Estimated Stream Baseflow Depletion by Natural Resources District in the Nebraska Platte Basin due to Gained and Lost Groundwater Irrigated Land after July 1, 1997

by

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Preface

The effect of gained and lost irrigated land after 1997 on stream baseflow was previously estimated (Luckey and others, 2006). This study differed from the previous study in three ways. The previous study estimated effects for 40 years; this study estimated effects for 50 years. This study estimated the stream baseflow effects of gained and lost irrigated land in each Natural Resources District, whereas the previous study estimated effects of gained and lost irrigated land for entire model areas. This study also changed recharge as irrigated land was gained or lost by amounts that were estimated during model calibration. This last difference had a large effect on the results presented herein and has led some on the COHYST Technical Committee to question if the differences between recharge on dryland and irrigated land applied during calibration were correct.

Since the models were calibrated, several issues have surfaced related to model calibration. While the models were calibrated to 1950 stream baseflow conditions, they were not rigorously calibrated to change in baseflow after 1950. The calibrated models did not account for supplemental pumpage on surface-water irrigated lands. The western model used too much recharge in some surface-water irrigated areas. The models used long-term average recharge in surface-water irrigated areas. The models used the River Package for larger streams, including the North Platte, South Platte, and Platte Rivers. The COHYST Technical Committee has a range of opinions on how much each of these things may have affected model calibration; they are in agreement that the effects of these things on model calibration should be tested in the future. If model calibration changes in the future, this analysis should be redone.

This study used average meteorological conditions for the entire 50 years to estimate stream baseflow effects. Some participants in COHYST have become more interested in what would happen in dry years, and particularly during prolonged droughts. This study was not designed to answer that question.

The calibration period of 1950 to 1998 did not include an extreme drought, like the one that began in 1999. How such a drought would have affected model calibration has not been evaluated.

If average future meteorological conditions are substantially different from those used in this study, average future stream baseflow also would be different.

The stream baseflow effects presented in this study were those that were due to only gained and lost irrigated land after 1997. Other stream baseflow effects, such as those due to increased use of supplemental groundwater on surface-water irrigated land, were beyond the scope of the present study, but may be the subject of a future study.

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Stream baseflow depletion by wells: *Reduction in stream baseflow due to pumping wells. Stream baseflow depletion may be due to either direct depletion of the stream or interception of groundwater that is moving toward the stream. The latter is more common in Nebraska. Steam baseflow depletion can occur across stream basin boundaries. Stream baseflow depletion also can occur across groundwater divides.*

Stream baseflow: *Streamflow sustained by groundwater discharge. Stream baseflow excludes runoff from precipitation or snowmelt, runoff from irrigation, and waste from diversions. Stream baseflow is the sustained, fair-weather flow of a stream.*

Introduction

In June, 2007, the Cooperative Hydrology Study (COHYST) entered into an agreement with High Plains Hydrology, LLC, to estimate stream baseflow effects in the Platte River basin due to gained or lost groundwater irrigated land after July 1, 1997. The analysis was to include a 50-year period starting May 1, 1998. The analysis was to estimate stream baseflow effects due to changes in pumpage and recharge due to gained or lost irrigated land within the various Natural Resources Districts that participate in COHYST. The analysis was done for five segments of streams in the Platte basin: Wyoming line to Kingsley Dam, Kingsley Dam to Tri-County Supply Canal diversion, Tri-County Supply Canal diversion to Lexington, Lexington to U.S. Highway 183, and U.S. Highway 183 to Chapman (fig. 1 – figures follow at the end of the text).

This work is an extension of work done in 2006 for the Nebraska Department of Natural Resources (Luckey and others, 2006). The previous work covered a 40-year period; the current work covers a 50-year period. The previous work did not adjust simulated recharge as irrigated land was gained or lost; the current work adjusts recharge. The current work analyzes stream baseflow effects for groundwater pumping within the various Natural Resources Districts. As will be noted in subsequent sections, much of the data developed for the previous work was used directly in the current work.

The analysis was limited to streams in the Platte River system, including the North Platte and South Platte Rivers, and its baseflow tributaries. Baseflow tributaries are those which flow essentially year-round because of groundwater discharge to them. Lodgepole Creek and Pumpkin Creek were included in this analysis. However, both had lost most of their baseflow by 1998, so they could have little additional baseflow depletion. The analysis extended beyond the surface-water and groundwater divides of the Platte River system because changes in the groundwater system beyond the surface-water and groundwater divides can still affect surface water within the Platte River system.

The analysis was done in two parts. The first analysis considered gained and lost groundwater irrigated land in the entire COHYST area. The second analysis only considered gained and lost groundwater irrigated land in a smaller area closer to the Platte River, much of which has regulatory significance in Nebraska. The smaller area is described in the Changes in Land Use section.

The analysis was done using groundwater flow models as revised following COHYST Peer Review by Eagle Resources. The Peer Review was conducted from December 2004 through September 2005. After Peer Review, the COHYST Technical Committee evaluated the review and summarized the comments into 52 items, many of which suggested model revisions or enhancements. The Technical Committee grouped the 52 items into priorities and recommend to the COHYST Sponsors that the high priority items related to the models be completed before the models were used for analysis. All high priority items were completed on the models, as well as some lower priority items, before this analysis was done. The models are more fully described in the next section.

Groundwater Models

Groundwater flow models covering three overlapping areas were used in this analysis (fig. 2). The Western Model Unit covers the area upstream from Kingsley Dam in central Keith County and extends 6 miles into Wyoming. The western model was used to estimate effects for Wyoming line to Kingsley Dam. The Central Model Unit covers the area from eastern Garden County to central Dawson County. The central model was used to estimate effects for Kingsley Dam to Tri-County Supply Canal diversion and Tri-County Supply Canal diversion to Lexington. The Eastern Model Unit covers the area from western Dawson County to eastern Platte County. The eastern model was used to estimate effects for Lexington to U.S. Highway 183 and U.S. Highway 183 to Chapman. All three models had cell sizes of 160 acres. The western model had a single layer. The central model had up to six layers and the eastern model had up to five layers, although most areas of these models required fewer layers.

The Western Model Unit was documented by Luckey and Cannia (2006). Subsequent to the published documentation, an error was found in a pumpage data set and the model was recalibrated by increasing recharge on irrigated land by 0.10 inches per year (in/yr) (Luckey and others, 2007, p. 5). The last change to the calibrated western model was made on October 23, 2006. The documentation for the Central Model Unit is still being prepared. The central model was obtained from the archival DVD for previous new depletions work (Luckey and others, 2006). Clint Carney (Nebraska Public Power District, electronic communication, June 15, 2007) said the last change to calibrated central model was made in the spring of 2006. During this analysis, a few errors in the stream linkage in the Central Model Unit were found. The stream linkages were fixed; the 1950-98 model was rerun to get the starting water levels for this analysis; and the updated stream linkages were used in this analysis. This fix had only a minor effect and only on the reaches from Kingsley Dam to Lexington. The documentation for the Eastern Model Unit is nearing completion. The eastern model was obtained from Steve Peterson (U.S. Geological Survey, electronic communication, September 7, 2007). The last change to the calibrated eastern model was made February 15, 2007.

Simulated water levels on May 1, 1998, were the starting water levels in the models used in this analysis. The models simulated two stress periods per year, an irrigation season (May through September) and a non-irrigation season (October through April). Although the latter period is called the non-irrigation season, some irrigation on small grains and alfalfa was simulated during this period (less than 5 percent of the annual total). Pumpage and recharge were held constant within a stress period but were varied between stress periods. Pumpage also was varied on a year-by-year basis through the year beginning May 1, 2005; after 2005, annual pumpage was held constant at 2005 levels. Simulation time steps were essentially monthly with the irrigation season simulated in 5 time steps and the non-irrigation season simulated in 7 time steps. The models simulated 50 years, from May 1, 1998, to May 1, 2048. As will be discussed in the Net Irrigation Requirements section, 1997 meteorological data were used for all 50 years of the simulation. Overall, 1997 was slightly dryer than the 1895-1998 average (-0.47 inches) with the range of 1997 deviation from average being +0.76 inches for Climate Division 1 to -1.98 inches for Climate Division 6 (fig. 3).

Changes in Irrigated Land

Changes in groundwater irrigated land after 1997 were estimated as part of a previous study (Luckey and others, 2006). Those data were used directly in this study without change. The description on how those estimates were made is repeated here for the convenience of the reader.

Changes in groundwater irrigated land were estimated using the 1997 land-use map (Dappen and Tooze, 2001), the 2001 land-use map (Dappen and Merchant, 2003), and the 2005 land-use map (Dappen and others, 2006). These three reports on land use were developed using Landsat remote sensing imagery, Farm Service Administration field data, and ground truth data collected by the Natural Resources Districts. The 1997, 2001, and 2005 land-use maps contained polygons showing irrigated lands. For 1997 and 2001, the polygons were registered to each other based on the centroids of the polygons. This registration resulted in small shifts, principally on center pivots. The 1997 polygons were then subtracted from the 2001 polygons in a geographical sense to produce polygons that indicated an increase in irrigated land between 1997 and 2001 (gained irrigated land). In a similar manner, the 2001 polygons were subtracted from the 1997 polygons to produce polygons that indicated a decrease in irrigated land between 1997 and 2001 (lost irrigated land). Polygons with areas less than 1 acre were removed because they were unlikely to represent real gains or losses in irrigated lands. Polygons whose centroids fell within a surface-water irrigation district were deleted because these were assumed to be irrigated with surface water and only temporarily gained or lost irrigated land. Because these surface-water polygons were deleted, gained or lost irrigated land really means gained or lost ***groundwater irrigated land*** throughout this report.

Some of the remaining polygons consisted of two concentric circles or parts of circles with a thin strip between them indicating either an increase or a decrease in irrigated land. These concentric circle polygons were due to imperfect field boundaries and are called *edge effects* here. The area of each 1997 to 2001 gained or lost irrigated land polygon was divided by its perimeter. For a 120 acre circle, the ratio of area divided by perimeter is 645. For an 80 acre rectangle that is 1,320 feet by 2,640 feet, the ratio of area divided by perimeter is 440. Edge effect polygons have much smaller ratios. Analysis indicated that deleting those 1997 to 2001 gained or lost irrigated land polygons with ratios of less than 100 removed most of the edge effect fields without removing real fields. The remaining polygons were deemed a map of estimated gained or lost irrigated land after July 1, 1997, and before June 30, 2001 (fig. 4).

A similar process was used for 2001 to 2005, although these maps generally used the same field boundaries so edge effects were less pronounced for 2001 to 2005. As with 1997 to 2001, polygons with areas less than 1 acre were discarded as were polygons with area to perimeter ratios of less than 100. The remaining polygons were deemed a map of estimated gained or lost irrigated land after July 1, 2001, and before June 30, 2005 (fig. 4). Table 1 (tables are at the end of the report) summarizes the gained and lost irrigated land by county for 1997 to 2001 and 2001 to 2005. The table also lists 1997 to 2005 net gained irrigated land. For 1997 to 2001, there was a net gain of approximately 204,000 irrigated acres. For 2001 to 2005, there was a net gain of approximately 304,000 irrigated acres. For 1997 to 2005, there was a net gain of approximately 508,000 irrigated acres. Table 2 summarizes the gained and lost irrigated land by Natural Resources District.

Table 3 summarizes the gained and lost irrigated land by county in an area closer to the Platte River. This area is made up of two parts, the Hydrologically Connected Area for the Overappropriated Basin (HCA/OA) and the Eastern Analysis Area (EAA) (fig. 4). The HCA/OA is an administrative area determined by the Nebraska Department of Natural Resources and has consequences under Nebraska water administration. The EAA has no legal standing in Nebraska law and is used only to aid in understanding potential sources of stream depletion. The HCA/OA starts at the Wyoming state line and ends at U.S. Highway 183. The EAA is an area bounded by the 10 percent stream depletion in 50 years lines between U.S. Highway 183 and Chapman. This area was determined by several agencies, including the Nebraska Department of Natural Resources, Central Platte Natural Resources District, and Upper Big Blue Natural Resources District. The 10 percent in 50 years lines do not exactly meet the HCA/OA, so a north-south line was used to connect them. Table 4 summarizes the gained and lost irrigated land only in the HCA/OA and EAA by Natural Resources District

Land use maps were available for 1997, 2001, and 2005. Between those years, the registered well database from the Nebraska Department of Natural Resources was used to scale the gained or lost groundwater irrigated land. All irrigation wells not specifically indicated as replacement wells with a completion date on or after July 1, 1997, were selected and the cumulative number of new irrigation wells was calculated for each model unit. Some of these wells were used on new irrigated land and some were used on existing irrigated land. The database does not include information to distinguish between new and existing irrigated land. The number of new registered wells was summed for July 1 through June 30 of the following year. For example, for the Western Model Unit, 59 new wells were registered from July 1, 1997, through June 30, 1998. This represented approximately 26 percent of the new registered wells for the model unit through June 30, 2001. Therefore, the gained or lost groundwater irrigated land for the model period that started May 1, 1998, was assumed to be approximately 26 percent of the gained or lost irrigated land for 2001. Similarly, for July 1, 1998, through June 30, 1999, an additional 49 new wells were added, so the cumulative effect was approximately 48 percent of the gained or lost irrigated land for 2001. A similar process was used for subsequent years.

The 2001 gained irrigated land is shown in brown on figure 4 and the 2001 lost irrigated land is shown in orange. This land was retained as gained or lost to irrigation to May 1, 2048, unless the 2005 irrigated land maps indicated otherwise. The process of estimating gained or lost irrigated land began anew with the differences between the 2001 and 2005 land use maps. The 2005 gained irrigated land is shown in cyan on figure 4 and the lost irrigated land is shown in red. This land was retained as gained or lost to irrigation to May 1, 2048. The 2002, 2003, and 2004 gained or lost irrigated land was interpolated between 2001 and 2005 using the registered well database as described above.

Gained or lost irrigated land was held constant beginning May 1, 2006, so the analysis does not project gained or lost irrigated land after that date. The assumption of no new net irrigated land after that date is reasonable because most of the area has been designated as Fully Appropriated or Overappropriated, which prohibits expansion of irrigated land.

Scaling gained or lost irrigated land between land-use map dates means that irrigated land gained or lost for other years was assumed to be near gained or lost irrigated land between land use map dates. This assumption seems reasonable and information to do otherwise was not available.

Net Irrigation Requirements

The net irrigation requirements were estimated in a previous study (Luckey and others, 2006). Those data were used directly in this study without change. A summary of how those estimates were made is repeated here for the convenience of the reader.

The average net irrigation requirements for the years beginning May 1 of 1997, 2001, and 2005 were estimated using CropSim with 1997 meteorological data. CropSim is an unpublished soil-water-balance model developed by Dr. Derrel Martin, University of Nebraska – Lincoln. The 1997-98 CropSim net irrigation requirement for each crop, reduced by 10 percent, was combined with the 1997 land-use map for each model unit to compute the area weighted average 1997 net irrigation requirement for each model unit for the year beginning May 1, 1997. The 10 percent reduction accounted for less-than-ideal crops in the real world, because real-world crops are less healthy, do not always receive all the nutrients and water they need, are stressed by insects and other pests, and thus consume less water than is predicted by CropSim. Table 5 shows the 1997, 2001, and 2005 net irrigation requirements for the year beginning May 1 for each model unit. Because the net irrigation requirements represent an area weighted average of all crops and because corn is the dominant crop in all areas, the net irrigation requirement for corn dominates the average.

The differences in net irrigation requirements shown in table 5 were solely a function of differences in crop mix because 1997 meteorological conditions were used in all calculations. For example, soybeans became a larger part of the crop mix between 1997 and 2001 and corn became a smaller part (although still dominant). Because soybeans use less water than corn, the 2001 net irrigation requirements were smaller than the 1997 net irrigation requirements. The net irrigation requirements for 1998 through 2000 were linear interpolations of the net irrigation requirement for 1997 and 2001 and the net irrigation requirements for 2002 through 2004 were linear interpolations of the 2001 and 2005 net irrigation requirements. The 2005 net irrigation requirements were used after 2005.

Changes in Net Pumpage

Changes in net pumpage were estimated in a previous study (Luckey and others, 2006). Those data were used directly in this study without change. A summary of how those estimates were made is repeated here for the convenience of the reader.

Gained or lost groundwater irrigated land (fig. 4) was multiplied by net irrigation requirements (table 5) for each year to get net pumpage due to increased or decreased groundwater irrigated land for that year. Most of this net pumpage occurred during the May through September period, although some net pumpage occurred on alfalfa and small grains during the October through April period. By the sign convention used in the groundwater flow models, net pumpage due to increased irrigated land was negative and net pumpage due to decreased irrigated land was positive. Table 6 shows the sum of net pumpage due to increased and decreased irrigated land for the years beginning May 1 of 2001 and 2005 for each model unit using the opposite sign convention.

Changes in Recharge

The calibrated COHYST models have different rates of recharge for rangeland, dryland, and irrigated land. Dryland has more recharge than rangeland because, when dryland is fallow, it is cultivated to capture and maintain soil moisture. As a result, soil moisture on dryland regularly exceeds that of rangeland. Therefore, when precipitation falls on dryland, it has a better chance to become recharge than precipitation that falls on rangeland. Likewise, soil moisture on irrigated land is maintained by irrigation and precipitation that falls on irrigated land has a better chance to become recharge than precipitation that falls on rangeland. Note that the extra recharge on irrigated land is not deep percolation of applied water. Deep percolation of applied water is accounted for by using net pumpage in the models.

The recharge rates for rangeland, dryland, and irrigated land were determined during model calibration. The rates were different for different areas, depending on location, topography, and soils. The recharge rates for irrigated land were always greater than the recharge rates for dryland. For the Western model Unit, the increased recharge on dryland ranged from 0.25 in/yr to 1.05 in/yr and the difference between dryland recharge and irrigated land recharge ranged from 2.95 in/yr to 3.65 in/yr. For the Central model Unit, the increased recharge on dryland ranged from 0.25 in/yr to 0.40 in/yr and the difference between dryland recharge and irrigated land recharge ranged from 4.7 in/yr to 6.4 in/yr. For the Eastern model Unit, the increased recharge on dryland ranged from 0.8 in/yr to 1.0 in/yr and the difference between dryland recharge and irrigated land recharge ranged from 5.0 in/yr to 5.9 in/yr. The recharge rates for the calibrated models were accepted for this analysis, but are discussed in the Limitations and Comments section.

As irrigated land was gained, it was assumed to have been converted from dryland, and recharge was increased accordingly. As irrigated land was lost, it was assumed to have been converted to dryland, and recharge was decreased accordingly. Unlike the previous data sets, data sets for changes in recharge were created as part of this analysis. The polygons described in the Changes in Irrigated Land section were used to compute changes in recharge. Where groundwater irrigated land was gained, recharge was increased by the appropriate amount. Where groundwater irrigated land was lost, recharge was decreased by the appropriate amount. The appropriate amount was the area of the polygon times the difference in dryland and irrigated land recharge for the area where the polygon occurred, all converted to model units of feet per day.

Modeling Procedures

The models were first run for 50 years using 1997 land-use conditions to establish a baseline condition. These baseline models did not have any changes in net pumpage or recharge from 1997 conditions. These models produced cumulative water budgets for each month of each year. The models were then run for 50 years with the changes due to gained and lost groundwater irrigated land after 1997. The gained and lost irrigated land caused changes in net pumpage and recharge after 1997. These models also produced cumulative water budgets for each month. The differences between the two water budgets on any given date are the stream baseflow effects of the gained and lost irrigated land on the hydrologic system. The models also were run with changes in pumpage and recharge due to gained and lost irrigated land in only one Natural Resources District at a time to get the stream baseflow effects of gained and lost irrigated land only in that Natural Resources District.

The models were also run with changes in net pumpage and associated changes in recharge only in an area closer to the Platte River. This area is made up of two parts, the HCA/OA and the EAA (fig. 4). The purpose of this part of the analysis was to provide technical information regarding the impacts on streamflow from changes in uses of groundwater from these areas and should not be interpreted as a policy of the COHYST Sponsors. The models also were run with changes in net pumpage and associated changes in recharge in only the HCA/OA and EAA of one Natural Resources District at a time. This was to get the get the stream baseflow effect of gained and lost irrigated land in that part of the Natural Resources District.

This analysis was done with a specialized version of the program ZoneBudget (Harbaugh, 1990), which computes water budgets for various subregions within the models. This version retains all the original functionality of ZoneBudget, increases the precision of the output, and adds a cumulative volumetric water budget to the output. The volumetric budget is what was used in this analysis.

This analysis stored the output from ZoneBudget in a Microsoft Access databases using a program written for this purpose (Rich Kern, Nebraska Department of Natural Resources, electronic communication, December 5, 2006). Data were then retrieved from the databases and placed in spreadsheets to summarize and graph the results. The databases and spreadsheets from this analysis have been archived with the Nebraska Department of Natural Resources.

Results

The results of the analysis are first presented for gained and lost irrigated land everywhere in the COHYST area (everywhere analysis). The results are shown for each of the five reaches in graphical form for 50 years and in tabular form for a few selected dates. The results are then presented for gained and lost irrigated land throughout one Natural Resources District at a time for those reaches where the effect is not minimal. Only the Districts that participate in COHYST are shown in the results, so not all Districts in the area are shown in this analysis. The sum of the individual Natural Resources District's analyses (including those not shown) was compared to the everywhere analysis, and the sum generally equaled the everywhere analysis within less than 0.1 cubic feet per second (ft^3/s), and frequently within less than 0.01 ft^3/s. The largest differences, up to about 0.2 ft^3/s, occurred for a few time steps in the Central Model Unit.

The results of the analysis are then presented for gained and lost irrigated land only in the HCA/OA and EAA. The results are shown for each of the five reaches. The results are then presented for gained and lost irrigated land throughout one Natural Resources District at a time for those Districts that participate in COHYST for those reaches where the effect is not minimal.

Results for Entire COHYST Area

Figure 5 is graphs of stream baseflow depletion due to gained and lost irrigated land everywhere after July 1, 1997, for each area. Table 7 shows stream baseflow depletion and cumulative depletion for various dates.

For Wyoming line to Kingsley Dam, stream baseflow depletion due to gained or lost irrigated land after July 1, 1997, rose very rapidly during the first decade of the analysis and averaged 9.3 ft^3/s for the year beginning May 1, 2007. Over the next decade, stream depletion rose only an additional 1.4 ft^3/s. Stream depletion rose more slowly after the second decade, rising 0.3 ft^3/s for the third decade, 0.2 ft^3/s each for the fourth decade, and 0.3 ft^3/s for the last decade. The fall-to-spring change in stream depletion was about 4.1 ft^3/s after the first decade of the analysis. Cumulative stream baseflow depletion due to gained or lost irrigated land through May 1, 2048, was 349,000 acre-feet.

For Kingsley Dam to Tri-County Supply Canal diversion, stream baseflow depletion due to gained or lost irrigated land after July 1, 1997, rose fairly rapidly during the first decade of the analysis and averaged 5.8 ft^3/s for the year beginning May 1, 2007. Over the next decade, stream depletion rose an additional 1.5 ft^3/s. Stream depletion rose more slowly after the second decade, rising 0.7 ft^3/s for the third decade, 0.5 ft^3/s for the fourth decade, and 0.4 ft^3/s for the last decade. The fall-to-spring change in stream depletion was about 9.2 ft^3/s after the first decade of the analysis. Cumulative stream baseflow depletion due to gained or lost irrigated land through May 1, 2048, was 254,000 acre-feet.

For Tri-County Supply Canal diversion to Lexington, stream baseflow depletion due to gained or lost irrigated land after July 1, 1997, had a fairly complex pattern, being positive at the end of the irrigation season and negative at the end of the non-irrigation season. There was a slight upward trend in stream depletion over time. Stream depletion averaged 2.4 ft^3/s for the year beginning May 1, 2007. Over the next decade, stream depletion rose an additional 0.9 ft^3/s. Stream depletion rose more slowly after the second decade, rising 0.3 ft^3/s for the third decade, and 0.5 ft^3/s for the fourth decade, and 0.3 ft^3/s for the fifth decade. The fall-to-spring change in stream depletion was about 10.4 ft^3/s after the first decade of the analysis. Cumulative stream baseflow depletion due to gained or lost irrigated land through May 1, 2048, was 118,000 acre-feet.

The reach Lexington to U.S. Highway 183 is fairly short, but includes two long tributaries, Spring Creek from the north and Plum Creek from the south. Stream baseflow depletion due to gained or lost irrigated land after July 1, 1997, in this reach showed a steady rise over the 50 years of the analysis, although the rate of rise decreased over time. Stream depletion averaged 2.1 ft^3/s for the year beginning May 1, 2007. Over the next decade, stream depletion rose an additional 1.1 ft^3/s. Stream depletion continued to rise after the second decade, rising 0.6 ft^3/s for the third decade, 0.4 ft^3/s for the fourth decade, and 0.3 ft^3/s for the fifth decade. The fall-to-spring change in stream depletion was about 0.3 ft^3/s after the first decade of the analysis. Cumulative stream baseflow depletion due to gained or lost irrigated land through May 1, 2048, was 115,000 acre-feet.

For U.S. Highway 183 to Chapman, stream baseflow depletion showed a steady rise for the period of analysis, although the rate of rise decreased over time. Stream depletion averaged 2.5 ft^3/s for the year beginning May 1, 2007. Over the next decade, stream depletion rose an additional 1.5 ft^3/s. Stream depletion continued to rise after the second decade, rising 1.1 ft^3/s for the third decade, 0.8 ft^3/s for the fourth decade, and 0.6 ft^3/s for the fifth decade. The fall-to-spring change in stream depletion also continued to increase over the 50 years of the analysis, and the spring stream depletion was larger than the fall depletion. The amplitude increased from 0.5 ft^3/s after the first decade of the analysis to 1.1 ft^3/s for the last decade of the analysis. Cumulative stream baseflow depletion due to gained or lost irrigated land through May 1, 2048, was 154,000 acre-feet.

Results by Natural Resources District

This section reports stream baseflow depletion due to gained or lost irrigated land after July 1, 1997, by Natural Resources District (NRD) by reach (table 8). If a NRD had minimal effect on a reach, defined as the NRD causing less than 1 percent of total stream baseflow depletion for the reach, results for that NRD are not reported in the text. Results are reported as averages for 5-year periods. For this analysis, each year was assumed to be 365¼ days, so that leap years did not affect the calculated volumes per year.

North Platte Natural Resources District

Gained and lost irrigated land in the North Platte NRD primarily affected the reach Wyoming line to Kingsley Dam (table 8). The average effect for this reach for the period of analysis was 6,800 acre-feet per year (AF/yr) and ranged from 1,000 AF/yr for the first five years to 8,000 AF/yr for the last 5 years. North Platte NRD accounted for 97 percent of the new stream baseflow depletion for Wyoming line to Kingsley Dam.

Gained and lost irrigated land in the North Platte NRD affected stream baseflow in other reaches by less than 1 percent of the total effect.

South Platte Natural Resources District

Gained and lost irrigated land in the South Platte NRD primarily affected the reach Kingsley Dam to Tri-County Supply Canal diversion (table 8). This is because the South Platte River and Lodgepole Creek are included in this reach. The average effect for this reach for the period of analysis was 300 AF/yr and ranged from 100 AF/yr for the first five years to 500 AF/yr for the last 5 years. South Platte NRD accounted for 5 percent of the new stream baseflow depletion for Kingsley Dam to Tri-County Supply Canal diversion.

Gained and lost irrigated land in the South Platte NRD affected stream baseflow in other reaches by less than 1 percent of the total effect.

Twin Platte Natural Resources District

Gained and lost irrigated land in the Twin Platte NRD primarily affected the reaches from Kingsley Dam to Lexington (table 8). The average effect for the reach Kingsley Dam to Tri-County Supply Canal diversion for the period of analysis was 4,900 AF/yr and ranged from 1,500 AF/yr for the first five years to 6,000 AF/yr for the last 5 years. Twin Platte NRD accounted for 97 percent of the new stream baseflow depletion for Kingsley Dam to Tri-County Supply Canal diversion.

For Tri-County Supply Canal diversion to Lexington, the average effect was 1,200 AF/yr and ranged from 500 AF/yr for the first 5 years to 1,500 AF/yr for the last 5 years. Twin Platte NRD accounted for 54 percent of the new stream baseflow depletions for Tri-County Supply Canal diversion to Lexington.

Twin Platte NRD had a small effect on the reach above Kingsley Dam. The effect averaged 100 AF/yr and ranged from 0 AF/yr for the first 5 years to 200 AF/yr for the last 5 years. Twin Platte NRD accounted for 2 percent of the new stream depletion for this reach.

Gained and lost irrigated land in the Twin Platte NRD affected stream baseflow in other reaches by less than 1 percent of the total effect.

Central Platte Natural Resources District

Gained and lost irrigated land in the Central Platte NRD primarily affected the reaches downstream from Tri-County Supply Canal diversion (table 8). The average effect for Tri-County Supply Canal diversion to Lexington for the period of analysis was 700 AF/yr and ranged from 500 AF/yr for the first five years to 1,000 AF/yr for the last 5 years. Central Platte NRD accounted for 32 percent of the new stream baseflow depletion for Tri-County Supply Canal diversion to Lexington.

For Lexington to U.S. Highway 183, the average effect was 700 AF/yr and ranged from 100 AF/yr for the first 5 years to 900 AF/yr for the last 5 years. Central Platte NRD accounted for 29 percent of the new stream baseflow depletions for Lexington to U.S. Highway 183.

For U.S. Highway 183 to Chapman, the average effect was 1,100 AF/yr and ranged from 400 AF/yr for the first 5 years to 1,500 AF/yr for the last 5 years. Central Platte NRD accounted for 37 percent of the new stream baseflow depletion for this reach.

Gained and lost irrigated land in the Central Platte NRD affected stream baseflow in other reaches considered in this analysis by less than 1 percent of the total effect.

Tri-Basin Natural Resources District

Gained and lost irrigated land in the Tri-Basin NRD primarily affected the reaches downstream from Lexington, but had a small effect on Tri-County Supply Canal diversion to Lexington (table 8). The average effect for Tri-County Supply Canal diversion to Lexington for the period of analysis was 200 AF/yr and ranged from 0 AF/yr for the first five years to 300 AF/yr for the last 5 years. Tri-Basin NRD accounted for 8 percent of the new stream baseflow depletion for Tri-County Supply Canal diversion to Lexington.

For Lexington to U.S. Highway 183, the average effect was 1,600 AF/yr and ranged from 300 AF/yr for the first 5 years to 2,200 AF/yr for the last 5 years. Tri-Basin NRD accounted for 69 percent of the new stream baseflow depletions for Lexington to U.S. Highway 183.

For U.S. Highway 183 to Chapman, the average effect was 1,600 AF/yr and ranged from 200 AF/yr for the first 5 years to 2,500 AF/yr for the last 5 years. Tri-Basin NRD accounted for 52 percent of the new stream baseflow depletion for this reach.

Gained and lost irrigated land in the Tri-Basin NRD affected stream baseflow in other reaches by less than 1 percent of the total effect.

Results for the Hydrologically Connected Area of the Overappropriated Basin and the Eastern Analysis Area

Figure 6 is graphs of stream baseflow depletion due to gained and lost irrigated land in the HCA/OA and EAA after July 1, 1997, for each area. Table 9 shows stream baseflow depletion and cumulative depletion for various dates.

For Wyoming line to Kingsley Dam, stream baseflow depletion due to gained or lost irrigated land in the HCA/OA and EAA after July 1, 1997, rose very rapidly during the first decade of the analysis and averaged 9.4 ft^3/s for the year beginning May 1, 2007. Over the next decade, stream depletion rose only an additional 1.3 ft^3/s. Stream depletion rose more slowly after the second decade, rising 0.2 ft^3/s for the third and fourth decades, and 0.1 ft^3/s for the last decade. The fall-to-spring change in stream depletion was about 4.2 ft^3/s after the first decade of the analysis. Cumulative stream baseflow depletion due to gained or lost irrigated land through May 1, 2048, was 347,000 acre-feet.

For Kingsley Dam to Tri-County Supply Canal diversion, stream baseflow depletion due to gained or lost irrigated land after July 1, 1997, rose fairly rapidly during the first decade of the analysis and averaged 5.6 ft^3/s for the year beginning May 1, 2007. Over the next decade, stream depletion rose an additional 1.0 ft^3/s. Stream depletion rose more slowly after the second decade, rising 0.3 ft^3/s for the third decade, 0.2 ft^3/s for the fourth decade, and 0.1 ft^3/s for the last decade. The fall-to-spring change in stream depletion was about 9.2 ft^3/s after the first decade of the analysis. Cumulative stream baseflow depletion due to gained or lost irrigated land through May 1, 2048, was 223,000 acre-feet.

For Tri-County Supply Canal diversion to Lexington, stream baseflow depletion due to gained or lost irrigated land after July 1, 1997, had a fairly complex pattern, being positive at the end of the irrigation season and negative at the end of the non-irrigation season. There was a slight upward trend in stream depletion over time. Stream depletion averaged 2.5 ft^3/s for the year beginning May 1, 2007. Over the next decade, stream depletion rose an additional 0.6 ft^3/s. Stream depletion rose more slowly after the second decade, falling 0.1 ft^3/s for the third decade, rising 0.2 for the fourth decade, and rising 0.1 ft^3/s for the fifth decade. The fall-to-spring change in stream depletion was about 10.2 ft^3/s after the first decade of the analysis. Cumulative stream baseflow depletion due to gained or lost irrigated land through May 1, 2048, was 104,000 acre-feet.

The reach Lexington to U.S. Highway 183 is fairly short, but includes two long tributaries, Spring Creek from the north and Plum Creek from the south. Stream baseflow depletion due to gained or lost irrigated land after July 1, 1997, in this reach showed a steady rise over the 50 years of the analysis, although the rate to rise decreased over time. Stream depletion averaged 2.0 ft^3/s for the year beginning May 1, 2007. Over the next decade, stream depletion rose an additional 0.8 ft^3/s. Stream depletion continued to rise after the second decade, rising 0.4 ft^3/s for the third decade, 0.3 ft^3/s for the fourth decade, and 0.1 ft^3/s for the fifth decade. The fall-to-spring change in stream depletion was about 0.3 ft^3/s after the first decade of the analysis. Cumulative stream baseflow depletion due to gained or lost irrigated land through May 1, 2048, was 98,000 acre-feet.

For U.S. Highway 183 to Chapman, stream baseflow depletion showed a steady rise for the period of analysis, although the rate of rise decreased over time. Stream depletion averaged 2.1 ft^3/s for the year beginning May 1, 2007. Over the next decade, stream depletion rose an additional 1.0 ft^3/s. Stream depletion continued to rise after the second decade, rising 0.7 ft^3/s for the third decade, 0.4 ft^3/s for the fourth decade, and 0.2 ft^3/s for the fifth decade. The fall-to-spring change in stream depletion also continued to increase slightly over the 50 years of the analysis, and the spring stream depletion was larger than the fall depletion. The amplitude increased from 0.5 ft^3/s after the first decade of the analysis to 0.7 ft^3/s for the last decade of the analysis. Cumulative stream baseflow depletion due to gained or lost irrigated land through May 1, 2048, was 115,000 acre-feet.

Results by Natural Resources District

This section reports stream baseflow depletion due to gained or lost irrigated land in the HCA/OA and EAA after July 1, 1997, by Natural Resources District (NRD) by reach (table 10). If a NRD had minimal effect on a reach, defined as the NRD causing less than 1 percent of total stream baseflow depletion for the reach, results for that NRD are not reported in the text. Results are reported as averages for 5-year periods. For this analysis, each year was assumed to be 365¼ days, so that leap years do not affect the calculated volumes per year.

North Platte Natural Resources District

Gained and lost irrigated land in the HCA/OA of the North Platte NRD primarily affected the reach Wyoming line to Kingsley Dam (table 10). The average effect for this reach for the period of analysis was 6,800 AF/yr and ranged from 1,000 AF/yr for the first five years to 7,900 AF/yr for the last 5 years. North Platte NRD accounted for 98 percent of the new stream baseflow depletion for Wyoming line to Kingsley Dam.

Gained and lost irrigated land in the HCA/OA of the North Platte NRD affected stream baseflow in other reaches by less than 1 percent of the total effect.

South Platte Natural Resources District

Gained and lost irrigated land in the HCA/OA of the South Platte NRD primarily affected the reach Kingsley Dam to Tri-County Supply Canal diversion (table 10). This is because the South Platte River and Lodgepole Creek are included in this reach. The average effect for this reach for the period of analysis was 100 AF/yr and ranged from 100 AF/yr for the first five years to 300 AF/yr for the last 5 years. South Platte NRD accounted for 3 percent of the new stream baseflow depletion for Kingsley Dam to Tri-County Supply Canal diversion.

Gained and lost irrigated land in the HCA/OA of the South Platte NRD affected stream baseflow in other reaches by less than 1 percent of the total effect.

Twin Platte Natural Resources District

Gained and lost irrigated land in the HCA/OA of the Twin Platte NRD primarily affected the reaches from Kingsley Dam to Lexington (table 10). The average effect for the Kingsley Dam to Tri-County Supply Canal diversion reach for the period of analysis was 4,500 AF/yr and ranged from 1,500 AF/yr for the first five years to 5,200 AF/yr for the last 5 years. Twin Platte NRD accounted for 97 percent of the new stream baseflow depletion for Kingsley Dam to Tri-County Supply Canal diversion.

For Tri-County Supply Canal diversion to Lexington, the average effect was 1,200 AF/yr and ranged from 600 AF/yr for the first 5 years to 1,300 AF/yr for the last 5 years. Twin Platte NRD accounted for 58 percent of the new stream baseflow depletions for Tri-County Supply Canal diversion to Lexington.

Twin Platte NRD had a small effect on the reach above Kingsley Dam. The effect averaged 100 AF/yr and ranged from 0 AF/yr for the first 5 years to 200 AF/yr for the last 5 years. Twin Platte NRD accounted for 2 percent of the new stream depletion for this reach.

Gained and lost irrigated land in the HCA/OA of the Twin Platte NRD affected stream baseflow in other reaches by less than 1 percent of the total effect.

Central Platte Natural Resources District

Gained and lost irrigated land in the HCA/OA and EAA of the Central Platte NRD primarily affected the reaches downstream from Tri-County Supply Canal diversion (table 10). The average effect for Tri-County Supply Canal diversion to Lexington for the period of analysis was 700 AF/yr and ranged from 500 AF/yr for the first five years to 800 AF/yr for the last 5 years. Central Platte NRD accounted for 35 percent of the new stream baseflow depletion for Tri-County Supply Canal diversion to Lexington.

For Lexington to U.S. Highway 183, the average effect was 500 AF/yr and ranged from 100 AF/yr for the first 5 years to 600 AF/yr for the last 5 years. Central Platte NRD accounted for 26 percent of the new stream baseflow depletions for Lexington to U.S. Highway 183.

For U.S. Highway 183 to Chapman, the average effect was 800 AF/yr and ranged from 300 AF/yr for the first 5 years to 1,000 AF/yr for the last 5 years. Central Platte NRD accounted for 34 percent of the new stream baseflow depletion for this reach.

Gained and lost irrigated land in the HCA/OA and EAA of the Central Platte NRD affected stream baseflow in other reaches considered in this analysis by less than 1 percent of the total effect.

Tri-Basin Natural Resources District

Gained and lost irrigated land in the HCA/OA and EAA of the Tri-Basin NRD primarily affected the reaches downstream from Lexington, but had a small effect on Tri-County Supply Canal diversion to Lexington (table 10). The average effect for Tri-County Supply Canal diversion to Lexington for the period of analysis was 200 AF/yr and ranged from 0 AF/yr for the first five years to 200 AF/yr for the last 5 years. Tri-Basin NRD accounted for 8 percent of the new stream baseflow depletion for Tri-County Supply Canal diversion to Lexington.

For Lexington to U.S. Highway 183, the average effect was 1,500 AF/yr and ranged from 300 AF/yr for the first 5 years to 2,000 AF/yr for the last 5 years. Tri-Basin NRD accounted for 74 percent of the new stream baseflow depletions for Lexington to U.S. Highway 183.

For U.S. Highway 183 to Chapman, the average effect was 1,500 AF/yr and ranged from 200 AF/yr for the first 5 years to 2,200 AF/yr for the last 5 years. Tri-Basin NRD accounted for 64 percent of the new stream depletion for this reach.

Gained and lost irrigated land in the HCA/OA and EAA of the Tri-Basin NRD affected stream baseflow in other reaches by less than 1 percent of the total effect.

Upper Big Blue Basin Natural Resources District

Gained and lost irrigated land in the EAA of the Upper Big Blue NRD primarily affected the reach downstream from U.S. Highway 183 (table 10). The table shows zero effect because the values were rounded to the nearest 100 AF/yr and all values are less than 50 AF/yr. Upper Big Blue NRD accounted for 1 percent of the new stream depletion for this reach.

Gained and lost irrigated land in the EAA of the Upper Big Blue NRD affected stream baseflow in other reaches by less than 1 percent of the total effect.

Limitations and Comments

This analysis is very dependent on the estimates of gained or lost irrigated land after 1997 and thus gained or lost net pumpage. Any errors in the estimates of gained or lost net pumpage would translate to proportional errors in stream baseflow depletion due to irrigated land gained or lost after 1997. An assessment of the accuracy of the data was provided in the reports which were used to provide mapped land uses for 1997 (Dappen and Tooze, 2001), 2001 (Dappen and Merchant, 2003), and 2005 (Dappen and others, 2006). These mapped irrigated lands were compared to county assessor tax data, Farm Service Administration data, and Census of Agriculture data for 20 counties that are completely in the COHYST area (Luckey and others, 2006, table 11). That report indicated that estimates of gained or lost irrigated land after 1997 were reasonable.

Specific land use information was not collected for every year; it was available only for 1997, 2001, and 2005. Necessary assumptions were made to interpolate land use changes temporally and spatially for years when specific data were not available. This may introduce small errors in the 1998 to 2005 part of the analysis. Interpolation of the estimated land use assumed that land gained or lost in the intervening years was near gained or lost irrigated land between those dates. This limitation should have little effect on estimated depletions over the modeled period.

To calibrate the models, additional recharge was added to cultivated land, both dryland and irrigated land, with more recharge add to irrigated land than to dryland. The different recharge rates were determined during model calibration and were accepted for this analysis. This analysis assumed gained or lost irrigated land after 1997 was converted from or to dryland and adjusted recharge accordingly. The differences in calibrated recharge on dryland and irrigated land were considerable, and ranged from less than 3 in/yr to more than 6 in/yr. This difference in recharge had a large effect on the analysis of stream baseflow depletion, because gained irrigated land was mitigated by gained recharge and lost irrigated land was mitigated by lost recharge. If the differences in recharge between dryland and irrigated land determined during model calibration were partially due to other factors that occurred concurrently with conversion of dryland to irrigated land during the period 1950-97, this analysis would underestimate stream baseflow depletion. Fortunately, the previous analysis (Luckey and others, 2006) ignored the recharge differences and thus overestimated stream depletion, so the real response to conversions from and to dryland may lie between the two analyses.

The additional recharge on cultivated land was changed during calibration in the central and eastern models. The central model changed both dryland and irrigated land recharge, and changed it in 1973 or 1979, depending on the area. The eastern model changed only irrigated land recharge, and made the change in 1973. This analysis used the recharge rates for the last part of the calibration period and used those rates through 2048. The last part of the calibration period was a wetter period, and if the higher recharge rates were caused by the wetter period rather than cultivation and conservation practices, this analysis would underestimate stream baseflow depletion. As in the previous paragraph, the real response to conversions from and to dryland may lie between the previous and the current analysis.

This analysis used 1997 meteorological conditions for the entire 50 years. While 1997 was near an average year in terms of meteorological conditions, it was somewhat wetter in the west and somewhat dryer in the east. Meteorological conditions directly affect net pumpage, so net pumpage under normal conditions could be larger in the west and smaller in the east. If average future meteorological conditions are much different from 1997 conditions, the current analysis must be adjusted accordingly. Use of average meteorological conditions throughout the analysis fails to capture the natural variability of meteorological conditions, but makes it easier to see the average long-term effects of gained or lost irrigated land after 1997.

Future meteorological conditions may be substantially different from the average meteorological conditions used in this report. The Twentieth Century probably was wetter than previous centuries and tended to have shorter droughts.

This analysis used a net irrigation requirement that changed over time because the crop mix changed over time. For all model units, the net irrigation requirements were largest for 1997 and for the Western Model Unit and the Eastern Model Unit net irrigation requirements were smallest for 2001. Changing net irrigation requirements added a complexity to estimated stream baseflow depletions that had nothing to do with gained or lost irrigated land. An unintended consequence of changing net irrigation requirement over time was noticed in the Central Model Unit, where a parcel of irrigated land was gained by 2001 and was then lost by 2005. Because the 2005 net irrigation requirement was smaller then the 2001 requirement, the effect of the parcel remained throughout the analysis. Use of a long term average net irrigation requirement would remove the unintended consequence and would better concentrate on the effects of gained or last irrigated land after 1997.

At the time of this analysis, COHYST had not yet completed estimates of supplemental groundwater use on surface-water irrigated land, so the use of supplemental groundwater was ignored in this analysis. The use of supplemental groundwater is known to exist and has become more common in recent years. However, if supplemental groundwater use were included in this analysis, it would have been included in both the baseline condition and the change in pumpage and recharge condition. By including it in both conditions, supplemental groundwater use effectively cancels itself out. This canceling out is hydrologically correct because the effects of supplemental groundwater use are independent of the effects of gained or lost irrigated land.

The Central Model Unit simulations exhibited some modest numerical instability. This was evident in slightly different total depletions when comparing the sum of the NRD depletions to the total depletions by reach. The numerical instability was small and averaged 0.02 ft^3/s for Kingsley Dam to Tri-County Supply Canal diversion and 0.07 ft^3/s for Tri-County Supply Canal diversion to Lexington.

The results of this analysis are probably affected by evapotranspiration of groundwater, especially downstream of U.S. Highway 183. Evapotranspiration is simulated in the model in areas where the groundwater is near land surface or in areas of riparian vegetation near large rivers and streams. In some areas, gained or lost net pumpage reduced or increased the amount of evapotranspiration instead of changing stream baseflow. Stream baseflow depletion results are directly affected by the evapotranspiration data used in the model, so any errors in evapotranspiration inputs would cause proportional errors in stream depletion results.

The results of this analysis are more reliable in earlier time and less reliable in later time. This is due to an accumulation of errors in estimates of changes in net pumpage and changes in recharge, and an accumulation of other model errors as the simulations progress.

References Cited

Dappen, Patti, and Merchant, Jim, 2003, Delineation of 2001 land use patterns for the Cooperative Hydrology Study in the central Platte River basin: Center for Advanced Land Management Information Technologies (CALMIT), University of Nebraska – Lincoln, 79 p.

Dappen, Patti, and Tooze, Marcus, 2001, Delineation of [1997] land use patterns for the Cooperative Hydrology Study in the central Platte River basin: Center for Advanced Land Management Information Technologies (CALMIT), University of Nebraska – Lincoln, 73 p.

Dappen, Patti, Merchant, Jim, Ratcliffe, Ian, and Robbins, Cullen, 2006, Delineation of 2005 land use patterns for the State of Nebraska Department of Natural Resources in the central Platte River basin: Center for Advanced Land Management Information Technologies (CALMIT), University of Nebraska – Lincoln, 87 p.

Harbaugh, A.W., 1990, A computer program for calculating subregional water budgets using results from the U.S. Geological Survey modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 90-392, 46 p.

Luckey, R.R., and Cannia, J.C, 2006, Groundwater flow model of the Western Model Unit of the Nebraska Cooperative Hydrology Study (COHYST) area: Cooperative Hydrology Study, 63 p.

Luckey, R.R., Woodward, D.A., and Carney, C.P., 2006, Estimated stream depletion in the Nebraska Platte basin due to new irrigated land developed after July 1, 1997: Cooperative Hydrology Study, 38 p.

Luckey, R.R., Woodward, D.A., and Carney, C.P., 2007, Simulated stream baseflow changes in the Nebraska Platte basin due to reduced groundwater irrigated land after July 1, 1997: Cooperative Hydrology Study, 46 p.

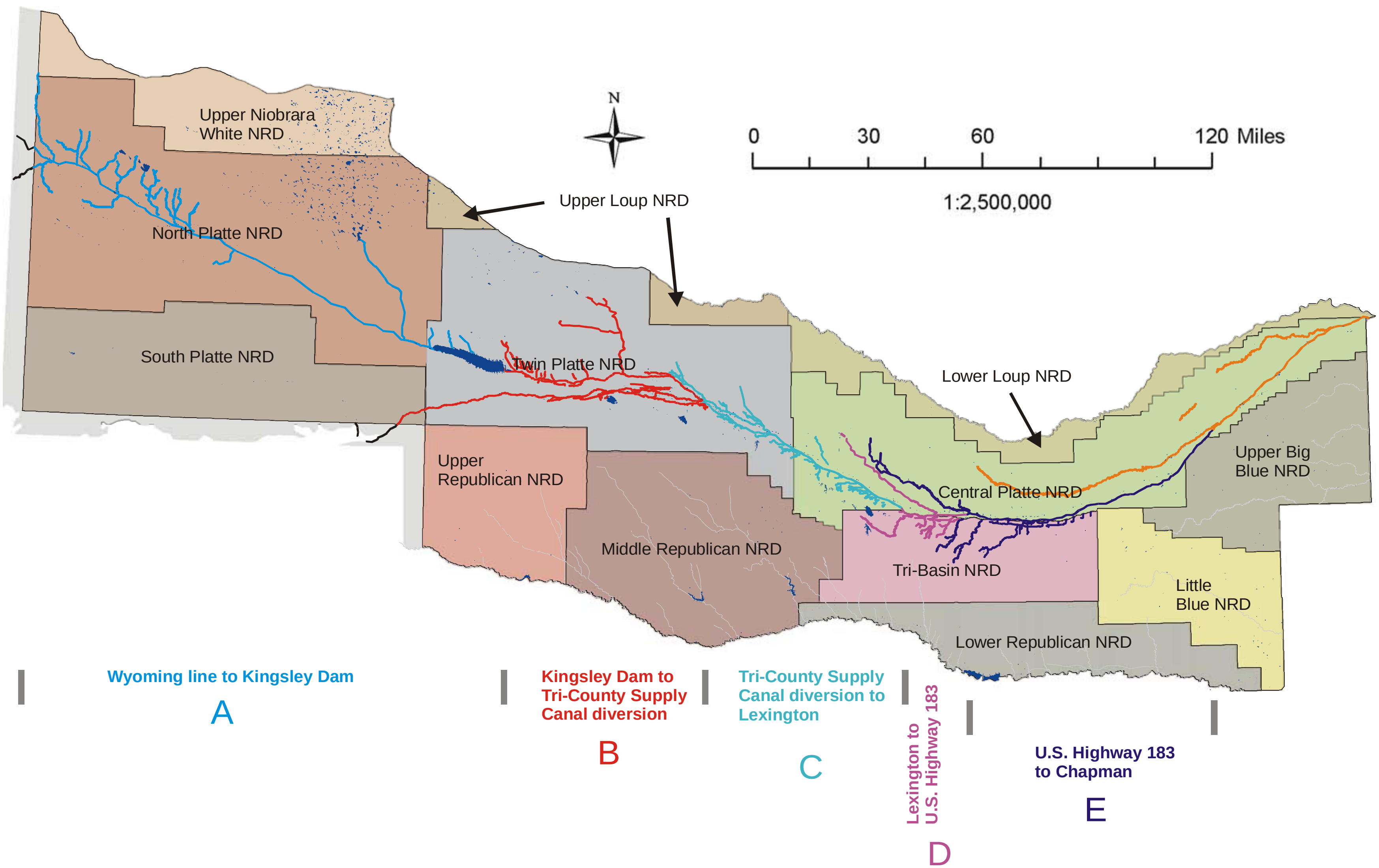


Figure 1. Cooperative Hydrology Study (COHYST) area, Natural Resources Districts, and the five sub-areas used in the analysis of stream baseflow depletion to the Platte River system due to groundwater-irrigated lands developed between July 1, 1997, and June 30, 2006 (modified from Luckey and others, 2006). Note that streams are grouped by the sub-area in which they reach the Platte River, including the North Platte River and South Platte River.

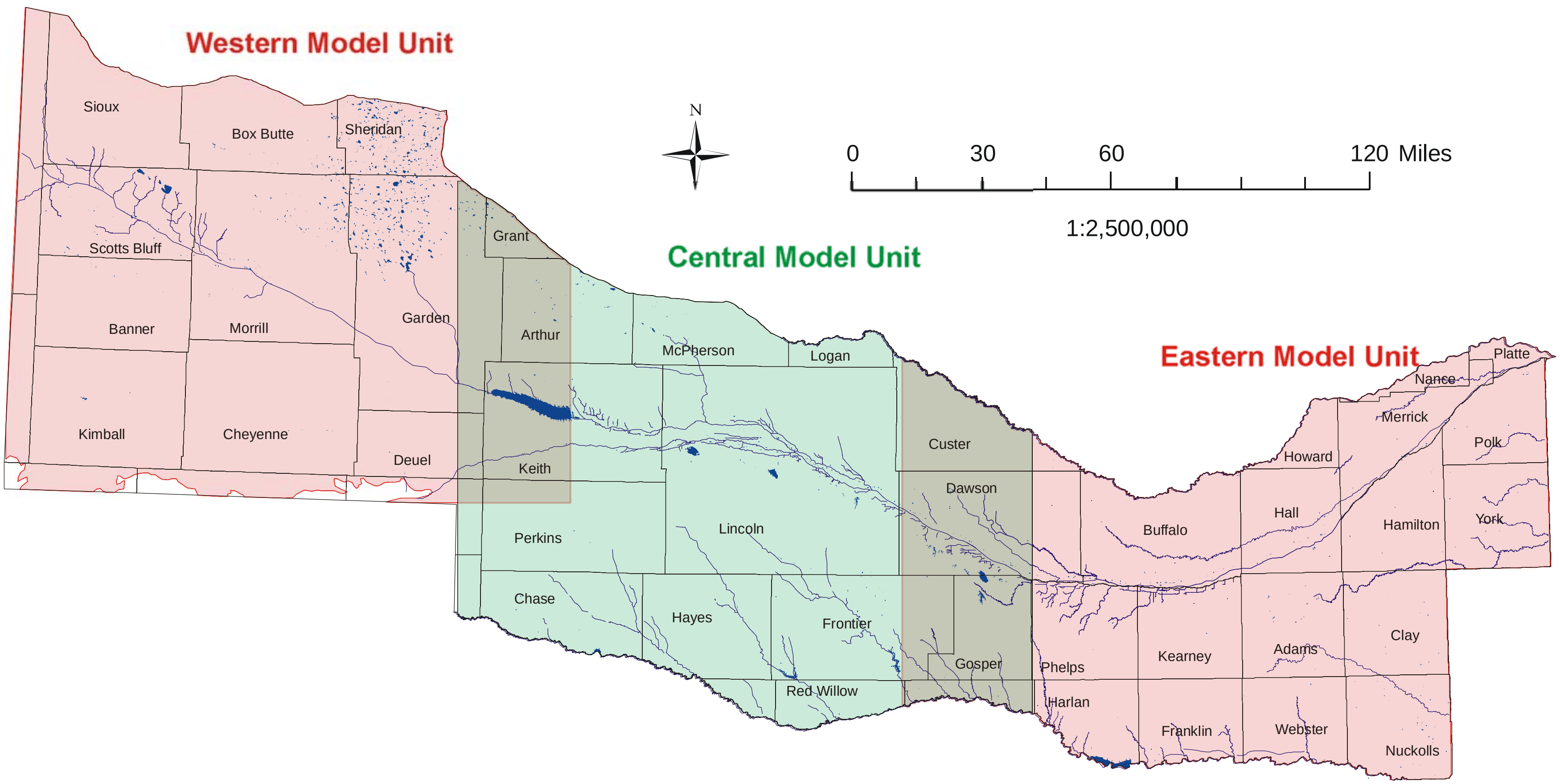


Figure 2. Cooperative Hydrology Study (COHYST) model units used in the analysis (modified from Luckey and others, 2006). The darker areas are where the model units overlap.

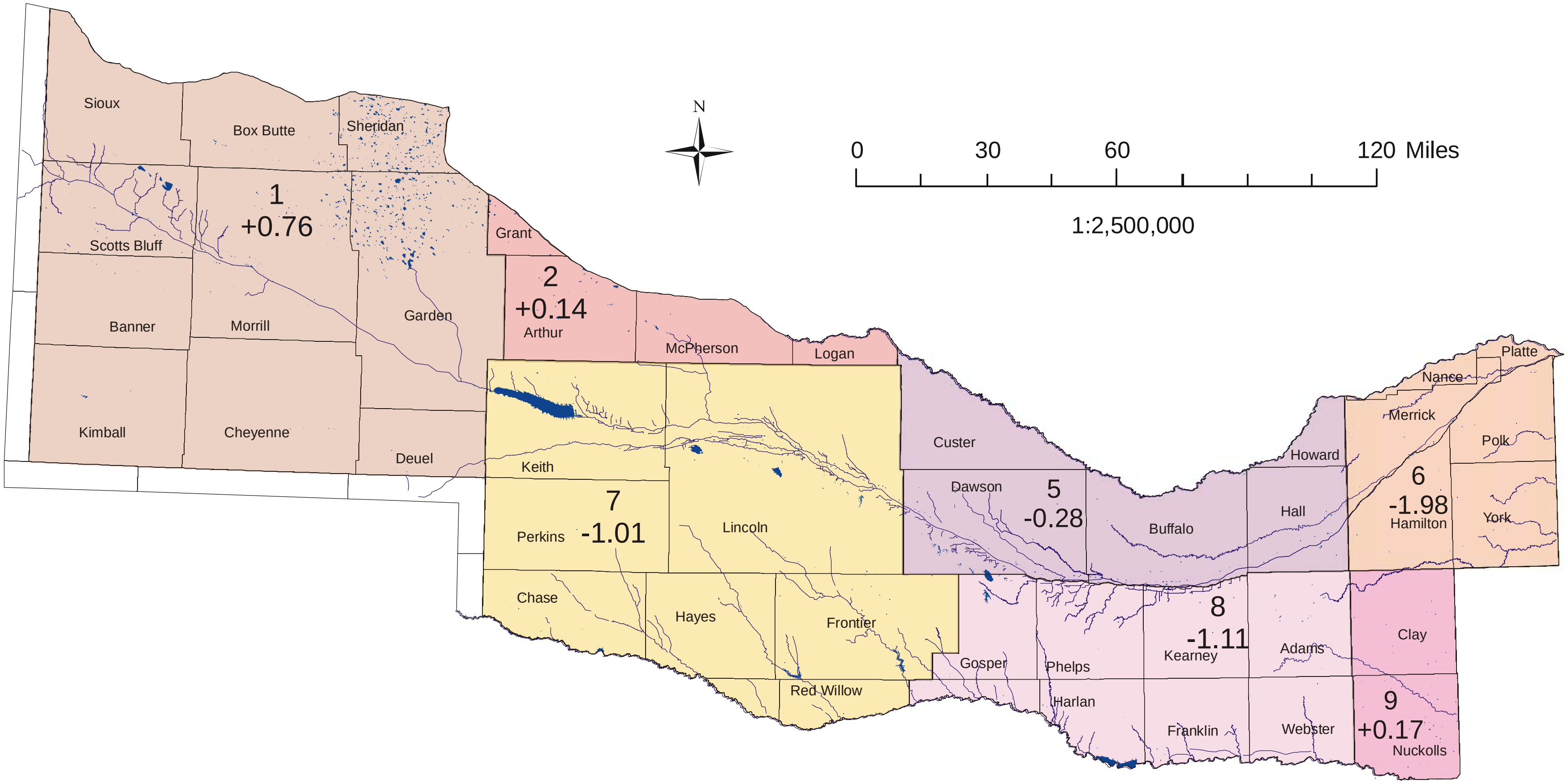


Figure 3. Climatic divisions and 1997 departure from average 1895-1998 precipitation.

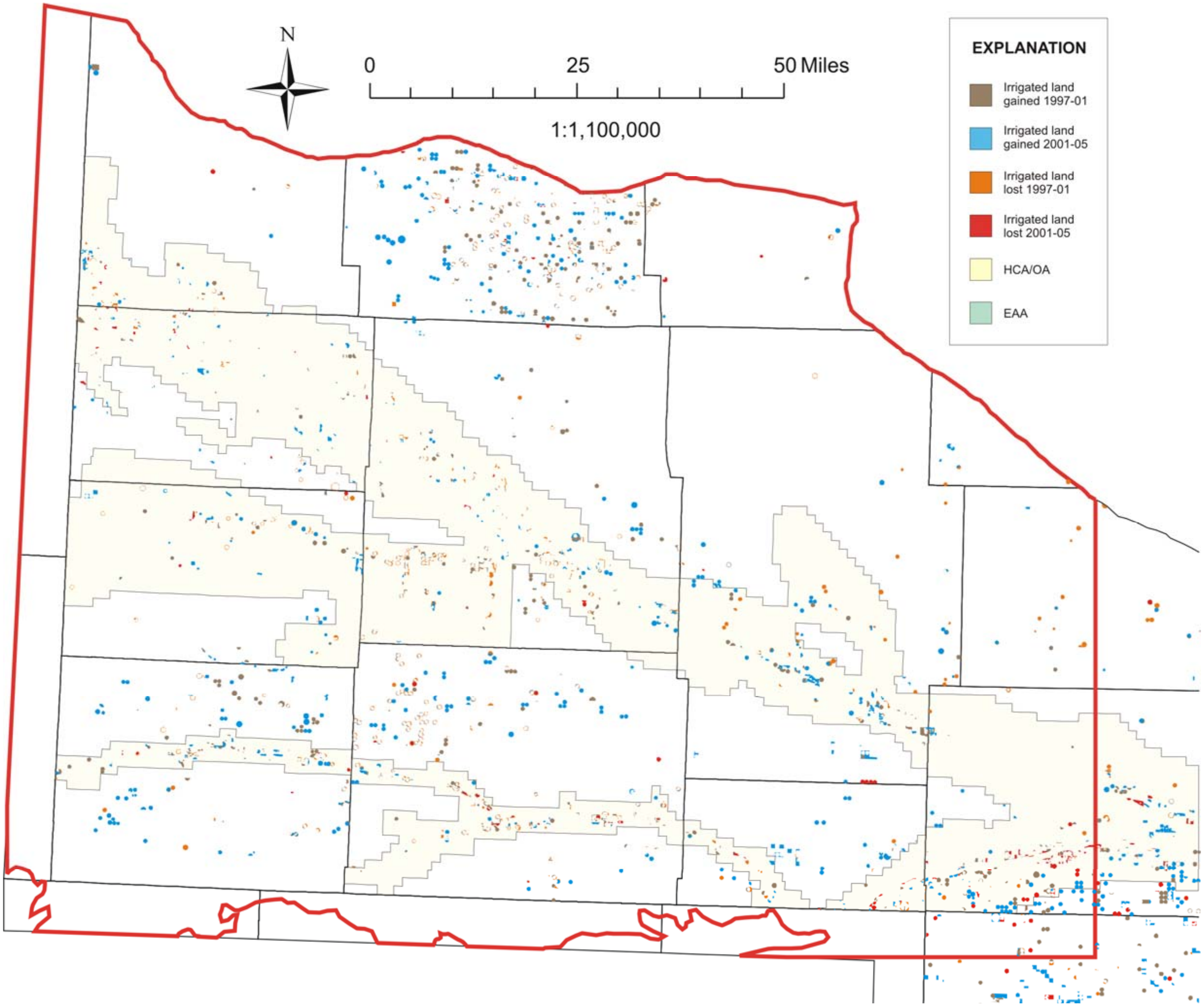


Figure 4. Groundwater-irrigated land developed between July 1, 1997, and June 30, 2001, and between July 1, 2001, and June 30, 2005, and the Hydrologically Connected Area of the Overappropriated Basin (HCA/OA) and the Eastern Analysis Area (EAA). Western Model Unit (from Luckey and others, 2006).

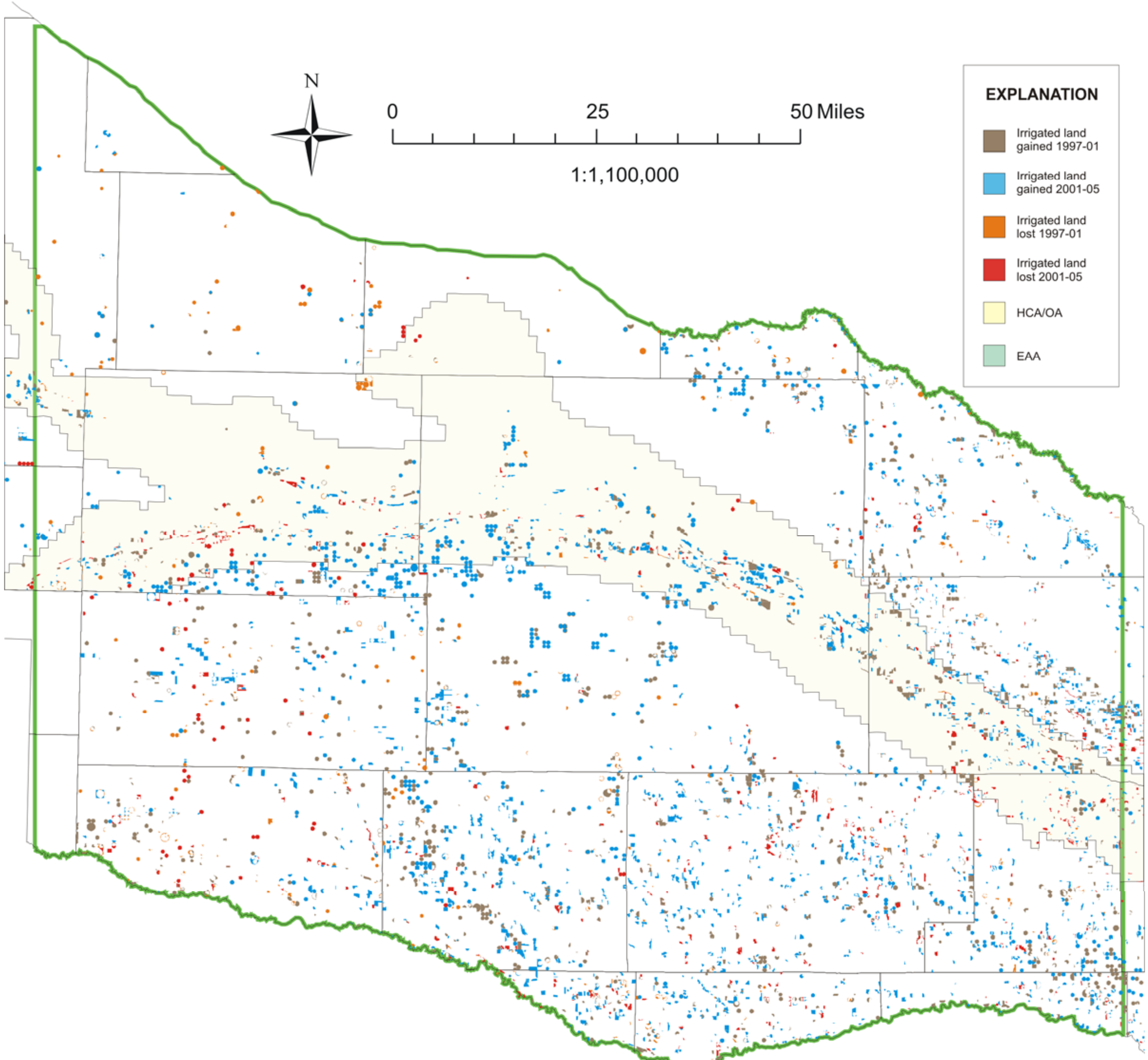


Figure 4 continued. Central Model Unit.

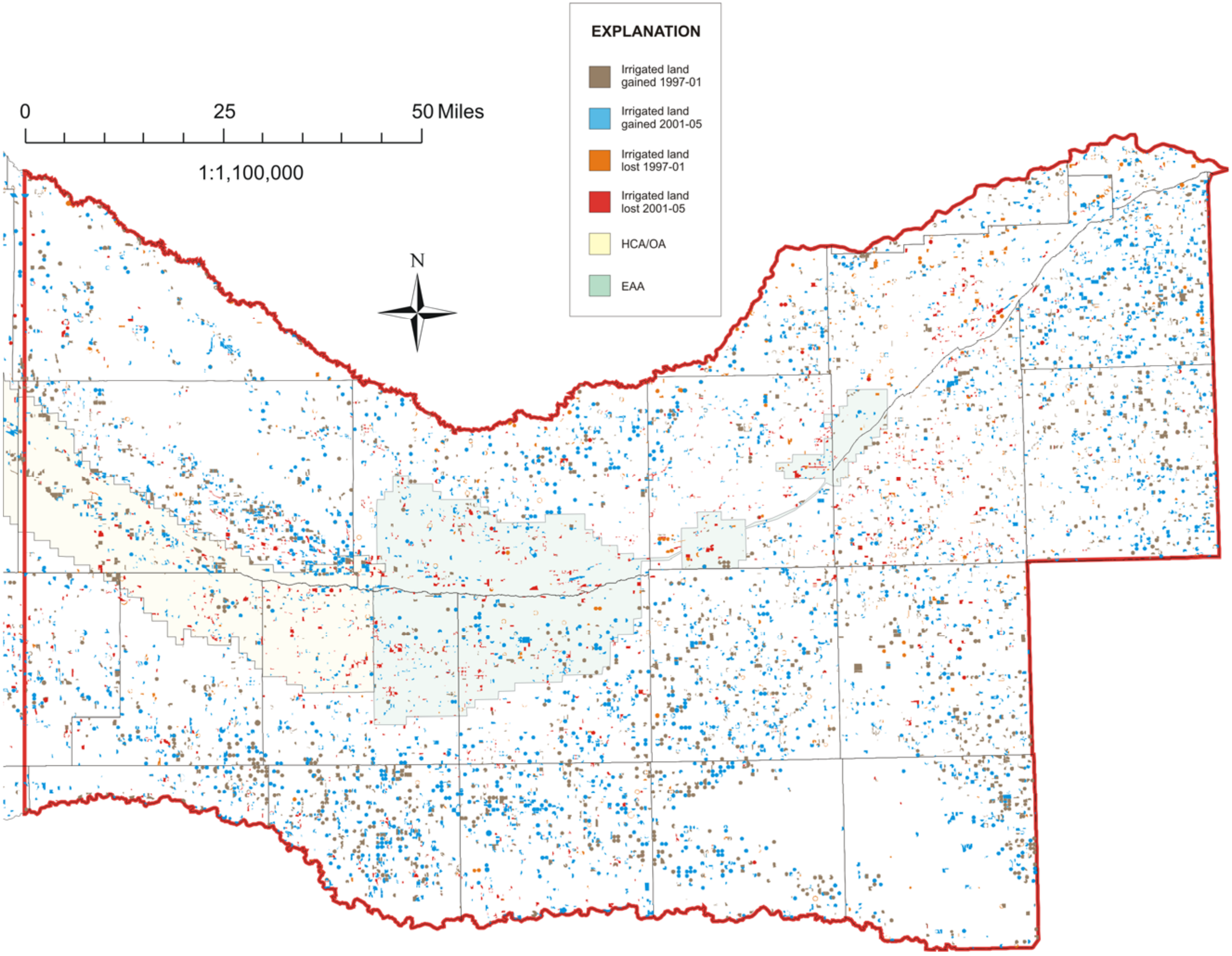
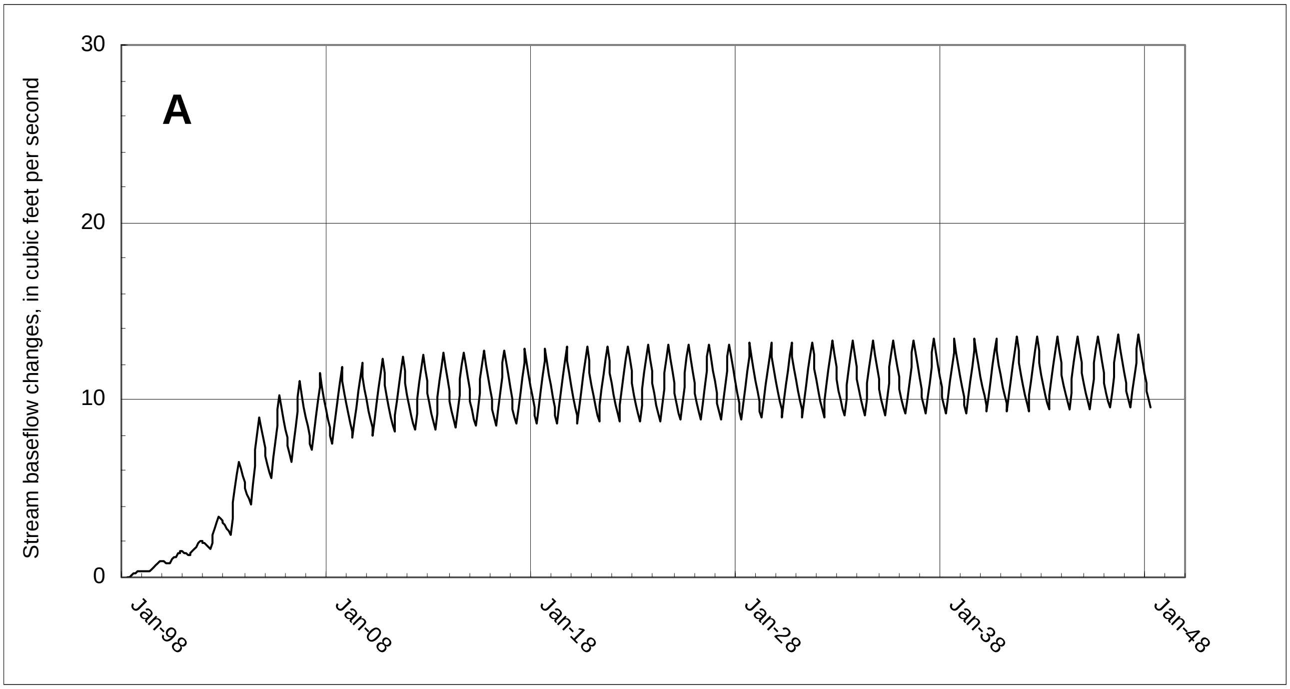


Figure 4 continued. Eastern Model Unit.



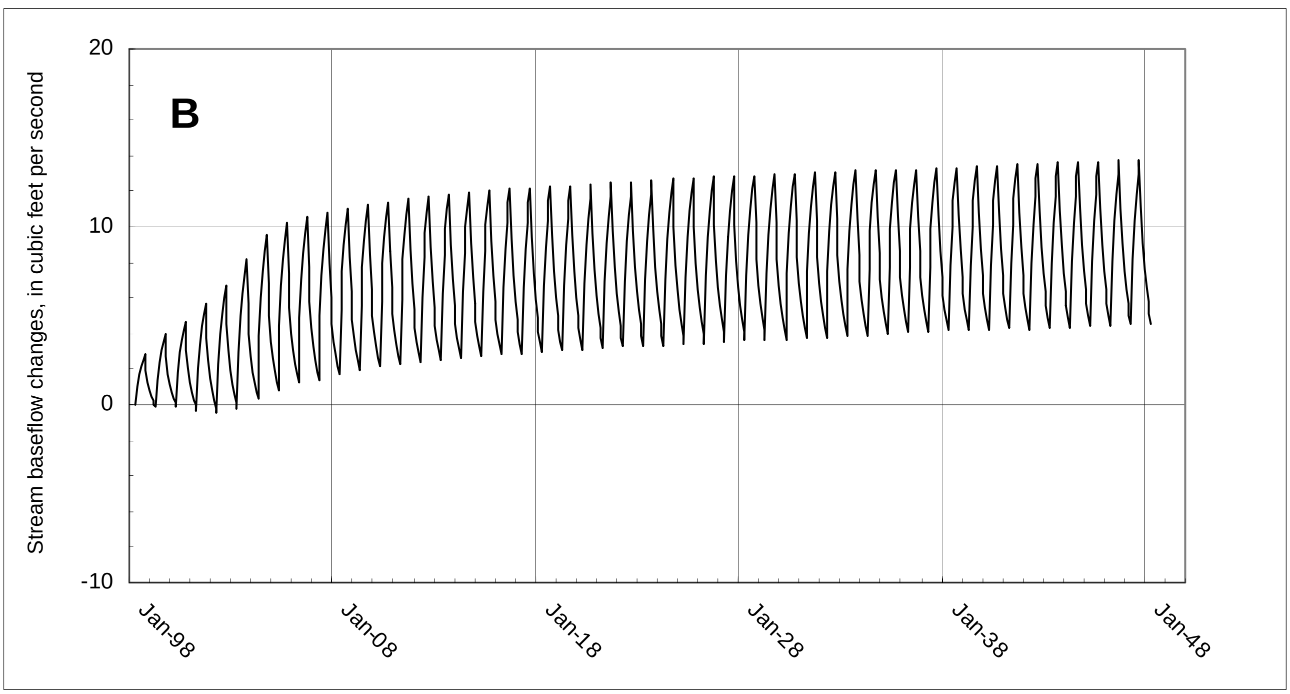
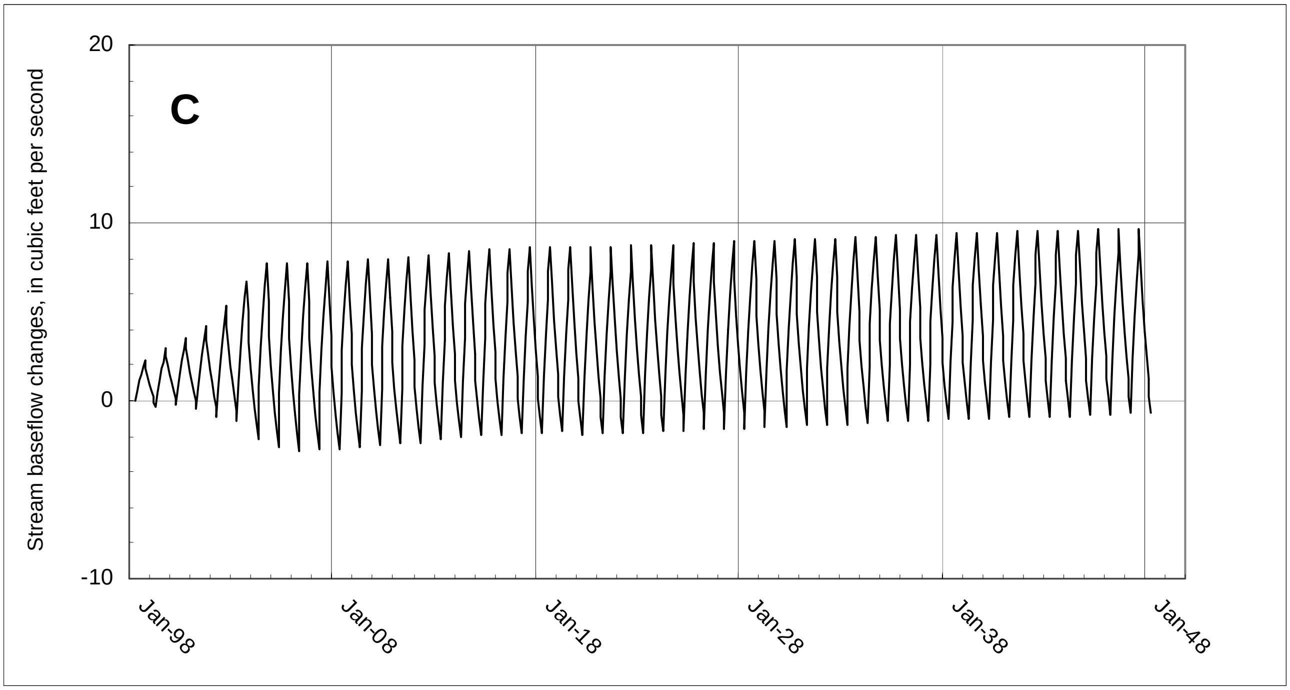
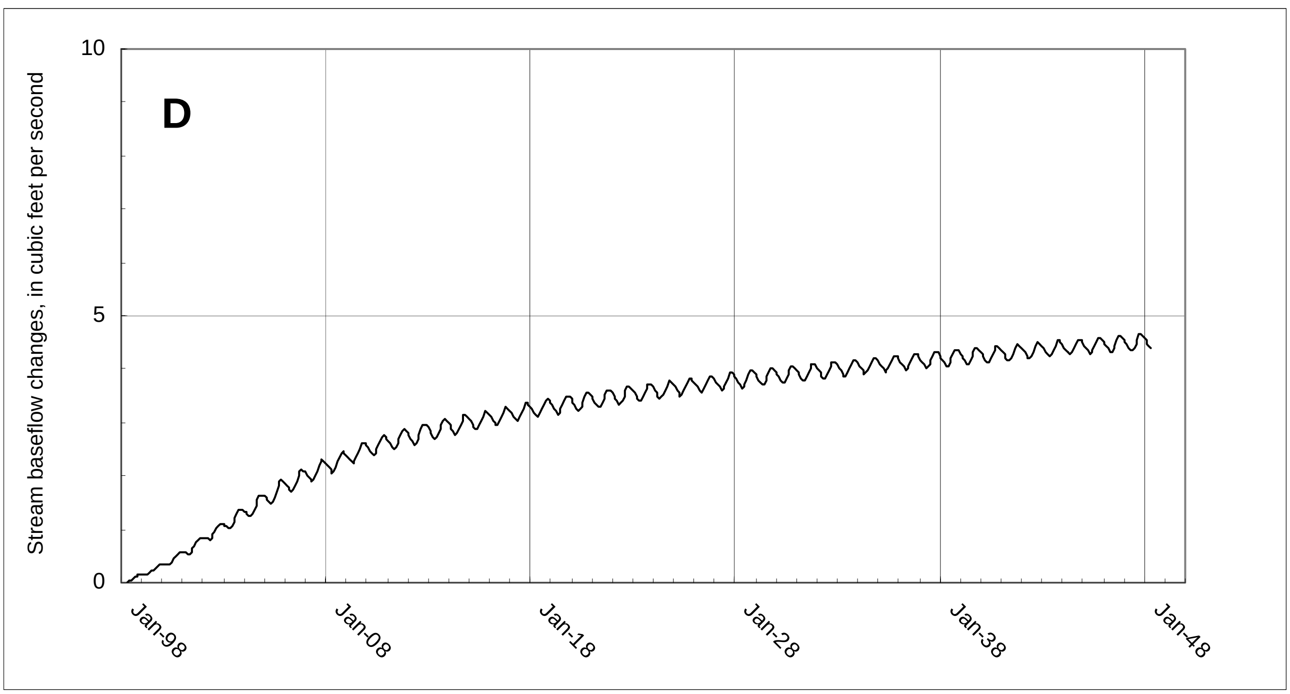


Figure 5. Monthly stream baseflow depletion to the Platte River system due to gained or lost groundwater-irrigated lands in the Cooperative Hydrology Study area between July 1, 1997, and June 30, 2006, for each area. A) Wyoming line to Kingsley Dam; B) Kingsley Dam to Tri-County Supply Canal diversion; C) Tri-County Supply Canal diversion to Lexington; D) Lexington to U.S. Highway 183; and E) U.S. Highway 183 to Chapman.





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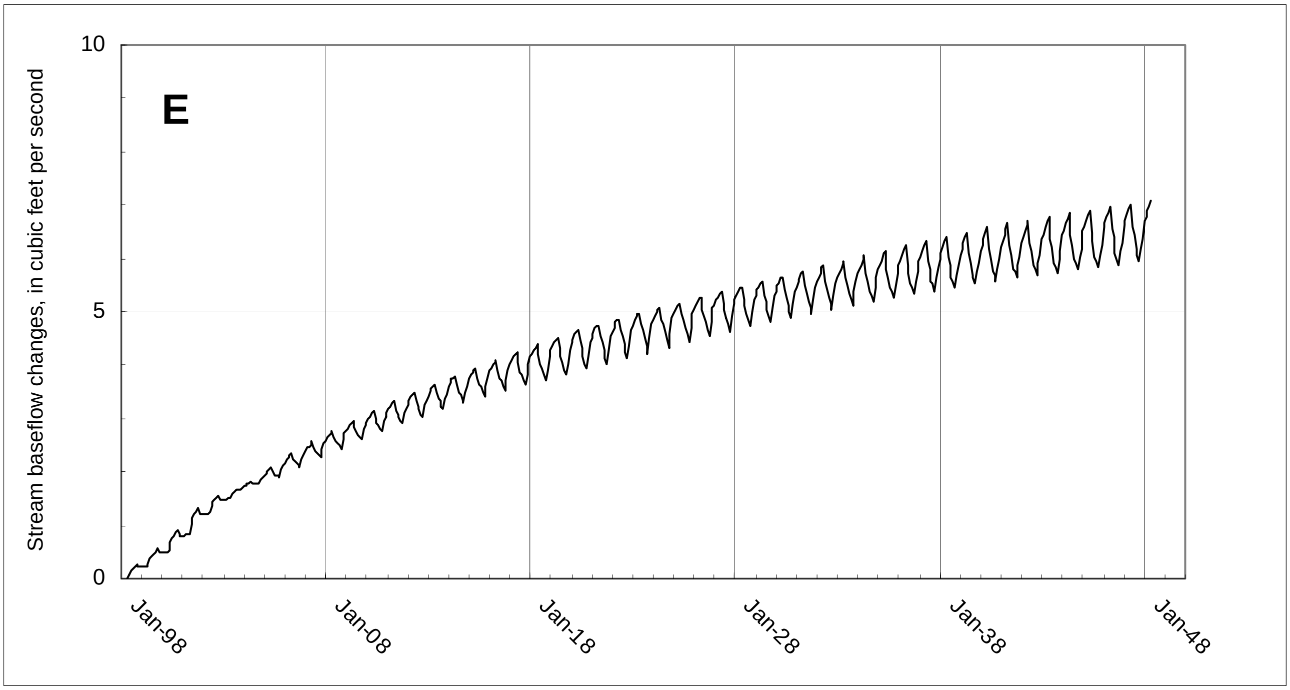

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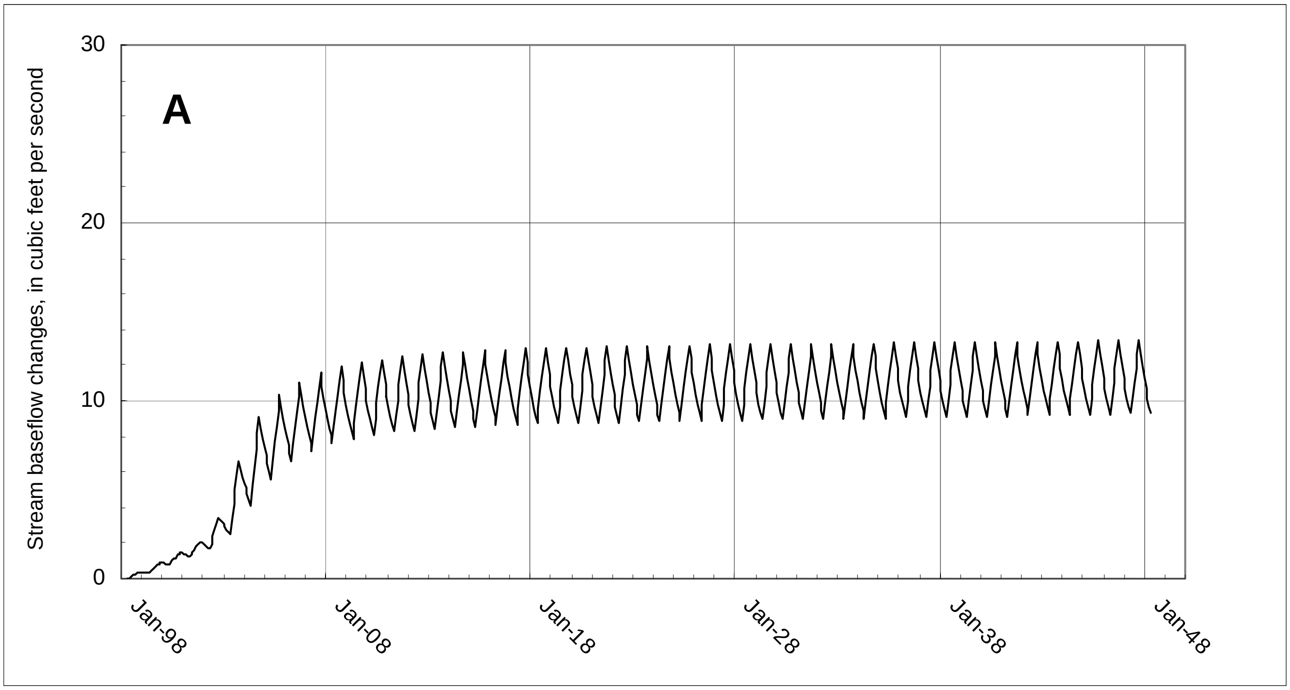


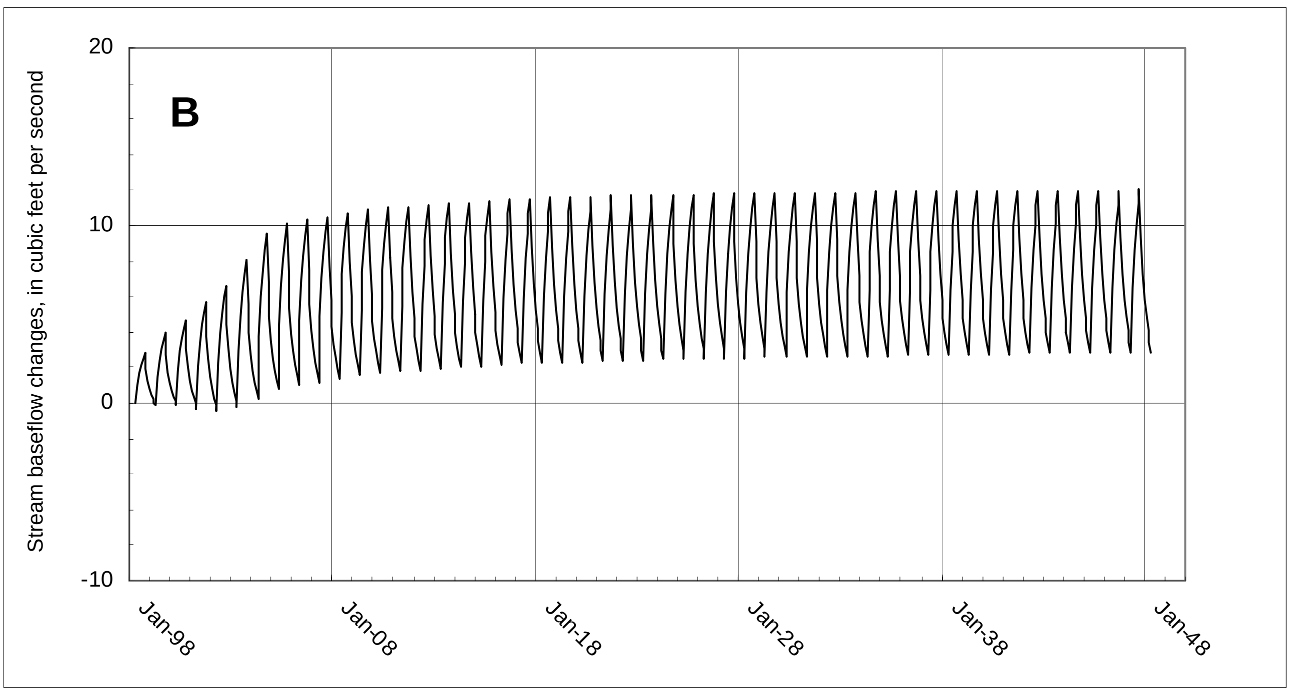
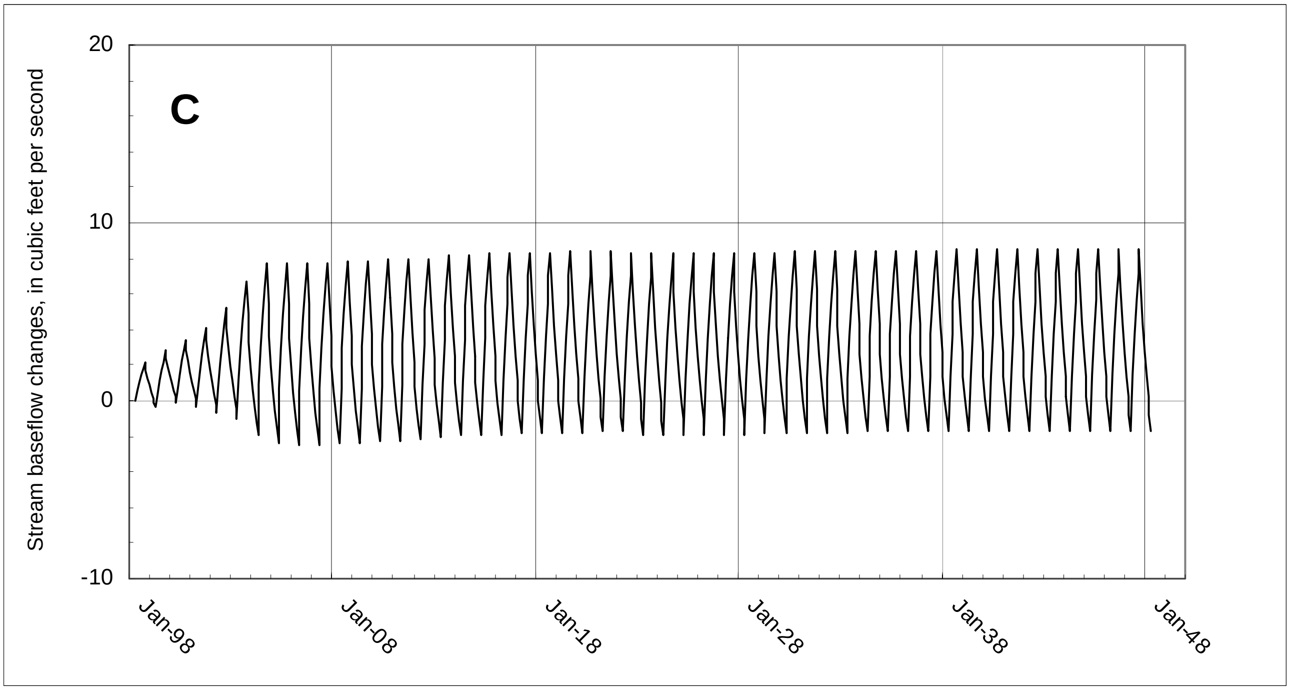
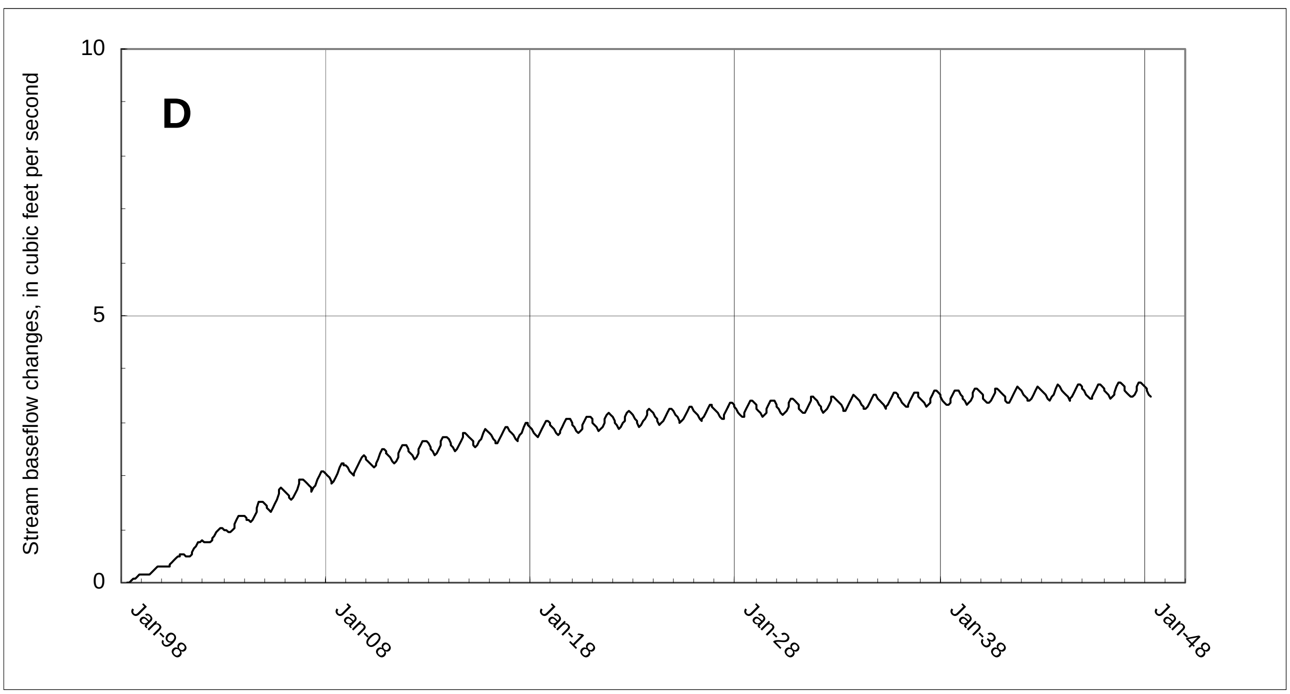


Figure 6. Monthly stream baseflow depletion to the Platte River system due to gained or lost groundwater-irrigated lands in the Hydrologically Connected Area of the Overappropriated Basin and the Eastern Analysis Area between July 1, 1997, and June 30, 2006, for each area. A) Wyoming line to Kingsley Dam; B) Kingsley Dam to Tri-County Supply Canal diversion; C) Tri-County Supply Canal diversion to Lexington; D) Lexington to U.S. Highway 183; and E) U.S. Highway 183 to Chapman.





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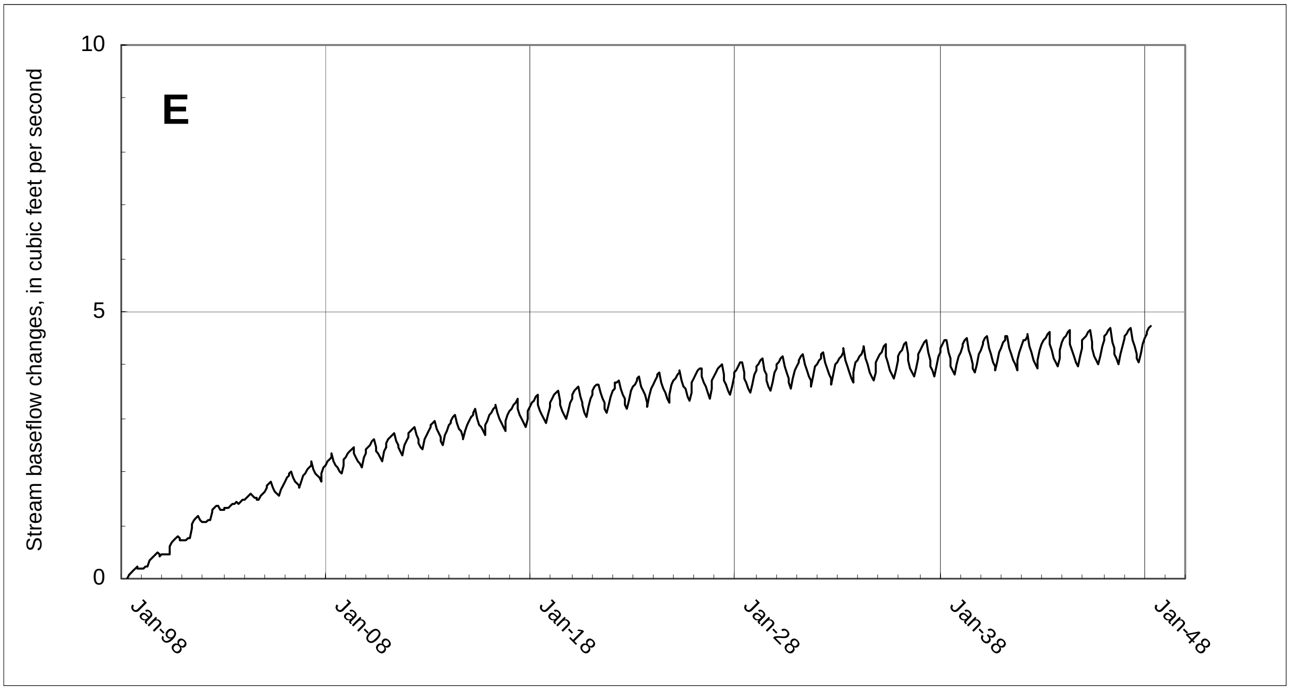

Figure 6 continued.

Table 1. Gained and lost groundwater irrigated land for July 1, 1997, through June 30, 2001, and July 1, 2001, through June 30, 2005, by county (from Luckey and others, 2006). Net columns may not be the same as the difference between Gained and Lost columns because the numbers were rounded to the nearest 10 acres. Likewise, Total row may not be the same as the sum of the shown numbers because of rounding. 1997 irrigated acres represents groundwater irrigated acres in the Cooperative Hydrology Study (COHYST) part of the county and is from Dappen and Tooze (2001). New wells are for that part of the county within the COHYST area.

County	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells
				Gained	Lost	Net	Gained	Lost	Net		
Adams	360,900	100	184,670	14,050	1,530	12,520	16,570	770	15,800	28,320	243
Arthur	459,400	90	11,650	310	2,150	-1,840	880	210	680	-1,160	3
Banner	477,300	100	26,860	1,400	1,720	-310	2,780	370	2,410	2,100	22
Box Butte	689,400	64	110,640	10,040	2,290	7,750	11,250	1,130	10,120	17,870	105
Buffalo	623,800	88	208,400	7,910	2,710	5,190	16,690	6,790	9,910	15,100	206
Butler	376,400	0	0	50	0	50	30	0	30	80	0
Chase	574,300	68	120,950	6,130	2,800	3,330	4,850	3,540	1,310	4,640	2
Cheyenne	765,200	100	54,600	4,570	3,840	730	6,770	1,580	5,200	5,930	55
Clay	366,900	100	190,940	13,280	1,510	11,770	9,660	1,430	8,230	20,000	152
Custer	1,647,600	24	48,980	6,660	1,920	4,730	7,580	1,110	6,470	11,200	44
Dawson	652,000	100	155,130	23,010	1,430	21,580	23,110	4,900	18,200	39,780	294
Deuel	281,900	100	18,990	850	1,160	-310	3,160	700	2,450	2,140	23
Franklin	368,700	79	74,050	10,190	990	9,190	15,470	2,360	13,110	22,300	104
Frontier	627,000	100	54,300	13,460	1,060	12,400	19,260	6,300	12,960	25,360	28
Furnas	461,100	22	11,350	4,370	120	4,250	3,630	560	3,070	7,320	78
Garden	1,107,100	99	27,990	3,240	3,880	-640	6,480	680	5,800	5,160	41
Gosper	296,000	100	68,140	7,060	1,280	5,780	8,360	2,490	5,870	11,650	115
Grant	500,900	17	490	0	390	-390	350	0	350	-40	0
Hall	353,200	100	205,270	4,460	3,480	980	7,850	4,110	3,740	4,720	201
Hamilton	349,700	100	239,240	9,160	2,560	6,600	7,360	4,650	2,710	9,310	99
Harlan	367,400	68	48,970	14,560	700	13,860	15,920	1,460	14,450	28,310	100
Hayes	456,400	96	44,250	12,910	2,190	10,720	18,980	2,700	16,270	26,990	132
Hitchcock	459,800	14	7,230	1,170	470	700	3,310	1,160	2,150	2,850	4
Howard	368,200	30	39,380	1,720	1,800	-80	3,720	770	2,950	2,870	59
Kearney	330,200	100	173,760	6,300	1,230	5,080	12,810	4,040	8,770	13,850	231
Keith	709,800	100	82,410	8,270	2,830	5,440	17,780	5,500	12,280	17,720	178

Table 1 continued.

County	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells
				Gained	Lost	Net	Gained	Lost	Net		
Kimball	609,100	100	30,200	4,060	2,600	1,460	7,550	340	7,210	8,670	40
Lincoln	1,647,100	100	184,470	18,710	6,340	12,370	39,520	3,890	35,640	48,010	350
Logan	365,300	75	14,680	1,840	650	1,190	3,130	110	3,030	4,220	32
McPherson	550,000	55	8,630	250	1,500	-1,250	510	940	-440	-1,690	1
Merrick	316,200	99	179,530	4,260	4,590	-330	5,580	2,590	2,990	2,660	255
Morrill	914,500	100	61,820	5,860	3,470	2,390	4,530	590	3,950	6,340	130
Nance	286,600	24	19,100	1,670	440	1,230	1,530	80	1,450	2,680	49
Nuckolls	368,600	96	35,640	9,970	580	9,390	8,160	130	8,020	17,410	107
Perkins	565,600	100	131,240	6,150	2,500	3,640	8,460	2,840	5,610	9,250	4
Phelps	345,900	100	157,530	3,900	740	3,160	9,090	4,600	4,500	7,660	270
Platte	438,100	13	23,060	740	1,300	-560	1,570	130	1,440	880	37
Polk	282,100	100	135,660	10,370	2,820	7,550	19,090	720	18,370	25,920	125
Red Willow	459,500	38	21,040	3,620	1,170	2,460	5,580	1,080	4,510	6,970	26
Scotts Bluff	476,800	100	7,190	1,110	810	300	1,920	700	1,220	1,520	104
Sheridan	1,580,200	16	2,900	430	370	60	230	240	-10	50	0
Sioux	1,322,600	38	5,830	890	770	130	1,300	680	620	750	30
Webster	368,000	81	35,240	9,420	360	9,060	8,800	330	8,460	17,520	129
York	368,400	100	230,890	14,420	1,350	13,070	12,630	880	11,750	24,820	183
TOTAL	**25,295,200**	**74**	**3,493,290**	**282,780**	**78,380**	**204,400**	**383,780**	**80,170**	**303,610**	**508,010**	**4,391**

Table 2. Gained and lost groundwater irrigated land for July 1, 1997, through June 30, 2001, and July 1, 2001, through June 30, 2005, by Natural Resources District (from Luckey and others, 2006). Net columns may not be the same as the difference between Gained and Lost columns because the numbers were rounded to the nearest 100 acres. Likewise, Total row may not be the same as the sum of the shown numbers because of rounding. 1997 irrigated acres represents groundwater irrigated acres in the Cooperative Hydrology Study (COHYST) part of the Natural Resources District and is from Dappen and Tooze (2001). New wells are for that part of the Natural Resources District within the COHYST area.

Natural Resources District	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells
				Gained	Lost	Net	Gained	Lost	Net		
Central Platte	2,136,500	100	812,800	46,000	13,600	32,400	63,200	19,400	43,800	74,500	1,032
Little Blue	1,538,100	57	294,900	33,400	2,600	30,800	29,300	1,200	28,000	58,900	395
Lower Loup	5,092,000	11	128,000	9,400	5,600	3,900	14,400	2,100	12,300	16,100	168
Lower Republican	1,587,100	60	163,300	35,900	2,200	33,600	42,300	4,700	37,600	71,200	412
Middle Republican	2,428,100	71	192,700	35,600	6,700	28,800	53,400	12,100	41,400	71,900	243
North Platte	3,307,000	99	128,800	12,100	10,600	1,500	16,700	2,900	13,800	15,300	323
South Platte	1,661,000	100	103,800	9,500	7,600	1,900	17,500	2,600	14,900	16,700	118
Tri-Basin	971,700	100	399,400	17,300	3,200	14,000	30,300	11,100	19,100	33,200	616
Twin Platte	2,736,300	93	215,700	21,600	10,400	11,200	51,600	9,300	42,300	53,500	477
Upper Big Blue	1,830,900	58	670,800	36,800	6,200	30,600	36,500	6,600	29,900	60,500	461
Upper Loup	4,299,800	6	16,400	2,000	1,600	500	3,600	300	3,300	3,800	32
Upper Niobrara White	4,175,700	21	114,400	10,800	2,700	8,200	11,800	1,500	10,300	18,500	109
Upper Republican	1,730,500	55	252,200	12,300	5,300	7,000	13,300	6,400	6,900	13,900	6
TOTAL	**33,494,700**	**53**	**3,493,300**	**282,800**	**78,400**	**204,400**	**383,800**	**80,200**	**303,600**	**508,000**	**4,391**

Table 3. Gained and lost groundwater irrigated land for July 1, 1997, through June 30, 2001, and July 1, 2001, through June 30, 2005, inside the HCA/OA and EAA by county (from Luckey and others, 2006). Net columns may not be the same as the difference between Gained and Lost columns because the numbers were rounded to the nearest 10 acres. Likewise, Total row may not be the same as the sum of the shown numbers because of rounding. 1997 irrigated acres represents groundwater irrigated acres in the HCA/OA and EAA and is from Dappen and Tooze (2001). New wells are for that part of the county within the HCA/OA and EAA areas.

County	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells in HCA/OA and EAA
				Gained	Lost	Net	Gained	Lost	Net		
Adams	360,900	100	0	0	0	0	0	0	0	0	0
Arthur	459,400	90	0	0	0	0	0	0	0	0	0
Banner	477,300	100	21,220	1,110	1,400	-290	2,170	250	1,910	1,620	19
Box Butte	689,400	64	0	0	0	0	0	0	0	0	0
Buffalo	623,800	88	89,050	1,770	600	1,170	4,700	4,620	80	1,260	74
Butler	376,400	0	0	0	0	0	0	0	0	0	0
Chase	574,300	68	0	0	0	0	0	0	0	0	0
Cheyenne	765,200	100	17,430	1,750	1,820	-80	1,650	960	690	610	14
Clay	366,900	100	0	0	0	0	0	0	0	0	0
Custer	1,647,600	24	0	0	0	0	0	0	0	0	0
Dawson	652,000	100	50,300	9,180	180	9,000	7,290	2,270	5,030	14,020	99
Deuel	281,900	100	11,730	780	590	180	550	700	-150	30	8
Franklin	368,700	79	0	0	0	0	0	0	0	0	0
Frontier	627,000	100	270	690	0	690	0	70	-70	610	0
Furnas	461,100	22	0	0	0	0	0	0	0	0	0
Garden	1,107,100	99	15,410	2,910	1,990	920	4,070	100	3,980	4,890	31
Gosper	296,000	100	22,630	1,250	280	970	1,460	1,380	80	1,050	29
Grant	500,900	17	0	0	0	0	0	0	0	0	0
Hall	353,200	100	18,630	730	550	180	630	1,460	-830	-650	21
Hamilton	349,700	100	3,550	190	10	180	40	60	-10	160	3
Harlan	367,400	68	0	0	0	0	0	0	0	0	0
Hayes	456,400	96	0	0	0	0	0	0	0	0	0
Hitchcock	459,800	14	0	0	0	0	0	0	0	0	0
Howard	368,200	30	0	0	0	0	0	0	0	0	0
Kearney	330,200	100	71,470	2,310	960	1,350	5,420	2,240	3,190	4,540	120

Table 3 continued.

County	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells in HCA/OA and EAA
				Gained	Lost	Net	Gained	Lost	Net		
Keith	709,800	100	57,720	6,040	2,020	4,020	10,450	4,470	5,980	10,010	109
Kimball	609,100	100	13,220	1,640	900	740	1,610	300	1,310	2,050	13
Lincoln	1,647,100	100	58,200	9,250	2,410	6,840	20,080	2,500	17,580	24,420	185
Logan	365,300	75	0	0	0	0	0	0	0	0	0
McPherson	550,000	55	2,890	50	20	30	0	240	-240	-210	0
Merrick	316,200	99	11,260	220	130	90	360	60	300	390	19
Morrill	914,500	100	41,410	3,690	3,220	460	3,070	360	2,710	3,170	112
Nance	286,600	24	0	0	0	0	0	0	0	0	0
Nuckolls	368,600	96	0	0	0	0	0	0	0	0	0
Perkins	565,600	100	0	0	0	0	0	0	0	0	0
Phelps	345,900	100	94,750	2,070	460	1,610	4,490	4,180	310	1,920	221
Platte	438,100	13	0	0	0	0	0	0	0	0	0
Polk	282,100	100	0	0	0	0	0	0	0	0	0
Red Willow	459,500	38	0	0	0	0	0	0	0	0	0
Scotts Bluff	476,800	100	4,980	1,090	540	550	1,490	450	1,040	1,590	103
Sheridan	1,580,200	16	0	0	0	0	0	0	0	0	0
Sioux	1,322,600	38	3,910	460	680	-230	920	200	710	490	25
Webster	368,000	81	0	0	0	0	0	0	0	0	0
York	368,400	100	0	0	0	0	0	0	0	0	0
TOTAL	**25,295,200**	**74**	**610,040**	**47,170**	**18,770**	**28,400**	**70,460**	**26,870**	**43,590**	**72,000**	**1,205**

Table 4. Gained and lost groundwater irrigated land for July 1, 1997, through June 30, 2001, and July 1, 2001, through June 30, 2005, inside the HCA/OA and EAA by Natural Resources District (from Luckey and others, 2006). Net columns may not be the same as the difference between Gained and Lost columns because the numbers were rounded to the nearest 100 acres. Likewise, Total row may not be the same as the sum of the shown numbers because of rounding. 1997 irrigated acres represents groundwater irrigated acres in the COHYST part of Natural Resources District that is in the HCA/OA and EAA and is from Dappen and Tooze (2001). New wells are for that part of the Natural Resources District within the HCA/OA and EAA areas.

Natural Resources District	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells
				Gained	Lost	Net	Gained	Lost	Net		
Central Platte	2,136,500	100	169,500	12,300	1,500	10,800	13,000	8,500	4,500	15,300	213
Little Blue	1,538,100	57	0	0	0	0	0	0	0	0	0
Lower Loup	5,092,000	11	0	0	0	0	0	0	0	0	0
Lower Republican	1,587,100	60	0	0	0	0	0	0	0	0	0
Middle Republican	2,428,100	71	0	0	0	0	0	0	0	0	0
North Platte	3,307,000	99	86,900	9,200	7,600	1,600	11,600	1,700	9,900	11,500	290
South Platte	1,661,000	100	42,400	4,200	3,300	800	3,800	2,000	1,800	2,600	35
Tri-Basin	971,700	100	188,900	5,600	1,700	3,900	11,400	7,400	4,000	7,900	370
Twin Platte	2,736,300	93	118,800	15,400	4,500	10,900	30,500	7,200	23,400	34,300	294
Upper Big Blue	1,830,900	58	3,500	100	0	100	0	100	0	100	3
Upper Loup	4,299,800	6	0	0	0	0	0	0	0	0	0
Upper Niobrara White	4,175,700	21	0	0	0	0	0	0	0	0	0
Upper Republican	1,730,500	55	0	0	0	0	0	0	0	0	0
TOTAL	**33,494,700**	**53**	**610,000**	**46,800**	**18,700**	**28,100**	**70,300**	**26,800**	**43,600**	**71,600**	**1,205**

Table 5. Net irrigation requirements for 1997, 2001, and 2005 for each model unit (from Luckey and others, 2006).

Area	Net irrigation requirement for the year beginning May 1 (inches)		
	1997	2001	2007
Western Model Unit	15.94	15.00	15.69
Central Model Unit	11.43	9.26	7.38
Eastern Model Unit	7.80	7.70	7.72

Table 6. New net pumpage for 2001 and 2005 for each model unit (from Luckey and others, 2006).

Area	New net pumpage for the year beginning May 1 (acre-feet)	
	2001	2005
Western Model Unit	16,900	71,500
Central Model Unit	60,700	135,400
Eastern Model Unit	94,100	205,100

Table 7. Stream baseflow depletion in the Platte River basin due to gained and lost irrigated land in the Cooperative Hydrology Study area between July 1, 1997, and June 30, 2006, for each reach. Total may be different from sum of numbers because of rounding.

Date	Stream baseflow depletion, in cubic feet per second	Cumulative stream baseflow depletion, in thousands of acre-feet
Wyoming line to Kingsley Dam **A**		
Oct. 1, 2001	2.0	2
May 1, 2002	1.6	3
Oct. 1, 2007	11.5	29
May 1, 2008	7.5	33
Oct. 1, 2013	12.6	73
May 1, 2014	8.5	77
Oct. 1, 2020	13.0	127
May 1, 2021	8.7	131
Oct. 1, 2027	13.2	182
May 1, 2028	8.9	186
Oct. 1, 2037	13.4	262
May 1, 2038	9.3	266
Oct. 1, 2047	13.7	344
May 1, 2048	9.6	349
Kingsley Dam to Tri-County Supply Canal diversion **B**		
Oct. 1, 2001	5.7	5
May 1, 2002	-0.5	5
Oct. 1, 2007	10.7	24
May 1, 2008	1.7	26
Oct. 1, 2013	11.8	52
May 1, 2014	2.6	55
Oct. 1, 2020	12.4	89
May 1, 2021	3.2	91
Oct. 1, 2027	12.8	128
May 1, 2028	3.6	131
Oct. 1, 2037	13.3	188
May 1, 2038	4.2	191
Oct. 1, 2047	13.7	251
May 1, 2048	4.5	254
Tri-County Supply Canal diversion to Lexington **C**		
Oct. 1, 2001	4.2	4
May 1, 2002	-0.9	4
Oct. 1, 2007	7.8	14
May 1, 2008	-2.7	14
Oct. 1, 2013	8.4	25
May 1, 2014	-2.0	26
Oct. 1, 2020	8.6	41
May 1, 2021	-1.9	42
Oct. 1, 2027	8.9	59
May 1, 2028	-1.6	59
Oct. 1, 2037	9.4	86
May 1, 2038	-1.0	87
Oct. 1, 2047	9.7	116
May 1, 2048	-0.7	118

Date	Stream baseflow depletion, in cubic feet per second	Cumulative stream baseflow depletion, in thousands of acre-feet
Lexington to U.S. Highway 183 **D**		
Oct. 1, 2001	0.8	1
May 1, 2002	0.8	1
Oct. 1, 2007	2.3	7
May 1, 2008	2.1	8
Oct. 1, 2013	3.0	19
May 1, 2014	2.8	20
Oct. 1, 2020	3.5	35
May 1, 2021	3.3	36
Oct. 1, 2027	3.9	53
May 1, 2028	3.6	54
Oct. 1, 2037	4.3	82
May 1, 2038	4.1	84
Oct. 1, 2047	4.6	113
May 1, 2048	4.4	115
U.S. Highway 183 to Chapman **E**		
Oct. 1, 2001	1.3	1
May 1, 2002	1.2	2
Oct. 1, 2007	2.3	10
May 1, 2008	2.8	11
Oct. 1, 2013	3.2	23
May 1, 2014	3.8	24
Oct. 1, 2020	3.9	43
May 1, 2021	4.7	45
Oct. 1, 2027	4.6	67
May 1, 2028	5.5	69
Oct. 1, 2037	5.4	107
May 1, 2038	6.4	109
Oct. 1, 2047	5.9	152
May 1, 2048	7.1	154
Wyoming line to Chapman **TOTAL**		
Oct. 1, 2001	13.9	13
May 1, 2002	2.3	16
Oct. 1, 2007	34.6	84
May 1, 2008	11.3	92
Oct. 1, 2013	39.0	191
May 1, 2014	15.6	201
Oct. 1, 2020	41.5	334
May 1, 2021	18.1	345
Oct. 1, 2027	43.5	488
May 1, 2028	20.1	500
Oct. 1, 2037	45.8	725
May 1, 2038	22.8	737
Oct. 1, 2047	47.7	977
May 1, 2048	24.9	990

Table 8. Average stream baseflow depletion by Natural Resources District in the Platte River basin due to gained and lost irrigated land in the Cooperative Hydrology Study area between July 1, 1997, and June 30, 2006, for each reach. Period begins and ends May 1 of indicated year. For the purposes of this table, a year is considered to be 365 ¼ days. Total may be different from sum of numbers because of rounding.

Period	Average stream baseflow depletion by Natural Resources District (NRD), in thousands of acre-feet per year							
	North Platte NRD	South Platte NRD	Twin Platte NRD	Central Platte NRD	Tri-Basin NRD	Upper Big Blue NRD	Other NRD's	All NRD's
Wyoming line to Kingsley Dam **A**								
1998-2003	1.0	0.0	0.0	0.0	0.0	Included in Other NRD's	0.0	1.0
2003-2008	5.5	0.0	0.1	0.0	0.0		0.0	5.6
2008-2013	7.1	0.0	0.2	0.0	0.0		0.0	7.3
2013-2018	7.5	0.0	0.2	0.0	0.0		0.0	7.6
2018-2023	7.6	0.0	0.2	0.0	0.0		0.0	7.8
2023-2028	7.7	0.0	0.2	0.0	0.0		0.0	7.9
2028-2033	7.8	0.0	0.2	0.0	0.0		0.0	8.0
2033-2038	7.9	0.1	0.2	0.0	0.0		0.0	8.1
2038-2043	7.9	0.1	0.2	0.0	0.0		0.0	8.2
2043-2048	8.0	0.1	0.2	0.0	0.0		0.0	8.3
Kingsley Dam to Tri-County Supply Canal diversion **B**								
1998-2003	0.0	0.1	1.5	0.0	0.0	Included in Other NRD's	0.0	1.6
2003-2008	0.0	0.1	3.7	0.0	0.0		0.0	3.8
2008-2013	0.0	0.1	4.7	0.0	0.0		0.0	4.8
2013-2018	0.0	0.2	5.1	0.0	0.0		0.0	5.3
2018-2023	0.0	0.2	5.4	0.0	0.0		0.1	5.7
2023-2028	0.0	0.3	5.5	0.0	0.0		0.1	6.0
2028-2033	0.0	0.3	5.7	0.0	0.0		0.2	6.2
2033-2038	0.0	0.4	5.8	0.0	0.0		0.2	6.5
2038-2043	0.0	0.5	5.9	0.0	0.0		0.3	6.7
2043-2048	0.0	0.5	6.0	0.0	0.0		0.3	6.9
Tri-County Supply Canal diversion to Lexington **C**								
1998-2003	0.0	0.0	0.6	0.5	0.0	Included in Other NRD's	0.0	1.1
2003-2008	0.0	0.0	1.1	0.5	0.1		0.0	1.7
2008-2013	0.0	0.0	1.2	0.5	0.1		0.0	1.9
2013-2018	0.0	0.0	1.4	0.7	0.2		0.0	2.3
2018-2023	0.0	0.0	1.4	0.8	0.2		0.1	2.4
2023-2028	0.0	0.0	1.3	0.8	0.2		0.1	2.5
2028-2033	0.0	0.0	1.4	0.9	0.2		0.2	2.7
2033-2038	0.0	0.0	1.4	0.9	0.3		0.2	2.8
2038-2043	0.0	0.0	1.5	1.0	0.3		0.3	3.0
2043-2048	0.0	0.0	1.5	1.0	0.3		0.3	3.1

Table 8 continued.

Period	Average stream baseflow depletion by Natural Resources District (NRD), in thousands of acre-feet per year							
	North Platte NRD	South Platte NRD	Twin Platte NRD	Central Platte NRD	Tri-Basin NRD	Upper Big Blue NRD	Other NRD's	All NRD's
Lexington to U.S. Highway 183 **D**								
1998-2003	0.0	0.0	0.0	0.1	0.3	Included in Other NRD's	0.0	0.4
2003-2008	0.0	0.0	0.0	0.5	0.8		0.0	1.3
2008-2013	0.0	0.0	0.0	0.6	1.3		0.0	1.9
2013-2018	0.0	0.0	0.0	0.7	1.5		0.0	2.2
2018-2023	0.0	0.0	0.0	0.7	1.7		0.0	2.5
2023-2028	0.0	0.0	0.0	0.8	1.9		0.0	2.7
2028-2033	0.0	0.0	0.0	0.8	2.0		0.0	2.8
2033-2038	0.0	0.0	0.0	0.8	2.1		0.1	3.0
2038-2043	0.0	0.0	0.0	0.9	2.2		0.1	3.1
2043-2048	0.0	0.0	0.0	0.9	2.2		0.1	3.2
U.S. Highway 183 to Chapman **E**								
1998-2003	0.0	0.0	0.0	0.4	0.2	Included in Other NRD's	0.0	0.6
2003-2008	0.0	0.0	0.0	0.8	0.7		0.1	1.5
2008-2013	0.0	0.0	0.0	1.0	1.1		0.2	2.2
2013-2018	0.0	0.0	0.0	1.1	1.4		0.2	2.7
2018-2023	0.0	0.0	0.0	1.2	1.7		0.3	3.2
2023-2028	0.0	0.0	0.0	1.3	1.9		0.4	3.6
2028-2033	0.0	0.0	0.0	1.3	2.1		0.5	3.9
2033-2038	0.0	0.0	0.0	1.4	2.2		0.6	4.2
2038-2043	0.0	0.0	0.0	1.4	2.4		0.6	4.4
2043-2048	0.0	0.0	0.0	1.5	2.5		0.7	4.6
Wyoming line to Chapman **TOTAL**								
1998-2003	1.0	0.1	2.1	1.0	0.5	Included in Other NRD's	0.0	4.7
2003-2008	5.5	0.1	4.9	1.7	1.5		0.1	13.8
2008-2013	7.1	0.1	6.0	2.0	2.4		0.2	17.9
2013-2018	7.5	0.2	6.7	2.5	3.1		0.3	20.2
2018-2023	7.6	0.2	6.9	2.7	3.6		0.5	21.6
2023-2028	7.7	0.3	7.0	2.9	4.0		0.7	22.6
2028-2033	7.8	0.4	7.2	3.0	4.3		0.9	23.6
2033-2038	7.9	0.5	7.4	3.1	4.6		1.1	24.6
2038-2043	7.9	0.6	7.6	3.3	4.8		1.3	25.4
2043-2048	8.0	0.7	7.7	3.4	5.0		1.5	26.2

Table 9. Stream baseflow depletion in the Platte River basin due to gained and lost irrigated land in Hydrologically Connected Area of the Overappropriated Basin and the Eastern Analysis Area between July 1, 1997, and June 30, 2006, for each reach. Total may be different from sum of numbers because of rounding.

Date	Stream baseflow depletion, in cubic feet per second	Cumulative stream baseflow depletion, in thousands of acre-feet
Wyoming line to Kingsley Dam **A**		
Oct. 1, 2001	2.0	2
May 1, 2002	1.7	3
Oct. 1, 2007	11.5	29
May 1, 2008	7.6	33
Oct. 1, 2013	12.7	73
May 1, 2014	8.5	77
Oct. 1, 2020	13.0	127
May 1, 2021	8.8	131
Oct. 1, 2027	13.1	182
May 1, 2028	8.9	187
Oct. 1, 2037	13.3	262
May 1, 2038	9.1	266
Oct. 1, 2047	13.4	343
May 1, 2048	9.3	347
Kingsley Dam to Tri-County Supply Canal diversion **B**		
Oct. 1, 2001	5.7	5
May 1, 2002	-0.5	5
Oct. 1, 2007	10.5	24
May 1, 2008	1.4	25
Oct. 1, 2013	11.2	50
May 1, 2014	2.0	52
Oct. 1, 2020	11.6	83
May 1, 2021	2.4	86
Oct. 1, 2027	11.8	118
May 1, 2028	2.6	120
Oct. 1, 2037	11.9	169
May 1, 2038	2.8	171
Oct. 1, 2047	12.0	220
May 1, 2048	2.8	223
Tri-County Supply Canal diversion to Lexington **C**		
Oct. 1, 2001	4.1	4
May 1, 2002	-0.7	4
Oct. 1, 2007	7.8	14
May 1, 2008	-2.4	14
Oct. 1, 2013	8.2	26
May 1, 2014	-1.9	26
Oct. 1, 2020	8.4	41
May 1, 2021	-1.8	42
Oct. 1, 2027	8.3	57
May 1, 2028	-1.9	57
Oct. 1, 2037	8.5	79
May 1, 2038	-1.7	80
Oct. 1, 2047	8.5	103
May 1, 2048	-1.7	104
Lexington to U.S. Highway 183 **D**		
Oct. 1, 2001	0.7	1
May 1, 2002	0.7	1
Oct. 1, 2007	2.1	7
May 1, 2008	1.9	8
Oct. 1, 2013	2.7	17
May 1, 2014	2.5	18
Oct. 1, 2020	3.1	31
May 1, 2021	2.8	32
Oct. 1, 2027	3.4	47
May 1, 2028	3.1	48
Oct. 1, 2037	3.6	71
May 1, 2038	3.3	73
Oct. 1, 2047	3.7	97
May 1, 2048	3.5	98
U.S. Highway 183 to Chapman **E**		
Oct. 1, 2001	1.2	1
May 1, 2002	1.1	2
Oct. 1, 2007	1.8	8
May 1, 2008	2.3	9
Oct. 1, 2013	2.5	19
May 1, 2014	3.1	20
Oct. 1, 2020	3.0	35
May 1, 2021	3.7	36
Oct. 1, 2027	3.4	53
May 1, 2028	4.1	54
Oct. 1, 2037	3.8	82
May 1, 2038	4.5	83
Oct. 1, 2047	4.0	113
May 1, 2048	4.7	115
Wyoming line to Chapman **TOTAL**		
Oct. 1, 2001	13.7	13
May 1, 2002	2.3	15
Oct. 1, 2007	33.7	82
May 1, 2008	10.8	90
Oct. 1, 2013	37.3	184
May 1, 2014	14.1	194
Oct. 1, 2020	39.2	317
May 1, 2021	15.9	327
Oct. 1, 2027	40.0	457
May 1, 2028	16.7	467
Oct. 1, 2037	41.0	663
May 1, 2038	17.9	673
Oct. 1, 2047	41.7	876
May 1, 2048	18.7	887

Table 10. Average stream baseflow depletion by Natural Resources District in the Platte River basin due to gained and lost irrigated land in the Hydrologically Connected Area of the Overappropriated Basin and the Eastern Analysis Area between July 1, 1997, and June 30, 2006. Period begins and ends May 1 of indicated year. For the purposes of this table, a year is considered to be 365 ¼ days. Total may be different from sum of numbers because of rounding.

Period	Average stream baseflow depletion by Natural Resources District (NRD), in thousands of acre-feet per year							
	North Platte NRD	South Platte NRD	Twin Platte NRD	Central Platte NRD	Tri-Basin NRD	Upper Big Blue NRD	Other NRD's	All NRD's
Wyoming line to Kingsley Dam **A**								
1998-2003	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
2003-2008	5.5	0.0	0.1	0.0	0.0	0.0	0.0	5.6
2008-2013	7.2	0.0	0.2	0.0	0.0	0.0	0.0	7.3
2013-2018	7.5	0.0	0.2	0.0	0.0	0.0	0.0	7.7
2018-2023	7.7	0.0	0.2	0.0	0.0	0.0	0.0	7.8
2023-2028	7.7	0.0	0.2	0.0	0.0	0.0	0.0	7.9
2028-2033	7.8	0.0	0.2	0.0	0.0	0.0	0.0	7.9
2033-2038	7.8	0.0	0.2	0.0	0.0	0.0	0.0	8.0
2038-2043	7.9	0.0	0.2	0.0	0.0	0.0	0.0	8.1
2043-2048	7.9	0.0	0.2	0.0	0.0	0.0	0.0	8.1
Kingsley Dam to Tri-County Supply Canal diversion **B**								
1998-2003	0.0	0.1	1.5	0.0	0.0	0.0	0.0	1.6
2003-2008	0.0	0.1	3.6	0.0	0.0	0.0	0.0	3.7
2008-2013	0.0	0.1	4.4	0.0	0.0	0.0	0.0	4.5
2013-2018	0.0	0.1	4.7	0.0	0.0	0.0	0.0	4.8
2018-2023	0.0	0.1	4.9	0.0	0.0	0.0	0.0	5.0
2023-2028	0.0	0.2	5.0	0.0	0.0	0.0	0.0	5.1
2028-2033	0.0	0.2	5.1	0.0	0.0	0.0	0.0	5.2
2033-2038	0.0	0.2	5.1	0.0	0.0	0.0	0.0	5.3
2038-2043	0.0	0.2	5.2	0.0	0.0	0.0	0.0	5.4
2043-2048	0.0	0.3	5.2	0.0	0.0	0.0	0.0	5.4
Tri-County Supply Canal diversion to Lexington **C**								
1998-2003	0.0	0.0	0.6	0.5	0.0	0.0	0.0	1.1
2003-2008	0.0	0.0	1.1	0.6	0.1	0.0	0.0	1.8
2008-2013	0.0	0.0	1.1	0.6	0.1	0.0	0.0	1.9
2013-2018	0.0	0.0	1.3	0.7	0.1	0.0	0.0	2.2
2018-2023	0.0	0.0	1.3	0.7	0.2	0.0	0.0	2.3
2023-2028	0.0	0.0	1.2	0.8	0.2	0.0	0.0	2.2
2028-2033	0.0	0.0	1.2	0.8	0.2	0.0	0.0	2.2
2033-2038	0.0	0.0	1.3	0.8	0.2	0.0	0.0	2.3
2038-2043	0.0	0.0	1.3	0.8	0.2	0.0	0.0	2.3
2043-2048	0.0	0.0	1.3	0.8	0.2	0.0	0.0	2.4

Table 10 continued.

Period	Average stream baseflow depletion by Natural Resources District (NRD), in thousands of acre-feet per year							
	North Platte NRD	South Platte NRD	Twin Platte NRD	Central Platte NRD	Tri-Basin NRD	Upper Big Blue NRD	Other NRD's	All NRD's
Lexington to U.S. Highway 183 **D**								
1998-2003	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.4
2003-2008	0.0	0.0	0.0	0.4	0.8	0.0	0.0	1.2
2008-2013	0.0	0.0	0.0	0.5	1.2	0.0	0.0	1.7
2013-2018	0.0	0.0	0.0	0.5	1.4	0.0	0.0	2.0
2018-2023	0.0	0.0	0.0	0.6	1.6	0.0	0.0	2.2
2023-2028	0.0	0.0	0.0	0.6	1.7	0.0	0.0	2.3
2028-2033	0.0	0.0	0.0	0.6	1.8	0.0	0.0	2.4
2033-2038	0.0	0.0	0.0	0.6	1.9	0.0	0.0	2.5
2038-2043	0.0	0.0	0.0	0.6	1.9	0.0	0.0	2.5
2043-2048	0.0	0.0	0.0	0.6	2.0	0.0	0.0	2.6
U.S. Highway 183 to Chapman **E**								
1998-2003	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.5
2003-2008	0.0	0.0	0.0	0.6	0.7	0.0	0.0	1.3
2008-2013	0.0	0.0	0.0	0.7	1.0	0.0	0.0	1.8
2013-2018	0.0	0.0	0.0	0.8	1.3	0.0	0.0	2.2
2018-2023	0.0	0.0	0.0	0.8	1.6	0.0	0.0	2.4
2023-2028	0.0	0.0	0.0	0.9	1.7	0.0	0.0	2.7
2028-2033	0.0	0.0	0.0	0.9	1.9	0.0	0.0	2.8
2033-2038	0.0	0.0	0.0	0.9	2.0	0.0	0.0	3.0
2038-2043	0.0	0.0	0.0	0.9	2.1	0.0	0.0	3.1
2043-2048	0.0	0.0	0.0	1.0	2.2	0.0	0.0	3.2
Wyoming line to Chapman **TOTAL**								
1998-2003	1.0	0.0	2.1	0.9	0.5	0.0	0.0	4.5
2003-2008	5.5	0.1	4.8	1.6	1.5	0.0	0.0	13.5
2008-2013	7.2	0.1	5.7	1.8	2.4	0.0	0.0	17.2
2013-2018	7.5	0.1	6.2	2.0	2.9	0.0	0.0	18.8
2018-2023	7.7	0.2	6.4	2.1	3.3	0.0	0.0	19.7
2023-2028	7.7	0.2	6.4	2.2	3.7	0.0	0.0	20.2
2028-2033	7.8	0.2	6.5	2.3	3.9	0.0	0.0	20.7
2033-2038	7.8	0.2	6.6	2.3	4.1	0.0	0.0	21.1
2038-2043	7.9	0.2	6.6	2.4	4.2	0.0	0.0	21.4
2043-2048	7.9	0.2	6.7	2.4	4.4	0.0	0.0	21.6