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. Because the three analyses are independent, no attempt was made to compute a consolidated damage or benefit to the affected lands. Two major factors limited the possibility for this consolidation. First, the interior drainage and groundwater analyses were done for representative sites – six interior drainage sites and four groundwater sites – instead of a comprehensive analysis of all land along the river. The complexity of the modeling processes limited these two analyses to these representative sites. Second, each analysis 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.

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**

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 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 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.

Flood Control for Tribal Reservations

All 13 of the Reservations identified have flood control impacts analyzed former 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.

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. Intermediate benefits of $0.06 million in damages per year are provided by the MCP. 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. The 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

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**

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 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. 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

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 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 $0.01 million per year. At that site, damages are $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 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 5.8-6 through 5.8-8 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.

Unfortunately, no methodology is available to forecast what total damages may be for all of the leveed areas on the Lower River. From the data presented for the six representative sites, it is apparent that the damages diminish in a downstream direction. The damages for L575 for a 15- and 20-kcfs spring rise are about $0.07 million and $0.09 million per year higher than the CWCP.

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.

7.8.3 Groundwater

Analyses of groundwater effects were computed for four representative sites along the Missouri River from Onawa, Iowa to Hermann, Missouri. These four 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 groundwater levels at 1-foot increments from zero feet deep up to 9 feet deep. These files were

Table 7.8-4. Distribution of 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**

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 7.8-5 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 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.

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.

Table 7.8-5. 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

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 Effects 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 7.8-6 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

Table 7.8-6. 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**

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 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 Effects 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.

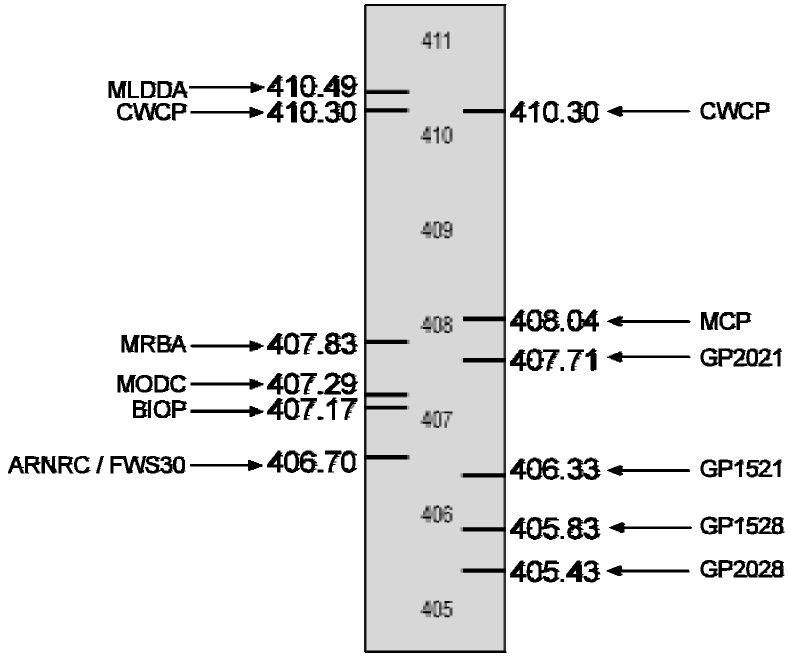

Figure 7.8-1. Average annual flood control benefits for submitted alternatives and the alternatives ($millions).

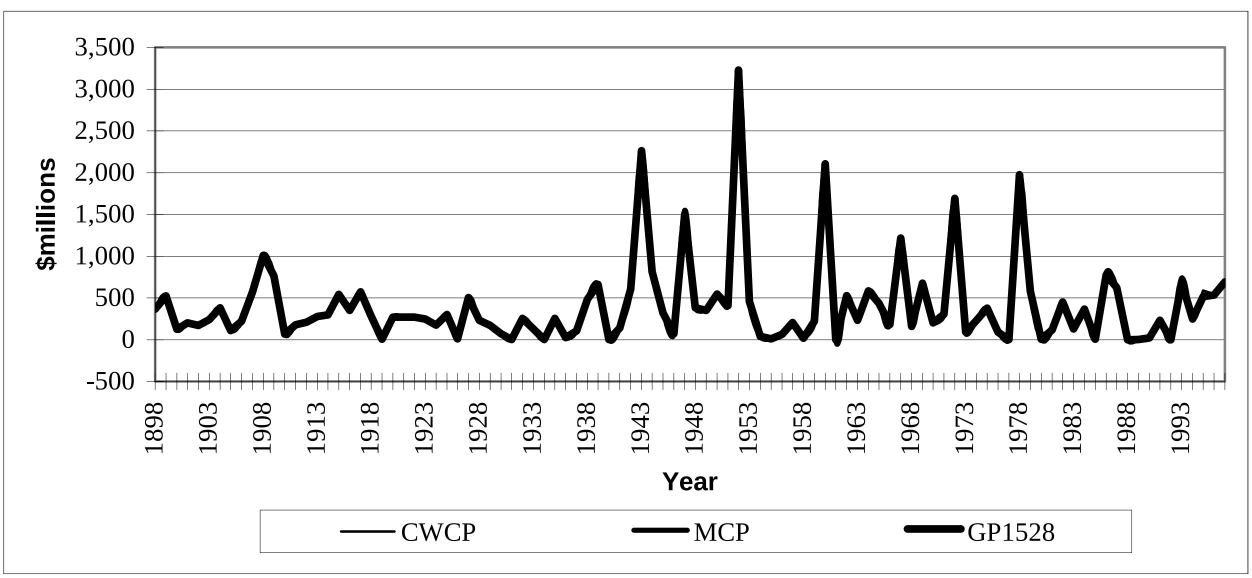

Figure 7.8-2. Average annual flood control benefits for CWCP, MCP, and GP1528.

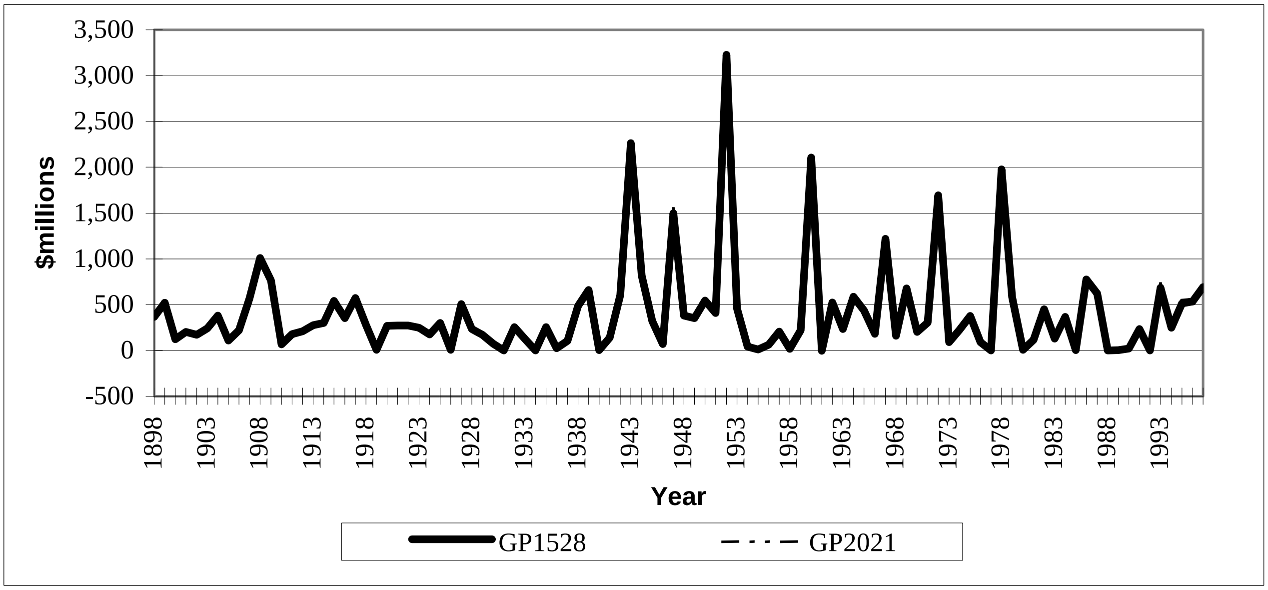

Figure 7.8-3. Average annual flood control benefits for GP1528 and GP2021.

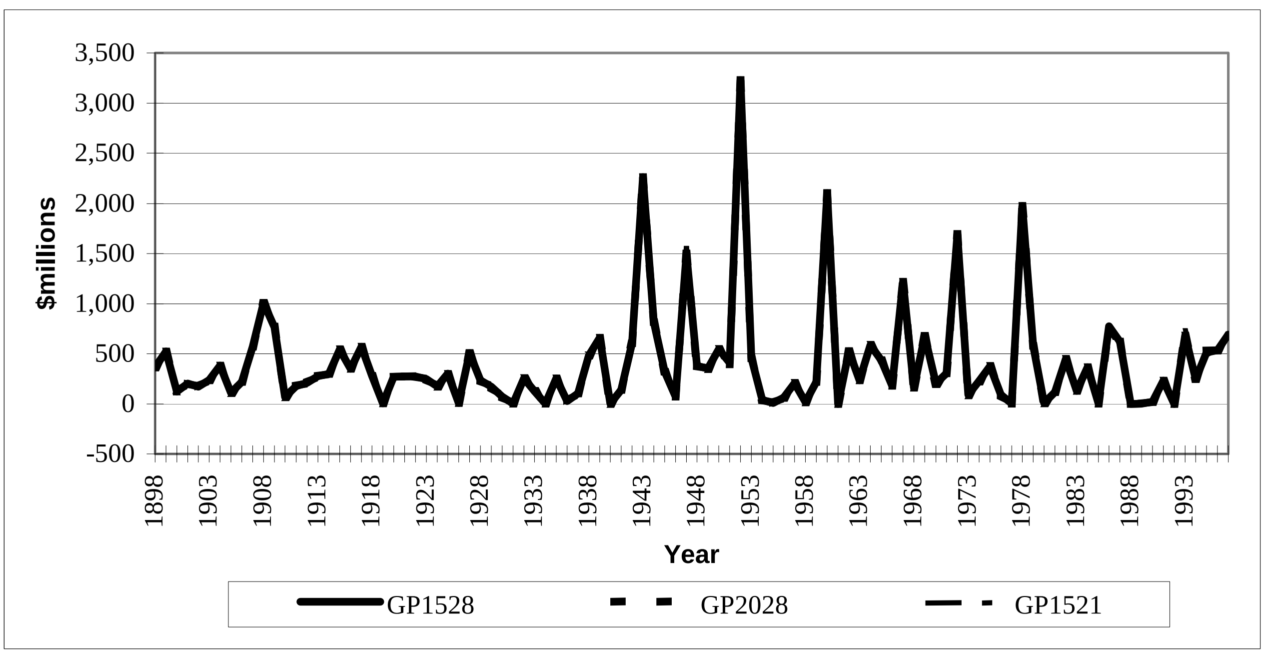

Figure 7.8-4. Average annual flood control benefits for GP1528, GP2028, and GP1521.

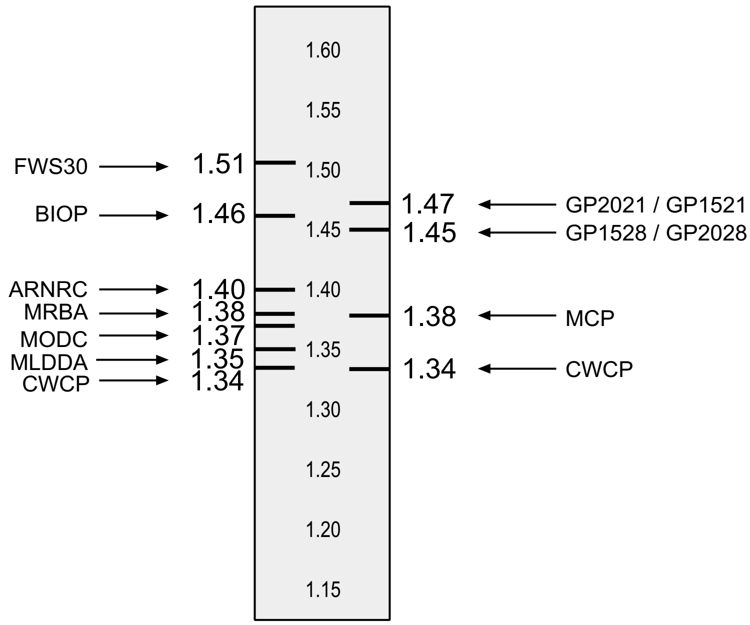

Figure 7.8-5. Average annual interior drainage damages for submitted alternatives and the alternatives ($millions).

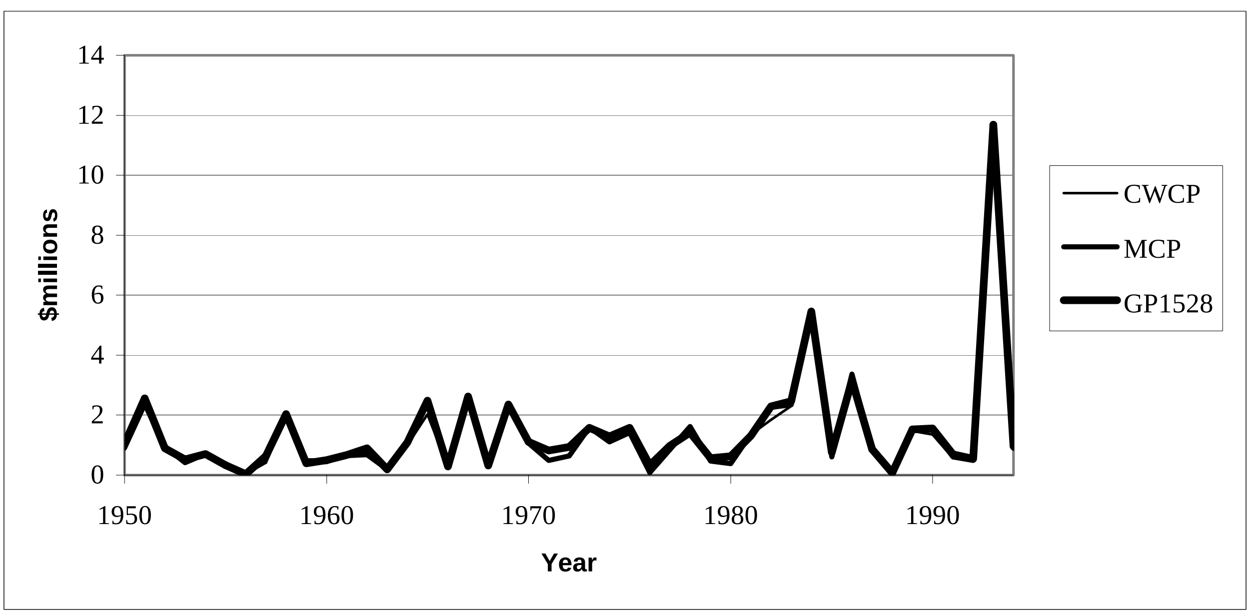

Figure 7.8-6. Average annual interior drainage damages for CWCP, MCP, and GP1528.

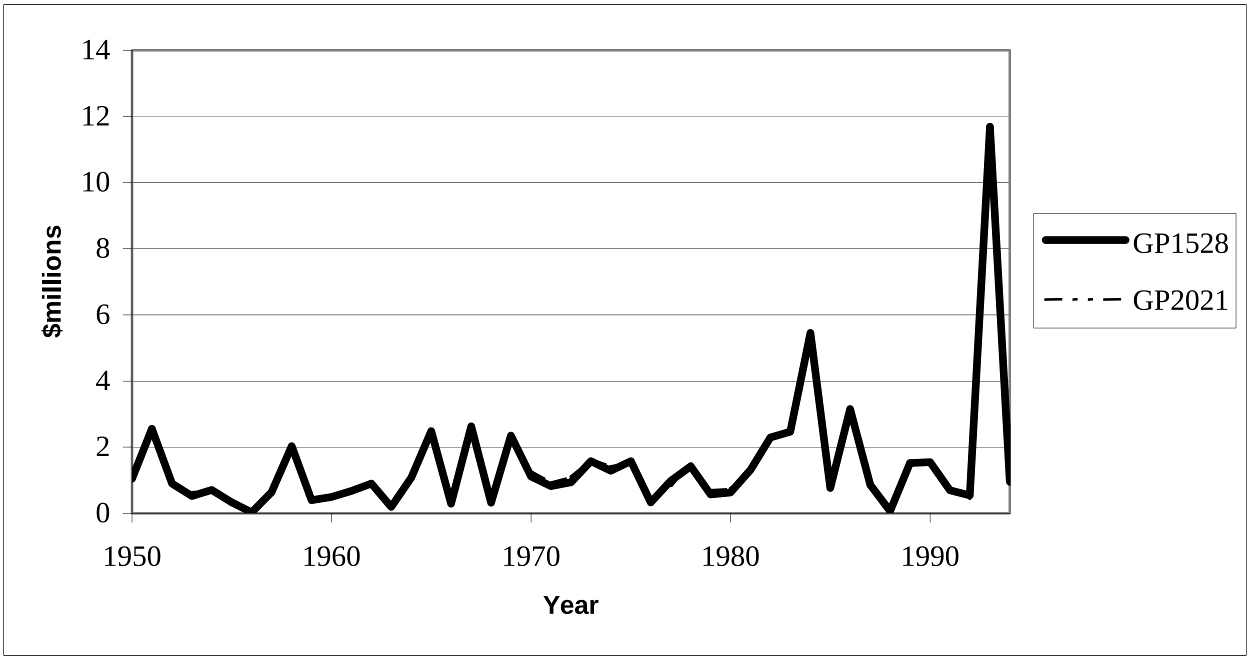

Figure 7.8-7. Average annual interior drainage damages for GP1528 and GP2021.

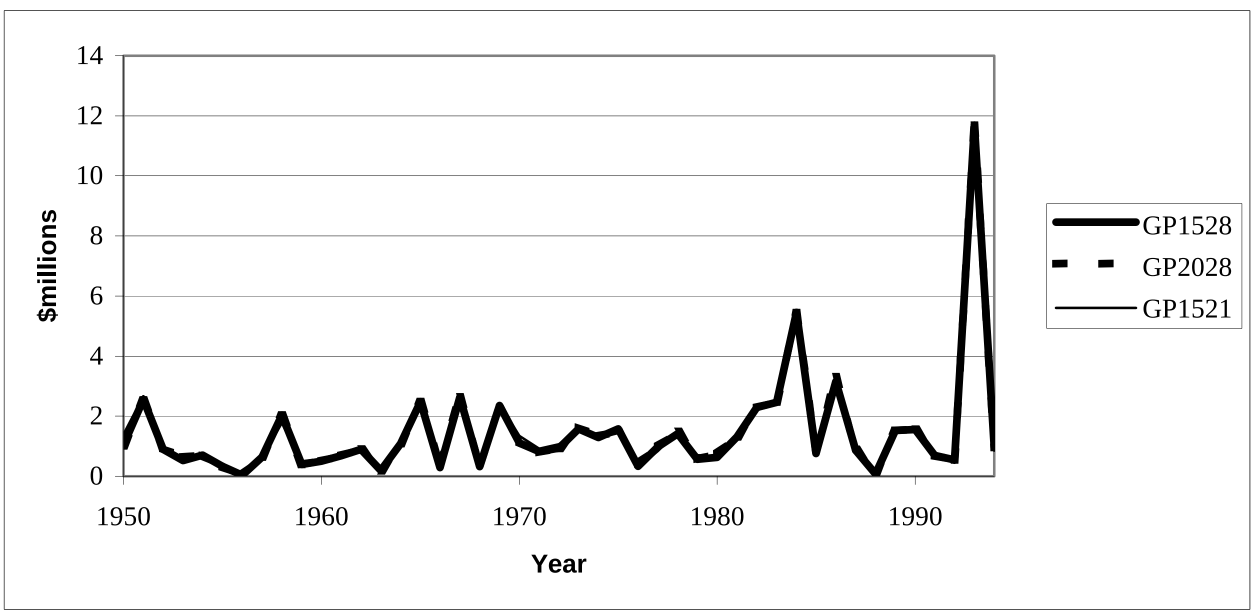

Figure 7.8-8. Average annual interior drainage damages for GP1528, GP2028, and GP1521.

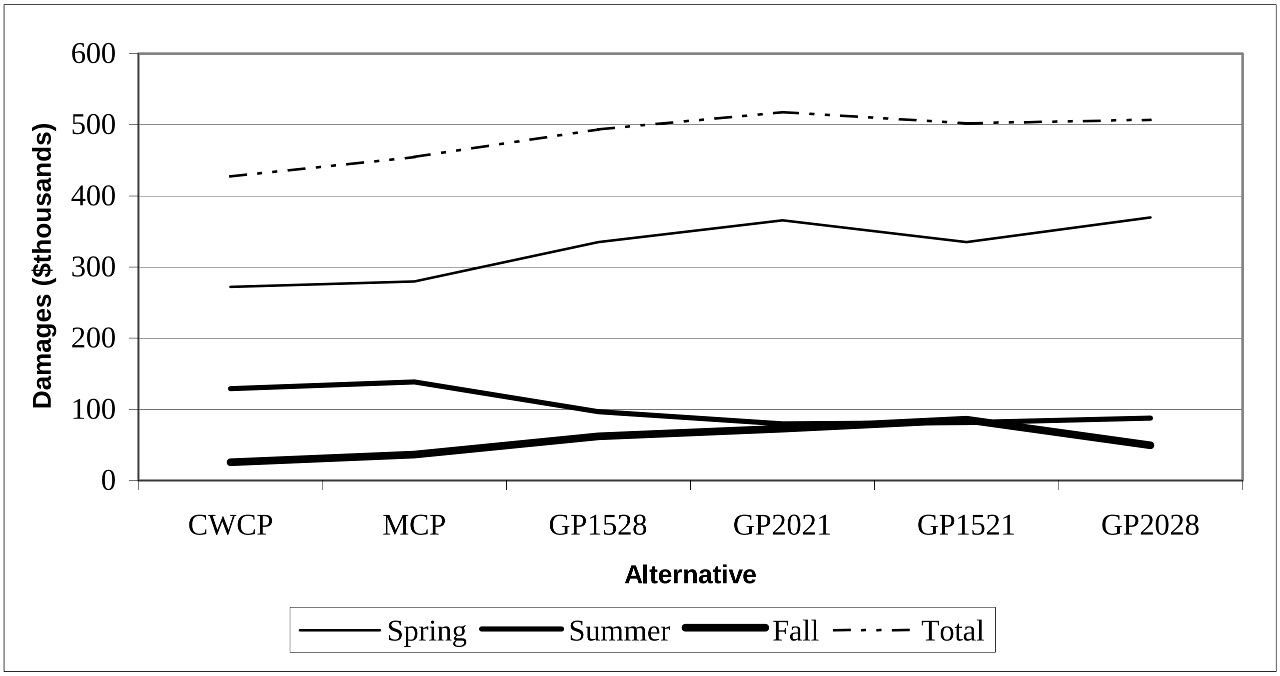

Figure 7.8-9. Average annual interior drainage damages for site L575 by season and total.

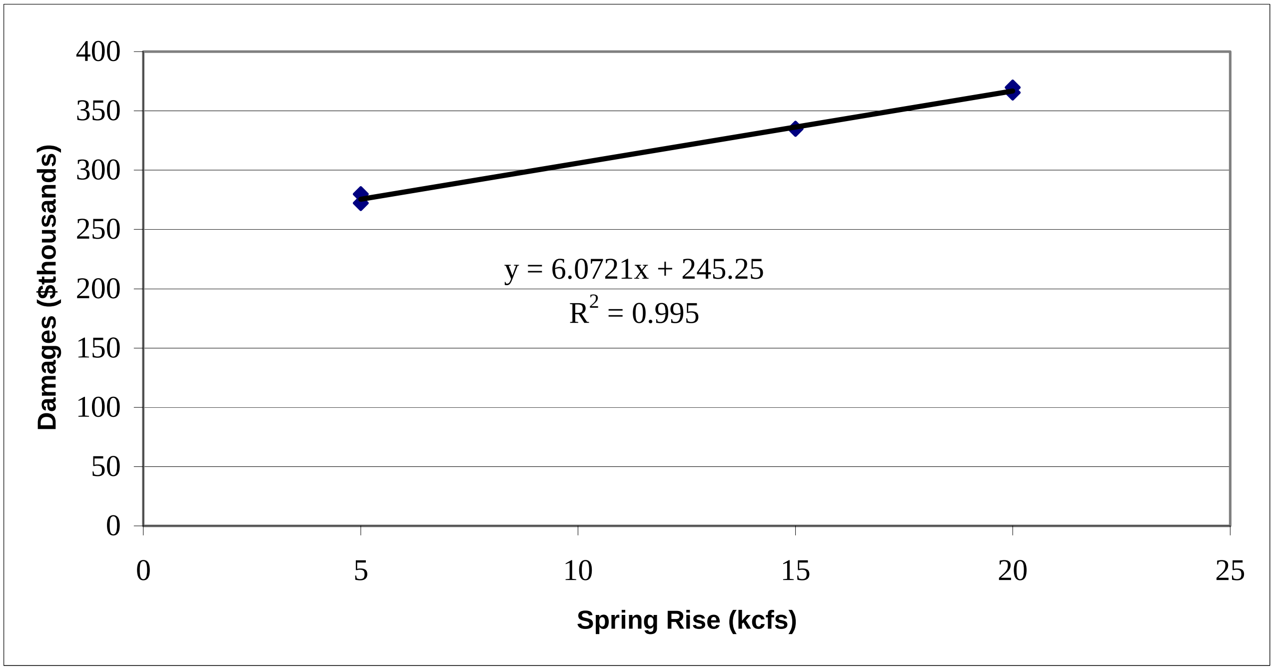

Figure 7.8-10. Average annual spring damages at site L575 versus amount of spring rise.

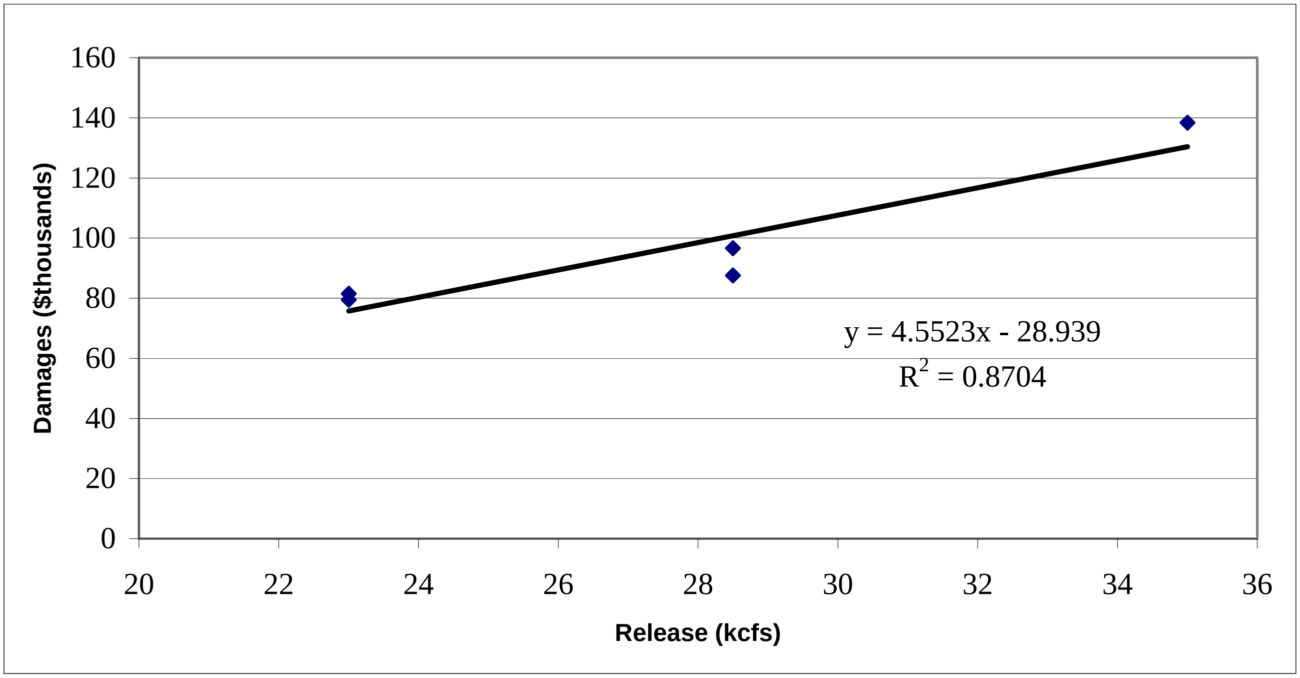

Figure 7.8-11. Summer interior drainage damages at site L575 versus summer average Gavins Point Dam release.

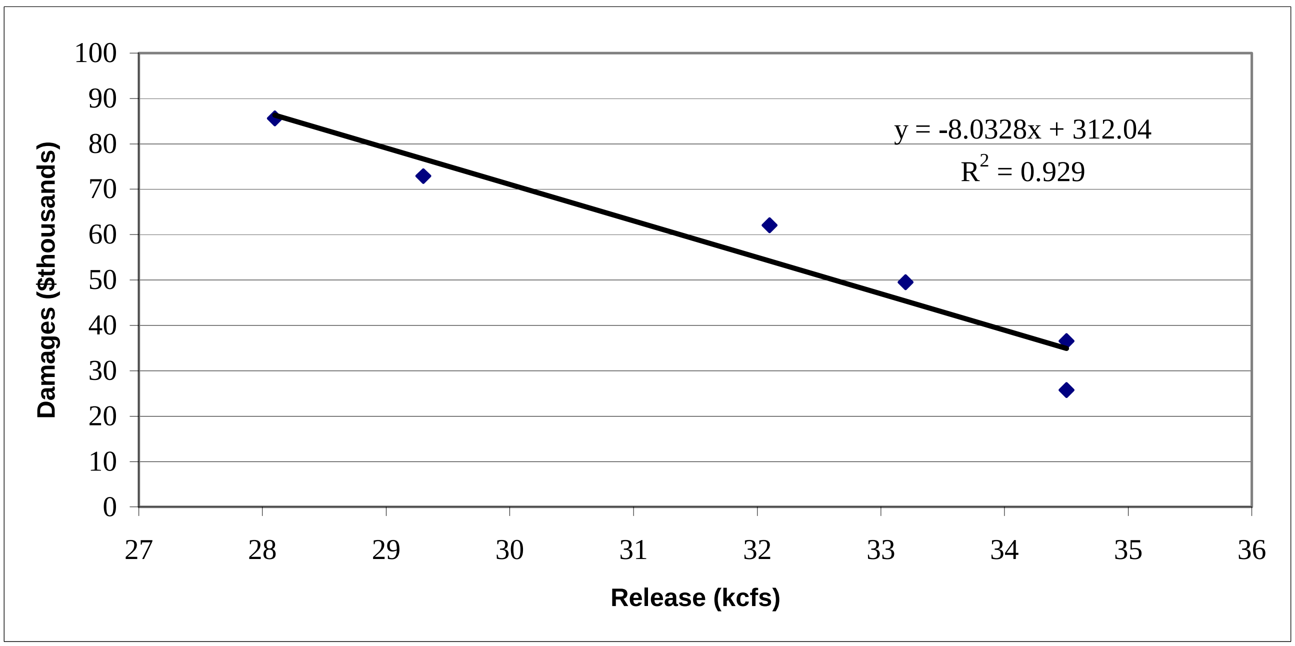

Figure 7.8-12. Average annual interior drainage damages for the post-September 6 timeframe at site L575 versus average May through August release from Gavins Point Dam.

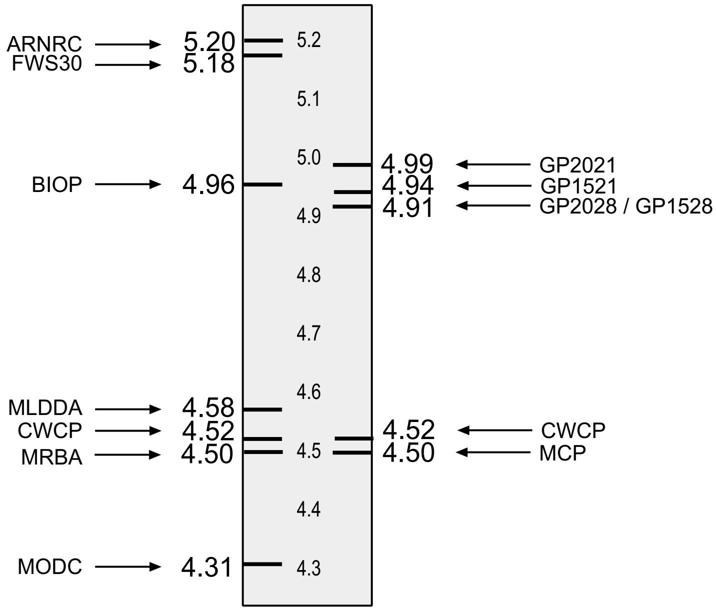

Figure 7.8-13. Average annual groundwater damages for submitted alternatives and the alternatives ($millions).

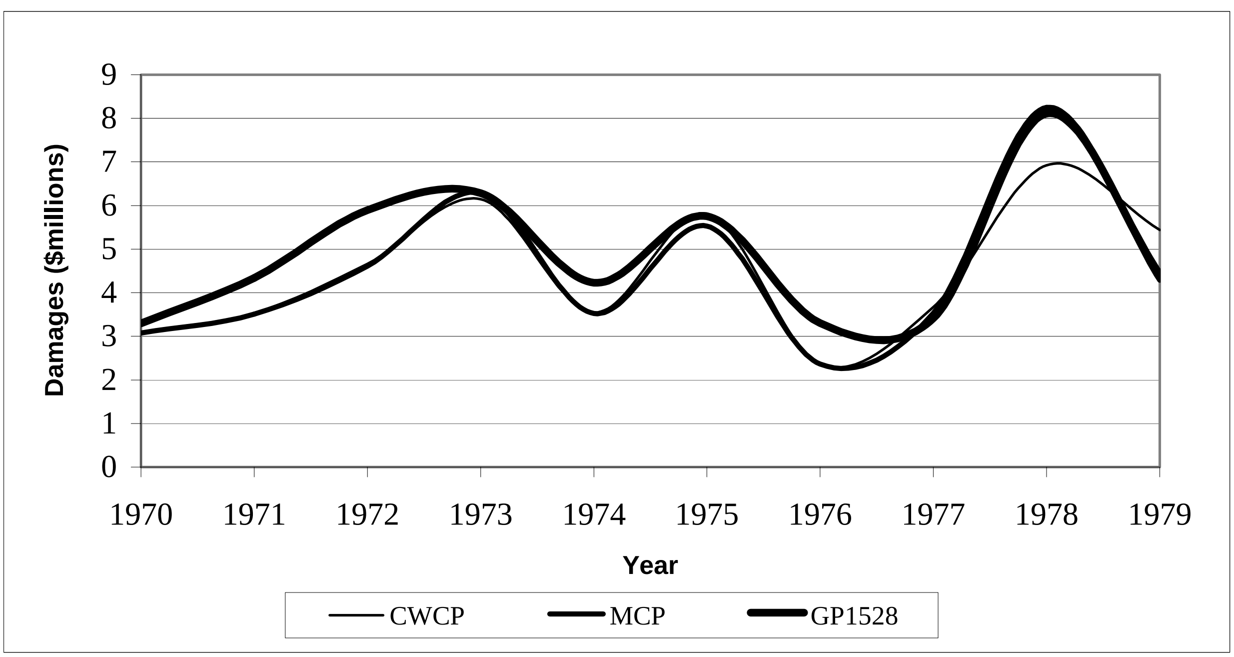

Figure 7.8-14. Average annual groundwater damages for CWCP, MCP, and GP1528.

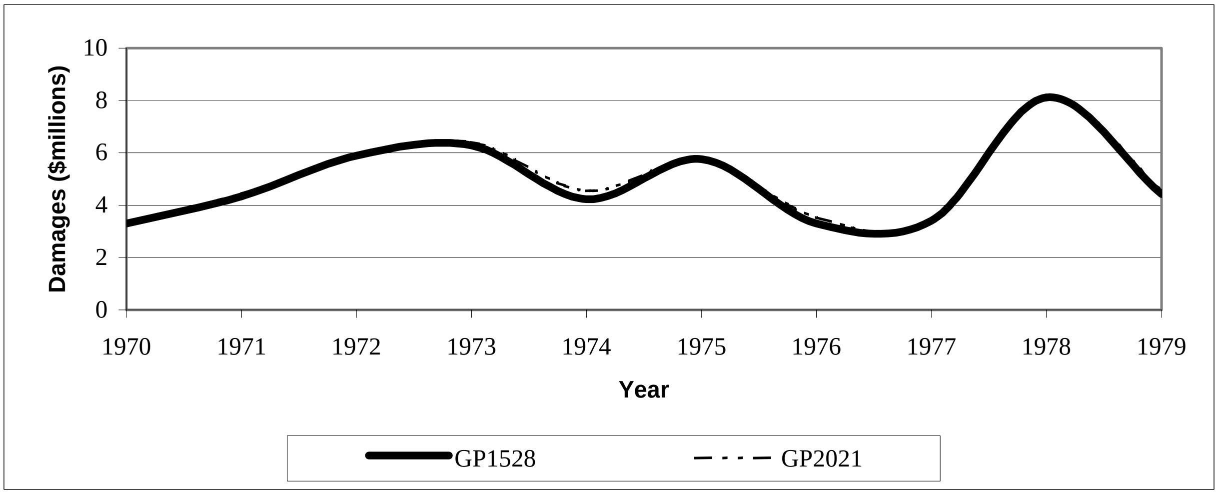

Figure 7.8-15. Average annual groundwater damages for GP1528 and GP2021.

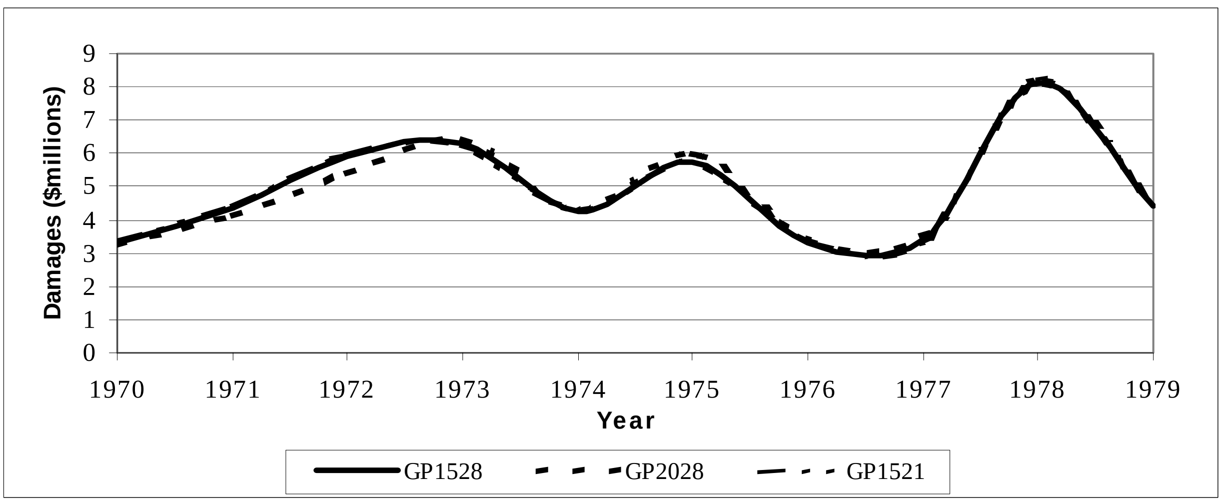

Figure 7.8-16. Average annual groundwater damages for GP1528, GP2028, and GP1521.

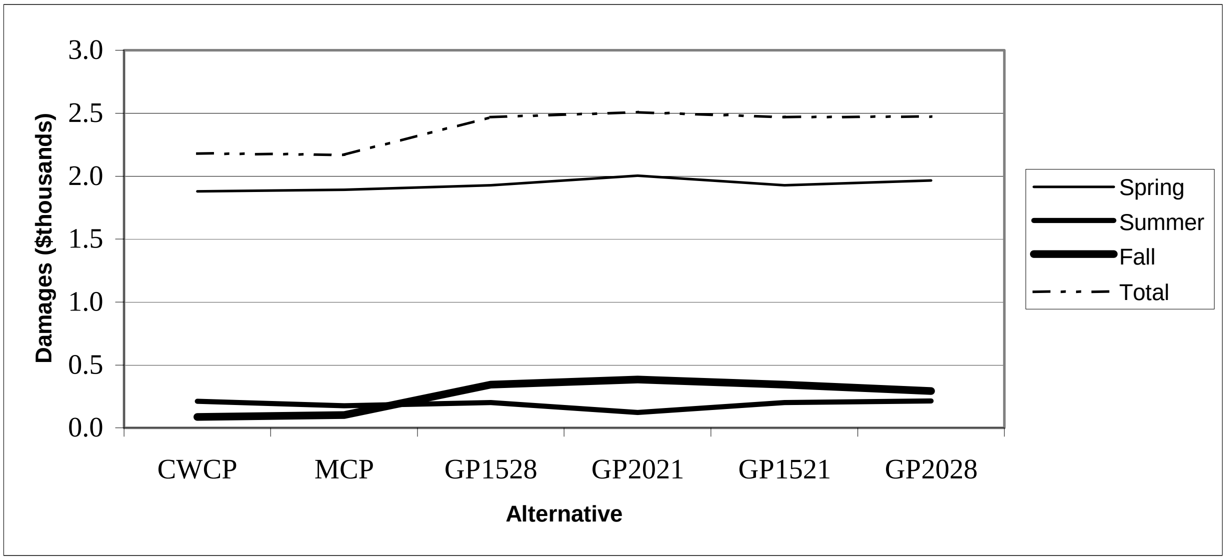

Figure 7.8-17. Average annual seasonal groundwater crop damages at site L575 by season and total.

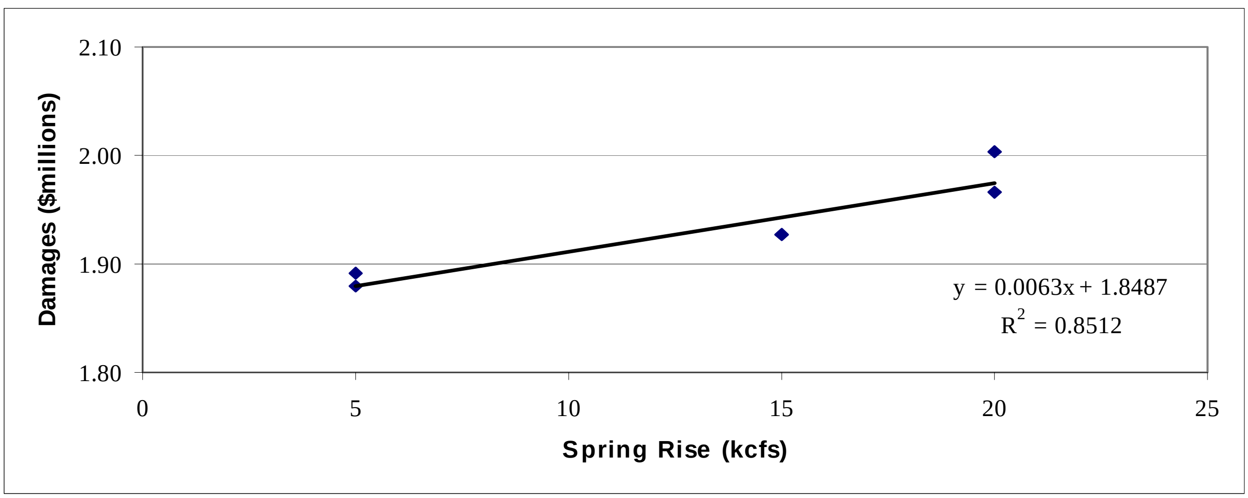

Figure 7.8-18. Average annual spring groundwater crop damages at site L575 versus amount of the Gavins Point Dam spring rise.

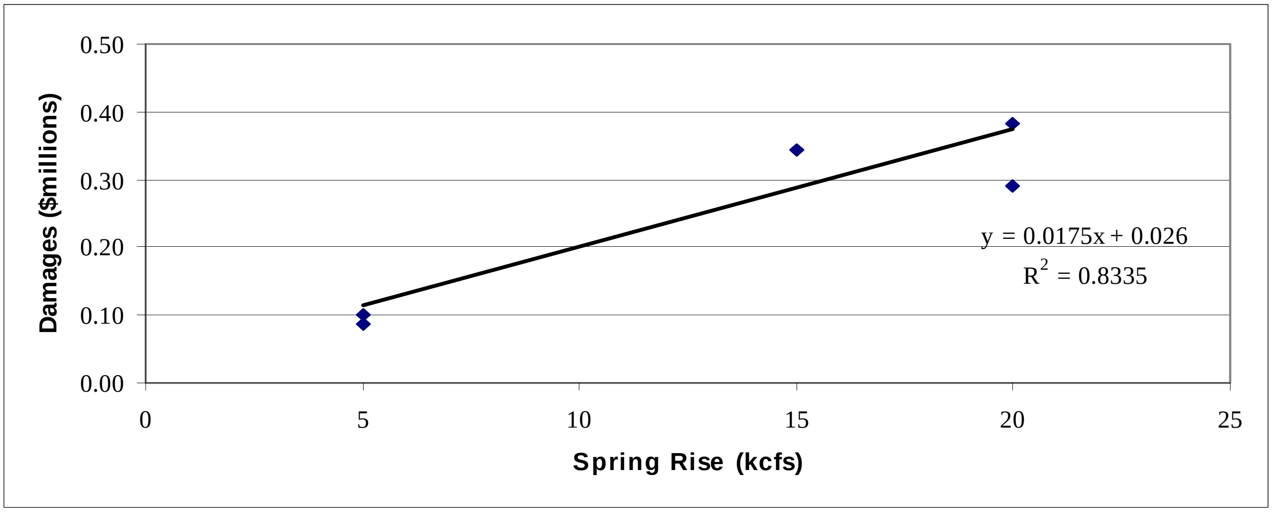

Figure 7.8-19. Average annual fall groundwater crop damages at site L575 versus amount of the Gavins Point Dam spring rise.

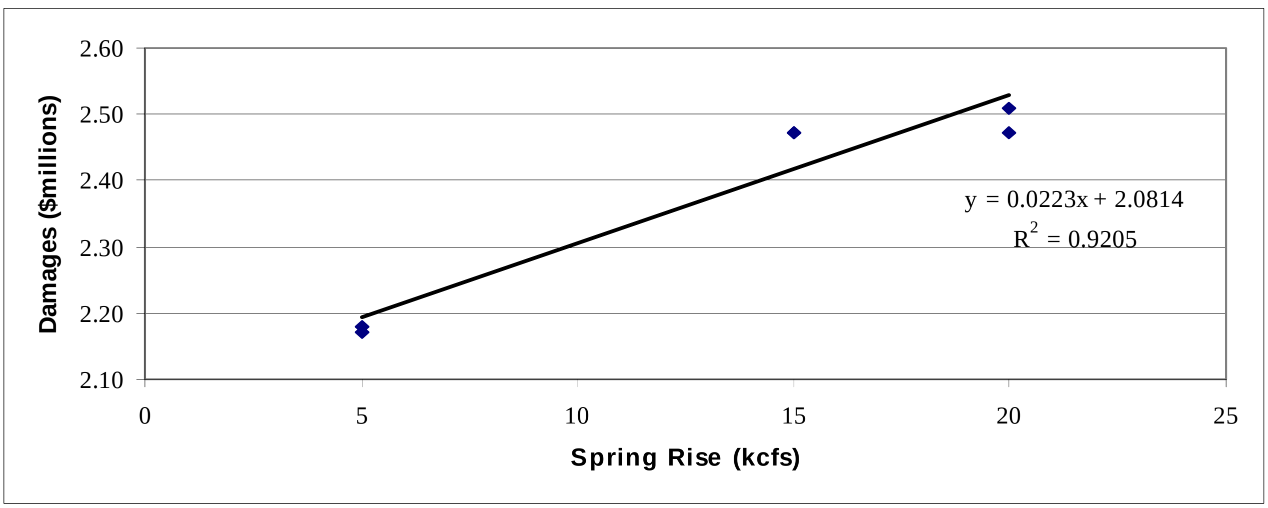

Figure 7.8-20. Average annual total groundwater crop damages at site L575 versus amount of the Gavins Point Dam spring rise.

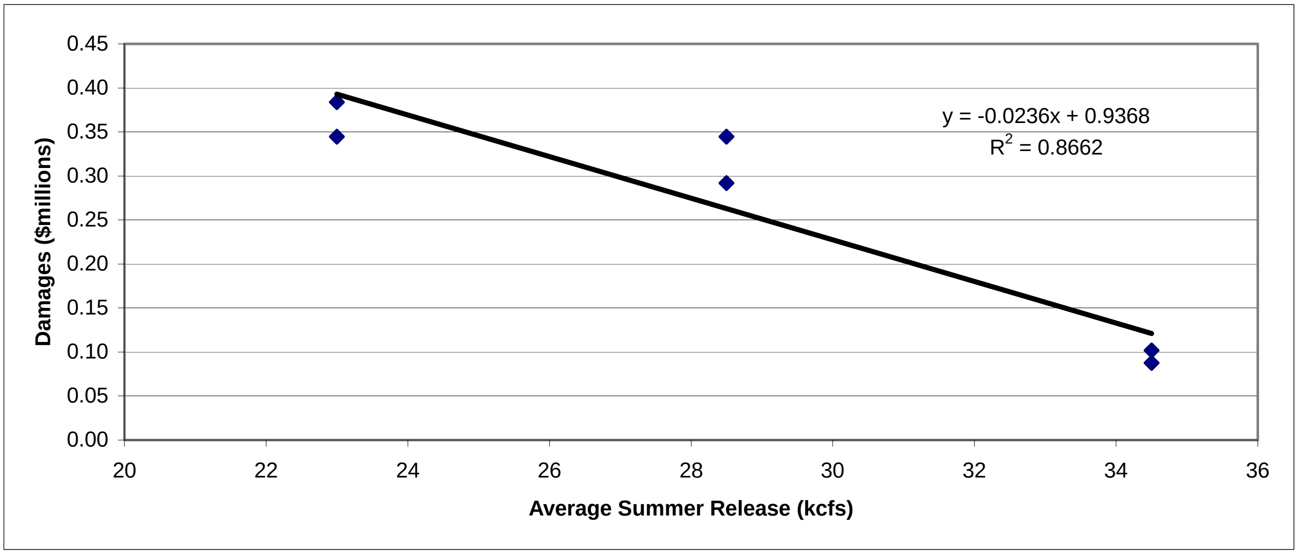

Figure 7.8-21. Average annual fall groundwater crop damages at site L575 versus amount of Gavins Point Dam average summer release.

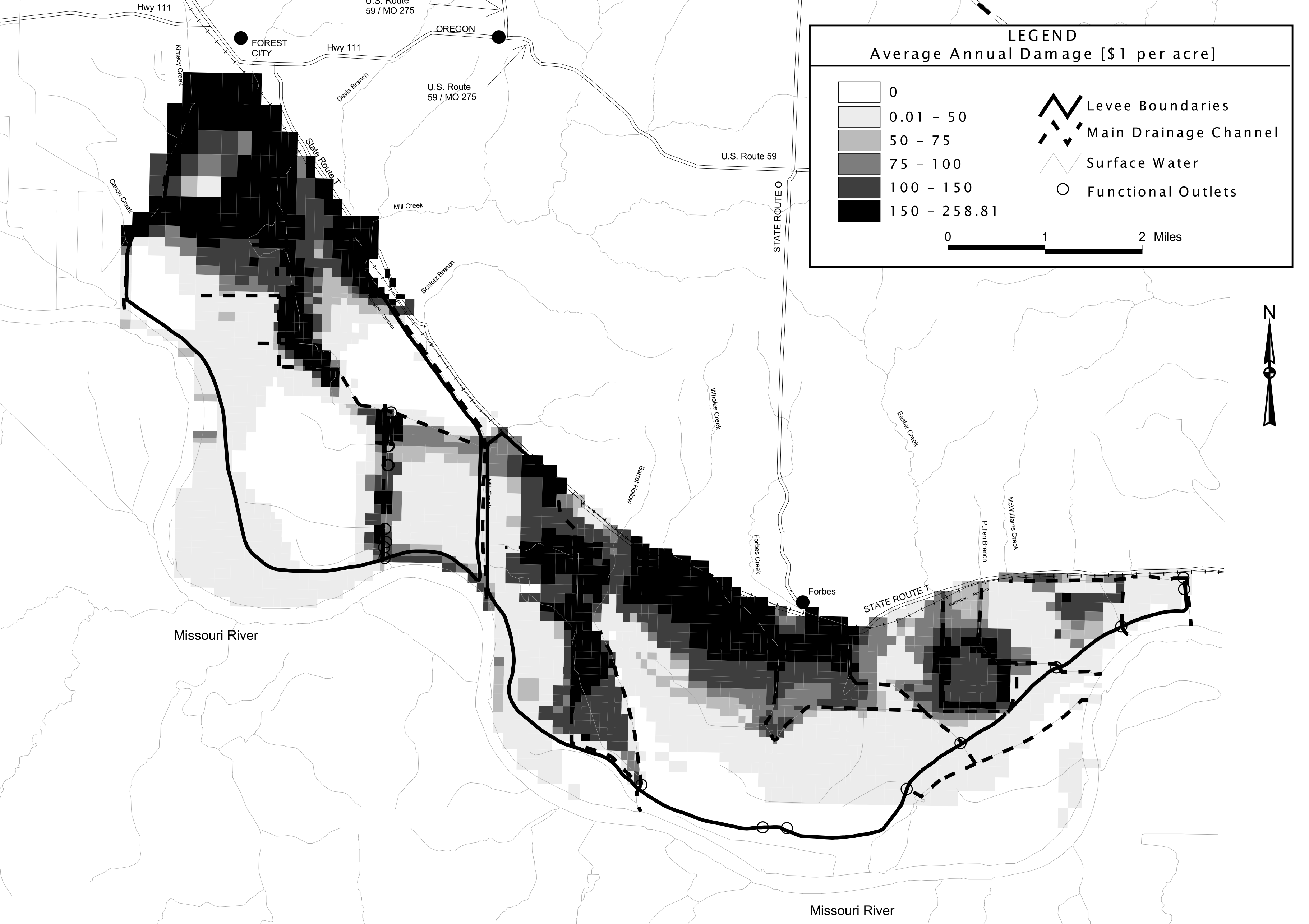

Figure 7.8-22. Average annual damages for CWCP at site L488/497.

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

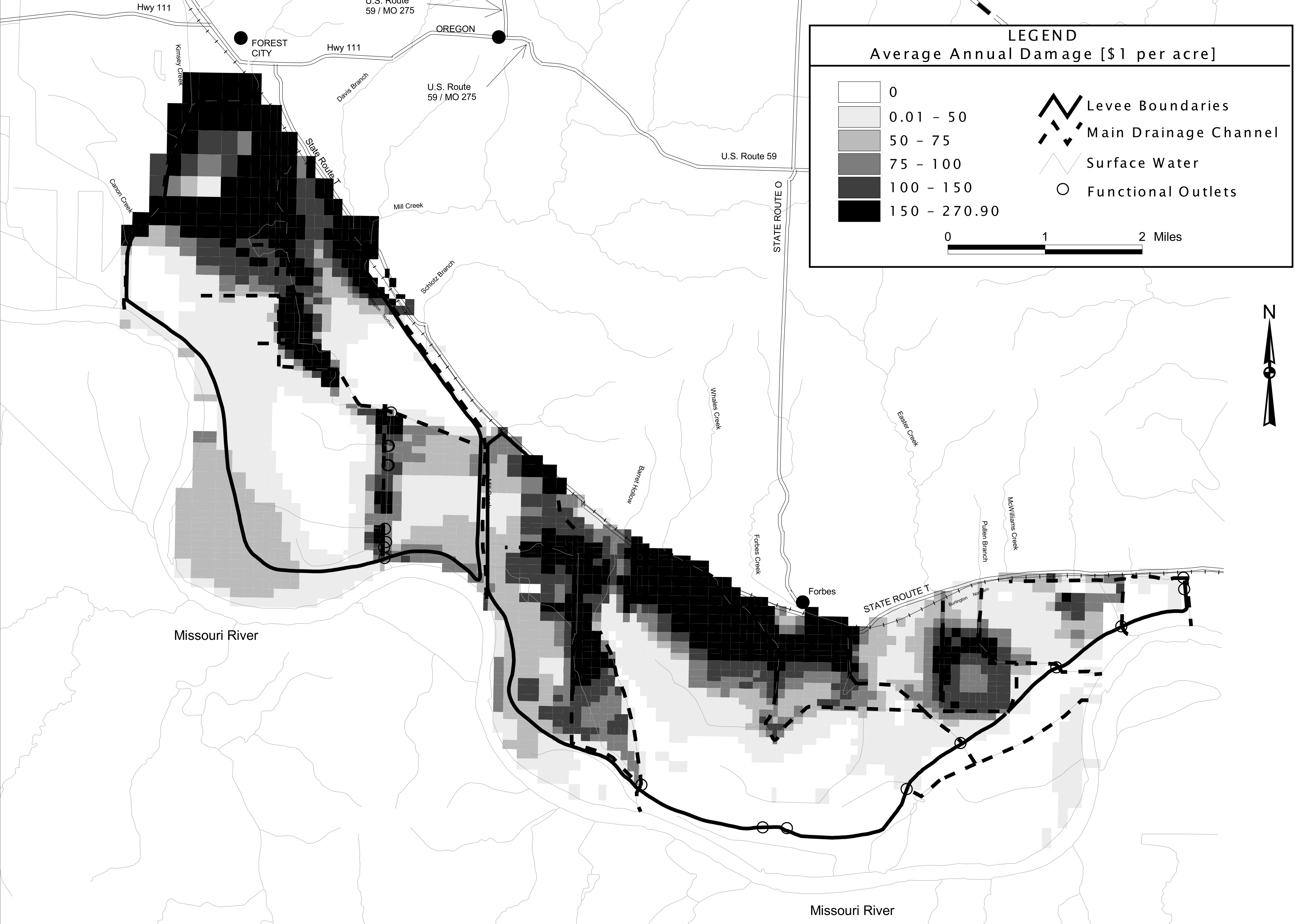

Figure 7.8-23. Average annual damages for MCP at site L488/497.

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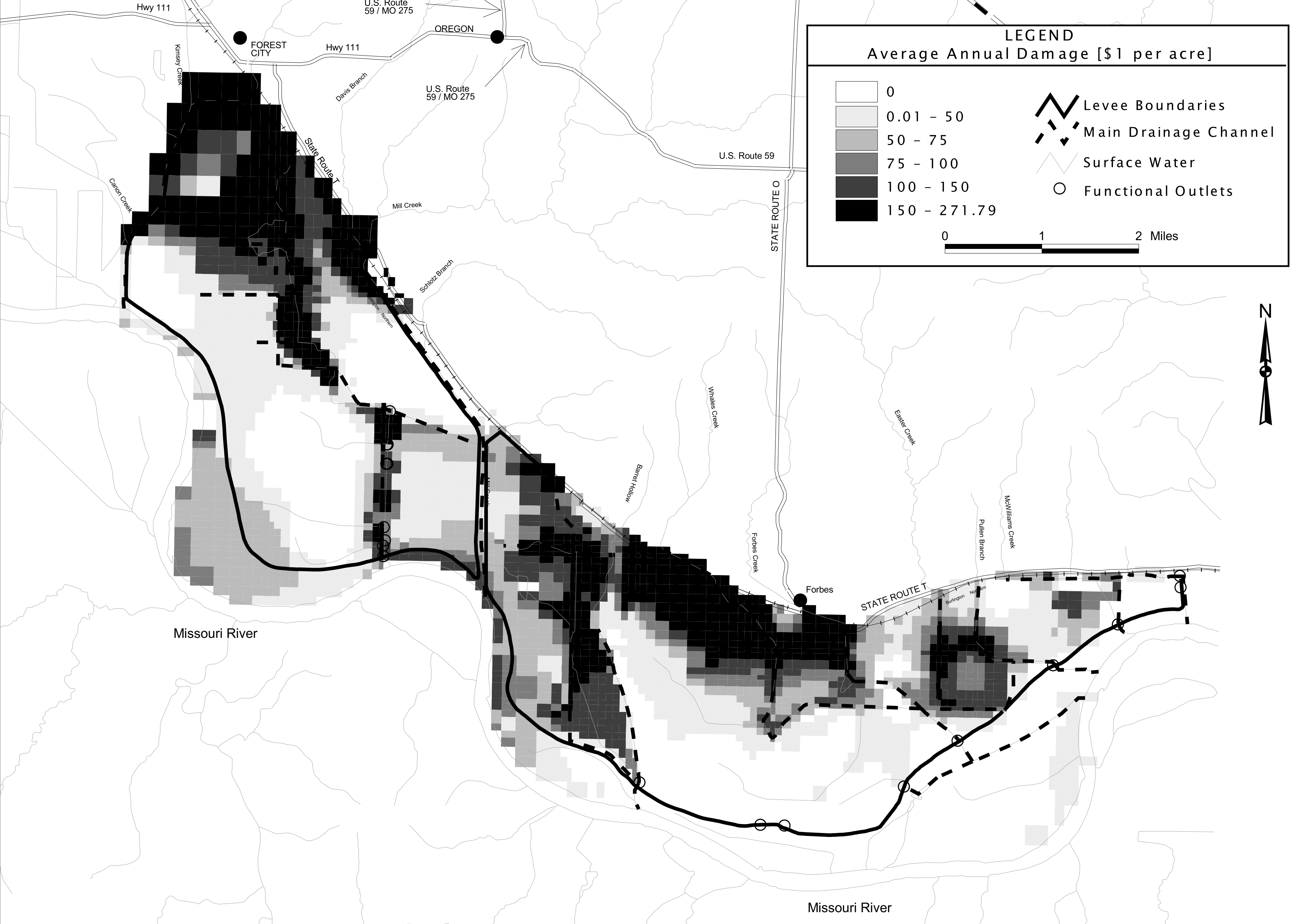

Figure 7.8-24. Average annual damages for GP1528 at site L488/497.

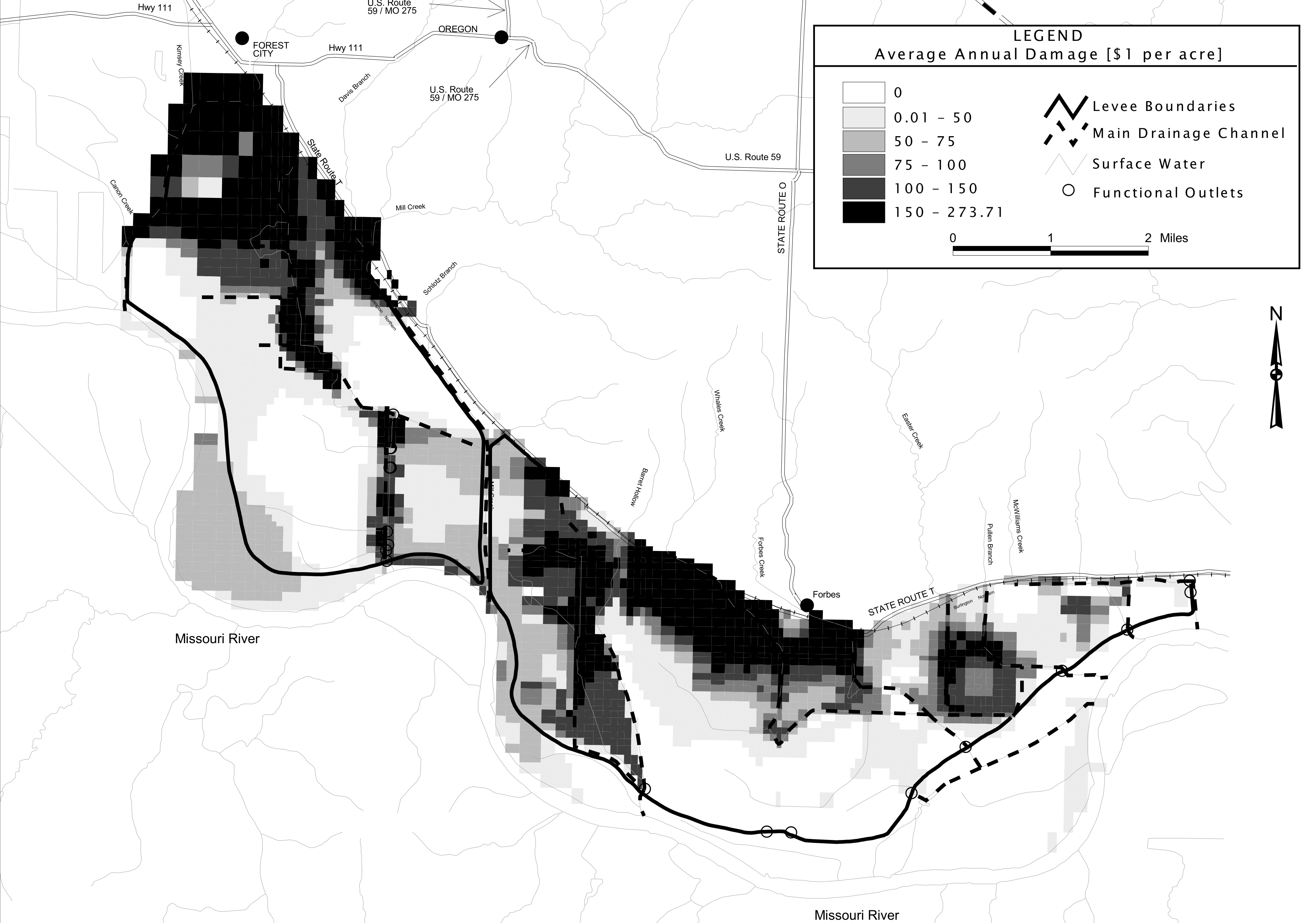

Figure 7.8-25. Average annual damages for GP2021 at site L488/497.

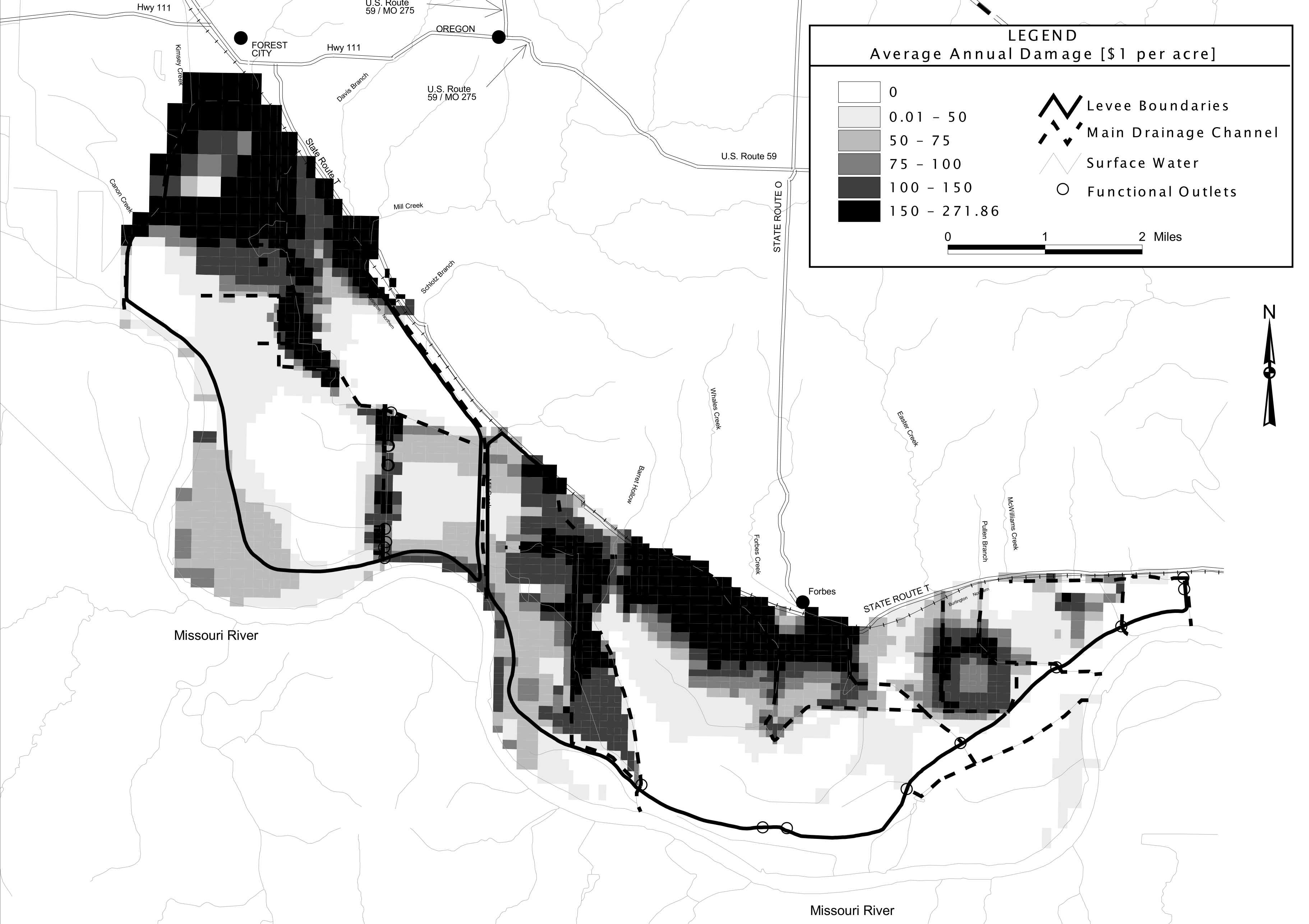

Figure 7.8-26. Average annual damages for GP1521 at site L488/497.

p:/projects_2001/missouri/missouri_review_l488.apr - MR1521-BW_l May 22, 2001

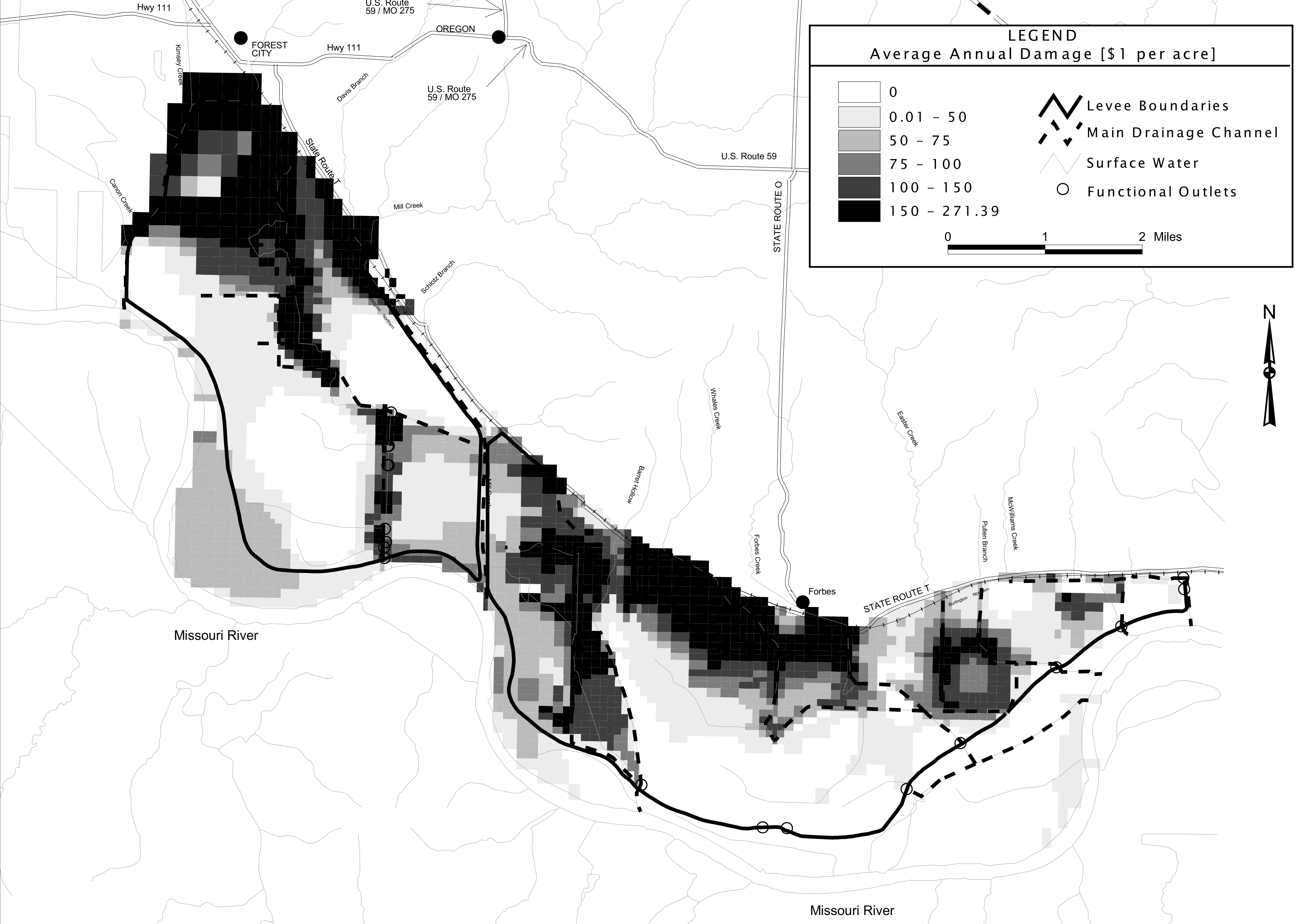

Figure 7.8-27. Average annual damages for GP2028 at site L488/497.

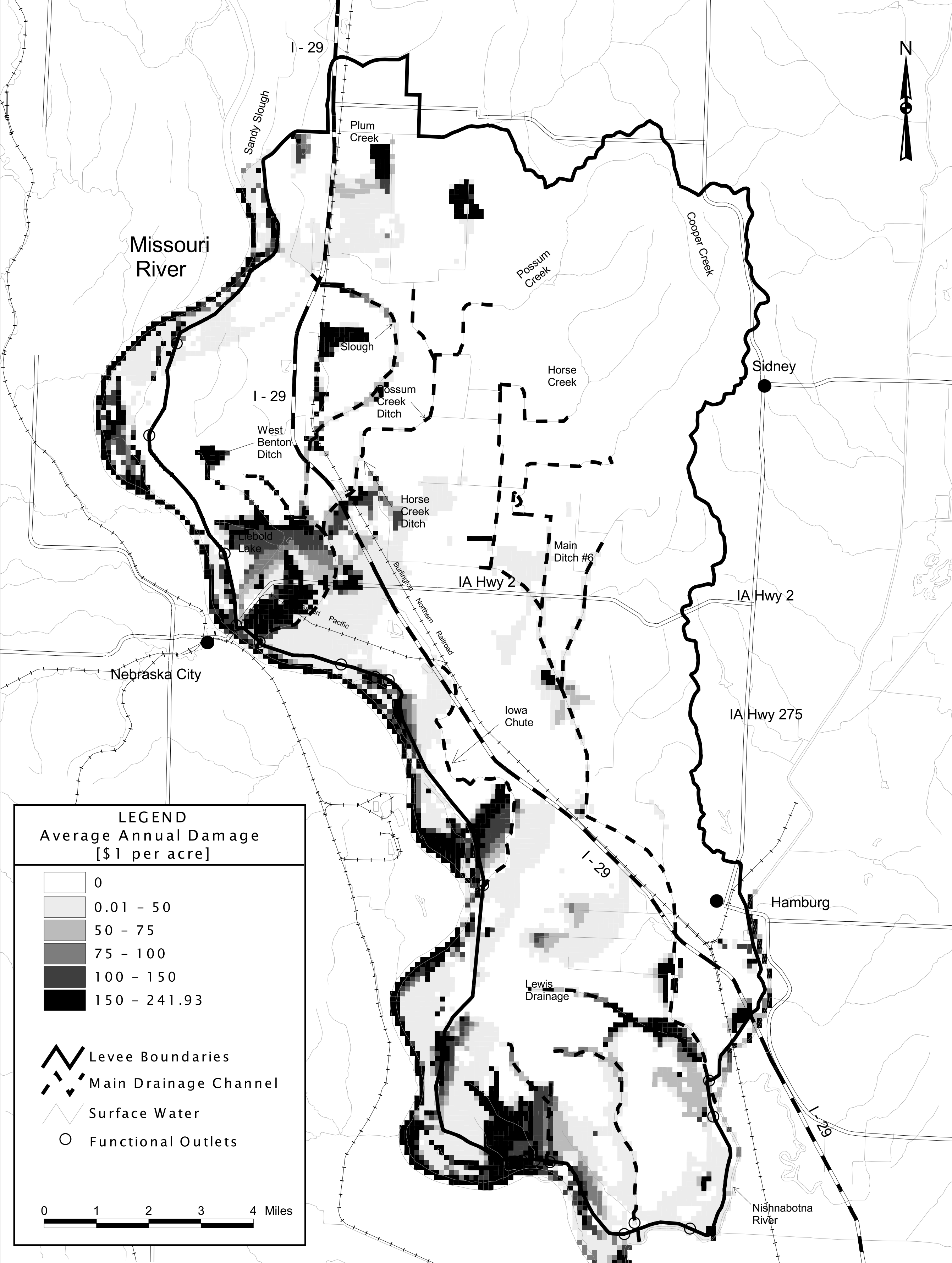

Figure 7.8-28. Average annual damages for CWCP at site L575.

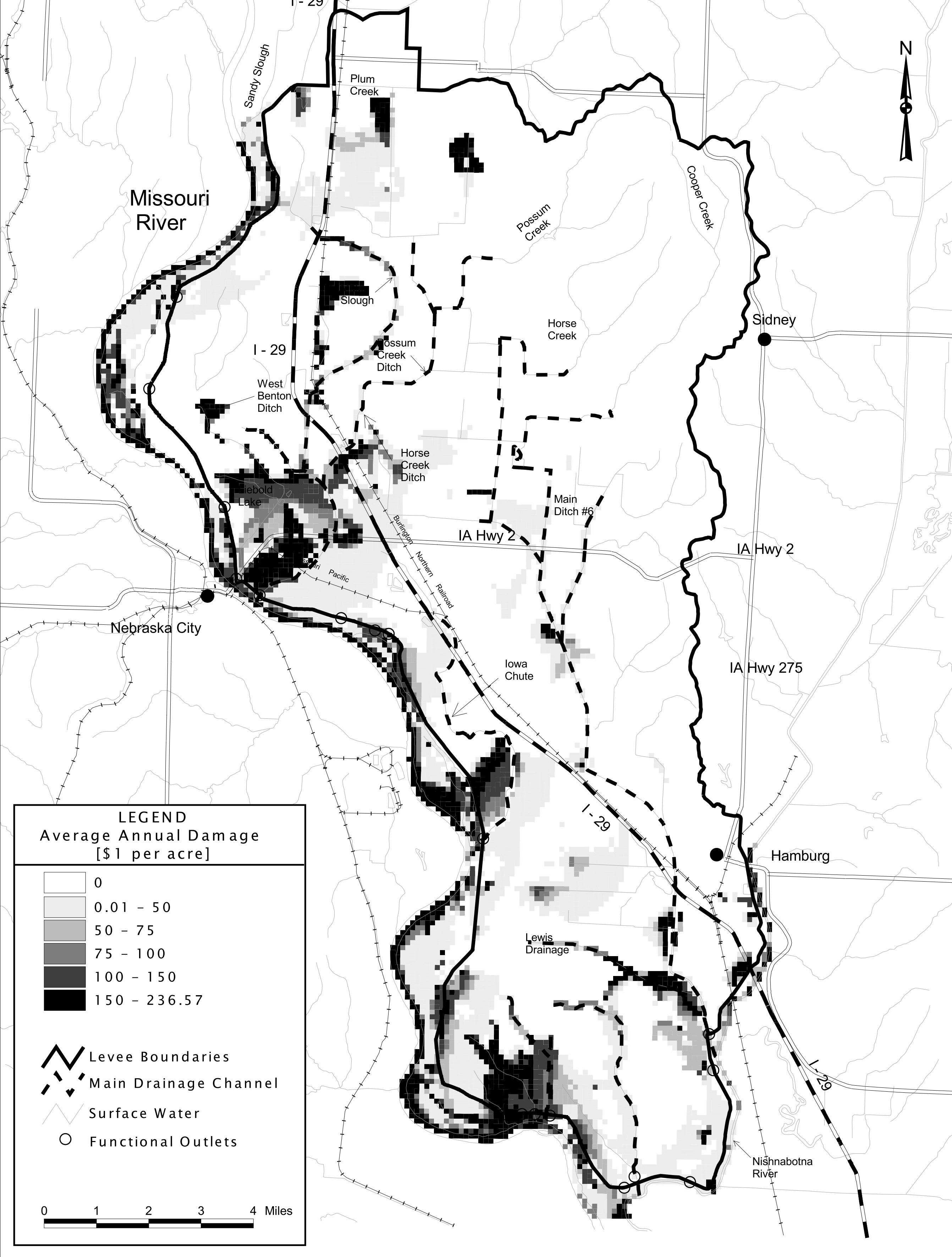

Figure 7.8-29. Average annual damages for MCP at site L575.

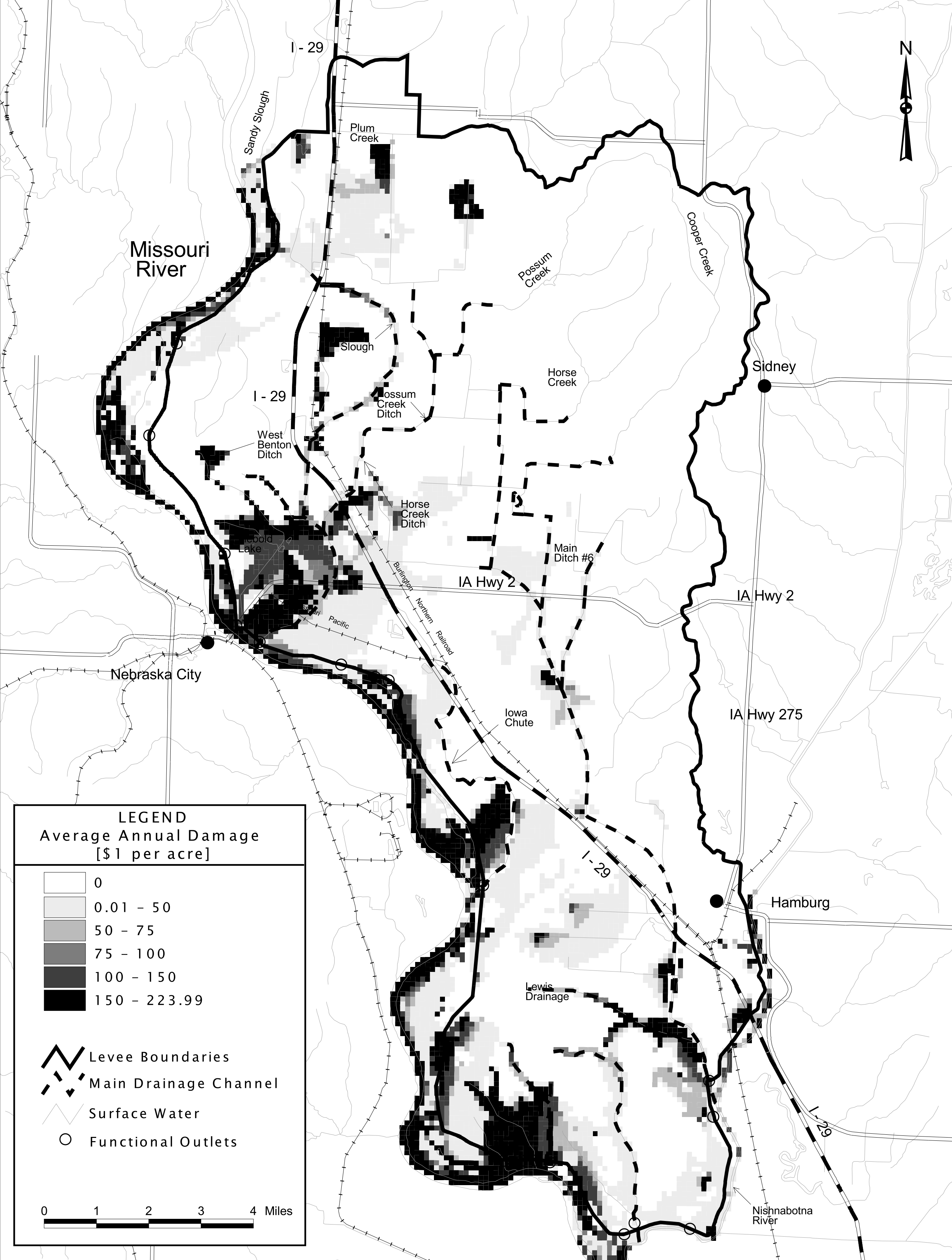

Figure 7.8-30. Average annual damages for GP1528 at site L575.

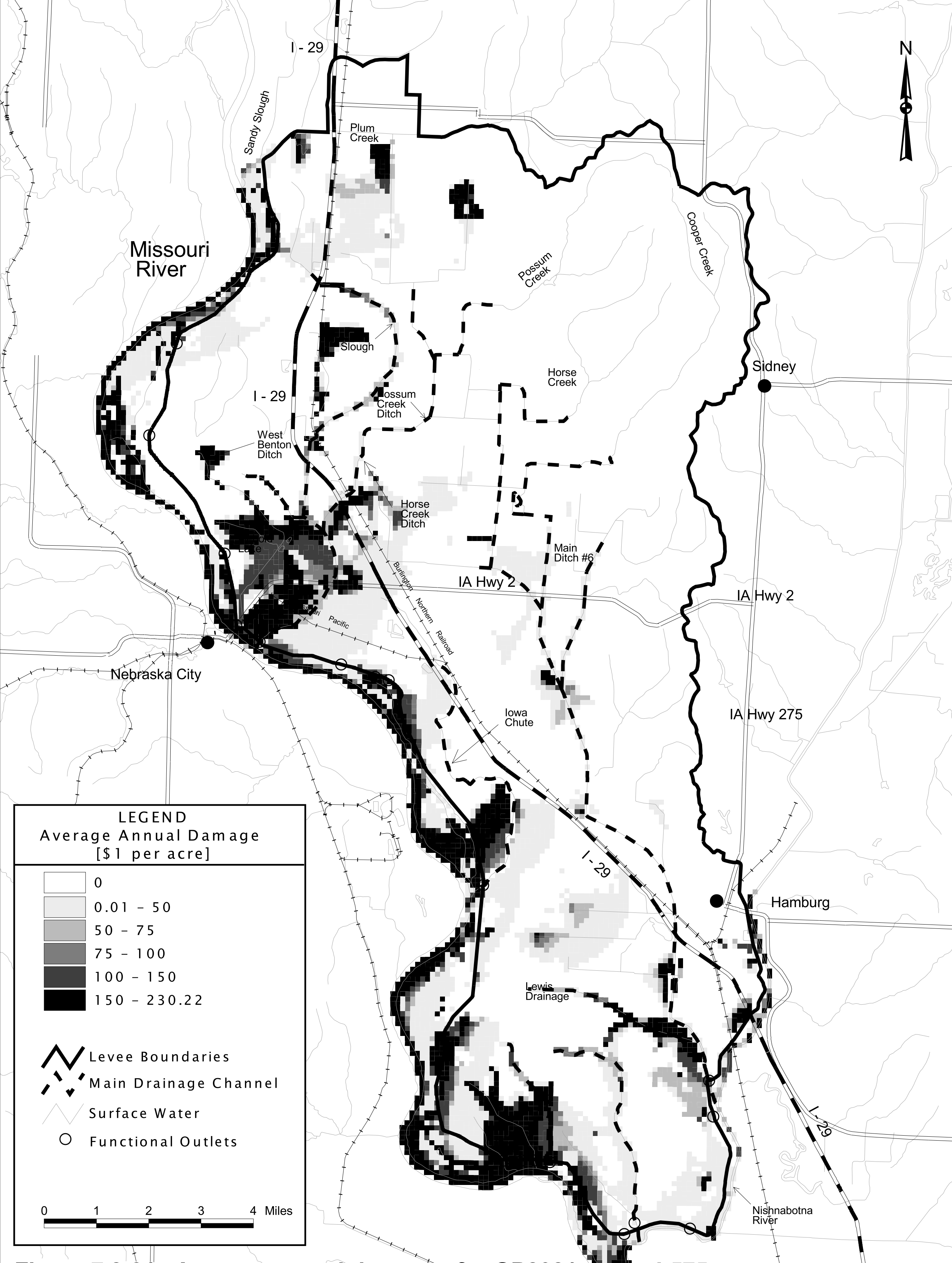

Figure 7.8-31. Average annual damages for GP2021 at site L575.

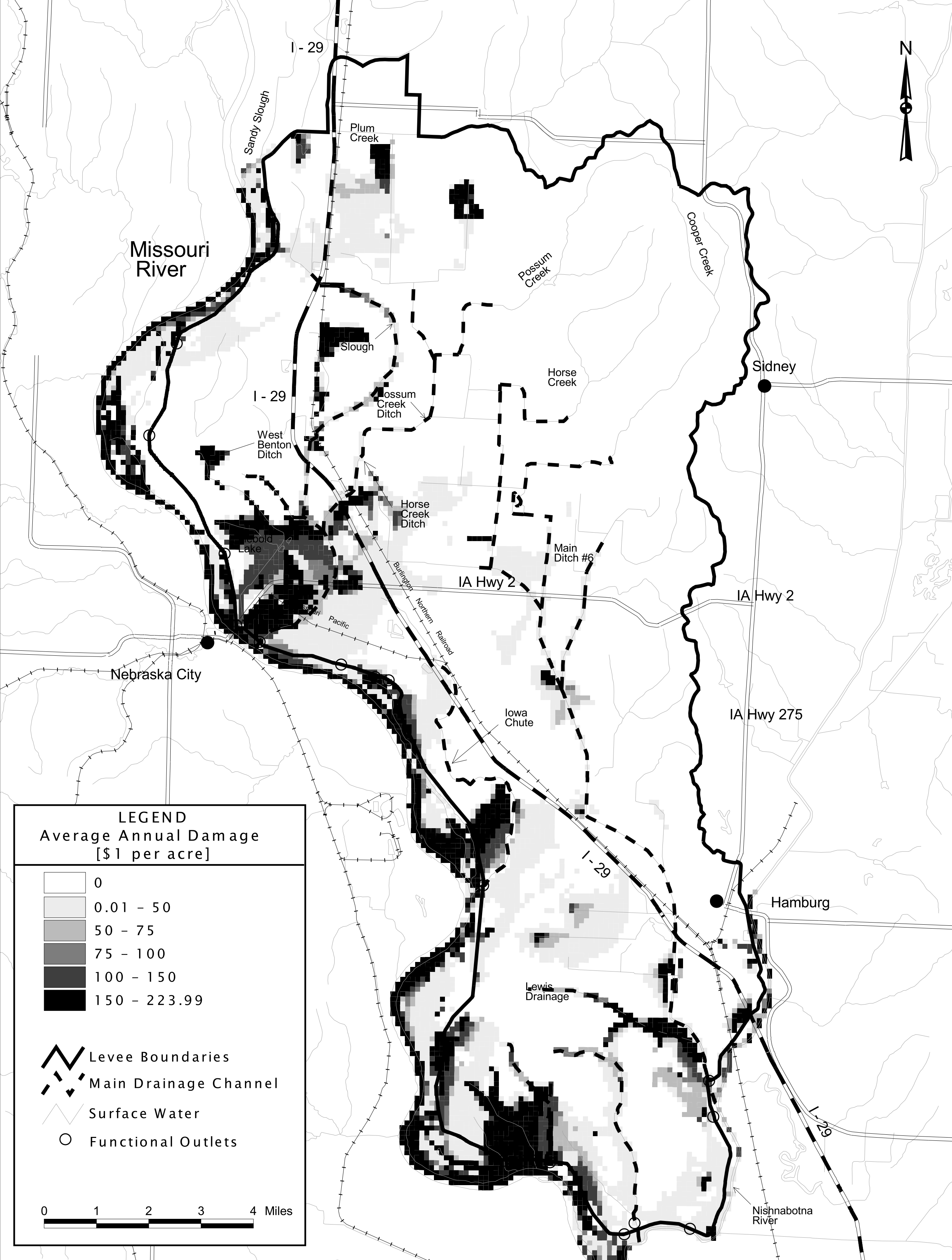

Figure 7.8-32. Average annual damages for GP1521 at site L575.

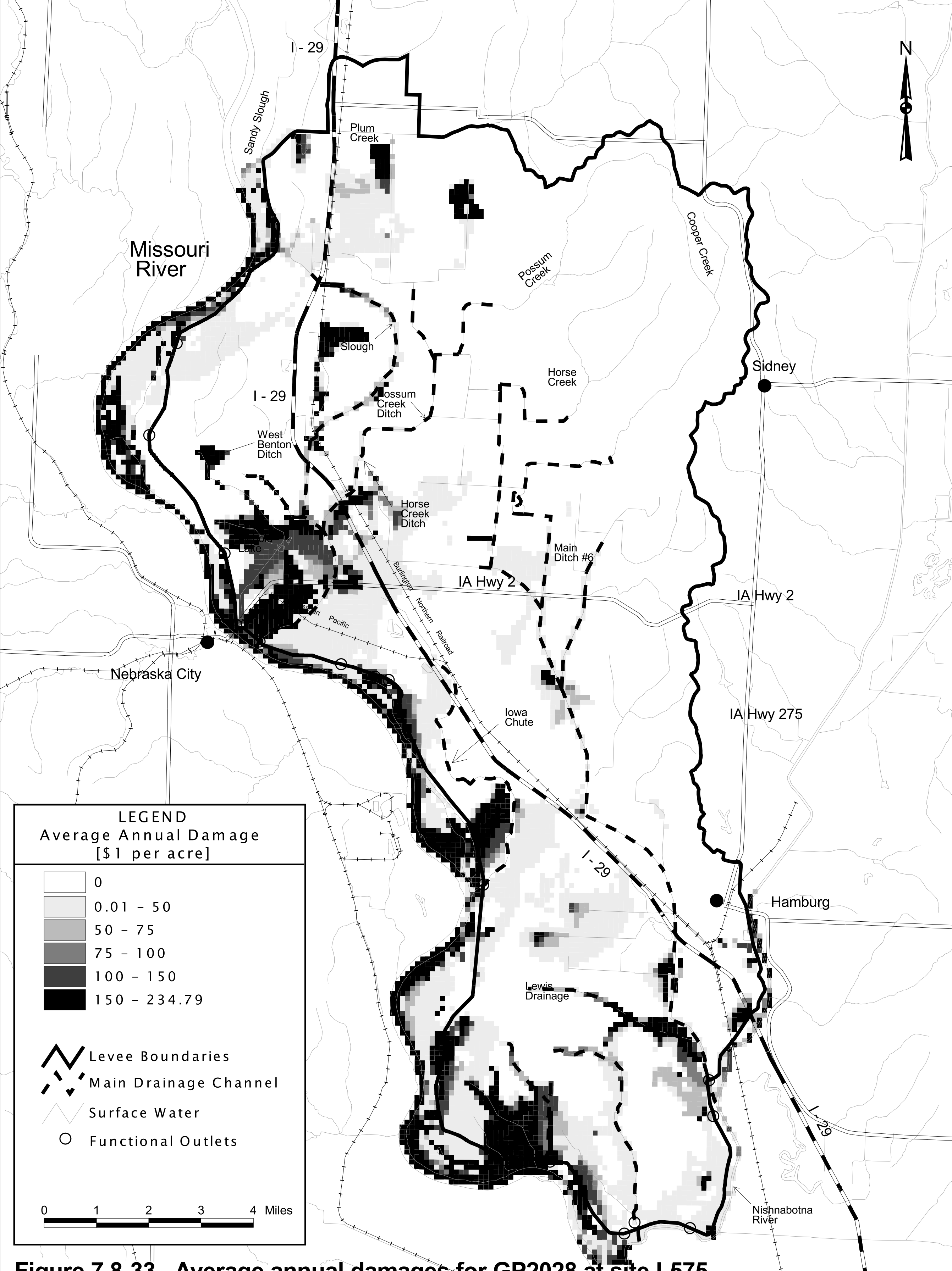

Figure 7.8-33. Average annual damages for GP2028 at site L575.

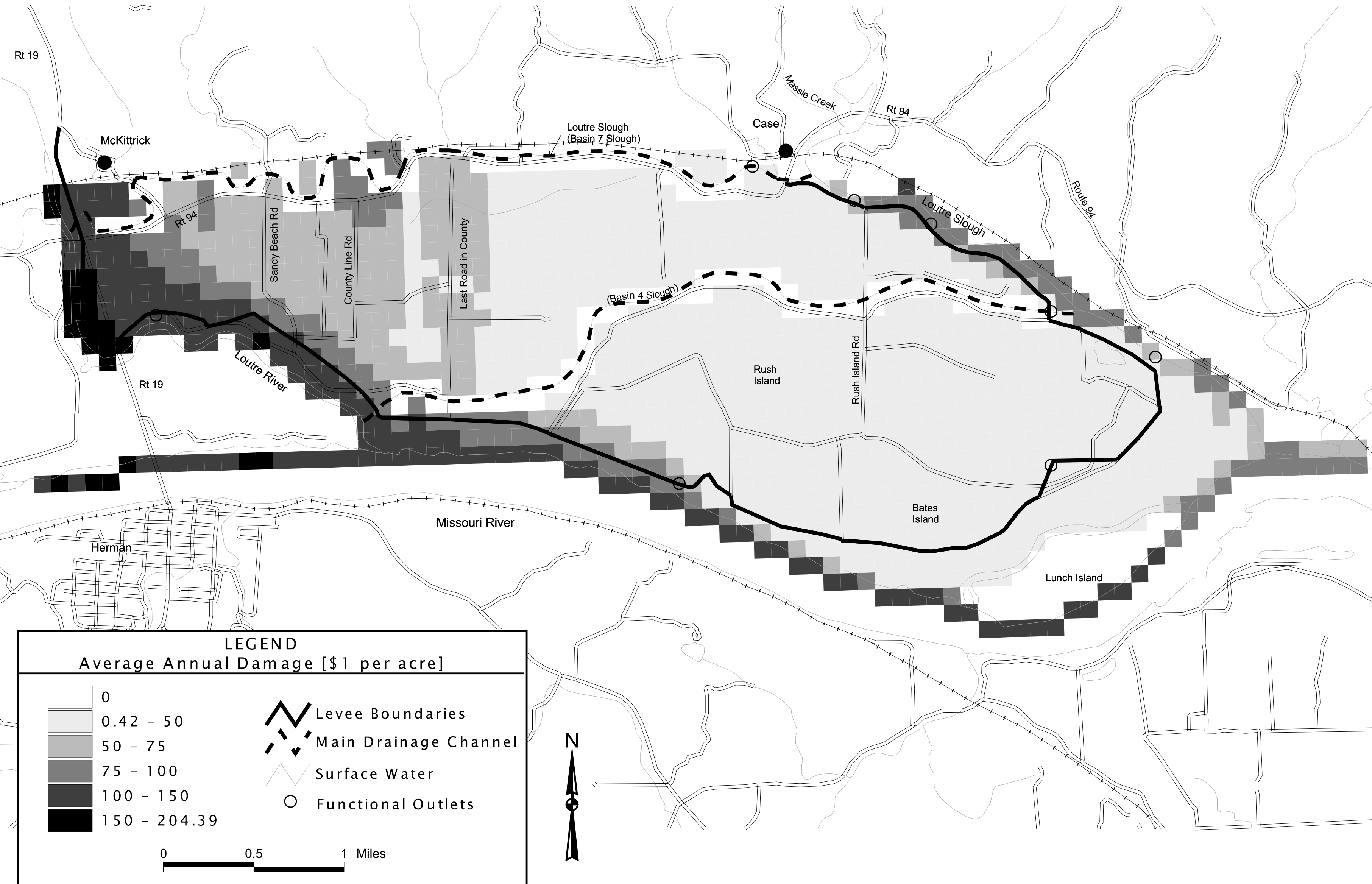

Figure 7.8-34. Average annual damages for CWCP at the Tri-County site.

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

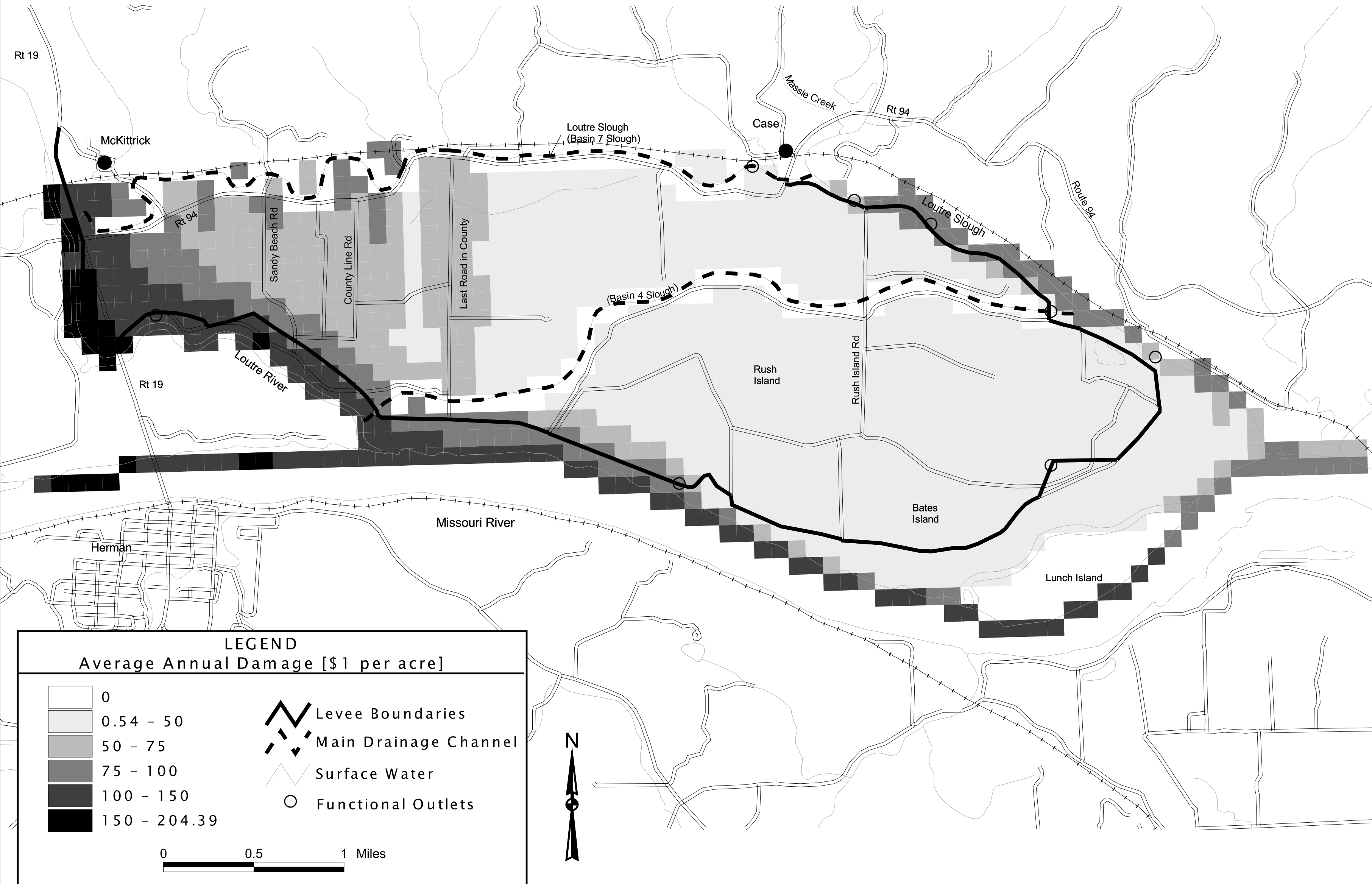

Figure 7.8-35. Average annual damages for MCP at the Tri-County site.

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

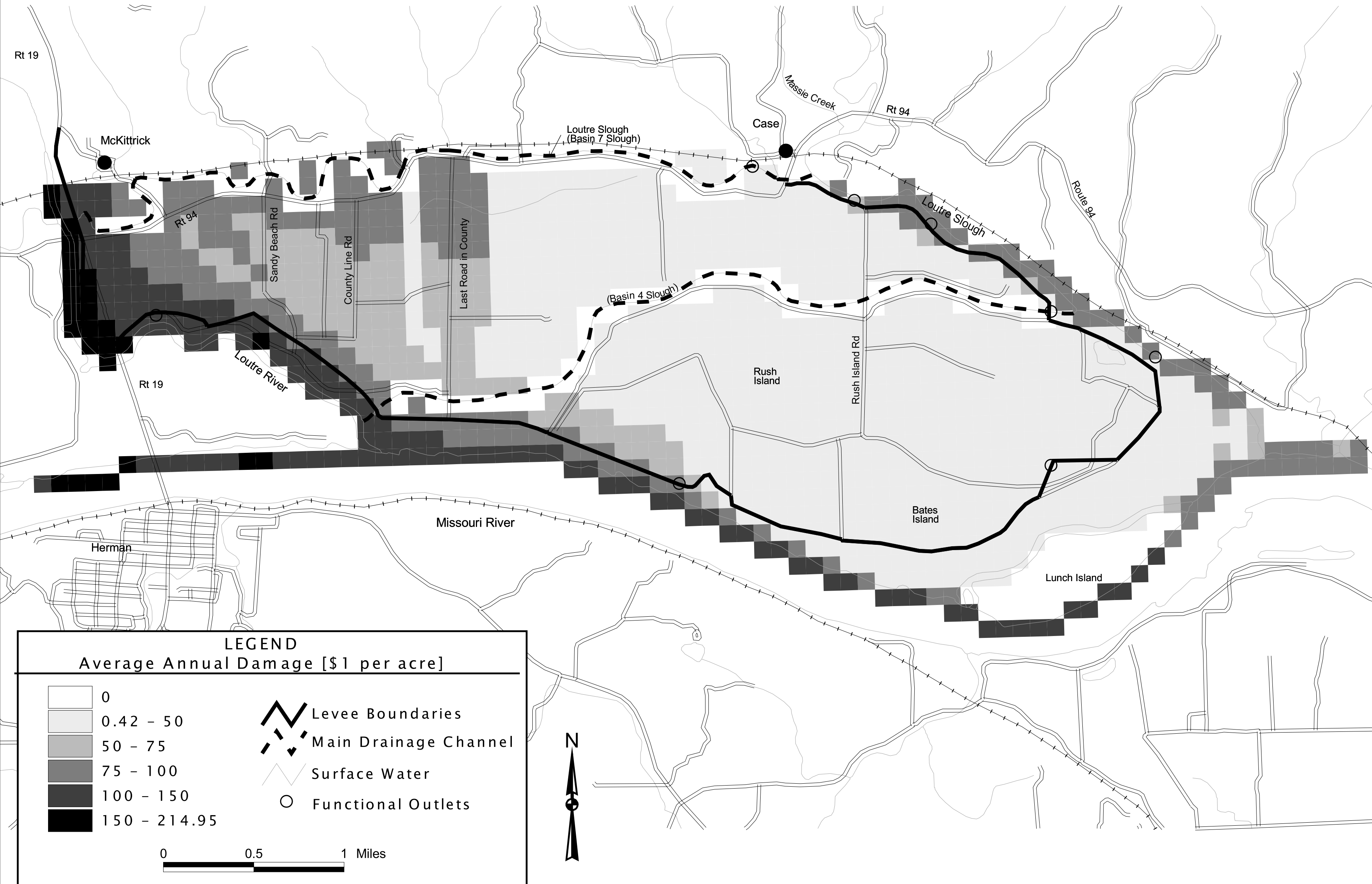

Figure 7.8-36. Average annual damages for GP1528 at the Tri-County site.

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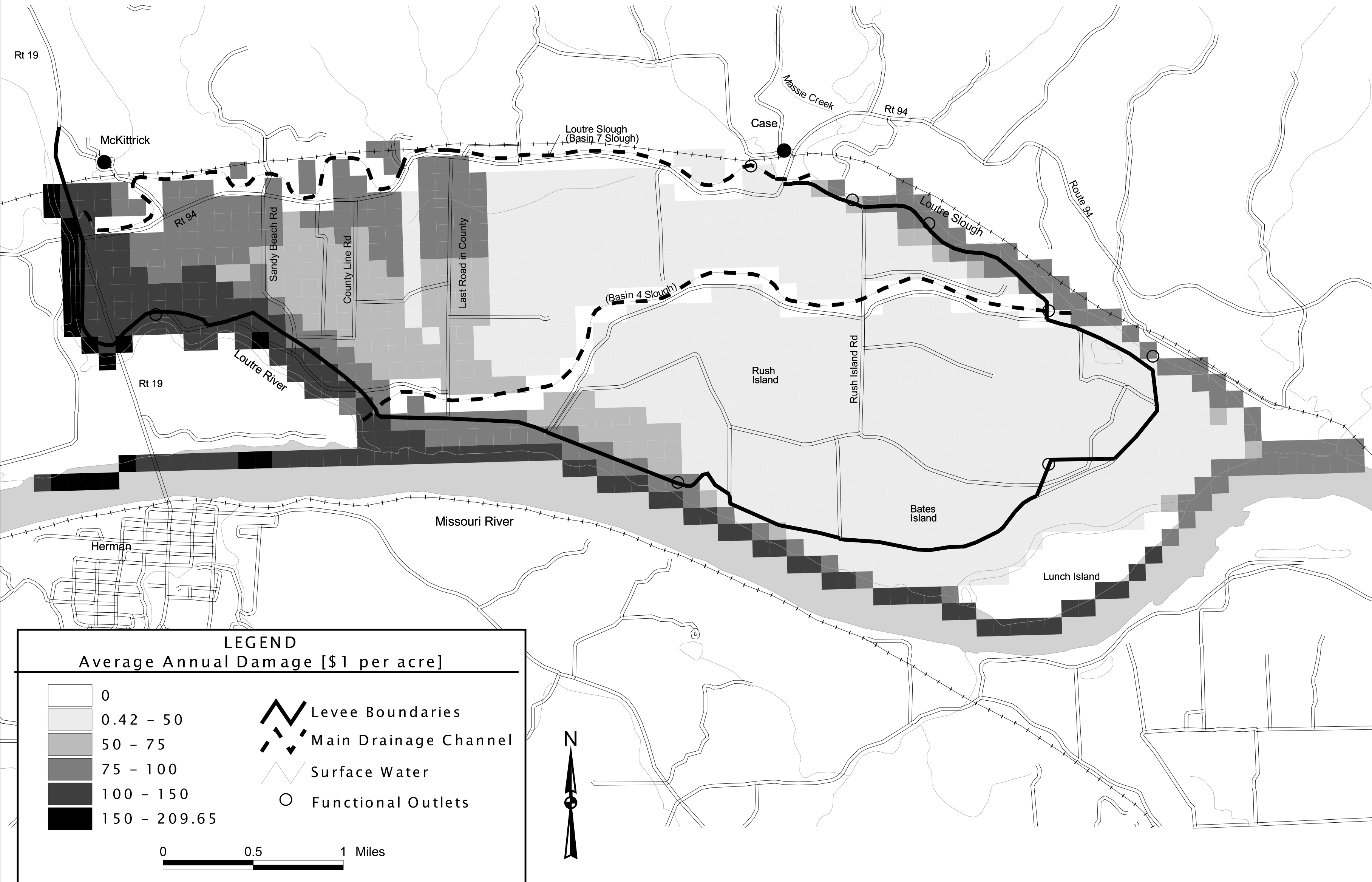

Figure 7.8-37. Average annual damages for GP2021 at the Tri-County site.

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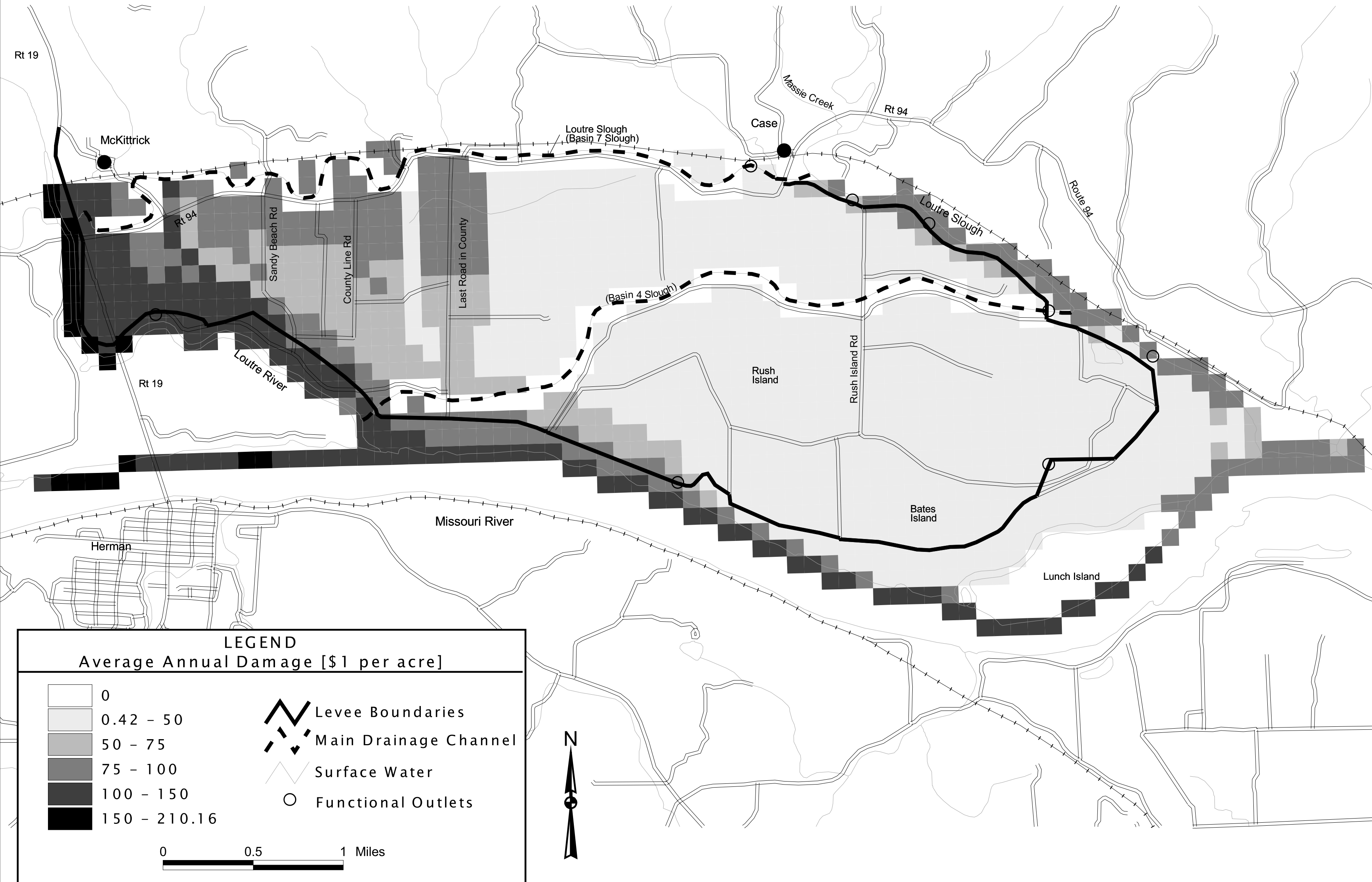

Figure 7.8-38. Average annual damages for GP1521 at the Tri-County site.

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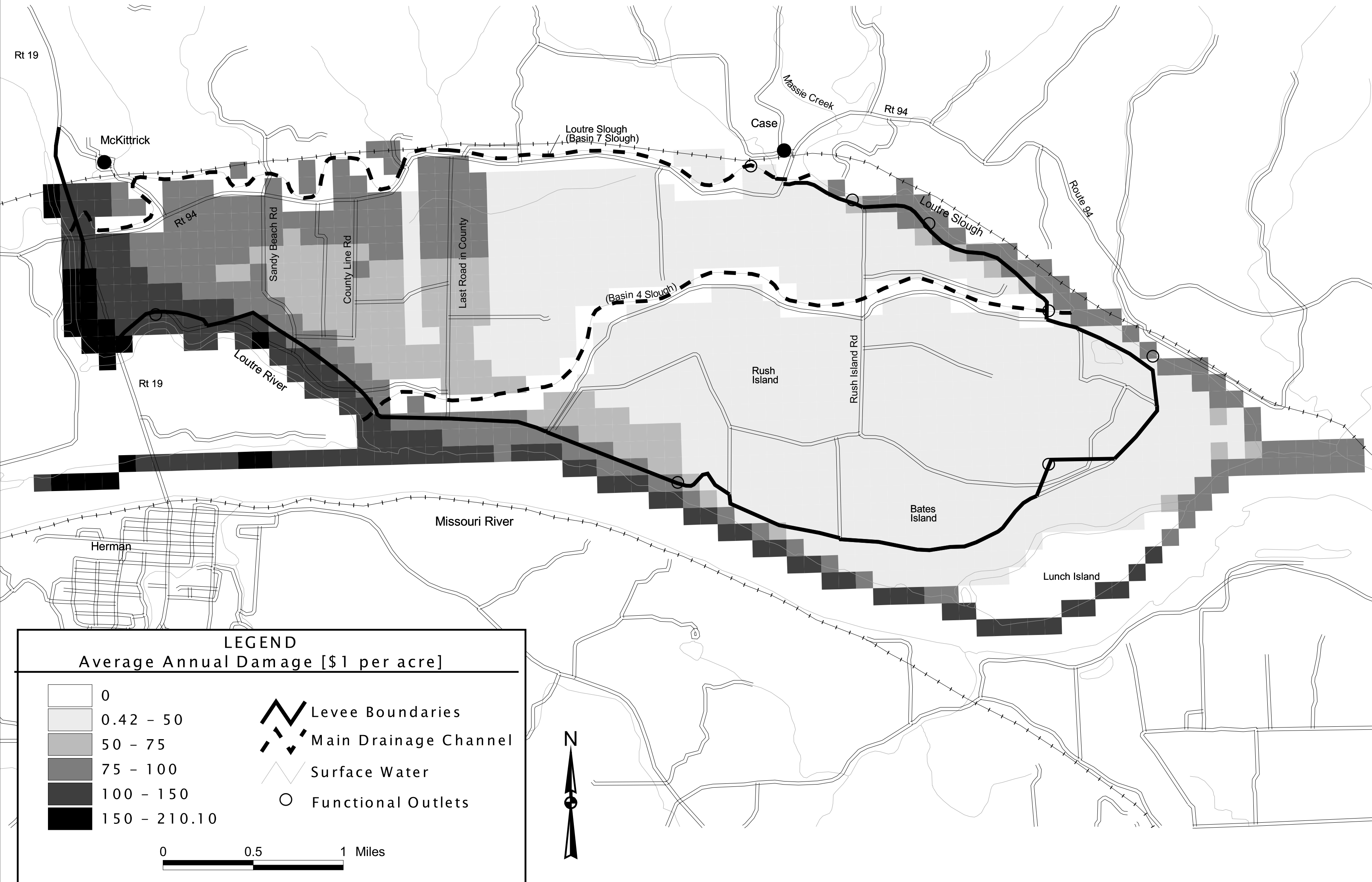

Figure 7.8-39. Average annual damages for GP2028 at the Tri-County site.

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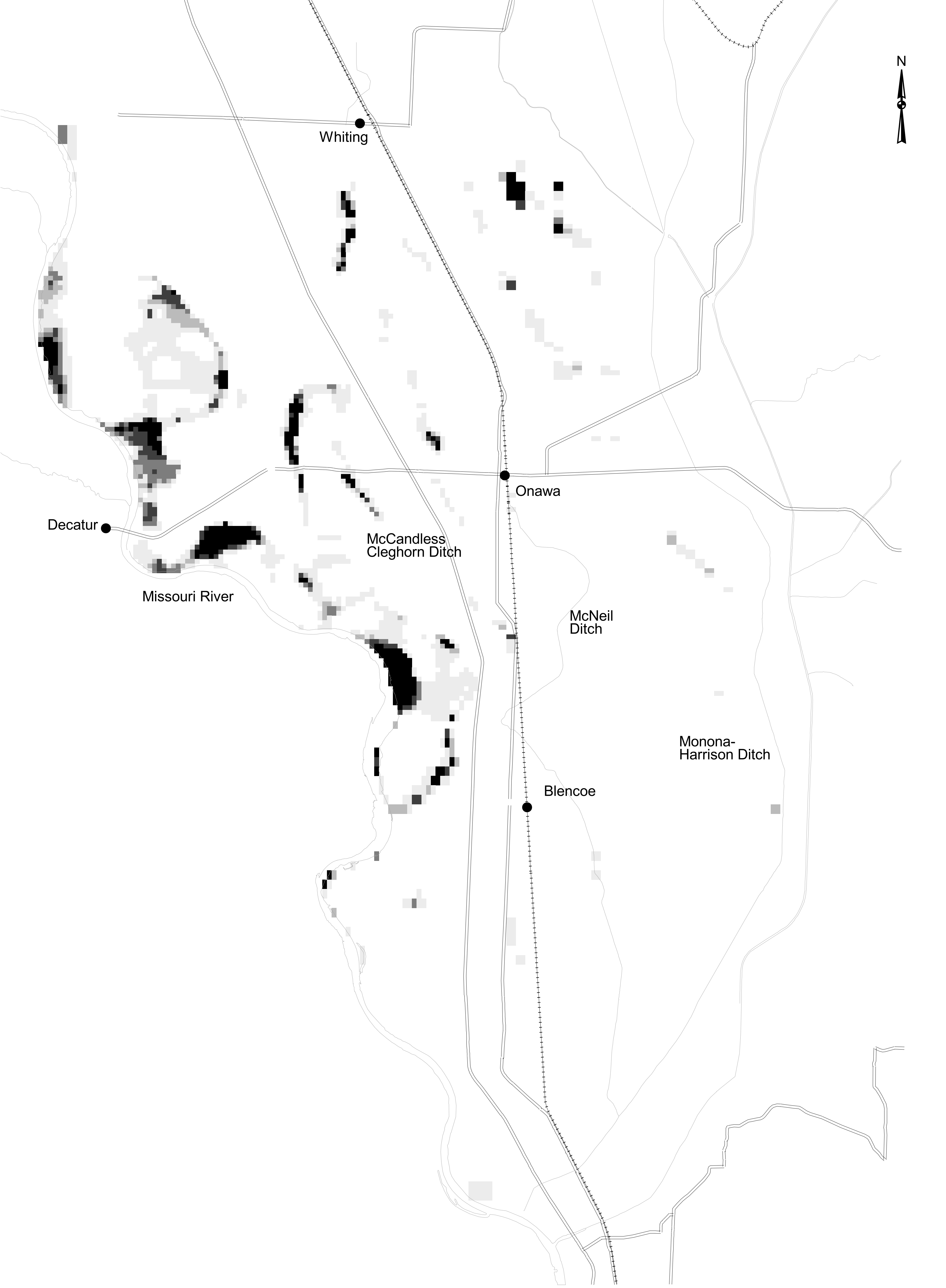

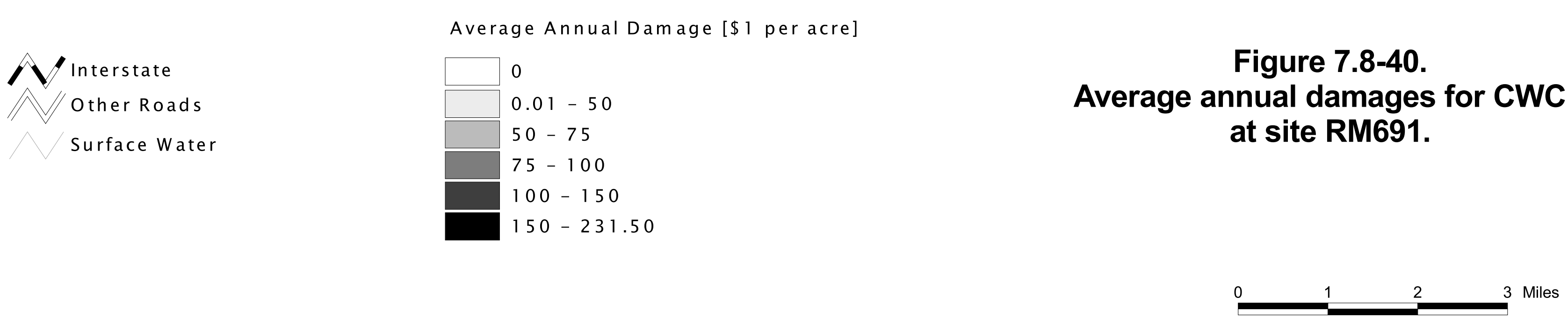

Figure 7.8-40.
Average annual damages for CWCP at site RM691.

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

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

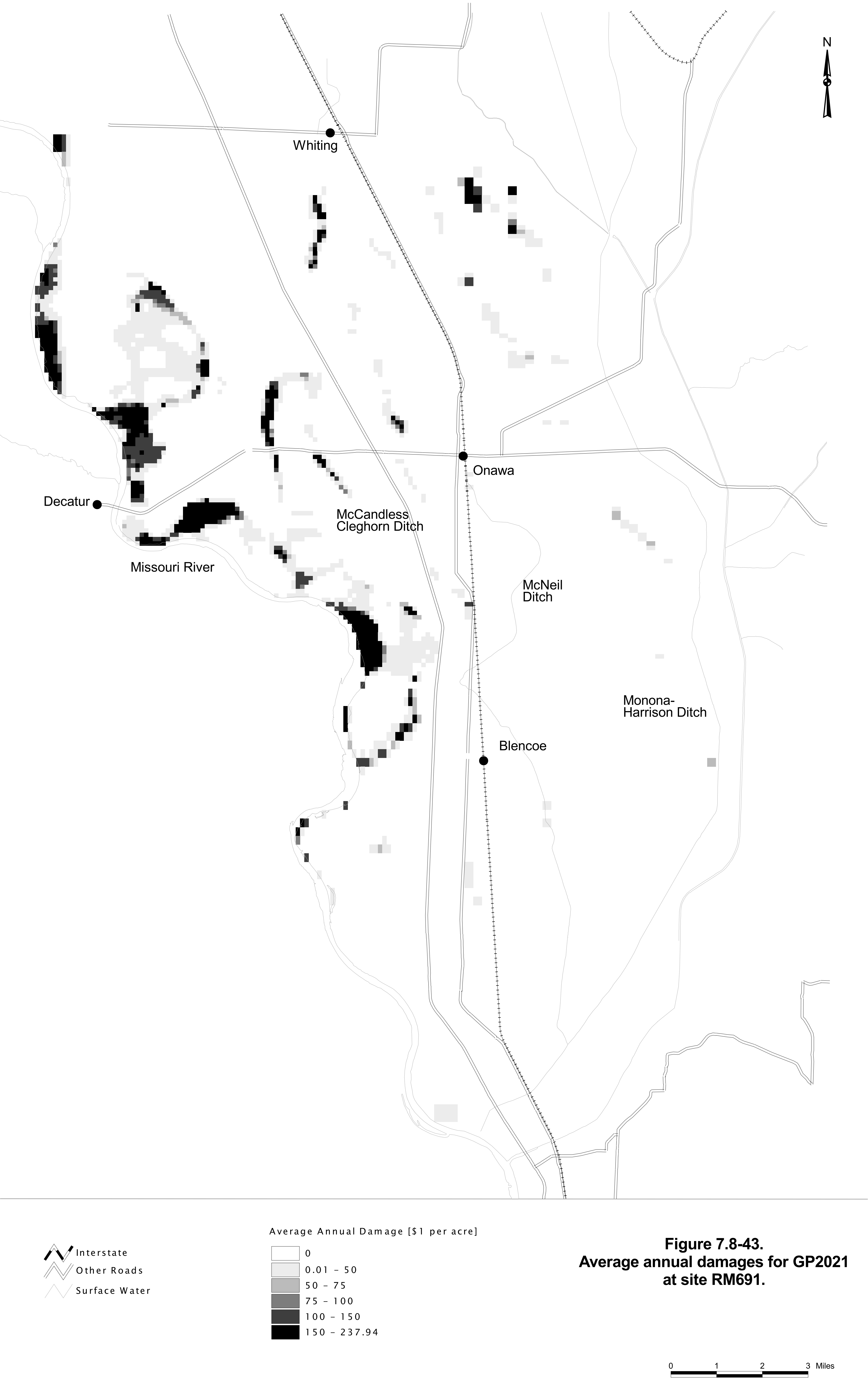

Figure 7.8-43.
Average annual damages for GP2021 at site RM691.

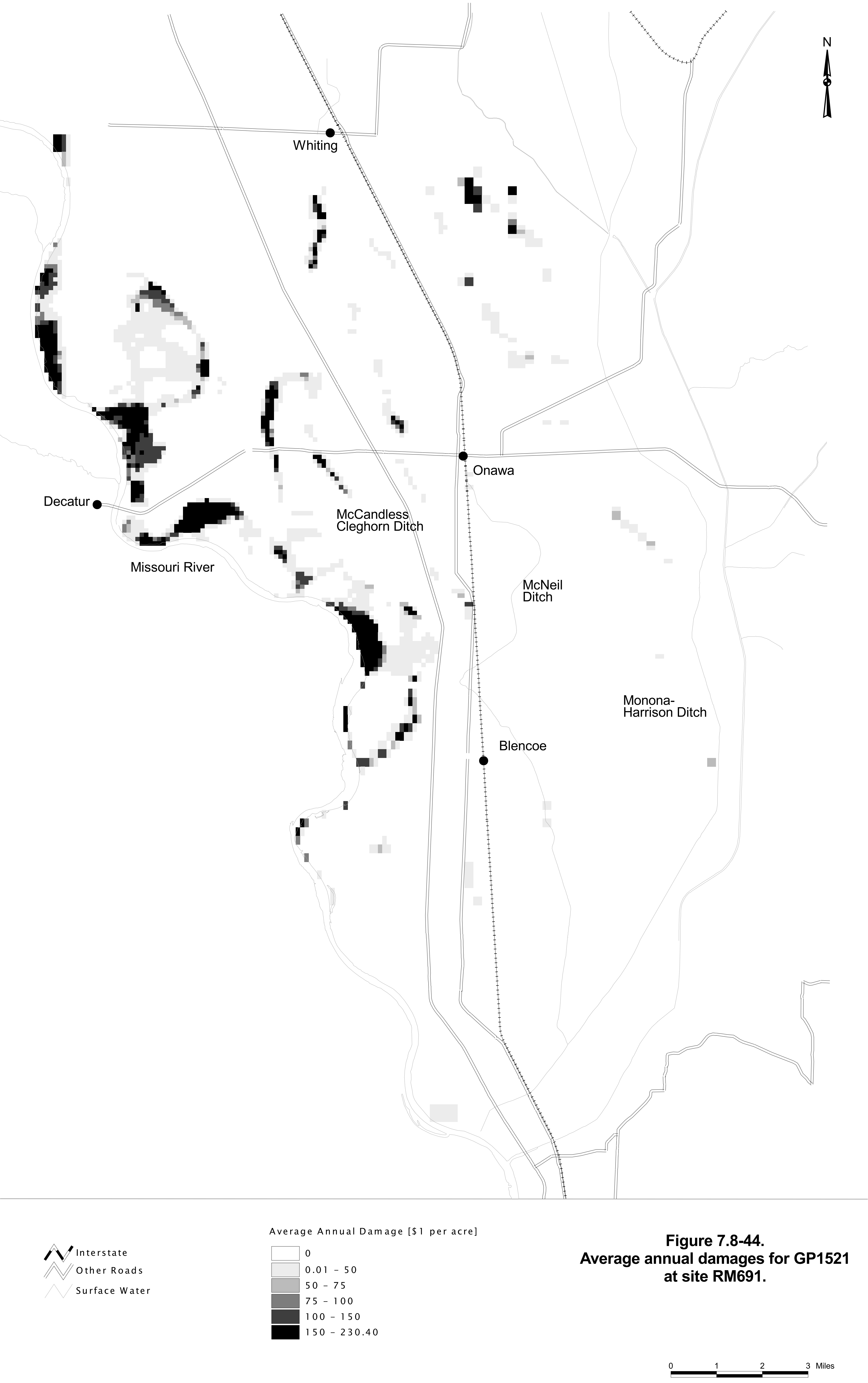

Figure 7.8-44.
Average annual damages for GP1521 at site RM691.

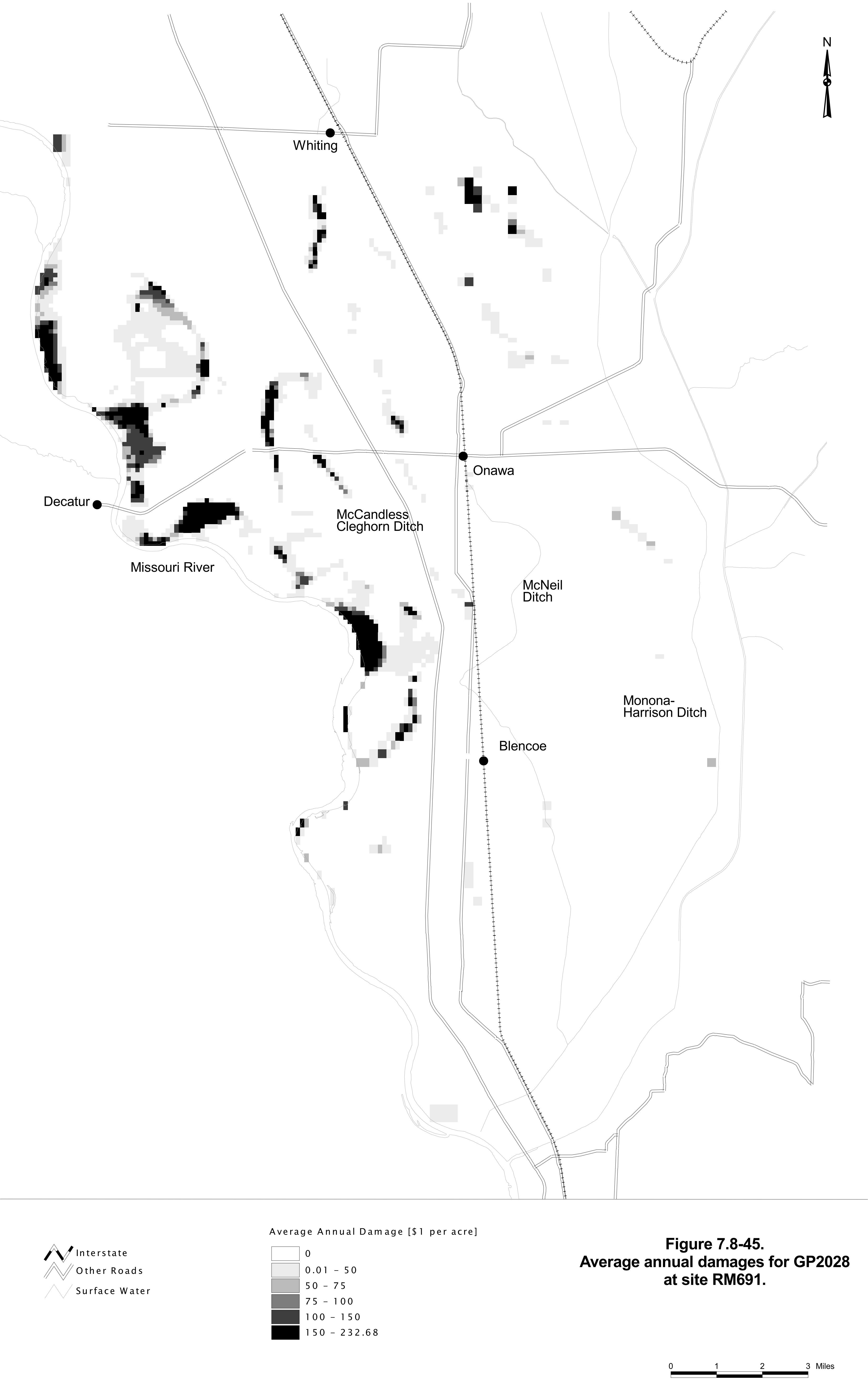

Figure 7.8-45.
Average annual damages for GP2028 at site RM691.