP. The lowest level of flood control benefit for this Reservation is provided by the GP2021 and GP1521 options with a 40.0 percent decrease from the level of the CWCP.

The highest benefit level for Cheyenne River Reservation is provided by the CWCP with $0.05 million in damages per year. The MCP provides intermediate benefits of $0.06 million in damages per year. The GP options range from $0.07 to $0.08 million in damages per year, which constitute a 40.0 to 60.0 percent decrease below the CWCP.

The level of benefit provided to Lower Brule Reservation and Crow Creek Reservation is the same for all alternatives analyzed in this chapter. The reach downstream from Fort Randall Dam, with benefits to Yankton Reservation, Ponca Tribal Lands, and Santee Reservation, also shows no differences for all alternatives analyzed in this chapter.

The Sioux City reach, which includes the Winnebago and Omaha Reservations, shows a slight difference in the level of flood control benefits provided by the alternatives analyzed in this chapter. For both Winnebago and Omaha Reservations, the highest benefits are provided by the CWCP at $8.52 million and $7.96 million, respectively. The MCP decreases the benefits to $8.49 million and $7.93 million, respectively, a decrease of $0.03 million for each Reservation. The percentage change from the CWCP for each Reservation is a decrease of 3.5 percent for Winnebago Reservation and a decrease of 3.8 percent for Omaha Reservation with the MCP. The GP options provide lower flood control benefits to the two Reservations. Losses in benefits range from $0.01 to $0.07 million, all of which are less than a 1.0 percent change from the CWCP.

There is no difference among the alternatives analyzed in this chapter in the level of flood control benefits provided to the St. Joseph reach, which includes Sac and Fox and Iowa Reservations.

7.8.2 Interior Drainage

Analysis of interior drainage impacts was completed for six representative sites downstream of Gavins Point Dam along the Missouri River from Nebraska City to Hermann. Following the review and comment period for the RDEIS, an effort was undertaken to make an estimate of total floodplain interior drainage impacts. This section of the FEIS discusses results of the representative site analysis, a more detailed analysis of one of the sites, potential interior drainage impacts to the Reservations, and the results of the total floodplain analysis.

Interior Drainage at the Six Representative Sites

The six representative interior drainage sites are levee unit L575 around Hamburg, Iowa; levee unit L536 near Corning, Missouri; levee unit L488 north of St. Joseph, Missouri; levee unit R351 east of Independence, Missouri; levee unit L246 near Boonville, Missouri; and the Tri-County levee unit, across the river from Hermann, Missouri. The sites represent combinations of the non-flow factors that contribute to interior drainage damage: topography, drainage structure size and placement, and rainfall that may be found at leveed areas along the river.

With the exception of site L575, all of the basins that drain directly to the Missouri River or the lower reaches of a tributary adjacent to each levee unit were modeled.

For site L575, the portion of the levee unit that drains into Main Ditch 6 was not modeled. Simulation runs were made of the alternatives for a 45-year period from October 1, 1949 through September 30, 1994 (water years 1950 through 1994). The simulation runs, completed using an adapted version of a model developed for the Corps' Hydrologic Engineering Center called HEC-IFH, computed the size of the ponding areas within the six levee units on a daily basis for this period. These files were input to an adapted version of a model developed for the Corps' Hydrologic Engineering Center called HEC-PBA. This model computed the damages to the potential crops raised in the areas where the water ponded. Each ponding site had an assumed area that stored water often enough that the farmer did not plant a crop in this portion of the site. This area was input to the HEC-PBA model as a "zero-damage" acreage that was subtracted from the total ponding area for each of the modeled basins within the levee unit. The resulting damages to the crops were not converted to benefits for this report because the primary interest is on the relative differences among the alternatives. A negative difference between two alternatives is a relative benefit.

Figure 7.8-5 presents the total average annual interior drainage damages for the alternatives discussed in this chapter and the Chapter 5 submitted alternatives for perspective. Table 7.8-3 presents the total average annual damages for the six representative sites for each alternative.

The CWCP does not have a spring rise or summer low-flow period. The flat release from mid-May through late August is 34.5 kcfs in non-drought periods and goes to 28.5 kcfs in major droughts. Over the 45-year simulation period, the CWCP has the lowest average interior drainage damages, at $1.34 million per year. All other alternatives discussed in this chapter have higher damages in total and the same or higher damages at each site. Due to the differences in sites, there can be significant variation in the interior damages for the same alternative. For example, for the 45-year period, the average annual damages for the CWCP range from a low of $0.06 million at site R351 to a high of $0.52 million at site L246. Both of these sites are downstream from Kansas City, and both sites have major inflows entering the Missouri River from upstream tributaries. The primary difference between the two sites is the amount of "zero-damage" acreage. Site R351 has a number of very large ditches that drain the site. These ditches provide considerable storage space for the runoff from the interior of the levee should the outlets to the Missouri River be blocked by high river stages.

Figure 7.8-5 shows that the range of average annual total damages for the alternatives is from $1.34 to $1.47 million, a difference of $0.13 million per year. The alternatives fall into two fairly close groupings. The CWCP and the MCP are grouped together at $1.34 and $1.38 million in damages. The MCP results in interior drainage damages similar to the MRBA and MODC alternatives discussed in Chapter 5. The four GP options are grouped closely together at $1.45 to $1.47 million in damages. They are more comparable to the level of damages seen in the FWS30 and BIOP alternatives in Chapter 5.

Table 7.8-3 shows that the effect of moderating releases from Gavins Point Dam declines at the sites further downriver from the dam. As one moves further from Gavins Point Dam, there are more outside influences on interior drainage damages, such as tributary inflow. This reduces the effect of controlling releases on sites further from the dam. Site L575 is closest to the dam and accounts for the majority of changes in damages due to the differences in alternatives.

Under the MCP, interior drainage damages increase to $1.38 million. This modified conservation plan has an unbalanced intrasystem regulation among the upper three lakes, provides greater conservation during drought periods, and provides higher navigation service levels with summer releases in drought periods. Compared to the CWCP, the MCP has 3.0 percent higher interior drainage damages, or an average of $0.04 million more per year. It has a lower increase in damages than the other alternatives discussed in this chapter. Site L575 shows an increase in damages of $0.03 million per year, or a 7.0 percent increase. The other sites do not show a difference in damages of over $0.01 million.

The GP1528 option serves as the potential starting point for comparison of the GP options with the

Table 7.8-3. Average annual interior drainage damages, 1950 to 1994 ($millions).

Alternative	Total	L575	L536	L488	R351	L246	Tri-County
CWCP	**1.34**	0.43	0.12	0.15	0.06	0.52	0.07
MCP	**1.38**	0.46	0.12	0.15	0.06	0.52	0.07
GP1528	**1.45**	0.50	0.13	0.16	0.06	0.53	0.07
GP2021	**1.47**	0.51	0.13	0.16	0.06	0.53	0.07
GP1521	**1.47**	0.52	0.14	0.16	0.06	0.52	0.07
GP2028	**1.45**	0.51	0.14	0.16	0.06	0.53	0.07

MCP. The GP1521, GP2028, and GP2021 options represent the range in changes from GP1528 that can be made under adaptive management. Consequently, GP1528 results are compared to the MCP, and then the results of the three other GP options, GP1521, GP2028, and GP2021, are compared to the GP1528 option.

The GP1528 option is the same as the MCP except that it has a spring rise of 15 kcfs and a flat summer release of 28.5 kcfs from Gavins Point Dam. This flat release represents minimum service to navigation (-6 kcfs from full service). The resulting interior drainage damages for GP1528 average $1.45 million per year, which is a $0.07 million increase over the MCP, or a 5.1 percent increase. Only site L575 shows a damage increase of over $0.04 million per year higher than the MCP, an 8.7 percent increase.

The other GP options have either a different summer flow level from Gavins Point Dam, a different level of spring rise, or both, compared to the GP1528 option. All four GP options have virtually the same average annual damages, ranging from $1.45 to $1.47 million.

The GP2021 and GP1521 options both include the 25/21-kcfs split season for summer flow. Although they have different spring releases (20 kcfs and 15 kcfs, respectively), they have the same total damages. The interior drainage damages for each average $1.47 million per year. The result of the 25/21-kcfs split season for summer low flow is a 1.4 percent increase, or $0.02 million, per year higher than the GP1528 option.

The GP2028 option has a higher spring rise than the GP1528 option (20 kcfs), but it has the same flat summer release of 28.5 kcfs from Gavins Point Dam. The change in the spring rise from 15 kcfs to 20 kcfs does not result in changes to the interior drainage damages.

Figures 7.8-6 through 7.8-8 show that there can be considerable variance through the years. For example, the CWCP shows average damages of $1.34 million, but yearly damages range from $0.03 in 1956 to $11.30 million in 1993, a flood year. In all but 7 years, the damages are less than $2.00 million and there are only 2 years, 1984 and 1993, above $3.00 million.

The alternatives discussed in this chapter follow a similar pattern as the CWCP, with the same low damage years and the same high damage years. The years of the highest damages are 1984 and 1993. In the flood of 1993, all alternatives show damages above $11.00 million.

There is not an obvious pattern of differences between the alternatives. The MCP shows the largest damage increases in the years 1965, 1982, and 1986, more than $0.40 million higher than the CWCP. During all but 8 of the 45 years, however, the difference is less than $0.10 million in any one year.

The largest average annual difference discussed above is between the MCP and the GP1528 option. The spring rise and low summer release of the GP1528 option increase damages by an average of $0.07 million per year. The years showing the largest increases, more than $0.30 million in each year, are 1971, 1972, and 1993.

The four GP options have a similar pattern of damages over the 45 years. Close evaluation of the annual data shows the same grouping of options as seen in the average total damages. While all four options are fairly close, the GP2021 and GP1521 options track more closely on a year-by-year basis, as do the GP1528 and GP2028 options. This supports the observation that a change in the spring rise from 15 kcfs to 20 kcfs has less effect than the change in low flow in the summer.

Interior Drainage by Season for Levee Unit L575

To better understand the relationships between flow changes throughout the crop growing season and damages to those crops, a breakdown of the damages by season (spring, summer, and fall) was completed. Levee unit L575 was selected for this more detailed analysis because it is the site with the greatest differences in damages among the CWCP, the MCP, and the GP options. Spring damages are those that occur prior to June 27, summer damages from that date to September 6, and fall damages after September 6. Five days were added after the Gavins Point Dam change in releases to account for travel time to L575.

The distribution of these damages for the alternatives is presented in Table 7.8-4 and shown in Figure 7.8-9. Total damages vary slightly from those presented in Table 7.8-3 because pumping costs are not included in the values presented in Table 7.8-4. The spring damages make up 62 to 73 percent of the total interior drainage damages at L575. Summer damages constitute 15 to 30 percent of the total, and fall damages constitute 6 to 17 percent, depending on the alternative.

Close examination of the figure indicates that there are trends in the data. Figures 7.8-10 through 7.8-12 are plots of the spring, summer, and fall damages, respectively, plotted against Gavins Point Dam releases. Spring damages correlate very well with the spring rise amount. The correlation coefficient is 0.995, with 1.0 being a perfect fit. For every kcfs increase in the spring rise, spring damages go up about $6,100. Similarly, the summer damages were plotted against the amount of the average summer release. The correlation coefficient is 0.87, which is still a good correlation.

In the case of summer flow, average summer damages go up about $4,550 for every kcfs increase in summer flow. Figure 7.8-12 shows the fall damages; however, the average Gavins Point Dam release over the May 15 through September 1 period was used for the release value in the plot. The correlation coefficient is 0.93, and damages go down as the amount of the water released in the spring and summer go up. Put differently, as the fall flow goes up, the fall damages go up. This conclusion can be drawn because the less water moved in the spring and summer normally means more water is available in the fall to be evacuated from the Mainstem Reservoir System. In this case, for a 1-kcfs change in the average spring and summer release, the damages go up by $8,030. In summary, as the flow goes up, no matter what time of year, the interior drainage damages tend to go up.

This analysis may add some confusion for those wondering what to do with the water stored in the system if damages go up as more water is released. Focusing on the total damages brings the picture back into focus. Total damages are lowest for the CWCP and the MCP, neither of which have a spring rise and both of which have the lowest spring releases from Gavins Point Dam. To minimize total damages over the long run, spring releases must be minimized. This conclusion makes sense because the spring damages make up at least two-thirds of the total damages.

Interior Drainage for Tribal Reservations

The sites included for interior drainage analysis did not include any Tribal Reservation land; therefore, damage estimates for interior drainage damages on Reservation land were not developed.

The Reservations located within this reach are Sac and Fox Reservation and Iowa Reservation. The nearest site analyzed to these Reservations is the L488 site, which is downstream and across the Missouri River. In terms of Reservation lands, it must be noted that Sac and Fox Reservation and Iowa Reservation floodplain land is protected by non-Federal levees that may or may not have non-flow factors similar to L488. To the extent that they are similar, damages would increase or decrease by alternative in similar ways. For Iowa and Sac and Fox Reservations, about 1,000 acres are located in the Missouri River floodplain. The value of the crops that could be damaged is estimated at $0.30 million. Four residential buildings are located in the floodplain and are subject to flooding. Their value is estimated to be $0.40 million.

Only $0.01 million separates the damages for the MCP at $0.15 million and for each of the GP options, all with damages of $0.16 million.

Estimate of Total Floodplain Interior Drainage Impacts

As the Corps worked toward a decision on what alternative should be selected as the preferred alternative for the FEIS, an in-house question was raised as to what is the potential total floodplain interior drainage damages to crops on an average annual basis. This question was asked to help put the floodplain crop damages in another perspective as discussions took place on a potential preferred

Table 7.8-4. Distribution of average annual interior drainage damages by season without pumping for L575 ($thousands).

Alternative	Spring	Summer	Fall	Total
CWCP	272.31	129.23	25.75	**427.29**
MCP	279.83	138.39	36.58	**454.79**
GP1528	334.93	96.64	62.01	**493.58**
GP2021	365.47	79.44	72.92	**517.84**
GP1521	334.97	81.54	85.60	**502.11**
GP2028	369.75	87.52	49.51	**506.78**

alternative. Before a total floodplain estimate was made, the factors making this effort a challenge were discussed. These included, but were not limited to, the potential for the crop losses included in the interior drainage analysis that may be included in the flood control or groundwater analyses, the potential that the sites are not "representative" of all of the levee units potentially impacted, and the fact that different periods of analyses were used for each of the three analyses addressing crop damages—flood control, interior drainage, and groundwater.

Two separate analyses were conducted, one based on an average of the damages computed for the six representative sites and the other based on a geometric mean of the damages at the four sites. The geometric mean analysis was selected for presentation in the FEIS. A primary reason for selecting this analysis was that the total floodplain crop losses varied by the same percent change among the alternatives as the percent change for the total losses for the six representative sites.

Table 7.8-5 presents the results of the total floodplain crop loss due to interior drainage problems. These impacts represent the average annual value over the 45-year period of analysis (1950 through 1994) for the estimated 1.4 million acres of floodplain land between Omaha and St. Louis (The reach upstream from Omaha is not leveed.). The CWCP interior drainage crop losses total an estimated $17.95 million per year. The MCP results in an additional $1.51 million of losses per year for a total of $18.46 million. Inclusion of the spring rise and lower summer flows downstream from Gavins Point Dam further increase crop losses due to reduced interior drainage. These losses range from $19.37 to $19.66 million per year. The two alternatives with the greatest crop losses are the GP2021 and GP1521 options. This is an indication that the summer low flows are a major factor in the ultimate differences among the alternatives as these two options have the lowest summer releases from Gavins Point Dam.

Not to diminish the significance of these crop losses due to inadequate interior drainage but to provide another perspective, the percent of the total crop value is also included in Table 7.8.5. The percent of total crop value (estimated at $475 million per year) lost due to imperfect interior drainage of farm fields that are leveed from the Missouri River range from 3.8 percent to 4.1 percent. This represents a range of 0.3 percent among the CWCP and five other alternatives. This is just another way of pointing out that a considerable portion of the floodplain crops is unaffected by interior drainage problems. The increase in crop losses on an entire floodplain basis is relatively small—as much as only 0.3 percent.

7.8.3 Groundwater

Analyses of groundwater effects were computed for four representative sites along the Missouri River from Onawa, Iowa to Hermann, Missouri. Following the review and comment period for the RDEIS, an effort was undertaken to make an estimate of total floodplain groundwater impacts. This section of the FEIS discusses results of the representative site analysis, a more detailed analysis of one of the sites, potential groundwater effects to the Reservations, and the results of the total floodplain analysis.

An independent analysis of potential groundwater damages and impacts to farmers was conducted in 1999 by the U.S. Geological Survey (USGS) and the Food and Agricultural Policy Research Institute (FAPRI) associated with the University of Missouri using funding provided by the Missouri Levee and Drainage District Association, Missouri Farm Bureau, the Missouri Legislature, and the USGS. The USGS used its own groundwater model to

Table 7.8-5. Interior drainage crop losses on the Missouri River floodplain.

	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Total Crop Losses ($millions)	$ 17.95	$ 18.46	$ 19.37	$ 19.64	$ 19.66	$ 19.46
% of Total Floodplain Crop Value[1/]	3.8	3.9	4.1	4.1	4.1	4.1

[1/] Based on a total crop value of $475 million per year for the floodplain reach from Omaha, Nebraska to St. Louis, Missouri.

simulate impacts of the alternatives on groundwater levels, and FAPRI conducted its own economic analyses of the potential crop damages. Levee unit R351 was the site modeled. This independent analysis arrived at similar results for R351 that the Corps had determined for the four sites it analyzed. This independent analysis was conducted in response to the unexpected results the Corps got for two alternatives with a spring rise and 30-day summer low-flow period. Analyses by both the Corps and USGS/FAPRI determined that crop damages would actually go down on an average annual basis for these two alternatives.

Groundwater at the Four Representative Sites

The four representative groundwater sites are designated as river mile (RM) 691, which is an unleveed site near Onawa, Iowa; levee unit L575 near Hamburg, Iowa (across the river from Nebraska City); levee unit L488/L497 north of St. Joseph, Missouri; and the Tri-County levee unit across the river from Hermann, Missouri.

Simulation runs were made of the alternatives discussed in this chapter for the 10-year period from October 1, 1969 through September 30, 1979 (water years 1970 through 1979). The results of the groundwater model simulation runs were in terms of percent of the modeled area that had groundwaterlevels at 1-foot increments from zero feet deep up to 9 feet deep. These files were input to another adapted version of the HEC-PBA model, which is the same model used for the interior drainage analysis. This economics model computed the annual crop damages associated with the shallow groundwater levels to the crops raised at each representative site. These damages were not converted to benefits for this report because the primary interest is in the relative differences among the alternatives. A negative difference between two alternatives is a relative benefit.

Figure 7.8-13 presents graphically the total annual damages for each of the alternatives discussed in this chapter and for the submitted alternatives in Chapter 5. Table 7.8-6 presents the average annual groundwater damages in total and at each area modeled for the alternatives discussed in this chapter.

Over the 10-year simulation period, the total damages for the modeled sites for the CWCP average $4.52 million per year. At individual sites the CWCP damages range from a low of $0.30 million per year at the Tri-County site near Hermann to a high of $2.18 million per year at site L575 near Hamburg, Iowa. Damages for the CWCP are distributed among site L575 (48.2 percent), site L488/497 (28.8 percent), site RM691 (16.4 percent), and the Tri-County site (6.5 percent). Two factors contribute to differences in the damages. First, there is a difference in the relative size of the sites (RM691 and L575 are much larger than Tri-County and L488/497). Second, there is a difference in the lay of the farmable land with respect to the river. Although site RM691 is larger than site L575, it has only 34 percent of the damages of site L575, which has more land with elevations closer to the river water surface.

Total average annual groundwater effects for the alternatives range between a high of $4.99 million for the GP2021 option to a low of $4.50 million for the MCP, compared to the CWCP at $4.52 million. This is a range of $0.49 million per year. Figure 7.8-13 shows that the alternatives in this chapter fall into two groupings. The MCP and the CWCP make up the first grouping. The second grouping is the four GP options. When compared to the Chapter 5 alternatives, the MCP is similar to the MRBA and MLDDA alternatives. The four GP options have damages that are more like the level of damages one sees in the alternative prescribed by the USFWS in the November 2000 BiOp.

The MCP has conservation measures added to the CWCP along with features that have no impact on groundwater analysis. Damages associated with the MCP are $0.02 million lower than the CWCP, a decrease of 0.5 percent, which is expected because it generally has the same spring and summer flows as the CWCP. The MCP has lower damages than all other alternatives discussed in this chapter and it is among the lowest at each site.

Table 7.8-6. Average annual groundwater damages 1970 to 1979 ($millions).

Alternative	Total	RM691	L575	L488/497	Tri-County
CWCP	**4.52**	0.74	2.18	1.30	0.30
MCP	**4.50**	0.74	2.17	1.29	0.30
GP1528	**4.91**	0.82	2.47	1.31	0.31
GP2021	**4.99**	0.87	2.51	1.29	0.32
GP1521	**4.94**	0.86	2.47	1.30	0.32
GP2028	**4.91**	0.82	2.47	1.30	0.31

There are four GP options. GP1528 serves as the potential starting point for comparison against the MCP because its spring and summer release changes are closest to the CWCP. The GP2021, GP1521, and GP2028 options represent the range in changes from GP1528 that could be made under adaptive management without going through the NEPA process again. Consequently, the GP1528 option results are compared to the MCP, and then the results of the other three GP options are compared to the GP1528 option.

The GP1528 option is the same as the MCP except that it has a spring rise of 15 kcfs and a lower flat summer release of 28.5 kcfs from Gavins Point Dam. This flat release represents minimum service to navigation (-6 kcfs from full service). The resulting groundwater damages for the GP1528 option average $4.91 million per year, a 9.1 percent increase, or $0.41 million more per year than the MCP. At the individual sites, the damages for the GP1528 option range from $0.01 million per year higher at the Tri-County site to $0.30 million per year higher at site L575. That is an increase of 3.3 percent at the Tri-County site to 13.8 percent at site L575.

The other three GP options have a different summer flow level at Gavins Point, a different level of spring rise, or both. Both a higher spring rise of 20 kcfs and the 25/21-kcfs split season option for summer flow are included in the GP2021 option. The 25/21-kcfs split season means that there will be a 25-kcfs flow from June 21 to July 15, then 21 kcfs from July 16 to August 15, and finally 25 kcfs again from August 16 to September 1. Implementing both changes increases damages more than just adding the damages of each change separately as seen in the GP1521 and GP2028 options. GP2021 damages average $4.99 million per year, a 1.6 percent increase, or $0.08 million per year higher than the GP1528 option. At the individual sites, there are differences in amount and in the direction of differences. The range is from $0.02 million (1.5 percent) lower damages per year at site L488/497 under GP2021 to $0.05 million (8.1 percent) higher damages per year at site RM691.

The GP1521 option provides the same spring rise of 15 kcfs as seen in the GP1528 option, but has the 25/21-kcfs split season option. The split season option results in an average of $0.03 million more damages per year than GP1528 with its flat 28.5-kcfs release, a 0.6 percent increase. At the individual sites, the range is a decrease in damages of $0.01 million per year (0.8 percent) at site L488/497 to an increase of $0.04 million per year (4.9 percent) at site RM691.

The GP2028 option has a higher spring rise than the GP1528 option (20 kcfs) but has the same flat summer release of 28.5 kcfs from Gavins Point Dam. The higher spring rise alone has virtually no effect because the groundwater damages are $4.91 million, the same as for the GP1528 option. When compared to the GP1528 option, the differences at each individual site are 1 percent or less.

Figures 7.8-14 to 7.8-16 show the annual damages of each alternative discussed in this chapter over the 10-year study period. The annual CWCP damages are an average of $4.52 million but damages in individual years range from $2.37 million in 1976 to $6.92 million in 1978, which was a very wet year in the upper Missouri River basin (second highest runoff year in the 100-year period of analysis). That is almost a threefold increase. All of the alternatives discussed in this chapter follow the same pattern as the CWCP through the decade, with peaks and low points in the same years. The MCP follows the CWCP very closely, except in 1978 and 1979. It is $1.33 million higher in 1978 and $1.15 million lower in 1979. The GP1528 option is higher than the MCP in all but peak years 1973, 1975, and 1978. In those years GP1528 is approximately the same as the MCP. There is very little difference among the four GP options.

Groundwater by Season at Levee Unit L575

Seasonal groundwater crop damages were also examined in more detail for levee unit L575. This levee unit has the greatest changes in damages of the four sites modeled. The average annual crop damages by season are presented in Table 7.8-7 and shown in Figures 7.8-17 to 7.8-21. The greater share of the groundwater damages for the CWCP occurs in the spring (86 percent). Of the total damages, 10 percent occurs in the summer and only 4 percent in the fall. A plot of the summer damages is not included because the summer data do not correlate very well with any hydrologic factors.

The spring and fall damages appear to correlate fairly well with changes in the spring rise, but the best correlation is for the total damages, as shown in Figure 7.8-20. The correlation coefficient is 0.92, and the groundwater damages to crops in site L575 increase by $22,300 per kcfs. This net change per unit change (kcfs) in flow is much larger than the change in interior drainage damages. Groundwater damages are spread over a much larger area than the interior damages, which occur in areas primarily adjacent to drainage structures through the levees.

An additional analysis of the fall data was conducted to determine if there were any other hydrologic variables that correlate better with the fall crop damage data for the six alternatives. Figure 7.8-21 presents the fall data plotted versus the average summer Gavins Point Dam release. The correlation coefficient increases from 0.83 for the spring rise plot to 0.87 for the average summer release plot. Each correlation is considered to be very good, which leads to the conclusion that both the spring rise and the summer flows are important factors. One way of looking at this conclusion is that the spring rise causes groundwater level increases that may have some lingering effect going into the fall months. The fall releases may be higher for the alternatives with lower summer flows (as the water not moved in the summer is moved in the fall). These two factors combine to result in greater crop damages in the fall for the alternatives with the higher spring rises and the lower summer flows (GP2021 option has the greatest fall crop damages at $0.38 million per year). The primary reason for looking further into fall crop damage relationships is that the slopes of the trendlines are greater for the fall damages, which means that they are the most sensitive to changes in flows. Slopes of the two fall plots are $17,500 per kcfs for the spring rise plot and $23,600 per kcfs for the average summer release plot (spring damage plot slope = $6,300 per kcfs).

Figures 7.8-22 to 7.8-45 show the distribution of the groundwater damages in the four sites modeled. These maps show the “concentration” of the damages. The darker the shading, the greater the damages per modeled cell. In the case of site L575, each cell is 500 feet by 500 feet, or 5.74 acres in size. Those cells with the darkest shading have damages in the range of $26 to $42 per acre on an average annual basis. A more detailed examination of the mapping for L575 shows the most severe groundwater damage areas are concentrated near the edge of the levee and in larger areas moving away from the levee adjacent to the major drainage ditches, most having structures through the levee. Interior drainage damages are most likely in a portion of the darkest shaded areas for site L575. This substantiates the decision not to make the groundwater and interior drainage damages additive because both analyses have common damage sites.

Comparison of the maps for each alternative at a single site shows that the damages remain in the same general areas for each alternative. The amount of damages within each portion of the site may intensify (darker shaded) or spread slightly (more cells become colored). This is an indication that the damages tend to affect the same areas under all of the alternatives, but the damages may

Table 7.8-7. Groundwater damages by season for levee unit L575 ($millions).

Alternative	Spring	Summer	Fall	Total
CWCP	1.88	0.21	0.09	**2.18**
MCP	1.89	0.18	0.10	**2.17**
GP1528	1.93	0.20	0.34	**2.47**
GP2021	2.00	0.12	0.38	**2.51**
GP1521	1.93	0.20	0.34	**2.47**
GP2028	1.97	0.21	0.29	**2.47**

increase and spread slightly as they increase with the amount of the spring rise of each alternative. When combined with the knowledge that interior drainage damages affect primarily the areas adjacent to the drainage ditches running through the levee to the river, one can make the general conclusion that those currently affected by interior drainage and groundwater damages under the CWCP are likely to be the only ones affected by these two sources of crop damage under any of the alternatives. The likelihood that damages will spread dramatically and impact all lands behind the levees for both interior drainage and groundwater damages is very low. Similarly, groundwater damages are expected to impact a limited number of farms in site RM691.

Groundwater for Tribal Reservations

The sites included for the groundwater analysis did not include any Reservation land; therefore, damage estimates for excessive groundwater on Reservations were not developed.

Sac and Fox Reservation and Iowa Reservation are in the vicinity of site L488/L497, which is downstream and across the Missouri River from the Reservation. If groundwater damage on the Reservation land responds similarly to site L488/497, damages on the Reservation would be expected to respond to the alternatives in the same way. Only $0.02 million per year separates the groundwater damages of the alternative with the lowest damages, the MCP, from the highest damages under the GP1528 option.

Winnebago and Omaha Reservations are located primarily across the river and upstream from site RM691. To the extent that these Reservation floodplain lands have similar characteristics to site RM691, groundwater damages would be expected to respond to the alternatives in the same way as on site RM691. An estimated $0.13 million per year separates the groundwater damages of the GP option with the highest damages from the MCP.

Estimate of Total Floodplain Groundwater Impacts

As the Corps worked toward a decision on what alternative should be selected as the preferred alternative for the FEIS, an in-house question was raised as to what is the potential total floodplain groundwater damages to crops on an average annual basis. This question was asked to help put the floodplain crop damages in another perspective as discussions took place on a potential preferred alternative. Before a total floodplain estimate was made, the factors making this effort a challenge were discussed. These included, but were not limited to, the potential for the crop losses included in the groundwater analysis that may be included in the flood control or interior drainage analyses, the potential that the sites are not "representative" of all of the levee units potentially impacted, and the fact that different periods of analyses were used for each of the three analyses addressing crop damages—flood control, interior drainage, and groundwater.

Two separate analyses were conducted, one based on an average of the damages computed for the four representative sites and the other based on a geometric mean of the damages at the four sites. The geometric mean analysis was selected for presentation in the FEIS. A primary reason for selecting this analysis was that the total floodplain crop losses varied by the same percent change among the alternatives as the percent change for the total losses for the four representative sites.

Table 7.8-8 presents the results of the total floodplain crop loss due to high groundwater level problems. These impacts represent the average annual value over the 10-year period of analysis (1970 through 1979) for the estimated 2.2 million acres of floodplain land between Sioux City and St. Louis. The CWCP crop losses due to high groundwater levels total an estimated $40.91 million per year. The MCP results in a reduction of $0.19 million of losses per year for a total of $40.72 million. Inclusion of the spring rise and lower summer flows downstream from Gavins Point Dam further increase crop losses due to reduced interior drainage. These losses range from $44.41 to $45.16 million per year. The two alternatives with the greatest crop losses are the GP2021 and GP1521 options. This is an indication that the summer low flows are a major factor in the ultimate differences among the alternatives as these two options have the lowest summer releases from Gavins Point Dam.

Not to diminish the significance of these crop losses but to provide another perspective, the percent of the total crop value is also included in Table 7.8.8. The percent of total crop value (estimated at $746 million per year) lost due to groundwater under farm fields along the Missouri River range from 5.5 percent to 6.1 percent. This represents a range of 0.6 percent among the CWCP

Table 7.8-8. Groundwater crop losses on the Missouri River floodplain.

	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Total Crop Losses ($millions)	40.91	40.72	44.41	45.16	44.77	44.43
% of Total Floodplain Crop Value 1/	5.5	5.5	6.0	6.1	6.0	6.0

1/ Based on a total crop value of $746 million per year for the floodplain reach from Sioux City, Iowa to St. Louis, Missouri.

and five other alternatives. This is just another way of pointing out that a considerable portion of the floodplain crops is unaffected by high groundwater problems. The increase in crop losses on an entire floodplain basis is relatively small—as much as only 0.6 percent.

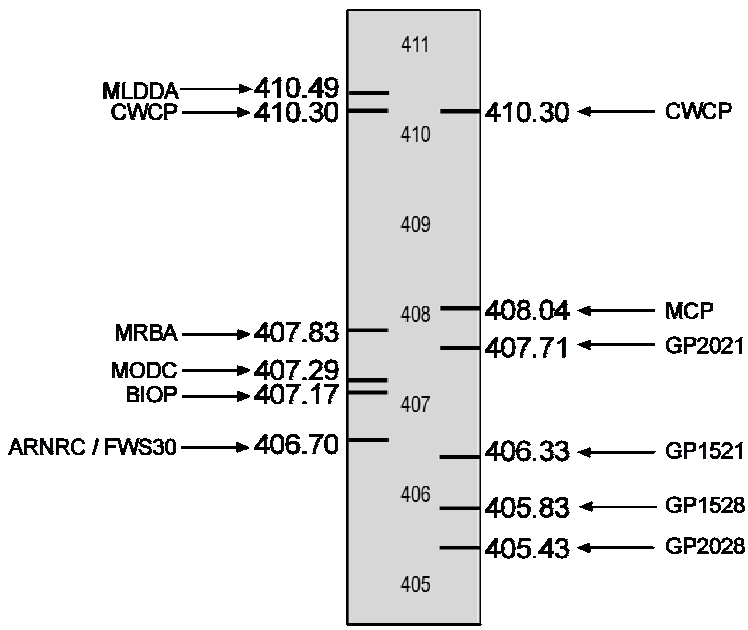

Figure 7.8-1. Average annual flood control benefits for submitted alternatives and the alternatives ($millions).

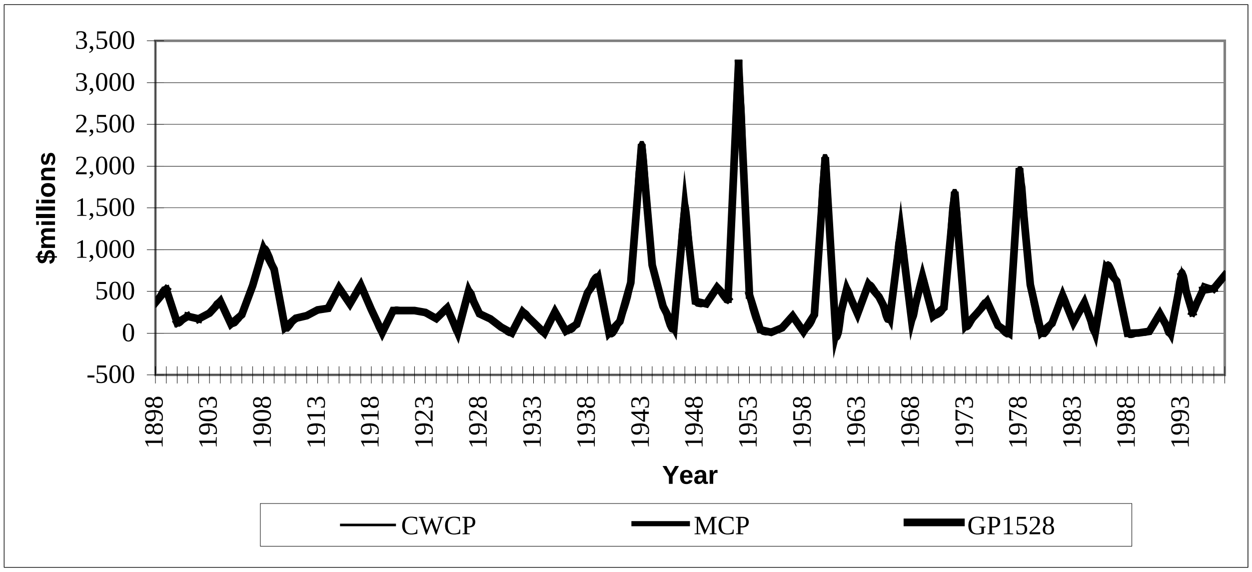

Figure 7.8-2. Annual flood control benefits for CWCP, MCP, and GP1528.

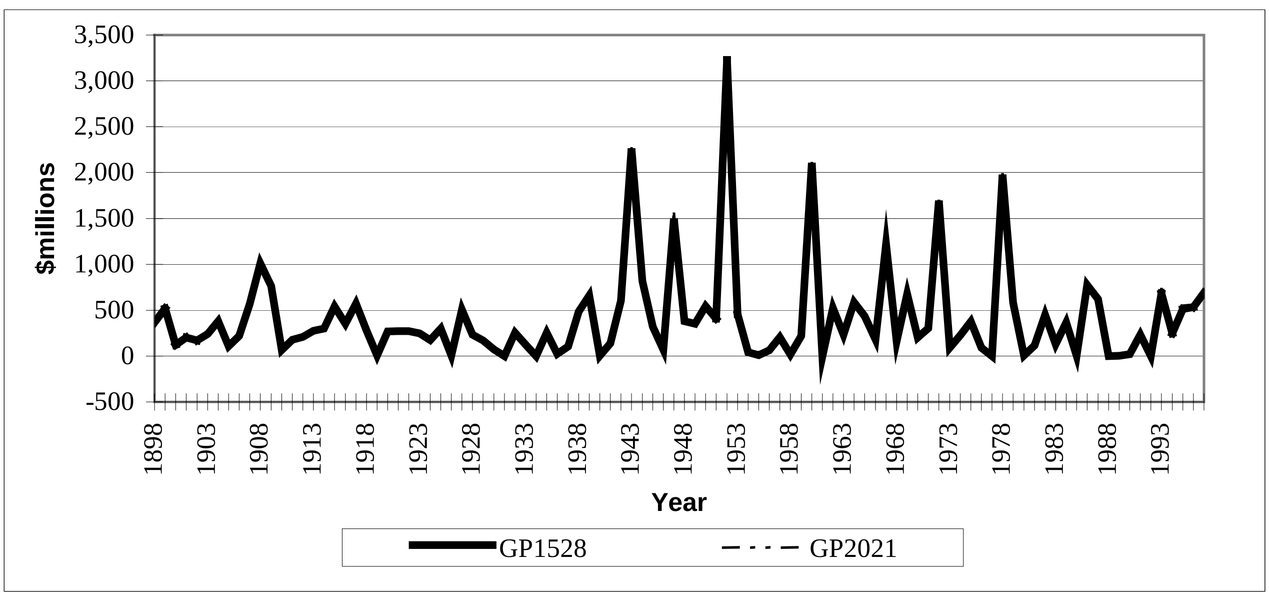

Figure 7.8-3. Annual flood control benefits for GP1528 and GP2021.

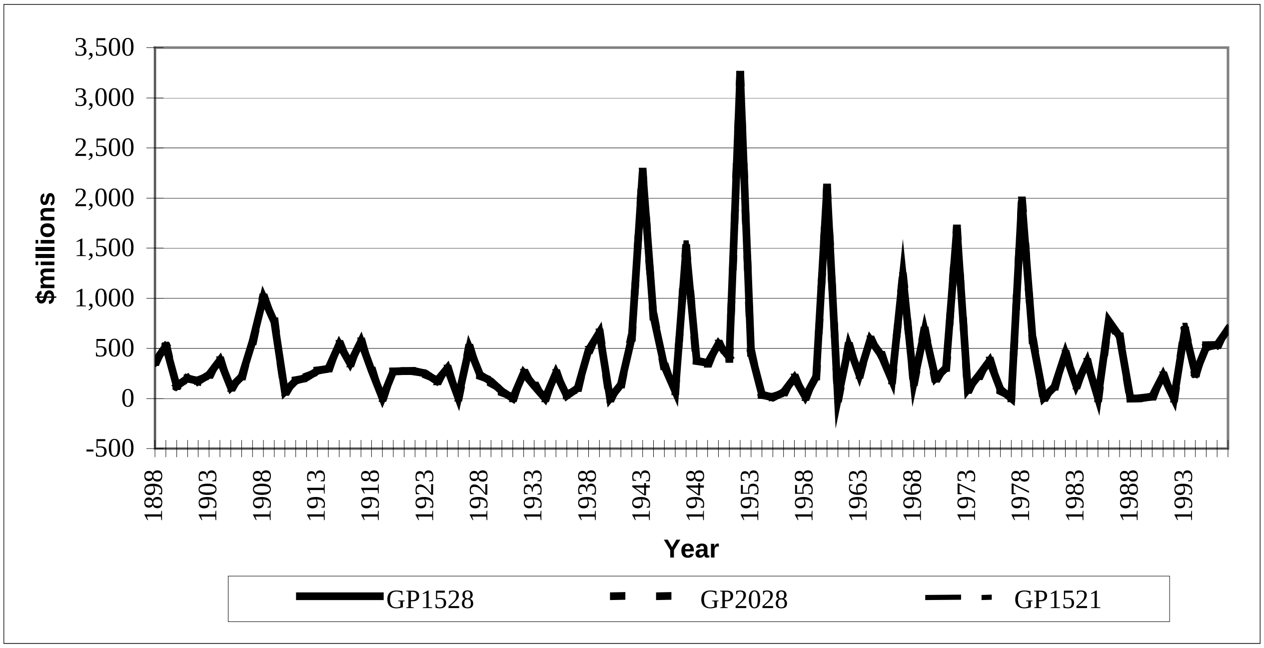

Figure 7.8-4. Annual flood control benefits for GP1528, GP2028, and GP1521.

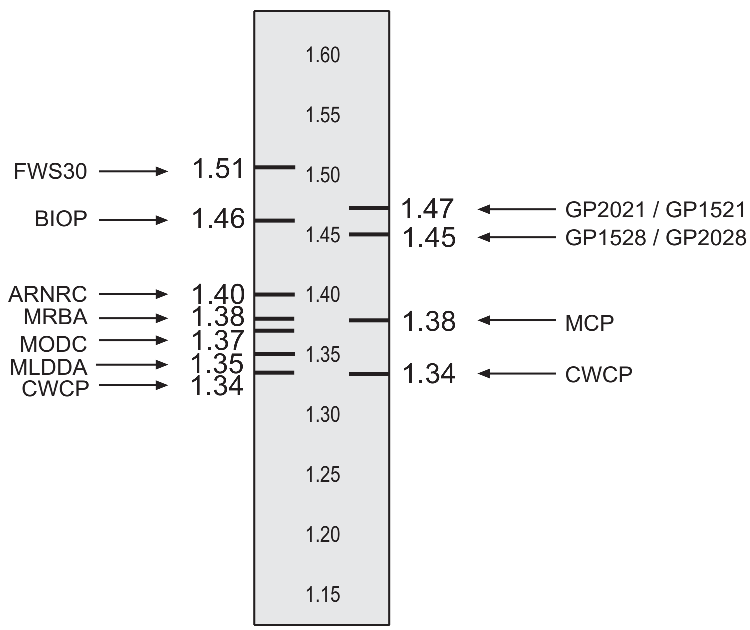

Figure 7.8-5. Average annual interior drainage damages for submitted alternatives and the alternatives ($millions).

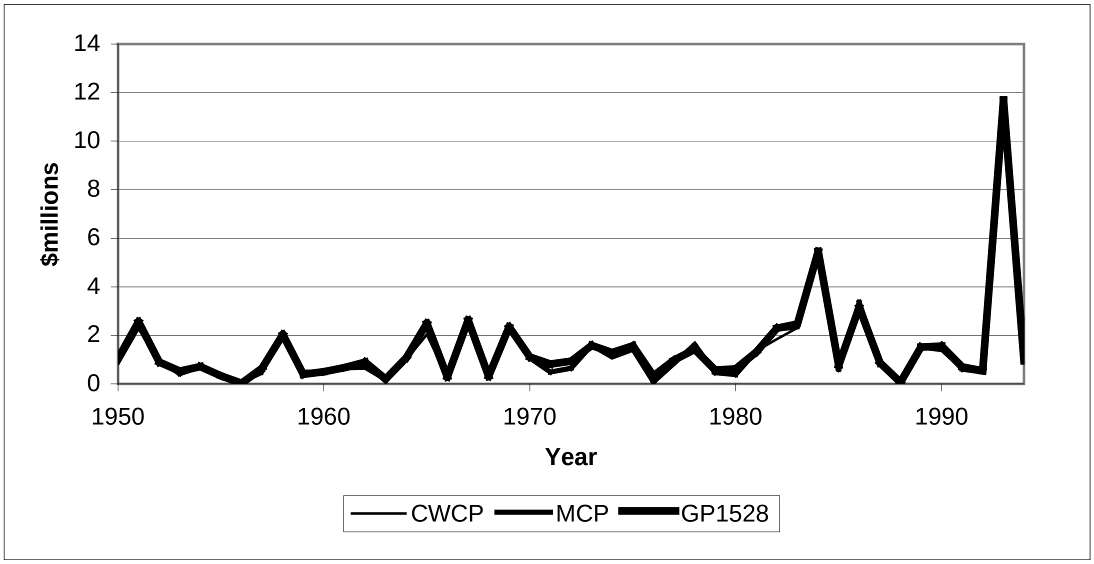

Figure 7.8-6. Annual interior drainage damages for CWCP, MCP, and GP1528.

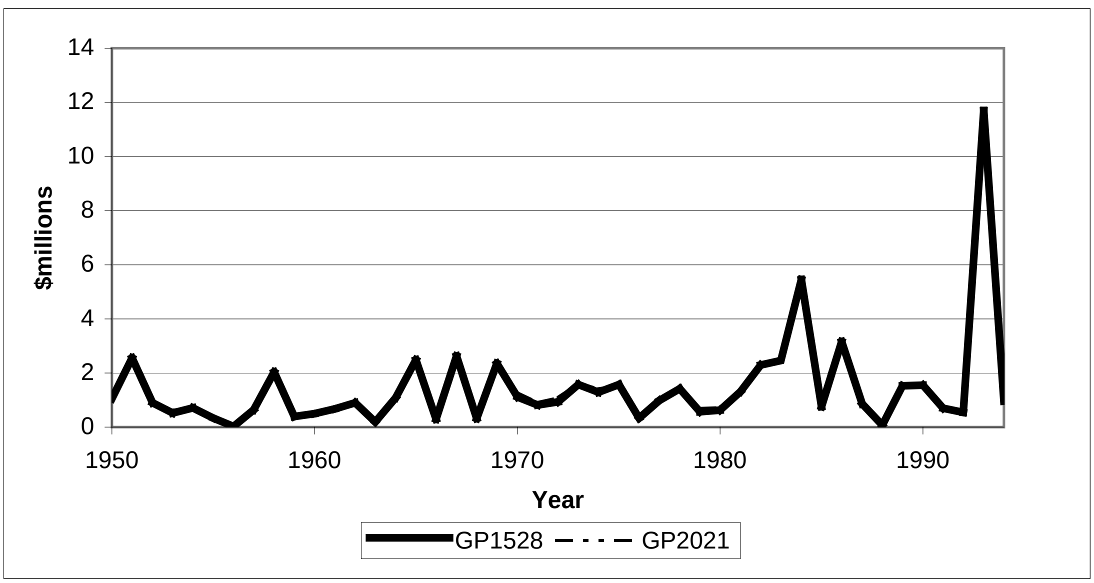

Figure 7.8-7. Annual interior drainage damages for GP1528 and GP2021.

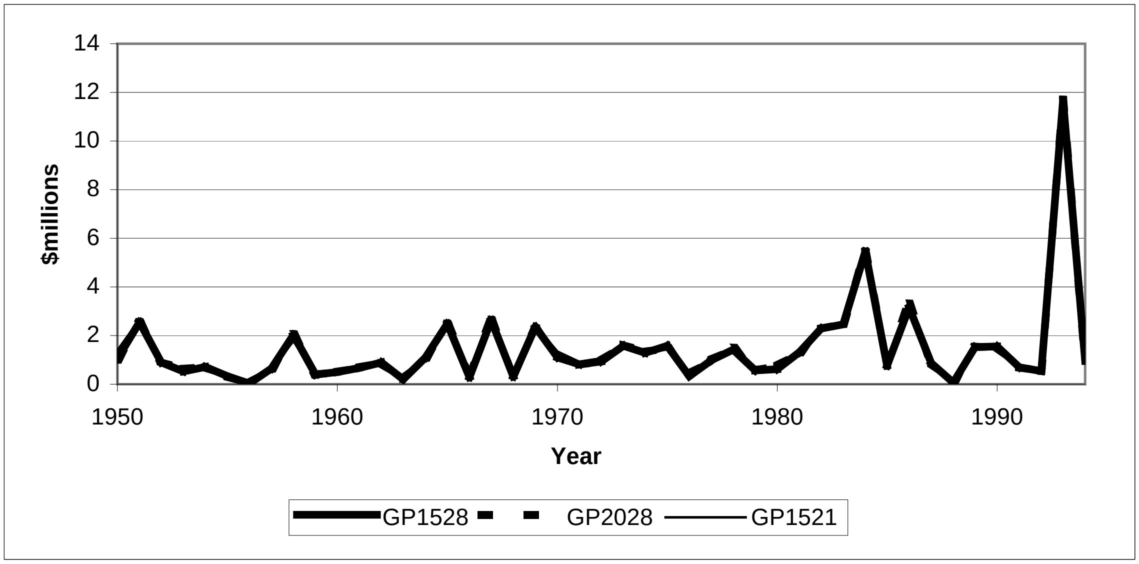

Figure 7.8-8. Annual interior drainage damages for GP1528, GP2028, and GP1521.

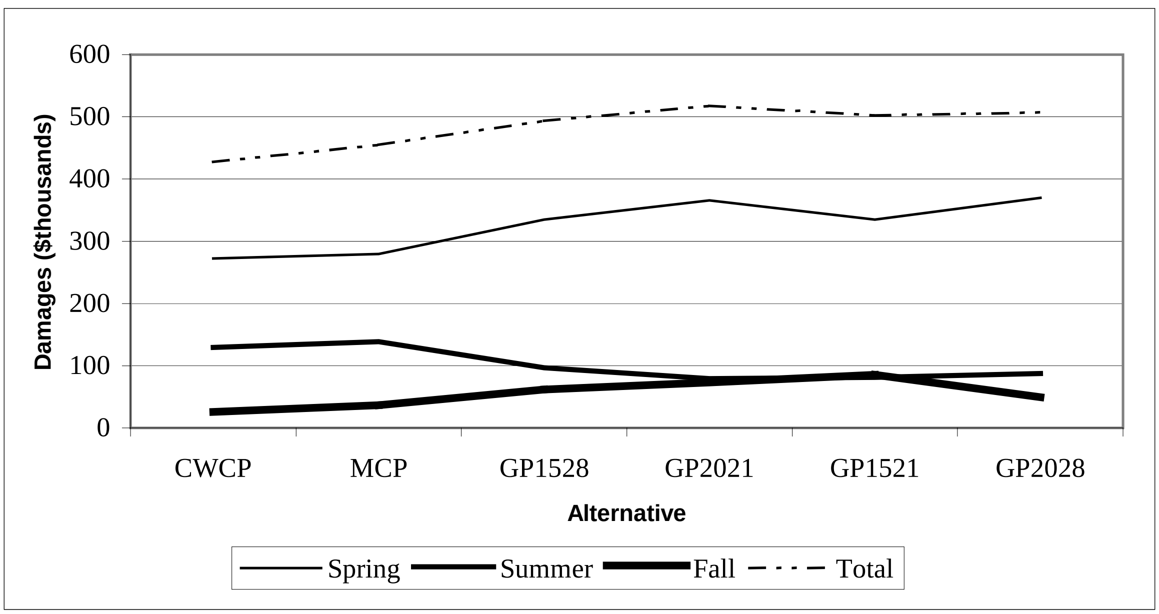

Figure 7.8-9. Average annual interior drainage damages for site L575 by season and total .

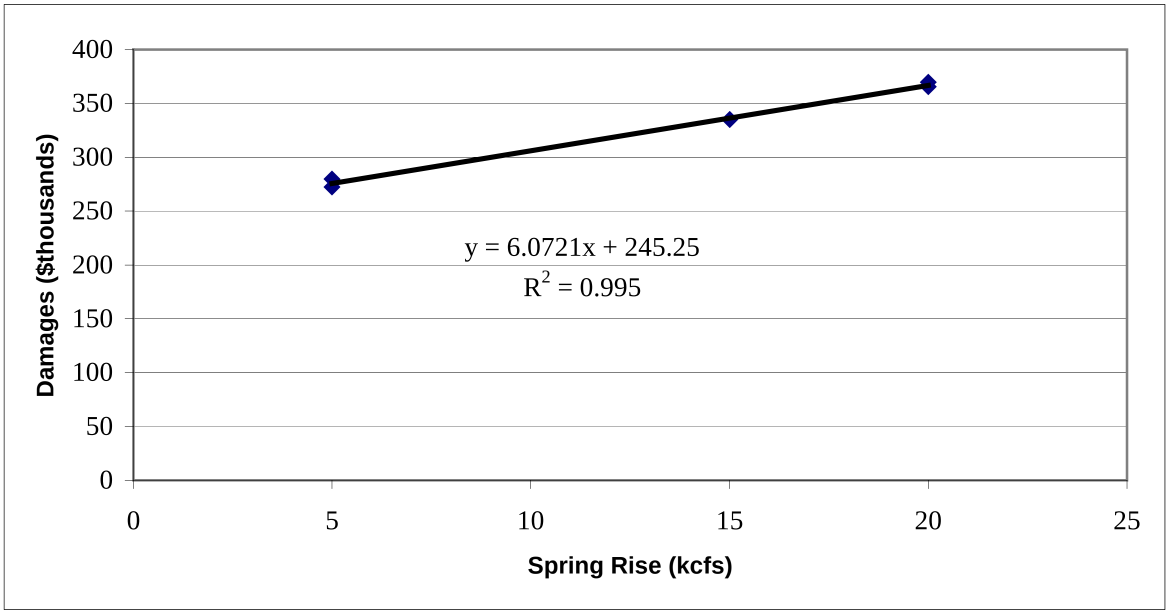

Figure 7.8-10. Average annual spring damages at site L575 versus amount of spring rise.

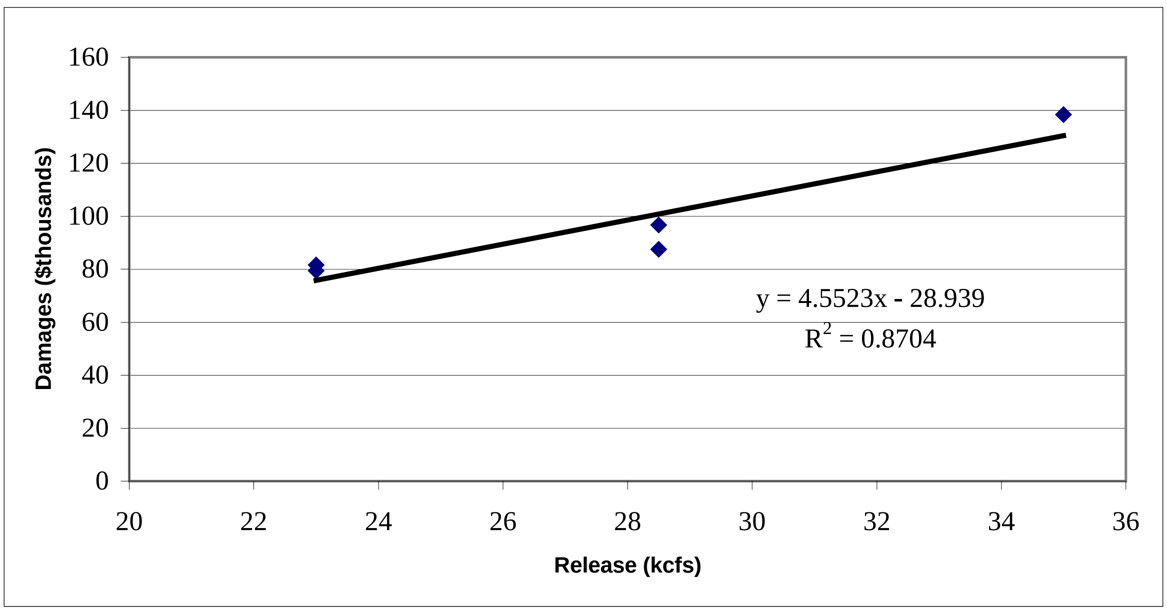

Figure 7.8-11. Summer interior drainage damages at site L575 versus summer average Gavins Point Dam release.

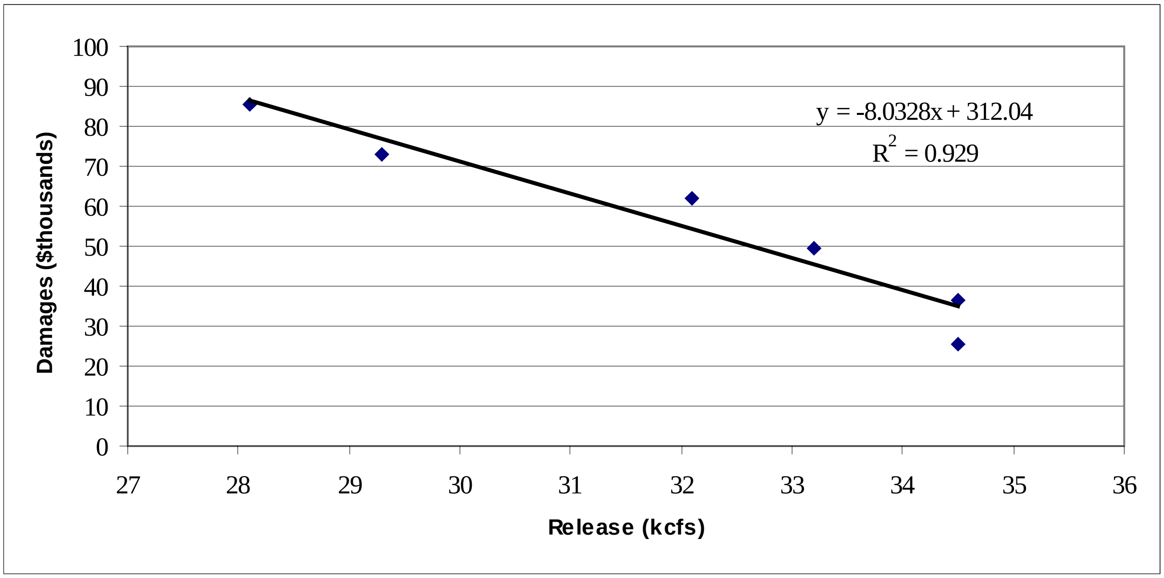

Figure 7.8-12. Average annual interior drainage damages for the post-September 6 timeframe at site L575 versus average May through August release from Gavins Point Dam.

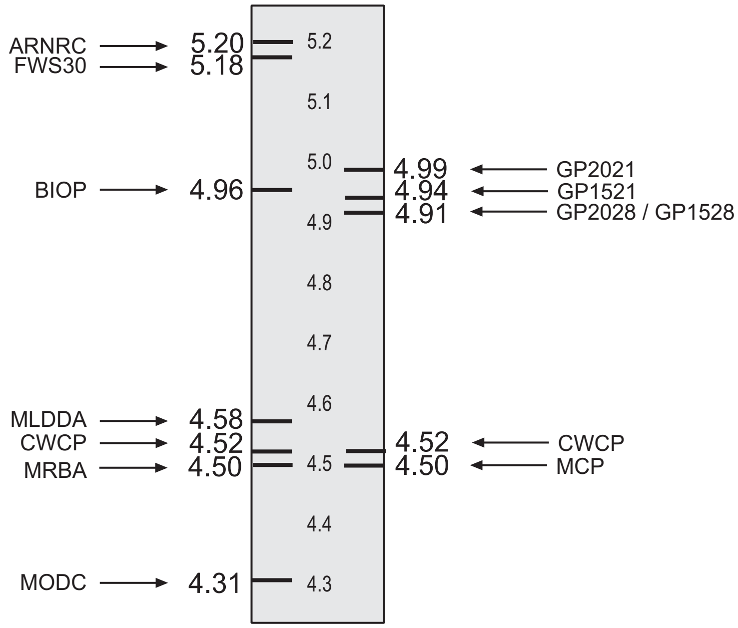

Figure 7.8-13. Average annual groundwater damages for submitted alternatives and the alternatives ($millions).

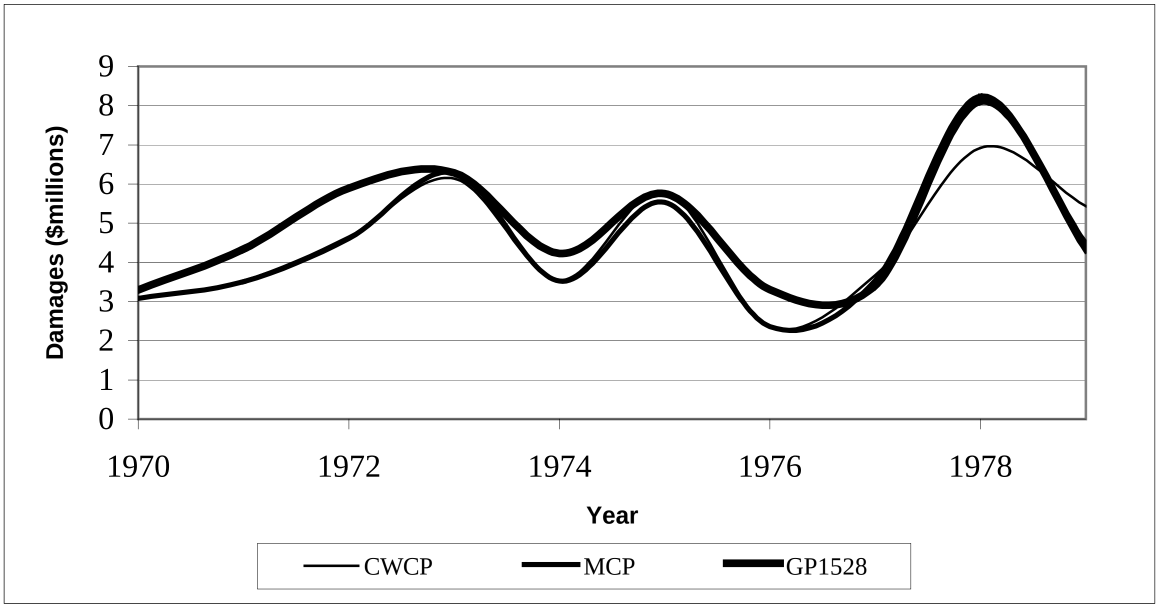

Figure 7.8-14. Annual groundwater damages for CWCP, MCP, and GP1528.

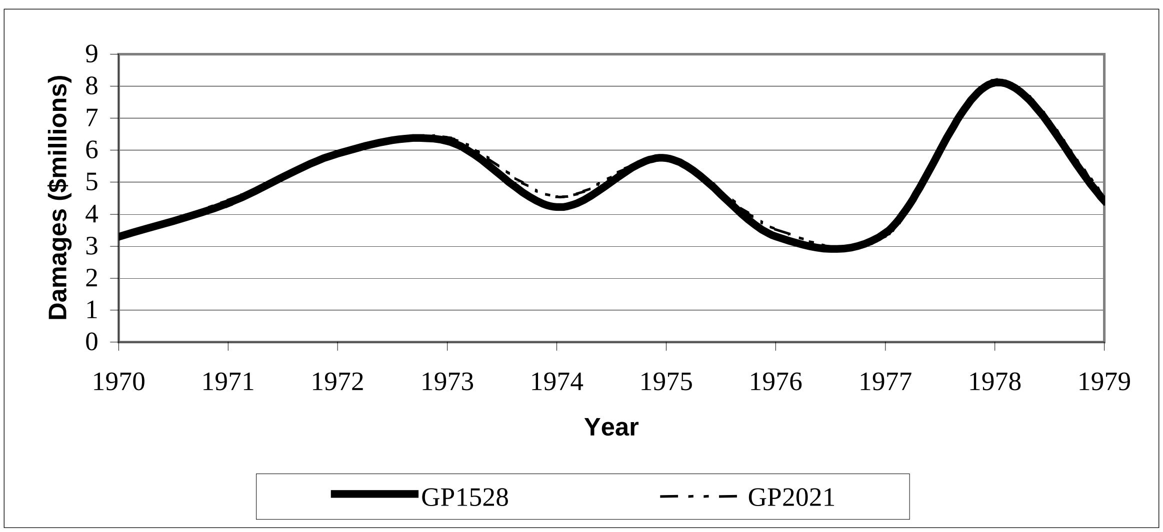

Figure 7.8-15. Annual groundwater damages for GP1528 and GP2021.

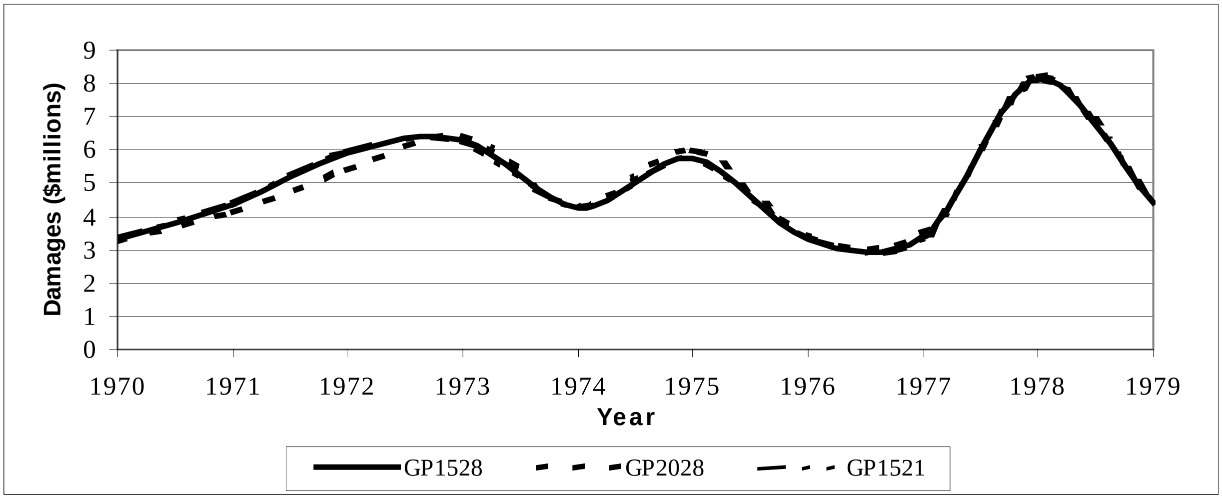

Figure 7.8-16. Annual groundwater damages for GP1528, GP2028, and GP1521.

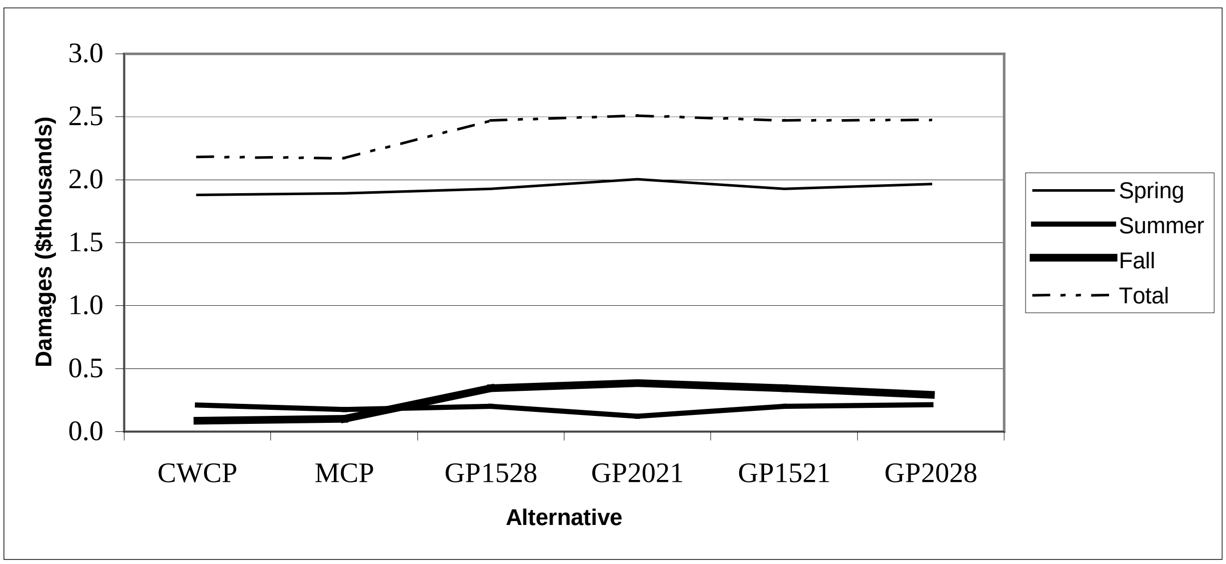

Figure 7.8-17. Average annual seasonal groundwater crop damages at site L575 by season and total.

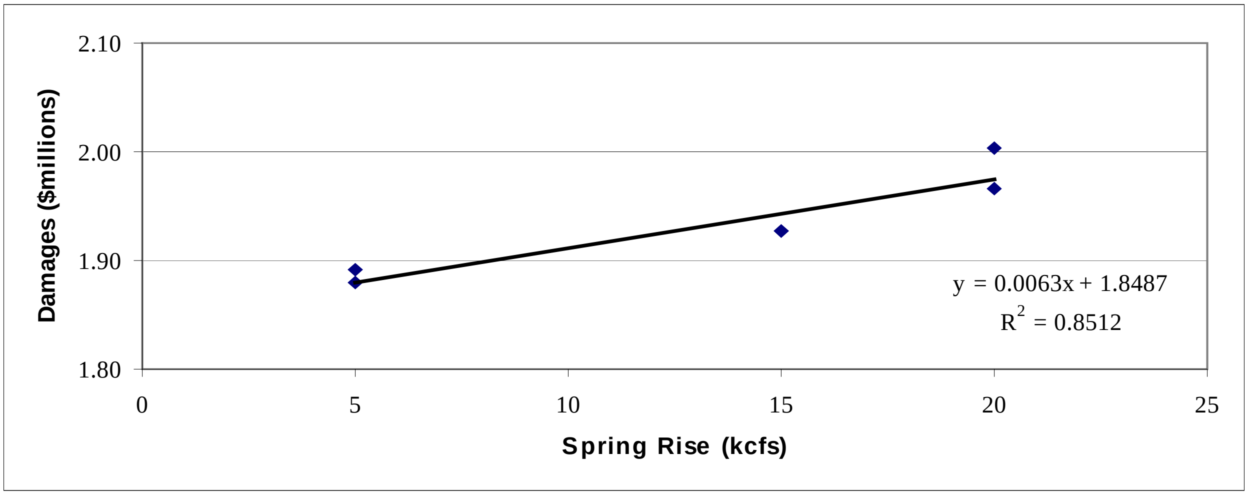

Figure 7.8-18. Average annual spring groundwater crop damages at site L575 versus amount of the Gavins Point Dam spring rise.

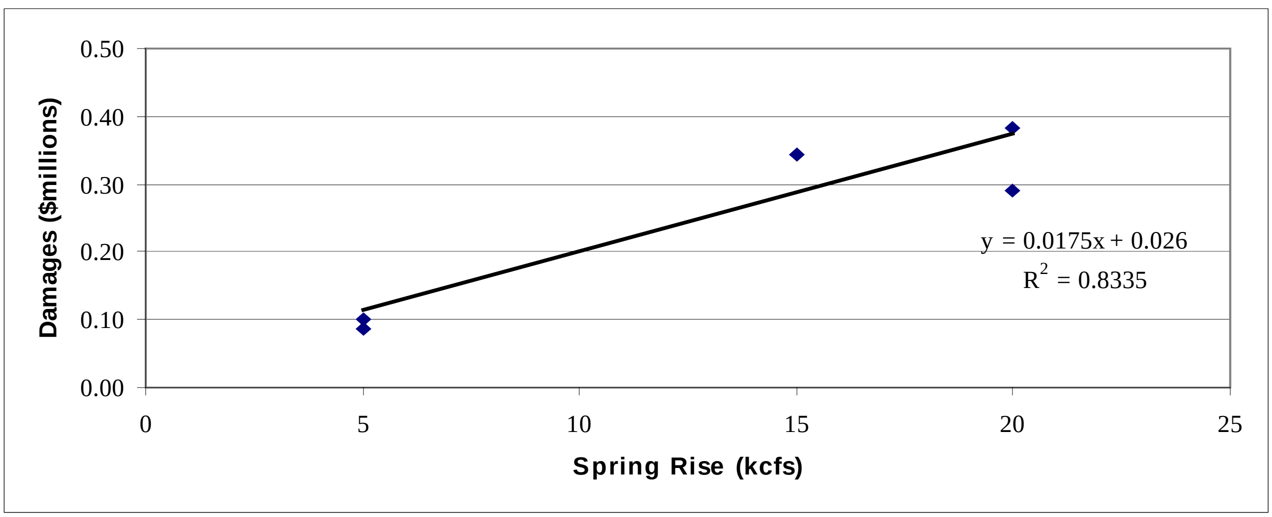

Figure 7.8-19. Average annual fall groundwater crop damages at site L575 versus amount of the Gavins Point Dam spring rise.

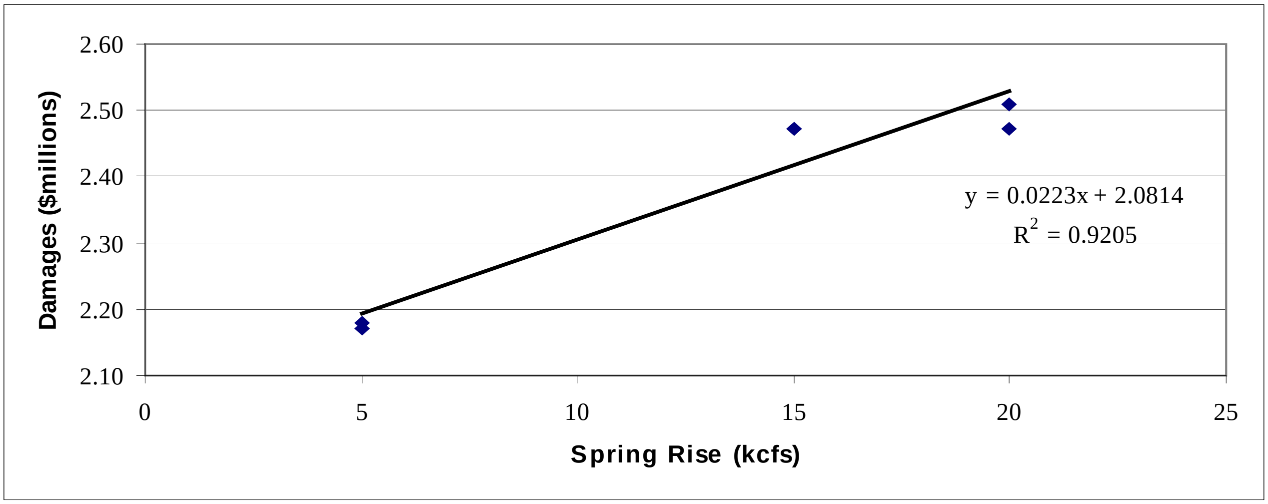

Figure 7.8-20. Average annual total groundwater crop damages at site L575 versus amount of the Gavins Point Dam spring rise.

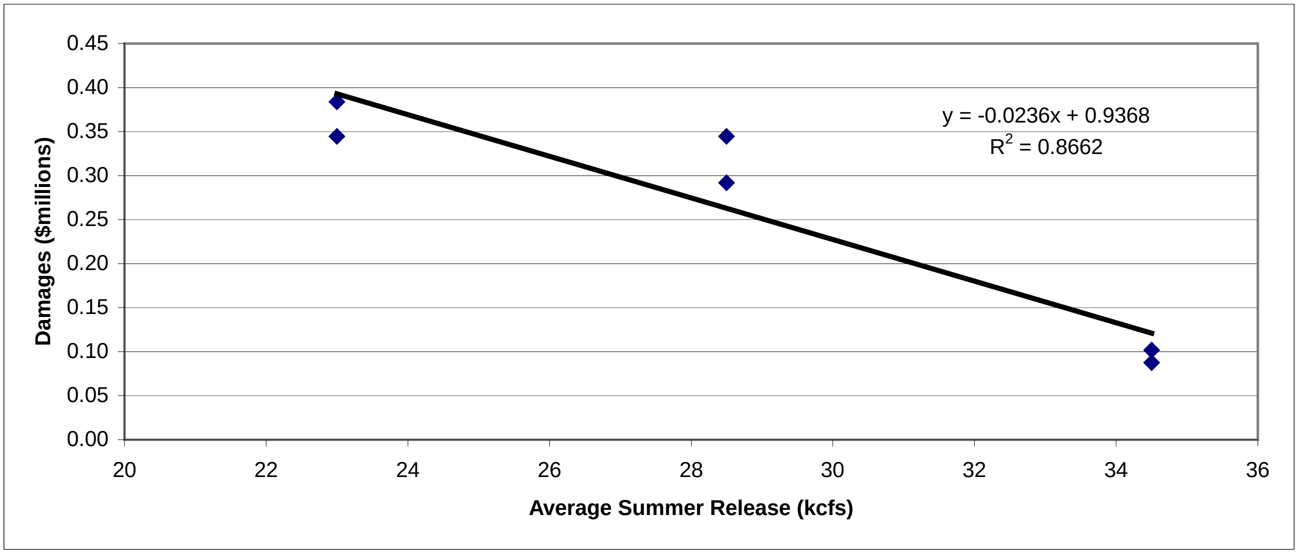

Figure 7.8-21. Average annual fall groundwater crop damages at site L575 versus amount of Gavins Point Dam average summer release.

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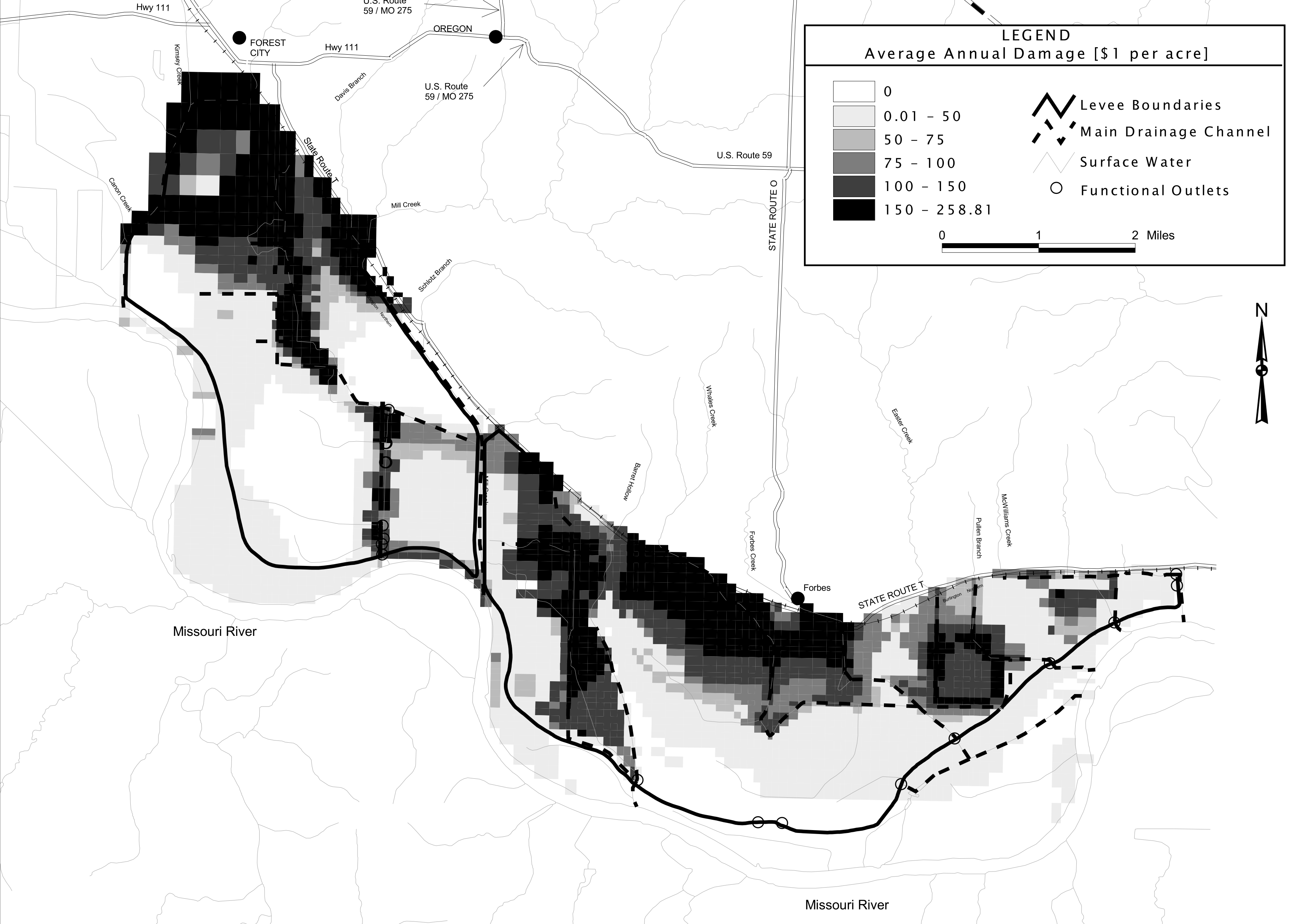

Figure 7.8-22. Average annual damages for CWCP at site L488/497.

p:/projects_2001/missouri/missouri_review_l488.apr - CWCP-BW_l May 22, 2001

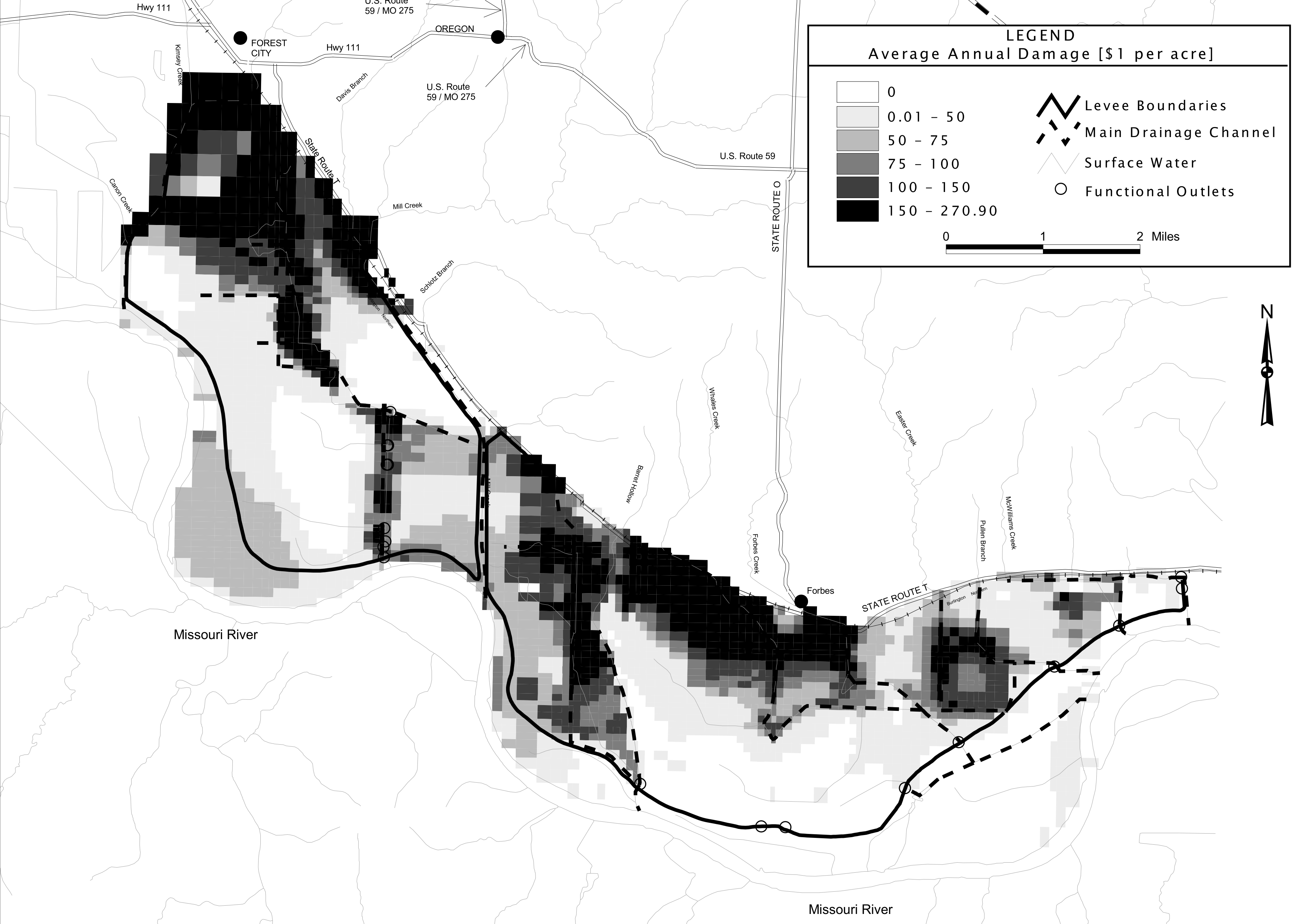

Figure 7.8-23. Average annual damages for MCP at site L488/497.

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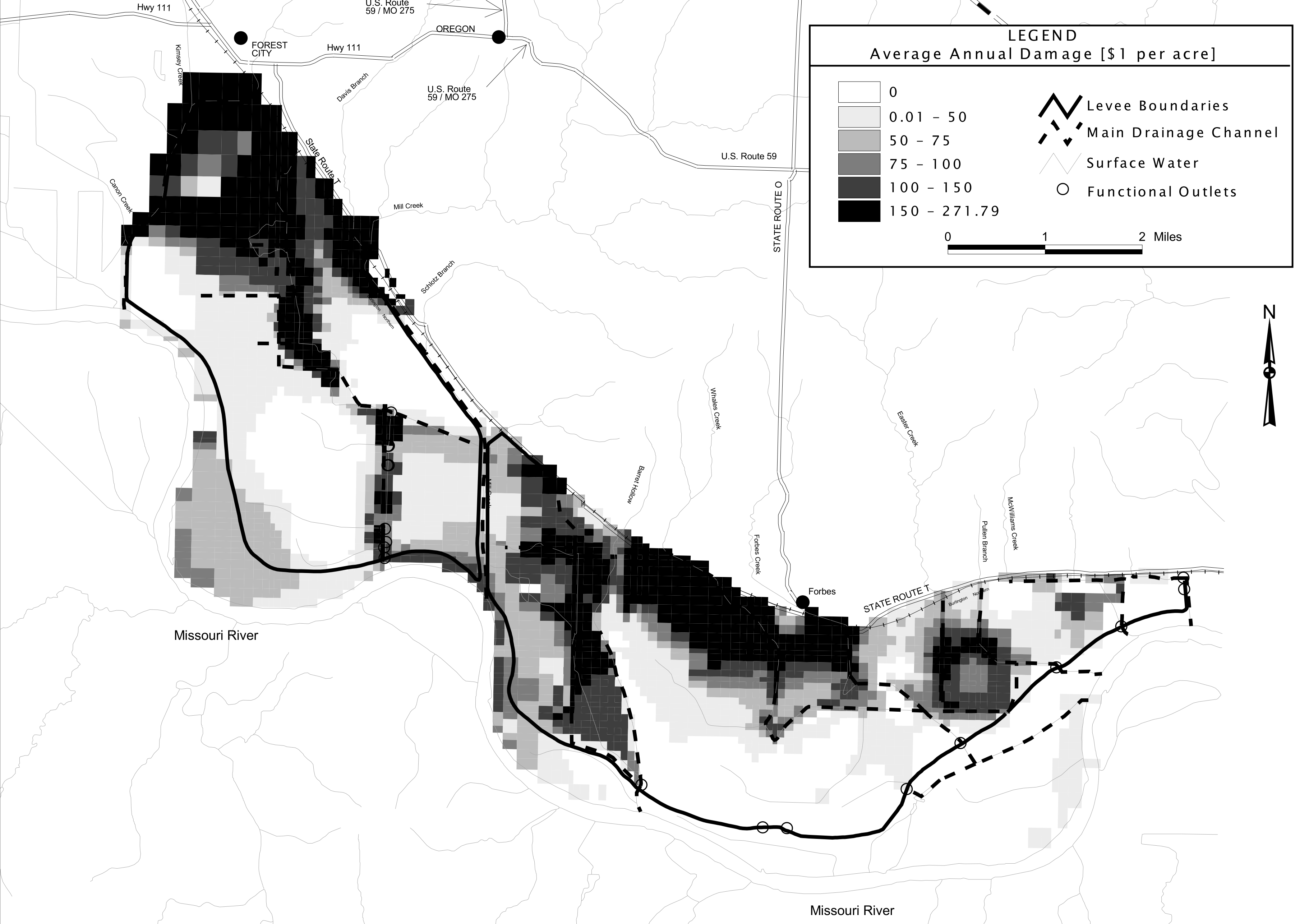

Figure 7.8-24. Average annual damages for GP1528 at site L488/497.

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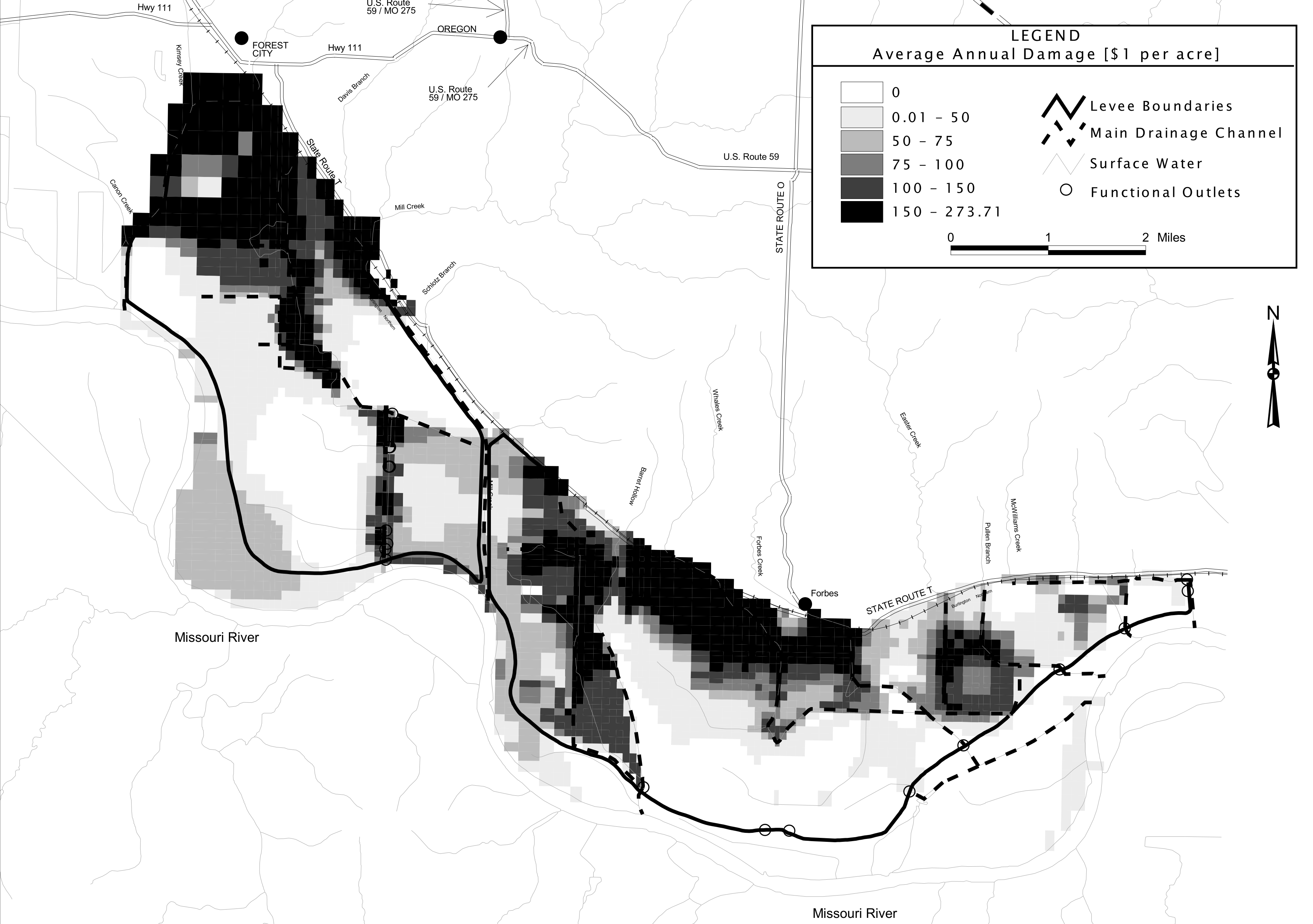

Figure 7.8-25. Average annual damages for GP2021 at site L488/497.

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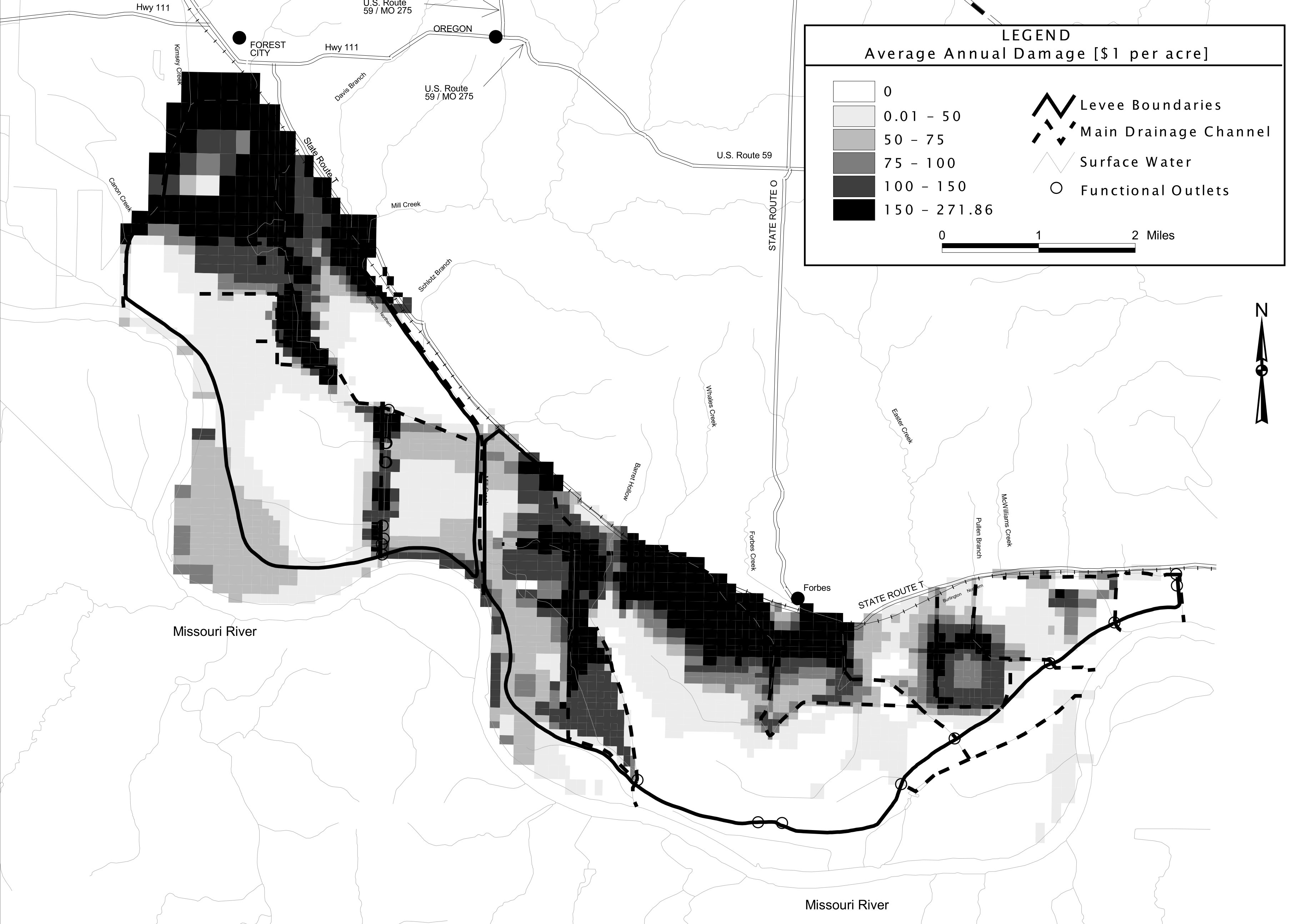

Figure 7.8-26. Average annual damages for GP1521 at site L488/497.

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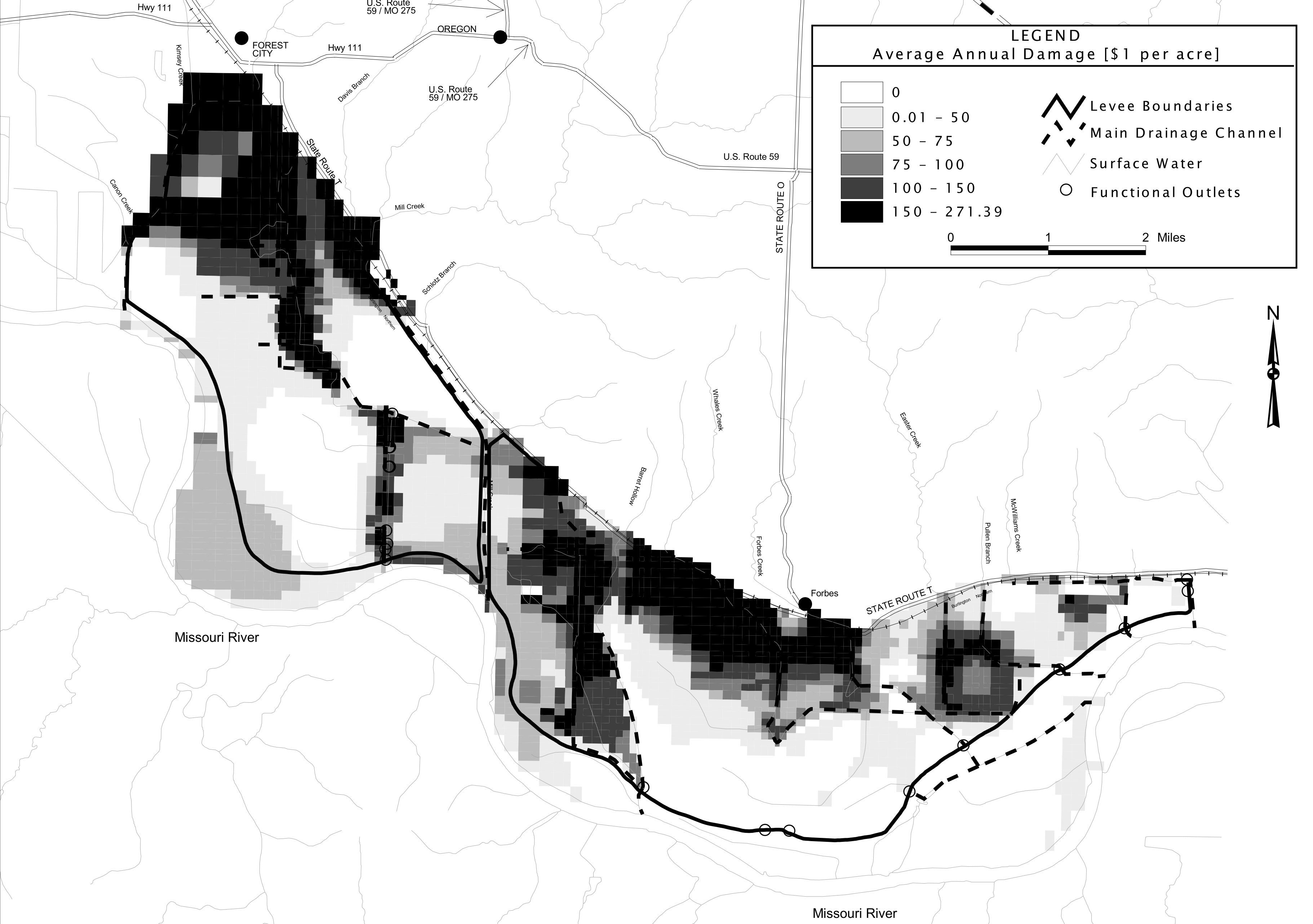

Figure 7.8-27. Average annual damages for GP2028 at site L488/497.

p:/projects_2001/missouri/missouri_review_l488.apr - MR2028-BW_l May 22, 2001

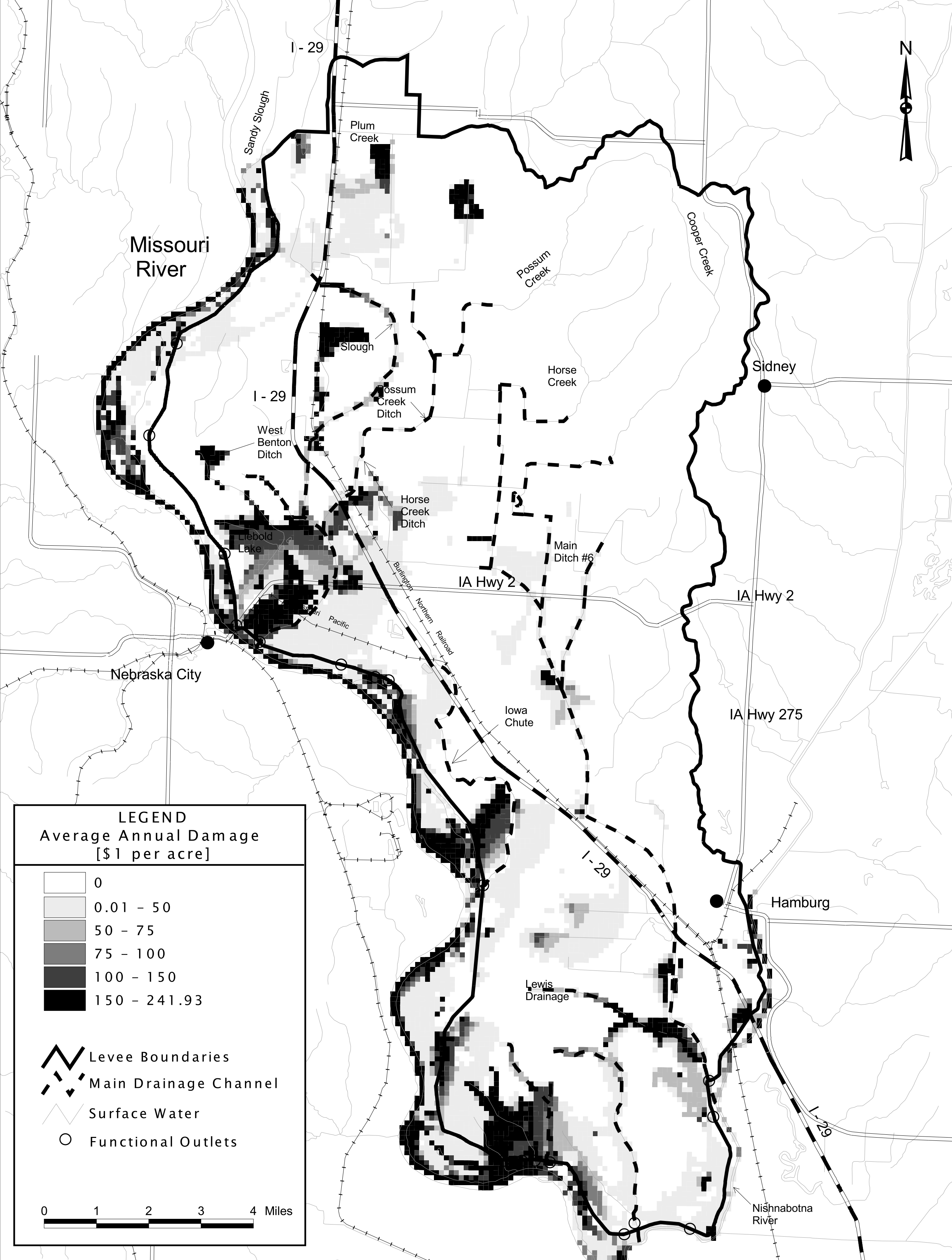

Figure 7.8-28. Average annual damages for CWCP at site L575.

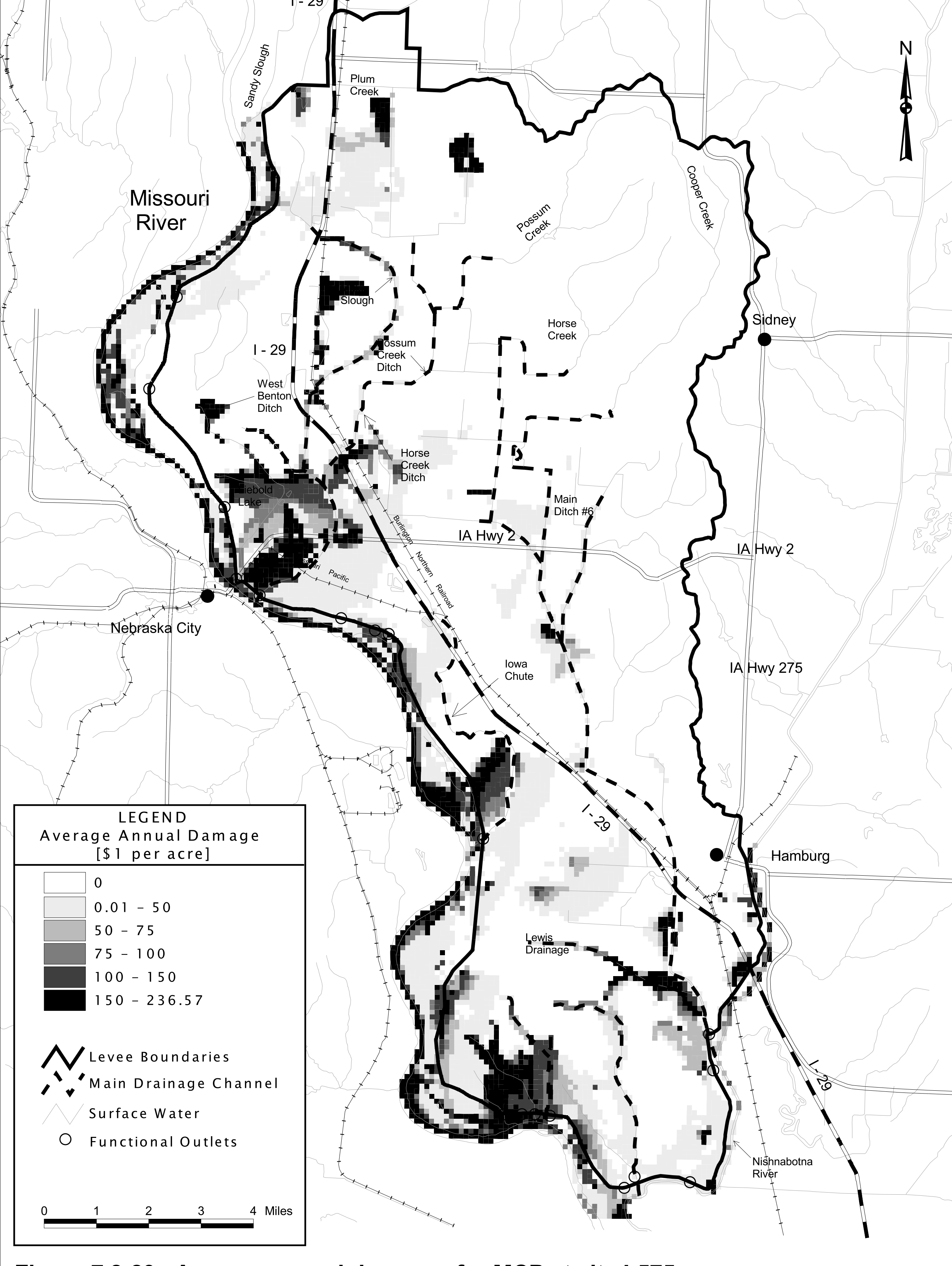

Figure 7.8-29. Average annual damages for MCP at site L575.

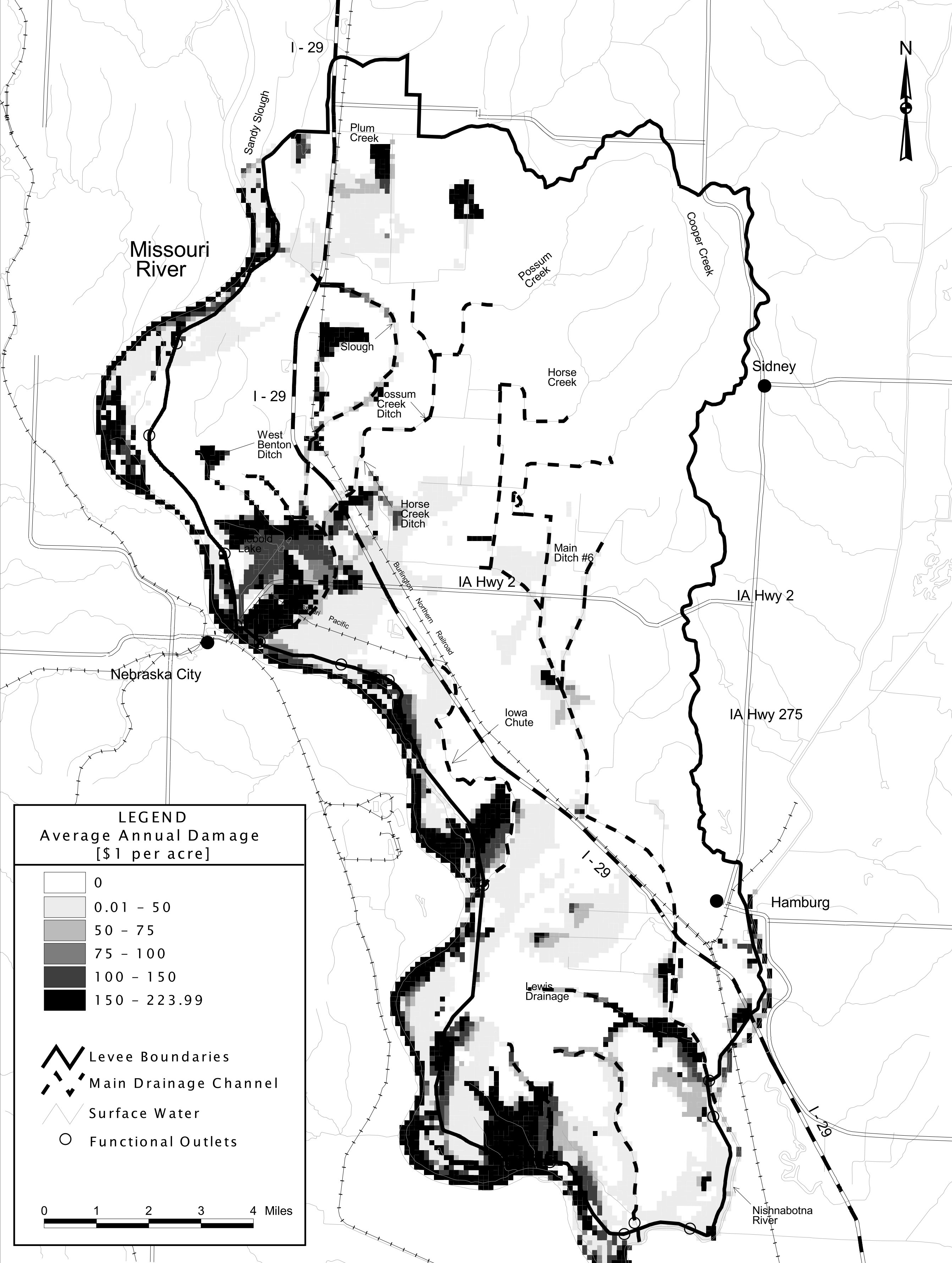

Figure 7.8-30. Average annual damages for GP1528 at site L575.

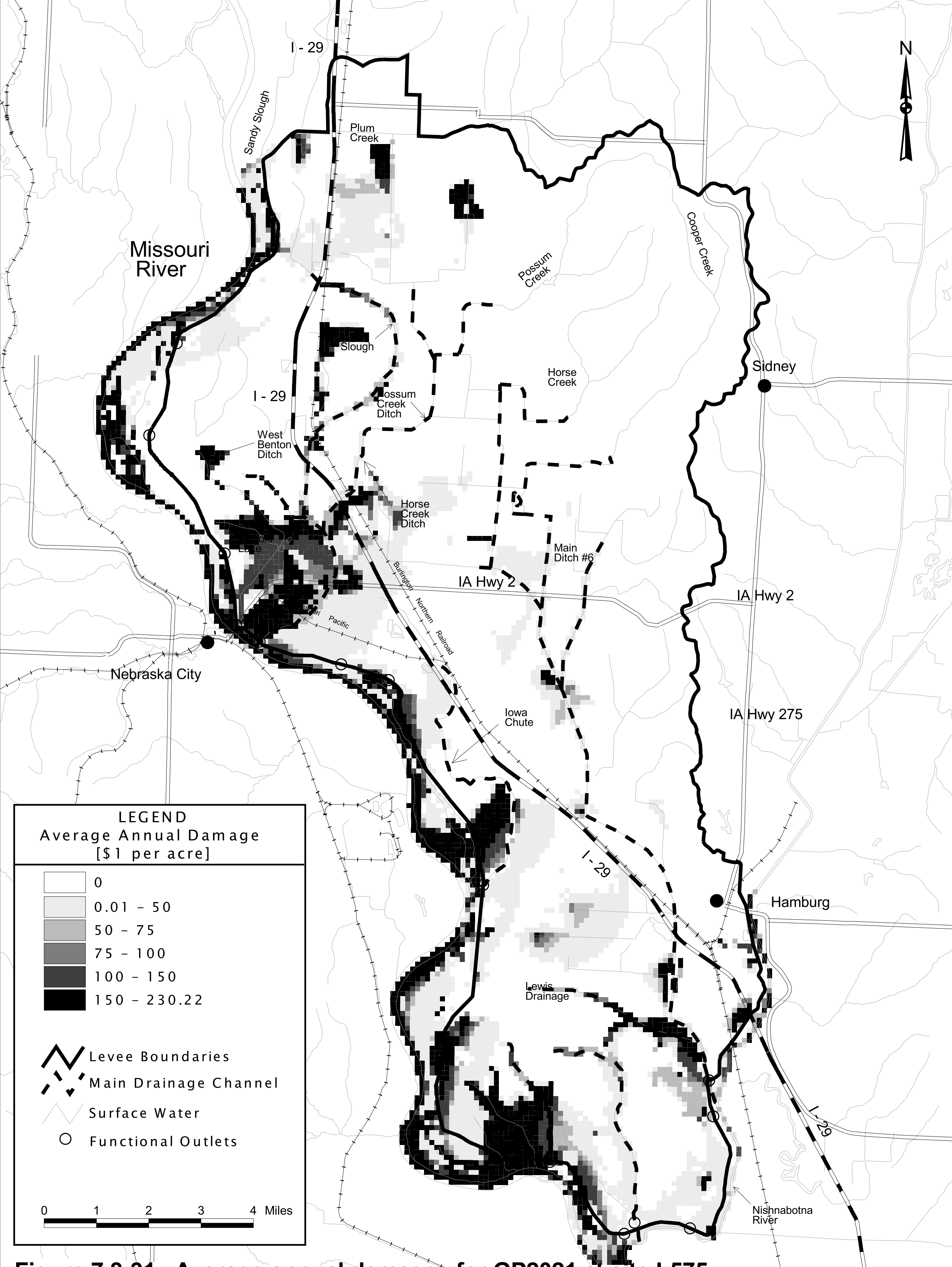

Figure 7.8-31. Average annual damages for GP2021 at site L575.

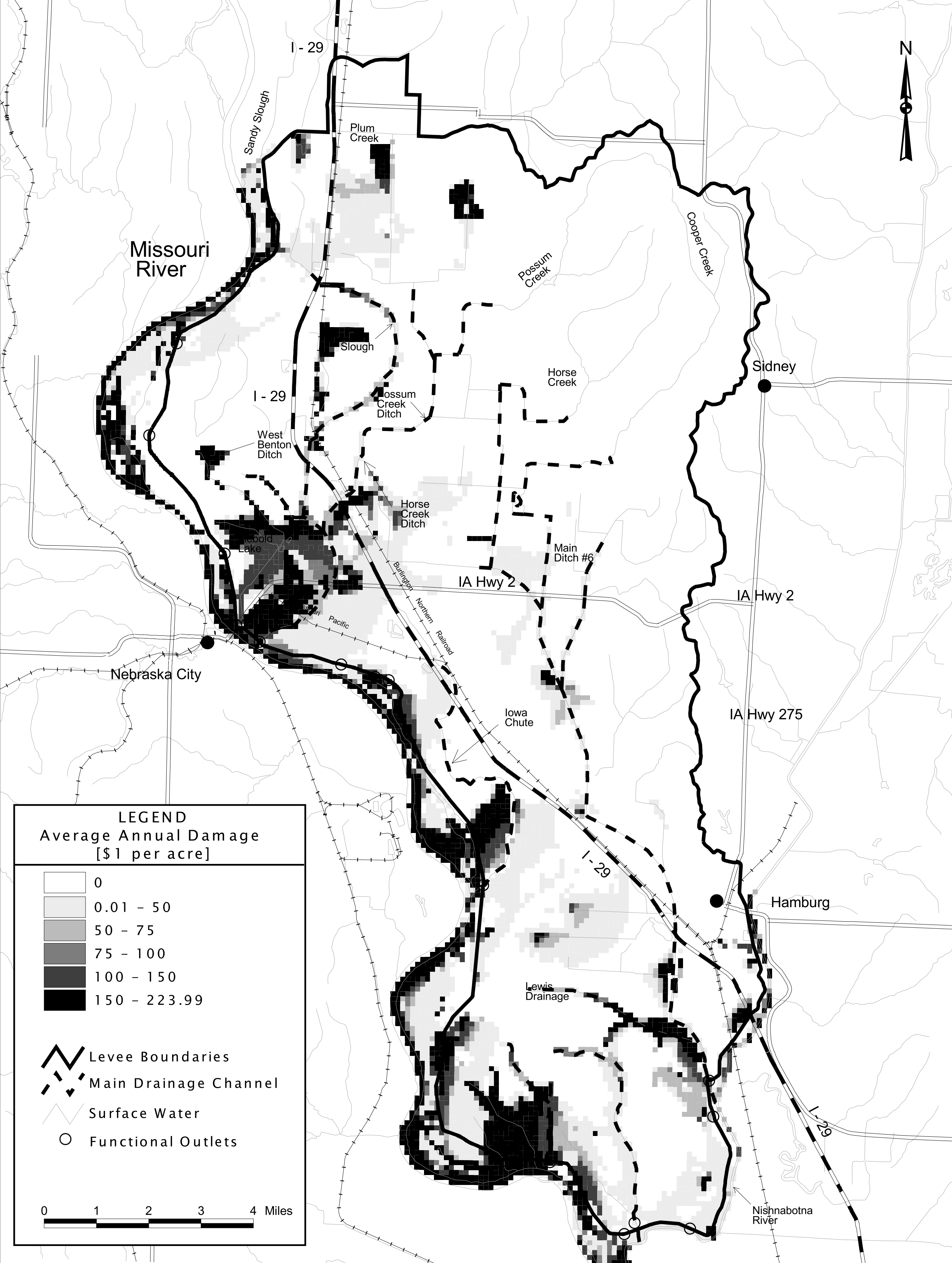

Figure 7.8-32. Average annual damages for GP1521 at site L575.

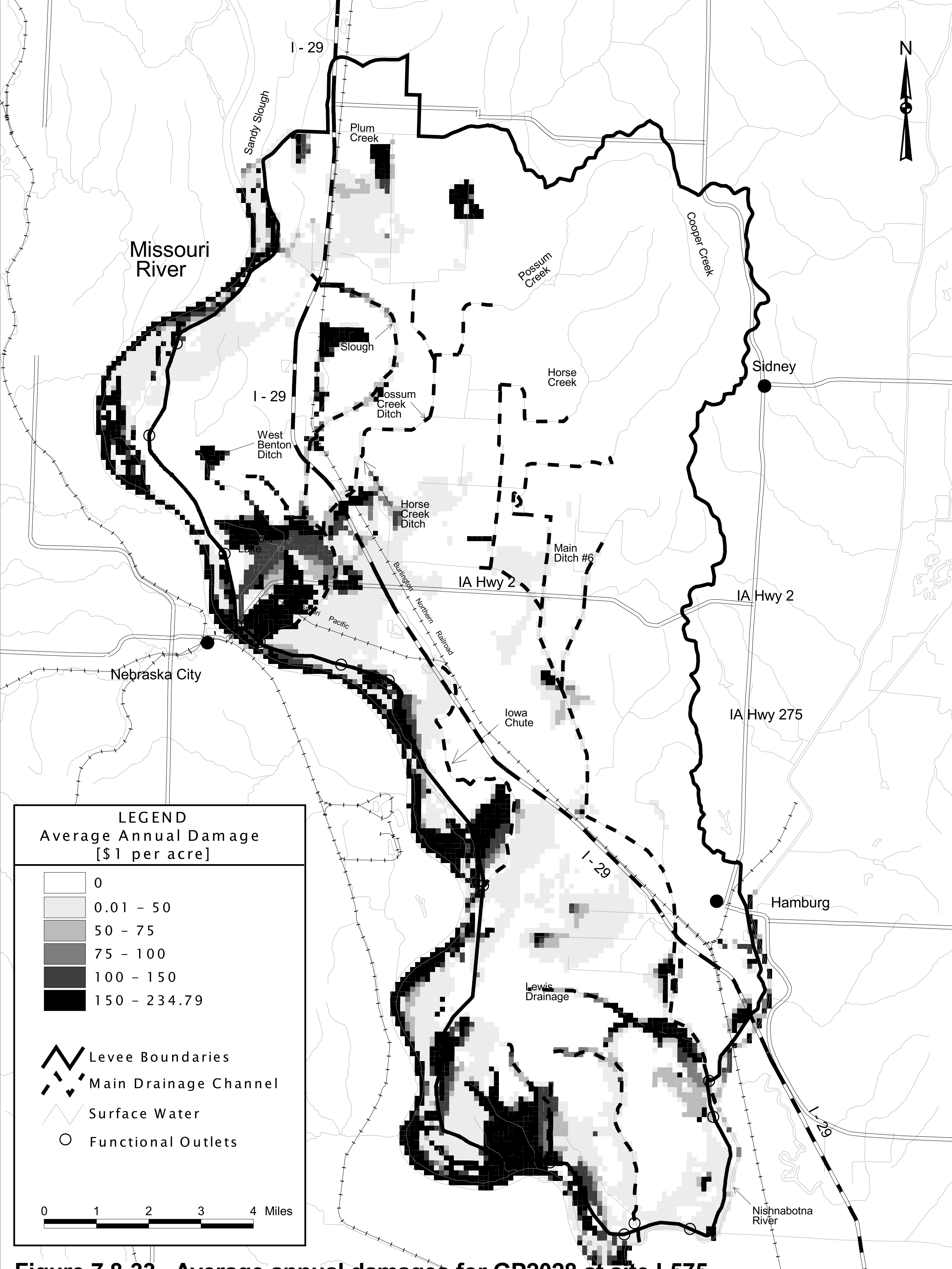

Figure 7.8-33. Average annual damages for GP2028 at site L575.

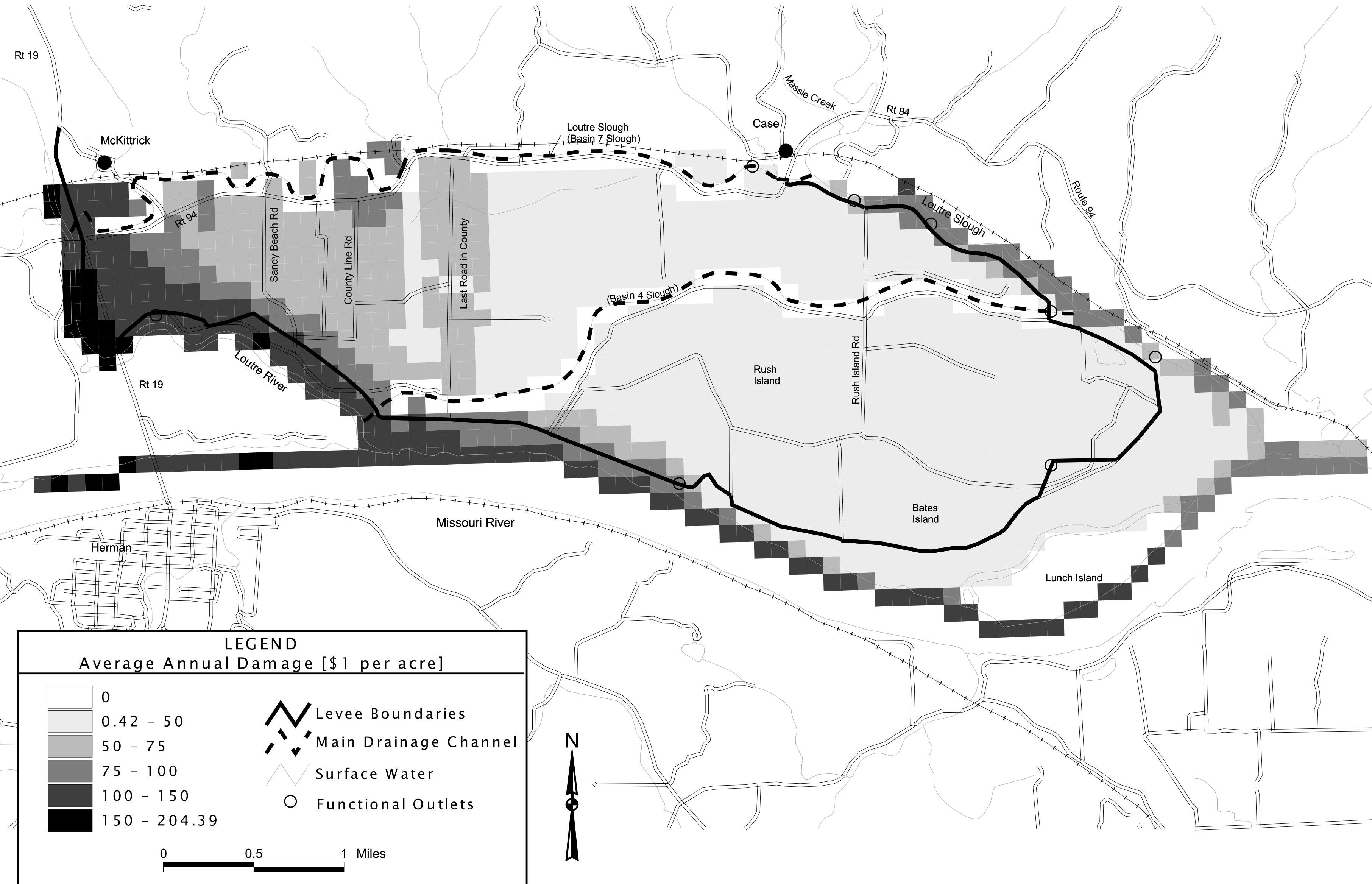

Figure 7.8-34. Average annual damages for CWCP at the Tri-County site.

p:/projects_2001/missouri/missouri_review_ld2.apr - CWCP00-BW_l May 22, 2001

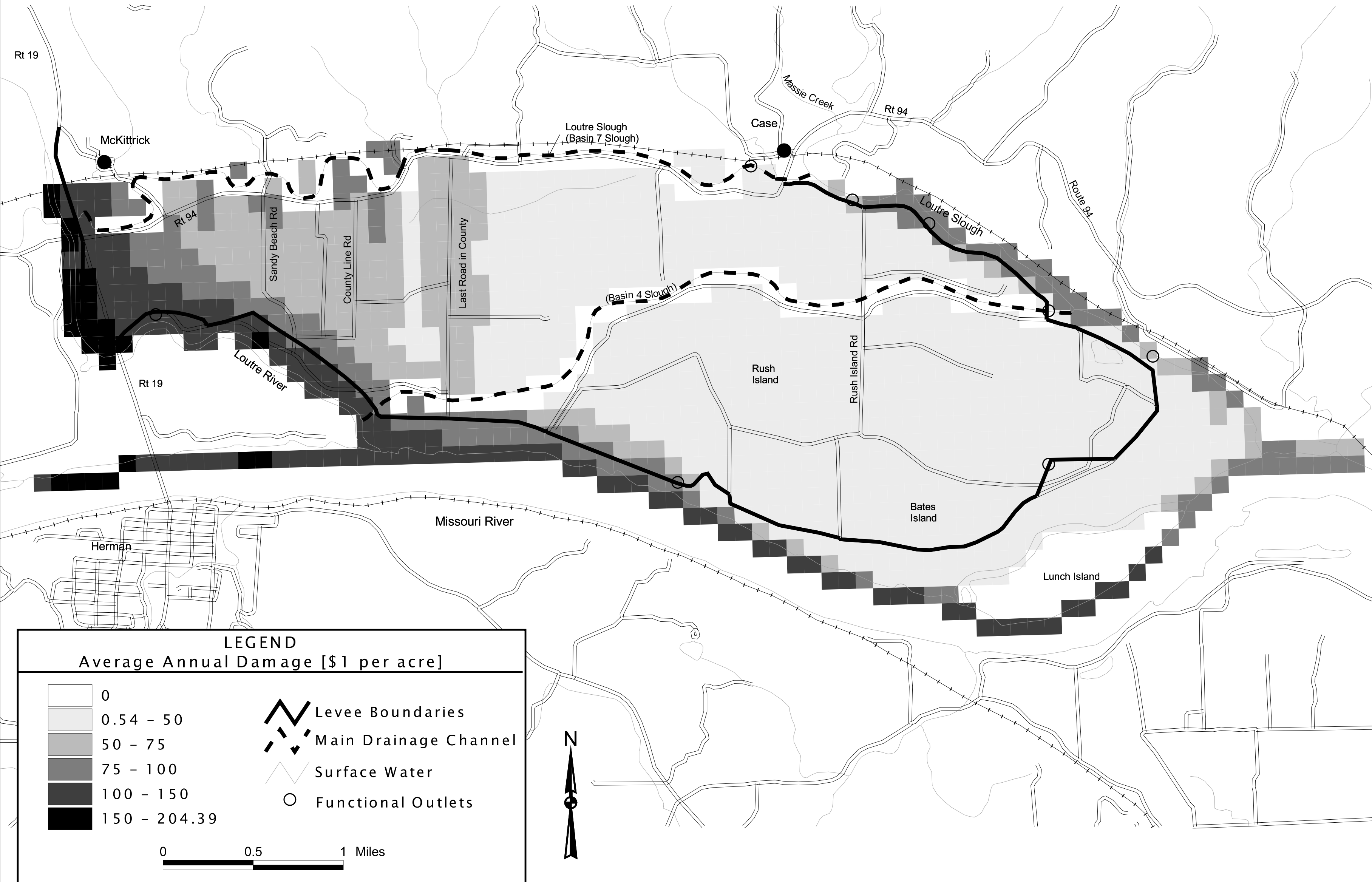

Figure 7.8-35. Average annual damages for MCP at the Tri-County site.

p:/projects_2001/missouri/missouri_review_ld2.apr - CORP00-BW_I May 22, 2001

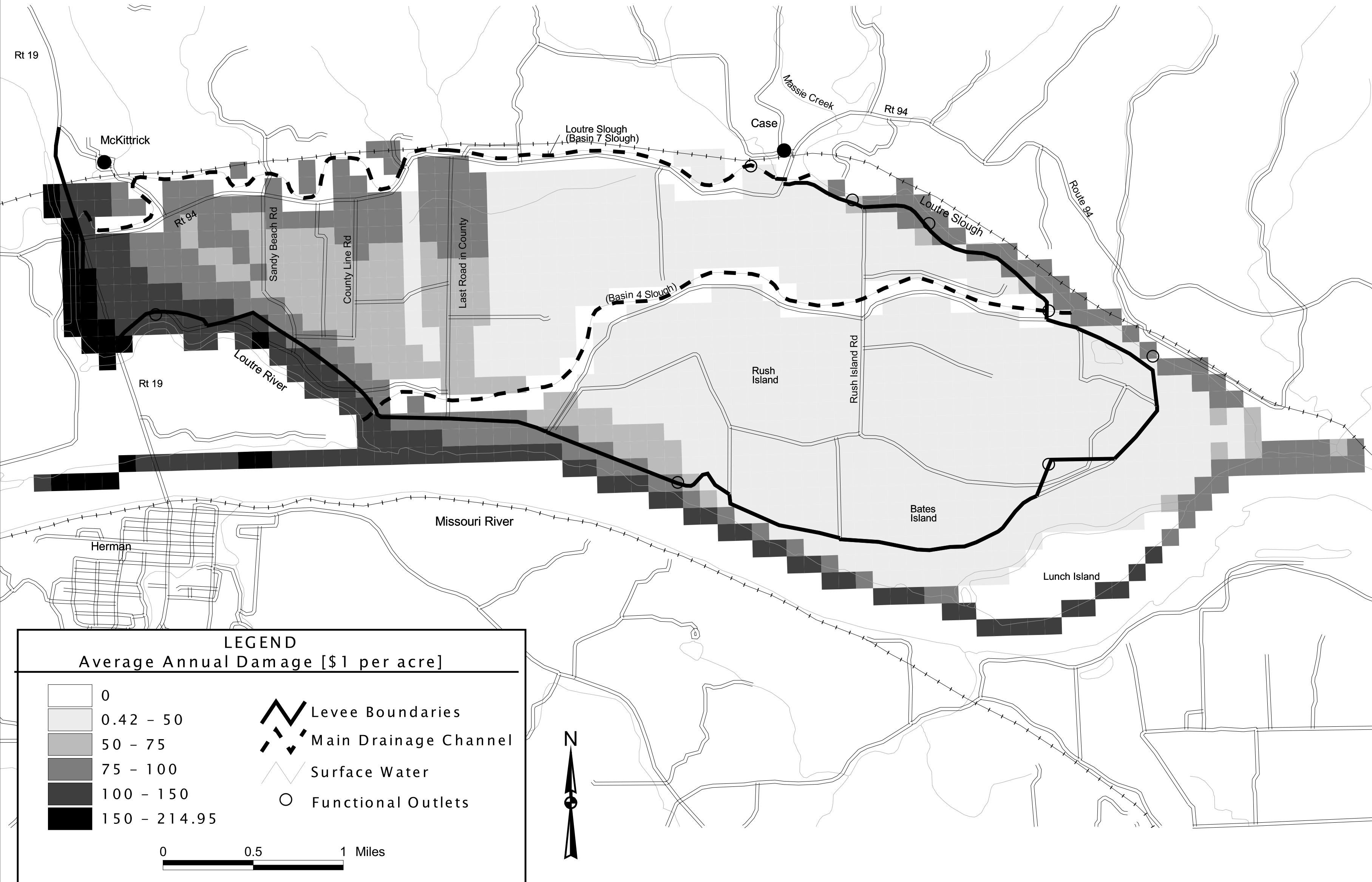

Figure 7.8-36. Average annual damages for GP1528 at the Tri-County site.

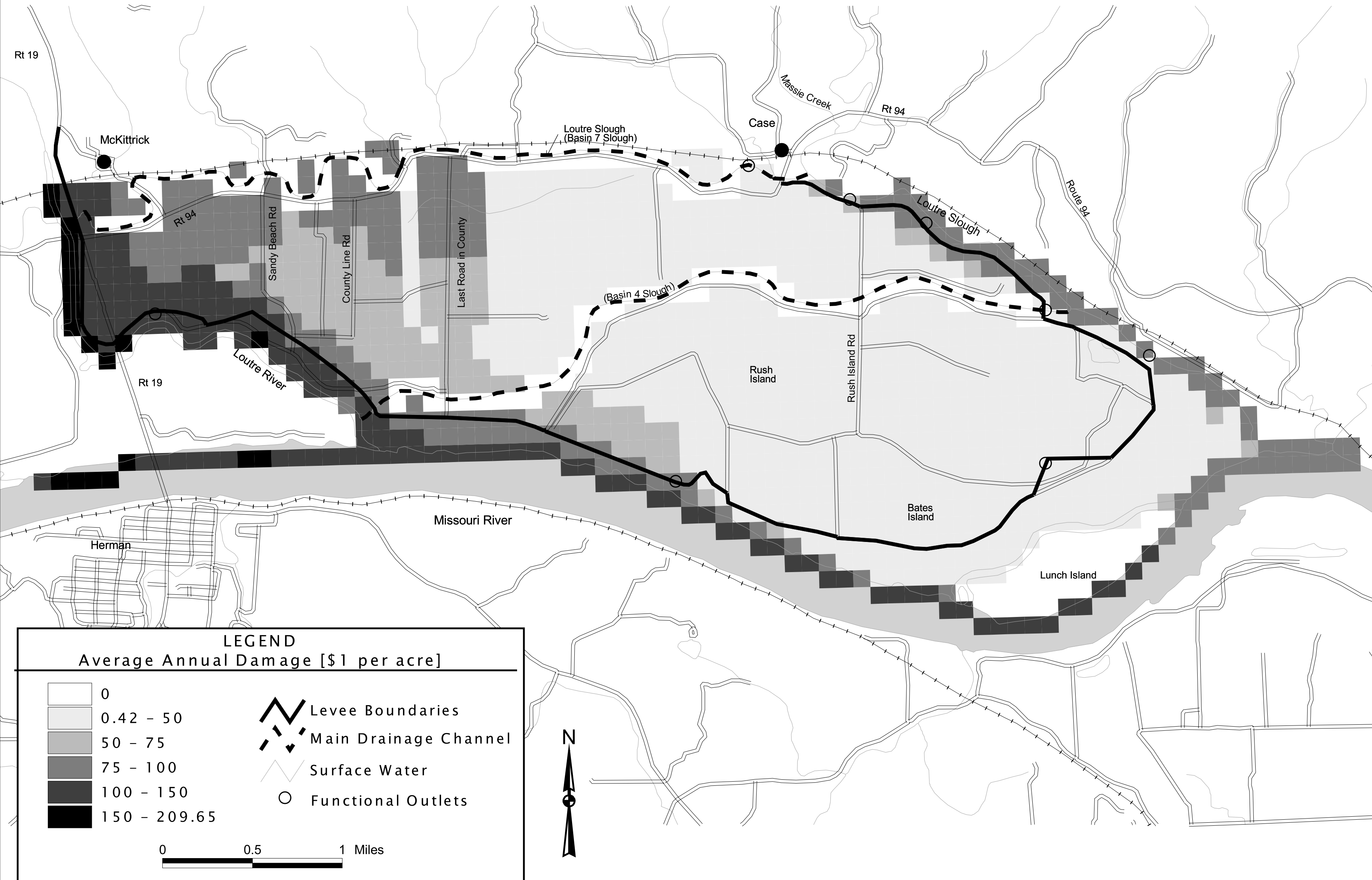

Figure 7.8-37. Average annual damages for GP2021 at the Tri-County site.

p:/projects_2001/missouri/missouri_review_ld2.apr - TR17ADA-BW_l May 22, 2001

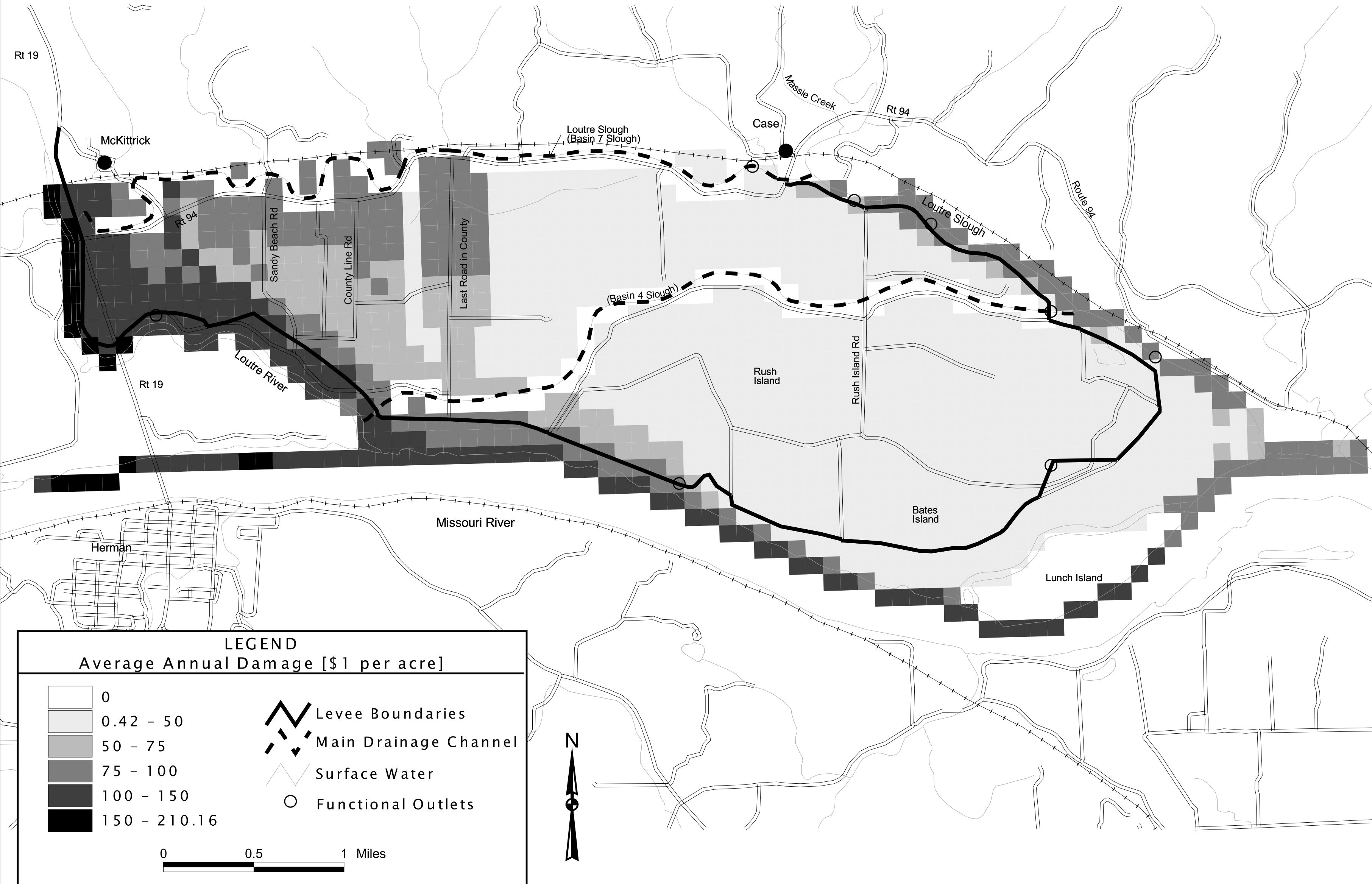

Figure 7.8-38. Average annual damages for GP1521 at the Tri-County site.

p:/projects_2001/missouri/missouri_review_ld2.apr - MR1521-BW_l May 22, 2001

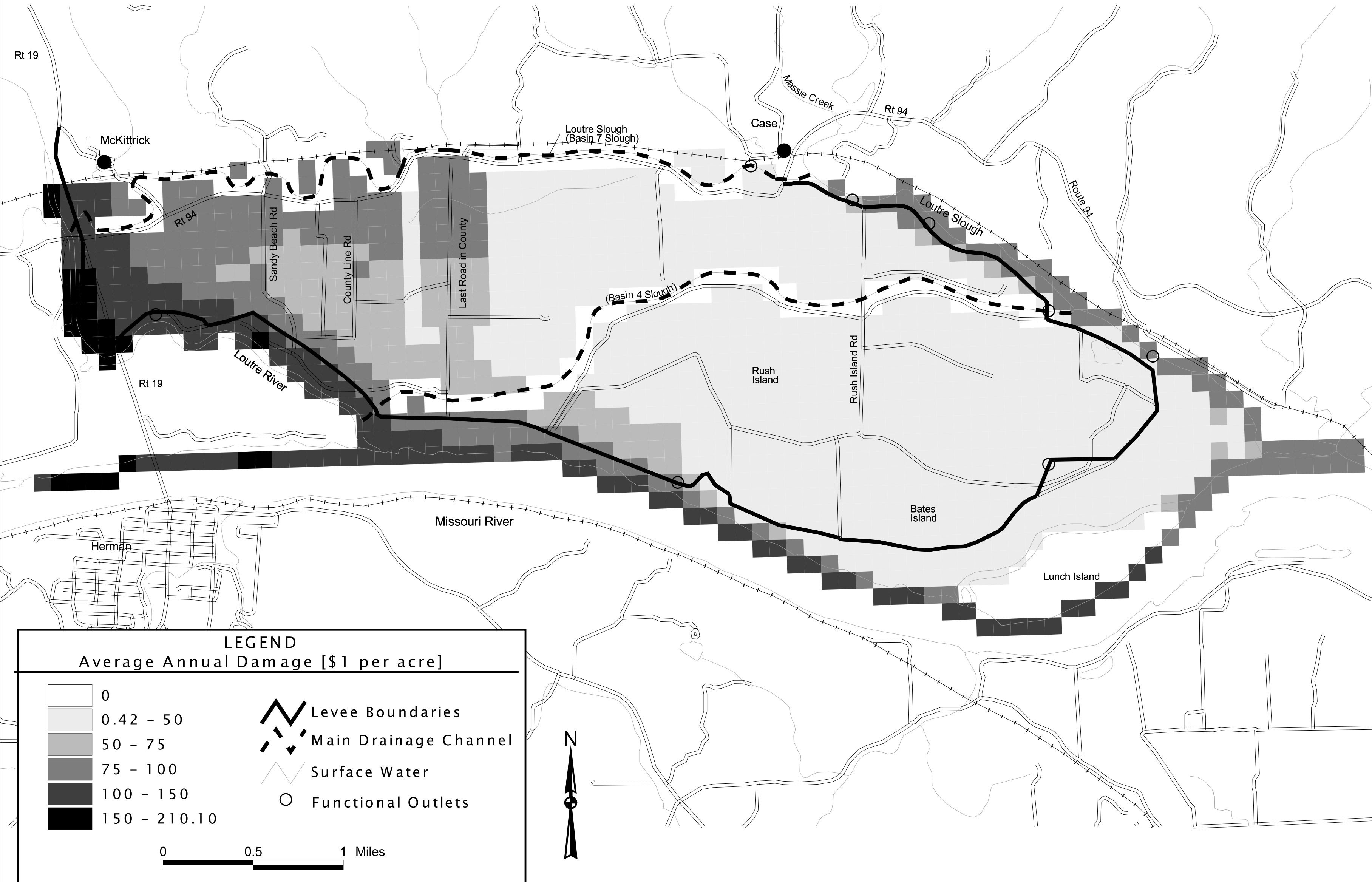

Figure 7.8-39. Average annual damages for GP2028 at the Tri-County site.

p:/projects_2001/missouri/missouri_review_ld2.apr - TR19ADA-BW_l May 22, 2001

**Figure 7.8-40.
Average annual damages for CWCP
at site RM691.**

Figure 7.8-41.
Average annual damages for MCP at site RM691.

Figure 7.8-42.
Average annual damages for GP1528 at site RM691.

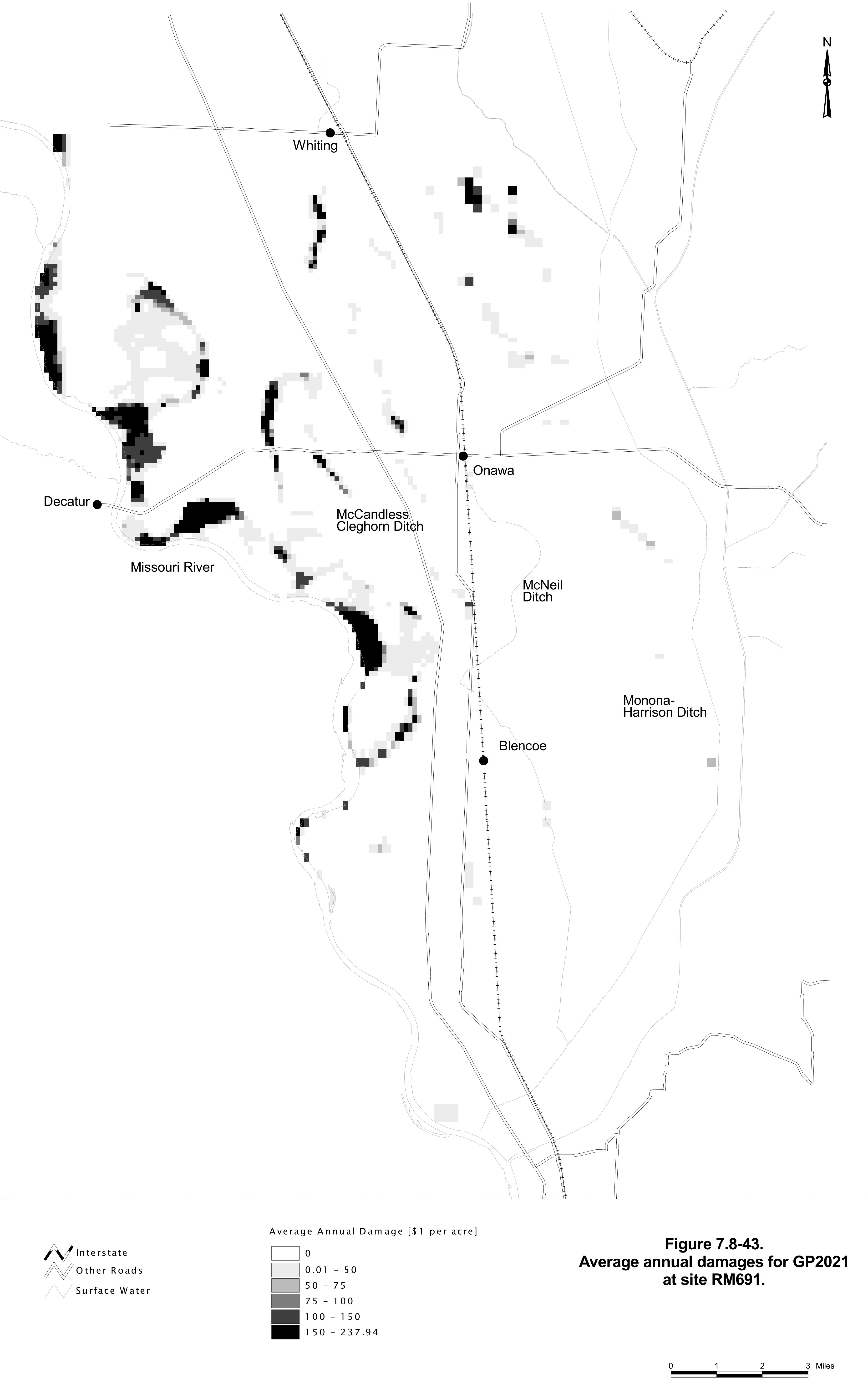

Figure 7.8-43.
Average annual damages for GP2021 at site RM691.

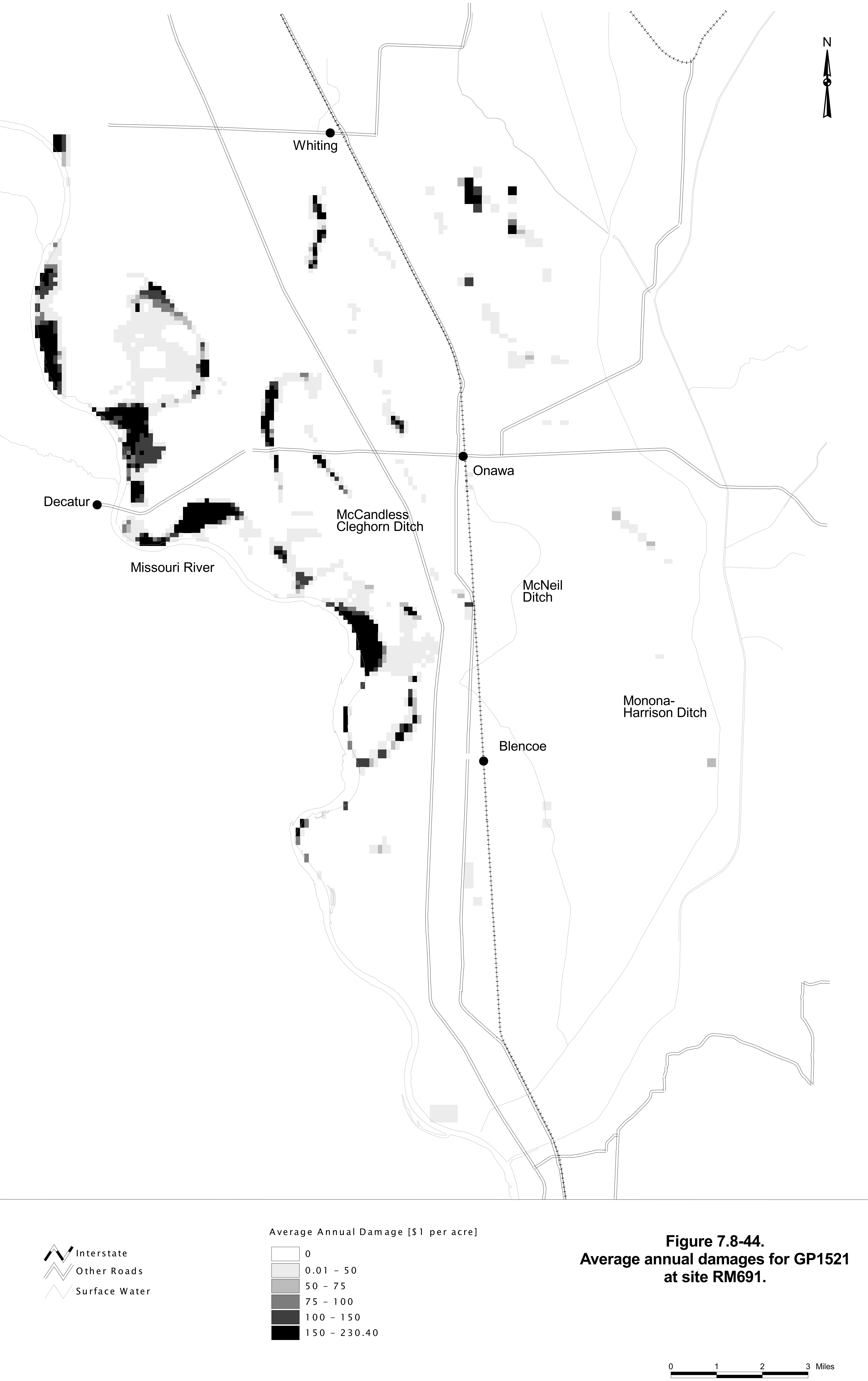

Figure 7.8-44.
Average annual damages for GP1521 at site RM691.

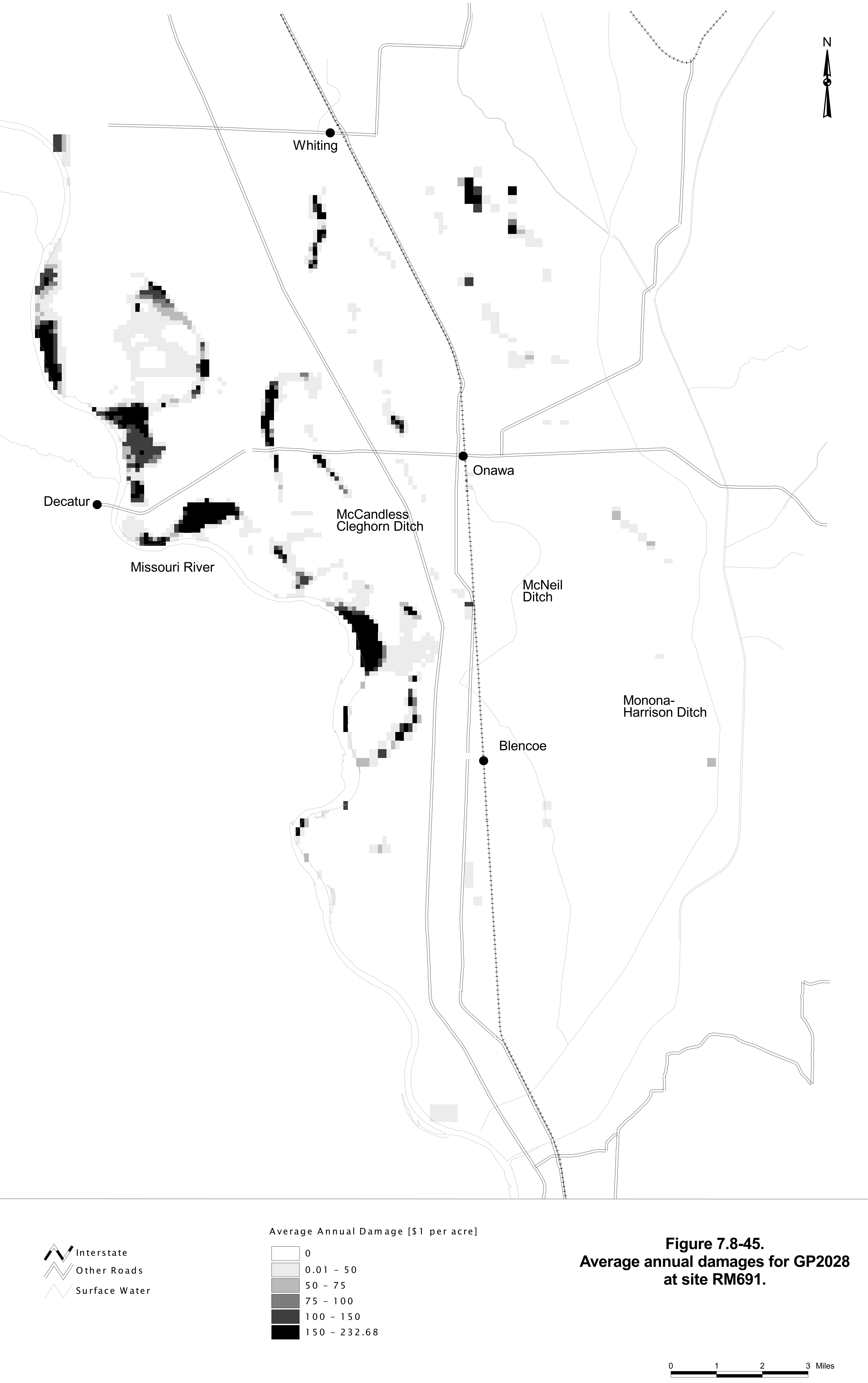

Figure 7.8-45.
Average annual damages for GP2028 at site RM691.

7.9 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. In this section, the estimated level of economic benefit, as it relates to water supply that could result from the alternative operating strategies, is compared to the estimated economic benefit if the CWCP were continued. Economic benefits are provided through the use of water for powerplants (other than hydroelectric), agriculture, drinking water, and other industrial uses of water. These benefits are described in greater detail in Economic Studies—Water Supply Economics (Corps, 1994g).

The major effects of the different operating strategies are the added costs that would be incurred to maintain water supplies during drought conditions. The main concern of most intake-facility owners is adequate access to water rather than an inadequate quantity of water. Drought conditions may require use of more expensive alternative water sources (e.g., wells) because intakes are above the water surface, may result in added mitigation costs to maintain water quality, or may cause temporary shutdowns (e.g., during toxic algae blooms) or increased maintenance and operation costs (e.g., increased pumping costs). To avoid "double counting" benefits that may be related to water quality or water supply, these effects have been combined.

Economic benefits in this section are measured in terms of millions of dollars generated at intake facilities. The economic benefits were estimated using the Daily Routing Model (DRM) and the Economic Impacts Model (EIM). The DRM is a hydrologic model (Corps, 1998b) that estimates water surface elevation and flow at 23 river reaches using the alternative operation strategies and the historic runoff levels between 1898 and 1997. The EIM (Corps, 1994r) uses the output from the DRM and economic value functions to estimate the economic benefit. The estimated economic benefits are used for comparative purposes only and may not represent actual economic returns under the different alternatives. The models were designed expressly for comparing the effects of changing the CWCP and not to provide economic forecasts.

Table 7.9-1 and Figure 7.9-1 present the average annual water supply benefits for the CWCP, the MCP, and the four GP options. Table 7.9-1 also includes data for individual lakes and river reaches. The CWCP provides $610.08 million in benefits along the entire Mainstem Reservoir System. This total benefit is distributed among the lake subtotal (3.0 percent), the Upper River (16.0 percent), and the Lower River (81.0 percent). Over the entire 100-year period of analysis from 1897 to 1997, total average annual benefits from water supply systems in the river system vary only slightly among the alternatives (less than 0.4 percent difference from highest to lowest).

Figure 7.9-1 shows that there are three separate groupings of total average water supply benefits of all of the alternatives analyzed in this chapter. The CWCP and the MCP are closely grouped between $610.08 and $610.44 million, a difference of $0.36 million. The two GP options with a flat summer low flow, the GP1528 option and the GP2028 option, are more closely grouped between $611.06 and 610.95 million, a difference of $0.11 million. The two GP options with a split summer release, the GP2021 and GP1521 options, are more closely aligned between $608.49 and $608.58 million, a difference of only $0.09 million. This figure also shows the values for the submitted alternatives discussed in Chapter 5 to provide perspective as to how the GP options perform relative to the Chapter 5 submitted alternatives. The GP1528 and GP2021 options provide water supply benefits that are closest to the MLDDA, BIOP, and FWS30 alternatives. Also, the MCP and MRBA alternative have similar benefits. These corresponding alternatives have the same summer flows.

The MCP is similar to the CWCP except that increased water conservation (retention of water in the lakes) will occur under drought conditions. Similar to the other alternatives, the average annual water supply benefits are not substantially different than the CWCP. Average annual water supply benefits under the MCP ($610.44 million) are about $0.36 million (0.1 percent) more than under the CWCP for the entire Mainstem Reservoir System.

Table 7.9-1. Average annual water supply benefits ($millions).

Lake/Reach	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Fort Peck Lake	0.57	0.58	0.57	0.57	0.57	0.56
Lake Sakakawea	6.28	6.61	6.73	6.54	6.54	6.73
Lake Oahe	5.97	5.96	6.06	6.05	6.07	6.03
Lake Sharpe	4.74	4.74	4.74	4.74	4.74	4.74
Lake Francis Case	2.34	2.32	2.34	2.38	2.38	2.34
Lewis and Clark Lake	0.65	0.65	0.66	0.66	0.66	0.66
Lake Subtotal	**20.55**	**20.87**	**21.09**	**20.93**	**20.95**	**21.06**
Fort Peck	1.39	1.39	1.46	1.47	1.47	1.46
Garrison	92.37	94.25	94.25	94.25	94.25	94.25
Fort Randall	0.01	0.01	0.01	0.01	0.01	0.01
Upper River Subtotal	**93.77**	**95.66**	**95.72**	**95.73**	**95.74**	**95.72**
Gavins Point	1.53	1.53	1.53	1.53	1.53	1.53
Sioux City	32.15	32.14	32.12	32.14	32.14	32.12
Omaha	198.76	197.68	197.81	196.21	196.25	197.74
Nebraska City	145.44	144.89	145.12	144.28	144.29	145.11
St. Joseph	24.26	24.25	24.24	24.24	24.24	24.24
Kansas City	49.18	49.03	49.04	49.04	49.05	49.03
Boonville	0.64	0.64	0.64	0.64	0.64	0.64
Hermann	43.81	43.76	43.76	43.76	43.76	43.76
Lower River Subtotal	**495.77**	**493.91**	**494.26**	**491.83**	**491.89**	**494.17**
Total	**610.08**	**610.44**	**611.06**	**608.49**	**608.58**	**610.95**

Under the MCP, the average annual water supply benefits increase in the lake subtotal by $0.32 million (1.6 percent) and in the Upper River by $1.89 million (2.0 percent). Compared to the CWCP, the MCP decreases water supply benefits in the Lower River by $1.86 million, or 0.4 percent.

The GP options differ from the MCP by adding a spring rise and summer low-flow measures at Gavins Point Dam. The GP1528 option, the GP option with the lowest spring rise and the highest summer flows, includes a 15-kcfs spring rise and a 28.5-kcfs flat release during summer. These measures result in a $0.62 million (0.1 percent) increase in total average annual water supply benefits over the MCP. Compared to the MCP, the GP1528 option increases water supply benefits in the lake subtotal by $0.22 million (1.1 percent), the Upper River by $0.06 million (0.1 percent), and the Lower River by $0.35 million (0.1 percent).

The GP2021 option includes a 20-kcfs rise during the spring that is similar to the GP2028 option. During the summer period, the GP2021 option includes a provision for low summer flows (the 25/21 flow option) similar to the GP1521 option. From July 15 to August 15, 21 kcfs will be released from Gavins Point Dam, and during the periods June 21 to July 15 and August 15 to August 31, flow releases will be set to 25 kcfs. Under the GP2021 option, average annual benefits are $608.49 million, $2.57 million (0.4 percent) less than under the GP1528 option. Compared to the GP1528 option, the GP2021 option decreases water supply benefits in the lake subtotal by $0.16 million (0.8 percent) and in the Lower River by $2.43 million (0.5 percent), but increases the water supply benefit in the Upper River by $0.01 million, or less than 0.1 percent.

The GP1521 option has a 15-kcfs rise during the spring, and includes a provision for low summer flows of 21 kcfs from July 15 to August 15. During the periods June 21 to July 15 and August 15 to August 31, Gavins Point Dam releases will be set to 25 kcfs. Total average annual water supply benefits under the GP1521 option ($608.58 million) are about $2.48 million (0.4 percent) less than the GP1528 option. As with the GP2021 option, the variable summer low-flow measures under the GP1521 option result in a water supply benefit decrease in the lake subtotal and Lower River and an increase in the Upper River. Compared to the GP1528 option, the GP1521 option provides $0.14 million (0.7 percent) less benefit in the lake subtotal and $2.37 million (0.5 percent) less benefit in the Lower River, but increases the water supply benefit by $0.02 million, or less than 0.1 percent in the Upper River.

The GP2028 option includes a 20-kcfs rise during the spring and a flat 28.5-kcfs summer release. Under the GP2028 option, total average annual water supply benefits will be $610.95 million, about $0.11 million (less than 0.1 percent) less than the GP1528 option. Compared to the GP1528 option, the GP2028 option decreases water supply benefits in the lake subtotal by $0.03 million (0.1 percent) and the Lower River by $0.09 million, or less than 0.1 percent. The GP2028 option does not change the water supply benefit from the GP1528 option in the Upper River.

The annual values of total water supply benefits for the CWCP, the MCP, and the four GP options are shown on Figures 7.9-2 through 7.9-4. All of the alternatives discussed in this chapter tend to respond similarly to changes made during the 100-year period of analysis. The average water supply benefits show a dramatic decrease during the early 1930s and 1960s and a lesser decrease during the early 1990s. These dips occur on a 30-year cycle when major water supply capital improvements are assumed to be made to all facilities.

Two conclusions can be made regarding the water supply benefits. First, benefits on Lake Sakakawea and Lake Oahe increase for all five alternatives compared to the CWCP. This is due primarily to the increased conservation, or retention, of water in the upper three lakes during droughts. A secondary factor is the minimum service summer low flow, because the GP1528 and GP2028 options have the highest water supply benefits for both lakes. The second conclusion relates to benefits on the Omaha and Nebraska City reaches of the Lower River where the GP1521 and GP2021 options have lower benefits than the other four alternatives. These lower benefits are due to the lower summer flow and the impacts on the thermal powerplants in these two reaches. The 25/21-kcfs lower summer release from Gavins Point Dam is not high enough to ensure that the powerplants can operate at full capacity due to thermal discharge limitations at lower river flows. Overall, the best options for the lakes appear to be those with minimum navigation service in the summers, and at least minimum service on the Lower River to ensure water supply benefits do not decline.

7.9.1 Water Supply for Tribal Reservations

American Indians own approximately 302 water supply intakes and intake facilities along the Mainstem Reservoir System. Table 7.9-2 presents the average annual water supply benefits of the alternatives for 10 Tribal Reservations during the full period from 1898 to 1997. Under the CWCP, total water supply benefits provided are $5.37 million. Each of the alternatives provides an increase in the total average annual benefits to the Tribes relative to the CWCP; however, the level of increase to individual Tribes is dependent upon the location of the Reservation within the river system and how that section of the river will be operated under the alternatives.

Depending upon the alternative, many Tribes in the Lower River are expected to have no increase in water supply benefits, but those in the Upper River reaches will be provided the bulk of the increase in water supply benefits. None of the Tribes is expected to have a decrease in water supply benefits. Note that values less than $5,000 ($0.005 million) are not represented in Table 7.9-2.

The CWCP provides $0.21 million of water supply benefits to the Fort Peck Reservation. Each of the four GP options increases the water supply benefits to this Reservation by 14.3 percent. The MCP does not result in a change in water supply benefits when compared to the CWCP.

Fort Berthold Reservation has 79 water supply intakes and intake facilities identified along Lake Sakakawea, on Reservation land. Under the CWCP, average annual benefits total $1.75 million. Within Fort Berthold Reservation, the GP1528 and GP2028 options provide the greatest increase in average annual water supply benefits (8.6 percent) and the MCP provides the second largest benefit increase (6.3 percent). Both the GP2021 and GP1521 options increase the water supply benefit within this Reservation by only 1.1 percent.

Standing Rock Reservation has 14 water supply intakes along Lake Oahe on Reservation land. Under the CWCP, average annual benefits total $0.67 million. Each of the four GP options provides the same amount of benefit increase within this Reservation (10.4 percent over the CWCP), while the MCP provides a 9.0 percent increase over the CWCP in water supply benefit.

Table 7.9-2. Average annual water supply benefits ($millions) to Tribes.

Reservation	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Fort Peck	0.21	0.21	0.24	0.24	0.24	0.24
Fort Berthold	1.75	1.86	1.90	1.77	1.77	1.90
Standing Rock	0.67	0.73	0.74	0.74	0.74	0.74
Cheyenne River	0.08	0.09	0.08	0.08	0.08	0.08
Lower Brule	0.54	0.54	0.54	0.54	0.54	0.54
Crow Creek	1.98	1.99	1.99	1.99	1.99	1.99
Yankton	0.00	0.00	0.00	0.00	0.00	0.00
Santee	0.11	0.11	0.11	0.11	0.11	0.11
Winnebago	0.01	0.01	0.01	0.01	0.01	0.01
Omaha	0.02	0.02	0.02	0.02	0.02	0.02
Total	**5.37**	**5.56**	**5.63**	**5.50**	**5.50**	**5.63**

Nine water supply intakes have been identified along Lake Oahe on Cheyenne River Reservation. Under the CWCP, average annual benefits to this Reservation total $0.08 million. None of the four GP options result in a change in water supply benefits to this Reservation; however, the MCP provides a 12.5 percent average annual water supply benefit increase over the CWCP.

Lower Brule Reservation has 22 water supply intakes identified along Lake Sharpe on Reservation land. Under the CWCP, average annual benefits for these intakes total $0.54 million. Compared to the CWCP, the MCP and the four GP options provide the same water supply benefits. The operation of Lake Sharpe does not vary under any of the alternatives.

There are 55 water supply intakes serving Crow Creek Reservation from Lake Sharpe and Lake Francis Case. Under the CWCP, average annual benefits to these intakes total $1.98 million. The MCP and the four GP options slightly increase the average annual water supply benefits to this Reservation by the same amount (increase of 0.5 percent).

Four irrigation intakes pulling water from Lake Francis Case are located on Yankton Reservation. The alternatives analyzed in this chapter do not result in a change in water supply benefits when compared to the CWCP. Santee Reservation has seven water supply intakes located on Lewis and Clark Lake. As with Yankton Reservation, none of the alternatives analyzed in this chapter results in a change in water supply benefits when compared to the CWCP.

Of the 49 water supply intakes located on the Missouri River in the Sioux City reach, there is one irrigation intake on Winnebago Reservation and two irrigation intakes on Omaha Reservation. For Winnebago and Omaha Reservation irrigation intakes, there is no change in water supply benefits from the CWCP under the MCP or the four GP options.

None of the nine water supply intakes located on the St. Joseph reach of the Missouri River is on Iowa Reservation or Sac and Fox Reservation.

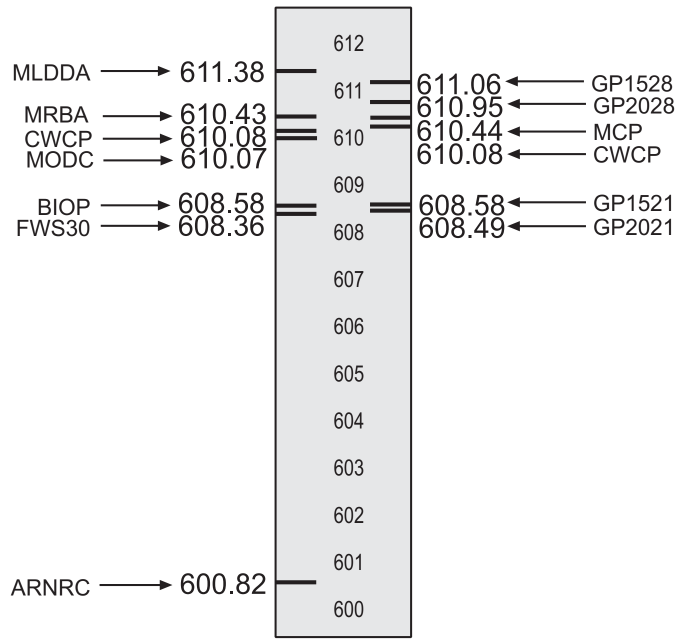

Figure 7.9-1. Average annual water supply benefits for submitted alternatives and the alternatives ($millions).

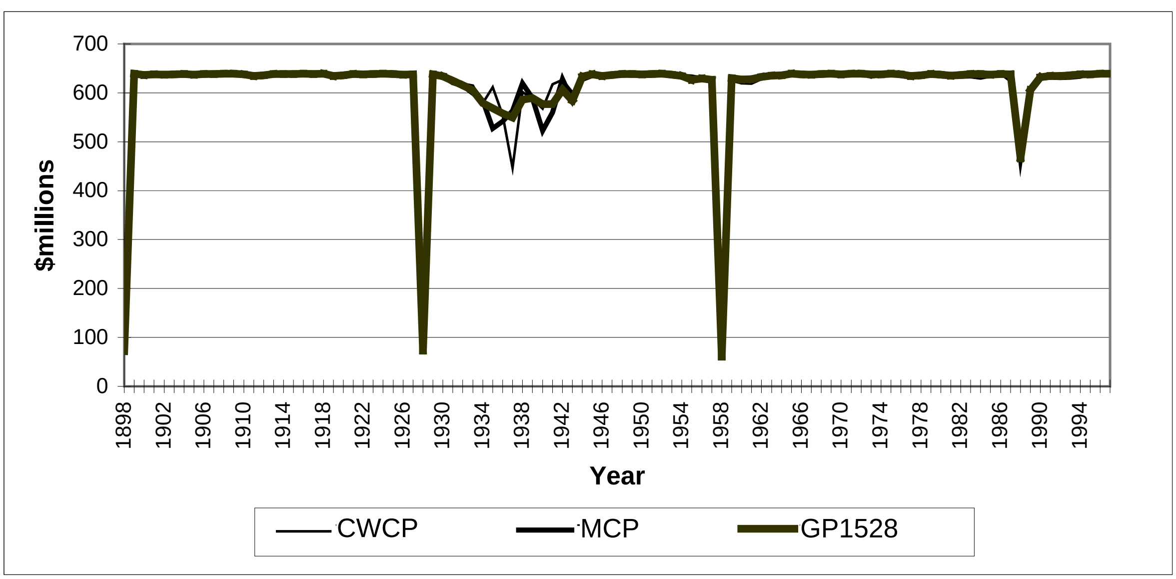

Figure 7.9-2. Annual water supply benefits for CWCP, MCP, and GP1528.

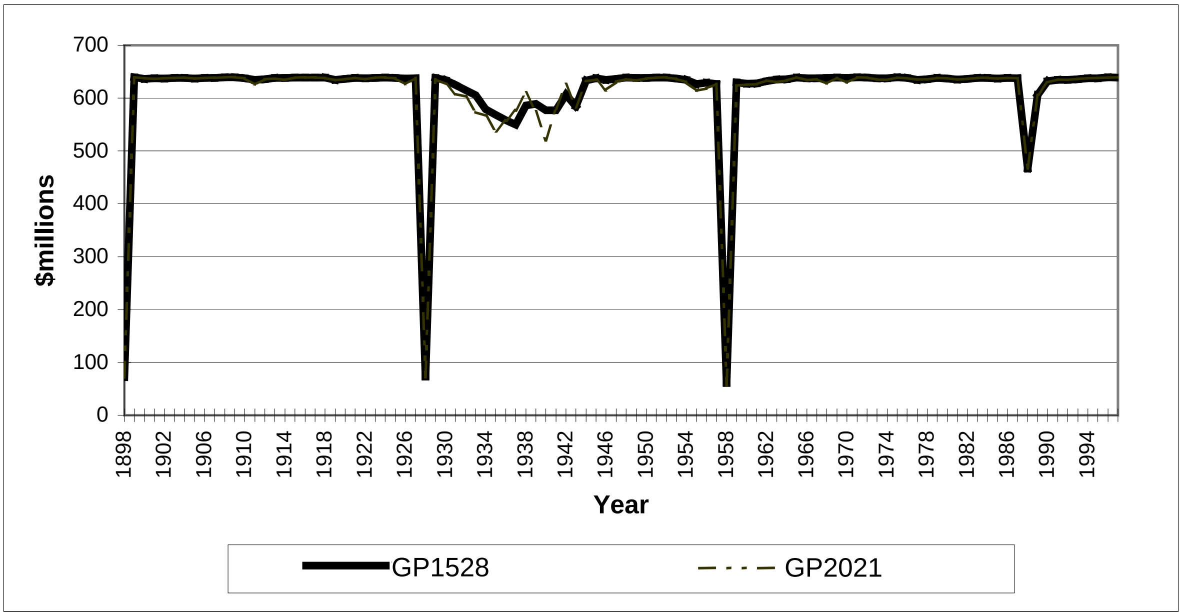

Figure 7.9-3. Annual water supply benefits for GP1528 and GP2021.

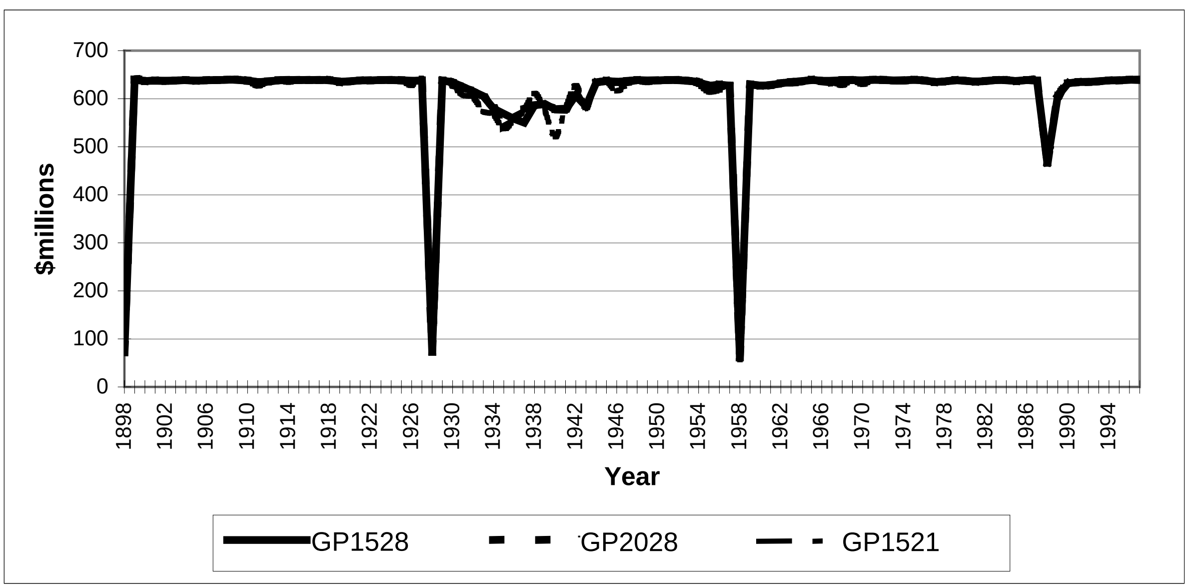

Figure 7.9-4. Annual water supply benefits for GP1528, GP2028, and GP1521.

7.10 HYDROPOWER

The impacts to hydropower are estimated using the traditional hydropower economic benefits analysis and using two other approaches to address concerns expressed by consumers of the hydropower. Traditionally, the Corps determines the economic value of hydropower by evaluating the total value of its production of both the capacity and energy components with respect to alternative replacement costs, as discussed in the Hydropower Economics technical report for the DEIS (Corps, 1994l). Section 7.10.1 reviews the differences in these hydropower benefits for the alternatives discussed in this chapter, examining average annual hydropower benefits and a breakdown of capacity and energy values. The capacity value represents the amount of generation capacity available from the hydropower units under various constraints. Energy is the amount of power generated during a specified time period.

Results of two additional analyses are discussed in this chapter. Section 7.10.2 presents an analysis of how much electric capacity and energy might be at risk in the basin during summer low-flow periods. This analysis looks at the hydropower generated at the six system dams and the electricity generated at the powerplants along the river that depend on the river for cooling of the thermal wastes resulting from the generation of the electricity. For Section 7.10.3, the Western Area Power Administration (WAPA), a cooperating agency in the preparation of the EIS and the Federal agency that markets the hydropower from the Mainstem Reservoir System, conducted a revenue analysis of the energy it would be able to market under the CWCP and each of the alternatives evaluated in detail in this chapter. WAPA takes the results of this analysis a step further and identifies the impacts of reduced revenues under each alternative in terms of what it might mean to wholesale electric customers that depend on hydropower for some or all of their electricity.

7.10.1 Hydropower Economic Benefits

This part of the hydropower discussion focuses on the National Economic Development (NED) benefits associated with hydropower generation by the Mainstem Reservoir System. It also includes the related information on the breakdown of these benefits between capacity and energy benefits. Data on capacity and energy are also presented.

It should be noted that the hydropower economic benefits presented in this FEIS reflect a recent re-analysis of the basic unit values for capacity and energy. The basic application of these values in the hydropower economic impact model has not changed from the application discussed in the Hydropower Economics technical report (Corps, 1994l); only the unit values used in the analysis have been adjusted. The values presented in Section 7.10.1 of the FEIS are lower than those presented in the RDEIS because the multipliers to go from the unadjusted capacity value to the adjusted capacity value were applied twice (once outside of the hydropower economic model and once within the model). This correction had essentially no impact on the relative differences among the six alternatives.

Table 7.10-1. Average annual hydropower benefits ($millions).

Alternative	Total	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
CWCP	**668.00**	63.62	139.67	197.60	115.14	111.98	40.00
MCP	**672.82**	64.07	142.44	200.07	114.84	111.57	39.83
GP1528	**682.41**	64.75	146.18	202.33	116.04	112.14	40.98
GP2021	**678.75**	64.67	145.29	201.14	115.59	111.47	40.60
GP1521	**679.23**	64.67	145.22	201.51	115.70	111.48	40.65
GP2028	**681.74**	64.71	146.08	201.93	116.07	112.02	40.93

The total economic hydropower benefits for the alternatives are presented in Table 7.10-1 and shown in Figure 7.10-1. Table 7.10-1 also includes data for each of the six mainstem dams. The greatest total average annual benefits for the 100-year period of analysis occur under the GP1528 option ($682.41 million), and the least occur under the CWCP ($668.00 million), a difference of approximately 2.2 percent.

The CWCP has a flat release of 34.5 kcfs from Gavins Point during spring and summer of most years; during major droughts, this release is reduced to 28.5 kcfs. This operational pattern results in $668.00 million in total average annual benefits for the Mainstem Reservoir System hydropower production. The majority of the hydropower benefits come from two dams, Oahe (29.6 percent) and Garrison (20.9 percent). The contributions of the remaining four dams are as follows: Big Bend (17.2 percent), Fort Randall (16.8 percent), Fort Peck (9.5 percent), and Gavins Point (6.0 percent). This distribution of hydropower benefits remains consistent among the alternatives.

As depicted in Figure 7.10-1, the total average annual hydropower benefits of the alternatives fall into three groups. At $668.00 million per year, the CWCP has the lowest value. The next grouping includes only the MCP, which results in $4.82 million (0.7 percent) more benefits than the CWCP. The highest grouping comprises the set of GP options. One of the two components of these options, the summer low flow, provides a pattern within this cluster: the options with a 28.5-kcfs flat release result in greater benefits than the options with a split-season (21/25-kcfs) low flow. The GP2028 and GP1528 options result in 2.1 and 2.2 percent more total hydropower benefits than the CWCP, respectively. The GP2021 and GP1521 options result in 1.6 and 1.8 percent more total hydropower benefits than the CWCP, respectively.

To allow comparison of the effects of the alternatives addressed in this chapter to those of the submitted alternatives, Figure 7.10-1 includes the values for the alternatives addressed in Chapter 5. The four GP options provide hydropower benefits similar to those provided by the two alternatives submitted by the USFWS (the BIOP and FWS30 alternatives). The USFWS alternatives included different spring rises but the same variable summer low flows, thus the hydropower benefits provided by those alternatives are essentially the same as those provided by the GP options with the variable summer flow pattern (GP1521 and GP2021). Of all the alternatives, the greatest hydropower benefits occur under the GP1528 option.

The MCP differs from the CWCP in that it includes greater conservation measures during drought periods, unbalanced intrasystem regulation, and a spring rise downstream from Fort Peck Dam. These changes result in a 0.7 percent increase in total average annual hydropower benefits over those modeled for the CWCP. Compared to the GP options, this represents the lowest percent increase in total hydropower benefits over the CWCP. The bulk of the increase under the MCP comes from Garrison and Oahe Dams, which increase 2.0 percent and 1.2 percent, respectively. At the three lower dams (Big Bend, Fort Randall, and Gavins Point), this alternative results in decreases ranging from 0.3 to 0.4 percent in average annual hydropower benefits.

The GP options differ from the MCP by including spring rises and low summer releases at Gavins Point Dam. The GP1528 option with the lowest spring rise and the highest summer flows, includes a 15-kcfs spring rise and a 28.5-kcfs flat release during summer. These measures result in a 1.4 percent increase in total average annual hydropower benefits, compared to the MCP. Increases occur at all six dams, with the greatest relative increases at Gavins Point (2.9 percent) and Garrison (1.4 percent) Dams. Notably, all four options result in greater average annual hydropower benefits than the MCP, both in total and at each dam.

To provide a perspective for how hydropower benefits could change in the future if changes are made to the GP1528 option, the following paragraphs describe the changes relative to the GP1528 option. The greatest total decrease (0.5 percent decrease from those of the GP1528 option) in hydropower benefits occurs under the GP2021 option. The GP2021 option has the 20-kcfs spring rise and 25/21-kcfs split summer release from Gavins Point Dam. This combination of change, when made to the GP1528 option, decreases by 0.1 percent hydropower benefits at Fort Peck Dam, decreases 0.6 percent at Garrison Dam, decreases 0.6 percent at Oahe Dam, decreases 0.4 percent at Big Bend Dam, decreases 0.6 percent at Fort Randall Dam, and decreases 0.9 percent at Gavins Point Dam. In summary, changing both the spring rise and summer low flow at the same time under adaptive management results in a negative change in hydropower benefits at all six dams.

With a change in the summer low flow from minimum service to the 25/21-kcfs split from Gavins Point Dam, as with the GP1521 option, total hydropower benefits also decrease by 0.5 percent compared to the GP1528 option. When only the summer flows are lowered from those of the GP1528 option, hydropower benefits decrease by 0.1 percent at Fort Peck Dam, decrease by 0.7 percent at Garrison Dam, decrease by 0.4 percent at Oahe Dam, decrease by 0.3 percent at Big Bend Dam, decrease by 0.6 percent at Fort Randall Dam, and decrease by 0.8 percent at Gavins Point Dam. In summary, changing summer low flows only under adaptive management results in a negative change in hydropower benefits at all six dams.

With a change in only the spring rise amount from 15 kcfs to 20 kcfs, as with the GP2028 option, total hydropower benefits decrease by 0.1 percent compared to the GP1528 option. When only the spring rise is increased over the GP1528 option, hydropower benefits decrease by 0.1 percent at Fort Peck Dam, decrease by 0.1 percent at Garrison Dam, decrease by 0.2 percent at Oahe Dam, decrease by 0.1 percent at Fort Randall Dam, and decrease by 0.1 percent at Gavins Point Dam. No change in benefits occurs at Big Bend Dam for the change in criteria. In summary, increasing the spring rise only under adaptive management results in a negative change in hydropower benefits at five dams and no change at one.

The annual values of total hydropower benefits for the alternatives are shown in Figures 7.10-2 through 7.10-4. Hydropower benefits are highly variable during the entire period of analysis, and none of the alternatives performs consistently better or worse than any of the others. As the figures show, the lowest total hydropower benefit values under all alternatives occur during the 1930 to 1941 drought. Additional low points occur during the late 1950s and late 1980s.

Figure 7.10-2 shows that the MCP and the GP1528 option, both of which feature increased drought conservation measures, differ from the CWCP most noticeably during and after periods of drought. The MCP produces higher annual hydropower benefits than the CWCP only during the 1930 to 1941 drought, while the GP1528 option does so during that period as well as the late 1950s and the late 1980s. As shown in Figures 7.10-3 and 7.10-4, there is very little difference in effects among the GP options. The GP1528 and GP2021 options are essentially identical for almost the entire 100-year period of analysis, with the GP1528 option producing higher benefits only in the late 1930s and the mid-1940s (Figure 7.10-3). This difference appears to be a result of the lower summer releases from Gavins Point Dam, because the options with the same summer releases match each other almost exactly (GP1528 and GP2028, Figure 7.10-4).

The month-to-month distributions of the average annual generating capacity values for the full 100-year period of analysis are presented in Table 7.10-2 and Figures 7.10-5 and 7.10-6. In general, the total generating capacity at the mainstem dams is at its highest level in the summer months. Under the CWCP and the MCP, the lowest levels of generating capacity occur during spring and fall, and an intermediate peak occurs during winter. Throughout the year, the MCP results in slightly higher generating capacity than the CWCP, consistently producing between 1.2 percent and 1.7 percent more hydropower capacity than the CWCP.

The four GP options result in a different annual pattern of generating capacity. Rather than having two peaks, each option has a single peak in summer, and then gradually drops off to a winter time low before increasing back to its summer peak. The effects of the four GP options are almost identical, differing from each other by no more than 0.5 percent at any time. Generally, all four options result in higher monthly average peaking capacity values than the CWCP and the MCP throughout the year. For most of the year, the two options with 28.5-kcfs summer releases (GP1528 and GP2028)

Table 7.10-2. Monthly average hydropower peaking capacity (MW).

Alternative	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
CWCP	2,146	2,148	2,053	2,009	2,130	2,244	2,270	2,255	2,089	2,071	2,150	2,141
MCP	2,180	2,185	2,086	2,037	2,163	2,277	2,300	2,287	2,119	2,096	2,182	2,175
GP1528	2,231	2,234	2,245	2,263	2,262	2,288	2,319	2,314	2,293	2,267	2,239	2,226
GP2021	2,221	2,224	2,236	2,253	2,251	2,276	2,310	2,310	2,292	2,267	2,233	2,216
GP1521	2,222	2,224	2,236	2,254	2,253	2,279	2,313	2,312	2,294	2,268	2,234	2,216
GP2028	2,230	2,232	2,244	2,262	2,261	2,286	2,317	2,310	2,291	2,265	2,237	2,224

produce the highest average hydropower peaking capacity, ranging between 0.3 percent and 0.4 percent above the options that feature variable summer flows. In late summer and autumn, this difference is reduced to less than 0.1 percent. Finally, for each set of GP options with the same summer flow, the option with the higher spring rise (20 kcfs spring rise) has very slightly lower capacity values in some months. This occurs because the lakes are drawn down slightly lower by the higher spring rise, which slightly reduces generating capacity because the head on the generators is lower.

The energy distributions, in thousands of megawatt-hours (MWh), or gigawatt-hours (GWh), are presented in Table 7.10-3 and in Figures 7.10-7 and 7.10-8. Overall, the annual patterns of the alternatives fall into two groups. Under all of the alternatives, average hydropower energy values are lowest in March and highest in late spring or summer. The greatest values under the CWCP and the MCP occur in August, while the GP options exhibit two peaks, in May and September. Compared to the CWCP, the increased drought conservation measures of the MCP generally result in lower energy values during the winter months, but higher values during spring, summer, and autumn. The GP options result in higher values than the CWCP and the MCP in spring and autumn, and lower values in summer and winter. The lowest average summer hydropower energy values occur under the two options with variable (25/21-kcfs) summer flows.

For the region in which the Mainstem Reservoir System hydropower facilities operate, Federal hydroelectric generating capacity is marketed based on the peak season firm demand, in both the summer and winter seasons. In the early 1980s, WAPA chose to use 1961 water conditions to determine adverse-year capability for the sale of firm capacity. The lowest peak capacities in the summer and winter periods for the Corps' 1961 annual operating year (March 1961 through February 1962) represent the criteria that determine the capacities marketed by WAPA. Table 7.10-4 presents the summer and winter values for dependable capacity in 1961 for all alternatives. This table also presents the currently marketed capacities in both seasons.

Under current depletion levels, the CWCP does not meet the currently marketed levels identified in the early 1980s at depletion levels assumed at that time. The CWCP almost meets the level in the summer (-2 megawatts [MW]), but falls much shorter of

Table 7.10-3. Monthly average hydropower energy values (GWh).

Alternative	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
CWCP	729	637	554	711	928	912	1,023	1,053	973	928	857	722
MCP	710	611	550	740	929	921	1,027	1,054	1,016	977	776	727
GP1528	743	610	561	802	1,028	924	980	970	1,018	960	772	716
GP2021	739	607	560	805	1,052	914	869	894	1,033	984	868	716
GP1521	741	608	560	809	1,025	900	872	901	1,044	994	874	719
GP2028	739	609	559	797	1,050	933	980	967	1,011	954	765	713

Table 7.10-4. Marketable capacity from the Mainstem Reservoir System hydropower facilities (MW).

	1961 Operating Year Minimum Capacity	
Alternative	**Summer Season**	**Winter Season**
Currently marketed	2,070	2,010
CWCP	2,068	1,973
MCP	2,102	2,015
GP1528	2,177	2,108
GP2021	2,177	2,099
GP1521	2,178	2,099
GP2028	2,176	2,107

meeting the level in the winter (-37 MW). The increased drought conservation measures of the MCP and the four GP options allow these alternatives to exceed the currently marketed hydropower capacity level both in summer and winter. The greatest increases above currently marketed levels occur under the four GP options, all of which are within 0.5 percent of each other in both summer and winter.

7.10.2 Power at Risk

All of the powerplants along the Missouri River rely on the river for cooling water. Given current efficiencies, these powerplants can convert only a portion of the raw fuel (coal or nuclear) into electricity via steam generation. About one-half of the energy from the burning of the fuel is lost as heat to the environment. There are six powerplants downstream from Garrison Dam and 17 powerplants along the banks of the Lower River that use "open cycle," or one-pass cooling, to dissipate the heat lost to the environment. These plants pump through large quantities of water each day and warm that cooling water as much as 20 degrees Fahrenheit. The heat discharged by the powerplants is limited by the requirement in National Pollutant Discharge Elimination System (NPDES) permits issued by State environmental agencies. Heat limits are based on a number of factors, including dilution, mixing zones, background river temperature, and in-stream temperature caps.

Dilution, or more precisely the mixing of the heated effluent in the river, is mediated by a large number of variables: river flows, effluent flows, discharge configuration, river morphology, etc. For thermal dischargers, the key factors to consider are: a) the relative size of the plants to the river at low flows and b) proximity to the upstream dam (the closer the less augmentation of river flow from tributaries). Another important consideration is the fact that powerplants must operate at peak capacity in the summer months.

Some of the alternatives discussed in this chapter consider a reduction of Gavins Point Dam releases in the summer from those that fully serve navigation (34.5-kcfs flat release modeled). These lower releases vary from a minimum service flat release of 28.5 kcfs (GP1528 and GP2028 alternatives) to as low as 21.0-kcfs flat release in mid-July through mid-August (GP1521 and GP2021 alternatives). Over the past 20 years or so, the gage records have included several summer low-flow events that create a design summer low-flow level equivalent to a release of 23.5 kcfs from Gavins Point Dam. This would lead one to suspect that there are adverse impacts to powerplants at flows less than that design level.

A key variable driving the heat limits for existing powerplants is the question of background heat in the river. Most permit calculations have been based on the assumption of a maximum summer river temperature of 85 degrees Fahrenheit and maximum temperatures at the end of the mixing zone have been capped at 90 degrees Fahrenheit by State water quality standards. This means that powerplants, when allotted a certain mixing zone for dilution, are allowed to increase the in-stream temperature at the end of the mixing zone by 5 degrees Fahrenheit under worst-case summer conditions.

During the past few years, summer river temperatures have been in the range between 85 and 90 degrees Fahrenheit. This greatly changes the amount of heat that can be discharged from powerplants without violation of the 90 degrees Fahrenheit cap at either end of the regulatory mixing zone. Studies by Region 7 of the U.S. Environmental Protection Agency (EPA) on four powerplants in Nebraska show that there is sufficient mixing within the State's 5000-foot mixing zone so that plants can discharge at current rates without exceeding the 90 degrees Fahrenheit cap even with background temperatures of 87 degrees Fahrenheit. If background temperatures rise another 1 degree Fahrenheit, then Nebraska's standards would be violated.

While State standards are currently being met, the local impacts from these sources increase as the background temperature of the river increases. Summer heat is a biological stressor to stream ecosystems, and peak summer temperature of the river is moving toward the maximums allowed in State water quality criteria.

A key question, not easily answered, is whether the decreased summer flows will cause or contribute to higher temperatures. EPA, in its letter commenting on the RDEIS, stated that it could not find evidence of study on the relation of temperature to flow for the river. The Corps, however, determined, using an EPA water quality model, QUAL2E, that there is a relationship between river flow and river temperature (Corps 1994d). Based on prior discussions with the utilities and documentation on potential water quality concerns, the Corps decided to conduct a worst-case analysis of potential impacts on the powerplants. Using data coordinated with, or supplied by, the utilities (Corps 1994d), an assessment of potential cutbacks in power generation was conducted.

Thermal capacity and energy impacts were analyzed for the CWCP, the MCP, and the GP options during the months of mid-June through mid-September at power-generating facilities that use the Missouri River for cooling. These facilities are identified in the Water Supply Economics Technical Report (Corps, 1994g). The 4-month period of analysis was selected for this assessment because it includes the peak power demand months and the river flows are potentially the lowest due to the lower summer releases from Gavins Point Dam in the four GP options. This analysis was conducted assuming the purchase of replacement capacity or energy once water quality permits could not be met. The thermal capacity and energy at-risk results were combined with the differences in hydropower generation to come up with the combined at-risk values for the Missouri River region of the United States.

Capacity at Risk

As flows drop on the river reaches, powerplants may have to cut back on their generating capacity to limit the amount of heated wastewater entering the river from their cooling facilities. Potential cutbacks were determined using the water supply model developed to identify the water supply benefits of the alternatives. An analysis was conducted that assumes that if flows are insufficient to meet water quality permit requirements, the impacted plant capacity must be replaced by purchased capacity from another facility. As part of determining the economic impacts on the powerplants under the water supply (and water quality, as both were combined into one analysis to ensure that the economic impacts to the powerplants were not double counted), the capacity and energy shortfalls are computed. The capacity data were retrieved from the model to be used in the analysis of capacity effects, which is referred to as capacity at risk during the Gavins Point low-flow release period. For the capacity-at-risk analysis, the period of June 15 to September 15 of each year was checked to determine the day that the thermal generating capacity was affected the most, and this lost capacity was recorded for each year. An average annual value was computed using the 100 annual values identified using the water supply model.

Figure 7.10-9 illustrates the relationship between the average annual capacity at risk and the Gavins Point Dam releases. Average annual capacity at risk appears to be highly correlated (R squared value near 1.0) and increases exponentially as Gavins Point Dam releases decrease during the summer. The CWCP with a capacity at risk of about 289 MW and the MCP with a capacity at risk of about 234 MW both have summer flows of about 34.5 kcfs, or full service navigation, except during drought. The GP options with a minimum navigation service release (GP1528 and GP2028) have an average summer release of about 28.5 kcfs and a capacity at risk of about 242 MW. The GP options with a split navigation season (GP1521 and GP2021) have an average July and August release of about 23 kcfs and a capacity at risk of about 839 MW. To assist with the analysis, the ARNRC alternative, one of the submitted alternatives discussed in Chapter 5, has a summer release of 18 kcfs and a capacity at risk of over 1,512 MW, which is also plotted. From this figure, the potential capacity at risk for a release of 21 kcfs is over 900 MW of generating capability. This value is more indicative of the impacts of the GP1521 and GP2021 options for the second half of July and the first half of August, when the Gavins Point Dam release is generally 21 kcfs.

Average annual capacity at risk during the summer at the river thermal plants is presented in Table 7.10-5, and the annual values over the period of record are presented in Figures 7.10-10 through 7.10-12. The capacity at risk is predominantly from powerplants in the Sioux City reach, with most of the remaining capacity at risk in plants located in the reach downstream of Garrison Dam and in the Omaha, Nebraska City, and Hermann reaches.

The CWCP has an average annual summer thermal capacity at risk at about 289 MW. Capacity at risk for the CWCP is primarily during the single non-navigation season, which occurred in 1937 in the model simulation. About two-thirds of the average annual capacity at risk is at powerplants in the Sioux City and downstream Garrison reaches, with most of the remaining capacity at risk in plants located in the Omaha and Nebraska City reaches. This alternative also has from 100 to 500 MW at risk in years when the summer releases are reduced because of downstream flooding. The simulation run of this alternative allows release reductions of

Table 7.10-5. Potential capacity at risk sometime from mid-June to mid-September at powerplants using Missouri River water for cooling (MW).

	Reach[1/]									
Alternative	**GARR**	**DS_G**	**SUX**	**OMA**	**NCNE**	**STJ**	**MKC**	**BN**	**HE**	**Total**
CWCP	11.35	36.46	151.40	17.96	16.77	10.27	7.92	0.00	37.11	**289.24**
MCP	0.00	41.40	95.02	29.15	12.71	8.83	1.69	0.00	45.07	**233.87**
GP1528	0.00	47.92	103.00	33.00	15.86	4.12	1.52	0.00	36.34	**241.76**
GP2021	0.00	57.39	466.89	105.34	69.70	10.76	5.86	0.00	122.81	**838.75**
GP1521	0.00	56.92	467.12	105.34	69.62	10.76	5.87	0.00	122.81	**838.43**
GP2028	0.00	47.25	103.33	33.00	15.71	4.12	1.51	0.00	36.34	**241.25**

1/ Reach names are abbreviated as follows: GARR = Garrison; DS_G = downstream Garrison; SUX = Sioux City; OMA = Omaha; NCNE = Nebraska City; STJ = Saint Joseph; MKC = Kansas City; BN = Boonville; HE = Hermann.

about 10 kcfs over a 2-day period that can result in flows downstream that impact powerplants, especially those in the Sioux City reach. This happens in about 20 percent of the years.

Three of the alternatives, the MCP, the GP1528 option, and the GP2028 option maintain at least minimum navigation service throughout the summer and place similar amounts of capacity at risk, predominantly during years of no navigation during the 1930 to 1941 drought. These alternatives have 5 to 6 non-navigation seasons during this period compared to the single non-navigation season for the CWCP. These three alternatives have the lowest average annual capacities at risk at 234 to 241 MW, which is a reduction of about 50 MW of the average annual capacity at risk compared to the CWCP. About 62 to 75 percent of the capacity at risk for these alternatives is at powerplants in the Sioux City and downstream Garrison reaches, with most of the remaining capacity at risk at powerplants located in the Omaha, Nebraska City, and Hermann reaches.

In comparison, the GP1521 and GP2021 options, both with a split in the navigation season, increase the amount of capacity at risk by about three times the CWCP, MCP, and GP1528 and GP2028 options. For the GP1521 and GP2021 options, the potential capacity loss occurs in all years except during years with high downstream inflow that keeps that summer's lowest flow above the threshold flow below which water quality temperature standards may not be met. For these alternatives, nearly 60 percent of the capacity at risk is from thermal plants in the Sioux City reach.

Figure 7.10-13 shows the duration of the impacts. The CWCP has a -100 MW or greater impact in about 35 percent of the years, the MCP has a 100-MW or greater impact in fewer than 20 percent of the years, and the minimum service summer flow options have impacts exceeding 100 MW in fewer than 16 percent of the years. In contrast, the split season options (GP1521 and GP2021) have a 300-MW impact in nearly 90 percent of the years.

The total average capacity at risk considering the mainstem hydropower plants and the thermal plants using Missouri River water for cooling is summarized in Table 7.10-6 and by year in Figure 7.10-14. Persistence of the capacity at risk for the GP options with summer flows below minimum navigation service (GP1521 and GP2021) is highlighted in the figure. The table shows that the average annual capacity at risk at the hydropower plants and thermal plants is negative (more capacity available than with the CWCP) for the MCP, GP1528, and GP2028 alternatives. Conversely, the GP1521 and GP2021 alternatives have net losses of over 500 MW when compared to the CWCP. The MCP and the GP1528 and GP2028 options have net gains in generating capacity in many summers, whereas the GP1521 and GP2021 options almost always have net losses.

Energy at Risk

When generating capacity has to be cut back to limit the impact of heated wastewater on the Missouri River, the amount of energy generated is adversely affected. Effects on the ability to generate energy were also identified using an analysis similar to that described for the capacity effects. These effects are also combined with the changes in energy availability at the mainstem hydropower facilities.

Table 7.10-6. Potential total thermal and hydropower average annual capacity at risk sometime from mid-June to mid-September compared to the CWCP (MW).

Alternative	Hydropower1/	Thermal Power	Total
MCP	-30	-55	-85
GP1528	-49	-47	-96
GP2021	-40	550	510
GP1521	-43	549	506
GP2028	-47	-48	-95

1/ Hydropower values are for the month of July.

Similar to the capacity-at-risk relationship with flows, energy at risk appears to be highly correlated and increases exponentially as Gavins Point Dam releases decrease during July, as shown by Figure 7.10-15. Impacts increase from about 111 GWh for the MCP with full service navigation flows in July to over 750 GWh for the ARNRC alternative that has Gavins Point Dam releases from mid-June through August of 18 kcfs, about 17 kcfs below full service navigation.

Average annual energy at risk during mid-June through mid-September at river thermal plants is presented in Table 7.10-7 and by year in Figures 7.10-16 through 7.10-18.

The CWCP minimizes energy at risk at about 70 GWh. Energy at risk is primarily during the single non-navigation season. Nearly 54 percent of the energy at risk is at powerplants in the Sioux City and downstream Garrison reaches.

The MCP together with the GP1528 and GP2028 options increase the energy at risk by over 50 percent. This increase is based on the 5 to 6 non-navigation seasons for these alternatives in the 1930 to 1941 drought compared to the single non-navigation season for the CWCP. About 60 percent of the energy at risk for these alternatives is from powerplants in the Sioux City and downstream Garrison reaches.

The GP1521 and GP2021 options increase the amount of energy at risk by about 5 times that of the CWCP, or about 3 times that of the GP1528 option. The energy at risk is predominantly produced in the Sioux City reach, with most of the remaining energy at risk at powerplants located in the reach downstream of Garrison Dam and in the Omaha, Nebraska City, and Hermann reaches. The analysis assumes that if flows are insufficient to allow the powerplants to meet water quality temperature standards, the impacted powerplant capacity must be replaced by purchased energy. In contrast to the CWCP, the MCP, and the GP1528 and GP 2028 options, where the potential energy losses are predominantly during years of no navigation service, the GP1521 and GP2021options have potential energy losses in almost all years. The exceptions occur in years with high downstream inflow that keeps the summer flow above the threshold flow below which water quality temperature standards may not be met.

The duration plot of energy at risk is presented in Figure 7.10-19. The CWCP shows potential thermal energy at risk of less than 50 GWh in less than 5 percent of the years. The MCP has 100 GWh at risk in less than 10 percent of the years, and the minimum service options (GP1528 and GP2028) have 100 GWh at risk in less than 15 percent of the years. In contrast, the split season options, GP1521 and GP2021, show more than 200 GWh at risk in more than 70 percent of the years and over 400 GWh at risk in over 20 percent of the years.

The total energy at risk considering the mainstem hydropower facilities and the thermal plants using Missouri River water for cooling is summarized on an average annual basis in Table 7.10-8 and on a yearly basis in Figure 7.10-20. The potential energy loss at the thermal plants is compounded by hydropower energy losses at the mainstem hydropower plants, except for the MCP, which shows a small hydropower energy gain (negative energy at risk value of -4 GWh). All of the alternatives have a greater combined energy at risk than the CWCP, with the MCP having the lowest amount at risk of 38 GWh. The GP1528 and GP2028 values are about 80 GWh at risk, and the GP1521 and GP2021 values are over 5 times greater than for the other two GP options with

Table 7.10-7. Potential energy at risk from mid-June to mid-September at the powerplants using Missouri River water for cooling (GWh).

	Reach[1/]									
Alternative	**GARR**	**DS_G**	**SUX**	**OMA**	**NCNE**	**STJ**	**MKC**	**BN**	**HE**	**Total**
CWCP	7.79	16.03	21.05	7.55	5.32	1.39	1.21	0.00	9.52	**69.86**
MCP	0.00	26.23	42.05	17.22	9.08	0.58	0.36	0.00	15.91	**111.43**
GP1528	0.00	33.15	43.18	14.31	7.65	0.18	0.21	0.00	9.81	**108.49**
GP2021	0.00	33.34	207.04	42.60	26.21	0.61	0.83	0.00	36.55	**347.17**
GP1521	0.00	32.62	206.62	42.55	26.19	0.61	0.83	0.00	36.61	**346.02**
GP2028	0.00	32.42	43.34	14.31	7.64	0.18	0.21	0.00	9.81	**107.92**

1/ Reach names are abbreviated as follows: GARR = Garrison; DS_G = downstream Garrison; SUX = Sioux City; OMA = Omaha; NCNE = Nebraska City; STJ = Saint Joseph; MKC = Kansas City; BN = Boonville; HE = Hermann

Table 7.10-8. Potential total thermal and hydropower energy impacts from mid-June to mid-September compared to the CWCP (GWh).

Alternative	Hydropower1/	Thermal Power	Total
MCP	-4	42	38
GP1528	43	39	82
GP2021	154	277	431
GP1521	151	276	427
GP2028	43	38	81

1/ Hydropower values are for the month of July.

higher summer flows. Figure 7.10-21 is a sorted plot of the annual values in Figure 7.10-20. This sorted plot shows that the two GP options with the higher summer flow have losses of energy during the summer in about 60 percent of the years, whereas the two options with the lowest summer flow have losses of energy production in over 90 percent of the years. The losses for these two latter options are over 500 GWh in about 60 percent of the years.

7.10.3 Hydropower Revenue Impacts to the Upper Great Plains Region of WAPA and its Customers

The Upper Great Plains Region of WAPA calculated revenue impacts of the CWCP, the MCP, and the GP options on the Pick-Sloan Missouri Basin—Eastern Division. Power from Federal generation resources in the Upper Great Plains region has been allocated through a succession of marketing plans. The marketing plans result in an amount of power that WAPA has agreed to provide (firm commitments). Water levels and releases fluctuate hour to hour, month to month, season to season, and year to year. Because of these fluctuations, WAPA may need to purchase power to fulfill its firm commitments or it may have power to sell after fulfilling its firm commitments. The monthly 100-year average generation was calculated for the CWCP, the MCP, and the four GP options (GP1528, GP2028, GP1521, and GP2021). Generation is compared to the firm commitments. If power is available beyond the firm commitments, it is sold. If there is not sufficient power generated to fulfill the firm commitments, additional power is purchased. Based on the Post-2000 Marketing Plan for the Pick-Sloan Missouri Basin Program—Eastern Division, these sales or purchases are made on the energy market. For this analysis, the sales and purchases were priced according to the monthly Cinergy Rates of January 30, 2001. (Cinergy provides monthly rate values for the upcoming year at the end of each month.)

The 100-year average sales and purchases for each alternative are shown in the Table 7.10-9. The MCP generates slightly more net revenue than the CWCP. The minimum navigation service options (GP1528 and GP2028) provide almost $9 million less average annual revenue than the CWCP, and the split season options (GP1521 and GP2021) provide nearly $30 million less revenue than the CWCP.

Sales and purchases were totaled for each alternative resulting in the 100-year average monthly sales (+) and purchases (-). The MCP and

Table 7.10-9. Average annual impact to WAPA for meeting Pick-Sloan firm power commitments ($millions).

	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Sales Revenue (+)	144.9	148.6	136.9	116.0	116.3	137.3
Purchase Cost (-)	25.2	27.3	25.8	26.2	26.0	26.3
Net Revenues	119.7	121.3	111.1	89.8	90.3	111.0
Lost Revenues Compared to CWCP	0.0	-1.6	8.6	29.9	29.4	8.7

the GP options are compared to the CWCP to obtain the increase or decrease in revenue. This comparison shows the overall impact to the Pick-Sloan Missouri Basin—Eastern Division firm power and is shown in Figure 7.10-22. July and August are notable as the only months where the alternatives deliver the distinctly different net revenue. In July, the CWCP and the MCP provide about $40 million in average net revenue; the minimum navigation service alternatives, GP1528 and GP2028, deliver less than $35 million average revenue. The split season alternatives, GP1521 and GP2021, provide less than $20 million in average revenue. The pattern is much the same in August, except GP1528 and GP2028 provide less than $30 million in revenue. Revenue in November also varies by alternative, but while the percentage differences between alternatives are great, the average dollar differences are less than $5 million between alternatives.

The Upper Great Plains Region of WAPA serves customers across more than 378,000 square miles in the northern Rocky Mountain and WAPA Great Plains states. Power is delivered through 98 substations across approximately 7,745 miles of Federal transmission lines, which connect with other regional transmission systems.

The Region's 300-plus customers include rural electric cooperatives, municipalities, public utility districts, irrigation districts, American Indian Tribes, and Federal and State agencies. The Upper Great Plains Region markets the power from six Corps mainstem dams and powerplants.

To analyze the impact of the proposals on Upper Great Plains Region Customers (a capital C is used when referring to a direct Customer of the Upper Great Plains Region), a representative sample of Customers was selected. To be representative, the sampling needed a Customer from each of the six states in which the Region provides service. Customers receiving approximately 10, 40, 60, 70, and 100 percent of their load were selected. The Customer sample includes Customers from each of the different types of entities receiving power from WAPA.

An example of one of the Region's Customers receiving 10 percent of its power and energy resources from Federal generation is a rural electric cooperative with offices in Bismarck, North Dakota. This cooperative has about 9,247 customers, and 8,264 of these are residential customers. This rural electric cooperative operates in four counties in south-central North Dakota. The summer peak is about 32 MW and the winter peak is about 29 MW. Another example of a 10 percent Customer would be a municipality in northeastern Nebraska with 1,844 customers, 1,461 of which are residential. The summer peak is 11 MW and the winter peak is 9 MW.

An example of a 40 percent load Customer is a municipality in northwestern Iowa with 1,306 customers, 1,105 of which are residential. The summer peak is 7 MW and the winter peak is 6 MW. Another 40 percent load Customer is a rural electric cooperative in Montana with a summer peak of 147 MW and a winter peak of 186 MW. A final example of a 40 percent load Customer is a rural electric cooperative in South Dakota, with 24 wholesale customers, a summer peak of 300 MW, and a winter peak of 314 MW.

An example of a 70 percent load Customer is a municipality in west-central Minnesota with 750 customers, 654 of which are residential. The summer peak is 2.6 MW and the winter peak is 3.2 MW. Another example of a 70 percent load Customer is a municipality in western South Dakota with 622 residential customers, a summer peak of 2.6 MW, and a winter peak of 2.5 MW.

One hundred percent load Customers include a municipality in northwest South Dakota, with 305 customers, of which 248 are residential customers. The summer peak is 1.2 MW and the winter peak is 1.5 MW. Another 100 percent load Customer is a municipality in Iowa with 881 customers, of which 728 are residential. The summer peak is 5.25 MW and the winter peak is 5.43 MW.

A representative Tribal Customer is a Tribe in South Dakota receiving 60 percent of its power from Federal resources. It covers 2.8 million acres and has a population of 14,861 people.

The increase or decrease in revenue from the 100-year averages compared to the firm commitments is applied to the power repayment study to determine the rate impact for each alternative water control plan. After selecting representative Customers, the increased or decreased rate for each proposal is then applied to the amount of power purchased from WAPA by these representative Customers. The increase or decrease in purchase power from WAPA is divided by the Customer's total purchase power cost to determine the percentage of change from their purchases under the CWCP. The above procedure was applied to all of the sample Customers. Figure 7.10-23 indicates the percentage increase in purchase power costs that would be experienced by each of the five sample Customers for the GP options.

Analyzing the sample Customers shows that the 100 percent load Customer impacts are increases of about 20 percent for GP1521. For the 10 percent load Customers, impacts are increases of about 1 percent. The analysis of the GP2021 option is almost identical to GP1521. The magnitude is smaller for the GP1528 and GP2028 options. One hundred percent Customer impacts are increases of about 6 percent. For the 10 percent load Customers, increases are about 0.3 percent for the GP1528 and GP2028 options. Using the results presented for the 100 and 10 percent Customers, the potential cost increase of hydropower to the Customers would be about 3.3 times as great under the GP1521 and GP2021 options as it would be under the GP1528 and GP2028 options.

As a result of the marketing plans and other events in the Upper Great Plains Region, those Customers that have 100 percent of their load served from Federal resources tend to be the smaller, poorer customers. These Customers have not had any load growth and may have, in fact, seen a reduction in load. On the other hand, those with less than 40 percent of their load furnished by Federal resources have seen load growth and thus the percentage of load served by Federal resources has decreased. The largest impact of any increase in the cost of the Federal resources greatly burdens the 100 percent load, small customer. The 10 percent load customer spreads the increase over a larger load base, making a 20 percent increase in the Federal resource price much less noticeable.

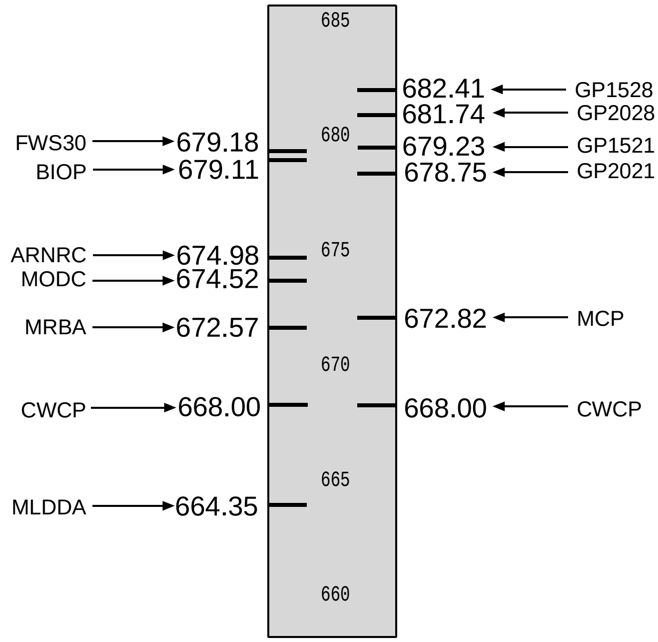

Figure 7.10-1. Average annual hydropower benefits for submitted alternatives and the alternatives ($millions).

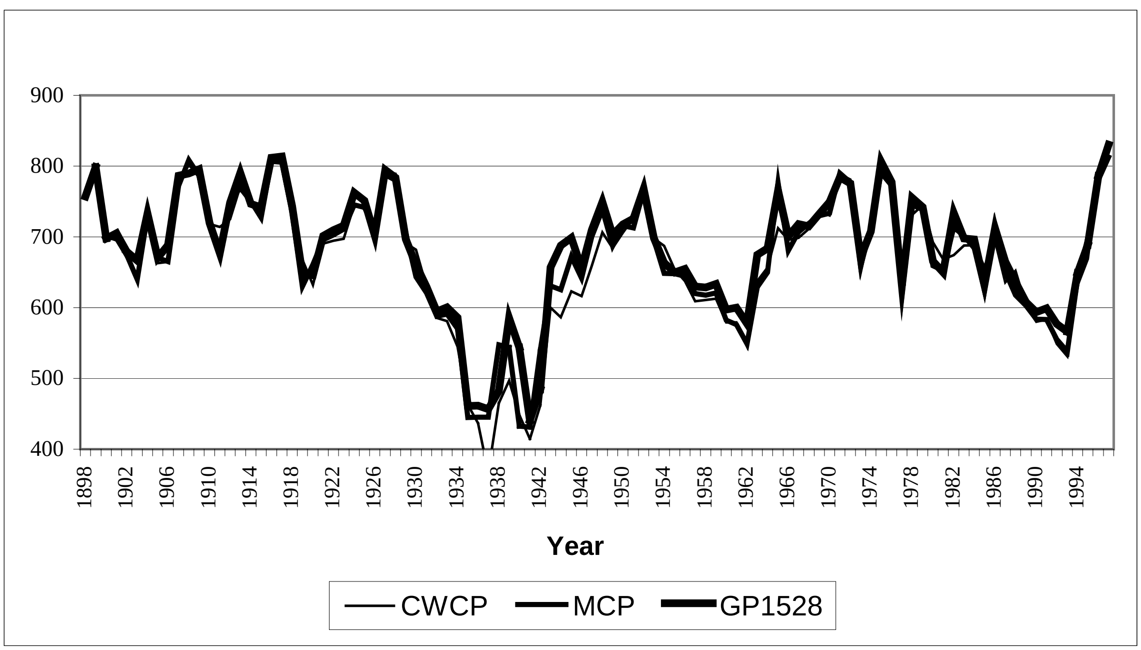

Figure 7.10-2. Annual hydropower benefits for CWCP, MCP, and GP1528.

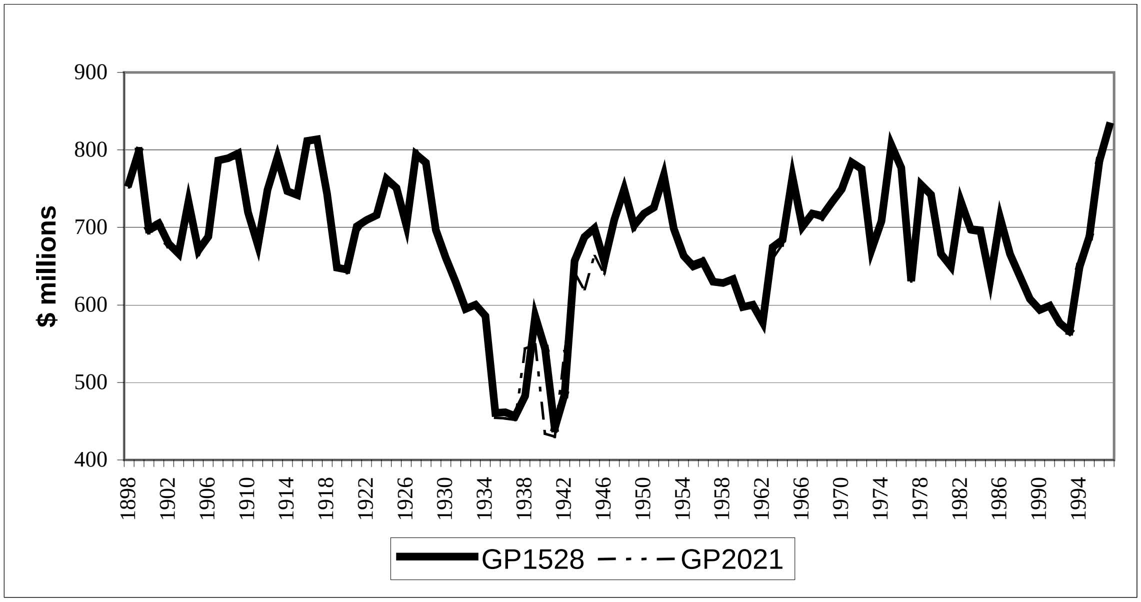

Figure 7.10-3. Annual hydropower benefits for GP1528 and GP2021.

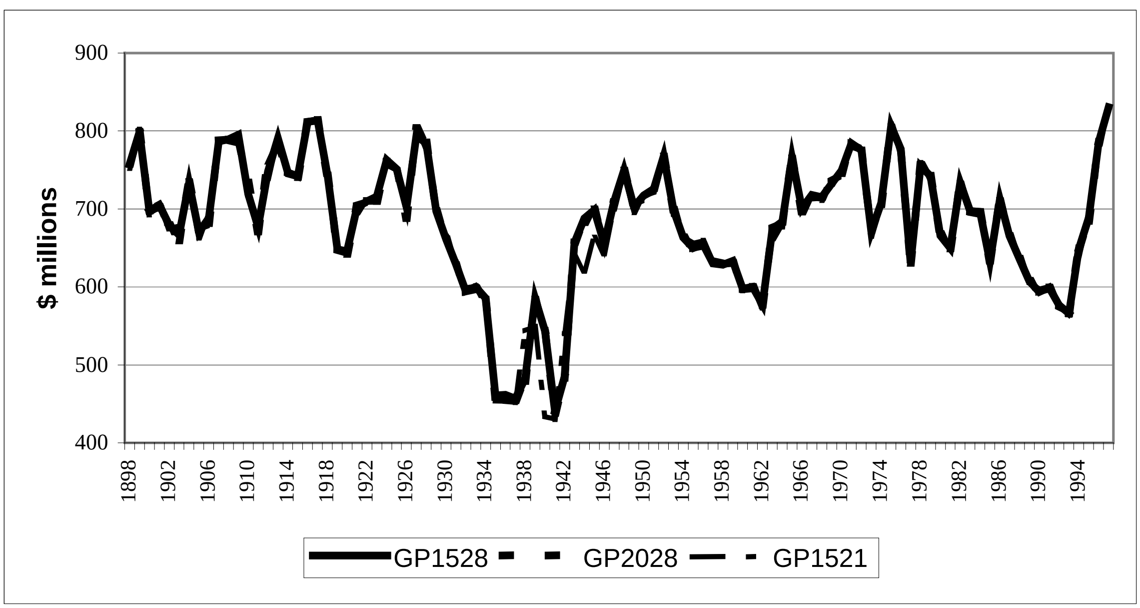

Figure 7.10-4. Annual hydropower benefits for GP1528, GP2028, and GP1521.

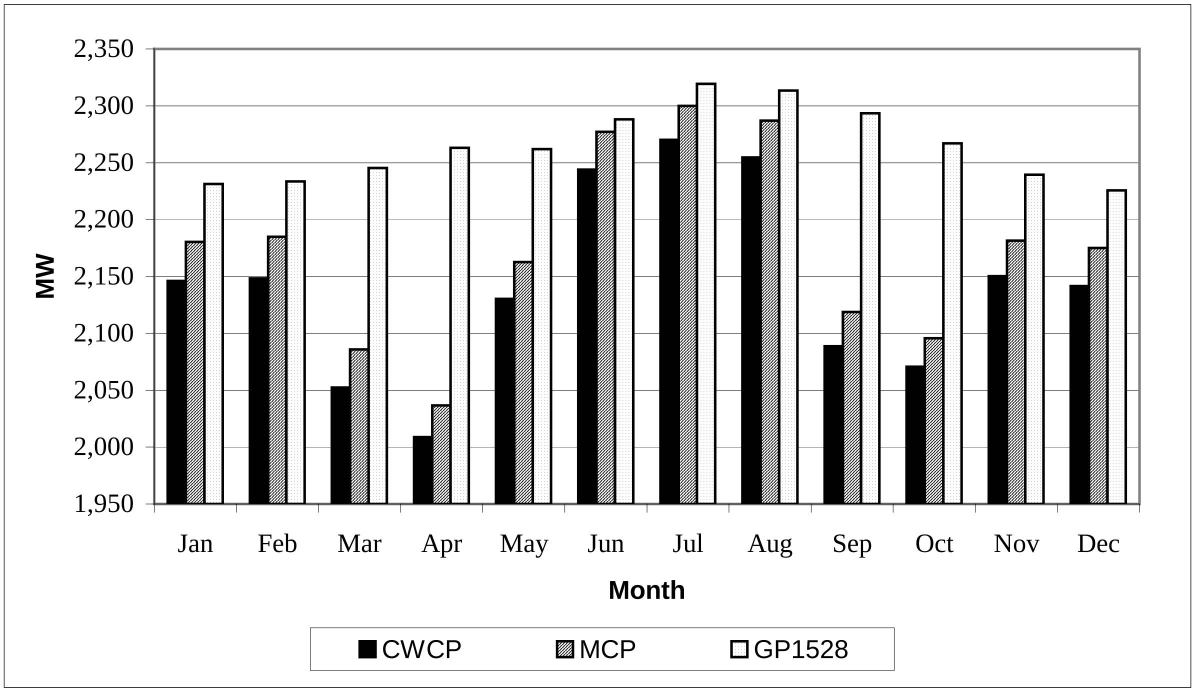

Figure 7.10-5. Monthly average hydropower peaking capacity for CWCP, MCP, and GP1528.

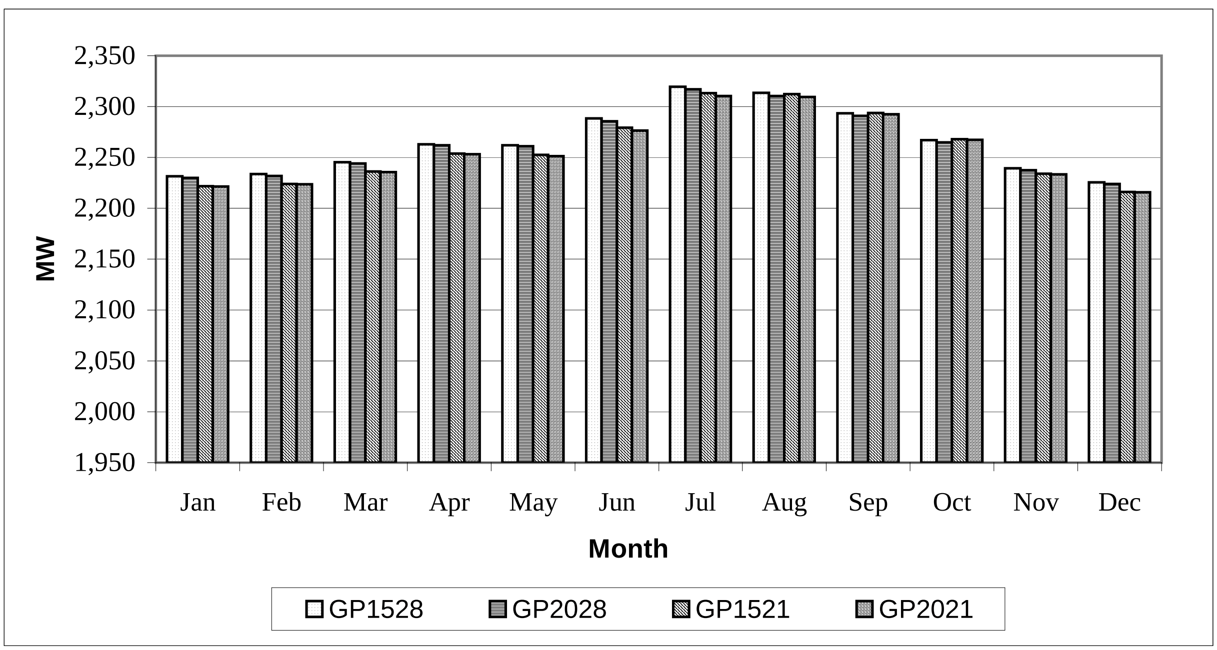

Figure 7.10-6. Monthly average hydropower peaking capacity for GP1528, GP2028, GP1521, and GP2021.

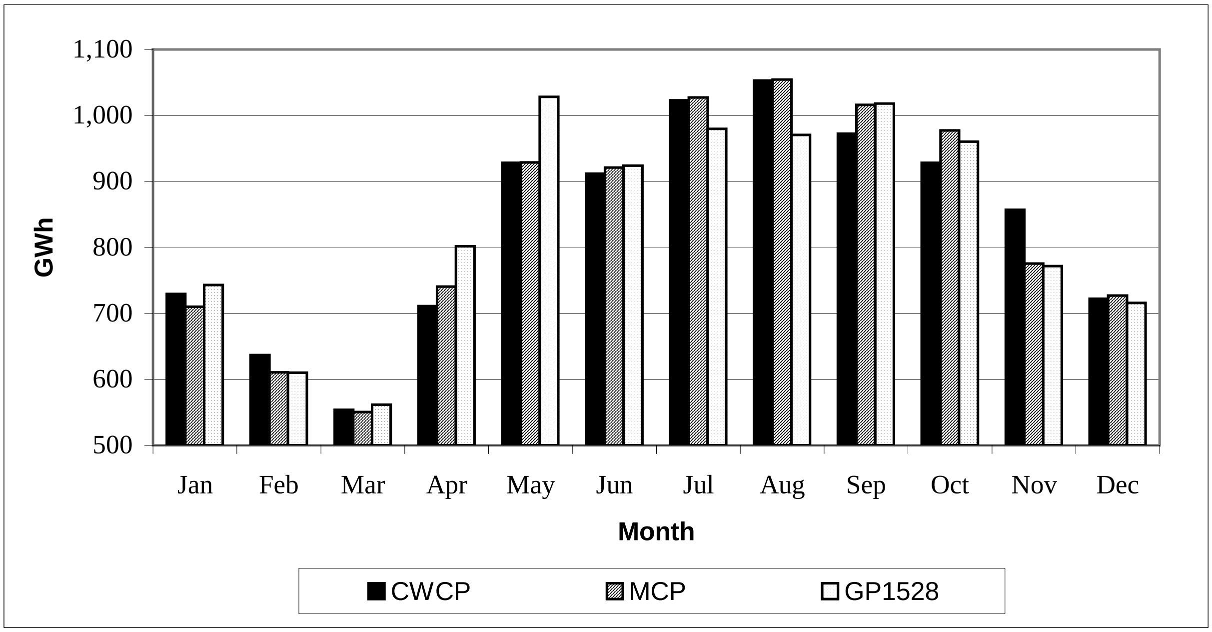

Figure 7.10-7. Monthly average hydropower energy values for CWCP, MCP, and GP1528.

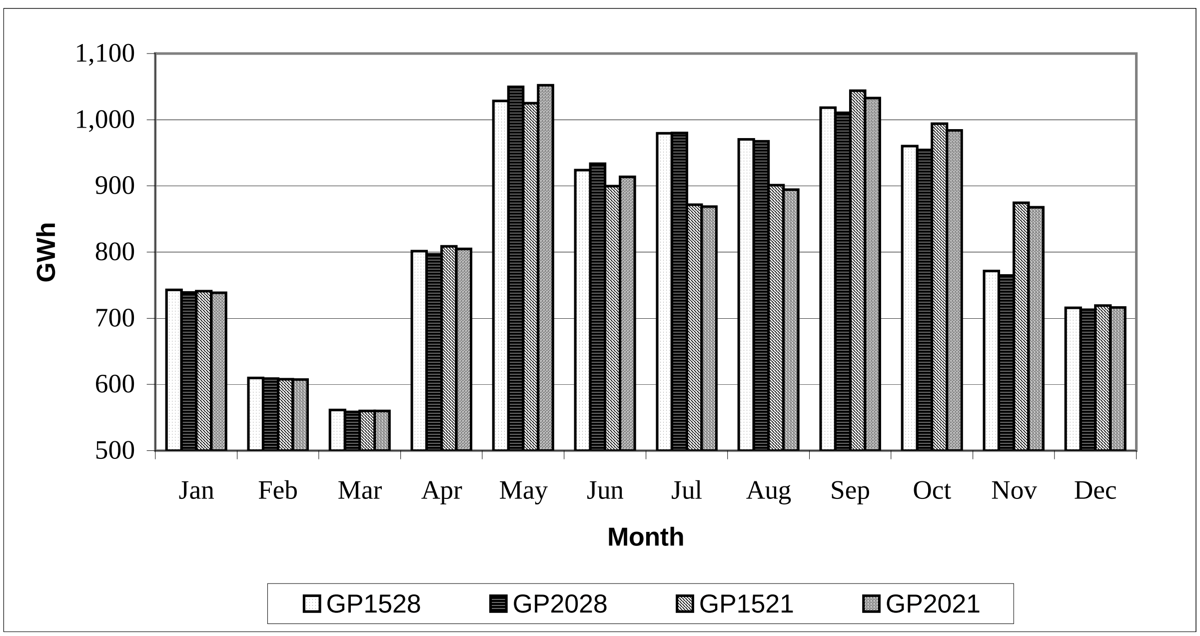

Figure 7.10-8. Monthly average hydropower energy values for GP1528, GP2028, GP1521, and GP2021.

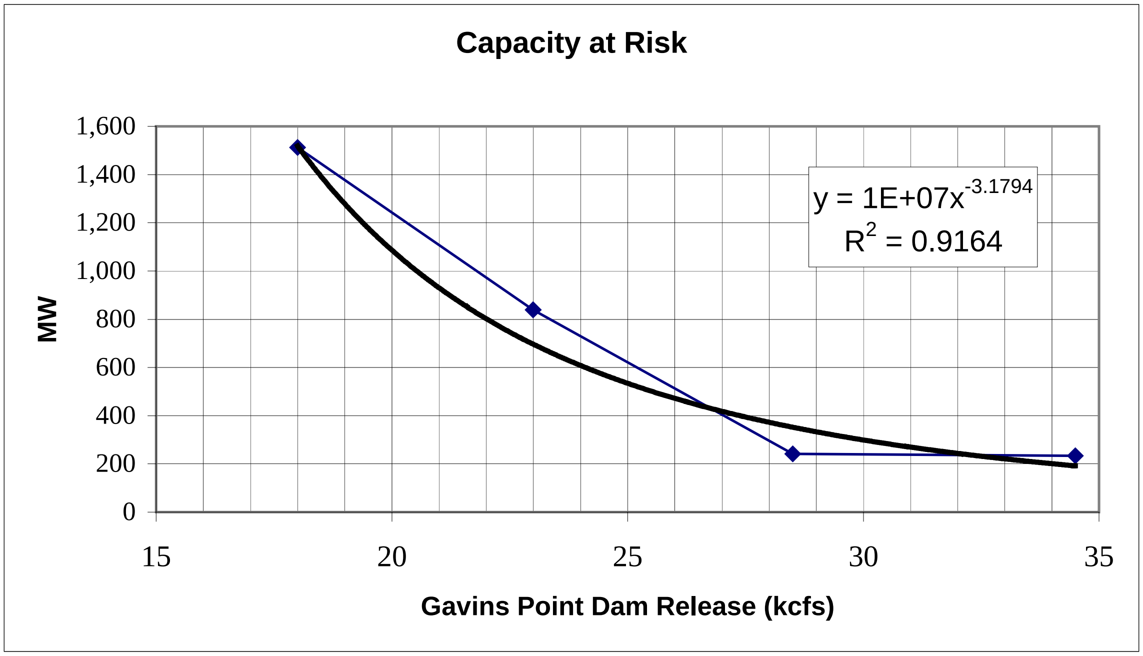

Figure 7.10-9. Missouri River thermal powerplants, capacity at risk in the summer (mid-June to mid-September).

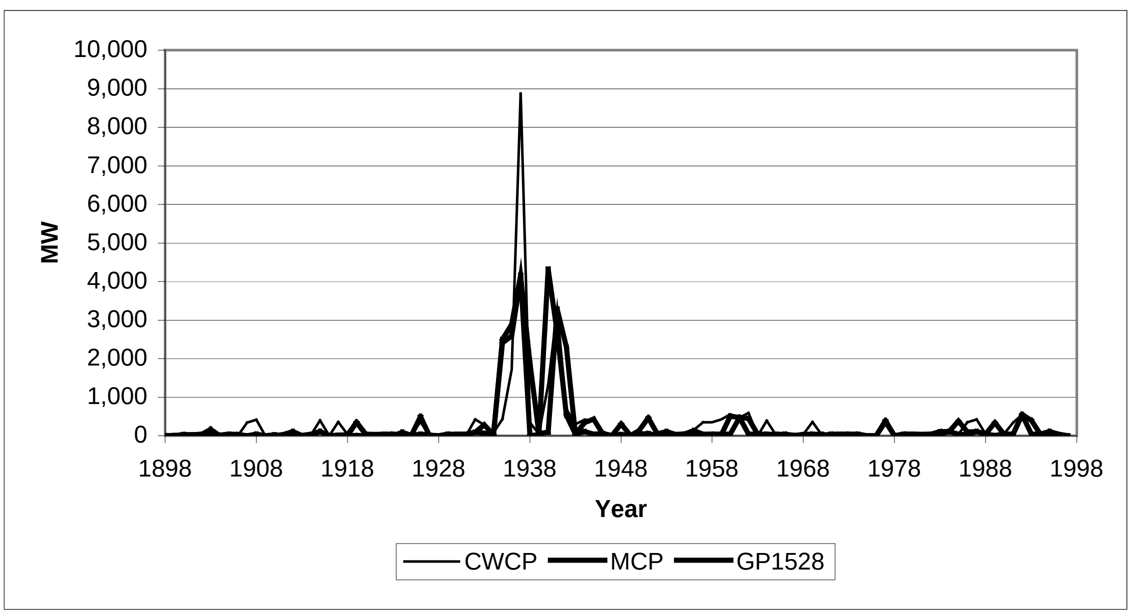

Figure 7.10-10. Potential capacity loss for CWCP, MCP, and GP1528 in the summer (mid-June to mid- September).

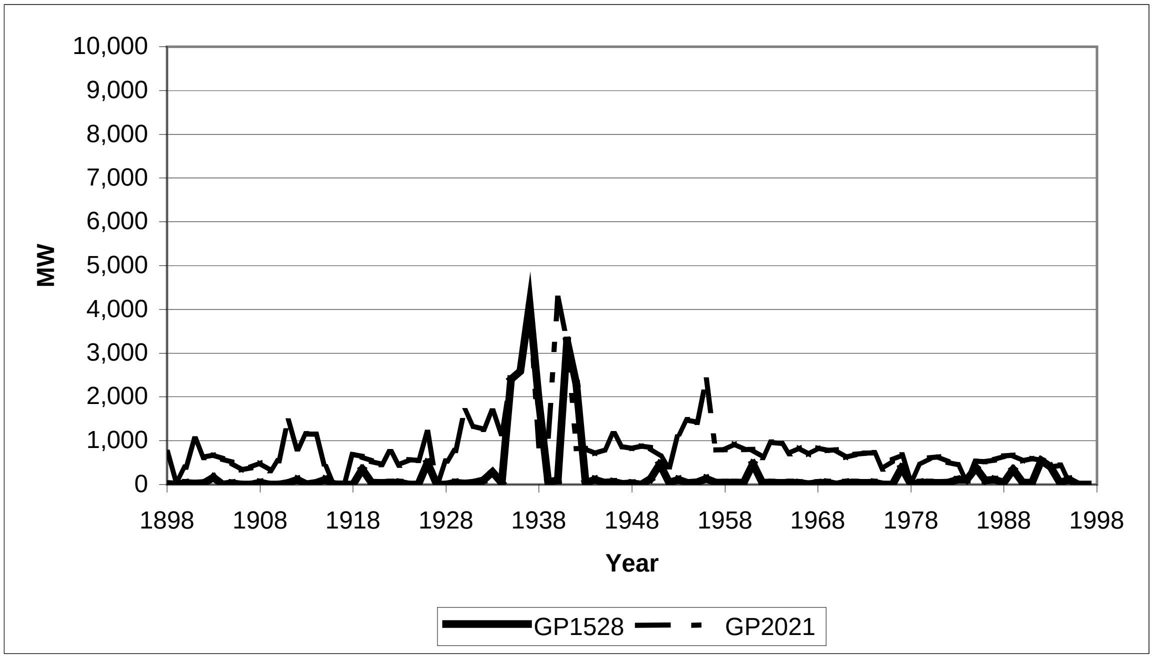

Figure 7.10-11. Potential capacity loss for GP1528 and GP2021 in the summer (mid-June to mid-September).

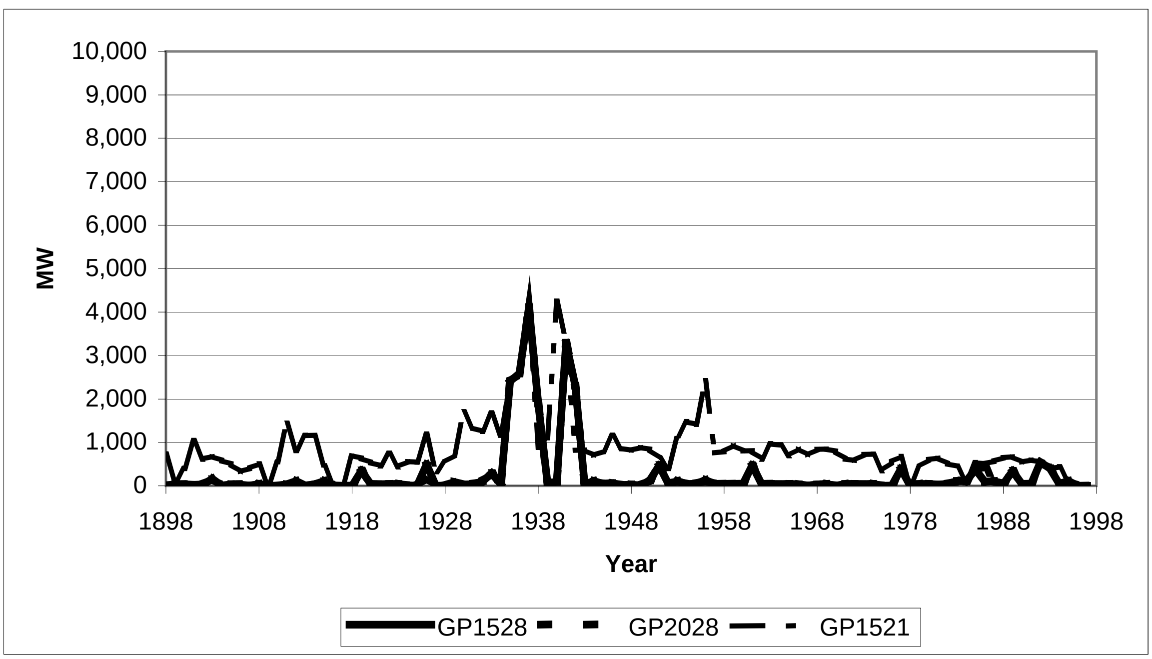

Figure 7.10-12. Potential capacity loss for GP1528, GP2028, and GP1521 in the summer (mid-June to mid-September).

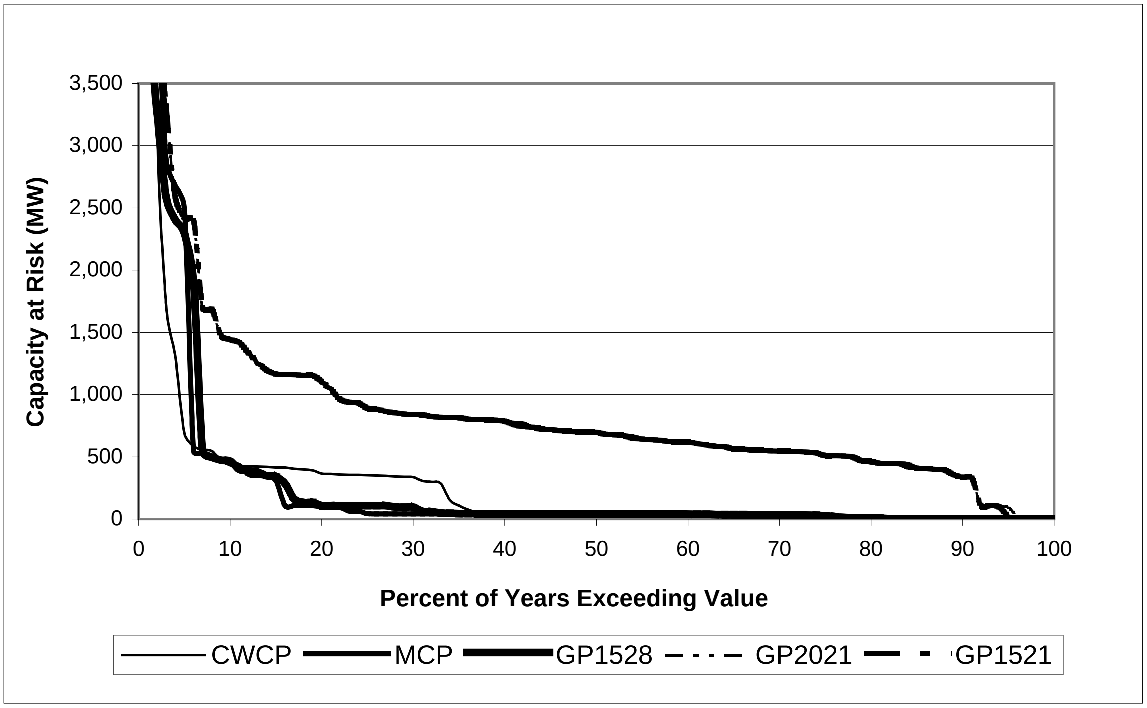

Figure 7.10-13. Potential thermal capacity at risk in the summer (mid-June through mid-September) duration plot.

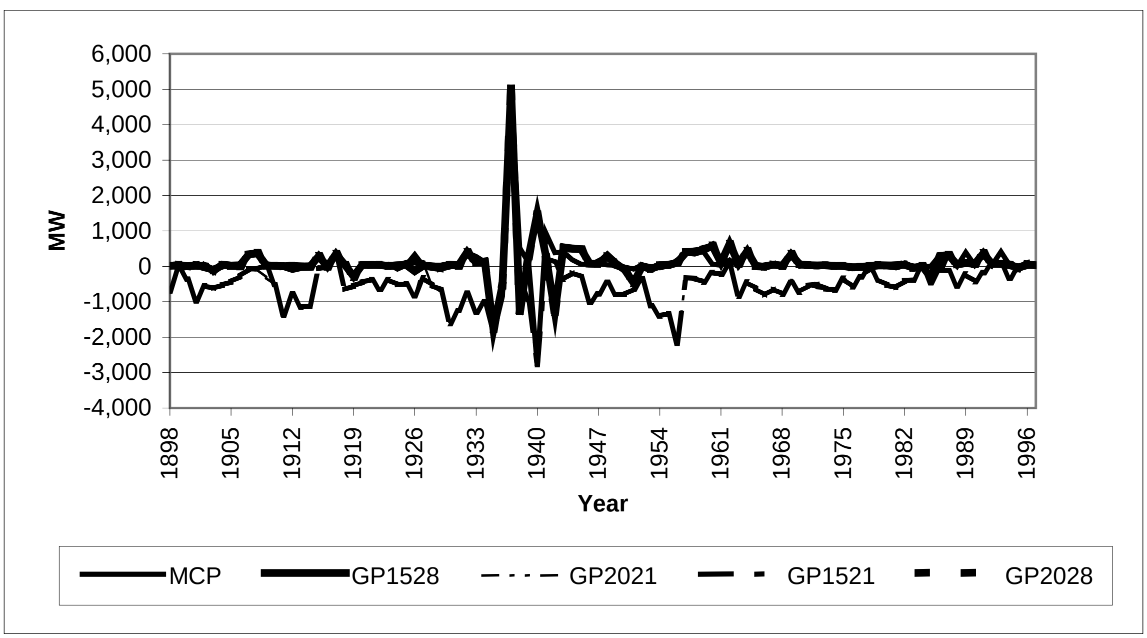

Figure 7.10-14. Total hydropower (in July) and thermal power capacity change from CWCP in the summer (mid-June to mid-September).

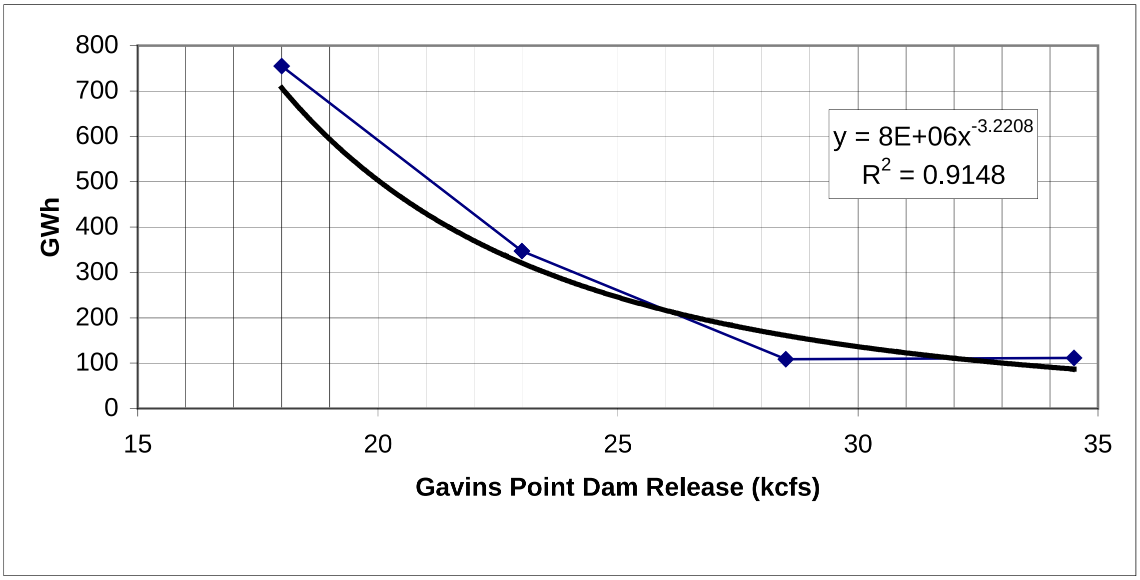

Figure 7.10-15. Missouri River thermal powerplants, energy at risk in the summer (mid-June to mid-September).

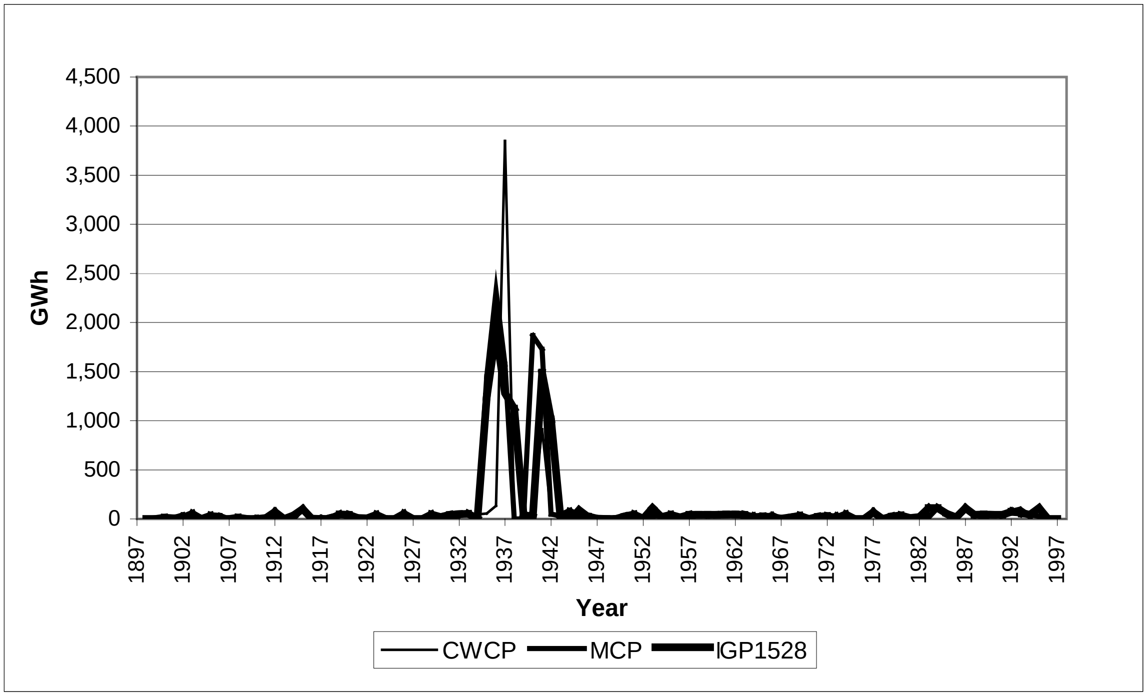

Figure 7.10-16. Potential thermal-generated energy loss for CWCP, MCP, and GP1528 sometime from mid-June through mid-September.

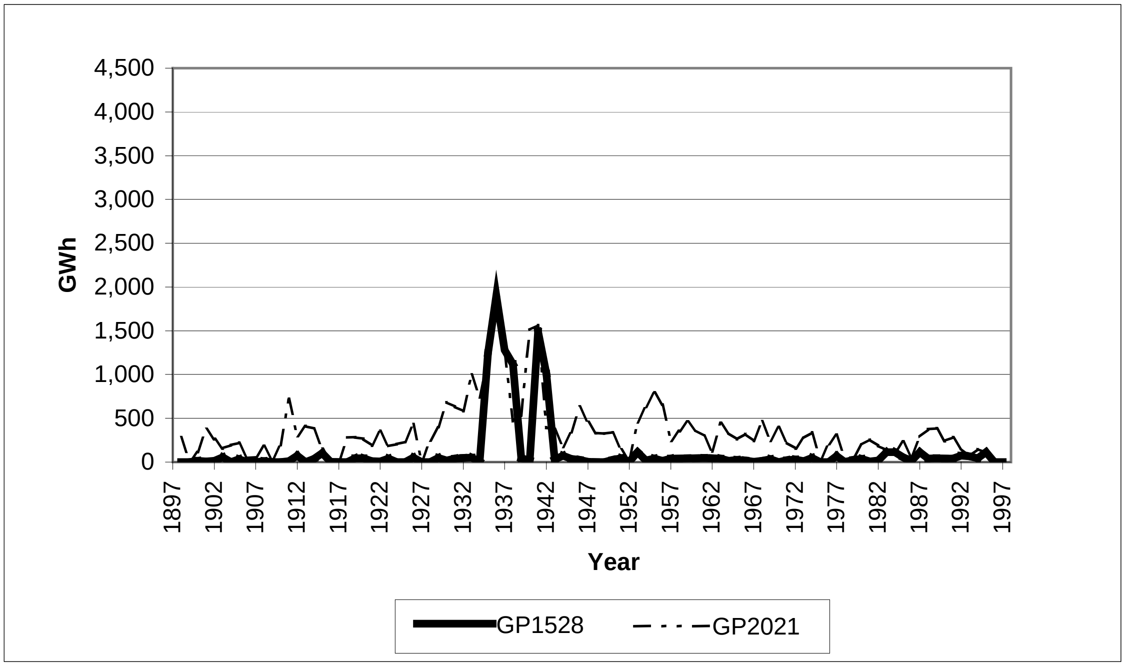

Figure 7.10-17. Potential thermal-generated energy loss for GP1528 and GP2021 from mid-June to mid-September.

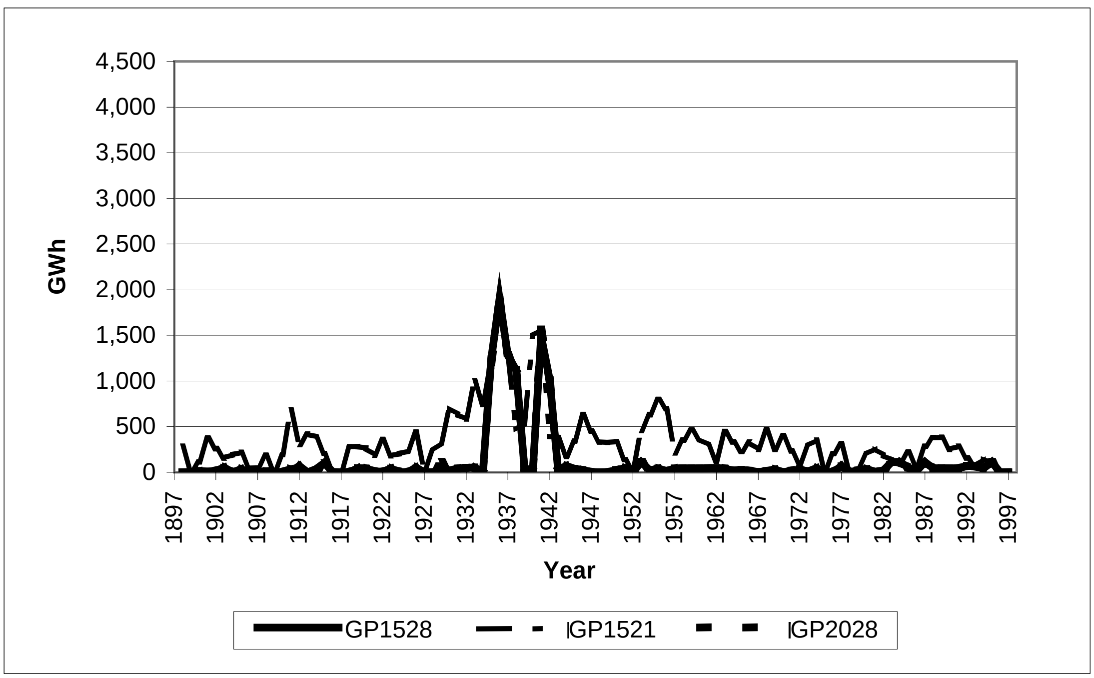

Figure 7.10-18. Potential thermal-generated energy loss for GP1528, GP2028, and GP1521 sometime from mid-June through mid-September.

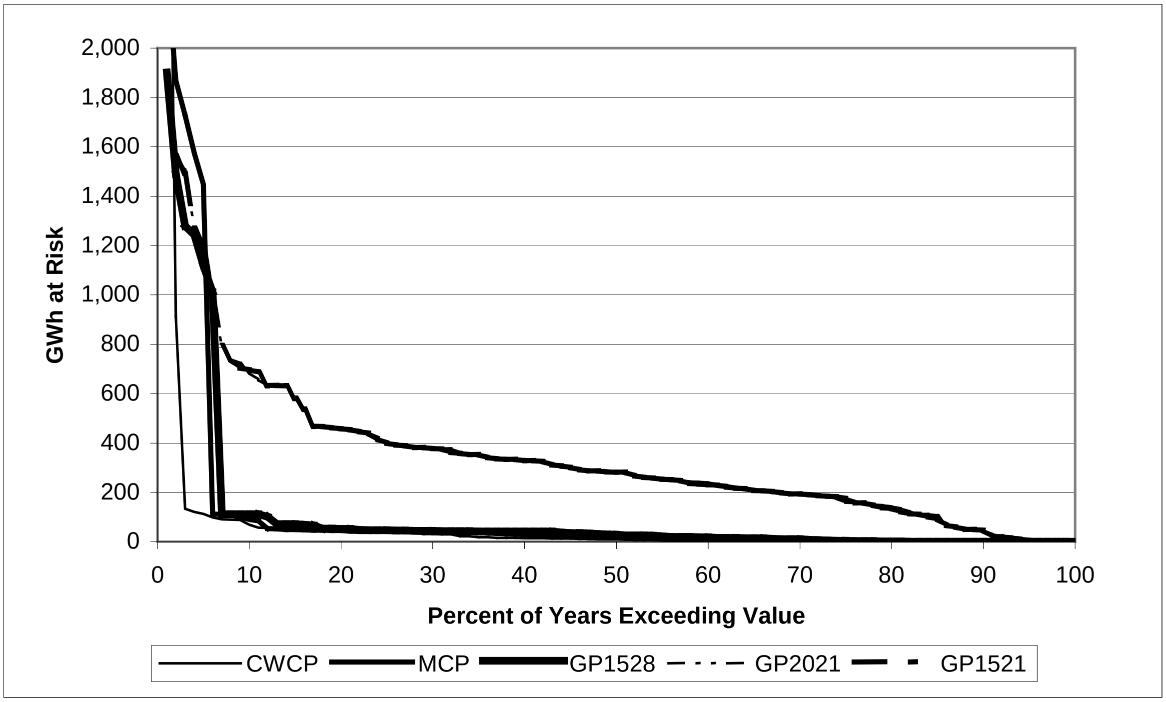

Figure 7.10-19. Thermal energy at risk from mid-June through mid-September, duration plot.

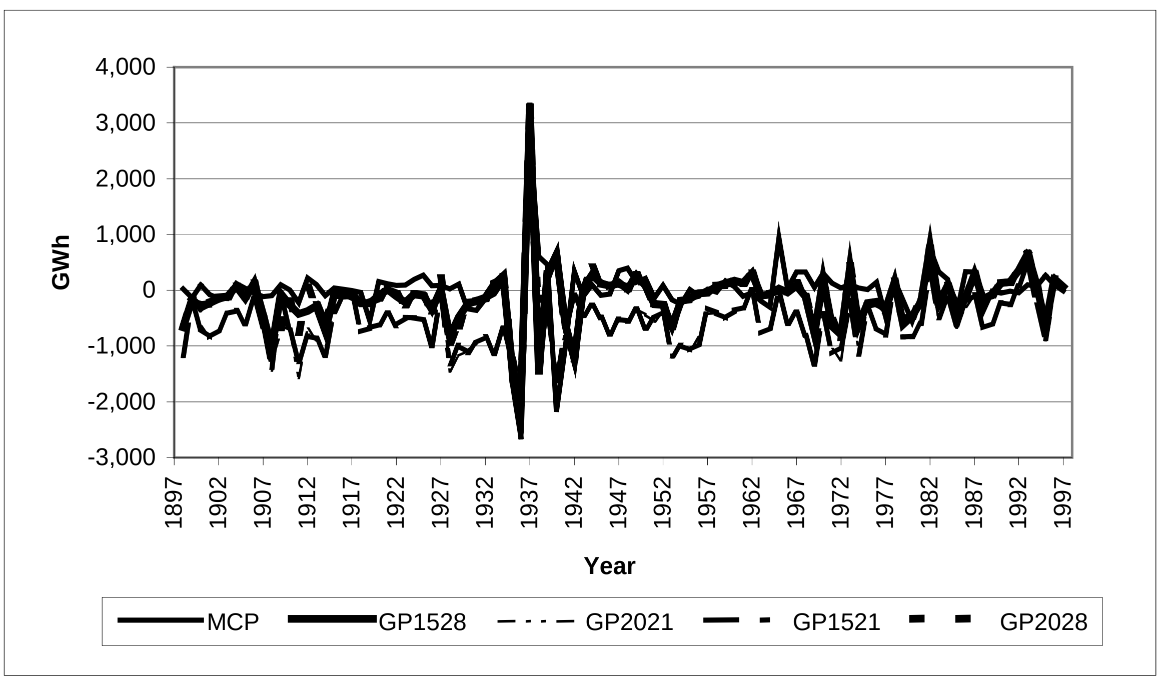

Figure 7.10-20. Total hydropower and thermal energy change from mid-June to mid-September from the CWCP.

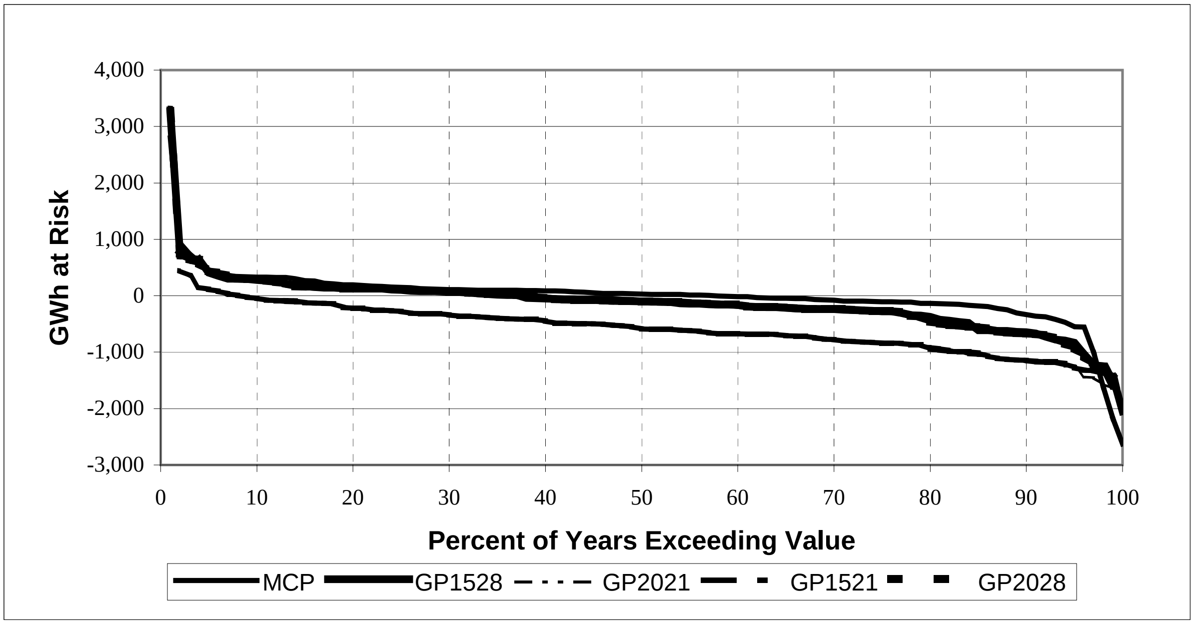

Figure 7.10-21. Total hydropower and thermal energy at risk from mid-June through mid-September, duration plot.

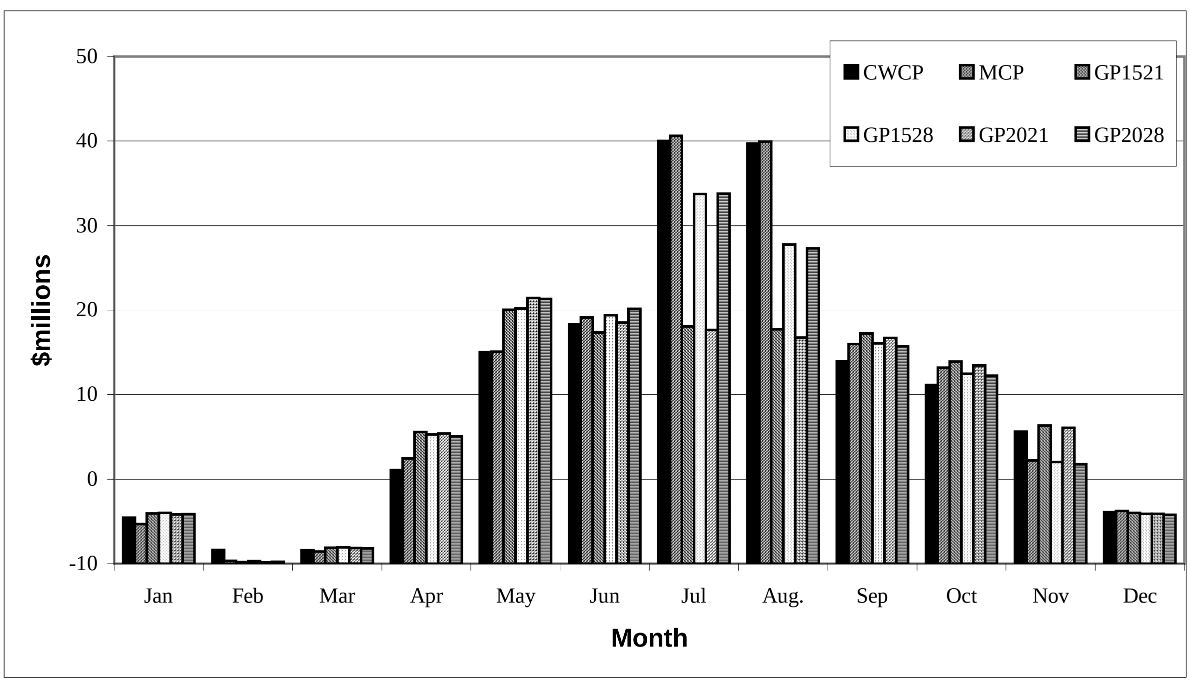

Figure 7.10-22. Net revenue: Pick-Sloan firm power marketing, 100-year monthly average at Cinergy Rates (Jan. 30, 2001).

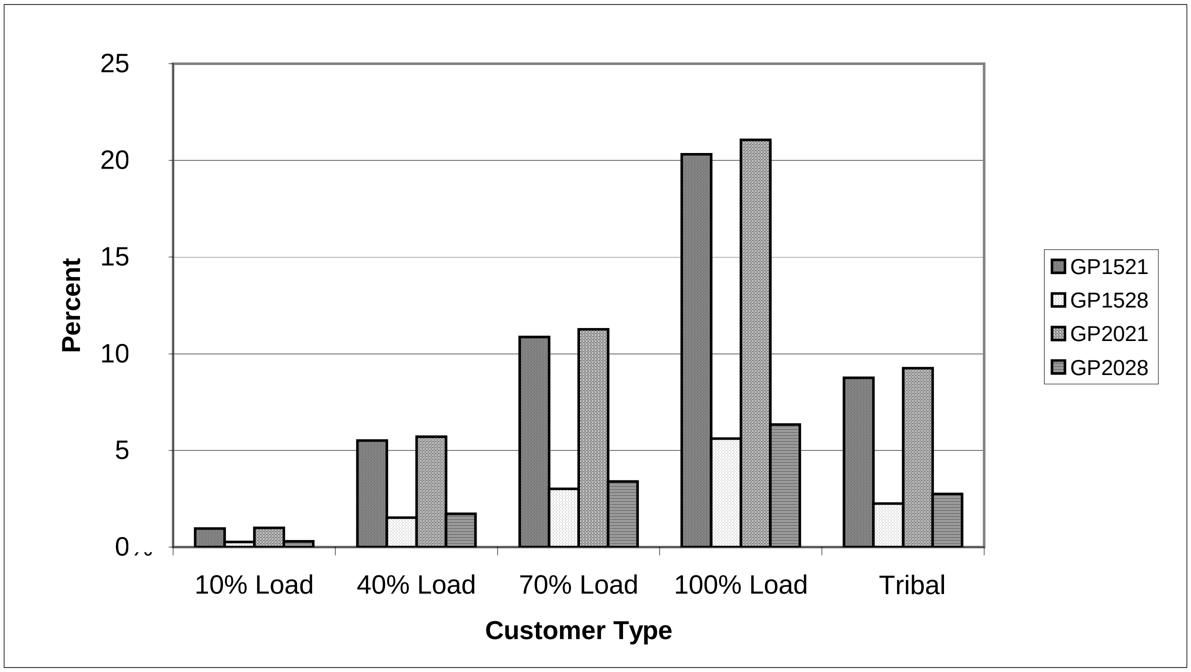

Figure 7.10-23. Percent increase in purchase power cost.

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7.11 RECREATION

Recreation is an important beneficial use of the Missouri River. These beneficial uses include both economic opportunities and improved quality of life for people living near or visiting the river. Each of the six lakes has recreation development and the river reaches between the lakes on the Lower River are used for recreation. Two important recreational activities related to the river include boating and fishing, both of which can be affected by water elevations. Under drought conditions, the river and lakes can become less accessible because boat ramps are not long enough to reach water. In addition to losing revenue caused by missed recreational opportunities, ramp owners may incur extra costs because of efforts to mitigate low water levels by extending ramps or building temporary access roads and ramps. Changes in water elevation (particularly during droughts) can also affect fishing success. Reductions in fishing and boating opportunities can reduce the number of people that visit the river and can also reduce the length of a visit to the river (Corps, 1994h).

The effects of the alternatives on recreation were evaluated based on the economic benefits, measured in millions of dollars. The economic benefits were estimated using the Daily Routing Model (DRM), a hydrologic model, and the Economic Impacts Model. The DRM (Corps, 1998b) estimates lake surface elevation and river flow at 23 reaches using the alternative operation strategies and the historic runoff levels between 1898 and 1997. The Economic Impact Model (Corps, 1994r) uses the output from the DRM and economic value functions for recreation benefits (Corps, 1994h) to estimate the economic benefit. The economic value functions for recreation benefits are computed by identifying changes in potential visitation, multiplying this visitation times composite values per visitation (one or more activities are usually associated with a visit), and subtracting any capital costs that may be incurred for facilities in each reach. Visitation computations are based on visitation surveys completed in the early 1990s (to determine changes in visitation based on lake-level and river-flow changes) and measured visitation in 1993. Capital costs are those that are incurred when facilities reach the end of their useful life and require replacement. Also included with the capital costs are the costs for boat ramp repairs and extensions required when lake levels drop. Finally, the resulting benefits were inflated by 12 percent to account for changes in visitation and costs since the early 1990s when the methodology was developed.

Recreation benefits presented in this section of Chapter 7 are National Economic Development (NED) benefits that reflect users' willingness to pay and include only entry and use fees. Consequently, the resulting values are somewhat less than if the values were Regional Economic Development benefits, which include the NED benefits plus other expenditures that are associated with recreation activities such as boat and equipment purchases, motel expenses, restaurant costs, etc. It is important to recognize that the estimated economic benefits are used for comparative purposes only and may not represent actual economic returns under the different alternatives. The models were designed expressly for comparing the effects of changing from the CWCP and not to forecast the future.

Figure 7.11-1 and Table 7.11-1 present the average annual recreation benefits under the alternatives during the 100-year analysis period. These benefits are also broken down for each of the reaches analyzed in Table 7.11-1. Total average annual recreation benefits for the alternatives range from $84.69 million (under the CWCP) to $88.68 million (under the GP2028 option), a difference of 4.7 percent.

The CWCP has a flat release of 34.5 kcfs from Gavins Point during spring and summer of most years; but during major droughts, this release is reduced to 28.5 kcfs. This operational pattern results in average annual recreation benefits of approximately $84.69 million, with 71.3 percent occurring in the mainstem lakes, 23.3 percent occurring along the Lower River reach, and 5.4 percent occurring along the Upper River reaches. This distribution of benefits along the river would not change substantially under any of the alternatives. All of the alternatives would result in

Table 7.11-1. Average annual recreation benefits ($millions).

Lake/River Reach	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Mainstem Lakes						
Fort Peck Lake	2.92	3.17	3.22	3.11	3.11	3.21
Lake Sakakawea	13.81	15.70	15.42	15.07	15.08	15.76
Lake Oahe	14.90	15.92	16.90	15.96	15.92	16.78
Lake Sharpe	7.97	7.97	7.97	7.97	7.97	7.97
Lake Francis Case	10.58	10.85	10.88	10.88	10.88	10.88
Lewis and Clark Lake	10.20	10.20	10.20	10.20	10.20	10.20
Lake Subtotal	**60.38**	**63.81**	**64.59**	**63.19**	**63.16**	**64.80**
Upper River						
Fort Peck	0.35	0.35	0.38	0.38	0.38	0.38
Garrison	3.24	3.15	3.17	3.17	3.18	3.17
Fort Randall	0.99	0.99	0.98	0.97	0.97	0.98
Upper River Subtotal	**4.58**	**4.49**	**4.53**	**4.52**	**4.53**	**4.53**
Lower River						
Gavins Point	5.10	5.06	5.01	4.84	4.86	4.99
Sioux City	11.45	11.39	11.21	10.91	10.95	11.18
St. Joseph	0.61	0.61	0.61	0.60	0.60	0.61
Kansas City	0.90	0.90	0.90	0.89	0.89	0.90
Boonville	0.71	0.71	0.71	0.71	0.70	0.71
Hermann	0.96	0.96	0.96	0.96	0.96	0.96
Lower River Subtotal	**19.73**	**19.63**	**19.40**	**18.91**	**18.96**	**19.35**
Total	**84.69**	**87.93**	**88.52**	**86.62**	**86.65**	**88.68**

greater total average annual benefits than the CWCP. Looking at individual lakes and river reaches, average annual recreation benefits from the alternatives range between about 5.1 percent below and 14.1 percent above the average annual benefits calculated for the CWCP. Under the alternatives, all of the lakes have either no change or an increase in recreation benefits relative to the CWCP. Benefits from the river reaches, except the Fort Peck reach, generally decline relative to the CWCP.

As depicted in Figure 7.11-1, all of the alternatives result in greater total average annual recreation benefits than the CWCP. The greatest increases occur under the two GP options that feature a 28.5-kcfs flat release from Gavins Point Dam, with GP2028 and GP1528 resulting in increases of $3.99 million and $3.83 million over the CWCP, respectively. The smallest increases occur under the GP1521 and GP2021 options, which result in increases of $1.96 million and $1.93 million, respectively. The MCP, with an increase of $3.24 million, falls between these groups. Increased drought conservation measures appear to have the most influence on recreation benefits because all of the alternatives feature these measures and all result in increases over the CWCP. The flat 28.5-kcfs summer release enhances this increase, but the variable (25/21-kcfs) summer release diminishes the increased benefits resulting from conservation measures.

To allow comparison of the effects of the alternatives addressed in this chapter to those of the submitted alternatives, Figure 7.11-1 includes the values for the alternatives addressed in Chapter 5. Of all the alternatives under consideration, the greatest benefits occur under the GP2028 option, closely followed by the GP1528 option.

The MCP, which features drought conservation measures similar to those of the MRBA and MODC alternatives, results in a similar level of recreation benefits. The BIOP alternative includes variable summer releases and a moderate spring rise, thus its recreation benefits are essentially the same as those provided by the GP options with the variable summer flow pattern (GP1521 and GP2021).

Under normal hydrologic conditions, the MCP operates the system similar to the CWCP, except that it includes unbalanced intrasystem regulation and a spring rise from Fort Peck Dam. Under drought conditions, however, navigation service levels under the MCP could be reduced to an 8-foot draft but could be as low as a 7.5-foot draft, and the navigation season could be reduced to 6 months depending upon the severity of the drought. Under the MCP, average annual benefits from recreation will be approximately $87.93 million, or $3.24

million higher than the CWCP. These benefit increases occur entirely in the mainstem lakes because of the availability of greater amounts of water for recreation. The MCP results in no benefit increases from any of the Upper or Lower River reaches; in most reaches no change occurs, and three reaches have decreases ranging from 0.5 percent (Sioux City reach) to 2.8 percent (Garrison reach) below the CWCP.

The GP options differ from the MCP by including spring rises and lower summer releases at Gavins Point Dam. The GP1528 option, the GP option with the lowest spring rise and the highest summer flows, includes a 15-kcfs spring rise and a 28.5-kcfs flat release during summer. Under this option, average annual recreation benefits are about $88.52 million, a 0.7 percent increase in total average annual recreation benefit, compared to the MCP. Increases from the mainstem lakes and the Upper River reaches compensate for decreases from two out of six Lower River reaches. Relative to the MCP, the greatest increase under the GP1528 option ($0.98 million) comes from Lake Oahe, and the greatest decrease ($0.28 million) comes from Lake Sakakawea. Among the river reaches, the greatest increase ($0.03 million) comes from the Fort Peck reach in the Upper River, and the greatest decrease ($0.18 million) comes from the Sioux City reach in the Lower River.

To provide a perspective for how recreation benefits could change in the future if changes are made to the GP1528 option, the following paragraphs describe differences in recreation benefits relative to the GP1528 option.

The greatest total average annual recreation benefits occur under the GP option with the higher spring rise and the higher summer low flow, the GP2028 option. Benefits under this option are 0.2 percent higher than under the GP1528 option, and 4.7 percent higher than under the CWCP. Benefits under the other two GP options are 2.1 percent lower than those under GP1528. The magnitude of summer releases appears to have the greatest influence on the relative effects of the four GP options. The total recreation benefits of the GP options with the 28.5-kcfs summer flow is about 2 percent higher than those of their counterparts with a split-season (25/21-kcfs) low flow. The effects of the spring rise from Gavins Point Dam are less consistent. The GP2028 option results in greater benefits than the GP1528 option, whereas the GP1521 option results in greater benefits than the GP2021 option.

The GP2021 option includes a 20-kcfs rise during the spring, and a provision for variable summer low flows (the 25/21 summer flow option). During the periods June 21 to July 15 and August 15 to August 31, Gavins Point releases are set to 25 kcfs. From July 15 to August 15, releases drop to 21 kcfs. According to the Economic Impact Model, the average annual recreation benefits under the GP2021 option are approximately $86.62 million, $1.90 million (2.1 percent) lower than the GP1528 option. Of all the alternatives addressed in this chapter, the GP2021 option results in the lowest level of recreation benefits from the Lower River reaches and the lowest level of total recreation benefits.

The GP1521 option includes a 15-kcfs rise during the spring and the 25/21-kcfs summer flow measure. Under this option, the average annual recreation benefits are $86.65 million, $1.87 million (2.1 percent) lower than the GP1528 option. Of the four GP options, GP1521 results in the lowest level of recreation benefits from the mainstem lakes, but slightly higher benefits than GP2021 from the Lower River reaches.

The GP2028 option includes a 20-kcfs rise during the spring and a flat 28.5-kcfs release during the summer, similar to GP1528. Under this option, the average annual recreation benefits are $88.68 million, $0.16 million (0.2 percent) higher than the GP1528 option. This is the highest level of total average annual recreation benefits of any of the alternatives addressed in this chapter. Of the four GP options, GP2028 results in the highest level of recreation benefits from the mainstem lakes, and the second-highest level of benefits from the Upper and Lower River reaches.

The major differences among the alternatives for recreation benefits occur during periods of drought. Figures 7.11-2 to 7.11-4 show a graphical depiction of annual recreation benefits over the 100-year analysis period. Higher drought conservation measures under the MCP and the GP options result in higher recreation benefits relative to the CWCP during the three major droughts. The greatest increase in recreation benefits comes from increased carryover storage in the upper three lakes, which improves accessibility for boating and fishing. The greatest difference is noted during the 1930 to 1941 drought and subsequent recovery period from the lake level declines. The sharpest decline and slowest recovery during this period occurs under the CWCP (Figure 7.11-2). The smallest decline and fastest recovery occurs under the GP2028 option (Figure 7.11-4).

7.11.1 Recreation for Tribal Reservations

Tables 7.11-2 and 7.11-3 allow comparison of how the different alternatives influence average annual recreation benefits for the affected Reservations during the 100-year period of analysis. Different data are available depending on the location of the Reservations. Effects to Reservations along river reaches are presented as an index of average annual recreation benefits, relative to the CWCP (Table 7.11-2). Effects to Reservations on the lakes are presented as average annual recreation benefits, measured in millions of dollars (Table 7.11-3). Changes in recreation benefits are discussed for each Reservation, starting with Fort Peck Reservation in Montana and proceeding downstream.

Fort Peck Reservation, downstream of Fort Peck Dam, currently has one boat ramp. No recreation areas identified along the Missouri River serve the Reservation. With future economic development in mind, the data in Table 7.11-2 indicate that, for the 100-year period analysis, the GP2021 option provides the maximum average annual recreation benefits to Fort Peck Reservation (9.0 percent). The other GP options provide increases of 8.0 percent, and the MCP results in no change from the CWCP.

Fort Berthold Reservation, located on Lake Sakakawea, has 15 recreation areas identified on Reservation land. These areas include two cabin developments, the McKenzie Marine Club and the New Town Marine Club. The CWCP provides $2.91 million in average annual recreation benefits. The data in Table 7.11-3 indicate that the GP2028 option provides the highest recreation benefits to the Fort Berthold Reservation at $3.33 million, a 14.4 percent increase over the CWCP. The MCP provides a 13.7 percent increase over the CWCP, and the GP1528 option provides an increase of 11.7 percent. The remaining two GP options (GP2021 and GP1521) both provide increases of 9.3 percent.

Four recreation sites have been identified on Standing Rock Reservation lands along Lake Oahe. The GP1528 and GP2028 options provide the largest increase in recreation benefits over the CWCP, which has a $0.42 million annual benefit (Table 7.11-3). The GP1528 and GP2028 options both provide a $0.05 million (11.9 percent) increase over the CWCP. The GP2021 and GP1521 options and the MCP all have a smaller increase of $0.03 million (7.1 percent) in average annual recreation benefits compared to the CWCP.

One recreation site has been identified on Cheyenne River Reservation. The average annual recreation benefits under any of the alternatives for Cheyenne River Reservation are less than $5,000. Recreation benefits less than $0.01 million are not shown in Table 7.11-3 due to rounding off to the nearest $10,000.

Table 7.11-2. Index of average annual recreation benefits to Reservations adjacent to Upper and Lower River reaches.

Reservation	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Fort Peck	1.00	1.00	1.08	1.09	1.08	1.08
Yankton/Ponca Tribal Lands	1.00	0.99	0.99	0.98	0.98	0.98
Winnebago	1.00	0.99	0.98	0.95	0.96	0.98
Omaha	1.00	0.99	0.98	0.95	0.96	0.98
Iowa and Sac and Fox	1.00	1.00	0.99	0.98	0.98	0.99

Table 7.11-3. Average annual recreation benefits for Reservations adjacent to lakes ($millions).

Reservation	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Fort Berthold	2.91	3.31	3.25	3.18	3.18	3.33
Standing Rock	0.42	0.45	0.47	0.45	0.45	0.47
Cheyenne River	0.00	0.00	0.00	0.00	0.00	0.00
Lower Brule	2.94	2.94	2.94	2.94	2.94	2.94
Crow Creek	1.41	1.41	1.41	1.41	1.41	1.41
Yankton	1.38	1.40	1.41	1.41	1.41	1.41
Santee	0.17	0.17	0.17	0.17	0.17	0.17
Total	**9.23**	**9.68**	**9.65**	**9.56**	**9.56**	**9.73**

Lower Brule and Crow Creek Reservations, located on Lake Sharpe, have no change in average annual recreation benefits under any alternative (Table 7.11-3). For the 100-year period of analysis, there are roughly $2.94 million in benefits for Lower Brule Reservation and $1.41 million in average annual recreation benefits for Crow Creek Reservation. Lower Brule Reservation has 10 existing recreation facilities identified on Reservation land, with one identified future site. There are seven existing recreation facilities located on Crow Creek Reservation.

Yankton Reservation has five recreation areas located on Lake Francis Case. The CWCP provides $1.38 million in average annual recreation benefits for Yankton Reservation (Table 7.11-3). The four GP options all provide increases of $0.03 million (2.2 percent) in average annual recreation benefits compared to the CWCP. The MCP increases average annual recreation benefits by about $0.02 million (1.4 percent) compared to the CWCP.

The data for the Fort Randall reach, which includes the majority of Yankton Reservation banks, indicate that all of the alternatives produce decreases in average annual recreation benefits compared to the CWCP (Table 7.11-3). The smallest decreases (1.0 percent) occur under the MCP and the GP1528 option. The other three GP options have a larger decrease of 2.0 percent.

Ponca Tribal Lands are located near the headwaters of Lewis and Clark Lake, and the Tribe currently has no recreation facilities on the lake or along the upstream river reach. If the Tribe were to develop facilities along the river, it could expect to have effects similar to that described above for Yankton Reservation banks along the Fort Randall reach. The Ponca Tribal Lands, therefore, are included in Table 7.11-2 with Yankton Reservation.

Santee Reservation, located on the headwaters of Lewis and Clark Lake, has two identified recreation areas. No change in average annual recreation benefits occur under any alternative (Table 7.11-3). For the 100-year period of analysis, all alternatives result in roughly $0.17 million in average annual recreation benefits for Santee Reservation.

Potential recreation development and use along Winnebago Reservation and Omaha Reservation are included in Table 7.11-2. The CWCP offers the greatest benefits for recreation development. On both Reservations, the GP2021 option has the largest decrease in average annual recreation benefits with a 5.0 percent decrease compared to the CWCP. The MCP, with a 1.0 percent decrease in recreation benefits compared to the CWCP, has the smallest decrease. The GP1528 and GP2028 options both result in decreases of 2.0 percent, and the GP1521 option has a decrease of 4.0 percent.

Along the St. Joseph reach, recreation development on either Iowa and Sac and Fox Reservations will be affected by the water control plans. The recreation benefits index in Table 7.11-2 indicates no change from the CWCP under the MCP. A decrease of 1.0 percent in average annual recreation benefits occurs under the GP1528 and GP2028 options, and a decrease of 2.0 percent occurs under the GP2021 and GP1521 options.

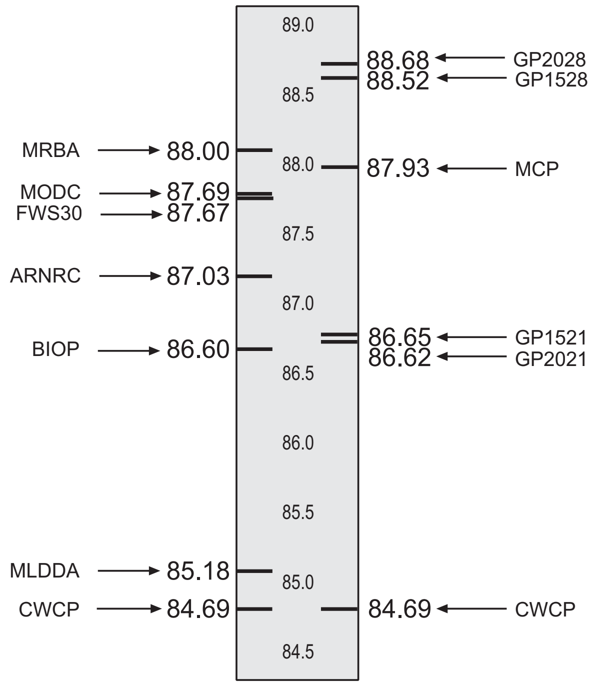

Figure 7.11-1. Average annual recreation benefits for submitted alternatives and the alternatives ($millions).

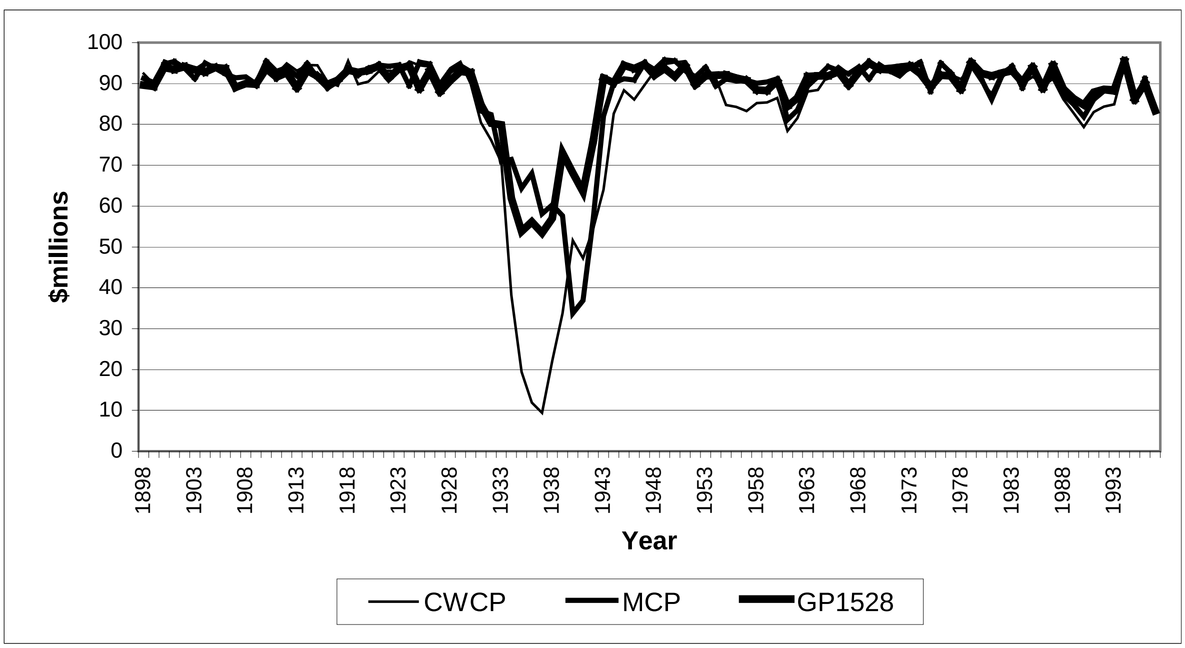

Figure 7.11-2. Annual values for recreation benefits for CWCP, MCP, and GP1528.

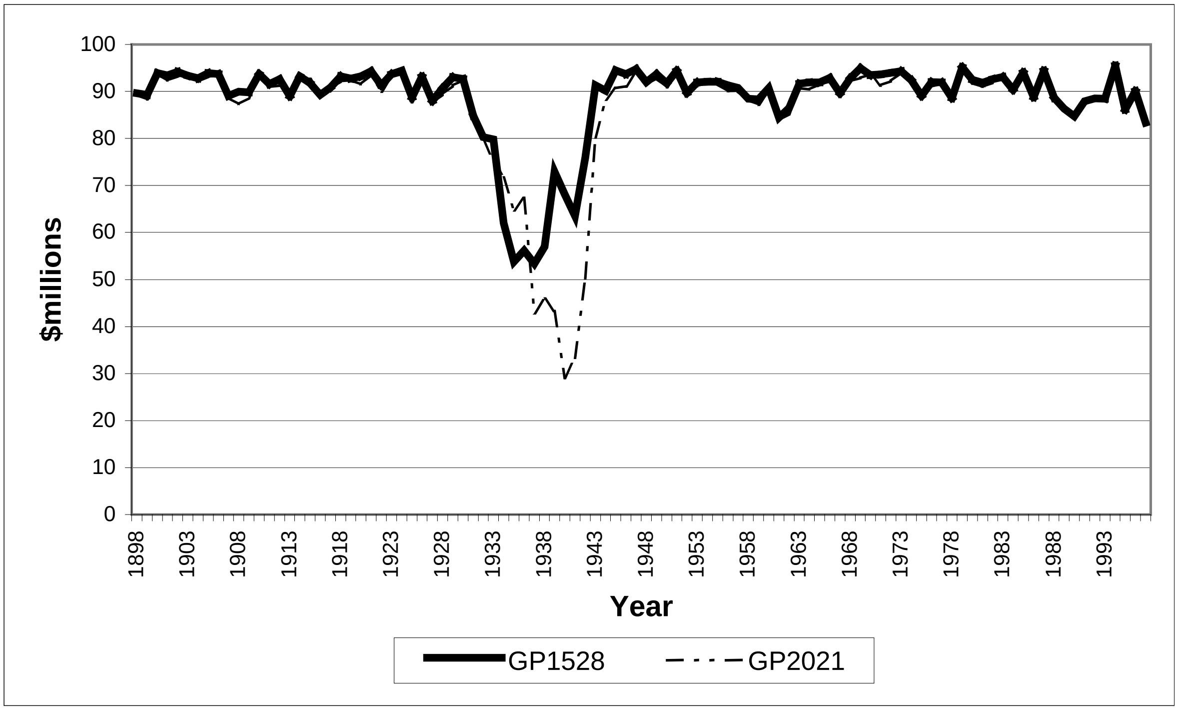

Figure 7.11-3. Annual values for recreation benefits for GP1528 and GP2021.

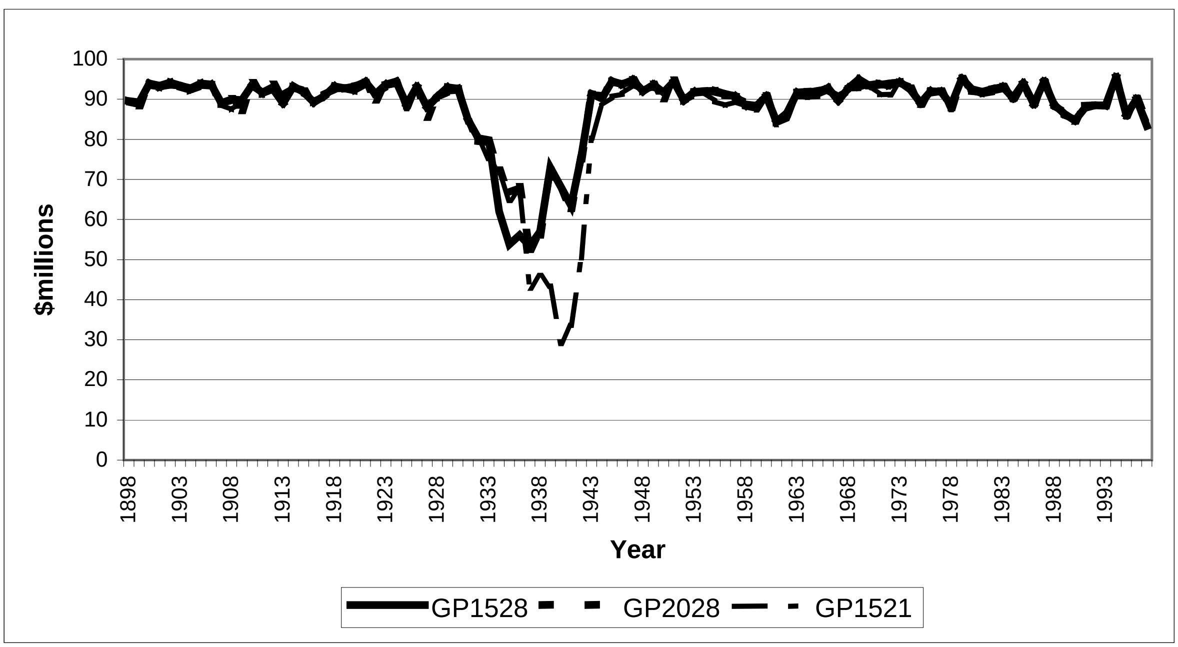

Figure 7.11-4. Annual values for recreation benefits for GP1528, GP2028, and GP1521.

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7.12 NAVIGATION

Navigation on the lower 735 miles of the Missouri River from Sioux City to St. Louis is determined in part by controlled releases from Gavins Point Dam. Changes in several of the criteria making up the alternatives discussed in this chapter affect Gavins Point Dam releases and navigation in differing ways. The drought conservation criteria change how navigation service is affected during droughts in terms of level of service flow support and minimum season lengths. The changes in Gavins Point Dam releases for endangered species affect how navigation is served in the non-drought periods. Two of the alternatives discussed in this chapter eliminate service to navigation for 2 months or longer in the June through August timeframe. This section of Chapter 7 describes the changes in navigation benefits that occur for these changes in the system operation.

Navigation benefits are computed based on the cost reduction the navigation industry provides to the Nation. Alternative modes of transportation can move the commodities that the navigation industry moves on the Missouri River; however, these other modes of transportation would move these commodities at a higher cost. For the RDEIS, the navigation benefits were computed by taking the difference in cost between the next highest costs and the costs of moving the various commodities by barge on the Missouri River from their various origins to the destinations for the commodities moved in 1994. This analysis derived the value per ton of each commodity moved that year by the barge operators on the Missouri River. The details of how these unit values were determined and the breakdown of the annual tonnage moved among the commodities are detailed in the Economic Studies—Navigation Economics (Revised) technical report (Corps, 1998c). This technical report also discusses how the operation and maintenance costs were deducted from the cost savings benefits to arrive at the navigation benefits presented in this section.

The Tennessee Valley Authority conducted an update on the navigation analysis following the release of the RDEIS using 1999 data on navigation movements on the Missouri River. The primary reason for this re-analysis was to better understand the potential impacts of having reduced summer flows, especially those that would require the suspension of navigation during the period from mid-June through mid-September (when the increased releases make it to the Missouri River mouth near St. Louis). Results of this analysis were documented in a report by the Tennessee Valley Authority (TVA, 2002). A primary finding of this analysis was that navigation could continue on the Missouri River even with a split navigation season. Another important finding was that navigation benefits would be dramatically lower in minimum service years. Overall, this analysis determined that navigation benefits (transportation cost savings) had gone up since the previous analysis. The updated numbers were incorporated into the analysis of Missouri River navigation benefits for the FEIS. Also, commercial navigation benefits associated with the movement of passengers on casino and sightseeing vessels were incorporated into the analysis.

The navigation benefits for the Chapter 7 alternatives are presented in Table 7.12-1 and shown in Figure 7.12-1. Figure 7.12-1 shows total average annual navigation benefits for each of the alternatives discussed in this chapter (right side of figure) and for the submitted alternatives from Chapter 5 (left side of figure). Table 7.12-1 presents the same average annual navigation benefits data for the Chapter 7 alternatives as well as the navigation benefits by the individual reaches for the full period of analysis from 1898 to 1997.

Table 7.12-1. Average annual Missouri River navigation benefits ($millions).

Alternative	Total	Sioux City	Omaha	Nebraska City	Kansas City
CWCP	**8.80**	1.20	0.91	0.66	6.03
MCP	**9.26**	1.34	1.03	0.83	6.06
GP1528	**5.78**	0.70	0.54	0.14	4.40
GP2021	**5.62**	0.68	0.24	0.16	4.54
GP1521	**5.86**	0.68	0.27	0.20	4.71
GP2028	**5.46**	0.66	0.49	0.09	4.21

The CWCP outperforms all of the other alternatives except the MCP, with average annual navigation benefits of $8.80 million. The majority (68.5 percent) of these benefits occur in the Kansas City reach that extends from Kansas City to the mouth ($6.03 million). Moving upstream, 7.5 percent of the benefits are in the Nebraska City reach, 10.3 percent are in the Omaha reach, and 13.6 percent are in the Sioux City reach.

Figure 7.12-1 shows that the alternatives cluster into two basic groupings. The MCP has benefits similar to the CWCP, while the GP options show reduced benefits. The GP1528 and GP2028 options have very similar benefits and average about 40 percent lower in value compared to the CWCP.

Figure 7.12-1 also presents the navigation benefits for the submitted alternatives discussed in Chapter 5 on the left side of the bar plot. The BIOP, ARNRC, and FWS30 alternatives have benefits very similar to the four GP options. This is appropriate because all seven of the alternatives have spring rises followed by reduced summer flows and similar (ARNRC alternative has slightly higher) drought conservation measures, which result in similar benefits. The MCP and the CWCP have benefits similar to the MRBA and MODC alternatives, and this again is appropriate because there is very little difference between the MRBA and MODC alternatives and the MCP in terms of releases from Gavins Point Dam. The MCP and MODC alternatives have a Fort Peck spring rise and the MRBA alternative does not, which should not affect Gavins Point Dam releases.

The MCP differs from the CWCP in that it has greater conservation during droughts. This difference has very little net impact on the average annual navigation benefits. The total navigation benefits of the MCP are slightly higher but very close to the CWCP at $9.26 million per year, an increase of $0.46 million per year (a 5.2 percent increase). The MCP values include increases for all four reaches, ranging from an increase of 26.6 down to 0.5 percent for Kansas City compared to the CWCP. The increases in navigation benefits, when compared to the CWCP, demonstrate that the increased service level and longer minimum season length (set at 7.1 months for all seasons with navigation) are beneficial for Missouri River navigation.

Also considered in this chapter are the four GP options (GP1528, GP2021, GP1521, and GP2028). The GP1528 option serves as the potential starting point for comparison against the MCP because its spring and summer releases are closest to the release during the same timeframe for the CWCP. The other GP options represent the range in changes from GP1528 that could be made under adaptive management without going through the NEPA process again.

The GP1528 option has the conservation features of the MCP and includes a Gavins Point Dam spring rise of 15 kcfs over full service navigation levels during non-drought periods and during the first year of a drought unless downstream flooding is imminent or occurring. It also provides for a flat release from Gavins Point Dam of 28.5 kcfs from June 21 to August 31, which is 6 kcfs less than the full service release included in the CWCP. The GP1528 option's benefits are $5.78 million per year, which are $3.48 million (37.5 percent) lower per year than the benefits for the MCP. This reduction in benefits is due primarily to the reduced summer flows. Benefits decrease in all reaches of between 27.1 and 78.7 percent compared to the MCP benefits.

The GP2021 and GP1521 options have a 25/21-kcfs split season option for summer flows. This includes a 25-kcfs flow from June 21 to July 15, then 21 kcfs from July 16 to August 15, and 25 kcfs again from August 16 to September 1. The GP2021 option's potential navigation benefits total $5.62 million per year. If the GP1528 option were selected sometime in the future, these benefits represent a reduction in total benefits of 2.8 percent compared to the benefits for the GP1528 option. The benefits increase in the Nebraska City and Kansas City reaches by 14.2 and 3.3 percent, respectively; however, they decrease in the Sioux City and Omaha reaches by 2.9 and 56.7 percent, respectively. Slightly different responses occur for the GP1521 option with the total percentage changes from the benefits of the GP1528 option being an increase of 1.3 percent and the individual reach changes being negative in the Sioux City and Omaha reaches (-2.9 and -50.3, respectively) and positive in the Nebraska City and Kansas City reaches (42.1 and 7.1 percent, respectively). The amount of the spring rise makes a slight difference in the effects of the alternatives on navigation benefits.

The GP2028 option is the same as the GP1528 option except that it has an increased Gavins Point Dam spring rise of 20 kcfs. The benefits of this option are $5.46 million per year, slightly lower than for the GP1528 option (a 5.7 percent decrease). The decreases in the individual reaches from the values for the GP1528 option range from a decrease of 4.2 percent to as much as a decrease of 37.5 percent. This, again, demonstrates that the amount of the spring rise has an effect on the navigation benefits, with the benefits decreasing as the spring rise value increases.

Table 7.12-2 summarizes navigation service level and season length expressed in years for the alternatives discussed in this chapter. Operation of the Missouri River Mainstem Reservoir System for navigation includes two check points for determining navigation service level and season length: the March 15 check and the July 1 check. Navigation service levels can range from full service to minimum service (6 kcfs less than full service). Navigation season length can range from 5.5 to 8.33 months. In addition, navigation support is suspended in years where the system storage falls below the navigation preclude level (31 MAF for the MCP and the GP options).

The CWCP provides full or partial service for 80 and 75 years for the March 15 and July 1 checks, respectively, and only one no-service year (1937) for the 100-year period of analysis. Note that navigation service levels of full service to minimum service represent a difference of 1 foot of draft (8.5 versus 7.5 feet). Under the CWCP, navigation season length can range from 5.5 to 8.33 months. The CWCP has 91 years where the season length is 8 months or longer out of the 99 years that navigation was possible. This is markedly greater than the other alternatives.

The MCP differs from the CWCP in that it has greater conservation during droughts. The navigation service levels remain higher throughout the droughts compared to the CWCP by limiting the reduction in service by only 3 kcfs in many years. A cutback to minimum service occurs in 8 years when there is no gain in the amount of water in system storage between the two checks. To offset the extra water used for the higher service levels, the navigation season length was cut at the same storage level as the cutback was made to service level, the top of the CWCP navigation guide curves for both checks. The resulting conservation is also reflected in more 7.0- to 7.5-month navigation seasons compared to the CWCP (Table 7.12.2), but fewer navigation seasons of 8 months or greater. The minimum season length for the MCP is 7.1 months instead of declining like the CWCP to as little as 5.5 months during the 1930 to 1941 drought.

The GP1528 option has the conservation attributes of the MCP and includes a Gavins Point Dam spring rise of 15 kcfs over full service navigation levels during many non-drought years and during the first year of the three extended droughts, unless downstream flooding is imminent or occurring. It also provides for a flat release from Gavins Point

Table 7.12-2. Summary of navigation service level and season length data (years).

1898 to 1997	CWCP	MCP	GP1528*	GP2021*	GP1521*	GP2028*
Service Level						
March Check						
Full	56	63	68	68	69	67
Partial	24	25	18	19	19	19
Minimum	19	7	8	8	7	8
No Service	1	5	6	5	5	6
July Check						
Full	59	60	64	64	65	63
Partial	16	27	20	22	22	21
Minimum	24	8	10	9	8	10
No Service	1	5	6	5	5	6
Season Length						
5.5 to < 6 Months	5	0	0	95	95	0
6.0 to < 6.5 Months	2	0	0	0	0	0
6.5 to < 7.0 Months	1	0	0	0	0	0
7.0 to < 7.5 Months	0	35	30	0	0	30
7.5 to < 8 Months	0	0	0	0	0	0
8 Months	45	10	11	0	0	11
8.33 Months	46	50	53	0	0	53

* The service levels for the mid-June through mid-September time frame may be less than specified. For those with a 28 for the two characters in the alternatives name, minimum service would be provided during this period, and for those with a 21, the Gavins Point Dam releases would not support navigation during this period.

Dam of 28.5 kcfs from June 21 to August 31, which is 6 kcfs less than the full service release included in the CWCP and 3 kcfs less than allowed in the remainder of the navigation season in many drought years. At the March 15 check, there are 5 more years with full service than with the MCP, bringing the years of full service at the March check to 68 of the 100 years studied. Based on the March 15 check, the GP1528 option provides for 86 full service or partial service years, while the MCP provides for 88 years. The summer low flow in the GP1528 option results in having 84 years with full or partial service at the July 1 check compared to 87 years for the MCP. This reflects the fact that flows will bump back up 3 kcfs to partial service or 6 kcfs to the full service level on September 1 in 84 years. This alternative has 4 more years with navigation season length greater than 8 months long for GP1528 (64 years compared to 60 years for the MCP). The minimum navigation season is 7.1 months, the same as the MCP.

For the GP2021 option, the navigation service levels at the March check are virtually the same as GP1528, but the July 1 check shows 86 years with full or partial service compared to 84 years for the GP1528 option. There are 5 years with no service, which is similar to the GP1528 option. The split season results in shorter navigation season lengths. The GP2021 option has a season length of only 5.5 to 6 months in all 95 years with service, compared to 64 years with at least 8 months of service in the GP1528 option. Similar results occur for the GP1521 option as occurred in GP2021. The navigation season ends November 23 in drought years.

The navigation service levels and season length are virtually the same for the GP2028 option as they are for the GP1528 option. The additional release of 5 kcfs in the spring rise does not have a significant effect on service level and season length.

Annual benefits for the 100-year simulation period for the CWCP and the submitted alternatives are shown in Figures 7.12-2 to 7.12-4. These figures show that the most noticeable difference among the alternatives occurs in the non-drought periods. This indicates that the spring rises and lower summer releases from Gavins Point Dam that are provided during the mid-June through August timeframe are both factors that cause the differences among the alternatives, with the lower summer releases being the dominant factor. There are less dramatic differences during the three major droughts, with the differences in the 1930 to 1941 drought being the greatest of the three.

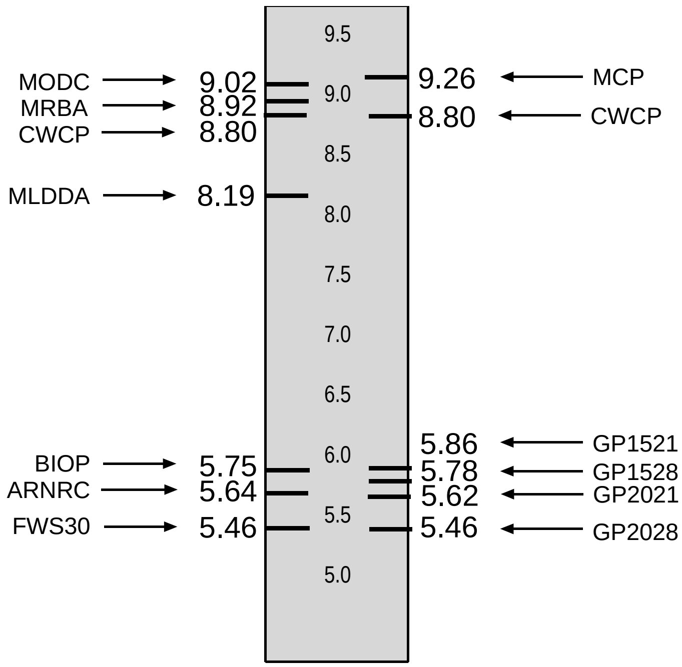

Figure 7.12-1. Average annual navigation benefits for submitted alternatives and the alternatives ($millions).

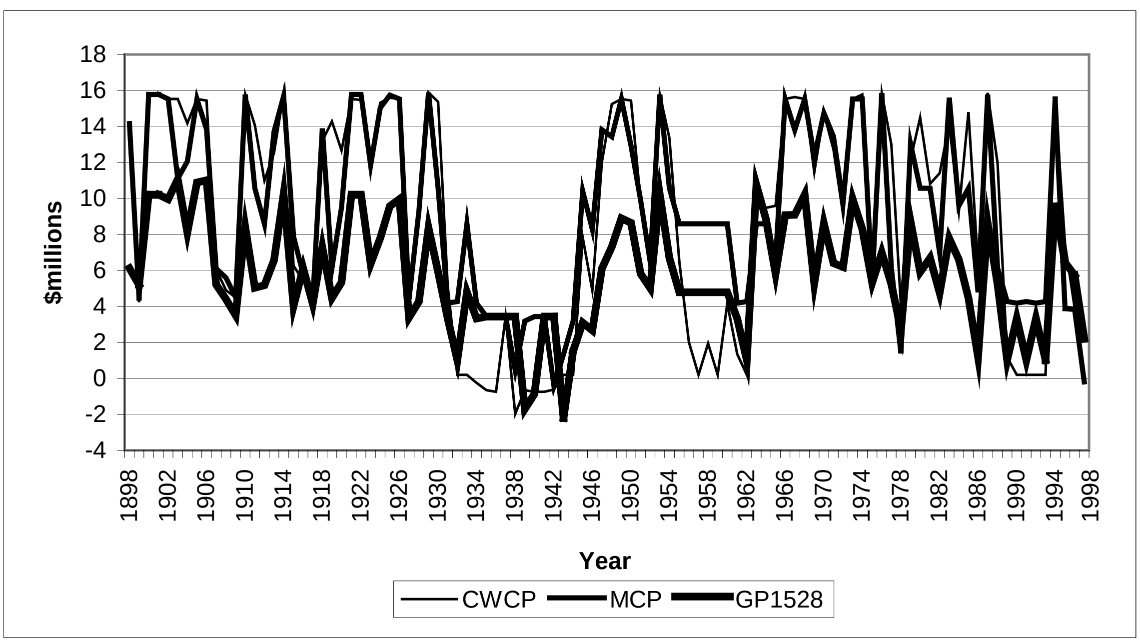

Figure 7.12-2. Annual Missouri River navigation benefits for CWCP, MCP, and GP1528.

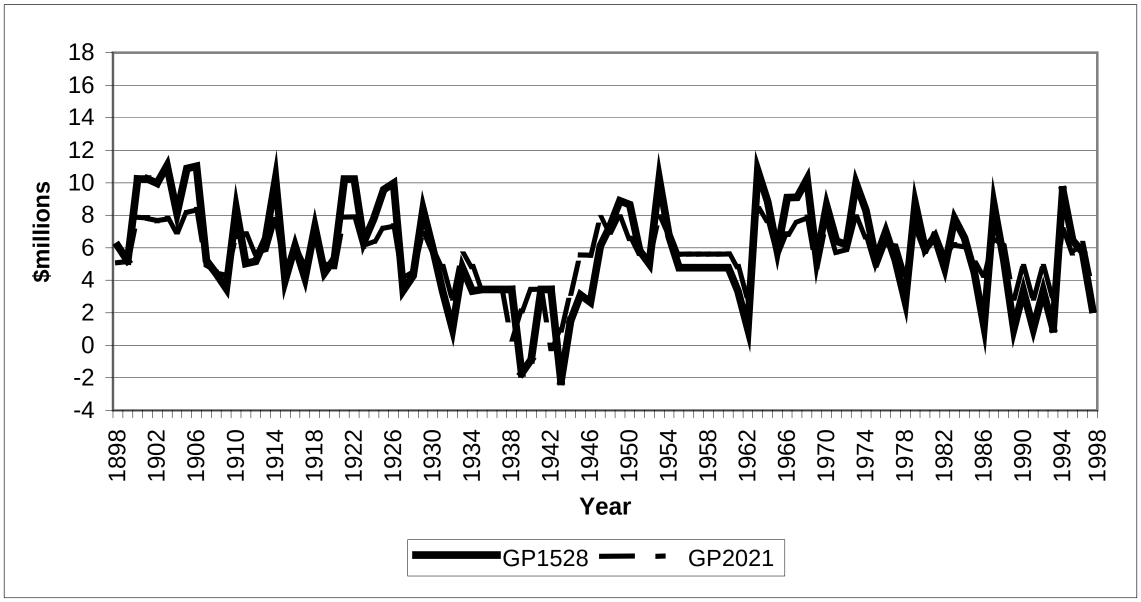

Figure 7.12-3. Annual Missouri River navigation benefits for GP1528 and GP2021.

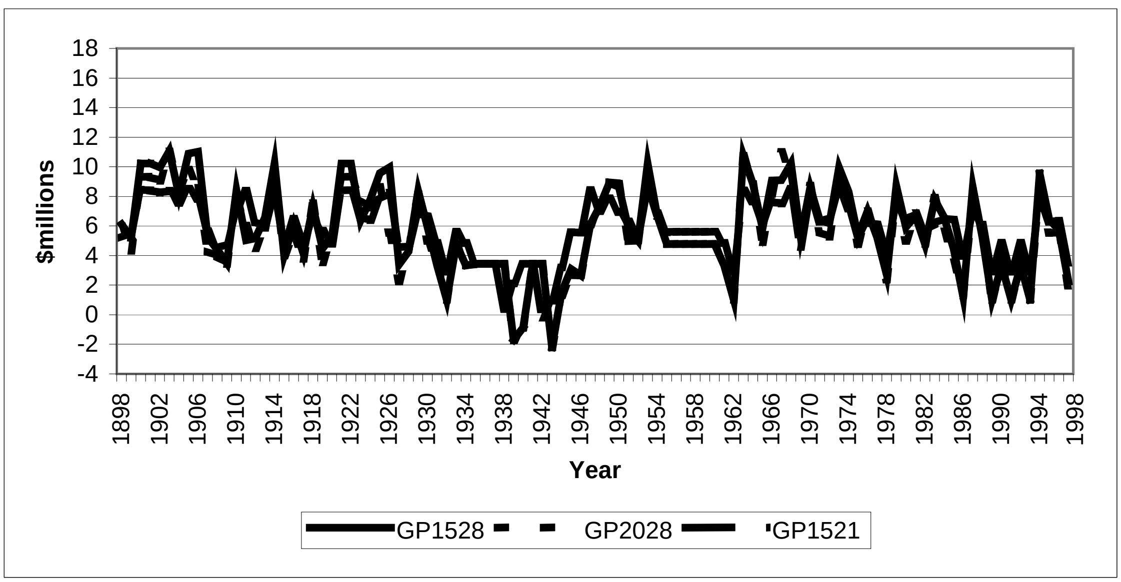

Figure 7.12-4. Annual Missouri River navigation benefits for GP1528, GP2028, and GP1521.

7.13 TOTAL NED ECONOMICS

Total average annual Missouri River National Economic Development (NED) benefits are the summation of economic benefits for flood control, recreation, water supply, navigation, and hydropower. A change in the Water Control Plan has positive or negative effects on the individual economic uses in response to the various changes incorporated in the alternatives. Detailed technical analyses and discussion of these topics are contained in individual technical reports supplemented by discussions in sections of this document describing impacts to the individual uses. The following summarizes the comparison of total NED benefits for the CWCP, the MCP, and the GP options.

Table 7.13-1 provides total average annual NED benefits for the 100-year period and for each major economic use. The CWCP provides fewer total benefits than the MCP or any of the four GP options. Among these alternatives, the CWCP maximizes only flood control benefits.

The MCP, which has the basic increased drought conservation measures and the Fort Peck spring rise included in the GP options, provides an average annual increase of $7 million, or 0.4 percent, in total NED benefits over the CWCP. The increase in benefits provided by the MCP is due primarily to increased hydropower benefits and, to a lesser extent, increased recreation benefits. This is the only alternative that has higher navigation benefits than the CWCP. The higher average lake levels resulting from the increased drought conservation measures positively affect the first two uses.

GP1528, the GP option with the lowest spring rise and highest summer flow, maximizes total NED benefits as well as hydropower and water supply benefits. It also has the second highest recreation benefits. Total average annual NED benefits are $5 million, or 0.3 percent more than the MCP. The GP1528 option decreases navigation benefits by $3.5 million, or about 38 percent, compared to the MCP.

The GP2021 option introduces both a higher spring rise than the GP1528 option, and summer flows each year below the minimum required for navigation service. All resource category benefits are reduced compared to the GP1528 option, except for flood control. Total NED benefits are reduced by $6 million, or 0.4 percent, relative to the GP1528 option.

The GP1521 option, which reduces only the summer flows relative to those of the GP1528 option, produces very similar effects on total NED benefits as the GP2021 option. Total benefits are reduced by $7 million, or 0.4 percent, compared to the GP1528 option.

The GP2028 option, which increases only the spring rise relative to the one included in the GP1528 option, produces very nearly identical total average annual NED benefits as the GP1528 option, and benefits are also very nearly the same for all economic resources, including the maximum value for recreation. Relative to the GP1528 option, the GP2028 option provides about $1 million, or 0.1 percent, fewer benefits.

Tables 7.13-2 and 7.13-3 compare the total NED benefits for the CWCP versus the MCP and the GP options during various time periods of the 100-year period of analysis. These data provide insight into the total economic benefits of the alternatives over the full 100-year period, each major drought and recovery period, and each period not under the

Table 7.13-1. Average annual total NED benefits by resource ($millions).

	CWCP	MCP	GP1528	GP2021	GP1521	GP2028
Navigation	8.8	9.3	5.8	5.6	5.9	5.5
Recreation	84.7	87.9	88.5	86.6	86.6	88.7
Flood Control	410.3	408.0	405.8	407.7	406.3	405.4
Water Supply	610.1	610.4	611.1	608.5	608.6	611.0
Hydropower	668.0	672.8	682.4	678.8	679.2	681.7
Total NED	**1,781.9**	**1,788.5**	**1,793.6**	**1,787.2**	**1,786.6**	**1,792.2**

Table 7.13-2. Average annual total NED benefits for different modeling periods ($millions).

		CWCP	MCP	GP1528	GP2021	GP1521	GP2028
1898-1929	Non-drought	1,749	1,746	1,745	1,741	1,742	1,744
1930-1950	Drought	1,663	1,697	1,713	1,692	1,693	1,712
1951-1953	Non-drought	2,831	2,831	2,833	2,830	2,832	2,827
1954-1965	Drought	1,673	1,682	1,695	1,689	1,689	1,695
1966-1987	Non-drought	1,919	1,916	1,917	1,911	1,910	1,913
1988-1993	Drought	1,434	1,437	1,444	1,455	1,454	1,444
1994-1997	Non-drought	1,978	1,968	1,969	1,982	1,963	1,974
Total Non-drought		**1,878**	**1,875**	**1,875**	**1,872**	**1,871**	**1,873**
Total Drought		**1,631**	**1,653**	**1,666**	**1,655**	**1,655**	**1,666**
Total Period		**1,782**	**1,788**	**1,794**	**1,787**	**1,787**	**1,792**
Difference from CWCP			7	12	5	5	10

Table 7.13-3. Differences in average annual total NED benefits from CWCP for different modeling periods ($millions).

		MCP	GP1528	GP2021	GP1521	GP2028
1898-1929	Non-drought	-3	-4	-7	-6	-5
1930-1950	Drought	34	50	29	30	49
1951-1953	Non-drought	0	2	-1	1	-4
1954-1965	Drought	9	23	16	16	23
1966-1987	Non-drought	-3	-2	-8	-9	-6
1988-1993	Drought	3	10	20	20	10
1994-1997	Non-drought	-10	-9	4	-15	-5
Total Non-drought		**-3**	**-3**	**-7**	**-8**	**-5**
Total Drought		**22**	**35**	**24**	**24**	**35**
Total Period		**7**	**12**	**5**	**5**	**10**

influence of a major drought. In general, total NED benefits are lower during drought periods and higher during non-drought periods.

The MCP and the GP options all provide increased benefits during drought periods compared to the CWCP. During drought periods, the MCP increases benefits by $22 million, or 1.3 percent.

The GP1528 option increases total drought period benefits by an additional $13 million, or 0.8 percent, above the MCP. The GP2028 option provides essentially the same drought period benefits as GP1528. GP1528 and GP2028 provide the highest total NED benefits during droughts.

The GP2021 and GP1521 options reduce drought period benefits by about $11 million, or 0.7 percent, compared to the GP1528 option. During the 1987 to 1993 drought, the GP2021 and GP1521 options provided the greatest total economic benefit. Ironically, the higher benefits during this drought for these two options are likely due in part to the greater flood control benefits provided by these alternatives during the great flood of 1993.

All alternatives provide nearly the same total average annual benefits during non-drought periods, with the variation from minimum to maximum equaling about $8 million of a total average annual benefit during non-drought periods of $1,878 million. During non-drought periods, none of the alternatives provides greater benefits than the CWCP.

Figure 7.13-1 provides a graphical presentation for each of the alternatives over the 100-year period. Very little difference in economic performance of the alternatives can be discerned from the figure for any of the years. Years with benefit spikes generally correspond to years with greater flood control benefits as illustrated by Figure 7.13-2 for alternative GP1528.

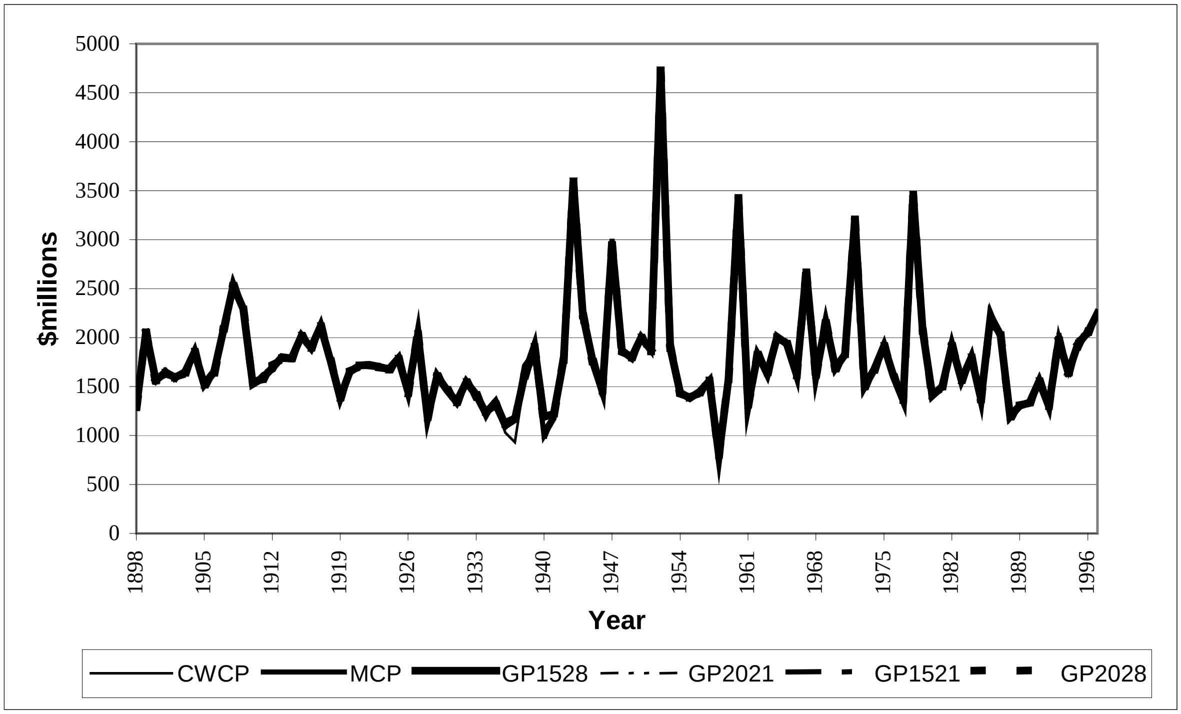

Figure 7.13-1. Annual total NED benefits for alternatives.

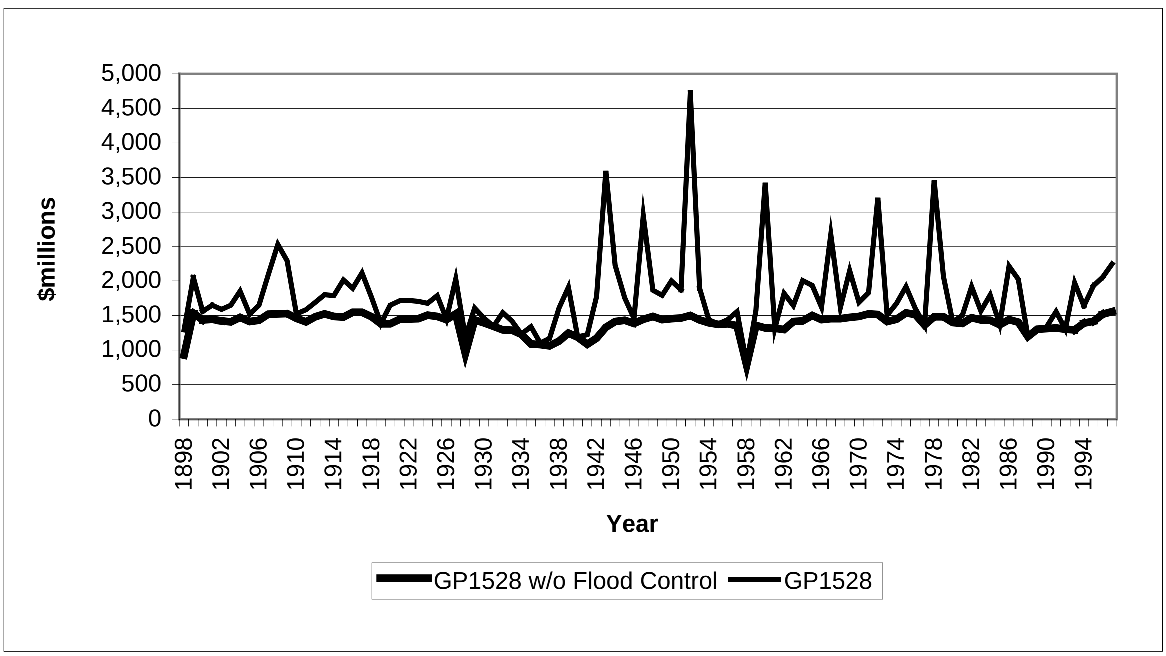

Figure 7.13-2. Annual total NED benefits for alternative GP1528: total and total without flood control.

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7.14 HISTORIC PROPERTIES

Historic properties, as defined by the National Historic Preservation Act, include historic and prehistoric archaeological sites, historic architectural and engineering features and structures, and resources of significance to American Indians and other social or cultural groups. Historic properties located within the lakes and adjacent zones are subject to the effects of impounded water, as described in Environmental Studies—Least Tern and Piping Plover (Corps, 1994q). Nearly all water-related effects on historic properties are a direct or indirect function of lake level, which determines if a given site is inundated or subject to shoreline erosion.

The long-term potential for erosion at each known site was evaluated based on the monthly water level in each of the four upper lakes (Fort Peck Lake, Lake Sakakawea, Lake Oahe, and Lake Sharpe). The index values derived for comparative purposes are inversely related to the number of months the known sites are potentially subject to shoreline erosion forces. The assumption for potential erosive action was that the site had to be within 3 feet above and 5 feet below the water surface of the lake to be affected by erosive forces. The historic properties index values presented and discussed in this section are, therefore, similar to other values computed for other resources and economic uses: the higher the value, the less adverse the effect on known historic properties within or adjacent to the four upper lakes.

When shoreline erosion forces are diverted to lower elevations in a lake, areas that may not have been intensively surveyed for historic properties before lake filling are affected. Undiscovered sites within the lake have already been damaged to some extent by inundation; however, inundated sites are somewhat protected from the adverse effects of shoreline erosion and looting. Lake levels during periods of drought decline further under the CWCP than the other alternatives and thereby potentially limit the loss of known sites from shoreline erosion. Alternatives that limit the drawdown of the upper three lakes with additional drought conservation measures will limit the erosive impact on the unknown sites. This is, no doubt, a benefit; however, since only the effect to known sites is considered in the historic properties index, these alternatives have a lower historic properties index than the CWCP. Overall, it is difficult to determine which alternative is the best plan to follow for the total set of historic properties within the Mainstem Reservoir System.

Although there are a significant number of historic properties on Lake Sharpe, the adverse effects on historic properties vary little among the alternatives because of the relatively stable water elevations. Water elevations in the two remaining downstream lakes (Lake Francis Case and Lewis and Clark Lake) vary little among the alternatives, and no significant change from current conditions is anticipated. Data concerning historic properties along open river reaches are inadequate for general analysis, but the river reaches are unlikely to measurably influence the index values established for the northernmost lakes.

Table 7.14-1 presents the average annual total and individual lake historic properties index values for the four upper lakes. The average annual total index value for the CWCP is 5,015. This total is distributed among Fort Peck Lake (2.8 percent), Lake

Table 7.14-1. Average annual historic property values for the upper three mainstem lakes and Lake Sharpe (relative index).

		1898 to 1997			
Alternative	**Total**	**Fort Peck Lake**	**Lake Sakakawea**	**Lake Oahe**	**Lake Sharpe**
CWCP	**5,015**	143	2,658	2,011	204
MCP	**4,876**	143	2,558	1,971	204
GP1528	**4,704**	148	2,434	1,918	204
GP2021	**4,739**	147	2,453	1,935	204
GP1521	**4,739**	146	2,455	1,934	204
GP2028	**4,707**	148	2,431	1,924	204

Sakakawea (53.0 percent), Lake Oahe (40.1 percent), and Lake Sharpe (4.1 percent). Compared to the CWCP, the MCP, and the four GP options have the same or greater index values within Fort Peck Lake and lesser index values for historic properties within Lake Sakakawea and Lake Oahe. Index values for historic properties within Lake Sharpe are the same for the CWCP, the MCP, and the four GP options.

Figure 7.14-1 shows three separate groupings of total index values for historic properties. The CWCP stands alone at 5,015 units. This value is 140 units more than the next grouping that includes only the MCP at 4,876 units. The four GP options are closely grouped between 4,704 and 4,739 units, a difference of 35 units. This figure also shows the values for the submitted alternatives discussed in Chapter 5 to provide perspective as to how the GP options perform relative to the submitted alternatives. The GP1528 option falls between the three alternatives with a spring rise followed by lower summer flows: the ARNRC, BIOP, and FWS30 alternatives.

One of the primary differences between the CWCP and the MCP is increased water conservation during drought. The MCP also has differences from the intrasystem regulation among the upper three lakes, where the CWCP is balanced and the MCP is unbalanced. These two differences result in a 2.8 percent decrease in total index values for historic properties within the four lakes. Compared to the CWCP, the MCP yields the same index value within Fort Peck Lake, and a 3.8 and 2.0 percent decrease in index values for historic properties within Lake Sakakawea and Lake Oahe, respectively. Compared to the four GP options, the MCP represents the smallest percent change in historic property index values within these lakes from the CWCP.

The GP1528 option, the GP option with the lowest spring rise and the highest summer flows, has a 15-kcfs spring rise every year from Gavins Point Dam when Lower River flows are below the flood control constraints and there is adequate water in system storage. Based on these factors, a spring rise occurs about one-third of the time over the 100-year period of analysis. The summer release from Gavins Point Dam is flat (28.5 kcfs) and represents a 6-kcfs decrease in the navigation service level (or minimum service) compared to the MCP, which has full navigation service during the majority of summers. These factors result in a 3.5 percent decrease in the total index value for historic properties within the four upper lakes, compared to the MCP's total value. Also, compared to the MCP, the GP1528 option increases the index value for historic properties within Fort Peck Lake (3.5 percent) and decreases the index values by 4.8 and 2.7 percent within Lake Sakakawea and Lake Oahe, respectively.

The percent changes resented will be with respect to the values for the GP1528 option because it has the lowest spring rise and the highest summer flows.

The GP2021 option has a 20-kcfs spring rise that occurs once every 3 years on average (5 kcfs higher than the GP1528 option) and a summer release in most years that is split between 25/21 kcfs from Gavins Point Dam. Compared to the GP1528 option, the GP2021 option results in a 0.7 percent increase in total index values for historic properties within the upper four lakes. The GP2021 option results in a 0.7 percent decrease within Fort Peck Lake and a 0.8 and 0.9 percent increase in index values within Lake Sakakawea and Lake Oahe, respectively, compared to the GP1528 option.

The GP1521 option has the same spring rise as the GP1528 option (15 kcfs); however, its summer flow is also split (25/21 kcfs from Gavins Point Dam) rather than flat (28.5 kcfs) as with the GP1528 option. The GP1521 option's effect on historic properties is similar to the GP2021 option because it results in a 0.7 percent increase in total index values and about the same percent decrease (0.9 percent and 0.8 percent) in index values within Lake Sakakawea and Lake Oahe, respectively. The GP1521 option reduces the historic property index value within Fort Peck Lake by 1.4 percent when compared to the GP1528 option. These results indicate that the factors affecting historic property index values under these two options will most likely be influenced by the variation in summer flows rather than the spring rise from Gavins Point Dam.

The GP2028 option has a 20-kcfs spring rise and a flat summer release of 28.5 kcfs that represents a minimum navigation service release from Gavins Point Dam. This combination of factors results in a 0.1 percent increase in total index values for historic properties over the GP1528 option. Compared to the GP1528 option, the GP2028 option results in an index value decrease (0.1 percent) within Lake Sakakawea, and an index value increase (0.3 percent) for the historic property index within Lake Oahe. The GP2028 option results in no change in the index value within Fort Peck Lake.

The annual values for total historic resources for the CWCP, the MCP, and the four GP options are shown on Figures 7.14-2 through 7.14-4. Primary differences among the alternatives are most noticeable in the three major droughts when the index values increase from the 4,000 to 5,000 range to about 7,500. As anticipated, the more stringent drought conservation measures result in lower values for the MCP, with the greatest difference at the end of the 1930 to 1941 drought. Almost noticeable is the effect the summer low flows have in the two other major droughts, especially the 1954 to 1961 drought when the index values are much lower for the GP options than under the MCP and the CWCP.

7.14.1 Historic Properties for Tribal Reservations

Five Tribal Reservations are located along the uppermost lakes of the Mainstem Reservoir System, where water level fluctuations may result in impacts to historic properties. Table 7.14-1 shows a comparison of how the different alternatives influence historic properties index values for the affected Reservations during the 100-year period of analysis. Changes in historic properties index values are discussed for each Reservation, starting with the Fort Berthold Reservation in North Dakota and proceeding downstream.

It should be noted that impacts to Reservations may not necessarily coincide with impacts to the associated Tribes. Historically, the various Tribes used lands in many different locations, not limited by the extent of their current Reservations; therefore, historic sites within the boundary of a particular Reservation may be important to Tribes on other Reservations. Further, this analysis does not attempt to address impacts to known sites and/or inundated sites.

The smallest impact to historic properties on Fort Berthold Reservation will occur under the CWCP, which has the highest historic property index values at Lake Sakakawea (Table 7.14-1). The MCP results in a decrease of 3.8 percent from this value, while the GP options result in even greater drops. The greatest decrease from the CWCP (and thus the greatest increase in risk to historic properties) occurs under the GP2028 option (8.5 percent), while the smallest decrease occurs under GP1521 (7.6 percent).

Standing Rock and Cheyenne River Reservations, located on Lake Oahe, will have the lowest risk to historic properties under the CWCP. The CWCP, at 2,011, has the highest historic property index value of all the alternatives addressed in detail (Table 7.14-1). The MCP results in a decrease of 2.0 percent from the CWCP. Decreases among the GP options range from 3.8 percent (GP2021 and GP1521) to 4.6 percent (GP1528).

Lower Brule and Crow Creek Reservations, located on Lake Sharpe, show no change in the historic properties index under any of the alternatives to the CWCP (Table 7.14-1). This is likely because the MCP and the GP options have very little effect on water level fluctuations in Lake Sharpe, compared to the CWCP.

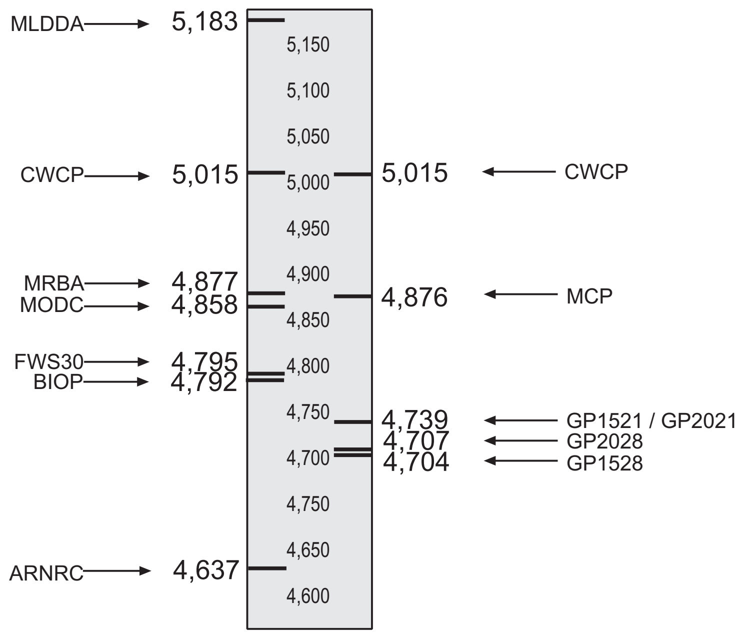

Figure 7.14-1. Average annual historic properties values for Fort Peck Lake, Lake Sakakawea, Lake Oahe, and Lake Sharpe for submitted alternatives and the alternatives.

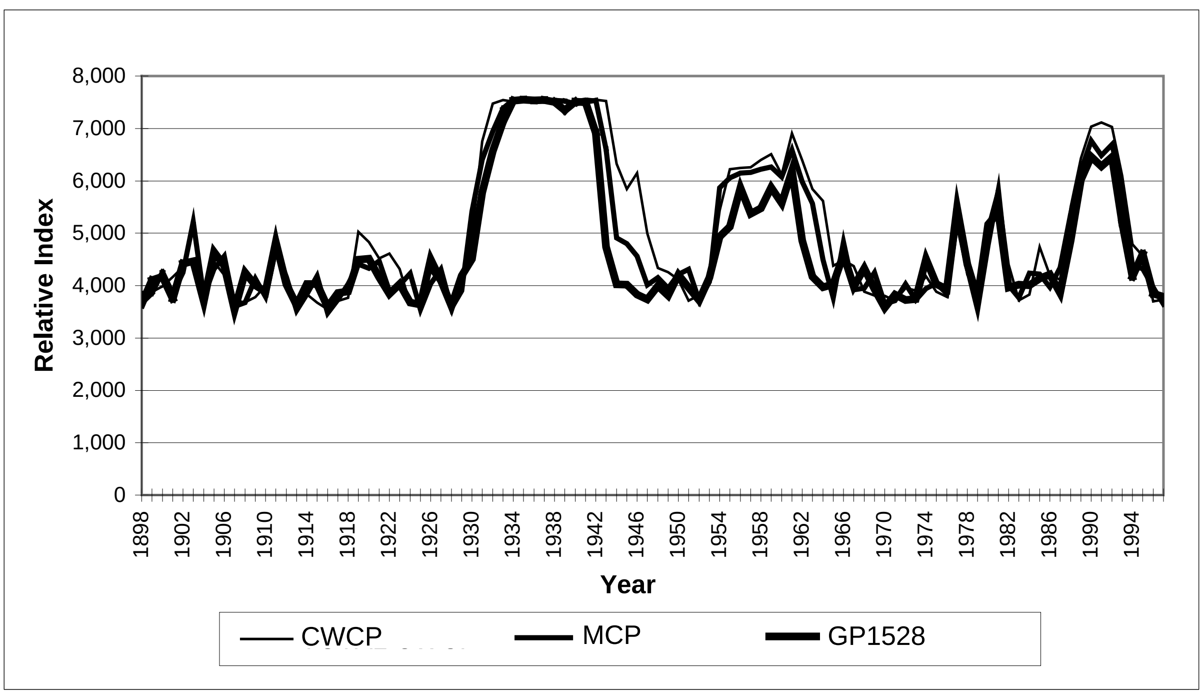

Figure 7.14-2. Annual values for historic properties for CWCP, MCP, and GP1528.

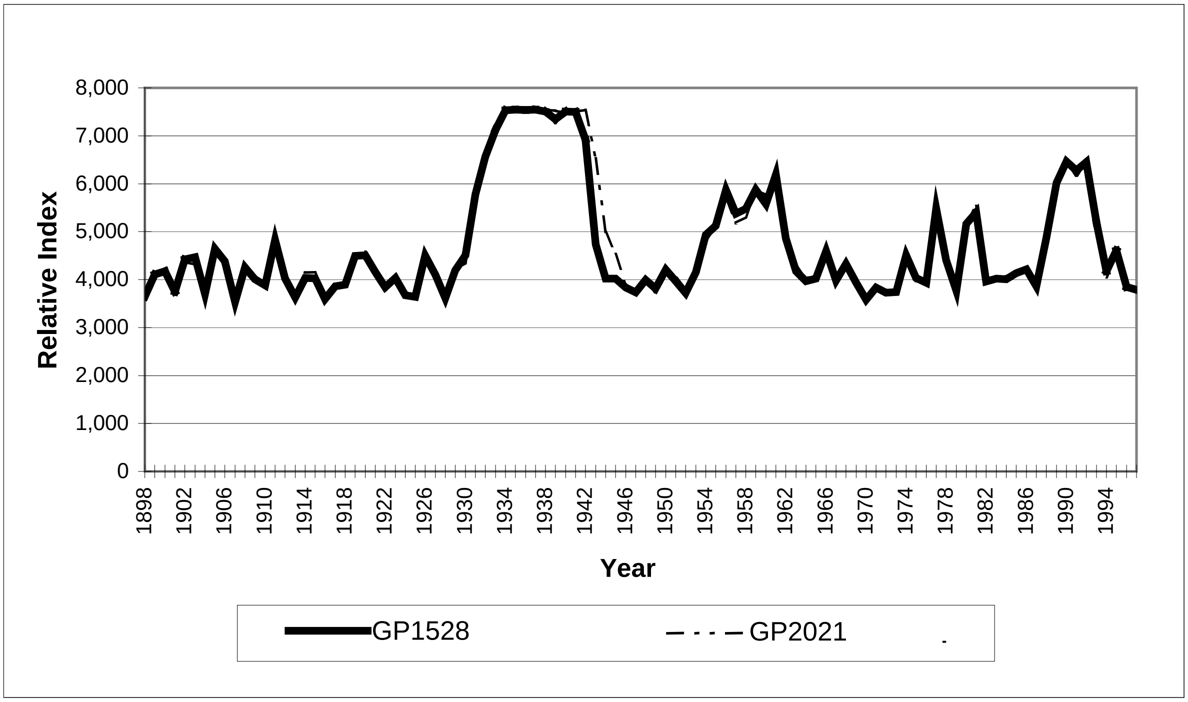

Figure 7.14-3. Annual values for historic properties for GP1528 and GP2021.

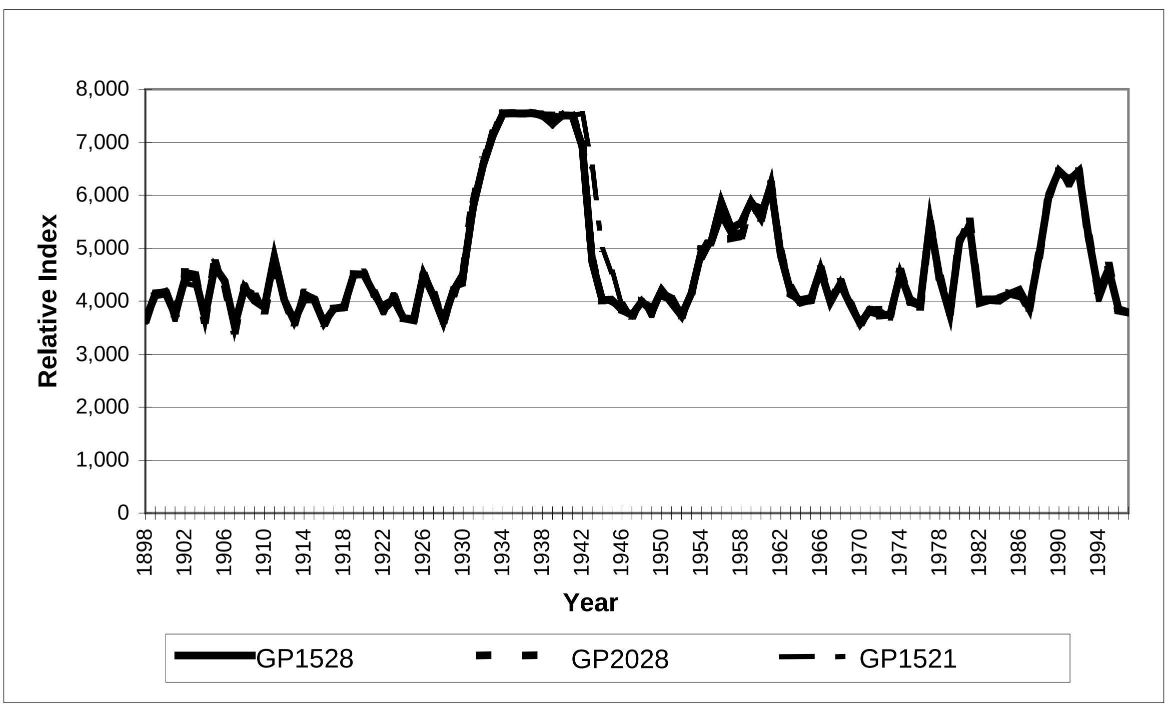

Figure 7.14-4. Annual values for historic properties for GP1528, GP2028, and GP1521.

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7.15 MISSISSIPPI RIVER IMPACTS

The changes in the operating criteria making up each of the alternatives presented in this chapter provide different release patterns from Gavins Point Dam. Some of these differences are more pronounced than others. In some cases, they are dramatic enough to show up on the annual hydrograph for Hermann, Missouri, which is the last location modeled on the Missouri River. These flows join those from the Upper Mississippi River to make up the flow that passes St. Louis, Missouri. Because of these differences and the concerns regarding impacts on the Mississippi River, an analysis was conducted of potential impacts on the Mississippi River, including impacts to the endangered pallid sturgeon. Prior studies and analysis of annual hydrographs indicated that continued evaluation of Mississippi River water intakes, saltwater intrusion, and flood damage were not warranted. Impacts on these resource categories were determined to be indistinguishable. For the alternatives addressed in this chapter, Mississippi River resource evaluations were conducted for hydraulics and hydrology, side channel improvements, dredging, navigation, and channel improvement features.

Details on methods employed in these studies and previous evaluations are included in the Mississippi River Studies technical report (Corps, 1998l).

7.15.1 Hydraulic Impacts on the Mississippi River

This portion of the EIS discusses the results of the hydraulic analyses performed to determine the impact of the Missouri River Mainstem Reservoir System operating alternatives on the stages and flows on the Mississippi River. Discussions are limited to the CWCP, the MCP, and the four GP options: GP1528, GP2021, GP1521, and GP2028. The discussion is also limited to the gaging stations at St. Louis, Missouri, and Cairo, Illinois, which were used to evaluate the economic impact on the Mississippi River. A brief discussion on the Missouri River flow at Hermann, Missouri is also included.

Hermann, Missouri

The only variable that differentiated the numerical model runs on the Mississippi River for each alternative was the flow at Hermann. The differences in flow patterns at Hermann that occur among the alternatives should, therefore, be reflected at downstream gaging stations along the Mississippi River. Figure 7.15-1 shows the average monthly flow on the Missouri River at Hermann, Missouri for the CWCP, the MCP, and the four GP options. In comparing the MCP to the CWCP, the average monthly flows at Hermann are similar through September with differences of less than 1 kcfs. The MCP results in slightly higher flows than the CWCP in October, but substantially lower flows in November. This occurs because the Missouri River navigation season is curtailed earlier during low water years as part of the additional drought conservation features of the MCP. The GP1528 option, which has the least amount of deviation from the CWCP of the four GP options, has a slight increase in average monthly flows at Hermann during the months of May and June, and a moderate reduction of monthly flows in July and August. Flows in September and October are slightly higher than the CWCP, but average slightly lower again in November as the additional conservation measures take effect in drought years. The other GP option with a 15-kcfs spring rise, GP1521, has a similar affect in May and June, but considerably lower flows than the GP1528 option during July and August as a result of the 25/21-kcfs summer low flows from Gavins Point Dam. The GP2028 and GP2021 options have higher flows in May and June than the other two GP options, due to their higher spring rise out of Gavins Point Dam, and July and August flows similar to the GP1528 and GP1521 options, respectively. The options with the lowest summer flows, GP1521 and GP2021, have the highest flows during the fall as excess flood evacuation is moved into the fall. The GP2028 option has fall flows similar to the GP1528 option. Mean monthly stages at Mississippi River gaging stations for the MCP and the four GP options should reveal similar patterns of increase or decrease in mean monthly stages when compared to the CWCP.

St. Louis, Missouri

Figure 7.15-2 shows the computed mean stage for each month at St. Louis for the CWCP, the MCP, and the four GP options. The pattern of flow change at Hermann is replicated here, as expected. The MCP is very similar to the CWCP except for having lower stages in November due to the drought conservation measures. The spring rise of the GP options becomes virtually indistinguishable at the St. Louis gage, making only about 0.1 foot of difference in May and June. The GP options with the minimum service summer low flows, GP1528 and GP2028, have nearly identical results at the St. Louis gage. Both result in a 0.4-foot decrease in mean monthly stage compared to the CWCP and the MCP during August and have slightly higher fall stages than the MCP. The GP1521 and GP2021 options result in a 1.0-foot decline in St. Louis stage in August when compared to the CWCP and the MCP. Fall stages for these options are considerably higher than both the CWCP and the MCP.

Figures 7.15-1 and 7.15-2 provide a glimpse of how the alternatives compare to the CWCP and with each other, but the impact of the alternatives on flooding, which begins at 30 feet on the St. Louis gage, and to navigation, which begins when the St. Louis gage falls below 2.0 feet, must be analyzed on an event-by-event basis using the daily stage hydrographs.

Figure 7.15-3 shows the maximum stage, in feet above the 30-foot flood stage, attained at St. Louis during each year under each alternative. By focusing on the feet above flood stage, critical periods for increased flood risk are identified. The greatest increase in the annual maximum stage during flooding conditions occurred during 1965. The MCP was 0.4 foot higher than the CWCP. The GP1528 and GP2028 options added an additional 0.2 foot to the MCP, and GP2021 and GP1521 were 0.5 foot higher than the MCP, or 0.9 foot higher than the CWCP. Other events that had a notable increase in the St. Louis peak stage include 1975, which had a 0.7-foot increase over the CWCP for the GP1521 option; 1986, which had a 0.6- to 0.8-foot increase with the four GP options; and 1995, which had a 0.3- to 0.7-foot increase with the GP options. The greatest decrease in the annual maximum stage while in flood was 0.4 foot, which occurred in 1992 under the MCP and the GP1528 and GP2028 options.

Figure 7.15-4 shows the minimum stage at St. Louis during each year for each alternative. The stage at which navigation on the Middle Mississippi River begins to be impacted is 2.0 feet. Under the CWCP, stages below 2.0 feet occur in all but 11 years out of the 66 years modeled (1930 to 1995). The 11 years in which the stage does not fall below 2.0 feet all occur between 1973 and 1995. In the 13 years between 1983 and 1995, there are only four years in which the stage falls below 2.0 feet. As shown in Figure 7.15-4, the greatest decrease in the annual minimum stage is 1.4 feet, which occurs in 1941 under the MCP. The minimum stage under all of the GP options is 0.3 foot higher than the MCP in 1941. In general, during the most severe low-flow periods when stages fall below -2 feet at St. Louis, none of the alternatives result in a stage that is more than 0.7 foot lower than the CWCP. The greatest increase in the annual minimum stage modeled was 0.7 foot in 1949 under the GP2021 and GP1521 options.

Figure 7.15-5 shows the annual stage duration curves at St. Louis for the CWCP, the MCP, and the four GP options. The duration curves show the percent of the time a given stage is equaled or exceeded. For example, under the CWCP, the stage of 2.0 feet (the stage at which navigation impacts begin) is exceeded about 77 percent of the time, meaning the river remains below 2.0 feet about 23 percent (100-77) of the time. An increase in the exceedance duration figure means that the river spends more time above that stage and less time below that stage, and conversely, a decrease in the exceedance duration figure means that the river spends less time above that stage and more time below that stage. Figure 7.15-5 shows virtually no difference in the stage duration at St. Louis for the CWCP, the MCP, and the four GP options. The greatest change in the annual exceedance duration at any given stage is a decrease of 0.87 percent at a stage of -1.0 foot under the MCP, compared to the CWCP. The 0.87 percent is equivalent to 3.2 days per year. The GP options also have their greatest effect on the low end of the duration curve with maximum decreases of less than one percent at a stage of 0.0 to 1.0 foot at St. Louis.

Figures 7.15-6 through 7.15-17 show stage exceedance duration curves for each month of the year. Although the annual duration curves (Figure 7.15-5) show no significant variation between the CWCP, the MCP, and the four GP options, monthly duration curves reveal significant differences during certain months. There is very little difference among the monthly flow duration curves for January through May; the maximum variation is generally much less than 1 percent. In June there is very little difference between the CWCP and the MCP, but the exceedance durations for the GP options are generally 1 to 1.5 percent higher than the CWCP as a result of the Gavins Point Dam spring rise having worked its way down to the St. Louis area. The greatest increases in exceedance durations during June are limited to stages in the 10-to-15 feet range, which has little impact on either flood control or navigation. Significant decreases in exceedance duration at lower stages occur during July and August under the GP2021 and GP1521 options, including a 9 percent decrease in exceedance duration at the 2.0-foot stage for both options. The MCP is very similar to the CWCP during July and August. The GP1528 and GP2028 options have a 1 to 2 percent reduction in exceedance frequency during July, and 2 to 3 percent reduction during August, for St. Louis stages in the range of 1 to 11 feet. All of the alternatives show moderate increases in exceedance duration at lower stages in October as a result of floodwater being evacuated from the mainstem lakes during the fall. Significant decreases in exceedance duration occur at low stages in November under the MCP and GP1528 and GP2028 options, including a 10.5 percent decrease at 0.0 feet stage under the MCP. The GP1521 and GP2021 options have a slight increase in the exceedance frequency at all stages below 25 feet during November.

Cairo, Illinois

Unlike the Middle Mississippi River, which typically crests in April or May and reaches the lowest levels in December and January, the Lower Mississippi River at Cairo, Illinois, typically crests in March or April and reaches its lowest levels in September or October. By December or January, the Cairo gage is usually on a rise. A change in the Missouri River flow, therefore, impacts the Lower Mississippi River somewhat differently than it does the Middle Mississippi River, particularly during the low-flow periods.

Figure 7.15-18 shows the computed mean stage for each month at Cairo for the CWCP, the MCP, and the four GP options. The pattern of flow change at Hermann is replicated as it was at St. Louis, although the impact on the stage at Cairo is a fraction of the St. Louis impact because of attenuation, the introduction of the Ohio River flow, and the fact that the river is much larger at Cairo than at St. Louis. All of the mean monthly stages for the MCP and the GP options are within 0.2 foot of the stages modeled for the CWCP.

Figure 7.15-19 shows the annual maximum stage in feet above the 40-foot flood stage, attained at Cairo under each alternative. The greatest increase from the CWCP in the annual maximum stage that occurred during the time the river was in flood was 0.6 feet under GP2021 in 1987. The greatest decrease from the CWCP in the annual maximum stage while in flood was 0.6 feet, which occurred under GP1528, GP2021, and GP1521 in 1938.

Figure 5.15-20 shows the minimum stage attained at Cairo each year under each alternative. The stage at which the navigation on the Lower Mississippi River begins to be impacted is 11.8 feet, which, under the CWCP, occurs in about 60 percent of the 61-year (1935 to 1995) study period. The greatest decrease in the annual minimum stage was 1.8 feet, which occurred in 1970 under the GP1528, GP2021, and GP1521 options; however, the reduction occurred when the stage was well above the 11.8-foot triggering stage for navigation impact. The greatest decrease in the annual minimum stage while the river was below the 11.8-foot triggering stage was 1.5 feet, which occurred in 1936 under the MCP and the GP2028 option. Higher releases from Gavins Point Dam provided during the month of October for the MCP and the GP options increase the minimum stage at Cairo many years in the study period. The greatest increase in the annual minimum stage was 2.8 feet in 1938 under the MCP and the GP2028 option, and in 1952 under the GP2021 option.

Figure 7.15-21 shows the annual stage duration curve at Cairo for the CWCP, the MCP, and the four GP options. The duration figures are given in percent of the time a given stage is equaled or exceeded. The figure demonstrates that there is no appreciable difference between the annual stage duration curves for the CWCP and other alternatives at the Cairo gage on the Mississippi

River. Monthly stage duration curves, though not presented, would likely show differences between the alternatives similar to those seen at St. Louis, but on a smaller scale.

7.15.2 Middle Mississippi River Environmental Resources

Subsequent to the release of the RDEIS, a more detailed evaluation and documentation of the Middle Mississippi River environmental consequences was conducted for the CWCP and five alternatives evaluated in detail. These studies addressed Middle Mississippi River side channel habitat use (Corps, 2002a), shallow water habitat availability (Corps, 2002b), and least tern nesting habitat availability (Corps, 2002c). Conclusions from these studies are provided below.

Side Channel Habitat Use

Connectivity between side channels and the river and physical chute attributes of volume, surface area, and depth for five alternative plans (GP1521, GP1528, GP2021, GP2028, and MCP) were compared to the CWCP. The low water season of July through November was evaluated over a 66-year period of record. Only qualitative differences from the CWCP could be discerned when investigating physical chute attributes. Differences in connectivity of the plans from the CWCP cannot be statistically confirmed on a local basis because the differences are very small in magnitude; however, it can be said with statistical certainty that the plans all slightly deviate from the CWCP on a consistent basis along the length of the Middle Mississippi River. Of the plans evaluated, GP1521 and GP2021 produce the most dramatic differences from the CWCP, with GP1528, GP2028, and MCP being very similar to the CWCP. In August, median stages tend to be slightly higher for the CWCP than for GP1521 and GP1521, while the opposite is true for the month of November.

Most side channels in the Middle Mississippi River are isolated from the main channel in the low-water season; therefore, they experience a lack of flow and a resultant lack of oxygen. Differences among the CWCP and the alternatives, while they were very small, could affect the timing at which oxygen depletions may occur within the Middle Mississippi River side channels, but overall, because the differences in the median stages of all plans evaluated with respect to the CWCP are very small and the isolated condition experienced by the chutes has been predetermined, very little impact is expected to be associated with any of the alternative plans. Possible worsening of the Gulf hypoxia as a result of any of the alternatives is also not likely because side channels provide very little potential for denitrification.

A low likelihood is expected that any of the alternatives would cause discernable changes in the accessibility of side channel habitats to fish or invertebrates, especially considering that most side channels are degraded to the point of inaccessibility during the low-water time frame. Current assemblages of fish and invertebrates that are associated with the side channels still connected in the summer may change some years in response to a changed stage elevation, although the degree to which this may occur is unclear due to the small differences of stage among alternatives, the variability of summer stages from year to year, and within year variability of the Middle Mississippi River hydrograph. Impacts to the Federally endangered pallid sturgeon are also unclear and immeasurable; however, if side channel habitats prove to be important to the rearing of young of year or essential to some other aspect of pallid sturgeon life history, even slight impacts to side channel connectivity could significantly impact the already presumably low populations of the pallid sturgeon. Slightly higher stages occur during the fall season with some of the plans that were evaluated compared to the CWCP (although to a lesser extent than the inverse relationship in August) that could lead to better accessibility to side channels during the time when fish are seeking winter refuge. In the fall, as in the late summer, most side channels are currently inaccessible under any of the alternatives evaluated, and the total area provided by those sites that would become available is very small in comparison to the numerous wing dikes that now provide suitable over-wintering habitat for fishes. Availability of over-wintering areas would not appear to be increased to any degree by any of the alternatives examined.

Aquatic vegetation would not be affected by any of the evaluated alternatives because Middle Mississippi River side channels have never supported extensive aquatic plant communities. Because alternatives do not appreciably deviate from the CWCP in the high-water months of the spring, impacts to terrestrial vegetation within the side channels (on associated islands and sandbars) are not anticipated.

Historically, freshwater mussels were not common in this stretch of the river either, which may be due to its large moving bed load (van der Schalie and van der Schalie 1950). The mussels that occur on the Middle Mississippi River are mainly found in side channels, and they have evolved to exist in slack-water habitats. It is unlikely that the alternatives evaluated in this report will affect mussels of the Middle Mississippi River.

Water-filled ditches and sloughs, which are common within the floodplain, provide for the life requisites of most frogs and toads that occur along the Middle Mississippi River, and they will not likely be affected by any of the alternatives being reviewed. Impacts to frogs or toads are, therefore, unlikely. Small changes in median river stages as a result of the alternatives may slightly affect nesting habitat for some Middle Mississippi River turtle species that rely on sandbars for egg laying, such as the Ouachita map turtle (*Graptemys ouachitensis)*, common map turtle (*Graptemys geographica*), and false map turtle (*Graptemys pseudogeographica*). The change to this habitat is expected to be small though, particularly during the spring when reproduction occurs. Other species of turtles common to the Middle Mississippi River are more reliant on upland sites for reproduction, and impacts are not likely.

The impacts of a change to any of the alternatives on waterfowl, wading bird, and songbird species are expected to be minimal. Impacts to shorebirds that rely on side channels for foraging only would not be affected; however, shorebirds that rely on the sandbar areas for nesting may be slightly affected by the various plans because of the impact on median river stages experienced during the spring and summer breeding periods (see least tern analysis).

Weighing the risk of these relatively small differences among plans to the ecosystem is very difficult given the size, complexity, and current degraded state of the Middle Mississippi River side channels and the low current state of knowledge on actual limiting factors to Middle Mississippi River species. A clear line has not been drawn for irremediable environmental change on the Middle Mississippi River, but it is clear that the current lack of the natural processes of cut-and-fill alluviation, channel avulsion, and floodplain connectivity have created a much more homogeneous environment on which Middle Mississippi River species rely prior to consideration of the Missouri River Master Manual alternatives.

The degradation of side channels in the Middle Mississippi River is clear and continuing. The implications of side channel loss on the ecological health of the Middle Mississippi River are great, with the loss of side channel habitat contributing to the already poor state of annual floodplain connectivity created by agricultural levees that currently isolate 82 percent of the Middle Mississippi River floodplain (Theiling et al., 2000). It is reasonable to assume that lower summer flows from the Missouri River contribute to the side channel connectivity problem, and these lower flows increase, to some level, the degradation of the Middle Mississippi River ecosystem. With that in mind, the physical restoration of side channel connectivity to the main channel would be much more conducive to improving the current and future condition of the Middle Mississippi River than would avoiding slight changes to Middle Mississippi River flows caused by changing flows from the Missouri River.

On a broad scale under the auspices of the Environmental Management Program, a habitat needs assessment (HNA) was conducted cooperatively among State and Federal agencies (Theiling and Korschgen et al., 2000). Needs and restoration goals cited by the HNA included the creation or restoration of 25,000 acres of backwater and secondary channel habitat and the restoration of more natural geomorphic processes. Provided that restoration of side channels is implemented as suggested by the HNA and a Corps report titled *Middle Mississippi River Side Channels: A Habitat Rehabilitation and Conservation Vision* (Corps, 2000b), the impacts of the alternative flows evaluated in this document would have minimal impact to the Middle Mississippi River.

Shallow Water Habitat

Shallow water habitat in the Middle Mississippi River provides important habitat for a myriad of aquatic species, including the endangered pallid sturgeon. A report titled *Analysis of Six Alternative Missouri River Water Regulation Plans on Shallow Water Habitat Availability in the Middle Mississippi River* (Corps, 2002b) was prepared to address the potential for loss of shallow water habitat. A comparison of shallow water habitat acreages between the CWCP and each alternative plan found that there was no statistical difference in the maximum, mean, and median habitat available on a monthly basis. Average daily differences between the CWCP and each alternative were less than 0.5 acre, but were found to be statistically significant.

On a daily basis, the area deviations between a plan and the CWCP can be zero, positive, or negative, and they can be as much as 54 acres. Negative differences are of biological concern because they represent a loss of shallow water habitat; however, available acres of shallow water habitat were found to be large (Table 7.15-1). Any losses in habitat would, therefore, have little biological effect because they were small when compared with available habitat. A ranking (least habitat loss to most habitat loss relative to the CWCP) of the alternative plans is: MCP (-0.12 acres) < GP1528 (-0.26 acres) < GP1521 (-0.30 acres) < GP2028 (-0.31 acres) < GP2021 (-0.32 acres).

Least Tern Nesting Habitat

The Federally endangered least tern uses sandbar habitat for nesting. A report titled. *Analysis of Six Alternative Missouri River Water Regulation Plans on Least Tern Nesting Habitat Availability in the Middle Mississippi River* (Corps, 2002a) was prepared to address sandbar availability during the least tern nesting/rearing period at 11 previously utilized or potential least tern breeding sites on the Middle Mississippi River using stage data for the CWCP and the five alternatives. The goal of the study was to determine if habitat values for the five alternatives differ from those of the CWCP.

The number of periods during which each sandbar was usable during the period 1930 through 1995 is shown in Table 7.15-2 for the 66-year period of record. Table 7.15-2 shows the number of usable periods of 50 or more days, 75 or more days, and 100 or more days. The table shows that the number of usable periods for a given sandbar is similar for the various plans.

When each of the 11 sandbars was analyzed separately, the difference between the CWCP and each alternative was minimal and not statistically significant. The largest difference between the CWCP and any alternative was 5 less years of least tern breeding habitat availability for the GP1521 and GP2021 options at Cottonwood Bend over the 66-year period of record. On an individual bar basis, the alternatives appear to have a minimal effect on least tern nesting habitat availability when compared with the CWCP. When the 11 sandbars were considered as a system, the GP1521 and GP2021 options differ significantly ($P < 0.1$) from the CWCP. The biological consequences of implementing any of the alternative Water Control Plans would be minimal.

7.15.3 Dredging

Subsequent to the release of the RDEIS, additional Mississippi River dredging impact evaluations were accomplished. Specific dredging-related impacts investigated included season start date, dredge season stop date, dredging quantities, late summer stages, and minimum stage. Documentation of these evaluations is incorporated in a St. Louis District of the Corps memorandum with the subject, "Revised Missouri Flow Releases - Dredging Impact Analysis" (Corps, 2002d).

The evaluations found very minor differences on the average in the five alternatives evaluated in detail when compared to the CWCP. Considering dredge season start date, no significant changes to the start of the summer falling trend were observed for the alternative Water Control Plans; therefore, the alternatives would not advance or delay the dredge season start date. The dredging season concludes when one of the following criteria is met: all dredging locations have been completed, a statistical forecast indicates the risk of further low water is minimal, or river levels increase. The alternative plans did not result in lower or prolonged lower stages during late season months of January and February.

Increased dredging quantities are affected. The alternative plans would require removal of an increased quantity of material. The Corps' mission is to provide a navigable channel at low water. Low water is defined as "the mean depth for a continuous period of 15 days of lowest water in the navigation season of any year." By this definition, the Corps is authorized to maintain depths to a –5.2 feet St. Louis stage at a flow of 40 kcfs; however, in an effort to be fiscally and environmentally responsible, the St. Louis District uses a risk-based system to determine actual dredging maintenance depths.

Some of the alternatives would provide lower summer river levels and would, therefore, require additional dredging efforts. The depth of the cut, length, width and, possibly, frequency may be affected. Historically, dredging quantities and cost for Middle Mississippi River dredging average about 5 million cubic yards at a cost of $6.9 million per year (1998 to 2000 data used for dollars). The average depth removed at the dredging site is between 4 to 5 feet. Some of the plans will lower the low water reference plane (LWRP) (low water flow at 56 kcfs used for design purposes) 0.4 feet. Even if factors such as length and width

Table 7.15-1. Mean monthly shallow water habitat acres for CWCP, MCP, GP1521, GP1528, GP2021, and GP2028 (1930 -1995).

		St. Louis						Chester						Thebes					
Month	**Statistic**	**CWCP**	**MCP**	**GP1521**	**GP1528**	**GP2021**	**GP2028**	**CWCP**	**MCP**	**GP1521**	**GP1528**	**GP2021**	**GP2028**	**CWCP**	**MCP**	**GP1521**	**GP1528**	**GP2021**	**GP2028**
1	Mean	40,339	40,190	40,343	40,380	40,344	40,379	32,407	32,322	32,944	32,948	32,972	32,953	27,317	27,262	27,474	27,475	27,474	27,476
2	Mean	31,997	32,700	32,048	32,049	32,048	32,323	29,603	29,561	29,570	29,572	28,898	29,745	22,406	22,803	22,838	23,357	22,871	23,425
3	Mean	30,778	30,794	28,996	28,866	28,996	29,090	28,318	28,248	27,566	27,471	27,566	27,782	19,018	19,086	18,945	18,877	18,945	18,879
4	Mean	7,867	7,450	7,450	5,104	7,450	5,104	11,881	11,370	11,379	10,494	11,379	10,494	9,393	9,387	9,389	8,516	9,389	8,516
5	Mean	15,624	17,698	14,121	15,331	14,121	15,331	13,151	13,388	13,508	12,061	13,508	12,061	9,850	11,422	12,403	10,220	12,403	10,220
6	Mean	16,572	21,902	16,755	16,751	18,245	18,407	14,963	16,483	15,344	14,673	15,164	14,405	17,455	17,372	15,778	15,074	15,689	14,984
7	Mean	23,664	22,005	24,941	23,086	24,941	23,086	22,712	22,636	24,272	22,393	24,272	22,393	20,899	20,590	19,647	20,378	19,647	20,378
8	Mean	31,879	31,176	34,336	31,331	34,384	31,329	28,262	28,563	29,707	28,639	29,709	29,194	25,226	23,843	26,200	25,448	26,228	25,477
9	Mean	28,993	31,356	29,166	29,261	29,669	29,992	27,680	26,175	27,668	27,499	27,771	27,607	24,818	25,266	24,726	23,879	23,904	23,473
10	Mean	40,106	40,811	41,751	39,599	40,973	39,813	33,372	32,598	32,583	32,738	31,956	32,917	28,185	27,559	27,332	28,250	28,063	26,513
11	Mean	40,327	43,179	37,206	40,276	37,326	40,894	32,533	35,558	33,457	35,316	33,503	35,296	27,964	28,893	28,017	30,055	28,721	30,260
12	Mean	42,029	40,651	42,415	42,217	42,459	42,514	35,214	34,652	35,121	35,138	35,268	35,190	30,963	31,080	30,771	30,868	30,804	31,018

Table 7.15-2. The number of occurrences of "continuous" days (>50, >75, >100) of sandbar exposure for 11 potential least tern nesting/rearing sites over the 66-year (1930-1995) period of record for the CWCP and the five alternatives.

	Number of Occurrences					
Sandbar	**CWCP**	**MCP**	**GP1521**	**GP1528**	**GP2021**	**GP2028**
Thompson Towhead						
>50	21	20	19	21	19	21
>75	7	8	6	6	5	6
>100	7	8	6	6	5	6
Brown's Bar						
>50	43	43	41	42	41	42
>75	26	26	23	24	23	24
>100	26	26	23	24	23	24
Bumgard Island						
>50	14	14	11	13	11	13
>75	5	4	3	5	3	5
>100	5	4	3	5	3	5
Billings Island						
>50	29	29	32	31	32	31
>75	14	14	15	14	15	14
>100	10	10	10	10	10	10
Marquette Island						
>50	31	31	32	32	32	32
>75	15	16	13	14	13	14
>100	15	16	13	14	13	14
Cottonwood Bar						
>50	55	54	53	55	53	55
>75	39	39	34	38	34	38
>100	39	39	34	38	34	38
Fountain Bluff Bar						
>50	8	8	9	8	8	9
>75	0	0	0	0	0	0
>100	0	0	0	0	0	0
McLean Point						
>50	61	61	61	60	60	61
>75	51	51	51	50	50	51
>100	51	51	51	50	50	51
Rockwood Island						
>50	26	26	23	26	23	26
>75	12	12	10	13	10	13
>100	2	2	1	2	1	2
Moro Island						
>50	32	32	32	32	32	32
>75	16	15	13	13	13	13
>100	16	15	13	13	13	13
Establishment Island						
>50	15	15	13	14	13	13
>75	5	5	4	3	4	3
>100	5	5	4	3	4	3

remain constant, a 0.4-foot additional dredging depth would increase quantities by 8 percent. This correlates to an additional 400,000 cubic yards and an increased cost of $560,000. If additional length and width are required, up to 10 percent more area may need to be dredged. In years when additional flows from the Missouri River are crucial, the additional dredging requirement could require an increased effort of 18 percent, which equates to 900,000 cubic yards and a cost of $1.2 million.

In summary, comparing the CWCP and the alternatives using only average values and percent changes will not accurately show impacts to channel maintenance activities. In average years and average months, channel maintenance activities only appear to be slightly affected. The real problem occurs when there is a less-than-average year or month with reduced flows from the Upper Mississippi River. In these instances, the effect of Missouri River flows on the St. Louis stage is magnified.

7.15.4 Navigation

Annual lost navigation efficiency costs are presented in Table 7.15-3 and Figures 7.15-22 through 24 for the six alternatives for the 66-year period of analysis (1930 to 1995). These figures show that these costs are highly variable, ranging from no cost in many years for all six alternatives to as much as $1,175 million in 1939 for the CWCP. Figure 7.15-22 shows that the differences in costs between the CWCP and the MCP occur during the three Missouri River basin droughts (1930 to 1941, 1954 to 1961, and 1987 to 1993). This is an indication that the increased drought conservation measures are the primary reason for the differences. The differences between the MCP and the GP1528 option are much smaller, which is an indication that the Gavins Point release changes have a relatively smaller impact on the Mississippi River navigation costs. Similarly, the differences between the GP1528 option and the other three GP options are all relatively small.

In summary, navigation impacts on the Mississippi River due to changes in a Water Control Plan for the Mainstem Reservoir System on the Missouri River are relatively minor on an average annual basis, no matter what the alternative is. As shown in the plots of the annual damages, however, these impacts can be very severe in a given year, as they were in 1939.

7.15.5 Mississippi River Channel Improvement Features, Mouth of Missouri River to Gulf of Mexico

The low water reference plane (LWRP) on the Mississippi River is used to establish crown elevation for dikes and other river engineering works. It is also used by navigation interests to obtain a general idea of the depth of water available at critical locations on the river. The LWRP profile along the Mississippi River is developed from LWRP stages computed at individual gaging stations based on the 97 percent exceedance flow for a specified period of record (typically from 1954 to the time of computation) being applied to a series of rating curves from a more recent period (typically the past 10 years). The LWRP was most recently re-computed in 1992 using the 1954 to 1991 period of record flows and 1982 to 1991 rating curves. Current LWPR stages for the Mississippi River downstream of St. Louis are shown in Table 7.15-4.

To assess the impact of the alternatives on the Mississippi River LWRP, the original LWRP computation procedure was modified to produce reasonable estimates of the impacts on the Mississippi River LWRP resulting from the change in the Missouri River flow. The current analysis consisted of four steps, as described below.

1. Compute the 97 percent exceedance flow at each of the 10 Mississippi River discharge gaging stations listed in Table 7.15-4 for the CWCP, the MCP, and the four GP options

Table 7.15-3. Mississippi River lost navigation efficiency average annual costs ($millions).

Missouri River Scenario	Cairo	St. Louis	Both Reaches	Difference From Scenario CWCP
CWCP	18.77	26.50	45.27	0
MCP	17.98	26.04	44.01	(1.26)
GP1528	15.59	23.56	39.15	(6.12)
GP2021	14.97	23.01	37.98	(7.29)
GP1521	14.94	22.95	37.88	(7.39)
GP2028	15.62	23.61	39.22	(6.05)

Table 7.15-4. Current Mississippi River LWRP stages (feet).

Station	Existing LWRP
St. Louis	-3.5
Chester	-0.6
Thebes	4.8
Cairo	9.9
Memphis	-6.7
Helena	-2.2
Arkansas City	-1.1
Vicksburg	2.4
Natchez	7.3
Red River Landing	12.3

using the 1954 to 1991 period of record. Table 7.15-5 contains the 97 percent exceedance flows at each gaging station for each alternative computed from model-routed flows.

2. Use the 1988 (low-water year) observed discharge measurements to develop low-water rating curves at each of the 10 gaging stations by drawing a best-fit curve through measured points. Then raise or lower the curve to match the point defined by the existing LWRP stage and the 97 percent exceedance discharge from the CWCP, which represents the base plan. The use of the single rating curve (1988) deviates from the actual method used in computing the LWRP. The actual method involves developing a set of 10 rating curves (one for each year from 1982 through 1991), converting the 97 percent exceedance flow to stages, and then taking the average of the 10 stages to determine the LWRP. A single rating curve was used in this study for the sake of expediency.

3. Draw a line tangent to each of the rating curves at a point defined by the existing LWRP stage and the 97 percent exceedance discharge from the CWCP. This tangent line defines the slope of the curve at the LWRP stage. The slopes, shown below, were rounded off and grouped by Corps District reaches for simplicity and consistency of results:

   St. Louis District 5.5 kcfs/foot
   (St. Louis, Chester, Thebes)

   Memphis District 13.0 kcfs/foot
   (Hickman, Memphis, Helena)

   Vicksburg District 14.0 kcfs/foot
   (Arkansas City, Vicksburg, Natchez)

   New Orleans District 18.0 kcfs/foot
   (Red River Landing)

4. Compute the impact on the LWRP by applying the slope to the difference in the 97 percent exceedance flows (between the CWCP and other alternatives). Table 7.15-6 shows the computed differences in the LWRP, with the positive values indicating the raising of the LWRP and the negative values indicating the lowering of the LWRP. Table 7.15-7 shows the adjusted LWRP stages.

Table 7.15-6 shows that all alternatives have negative impacts by lowering the LWRP, typically by 0.2 to 0.4 foot along the Middle Mississippi River and 0.2 to 0.3 foot along the Lower Mississippi River. The lowering of the LWRP would require the training dikes on the Mississippi River to be extended farther into the river at a substantial cost.

Table 7.15-8 presents the cost associated with Mississippi River channel improvement feature modifications resulting from the respective alternatives. A previous study by the St. Louis District determined that, for each 0.1 foot of reduction in the existing LWRP, the cost of new construction of training structures for the Middle and Lower Mississippi River reaches would be $5 million. This cost is associated with maintaining a 9-foot navigation channel in the Mississippi River. This does not include environmental impacts that may accrue from changing channel improvement features.

Table 7.15-5. 97 percent exceedance flow (kcfs).

Alternative	St. Louis	Chester	Thebes	Hickman	Memphis	Helena	Ark City	Vicksburg	Natchez	RRL
CWCP	56.4	59.2	60.1	138.9	147.7	151.2	170.0	176.7	173.9	130.0
MCP	54.4	56.8	57.7	136.7	146.0	149.2	167.3	172.8	170.3	127.8
GP2028	54.5	56.9	57.9	135.6	145.3	149.0	167.5	172.9	170.8	128.3
GP1521	55.5	58.2	59.2	135.0	144.6	147.7	167.1	172.9	172.4	128.3
GP2021	55.5	58.2	59.2	135.1	144.6	147.5	167.1	172.9	172.4	128.3
GP1528	54.8	57.2	58.3	135.6	145.3	149.0	167.5	172.9	170.8	128.3

RRL = Red River Landing

Table 7.15-6. Change in Mississippi River LWRP relative to the CWCP (feet).

Alternative	St. Louis	Chester	Thebes	Hickman	Memphis	Helena	Ark City	Vicksburg	Natchez	RRL
CWCP	0	0	0	0	0	0	0	0	0	0
MCP	-0.35	-0.43	-0.44	-0.17	-0.13	-0.16	-0.19	-0.28	-0.25	-0.13
GP2028	-0.35	-0.41	-0.39	-0.26	-0.19	-0.17	-0.18	-0.27	-0.22	-0.09
GP1521	-0.17	-0.17	-0.16	-0.30	-0.25	-0.27	-0.20	-0.27	-0.11	-0.09
GP2021	-0.17	-0.17	-0.16	-0.29	-0.25	-0.29	-0.20	-0.27	-0.11	-0.09
GP1528	-0.29	-0.35	-0.34	-0.26	-0.19	-0.17	-0.18	-0.27	-0.22	-0.09

RRL = Red River Landing

Table 7.15-7. Revised Mississippi River LWRP (feet).

Alternative	St. Louis	Chester	Thebes	Hickman	Memphis	Helena	Ark City	Vicksburg	Natchez	RRL
CWCP	-3.50	-0.60	4.80	9.90	-6.70	-2.20	-1.10	2.40	7.30	12.30
MCP	-3.85	-1.03	4.36	9.73	-6.83	-2.36	-1.29	2.12	7.05	12.18
GP2028	-3.85	-1.01	4.41	9.64	-6.89	-2.37	-1.28	2.13	7.08	12.21
GP1521	-3.67	-0.77	4.64	9.60	-6.95	-2.47	-1.30	2.13	7.19	12.21
GP2021	-3.67	-0.77	4.64	9.61	-6.95	-2.49	-1.30	2.13	7.19	12.21
GP1528	-3.79	-0.95	4.46	9.64	-6.89	-2.37	-1.28	2.13	7.08	12.21

RRL = Red River Landing

Table 7.15-8. Mississippi River channel improvement features cost by alternative.

Alternative	St. Louis LWRP (feet)	Change in LWRP (feet)	Increased Cost ($million)
CWCP	-3.50	0	0
MCP	-3.85	-0.35	17.5
GP2028	-3.85	-0.35	17.5
GP1521	-3.67	-0.17	8.5
GP2021	-3.67	-0.17	8.5
GP1528	-3.79	-0.29	14.5

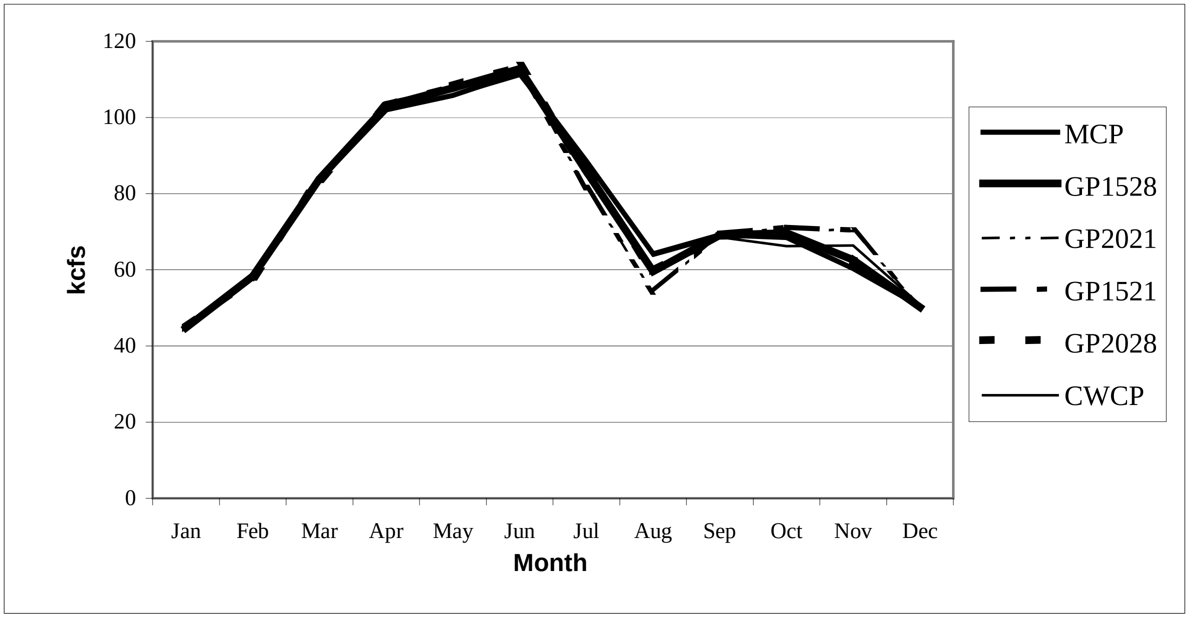

Figure 7.15-1. Average monthly flow at Hermann, Missouri.

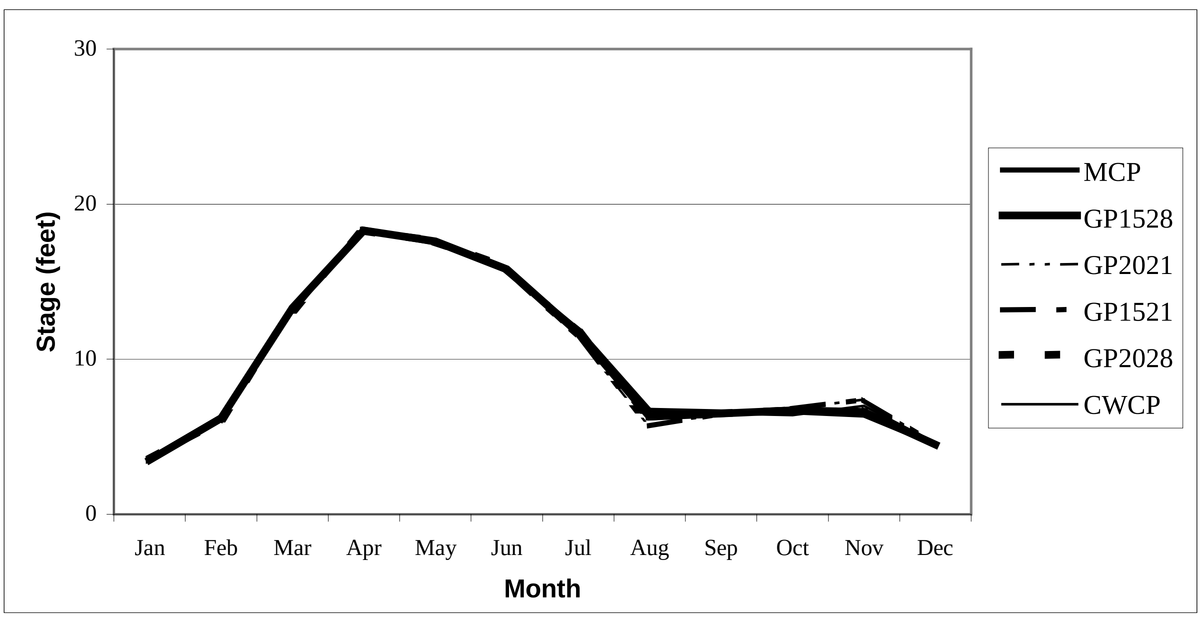

Figure 7.15-2. Mean monthly stage at St. Louis.

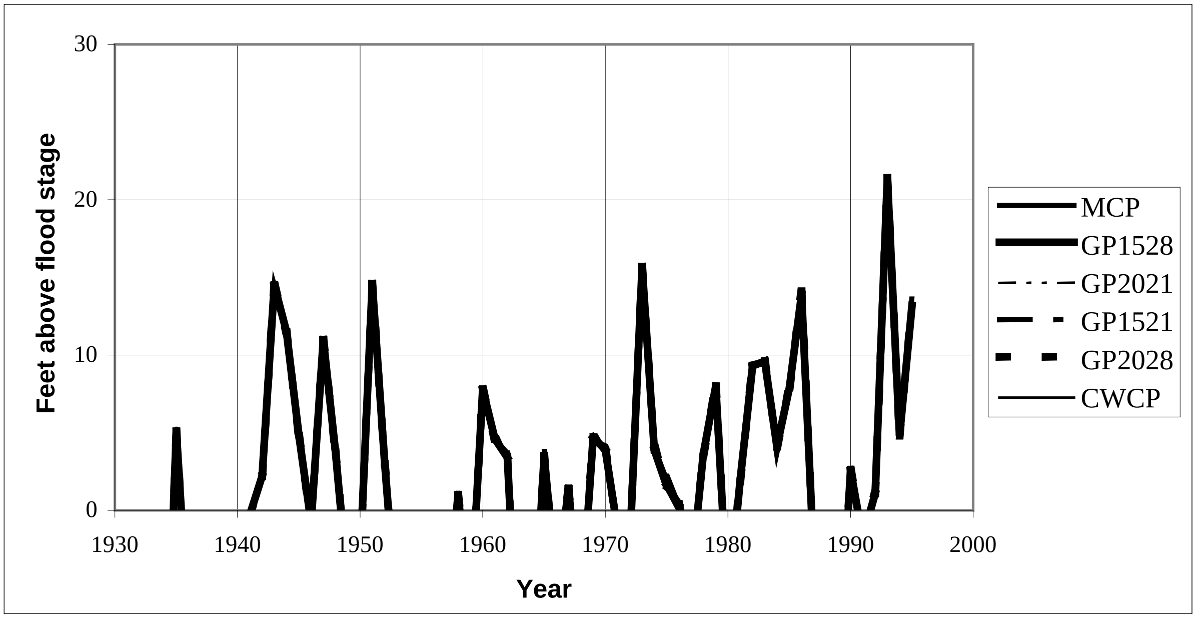

Figure 7.15-3. Maximum annual stage at St. Louis.

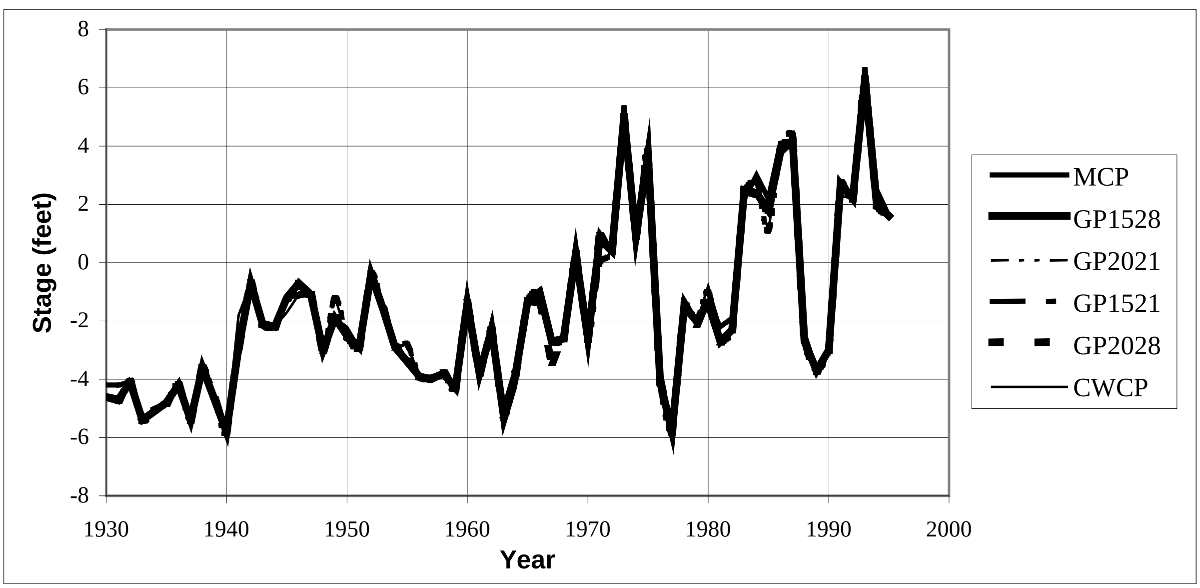

Figure 7.15-4. Minimum annual stage at St. Louis.

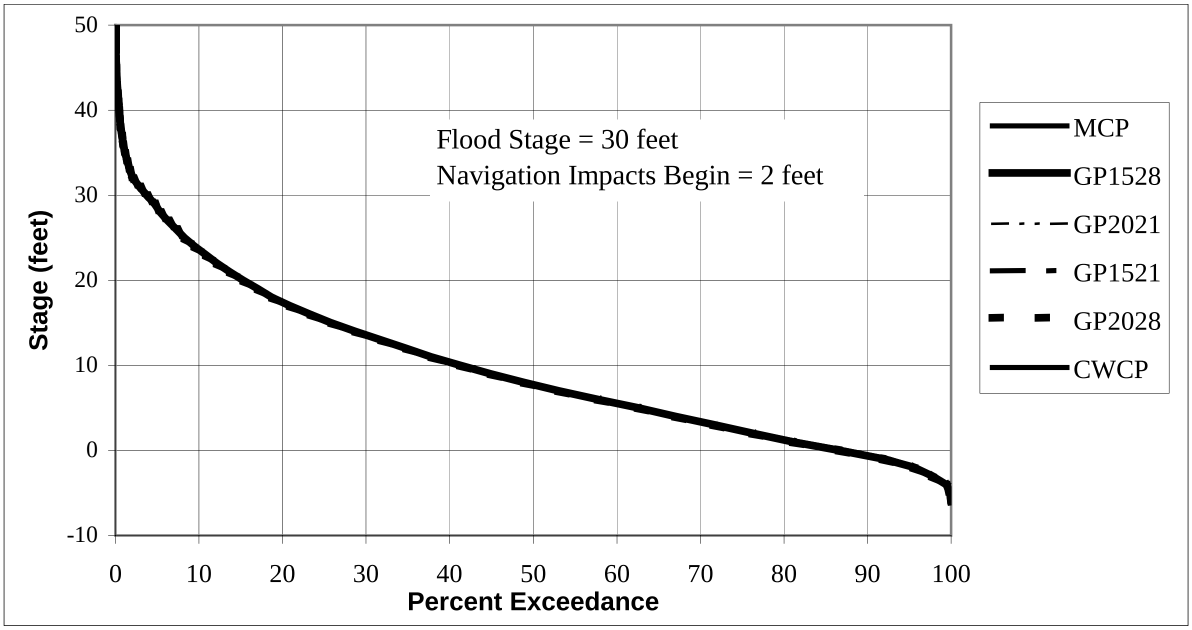

Figure 7.15-5. Average annual St. Louis stage duration.

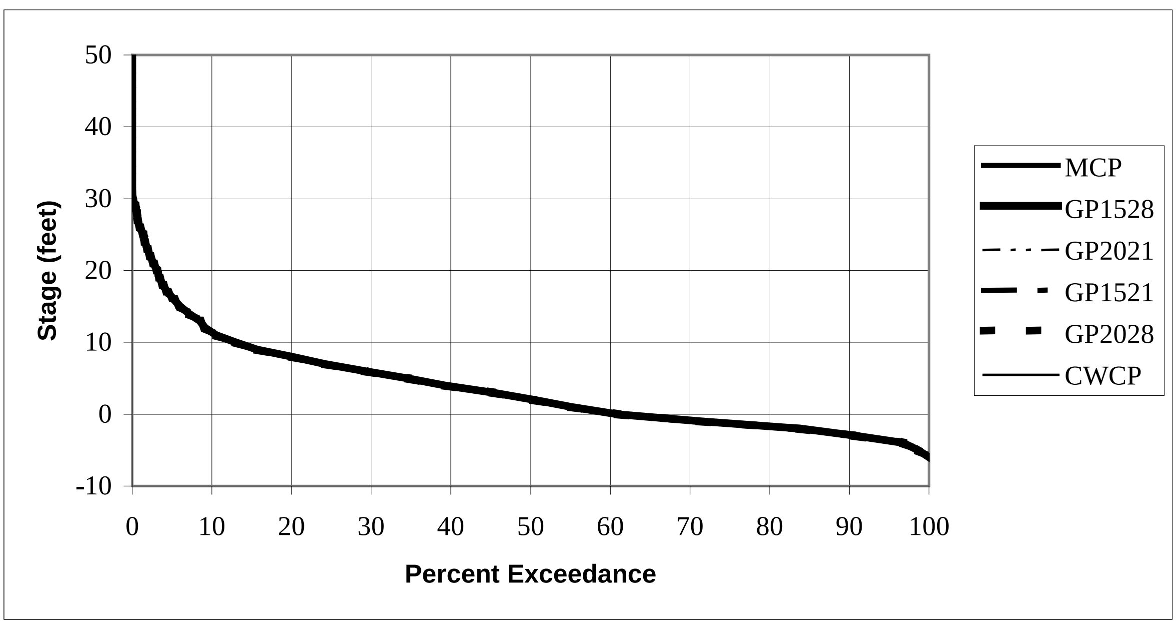

Figure 7.15-6. St. Louis stage duration, January.

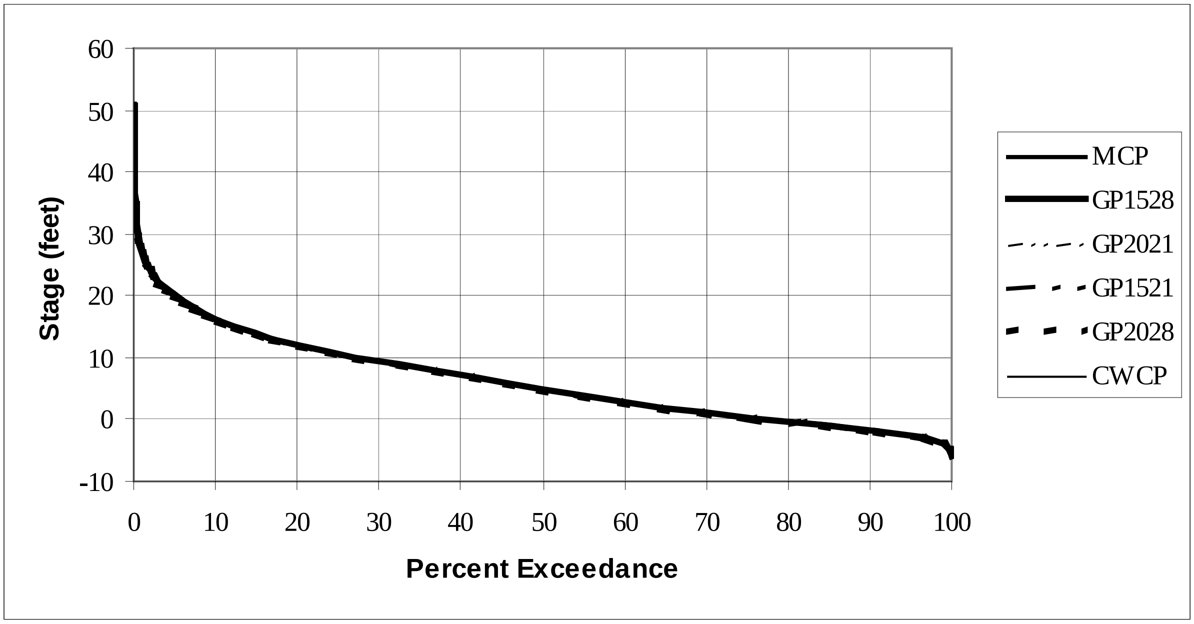

Figure 7.15-7. St. Louis stage duration, February.

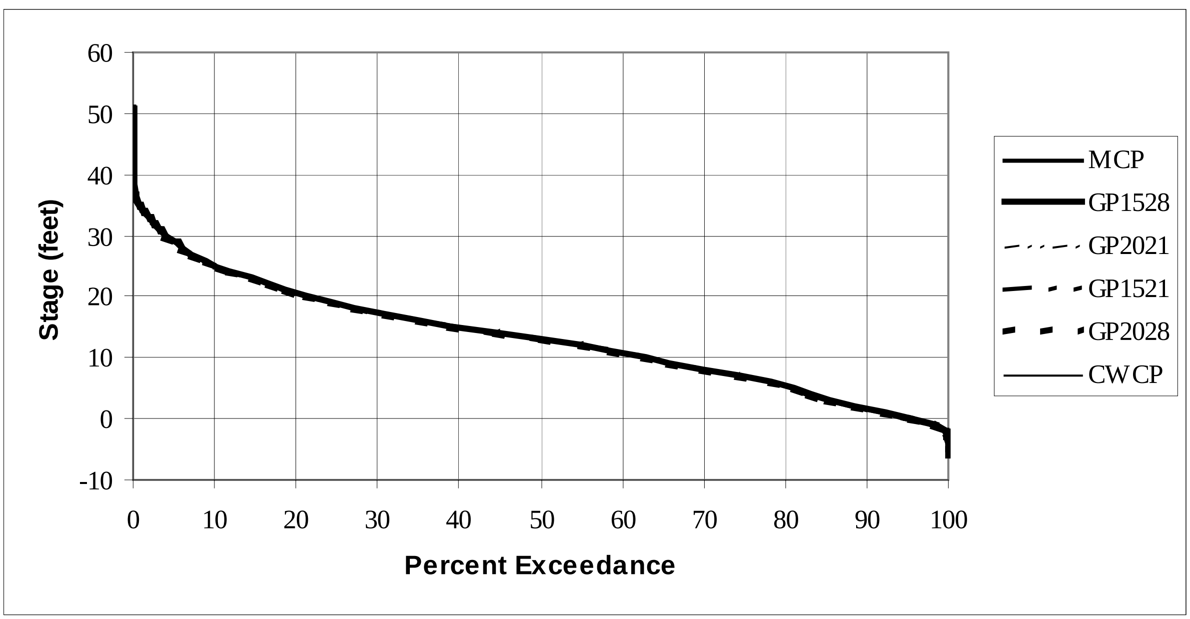

Figure 7.15-8. St. Louis stage duration, March.

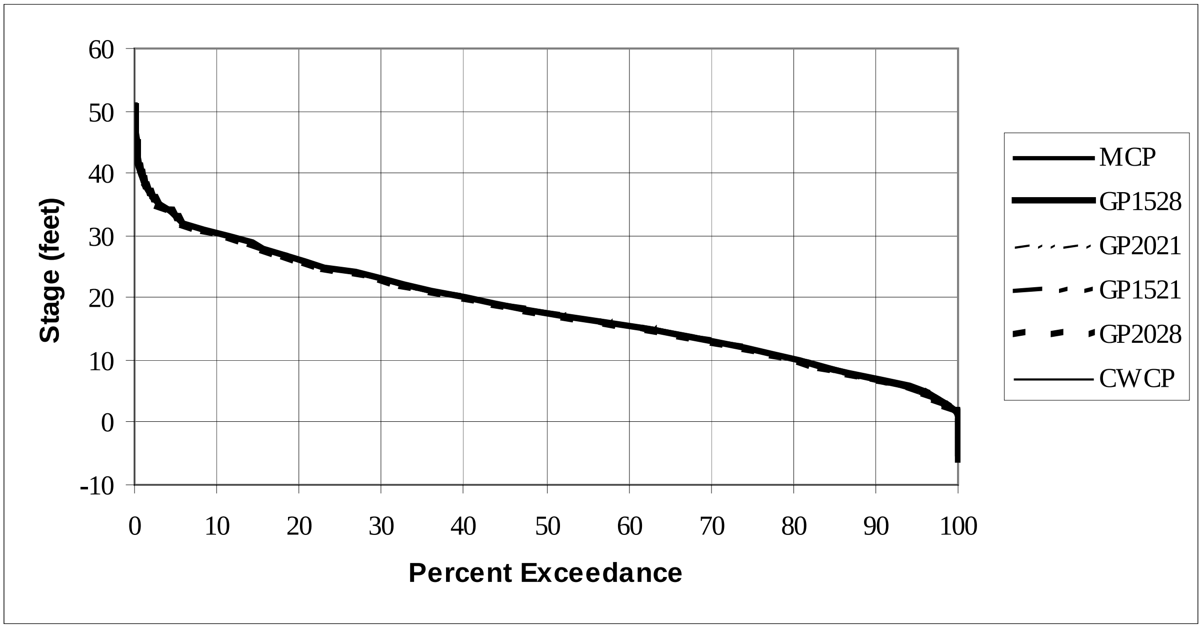

Figure 7.15-9. St. Louis stage duration, April.

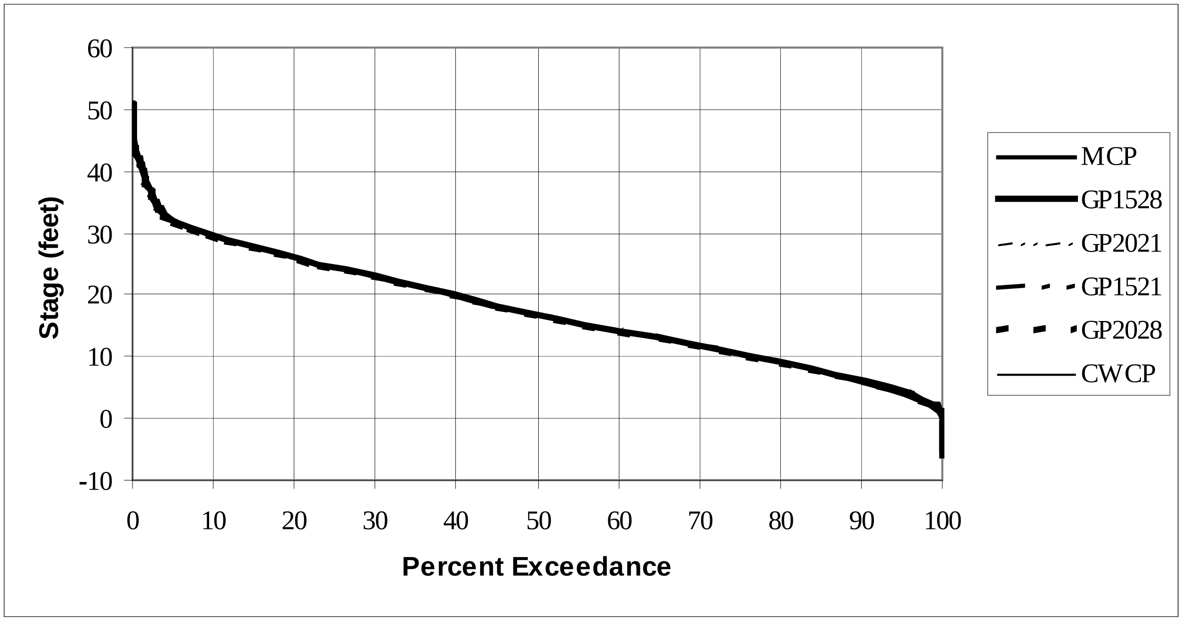

Figure 7.15-10. St. Louis stage duration, May.

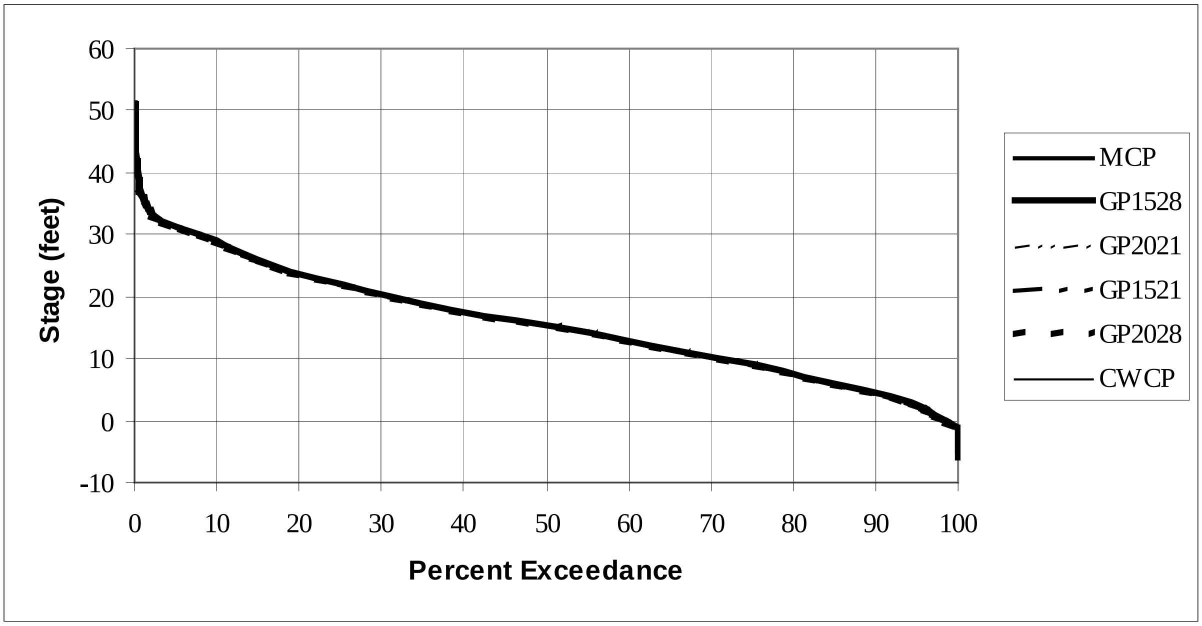

Figure 7.15-11. St. Louis Stage Duration, June.

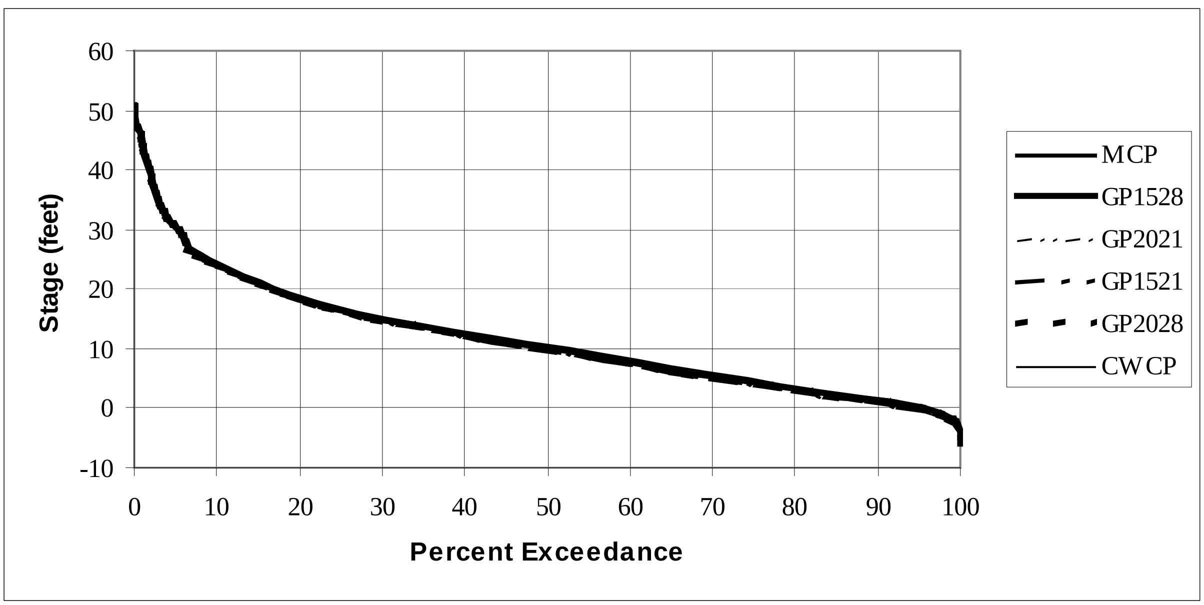

Figure 7.15-12. St. Louis stage duration, July.

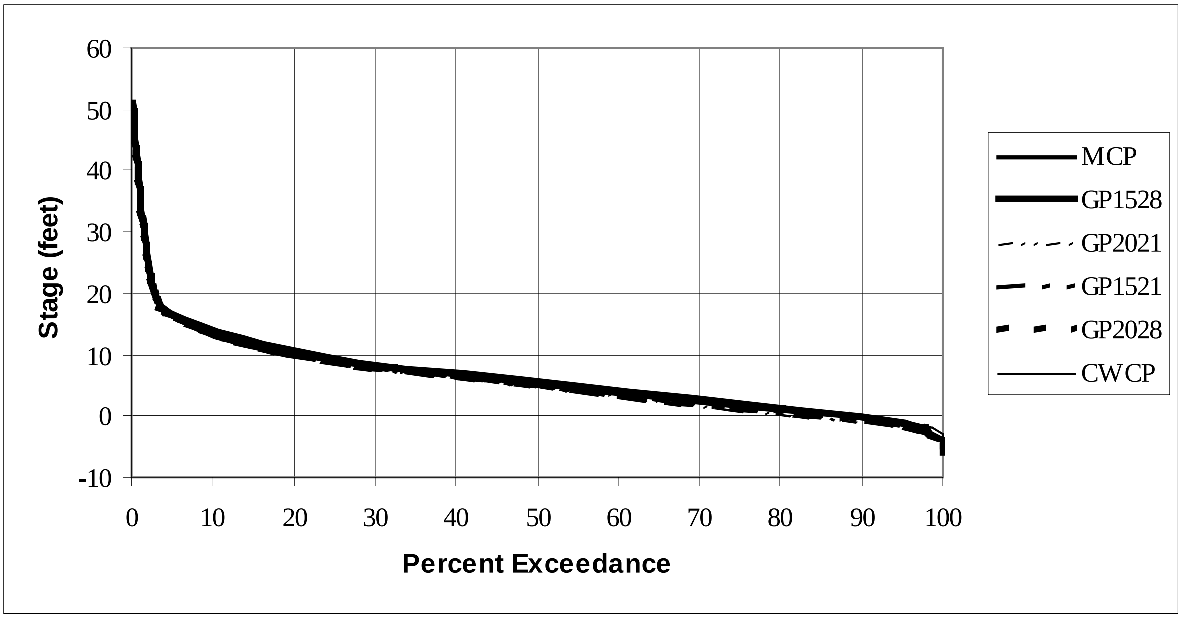

Figure 7.15-13. St. Louis stage duration, August.

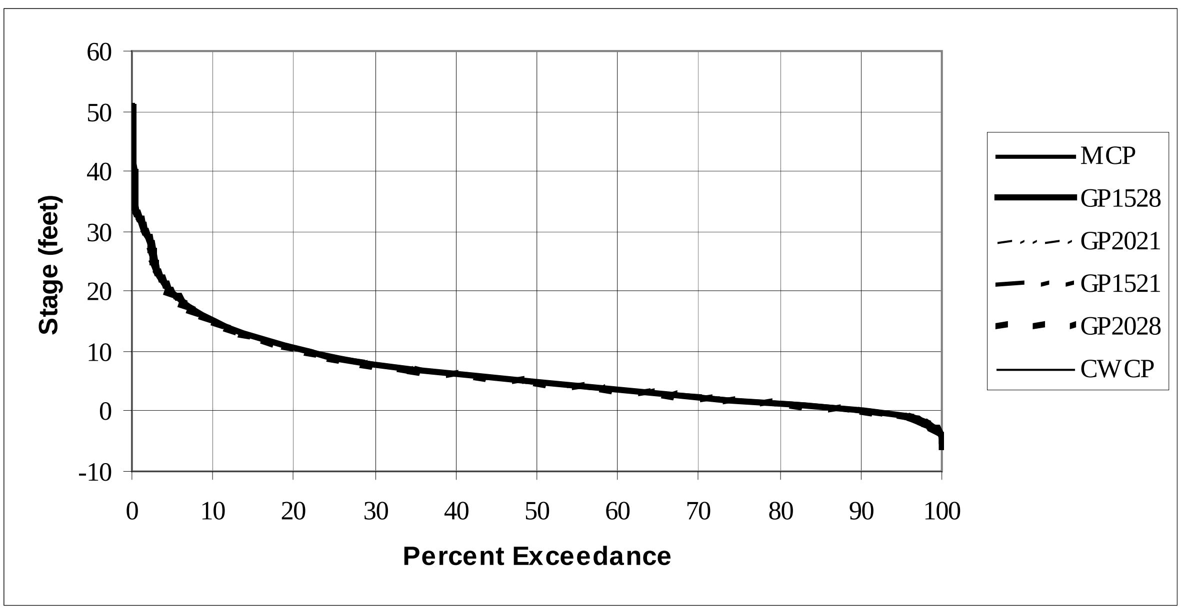

Figure 7.15-14. St. Louis stage duration, September.

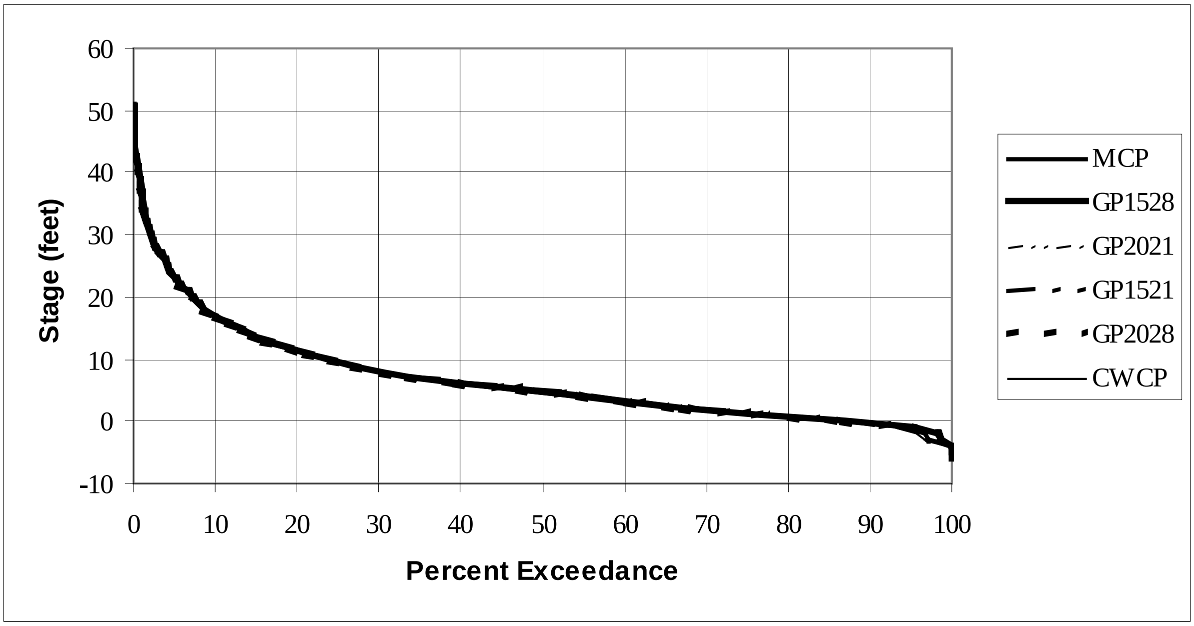

Figure 7.15-15. St. Louis stage duration, October.

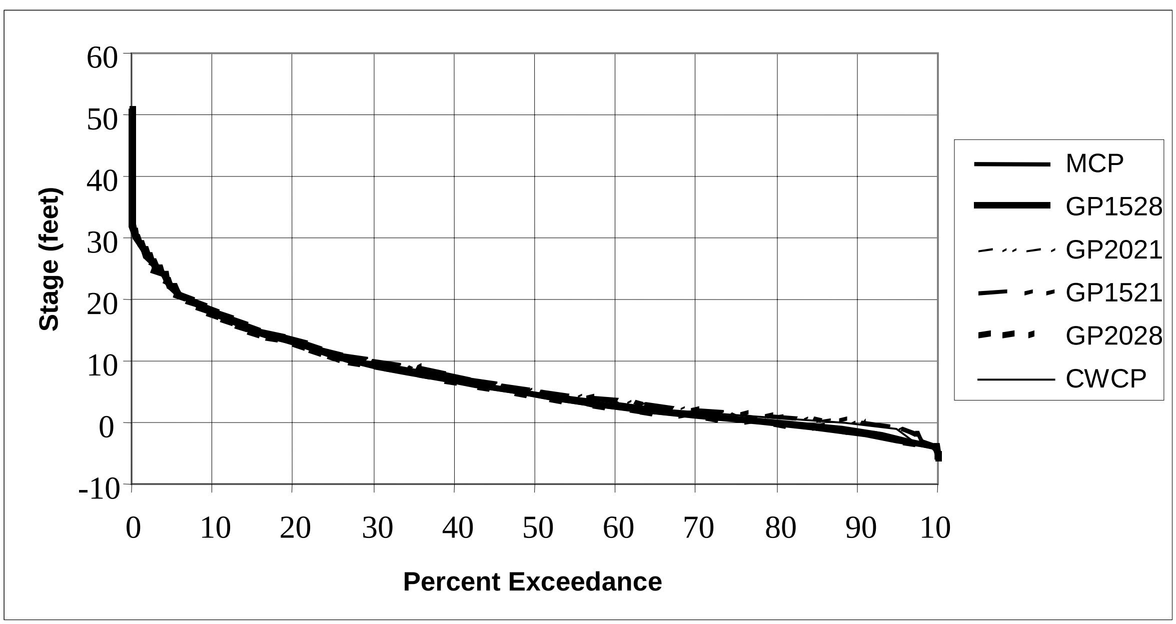

Figure 7.15-16. St. Louis stage duration, November.

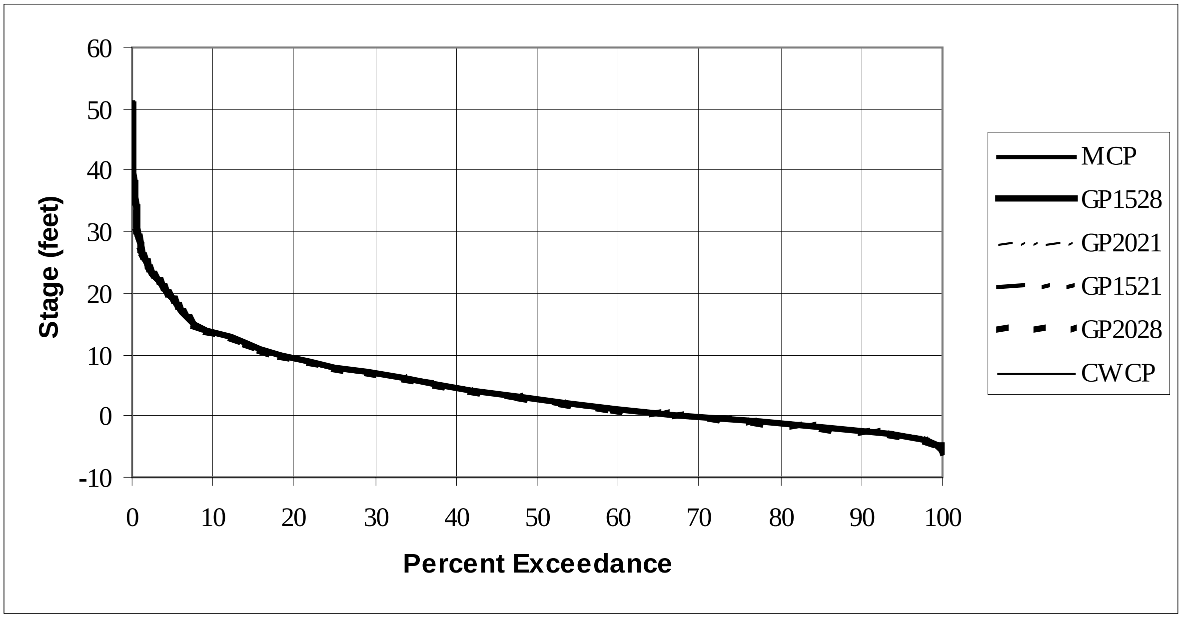

Figure 7.15-17. St. Louis stage duration, December.

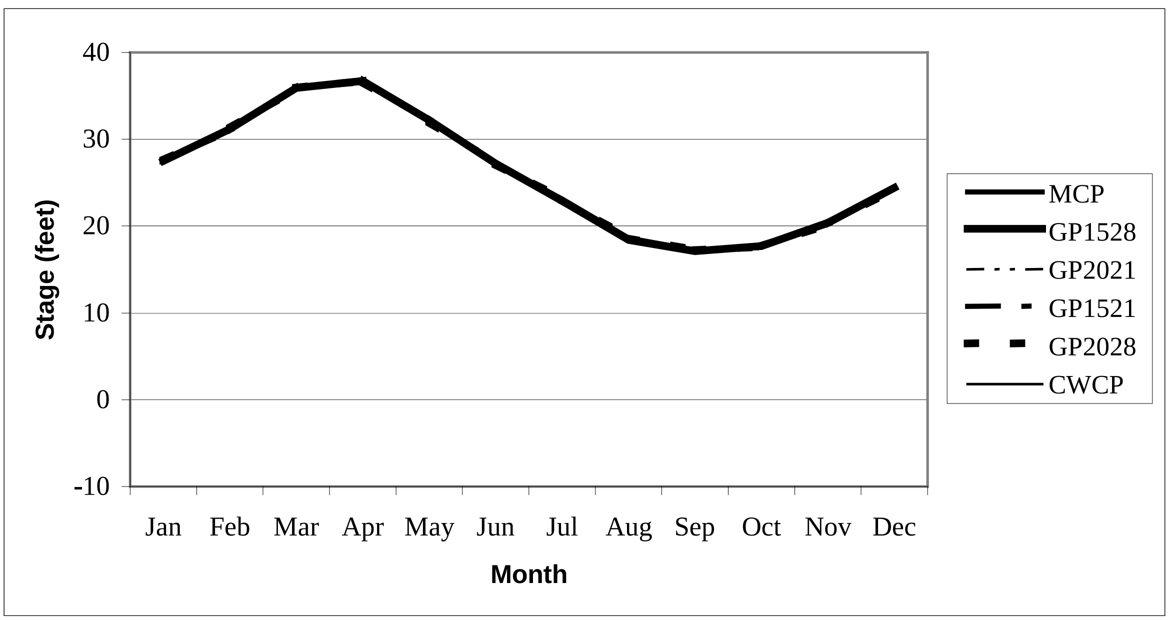

Figure 7.15-18. Mean monthly stage at Cairo.

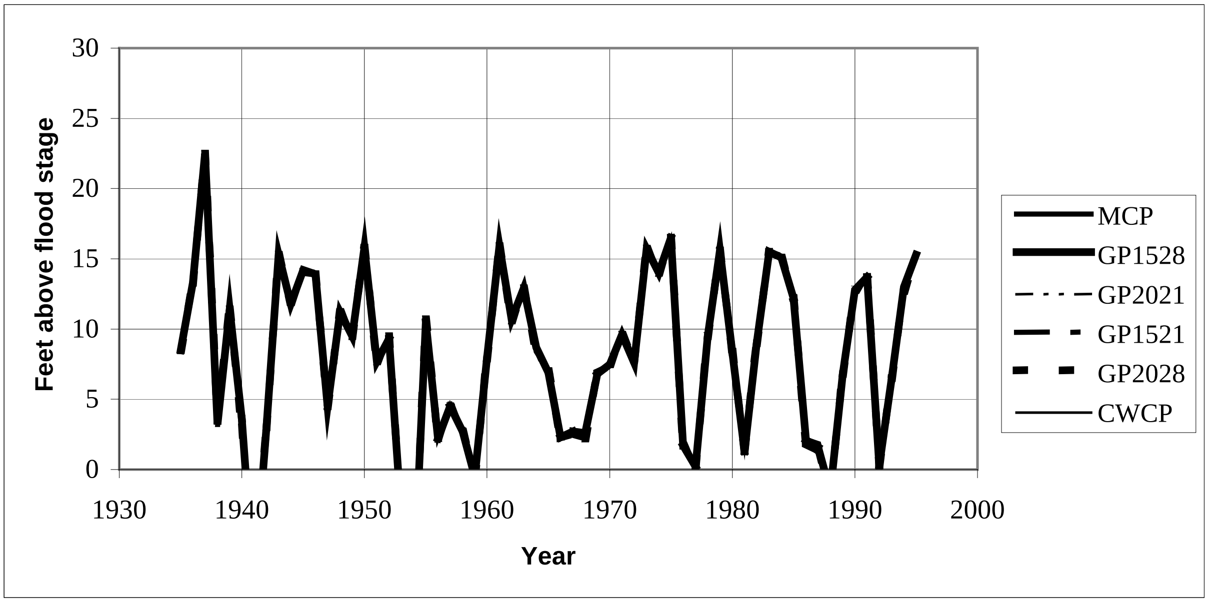

Figure 7.15-19. Maximum annual stage at Cairo.

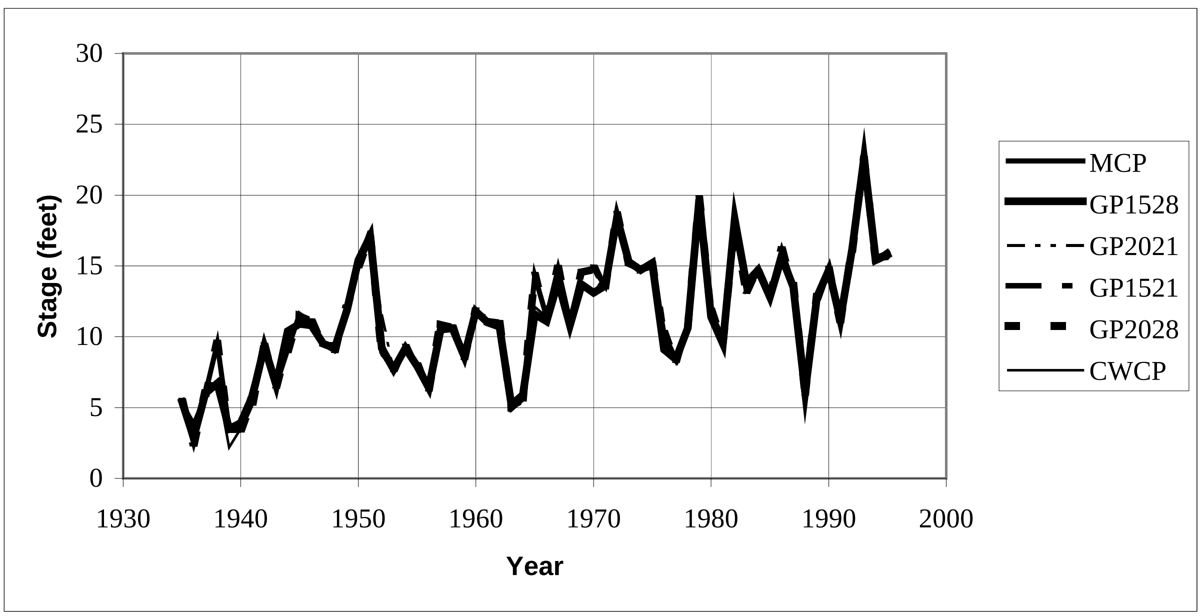

Figure 7.15-20. Minimum annual stage at Cairo.

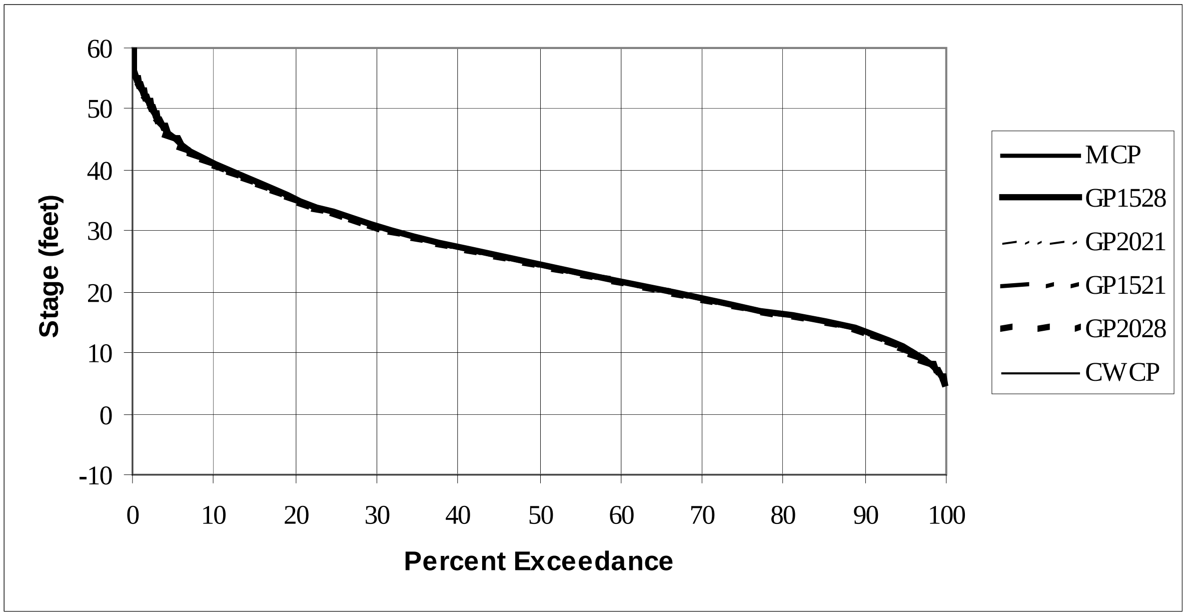

Figure 7.15-21. Cairo stage duration.

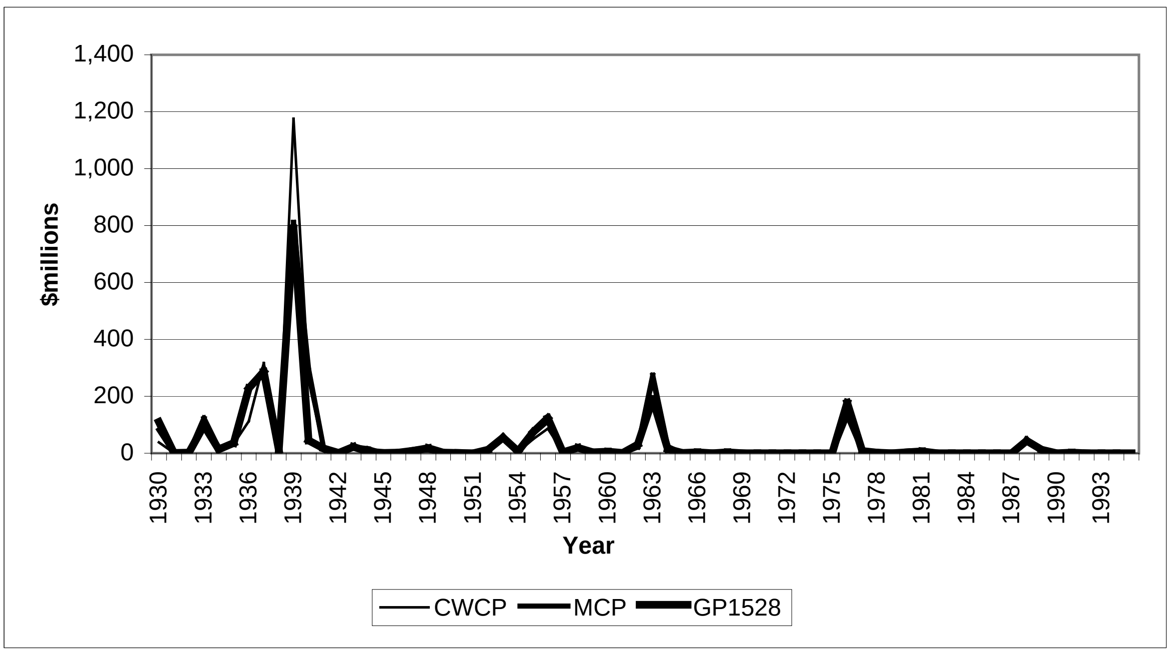

Figure 7.15-22. Increased costs associated with Mississippi River navigation inefficiencies for CWCP, MCP, and GP1528.

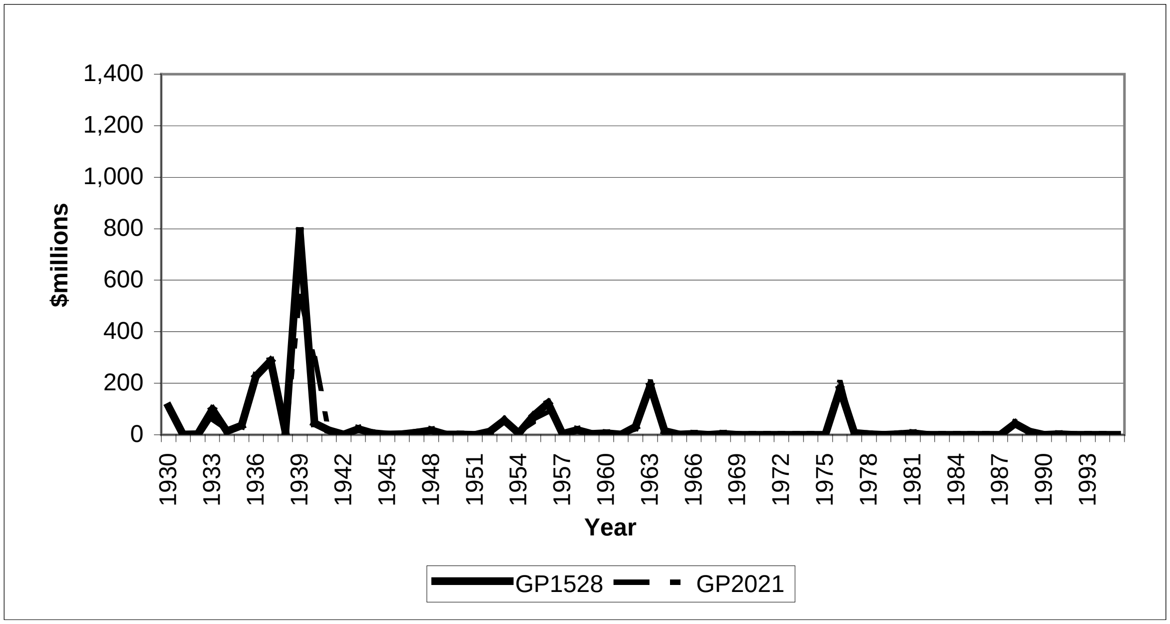

Figure 7.15-23. Increased costs associated with Mississippi River navigation inefficiencies for GP1528 and GP2021.

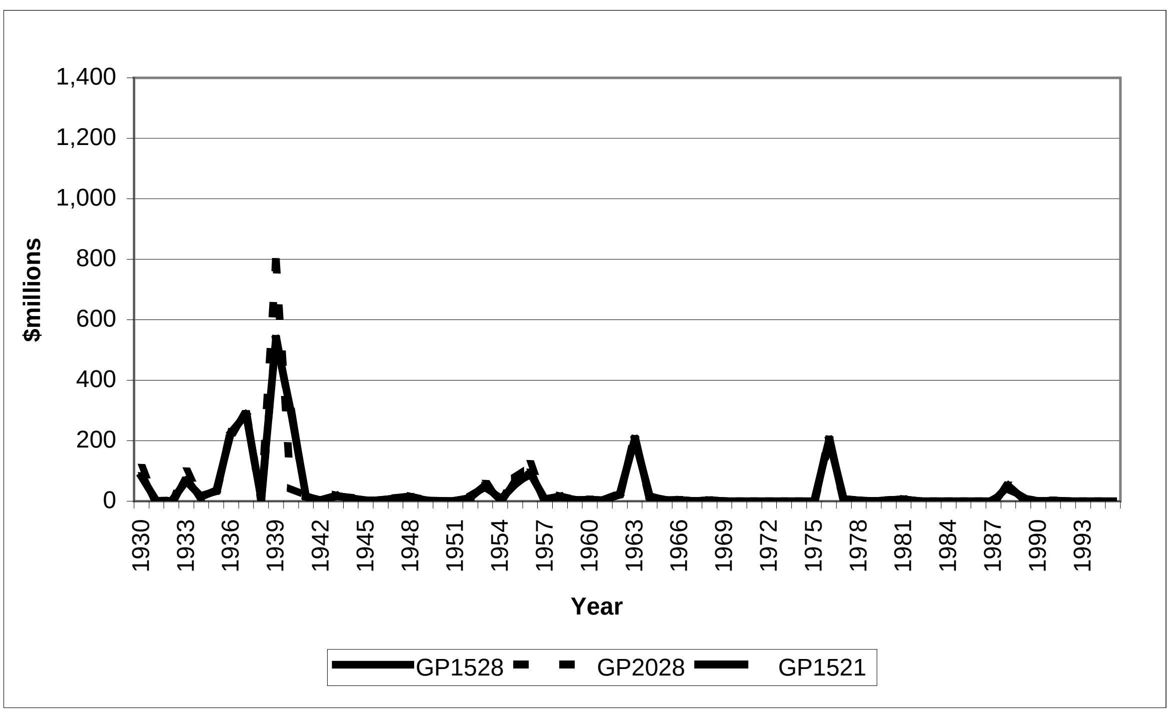

Figure 7.15-24. Increased costs associated with Mississippi River navigation inefficiencies for GP1528, GP2028, and GP1521.

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7.16 SUMMARY OF IMPACTS OF ALTERNATIVES SELECTED FOR DETAILED ANALYSIS TO AMERICAN INDIAN TRIBES

The individual sections of this chapter discuss the impacts to the various environmental resources and economic uses analyzed for the Study on the 13 Tribal Reservations along the Mainstem Reservoir System and Lower River (see Figure 1.5-1 for locations). In the introduction to Chapter 7, readers were encouraged to consider the relative effects among the alternatives, not the absolute values presented for the various resources or uses. This section of Chapter 7 synopsizes the impacts into 12 tables, one for each Reservation except for Iowa and Sac and Fox Reservations, for which impacts are addressed on a single table. (Individual tables would be identical for each Reservation.)

Tables 7.16-1 to 7.16-12 present the summary of impacts for the 13 Tribes. The numbering of the tables corresponds with the order of the Reservation locations going from upstream to downstream. The order of the listing of the environmental resources and economic uses corresponds with the order they are presented in this chapter to make it easier to refer back to the individual sections for more information on an individual resource or use.

Individual numbers for each use/resource in the tables are computed by taking the value for each alternative, subtracting the CWCP value for that specific use or resource for that Reservation from it, dividing the difference by the CWCP value, and then multiplying by 100 to get the percent change from the CWCP value. If a specific alternative increases the value from the CWCP, the percent change presented in the table is positive. If the value decreases relative to the CWCP, the percent change is negative. The reader is asked to focus attention on the "significant" changes. Significant positive changes are those greater than a +1 percent and are shaded a light gray. Significant negative changes are greater than -1 percent and are shaded black with white lettering. A change of +1 represents changes up to 1.49 percent more than, or 101.49 percent of, the CWCP value due to rounding. Similarly, a -1 represents a change up to 1.49 percent less than, or 98.51 percent of, the CWCP value.

Caution must be used when focusing on the shaded percent changes because a resource may have a special meaning to those on one or more of the Reservations, and an "insignificant" change (+1, 0, or -1 in the tables) may be an important change to those on that Reservation. If one of the resources or uses falls into that category for those associated with that Reservation, those individuals are encouraged to note whether the change is slightly positive (+1), no change (0), or slightly negative (-1). A double dash (--) indicates data were not available for that resource or use for that Reservation or that resource or use is not applicable to the reach in which the Reservation is located. Readers are encouraged to review the table/s of interest and to make their own "value" judgments.

Table 7.16-1. Fort Peck Reservation impacts summary.

	Percent Change From CWCP				
	MCP	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Wetland Habitat	3	-14	-14	-8	-7
Riparian Habitat	0	0	0	0	0
Riverine Tern and Plover Habitat	61	-43	-30	-28	-46
Lake Tern and Plover Habitat	--	--	--	--	--
Lake Young Fish Production	--	--	--	--	--
Lake Coldwater Fish Habitat	--	--	--	--	--
River Coldwater Fish Habitat	1	8	8	8	9
River Warmwater Fish Habitat	-8	-17	-17	-17	-19
Native River Fish Physical Habitat	1	2	2	2	2
Flood Control	0	-2	-2	-2	-2
Water Supply	0	14	14	14	14
Hydropower	--	--	--	--	--
Recreation	0	8	9	8	8
Navigation	--	--	--	--	--
Historic Properties	--	--	--	--	--

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-2. Fort Berthold Reservation impacts summary.

	Percent Change From CWCP				
	MCP	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Wetland Habitat	--	--	--	--	--
Riparian Habitat	--	--	--	--	--
Riverine Tern and Plover Habitat	--	--	--	--	--
Lake Tern and Plover Habitat	1	28	29	24	25
Lake Young Fish Production	0	13	15	15	15
Lake Coldwater Fish Habitat	-2	10	10	9	10
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	--	--	--	--	--
Native River Fish Physical Habitat	--	--	--	--	--
Flood Control	-33	-67	-67	-67	-67
Water Supply	6	9	1	1	9
Hydropower	--	--	--	--	--
Recreation	14	12	9	9	14
Navigation	--	--	--	--	--
Historic Properties	-4	-8	-8	-8	-9

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-3. Standing Rock Reservation impacts summary.

	Percent Change From CWCP				
	MCP	GP1528	GP2021	GP1521	GP2028
Wetland Habitat	-10	-62	2	-40	-59
Riparian Habitat	2	5	-9	-14	1
Riverine Tern and Plover Habitat	--	--	--	--	--
Lake Tern and Plover Habitat	9	5	16	11	10
Lake Young Fish Production	2	-3	0	2	2
Lake Coldwater Fish Habitat	6	8	10	10	7
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	--	--	--	--	--
Native River Fish Physical Habitat	--	--	--	--	--
Flood Control	-20	-20	-40	-40	-20
Water Supply	9	10	10	10	10
Hydropower	--	--	--	--	--
Recreation	7	12	7	7	12
Navigation	--	--	--	--	--
Historic Properties	-2	-5	-4	-4	-4

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-4. Cheyenne River Reservation impacts summary.

	Percent Change From CWCP				
	MCP	GP1528	GP2021	GP1521	GP2028
Wetland Habitat	-19	-9	-14	7	-7
Riparian Habitat	-11	-33	-22	-28	-28
Riverine Tern and Plover Habitat	--	--	--	--	--
Lake Tern and Plover Habitat	9	5	16	11	10
Lake Young Fish Production	2	-3	0	2	2
Lake Coldwater Fish Habitat	6	8	10	10	7
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	--	--	--	--	--
Native River Fish Physical Habitat	--	--	--	--	--
Flood Control	-20	-40	-40	-60	-40
Water Supply	13	0	0	0	0
Hydropower	--	--	--	--	--
Recreation	0	0	0	0	0
Navigation	--	--	--	--	--
Historic Properties	-2	-5	-4	-4	-4

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-5. Lower Brule Reservation impacts summary.

	Percent Change From CWCP				
	MCP	GP1528	GP2021	GP1521	GP2028
Wetland Habitat	--	--	--	--	--
Riparian Habitat	--	--	--	--	--
Riverine Tern and Plover Habitat	--	--	--	--	--
Lake Tern and Plover Habitat	--	--	--	--	--
Lake Young Fish Production	-2	12	12	12	9
Lake Coldwater Fish Habitat	--	--	--	--	--
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	--	--	--	--	--
Native River Fish Physical Habitat	--	--	--	--	--
Flood Control	0	0	0	0	0
Water Supply	0	0	0	0	0
Hydropower	--	--	--	--	--
Recreation	0	0	0	0	0
Navigation	--	--	--	--	--
Historic Properties	0	0	0	0	0

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-6. Crow Creek Reservation impacts summary.

	Percent Change From CWCP				
	MCP	GP1528	GP2021	GP1521	GP2028
Wetland Habitat	--	--	--	--	--
Riparian Habitat	--	--	--	--	--
Riverine Tern and Plover Habitat	--	--	--	--	--
Lake Tern and Plover Habitat	--	--	--	--	--
Lake Young Fish Production	-2	12	12	12	9
Lake Coldwater Fish Habitat	--	--	--	--	--
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	--	--	--	--	--
Native River Fish Physical Habitat	--	--	--	--	--
Flood Control	0	0	0	0	0
Water Supply	1	1	1	1	1
Hydropower	--	--	--	--	--
Recreation	0	0	0	0	0
Navigation	--	--	--	--	--
Historic Properties	0	0	0	0	0

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-7. Yankton Reservation impacts summary.

	Percent Change From CWCP				
	MCP	GP1528	GP2021	GP1521	GP2028
Wetland Habitat	1	5	5	3	6
Riparian Habitat	-2	-4	-4	-1	-5
Riverine Tern and Plover Habitat	18	60	98	103	63
Lake Tern and Plover Habitat	--	--	--	--	--
Lake Young Fish Production	0	28	32	23	22
Lake Coldwater Fish Habitat	--	--	--	--	--
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	-9	-16	-22	-22	-17
Native River Fish Physical Habitat	-1	0	-1	-1	0
Flood Control	0	0	0	0	0
Water Supply	0	0	0	0	0
Hydropower	--	--	--	--	--
Recreation	-1	-1	-2	-2	-2
Navigation	--	--	--	--	--
Historic Properties	--	--	--	--	--

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-8. Ponca Tribal Lands impacts summary.

	Percent Change From CWCP				
	MCP	GP1528	GP2021	GP1521	GP2028
Wetland Habitat	-1	0	-6	-6	0
Riparian Habitat	-5	-2	5	5	-2
Riverine Tern and Plover Habitat	18	60	98	103	63
Lake Tern and Plover Habitat	--	--	--	--	--
Lake Young Fish Production	--	--	--	--	--
Lake Coldwater Fish Habitat	--	--	--	--	--
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	-9	-16	-22	-22	-17
Native River Fish Physical Habitat	-1	0	-1	-1	0
Flood Control	0	0	0	0	0
Water Supply	--	--	--	--	--
Hydropower	--	--	--	--	--
Recreation	-1	-1	-2	-2	-2
Navigation	--	--	--	--	--
Historic Properties	--	--	--	--	--

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-9. Santee Reservation impacts summary.

	Percent Change From CWCP				
	MCP	GP1528	GP2021	GP1521	GP2028
Wetland Habitat	-1	0	-6	-6	0
Riparian Habitat	-5	-2	5	5	-2
Riverine Tern and Plover Habitat	18	60	98	103	63
Lake Tern and Plover Habitat	--	--	--	--	--
Lake Young Fish Production	13	25	25	19	19
Lake Coldwater Fish Habitat	--	--	--	--	--
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	--	--	--	--	--
Native River Fish Physical Habitat	--	--	--	--	--
Flood Control	0	0	0	0	0
Water Supply	0	0	0	0	0
Hydropower	--	--	--	--	--
Recreation	0	0	0	0	0
Navigation	--	--	--	--	--
Historic Properties	--	--	--	--	--

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-10. Winnebago Reservation impacts summary.

	Percent Change From CWCP				
	MCP	GP1528	GP2021	GP1521	GP2028
Wetland Habitat	3	-2	-3	0	-2
Riparian Habitat	0	-2	-7	-3	-6
Riverine Tern and Plover Habitat	--	--	--	--	--
Lake Tern and Plover Habitat	--	--	--	--	--
Lake Young Fish Production	--	--	--	--	--
Lake Coldwater Fish Habitat	--	--	--	--	--
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	--	--	--	--	--
Native River Fish Physical Habitat	0	0	-1	-1	0
Flood Control	0	-1	0	-1	-1
Water Supply	0	0	0	0	0
Hydropower	--	--	--	--	--
Recreation	-1	-2	-5	-4	-2
Navigation	--	--	--	--	--
Historic Properties	--	--	--	--	--

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-11. Omaha Reservation impacts summary.

	Percent Change From CWCP				
	MCP	GP1528	GP2021	GP1521	GP2028
Wetland Habitat	3	-2	-3	0	-2
Riparian Habitat	0	-2	-7	-3	-6
Riverine Tern and Plover Habitat	--	--	--	--	--
Lake Tern and Plover Habitat	--	--	--	--	--
Lake Young Fish Production	--	--	--	--	--
Lake Coldwater Fish Habitat	--	--	--	--	--
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	--	--	--	--	--
Native River Fish Physical Habitat	0	0	-1	-1	0
Flood Control	0	-1	0	-1	-1
Water Supply	0	0	0	0	0
Hydropower	--	--	--	--	--
Recreation	-1	-2	-5	-4	-2
Navigation	--	--	--	--	--
Historic Properties	--	--	--	--	--

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

Table 7.16-12. Iowa and Sac and Fox Reservations impacts summary.

	Percent Change From CWCP				
	MCP	GP1528	GP2021	GP1521	GP2028
Wetland Habitat	2	7	4	6	7
Riparian Habitat	-1	-4	-3	-3	-4
Riverine Tern and Plover Habitat	--	--	--	--	--
Lake Tern and Plover Habitat	--	--	--	--	--
Lake Young Fish Production	--	--	--	--	--
Lake Coldwater Fish Habitat	--	--	--	--	--
River Coldwater Fish Habitat	--	--	--	--	--
River Warmwater Fish Habitat	--	--	--	--	--
Native River Fish Physical Habitat	1	3	3	3	3
Flood Control	0	0	0	0	0
Water Supply	--	--	--	--	--
Hydropower	--	--	--	--	--
Recreation	0	-1	-2	-2	-1
Navigation	--	--	--	--	--
Historic Properties	--	--	--	--	--

Light gray shading denotes a beneficial impact when compared to the CWCP.
Black shading denotes an adverse impact when compared to the CWCP.
-- denotes not available or not applicable.

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7.17 SUMMARY OF IMPACTS OF ALTERNATIVES SELECTED FOR DETAILED ANALYSIS

The individual sections of this chapter discuss the impacts to the various environmental resources and economic uses analyzed for the Study. In the introduction to Chapter 7, readers were encouraged to consider the relative differences in impacts among the alternatives, not the absolute values presented for the various resources or uses. This section of Chapter 7 summarizes the impacts into a single table.

Table 7.17-1 presents the summary of impacts for the MCP and the four GP options. The order of the listing of the environmental resources and economic uses corresponds with the order they are presented in this chapter to make it easier to refer back to the individual sections for more information on an individual resource or use. Individual numbers for each use/resource in the tables are computed by taking the average annual value of each alternative, subtracting the CWCP value for that specific use or resource from it, and dividing the difference by the CWCP value and then multiplying by 100 to get the percent change from the CWCP value. If a specific alternative increases the value from the CWCP, the percent change presented in the table is positive. If the value decreases relative to the CWCP, the percent change is negative. The reader is asked to focus attention on the "significant" changes of greater than a plus or minus 1 percent. Positive changes greater than 1 are shaded a light gray. Negative changes greater than -1 are shaded black with white lettering. (Note: A change of +1 represents changes up to 1.49 percent more than, or 101.49 percent of, the CWCP value due to rounding. Similarly, a -1 represents a change up to 1.49 percent less than, or 98.51 percent of, the value for the CWCP.) Caution must be used when focusing on the shaded percent changes because a resource may have a special meaning to an individual, and an "insignificant" change (+1, 0, or -1 in the tables) may be an important change to that person. Those individuals that situation applies to are encouraged to note whether the change is slightly positive (+1), no change (0), or slightly negative (-1). Readers are encouraged to review the table and to make their own "value" judgments.

Missouri River navigation for the two split season GP options (GP1521 and GP1528) has two percentage changes that represent the two extremes for impacts relative to the CWCP. The smaller negative value represents the end of the spectrum where navigation would continue on both sides of the summer low-flow period. The second, greater, negative value represents the other end of the spectrum when only sand and gravel mining and the movement of waterway materials to repair channel structures are the only viable forms of navigation using the river.

Two values are included for the spawning cue, one for the reach closest to Gavins Point Dam and one for Boonville, which is midway between Kansas City and the mouth of the Missouri River. For this resource category, the values for each reach cannot be summed to arrive at a single average annual value for that resource or use. A single value, the 25 percent exceedance value (value exceeded in just 25 percent of the years analyzed), was selected to be representative of the relative differences among the alternatives for connectivity (see Figure 7.7-21). This value was selected because spring rises generally occur about one-third of the time or less. The 25 percent value would, therefore, provide better insight regarding differences among alternatives for the extent of the connectivity that would occur in years with spring rises. The 25 percent exceedance values for the individual reaches were summed to come up with a single value for each alternative on which the computations for the table could be computed.

Table 7.17-1. Impacts summary for the alternatives selected for detailed analysis.

	Percent Change from CWCP				
	MCP	**GP1528**	**GP2021**	**GP1521**	**GP2028**
Missouri River					
Wetland Habitat	1	1	1	2	1
Riparian Habitat	-2	-4	-4	-4	-5
Riverine Tern and Plover Habitat	43	62	74	68	60
Lake Tern and Plover Habitat	4	19	24	19	19
Lake Young Fish Production	2	7	7	6	7
Lake Coldwater Fish Habitat	3	9	9	9	8
River Coldwater Fish Habitat	2	7	7	7	8
River Warmwater Fish Habitat	-8	-14	-15	-16	-16
Native River Fish Physical Habitat	0	1	1	1	1
Historic Properties Index	-3	-6	-6	-6	-6
Floodplain Connectivity (25% Recurrence)	0	3	5	3	5
Shallow Water Fish Habitat	1	11	32	32	12
Spawning Cue—Gavins Point	22	106	117	72	156
Spawning Cue—Boonville	0	-6	6	6	3
Flood Control	-1	-1	-1	-1	-1
Interior Drainage	-3	-8	-9	-10	-8
Groundwater	0	-9	-10	-9	-9
Water Supply	0	0	0	0	0
Hydropower	1	2	2	2	2
Recreation	3	4	2	2	5
Navigation	5	-34	-36	-33	-38
Total NED Economics	0	1	0	0	1
Mississippi River					
Navigation Efficiency	0	0	0	0	0

Light gray shading denotes a beneficial impact greater than 1 when compared to the CWCP.
Black shading denotes an adverse impact greater than -1 when compared to the CWCP.

7.18 CUMULATIVE IMPACTS

The Council on Environmental Quality (CEQ) Regulations For Implementing NEPA (40 Code of Federal Regulations [CFR] 1500) defines a cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such other actions." The CEQ Regulations further state that "cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." In the case of the potential revision of the Water Control Plan for the Missouri River, a major action will be taking place. Similar actions of this magnitude would be changes in operations on major river systems such as the Upper Mississippi River, the Tennessee River, and the Ohio River. Determination of the cumulative impacts of any combination of changes on the Lower Mississippi River would be extremely complex and well beyond the scope of this Study. Effects of changing only the Missouri River Mainstem Reservoir System Water Control Plan on the Middle and Lower Mississippi Rivers are addressed in this FEIS (see Section 7.15).

In lieu of addressing the cumulative impacts of water control operational changes across a major part of the United States, another type of discussion follows. Three types of information will be summarized. First, the complexity of selecting a Water Control Plan for the Mainstem Reservoir System will be discussed. Second, some users within the system and along the Lower River are very sensitive to changes in operations, and a synopsis of how these users tend to view the Corps' ability to meet their needs is discussed. Finally, some examples are presented of the factors several sample projects in some stage of planning or construction at this time should consider as these projects move toward implementation.

7.18.1 Complexities in Selecting a Water Control Plan and Need for Awareness of Water Level Changes

A revision of the Mainstem Reservoir System Water Control Plan is a major undertaking in terms of the amount of time and effort taken to get to the point of preparing this FEIS. Many individuals within and outside of the Missouri River basin would support the contention that this is probably the most important decision that will be made regarding water resources in the basin. This support is based on the breadth of the geographical area of the potential impacts and the potential severity of the impacts to a small segment of the environmental resources or economic uses relying on the river.

This FEIS presents a cumulative impact assessment of the combined effects of many past, present, and foreseeable future actions in the Missouri River basin in general, and along the river, specifically. The results of these past and present actions are identified in Chapter 3. The current conditions in the basin serve as the baseline for the impacts presented in Chapters 5 (of submitted alternatives), 7 (of alternatives selected for detailed analysis), and 8 (preferred alternative).

As an example of cumulative impacts of past, present, and foreseeable actions, the FEIS addresses the amount of available habitat for three endangered or threatened species: the least tern, piping plover, and pallid sturgeon. Available habitat for all three species has diminished from historic levels. Construction of the Mainstem Reservoir System and downstream Missouri River Bank Stabilization and Navigation Project, the operation of the system over the past 30+ years (60+ years for Fort Peck Dam and Lake), and the continuing operation under the CWCP have all contributed to this loss. Impacts to the habitat, as described in this chapter, are based on the amount of habitat that was available at various times in the

1990s, which is a reflection of the past and present (at that time) actions. The amount of habitat will fluctuate as the flows and lake levels respond to the future operation of the system. Continued operation of the Mainstem Reservoir System under the Water Control Plan that is ultimately implemented will be the major factor that will continue to affect the amount of habitat for these species. For this reason, the USFWS included changes in how the Water Control Plan addresses releases from Fort Peck and Gavins Point Dams. The Water Control Plan changes included as part of the November 2000 USFWS BiOp RPA are recommended to ensure that needed habitat is available for these three species. The effects of four plans (four GP options) that the Corps feels address the November 2000 USFWS BiOp RPA flow recommendations on the habitat for these species are discussed in several sections of Chapter 7 (7.3, 7.6, 7.7, 7.15, 7.16, 7.17, 7.19, and 7.20). Flow changes alone are not adequate for the pallid sturgeon, least tern, and piping plover. Additional shallow water habitat and emergent sandbar habitat are currently being constructed or formed naturally as the result of floods. Considerably more habitat will have to be constructed to meet minimal needs, as identified in the BiOp.

Section 7.17 identifies the economic uses and environmental resources that could be adversely affected under the six potential Water Control Plans addressed in this chapter. Adverse impacts could continue to occur under the CWCP, and the only way to quantify the future changes is to look at past trends. Adaptive management has always been a part of the CWCP, and changes to the CWCP continue to evolve to some extent as adaptive management requirements continue to fit within the discretionary authority of the Corps. The baseline for all impacts in each Master Manual EIS has always been the CWCP; therefore, Table 7.17-1 presents the relative impacts of the MCP and the GP options compared to the CWCP. This table shows that highlighted (greater than a 1 percent change) adverse impacts occur in up to three economic use categories and up to four environmental resource categories. These adverse effects are anticipated to occur if the Water Control Plan is ultimately revised to reflect the MCP or one of the GP options. There is nothing in the foreseeable future that could significantly limit or eliminate any of these impacts other than to continue to operate under the CWCP or select an alternative Water Control Plan not included in Chapter 7. For example, Table 5.17-1 shows that the highlighted negative groundwater, navigation, and riparian habitat impacts could be removed from the highlighted adversely affected list by operating under the MRBA alternative. Adverse impacts greater than those currently occurring under the CWCP would occur to warmwater river fish habitat, historic properties, and interior drainage under the MRBA alternative. Even though this alternative would limit adverse impacts, it does not include any immediate measures to address the needs of the three listed species other than intrasystem unbalancing among the upper three lakes.

7.18.2 Need for Awareness of Water Level Changes

As the 1987 to 1993 drought began, many individuals expressed concerns regarding negative impacts to different economic uses. Corps staff readily recognized that many decisions by some individuals with adverse economic consequences had been made without fully considering that the status quo that existed since the Mainstem Reservoir System first filled in 1967 could change. In some cases, some of those individuals adversely affected were not aware that the declining lake levels and river flows could occur, and others made decisions knowing that they were taking some economic risks. In either case, it became readily apparent to the Corps and many individuals that none of the project purposes could be served in the same manner they had been over the previous 20 years of full system operation.

Even after the 1987 to 1993 drought (the first major drought since the system first filled and became fully operational in 1967), some users dependent on the lakes and river to meet their needs did not take appropriate action to protect themselves from future drought impacts. They could have undertaken measures to alleviate or eliminate adverse effects; however, they elected to not undertake these measures. The Corps continued to make it clear to some users that it could not adequately serve all users in droughts. For example, the Nearman Creek Power Station, owned and operated by the Board of Public Utilities (BPU), Kansas City, Kansas, had to shut down for several days in late 2000 when the Corps reduced winter releases because of drought. Major increases in the Gavins Point Dam releases would have been required to allow continued operation of this powerplant that winter. The shutdown continued until BPU could implement temporary measures to pump enough water to allow full powerplant production. No measures were taken to assure continued access to the river at lower stages after the 1987 to 1993 drought, or after the 1993 flood on the Missouri River caused considerable degradation through the Kansas City reach. In its comments on the DEIS, the BPU indicated that it would have problems operating in another drought under the winter drought releases required under the CWCP. Although BPU knew as early as 1994 (letter dated October 3, 1994) that they would have problems in droughts, BPU did not have any temporary or permanent structural measures in place by December 2000 to preclude water access problems when another drought started in 2000. BPU suffered a significant economic loss before the temporary measures were in place and the plant again became fully operational.

Representatives for Mid-American Energy, the utility in Iowa that operates the Port Neal Station south of Sioux City, met with Corps staff in late 2000. They were concerned that the low winter releases would adversely affect the operations of the power units. They indicated that they were in the initial stages of planning, designing, and building a new intake to serve the powerplant at a cost in the neighborhood of $40 million. The need to build the new intake became more imminent when additional degradation of the riverbed in the Sioux City reach occurred during the much higher than normal flows in 1997, a record runoff year for the Mainstem Reservoir System and basin draining into the river above Sioux City. Minor increases in releases above those planned were made to allow this facility to remain fully operable. Construction of the new intake will need to accommodate future degradation in the reach and the cutback in releases to meet a water supply target along the Lower River as low as 9 kcfs in droughts. All of the alternatives being considered at this time have similar low-flow criteria as part of their drought conservation measures. The summer low-flow releases from Gavins Point Dam in all of the alternatives evaluated in Chapter 7 should have no adverse impact on the ability of the future intake to pull water from the river if it is properly designed.

In 2001, Mid-American Energy decided to stop actions leading towards construction of a new intake. This decision was based on the potential that all powerplants are going to have to use cooling towers to dissipate water heat in the future. Water to meet powerplant needs would be greatly reduced, eliminating the need for the currently planned intake. Unfortunately, this measure could be costly should the current drought persist and flows be reduced to 9 kcfs in the Sioux City reach.

Some users cannot make changes and have to be able to financially manage the bad years with the good years. For example, some farmers raise crops on marginal lands, and they can successfully make a profit in some years such that they will continue to take the risks to farm the marginal areas. Similarly, some individuals invested funds in recreation-related facilities that were significantly adversely affected during the 1987 to 1993 drought. These individuals began to worry and likely suffered financially when another drought started in 2000. When a succession of “bad” years comes, these users’ attention naturally goes toward the Corps to determine what the Corps is doing wrong as it operates the system. When they discover that the Corps is following the Water Control Plan specified in the Master Manual, in this case, the CWCP, they determine the plan is wrong and should be changed to minimize their impacts. The Corps has the limited discretion to make some changes from historic operations under the CWCP; however, it must continue to serve the project purposes Congress required it to meet as part of the authorization of the Mainstem Reservoir System and other downstream projects on the Lower River. Some changes do not fall within this discretionary authority and require a revision of the Water Control Plan in the Master Manual, which requires that certain procedures be followed. This is not an easy accomplishment based on the current effort to review and potentially revise the Master Manual.

The Corps faced a difficult decision following the review and comment period for the RDEIS regarding the selection of a preferred alternative to present in the FEIS. This decision was ultimately made, and the FEIS was completed. Release of the FEIS with the preferred alternative did not come easily as the release was delayed pending discussions between the Corps and the USFWS. This delay was significant such that it eliminated the chance to implement the preferred alternative as part of the 2003 Mainstem Reservoir System operations under the Annual Operating Plan for that year. Many factors were considered, including the November 2000 USFWS BiOp, comments made during the RDEIS review and comment period, and dialogue the Corps has with the public, river users, and other entities (the Tribes, States, other Federal agencies, MRBA, MRNRC, etc.).

Once the preferred alternative is implemented, future changes under the adaptive management process may be required as the Corps continues to work with the USFWS and with basin stakeholders through some form of participation that may be integrated into a stakeholder group the Corps is calling the Missouri River Implementation Committee (MRRIC). This group will be formed to provide input into the Missouri River Recovery Implementation Program (MRRIP). Adaptive management is required through MRRIP because uncertainties currently exist regarding the potential needs of the three listed species specifically addressed by the November 2000 USFWS BiOp RPA. The science is not completely known; therefore, the needs are not fully understood. Future monitoring and analysis will better define the science and, subsequently, the needs of these species.

Some say that the spring rise and the lower summer flows are a move toward providing flows on the Lower River that mimic the historic hydrograph and a move toward total ecosystem management. At this point in time, the Corps views the spring rise and lower summer releases from Gavins Point as being provided primarily for specific needs of the least terns, piping plovers, and pallid sturgeon. Based on the data presented in this FEIS, the spring rise does not provide island building for the terns and plovers (see Section 7.2). This type of geomorphic change occurs in years with the higher volumes of water that must be moved in a single year (such as 1975, 1997, etc.). The prescribed spring rise may not even be of sufficient magnitude or duration to adequately scour vegetation off of the sandbars and islands. It also does not significantly improve connectivity to floodplain lands along the river (see Section 7.7.6). The primary reason for implementation of a spring rise at this time is to provide a spawning cue; however, very little is currently known about the pallid sturgeon's specific spawning cue requirements (see Section 7.7.8). Lower summer flows are required to maximize the amount of relatively clear sandbar habitat (see Section 7.6), and the lower the summer flow, the greater the amount of habitat for the least tern and piping plover (and potential fledge ratios and populations). The USFWS also recommended these same lower summer flows to increase shallow water habitat for the pallid sturgeon during its fragile larval stage; however, the increases in habitat provided by the reduction in flows is minimal compared to identified pallid sturgeon acreage of shallow water habitat needs (see Section 7.7.7).

In summary, the Gavins Point Dam release changes required for the species are primarily to provide a spawning cue for the pallid sturgeon (spring rise) and increase habitat for terns and plovers (lower summer flows). The effectiveness of any of the GP options in accomplishing these two requirements is not completely known at this time, and research, monitoring, and evaluation of additional data is required before the Corps will consider modifying any preferred alternative that would be implemented as a result of the Study. The uncertainty of actually meeting these needs made plan selection of one of the GP options difficult. Plan selection was difficult knowing that the spring rise adversely impacts crop production along the Lower River (see Sections 5.8.2, 5.8.3, 7.8.2, and 7.8.3) and the lowest summer flows may eliminate commercial navigation from the river (see Section 7.12), adversely affect Lower River (and Fort Randall downstream reach) recreation (see Section 7.11), and decrease hydropower revenues, which will potentially result in higher costs to the consumers of this electricity (see Section 7.10).

7.18.3 Projects Currently Being Considered

At the time the RDEIS was prepared, many projects or facilities within the basin were in some phase of planning, design, or construction that may, in some way, be dependent on the Mainstem Reservoir System lake levels, on river reach flows, or on the flows moving through the Lower River. In many cases, lake levels and flows provide considerable benefits to those using the facilities directly or to the outputs from those projects or facilities. As these projects or facilities move closer to construction and implementation, considerations must be made of the variability that can occur under the wide variety of conditions the system operates under on a day-by-day, month-by-month, and year-by-year basis. No Water Control Plan can optimally meet any users or resources needs, but the adverse impacts can be minimized with some appropriate planning and implementation actions. The remainder of this cumulative impacts section identifies several projects and activities that were almost completed at the time the RDEIS was released for review or will be making significant advances toward completion over the next few years. These projects are just a sample of the projects being planned or implemented and are not intended to be all-inclusive. Suggestions for considerations that should be taken into account are identified to help minimize adverse impacts from system operations. There is no set order for these projects, activities, etc. The general recommendations for each of the projects listed should be considered representative and applied to similar projects at an appropriate scale.

Numerous efforts up and down the Lower River have been initiated over the last couple of years to reconnect with the river. For example, Omaha riverfront development has escalated in recent years. The upcoming Lewis and Clark Bicentennial Commemoration is one factor leading to this recent escalation for some communities. Direct access to the river may be a big part of the plans of these communities as they conduct these "back to the river" efforts. Access to and from the river will be a major requirement during the Commemoration and into the future as this river reconnection continues. Access may be a problem under some alternatives, if not all of the alternatives, and keeping the access facilities open will require some dredging under all of the alternatives, with the amount and cost of dredging potentially increasing as the summer low flows decrease. This same dredging requirement applies to all recreational navigation facilities and users along the Lower River.

Another form of recreational navigation use recently began operations on the river in the Omaha area. River Barge Excursion is a venture that previously provided river excursions on the Mississippi, Ohio, and Cumberland Rivers. In 1999 it began operations on the Missouri River. The company is based in New Orleans, and a considerable investment in the tens of millions of dollars has been made. The excursion vessel, the River Explorer, is made up of two barges and a towboat. The barges have a draft of 5.5 to 6 feet, and the towboat, the MISS NARI, drafts 8.5 feet, which will require full navigation service flows to operate on the Missouri River in most years. In 2001 the River Explorer made four trips on the Missouri River between St. Louis and Kansas City. It also made a trip in 2001 as far upstream as Bellevue, Nebraska, located just south of Omaha. Plans to make a trip all of the way to Sioux City in 2002 and 2003, with a goal of developing a market for passengers for the upcoming Lewis and Clark Bicentennial Commemoration had to be cancelled as the support to navigation was suspended for part of both summers to either ensure that terns and plovers were not adversely affected when releases would have had to be increased to maintain navigation service (2002) or to respond to a court order (2003). Under any of the alternatives addressed in Chapter 7, persistence of the current drought could adversely affect these plans, as it did in 2002. Under the CWCP, navigation service was 6 kcfs less than full service in 2003, which is minimum service for navigation. Under the MCP, storage in the system would require a service level 3 kcfs higher than was provided under the CWCP in all years until the drought is over, unless an extremely dry upper basin results in no storage gain between the March 15 and July 1 service level checks. If this were to occur, navigation service would drop to minimum service for the remainder of that season and likely through much of the next year up to about the end of August. Under the GP options with minimum service flows in all years (unless flood storage evacuation requires movement of extra water in the summer), minimum service would be nearly an annual occurrence. Similarly, there would be no navigation service under the other two GP options with the 25/21-kcfs split during the summer. All of the GP options could basically eliminate the Missouri River as a source of business for this venture.

A 2001 announcement was made by the Winnebago Tribe to launch a ferry service between the Reservation lands in northeastern Nebraska to lands on the Reservation across the river in Iowa, where the Tribe operates a casino. The ferry would provide a more direct access from homes in Nebraska to the casino for the Tribal members working there and for customers. It would also provide a more direct access to Interstate 29 in Iowa, which would open up additional job opportunities for Tribal members. An estimated 800,000 vehicles on one-way trips are forecasted to use this ferry on an annual basis at a cost of $3 to $5 per vehicle for a round trip. This ferry is expected to have a draft of 2 to 2.6 feet, and the terminals on either side of the river would be designed for river fluctuations ranging from the lower water levels in the winter months to a 100-year flood event level. Based on these parameters, this undertaking should be able to operate successfully under any of the alternatives addressed in Chapter 7; however, the harbor for the east river terminal may require additional dredging support during the 25/21-kcfs split-season of the GP1521 and GP2021 options.

Similar to actions in the planning stage in Omaha, the St. Joseph Port Authority initiated construction of a new port on August 31, 2001, at a cost of about $1 million. This facility was constructed to give businesses in St. Joseph a competitive advantage because shipping and receiving by barge is known to be the most cost-effective alternative for the bulk movement of commodities. Negotiations were finalized with Global Materials Services LLC to operate the port. Operation of this facility began in 2003; however, its operation could be dramatically affected, depending on which alternative is selected as the Water Control Plan for the Master Manual. Under the CWCP and the MCP, no long-term problems obtaining service from towing companies are anticipated. Problems begin to surface on an annual basis with the two GP options with minimum navigation service releases each summer. A high likelihood that there is no summer service, and maybe no service at all, occurs for the two GP options with the 25/21-kcfs summer split releases from Gavins Point Dam. If either of the two latter alternatives becomes the selected Water Control Plan, accommodations for other modes of transportation may be required at this facility to allow it to continue to operate. Plans are currently underway in St. Joseph to develop its waterfront to complement the new port facility. This effort may face problems depending on how successful the new port is able to meet the development's needs.

The Corps is currently nearing the completion of the construction of numerous fish and wildlife habitat sites as mitigation for the loss of this habitat to the Missouri River Bank Stabilization and Navigation Project from Sioux City to the mouth of the river. Additional mitigation has been authorized, and the Corps will continue to construct fish and wildlife habitat. How the funds are used has not yet been fully determined; however, much of it will be used to construct aquatic habitat meeting the shallow water habitat recommendations specified by the USFWS in its November 2000 BiOp. These sites will need to be constructed with some flexibility relative to meeting the requirements of the pallid sturgeon because adaptive management may change river flows. Summer river stages could be approximately 1 to 1.5 feet different for an adaptive management switch from the CWCP to a Water Control Plan with minimum navigation service releases during the summer. The difference increases to approximately 2 to over 3 feet for a change to a plan with a 25/21-kcfs split.

All four of the GP options adversely affect hydropower revenues as this power is marketed by WAPA in the region. The summer minimum service options have an $8 to $9 million average annual adverse impact, and the 25/21-kcfs flow options have about a $30 million average annual adverse impact (see Section 7.10). Replacement of the hydropower generating units is currently occurring at Garrison Dam, and plans are in various stages of consideration and planning for units at Fort Randall and Gavins Point Dams. The replacement units are more efficient than the existing units; therefore, more electricity will be generated with the same amount of water moving through the units. This may help offset some of the adverse economic effects of the GP options. It may also offset some of the potential adverse impacts lower summer flows may have on the generating capability from powerplants along the Lower River (see Section 7.10).

Recreation development continues around the upper three lakes of the Mainstem Reservoir System. This development escalated on Lake Oahe in 2002 as the State of South Dakota began improvements of the recreation sites. This effort was begun after much of the lands and recreation facilities were turned over to the State, as originally authorized by Title VI of PL 106-53. As sites are developed, the State needs to account for the fact that the lake will drop during major droughts. If a site has poor access during the current drought, it will have poor access in the future, no matter what the Water Control Plan turns out to be. The level of the lake in November 2003 was 1,578, which is 3 feet lower than it dropped to in the 1987 to 1993 drought. It will drop to even lower levels during upcoming months. If the current drought persists, Lake Oahe could continue to drop until the drought ends.

Several major water supply projects have been built in the last 20 years that rely on the lakes as the source of raw water. Additional projects are in the planning stage, particularly in North Dakota, and the intakes need to be deep enough to ensure access to the water even in the most severe droughts if the new systems are to be dependable.

7.19 DEPLETION ANALYSIS

Future depletions of water from the Missouri River basin are going to affect the amount of water that is available to move through the Mainstem Reservoir System. Examples of potential depletions include the transfer of water from the Missouri River to the Red River Valley Water Supply Project currently being evaluated by the Bureau of Reclamation for northeastern North Dakota, and use of water by the Tribes under their reserved water right provided under treaties with the U.S. government. These depletions, in turn, will have an effect on the availability of water needed to meet the various project purposes, and will affect the benefits that are provided by the economic uses and environmental resources dependent upon the Mainstem Reservoir System lake levels and releases. This section of the FEIS presents a brief description of how the depletion analysis was conducted and describes the changes in the use and resource values computed by the economic impacts model, the environmental impacts model, and the Mississippi River navigation model.

The first step in conducting the depletion analysis was to complete the Daily Routing Model (DRM) simulation runs for the alternatives selected for analysis. Three alternatives were selected for this analysis for the RDEIS: the CWCP, the GP1528 option, and the GP2021 option. Two more alternatives were added for the FEIS: the MCP and GP2028 option. Five levels of depletions were run through the DRM: the current level of depletion (data in previous sections of Chapter 7 of this EIS) and 0.8 MAF, 1.6 MAF, 2.4 MAF, and 3.2 MAF of additional depletions. The analyses on these runs will have five data points, one for each level of depletion. The DRM depletion input file was adjusted for each run with all of the water taken from the inflows within the system (versus downstream from the system from tributaries to the Lower River). Figure 7.19-1 shows the average annual release from Gavins Point Dam over the 100-year period of analysis. The analysis demonstrates that an equal amount of water was removed upstream from Gavins Point Dam for each model run, as this plot is a linear plot. The values for each alternative are not identical because evaporation from the lakes will be slightly different for each alternative.

The DRM output files were run through the three economic use or environmental resource models to determine the average annual benefits or values provided for each use or resource category. Figures 7.19-2 and 7.19-3 show the depletion plots for the Missouri River navigation model benefits and young fish production index for the CWCP depletion runs. The first plot was selected to show one with a very good linear correlation of the benefits for the five depletion runs—in this case, navigation (Figure 7.19-2). To show the contrast, the young fish production index plot (Figure 7.19-2) was selected to show what a poor correlation of the data looks like. The plots show the slope of the line and the R-squared value, which is a correlation index. The closer the correlation index is to 1.0, the better the correlation.

The slope of the linear correlation line (change per MAF of depletion) and the R-squared values are listed in Table 7.19-1 for all of the economic use or environmental resource categories on which the three impacts models provided data. Data with very poor correlation coefficients (i.e., R-squared values less than 0.4) are marked with gray shading. For these resources, increasing levels of depletion have unknown effects on use or resource values.

The remaining slope values were then compared for each use or resource category to determine which of the three alternatives had the greatest change per unit of depletion; these values are highlighted as white text on a black background. Next, for each use or resource category, the alternative with the least change per MAF of depletion was surrounded by a border. Because sensitivity assessments are based on a comparison of values, only those resources for which all three alternatives have good correlation coefficients are included in this analysis. This allows a quick scan of the table to see which of the three alternatives is most sensitive to future depletions and which alternative is least sensitive.

It is readily apparent that the CWCP is by far the most sensitive to future depletions. It has the greatest change (steepest positive or negative slope on the depletion plot) in 11 of the 16 categories. The GP2021 option is by far the least sensitive, as it has the least change (flattest slope on the depletion plot) in 6 of the 16 categories. It also has only one use, Mississippi River navigation, with the highest value. The other three alternatives are the middle-of-the-road alternatives with four of the highest change value and six of the lowest values among them.

Another conclusion can be drawn from the total NED economics (Missouri River only) data in Table 7.19-1. The value of 1 MAF of water in the system is about $19.3 million per year for the CWCP. This value drops to $15 million per year for the GP1528 option. The values for the other three alternatives range from about $15.2 million to about $16.9 million. The greatest share of these values come from the hydropower benefits.

With regard to the three endangered species, future depletion of water from the Mainstem Lake System is good for the terns and plovers (a general gain of 15 to 29 acres of habitat on an annual basis). Future depletion effects are unknown for the pallid sturgeon, because the correlation of the data was generally poor. In the case of the CWCP, the index value dropped a very small negative 0.11 unit per MAF of depletion, which is 0.1 percent of the average annual value, or essentially no change in value. One other alternative, the MCP, had a good correlation; however, it showed a gain in habitat for the pallid sturgeon with a positive 0.11 unit per MAF of depletion The other three alternatives had very poor correlation of data for the physical habitat for the native river fish index.

Depletions are generally good for flood control, tern and plover habitat, riparian habitat, and historic properties index. Conversely, depletions are generally bad for navigation, hydropower, water supply, recreation, total NED economics, reservoir coldwater habitat, and river coldwater habitat. All of these general relationships are expected changes based upon less water available in the system for year-to-year operation.

Resource/Use	Units	CWCP		MCP		GP1528		GP2021		GP2028	
		Chg/Units	R squared	Chg/Units	R squared	Chg/Units	R squared	Chg/Units	R squared	Chg/Units	R squared
Flood Control	$millions	1.74	0.753	1.55	0.992	2.20	0.981	1.99	0.968	2.26	0.966
Navigation	$millions	-0.45	0.915	-0.32	0.833	-0.23	0.827	-0.20	0.842	-0.21	0.710
Hydropower	$millions	-15.63	0.999	-13.13	0.990	-12.97	0.978	-14.27	0.983	-14.94	0.982
Water Supply	$millions	-3.29	0.991	-1.76	0.992	-2.74	0.569	-1.84	0.441	-2.67	0.566
Recreation	$millions	-1.64	0.772	-1.76	0.948	-1.26	0.925	-0.84	0.659	-1.33	0.941
Total NED Economics	$millions	-20.09	0.987	-15.80	0.992	-15.59	0.957	-15.95	0.930	-16.88	0.956
Young Fish Production	Index	-0.003	0.024	0.010	0.337	-0.005	0.063	-0.0008	0.003	-0.01	0.091
Res. Coldwater Habitat	MAF	-0.66	0.976	-0.47	0.993	-0.53	0.967	-0.49	0.976	-0.50	0.979
Riv. Coldwater Habitat	miles	-4.07	0.991	-1.59	0.959	-0.61	0.763	-0.61	0.546	-0.97	0.593
Riv. Warmwater Habitat	miles	1.93	0.799	2.24	0.886	0.005	0.0004	-0.01	0.001	0.22	0.334
Riv. Fish Physical Habitat	Index	-0.11	0.613	0.11	0.727	0.04	0.201	0.01	0.081	0.01	0.045
Tern and Plover Habitat	acres	28.8	0.795	4.87	0.356	23.9	0.634	15.0	0.449	9.49	0.206
Wetland Habitat	1000 acres	-2.03	0.902	-1.00	0.620	-0.40	0.229	-0.35	0.083	-0.32	0.122
Riparian Habitat	1000 acres	4.24	0.969	2.01	0.937	2.25	0.988	2.10	0.977	1.94	0.961
Historic Properties	Index	236	0.992	173	0.987	156	0.953	148	0.925	166	0.940
Mississippi River Navigation	$millions	-3.78	0.765	-7.98	0.825	-9.93	0.929	-10.36	0.896	-10.07	0.922

Table 7.19-1. Comparison of the depletion effects to the economic use or environmental resources.

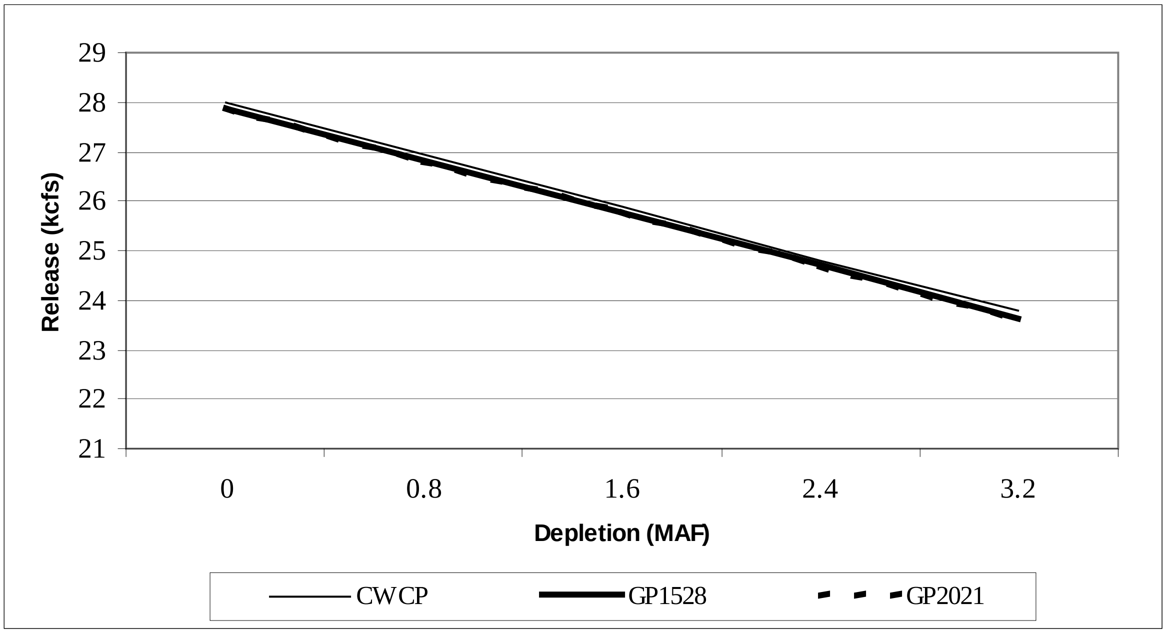

Figure 7.19-1. Average annual release from Gavins Point Dam at different levels of depletion.

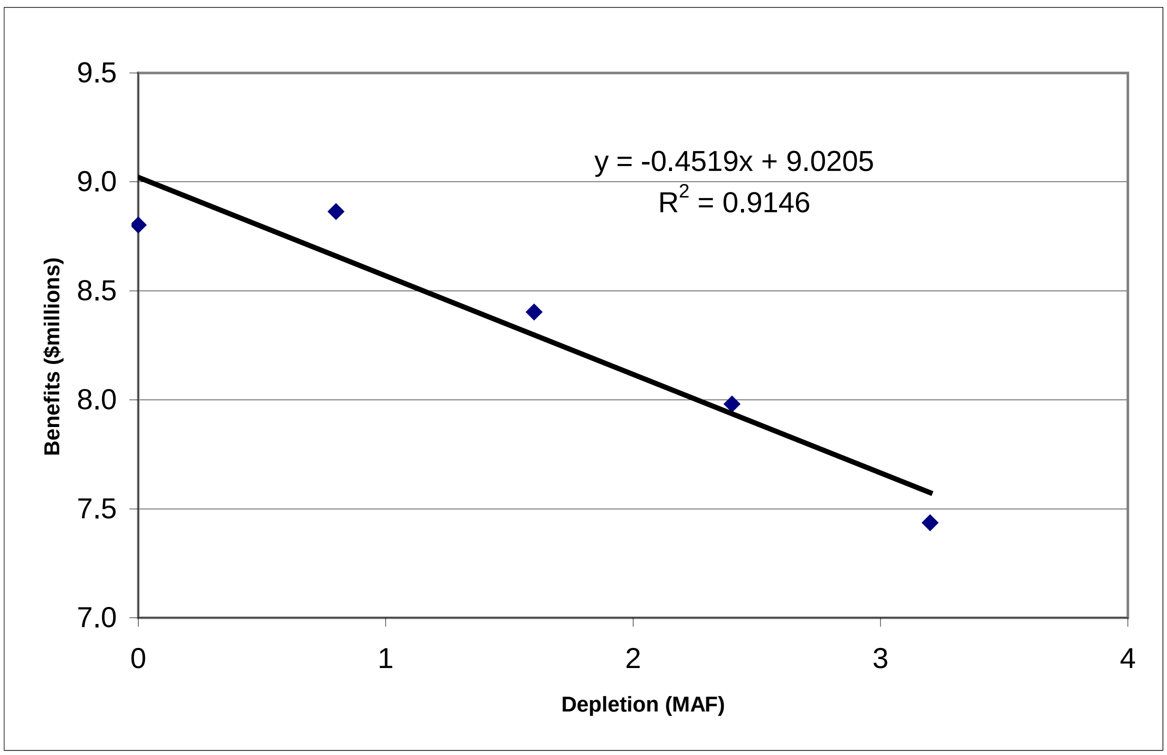

Figure 7.19-2. Effects of depletion on navigation benefits for the CWCP.

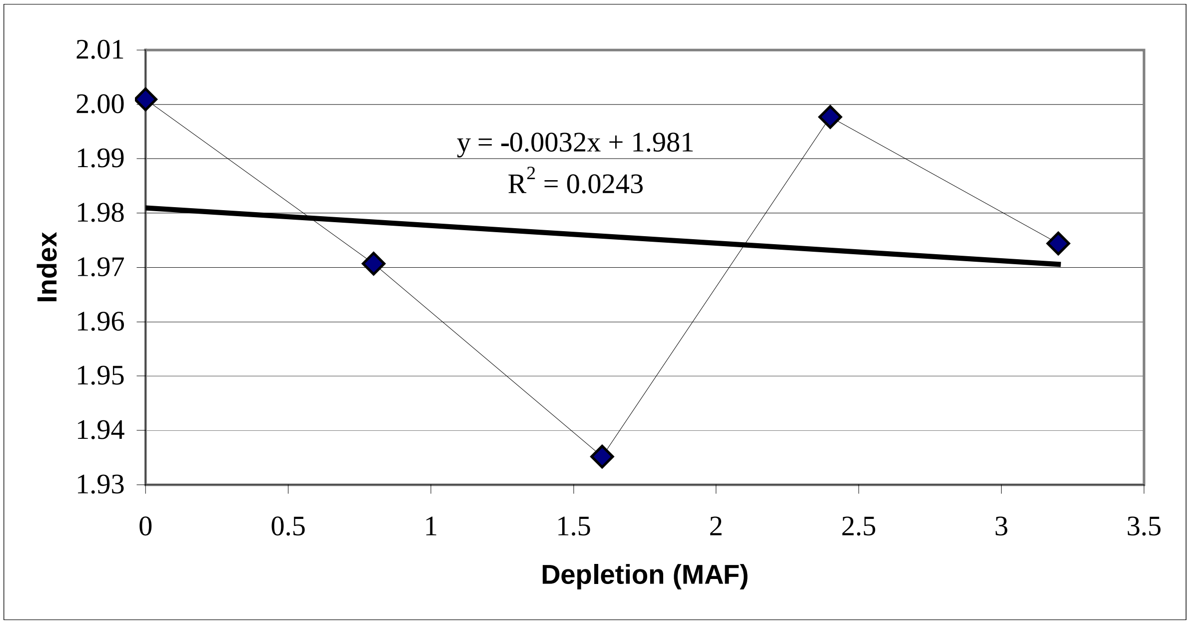

Figure 7.19-3. DRM depletion run results for young fish production for the CWCP.

7.20 MODIFICATIONS THAT COULD BE INCLUDED IN THE GP OPTIONS

As the GP options were being developed, some modifications to two plan components were simulated and the impacts analyzed to determine the potential for including these changes as part of the GP options. The two plan components that were modified in the additional simulation runs were the spring rise and the minimum navigation service releases during the summer low-flow period. Both were evaluated to determine if adverse impacts could be diminished without changing the overall effects of the alternatives.

7.20.1 Constrain Higher Spring Flows while Moving Some Spring Rises to Extended Droughts

Spring rises are limited to the "normal" inflow years according to the USFWS November 2000 BiOp RPA and the subsequent modeling of that alternative and the GP options. These alternatives were modeled with flow targets for the flood control constraints on the Lower River raised by an amount equal to the spring rise. For example, the flow target for the flood control constraint at Omaha is 41 kcfs for the reduction of releases to the full navigation service target. This value was raised by 15 kcfs to 56 kcfs for the GP1528 option, which has a 15-kcfs spring rise release from Gavins Point Dam. Because of the flood control constraints, spring rises do not occur in years with high tributary flows in the reaches between Sioux City and Kansas City. Also, the spring rise was generally suspended in the second year of an extended drought, and it was not reinitiated until system storage had recovered following the drought.

Even with constraints on the spring rise in high Lower River inflow years, crop damages via groundwater level increases and interior drainage blockages increased for these alternatives over that of the CWCP. Two potential solutions were combined and evaluated to determine their impacts on the crop damage risk.

To ensure that there would be an adequate number of spring rises, which was approximately one-third of the time, the restriction on spring rises in droughts was relaxed. Second, to reduce the crop damage risk, the flood control constraints were not increased by the same amount as the spring rise increase. Instead successive model runs, or simulations, were made beginning with no change in constraint to runs with greater and greater limitations on the amount that the flood control constraints were raised. The base simulation selected for the analysis had a spring rise of 17.5 kcfs followed by a flat release of 28.5 kcfs for minimum navigation service. This simulation was labeled FWMS. Subsequent runs were made with lower and lower flood control constraint increases. These were labeled FC0 (no reduction in flood control constraints) FC1, FC2, and FC3. Figure 7.20-1 shows the resulting spring rises on a duration plot. It shows that the FC0 run and subsequent runs with lower flow values for the flood control constraints had generally the same number of spring rises, with a slight reduction in the duration of the spring rise in the 45 to 55 percent range for the FC3 run. This figure demonstrates that there was essentially no loss in the number of years in which spring rises were provided. This plot also shows that these runs had more spring rises of 14 days or longer than the BIOP alternative (see Chapters 4 and 5), which was the alternative included in the USFWS November 2000 BiOp RPA.

Figure 7.20-2 shows a second duration plot of the number of days in May that the flow at Levee Unit L575 was 55 kcfs (flow at which interior drainage begins to be impacted) or greater. This levee unit was selected for this discussion because it had the greatest interior drainage and groundwater damages resulting from the spring rise (Sections 5.8.2, 5.8.3, 7.8.2, and 7.8.3). This figure shows that the number of years with flows of 55 kcfs or greater was reduced from over 80 percent to about 70 percent. More significantly, the number of days the flow was greater than 55 kcfs was reduced by about 50 percent. The number of days was still greater than the MCP, which is also shown on the figure. The percent of years with the number of days greater than 6 (out of 31 days in May) was nearly the same (generally zero to 5 percent more for FC3) as those of the MCP.

Figure 7.20-3 shows a plot of the number of days in May and June with discharges greater than 45 kcfs (potential spring rise occurrences) under the BIOP alternative, and Figure 7.20-4 shows a similar plot with the higher releases included in the extended droughts under the FC3 option. The second plot shows that there is a more even distribution of higher releases throughout the 100-year period of analysis. Under the BIOP alternative, no spring rises occur during or immediately after the three major droughts—from 1931 through 1946, 1954 through 1966, and 1988 through 1995. These gaps are 16, 13, and 8 years long, respectively. The longest gap without at least 10 days with 45 kcfs or more under the FC3 alternative was 1989 through 1994, or 6 consecutive years. There are also 5 more years that the FC3 alternative had at least 14 days that the Gavins Point Dam releases exceeded 45 kcfs (29 for the BIOP alternative and 34 for FC3).

The bottom line on the hydrologic aspects of this analysis is that the number of years with high spring releases goes up when the drought constraints are removed and the flood control constraints on the Lower River are tightened. These years are more evenly spread over the 100-year period of analysis with much shorter gaps between high flows. Furthermore, the percent of years with flows equal to or greater than 55 kcfs at Nebraska City for more than 5 days in May are nearly the same for the FC3 and MCP simulations.

The analysis was taken a step further to determine if there were differences in the average annual impacts for those uses or resources that were easily modeled (i.e., not interior drainage and groundwater effects). Tables 7.20-1 and 7.20-2 present the results of the economic use and environmental analyses, respectively. It is readily apparent that there is essentially no difference in the average annual impacts to these uses and resources. This indicates that the aforementioned hydrologic benefits in terms of high spring flows can be attained with relatively small differences in the economic use and environmental resources benefits over the 100-year period of analysis.

7.20.2 Switch to Navigation Targets to Conserve Water in the System During Extended Droughts

All of the alternatives in Chapter 7 were run with flat releases or the split-navigation release of 25/21 kcfs. In many drought years, the flat releases used more water than was required to meet navigation service. In other years, not enough water was released to meet the targets in every day of the flat-release period. This demonstrates that the actual value for the flat release would need to be determined each year, using conditions (wet or dry) of the portion of the basin feeding directly into the river as a basis for setting the release rate. This differs from how the alternatives were modeled with a set flat release of either 34.5 kcfs for full navigation service, 28.5 kcfs for minimum navigation service. Another way to potentially save water in the lakes while fully serving navigation every day is to go to target releases all summer long. A recommendation was made by the ACT to go to target releases in the summer of 2001. It was determined that sufficient habitat existed in the river below Gavins Point Dam so that, even with increasing releases through the summer to meet the navigation target, fledge ratio and population goals of the two listed birds would be met. Lower River direct flows were very high during the early portion of the normal flat release period, and considerable water was saved during May through July. This

Table 7.20-1. Average annual economic benefits of flood control alternatives and two GP options relative to the CWCP (percent).

	Flood Control	Navigation	Hydropower	Water Supply	Recreation	Total NED
GP1528	-1	-24	2	0	4	1
GP2021	-1	-32	2	0	2	0
FWMS	-1	-23	2	0	5	1
FC0	-1	-27	2	0	4	1
FC1	-1	-27	2	0	4	1
FC2	-1	-27	2	0	4	1
FC3	-1	-26	2	0	4	1

Table 7.20-2. Average annual environmental effects of flood control alternatives and two GP options relative to the CWCP (percent).

	Fish Production	Coldwater Reservoirs	Coldwater Rivers	Warmwater Rivers	Physical Habitat	Tern & Plover Habitat	Wetland Habitat	Riparian Habitat	Historic Properties
GP1528	6	9	7	-16	1	68	2	-4	-6
GP2021	7	9	7	-15	1	74	1	-4	-6
FWMS	5	6	7	-13	1	51	1	-5	-5
FC0	5	6	7	-14	1	69	3	-6	-4
FC1	6	8	7	-15	1	66	4	-6	-5
FC2	7	8	7	-15	1	73	3	-5	-5
FC3	8	9	7	-16	0	76	1	-4	-6

operation had little noticeable effect on the birds, as the fledge ratio was again met in 2001 for the reach downstream from Gavins Point Dam.

The 1954 to 1961 and the 1987 to 1993 droughts had several years that the flat release used more water than required to serve navigation without missing targets all summer. Historically, opportunities exist to set the flat releases lower than modeled. Conversely, if the tributaries to the Lower River turn out to be much drier than anticipated, the flat release could be set too low, and navigation targets may not be met for some extended periods in the summer. To increase the potential for saving water while ensuring that the navigators have adequate water to meet targets, the releases may be based periodically on targets instead of flat releases. The ACT and Corps staff would consider many factors as the tern and plover nesting season approaches during extended droughts. If a spring rise were to occur in the May and June timeframe, the potential for having to take actions, such as picking up eggs in nests that may be flooded, would be minimized as long as adequate habitat existed at relatively high flows so that the birds could nest during the high-flow period. Water could then potentially be saved during the post-high-flow period if target releases were followed in such a way that the net use of water may be comparable to having a flat release all summer.

When this mode of operation was modeled and the impacts computed, differences in the average annual values occurred throughout the drought period. This indicates that changing the release pattern makes a difference. It is apparent that such a mode of operation would need to be acceptable to the many interests that rely on lake levels and river flows. The ACT and basin stakeholders would need to concur in the switch to navigation targets should any of the alternatives other than those that do not serve navigation during the summer become the selected water control plan.

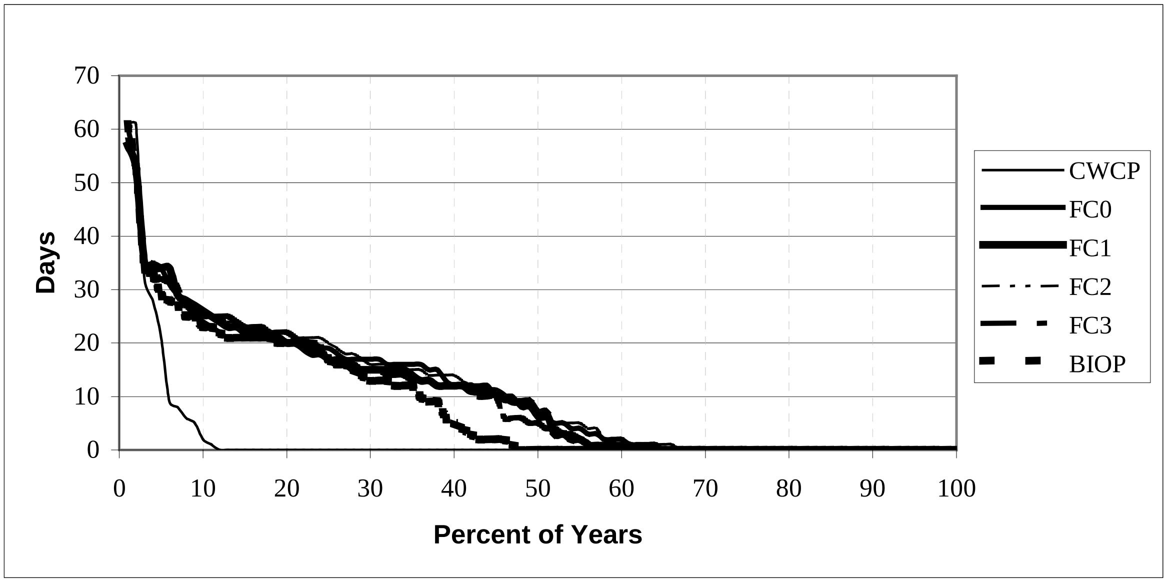

Figure 7.20-1. Duration plot of the total number of days in May and June releases from Gavins Point Dam exceed 45 kcfs.

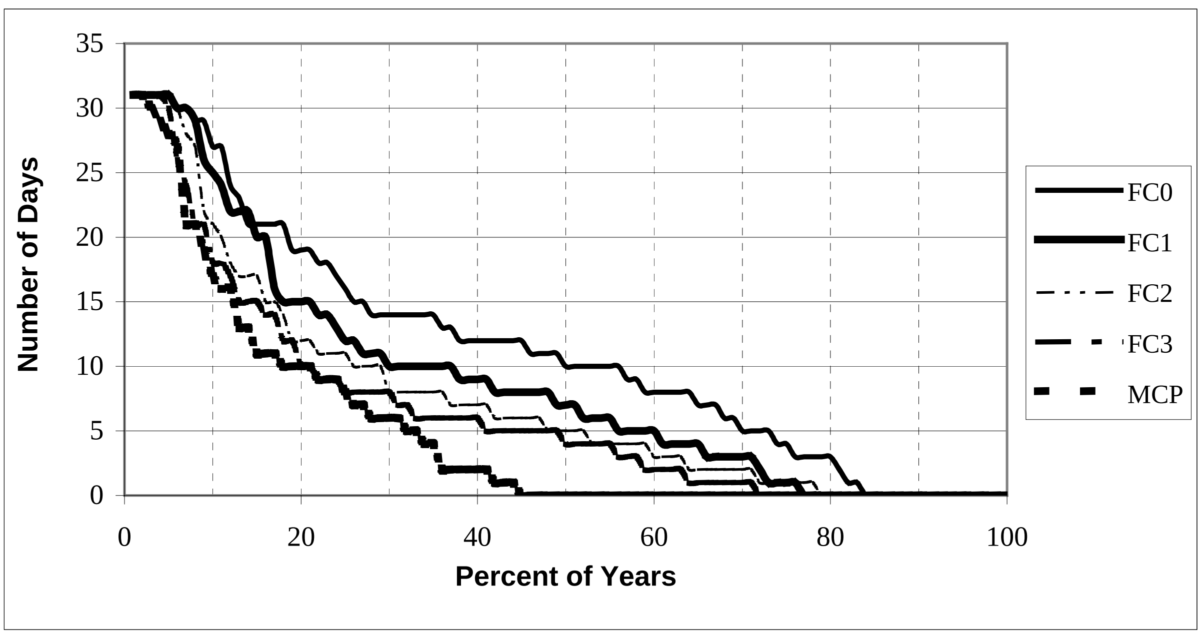

Figure 7.20-2. Duration plot of the number of days flows exceed 55 kcfs at Nebraska City during May.

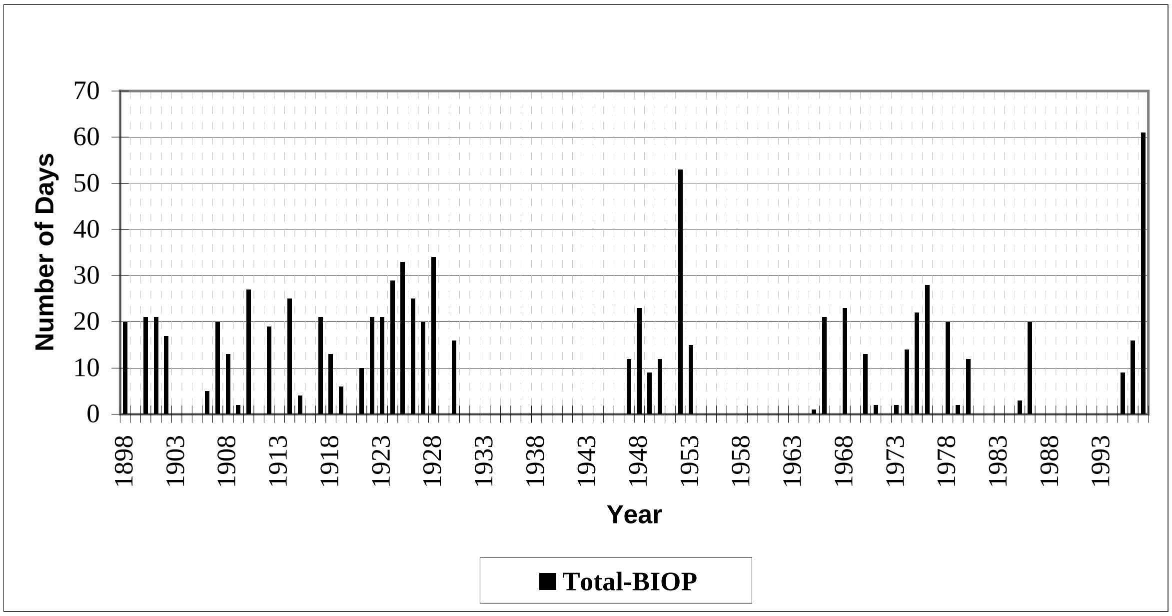

Figure 7.20-3. Total number of days in May and June releases from Gavins Point Dam equaled 45 kcfs or greater for the BIOP alternative.

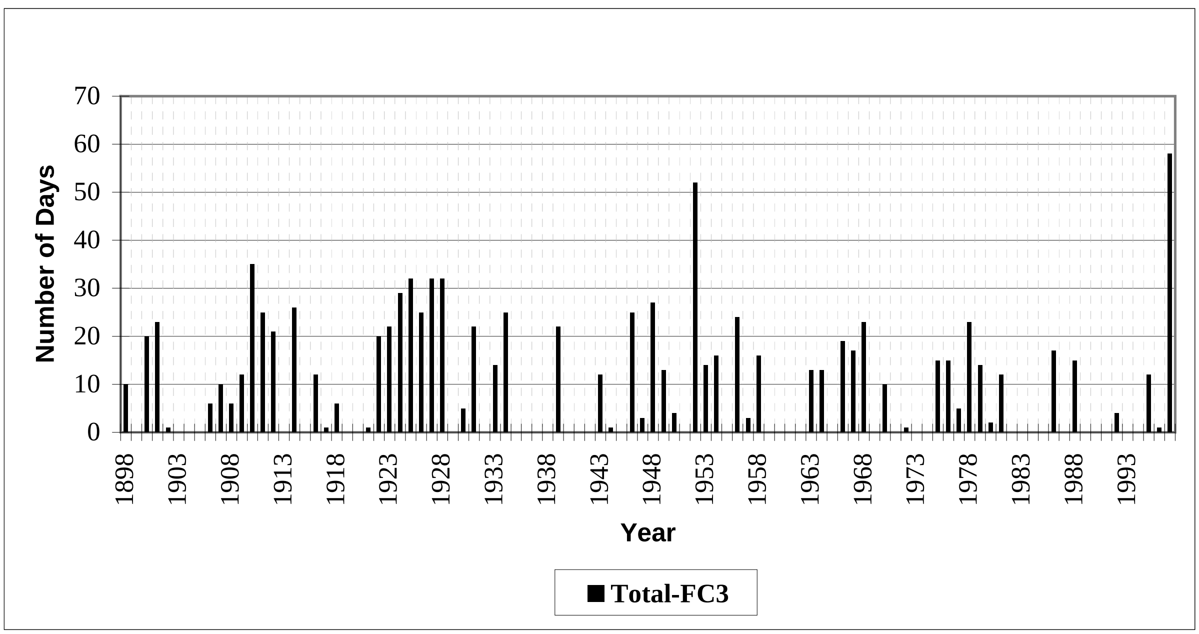

Figure 7.20-4. Total number of days in May and June releases from Gavins Point Dam equaled 45 kcfs or greater for the FC3 alternative.

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