2019

Upper Platte Basin Robust Review

A REPORT ON MANAGEMENT ACTIVITIES AIMED AT FULFILLING THE GOALS AND OBJECTIVES OF THE UPPER PLATTE BASIN-WIDE PLAN, THE UPPER PLATTE BASIN INDIVIDUAL NRD IMPS, AND THE NEBRASKA NEW DEPLETIONS PLAN

Preface

The Nebraska Department of Natural Resources (NeDNR), working in conjunction with the five Upper Platte River Basin natural resources districts (Upper Platte Basin NRDs) through the Platte Overappropriated Area Committee (POAC), have published this report to provide an update on management activities aimed at fulfilling the goals and objectives of the *Basin-Wide Plan for Joint Integrated Water Resources Management of Overappropriated Portions of the Platte River Basin, Nebraska* (BWP); NRD-level integrated management plans (IMPs); and the Nebraska New Depletion Plan (NNDP) for the Platte River Recovery Implementation Program (PRRIP). This report is a comprehensive update to the report, *Estimated Stream Baseflow Depletions by Natural Resources District in Nebraska Platte Basin due to Gained or Lost Groundwater Irrigated Land after July 1, 1997* (Luckey, 2008), and reports provided to the PRRIP Governance Committee; and synthesizes the various activities (controls, regulations, incentives, new permits, unpermitted activities, and projects) that have been completed through 2013 during the first increment of the BWP. NeDNR and the Upper Platte Basin NRDs have developed and submitted a number of annual reports and updates in support of the BWP and NNDP implementation, and this evaluation is provided as a means of summarizing the combined outcomes of those activities through a "robust review." Detailed technical reports, memos, and supporting documentation describing further details of specific components of the analyses are included in Appendix A. The results of the robust review serve as the basis for establishing second increment (September 2019 to September 2029) goals and objectives that are included in the updated BWP and IMPs.

INTRODUCTION

NeDNR and the Upper Platte Basin NRDs adopted the first increment BWP and NRD-specific IMPs in 2009. Those plans contain a number of goals and objectives, chief among them are those related to addressing depletions in Upper Platte River streamflow due to new water uses developed after July 1, 1997. NeDNR and the Upper Platte Basin NRDs have carried out a number of controls and management actions to support the implementation of those goals and objectives. The NeDNR and Upper Platte Basin NRDs, in coordination with basin stakeholders, developed and updated a number of datasets and models to support the evaluation of first increment activities through 2013. Foremost among those updates were efforts to refine groundwater models, develop surface water operations models, and extend land use datasets, which were used as the primary tools to conduct this "robust review" evaluation.

This evaluation provides summarized estimates of the streamflow impacts resulting from increases or decreases in irrigated acres, controls (allocations and transfers), increases or decreases in municipal and industrial uses, managed recharge, stream augmentation, and permitted uses. Additional evaluations of unpermitted uses (e.g., sand and gravel mining operations, small reservoirs [less than 15 acre-feet in storage capacity], livestock uses, and small-scale domestic uses) were also conducted through the first increment. This report is a synthesis of all of these efforts, and also provides summarized updates of new targets that will be used to guide second increment planning goals and objectives.

A series of detailed technical memos and model reports containing further documentation and data are listed in Appendix A. The reader is referred to those technical memos and reports for details regarding the specifics of each model and evaluation component. The projections of future streamflow impacts will be reviewed and updated through the course of the second increment, with future evaluations guiding any necessary refinements and modifications to the planning goals, objectives, actions, and controls.

This evaluation represents the best data and information currently available for evaluating progress in achieving first increment goals and objectives, and for establishing second increment goals and objectives outlined in the planning documents. Various modeling and data updates are expected to be completed in the second increment, which may modify the results presented in this report. Furthermore, the technical memos listed in Appendix A outline specific limitations that may be associated with each analysis. Examples of limitations associated with the analyses include:

1) In the COHYST model, future projections are based on 2013 groundwater irrigated acres data, with the exception of temporary retirements, which were reincorporated into subsequent years until the retirements terminated. In the WWUM model, future projections are based on repeated 2009-2013 groundwater irrigated acres and metered pumping data;
2) Crop type data are held constant based on the distribution available in 2010 for the COHYST model, and repeating 2009-2013 crop typing data in the WWUM model;
3) Conservation measures, primarily tillage practices, may not fully reflect present-day practices and associated water supply benefits;
4) Management actions implemented after 2013 are excluded, including N-CORPE operations and conjunctive management operations in Central Platte NRD;
5) Water budget changes associated with modeled changes in on-field runoff have not been incorporated into the new depletions estimates;

6) Groundwater pumping in certain portions of the groundwater models is estimated and may be refined with the collection of measurement data;
7) Certain model areas exhibit dry cells that may limit the incorporation of pumping and recharge changes;
8) The regional nature of the models may not appropriately express the degree of connection between aquifers and streams for capturing smaller scale management actions;
9) Streamflow routing of runoff and diversions were not included and may warrant further evaluation of the impacts on results; and
10) Future projections are based on a single, repeating historical climate scenario and may not be representative of future climate conditions.

NeDNR and the Upper Platte Basin NRDs will continue to work to address these limitations through the second increment, and update the robust review as limitations are evaluated in the future.

Evaluation Procedures and Data

A broad description of this evaluation process is contained within each of the Upper Platte Basin NRDs' IMPs. This evaluation process serves to supplement and refine reviews conducted by NeDNR and each NRD on an annual basis. The IMPs require that a "robust review" is conducted to evaluate the progress made toward achieving the goals and objectives of each IMP for the first ten (10) year increment. The robust review process is described below.

Excerpt from the Twin Platte NRD's IMP:

(i) *The ground water models used for this process will be calibrated to baseflows and ground water levels in the area with sufficient temporal variability to assess the impacts on a monthly basis. The ground water models will be updated periodically to simulate the management practices that have been implemented to date. The evaluation period of these models will be 1998 through 2048 (fifty years).*

(ii) *The following two ground water model runs will be conducted to measure the success toward reaching the objectives of Goal I.A.1.a and Goal I.A.2.a:*

(ii.a.) The 1997 Development Level Run - A model run which simulates the number of irrigated acres in 1997 and the associated crop mix. It will incorporate the full crop irrigation requirement for the 1997 crop mix. This model run will serve as the baseline to which the evaluation run will be compared. The run will be conducted using data through the current date and will include an update from the current date through the year 2048 (fifty years into the future).

(ii.b.) The Evaluation Run - A model run which simulates the annual changes between the irrigated acres throughout the evaluation period and the irrigated acres in 1997. The model will use available flow meter data or, in the absence of flow meter data, assume the full crop irrigation requirement. The run will be conducted using data through the

current date and will include an update from the current date through the year 2048 (fifty years).

(ii.c.) Difference between the Evaluation Run and the 1997 Run - The simulated baseflow output from each model run will be compared to determine the difference.

(ii.d.) Surface Water Accretions and Other Uses not Covered by the Model - If surface water acres are retired to offset streamflow depletions due to new uses begun subsequent to July 1, 1997, accretions resulting from those retirements will be determined using agreed upon methodologies.

(ii.e.) Evaluation Results - For the first ten (10) year increment to be considered achieved, the results of combining the difference between the evaluation run and the 1997 development level run with the addition of surface water accretions and other uses not covered by the model will be less than or equal to zero. See the following equation.

(baseflow from the Evaluation Run) - (baseflow from the 1997 Development Level Run) + (Surface Water Accretions) = Net Depletions

This broad description of the evaluation process serves as the guidance under which the various data sets were developed and models simulated. Within this report, the Evaluation Run referenced in the IMP will be referred to as the **Historical Run** because it simulates historical development and management actions; and the 1997 Development Level Run will be referred to as the **1997 Development Run**. The post-1997 streamflow impacts referred to in this report are the depletions and accretions calculated as the difference in the baseflow between the Historical Run and baseflow in the 1997 Development Run (Net Depletions from the referenced IMP). Further details of the specific evaluation processes are contained in the POAC's detailed scope of work that supported completion of these evaluations for each NRD. Additional evaluations have been made through the first increment to determine the impacts of unpermitted activities (e.g., sand and gravel mining operations, small reservoirs [less than 15 acre-feet in storage capacity], livestock uses, and small-scale domestic uses). The results of those analyses were not updated as part of this evaluation, but those reports are included within Appendix A for reference.

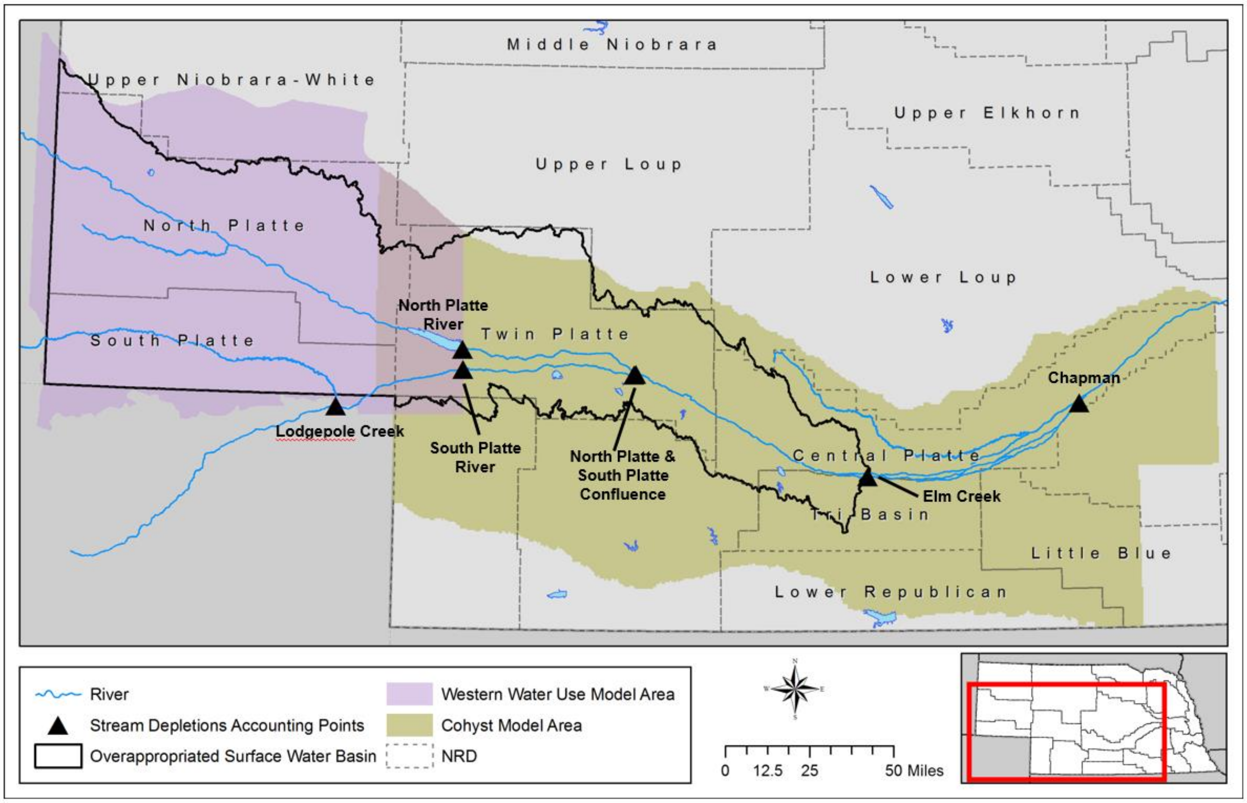

Figure 1. Upper Platte River Basin NRDs, Overappropriated Basin, accounting points, and model domains.

RESULTS

Previous analyses have been conducted throughout the first increment to evaluate compliance with IMP related triggers and the NNDP. Table 1 summarizes the most recent evaluation provided to the PRRIP Governance Committee on April 21, 2017, of the overall impacts to Upper Platte River streamflow resulting from depletive activities and mitigation measures, including all post-1997 new or expanded uses. The results of the 2017 evaluation indicated compliance with NNDP requirements and noted that the evaluation would be updated as part of this robust review.

The results of the robust review evaluation represent the impacts to streams in the Upper Platte River system (e.g., North Platte River, South Platte River, Lodgepole Creek, and the Platte River) and their extents within the Overappropriated Basin and/or upstream of Chapman, NE (Figure 1). The Overappropriated Basin (upstream of Kearney Canal Diversion) is an administrative area established by NeDNR and has significance within the context of Nebraska state law. The Upper Platte Basin upstream of Chapman, NE, is used as the reporting area for the NNDP because it represents the downstream end of the PRRIP Critical Habitat Reach. Analyses of groundwater pumping activities and their impacts to streamflow were conducted for each of the Upper Platte Basin NRDs. An additional analysis was conducted to evaluate the streamflow impacts caused by groundwater pumping changes in NRDs that are located outside of the Upper Platte Basin, but within the extent of the groundwater modeling domains.

Changes in groundwater irrigated acres and crop types subsequent to July 1, 1997, were identified through a variety of techniques, as described in Appendix A. Table 2 illustrates the total number of groundwater-only irrigated acres within each NRD for the years 1997, 2005, 2013, and 2023. Acres values were maintained at constant levels after 2013 in the COHYST model, with the exception of temporary retirements that were reincorporated into subsequent years until the retirements terminated. In the WWUM model, groundwater-only irrigated acres values repeated data from 2009-2013. Table 3 illustrates the changes in groundwater-only irrigated acres relative to 1997 levels of groundwater-only irrigated acres in each NRD.

Figures 2 through6 display the average annual change in net recharge by NRD, accounting for changes in groundwater-only irrigation pumping and related changes in recharge, and changes in municipal and industrial pumping, for the period 2014 – 2063. The average change in net recharge in the COHYST model area is based on 2013 land use conditions (with temporary retirements lapsing after 2023) with variable, but repeating, future climate conditions. In the WWUM model area, the average change in net recharge is based on the average of the repeating 2009-2013 land use data, 2009-2013 metered pumping data, and variable, but repeating, future climate conditions. Red areas indicate conditions where net recharge has decreased (increased withdrawal from the aquifer relative to 1997 conditions) and areas in blue indicate conditions where net recharge increased (decreased withdrawal from aquifer relative to 1997 conditions). Water budget data, including recharge, groundwater irrigation pumping, municipal and industrial groundwater pumping, and net recharge within each NRD area, are summarized in Tables 4 through 8.

The results of the groundwater modeling evaluation of impacts on streamflow due to post-1997 activities (post-1997 streamflow impacts) are summarized in Figures 7 through 22. In the figures, positive results represent accretions to streamflow and negative results represent depletions to streamflow. The results summarize the impacts (increase or decrease in streamflow relative to 1997 levels of development) based on changes within each of the Upper Platte Basin NRDs. In addition, Figure 23 depicts the impact to streamflow in the Upper Platte River Basin due to groundwater-only irrigation and municipal and industrial water uses in the areas that are outside of the five Upper Platte Basin NRDs, but within the modeling domain. Figure 24 shows the combined impact to streamflow due to changes within the five Upper Platte Basin NRDs, relative to 1997 levels of development; as well as the combined impact to streamflow due to changes in the modeled area, including areas within and outside of the Upper Platte Basin NRD's. The five stream reaches used in the analysis include: 1) Lodgepole Creek; 2) North Platte River; 3) South Platte River; 4) Platte River between the North Platte and South Platte confluence and Elm Creek; and 5) Platte River between Elm Creek and Chapman.

The results of the groundwater modeling evaluation have been combined with the results from evaluations of other post-1997 activities, such as permanent surface water retirements and augmentation pumping, to illustrate the total net streamflow impact for each Upper Platte Basin NRD. The streamflow impacts for the period 2014-2063 are modeled based on assumptions of a representative climate without additional management actions or changes in land use incorporated after 2013. Figures 7 through 22 include graphs with a linear fit applied to the modeled depletion values from 2014-2063 to illustrate a 50-year trend. The inter-annual variability of modeled streamflow impacts for 2014-2063 is shown as a band of the maximum residual, or difference between the modeled data and trend. The modeled streamflow impacts are not exactly periodic along the trend despite having explicit period climate inputs and constant land use. This result is primarily due to the inclusion of all management actions in the analysis prior to 2013 and discontinuing many of those management actions in the future projection (2014-2063). An additional summary of the annual estimates based on the linear trend is provided for the period 2019-2029 in Tables 9 through 13. The annual values contained in Tables 9 through 13 will be used to support second increment IMP planning goals, objectives, actions, and controls.

A variety of new outcomes can be observed within this evaluation. First, the results for both the North Platte NRD and South Platte NRD indicate that post-1997 depletions have been mitigated and the net effect of post-1997 activities, including regulatory limits on groundwater irrigation withdrawals (allocations), have had a significant positive impact to streamflow. Second, updates to modeling methods and data developed by COHYST have resulted in significant increases in groundwater depletion estimates associated with post-1997 groundwater irrigation development in the Twin Platte NRD and Central Platte NRD. This change was primarily the result of work performed on the COHYST model to address previously noted limitations outlined in the Luckey (2008) report. Third, management actions taken to recharge and retime excess flows have had positive impacts on streamflow throughout the Basin. Fourth, crop type conversions in certain areas of the Basin, most notably eastern portions of the Central Platte NRD and the Tri-Basin NRD, have trended toward lower consumption (corn to soybean conversions) through the period of this evaluation. Fifth, the impacts from groundwater pumping changes outside of the Upper Platte River Basin NRDs are projected to be positive (accretions) through the second increment (Table 14) and no additional mitigation is required at this time. Finally, the overall results (Table 15) indicate that significant progress has been made in the first increment toward addressing groundwater depletions, but that additional actions will be required in certain NRDs to meet second increment goals.

Summary

NeDNR and the Upper Platte Basin NRDs have worked extensively through the course of the first increment to implement a variety of actions in accordance with in each NRD's respective IMP, as well as the Upper Platte's BWP. Those actions have included a variety of regulatory and non-regulatory management actions aimed at addressing streamflow depletions associated with post-1997 activities. Additionally, NeDNR and the Upper Platte Basin NRDs have made considerable efforts to update the datasets and models used to evaluate progress toward meeting key IMP goals and objectives. The results of this robust review indicate that key first increment goals and objectives related to addressing post-1997 depletions were met in many areas, but that additional efforts will be necessary to address updated post-1997 depletions targets in the second increment.

A number of limitations associated with this analysis have been identified. Efforts will continue to be made toward refining the models, datasets, and methods used through the course of this evaluation to support future updates and address limitations. The NeDNR and Upper Platte Basin NRDs will continue to evaluate the impacts that increased field-level conservation practices and irrigation efficiencies may have on future evaluations. Landuse information will continue to be updated and refined, along with continued incorporation of metered and measured water use data to support updates reflective of various NRD management efforts. The integration of these activities will be noted when incorporated into future robust review evaluations. Unpermitted activities such as sand pits, small reservoirs, livestock uses, and non-municipal domestic uses have been previously evaluated and results indicate that these activities have not had an overall negative impact and are not projected to have an overall negative impact in the second increment. Efforts to further update and track details associated with unpermitted activities will be limited in the second increment. Municipal and industrial uses will continue to be tracked and incorporated into future updates.

Many planning goals and objectives in the Upper Platte River Basin will be refined as a result of this robust review. The IMPs of NRDs for which this evaluation indicated post-1997 depletions remain to be offset will contain goals and objectives aimed at ensuring that those depletions are addressed through the course of the second increment. The IMPs of NRDs for which this evaluation indicated post-1997 depletions have been addressed will continue to monitor those outcomes and use available resources to maintain the progress that has been made to date. The Twin Platte NRD will begin the use of the N-CORPE project at the beginning of the second increment to provide up to 5,600 acre-feet of annual depletion mitigation through the second increment. This project, in conjunction with other activities, will be implemented by the Twin Platte NRD to incrementally address remaining post-1997 groundwater depletions by the end of the second increment. The Central Platte NRD plans to use conjunctive management projects and other management actions to address remaining post-1997 groundwater depletions by the end of the second increment. Accretions resulting from the progress made by the other three NRDs will be used to bridge any remaining gap between post-1997 depletions and mitigation measures that are necessary to meet the terms of the NNDP. In all Upper Platte NRD's, it is acknowledged that when implementing or assessing management actions outlined in the IMPs, NeDNR and the NRDs need to consider when and where depletions occur and how they may impact current water users, as well as state-protected or PRRIP target flows. The NeDNR and NRDs will continue to provide annual reports and updates at the annual Upper Platte River BWP meetings and through the annual reports provided to PRRIP.

CHANGE IN NET RECHARGE FIGURES

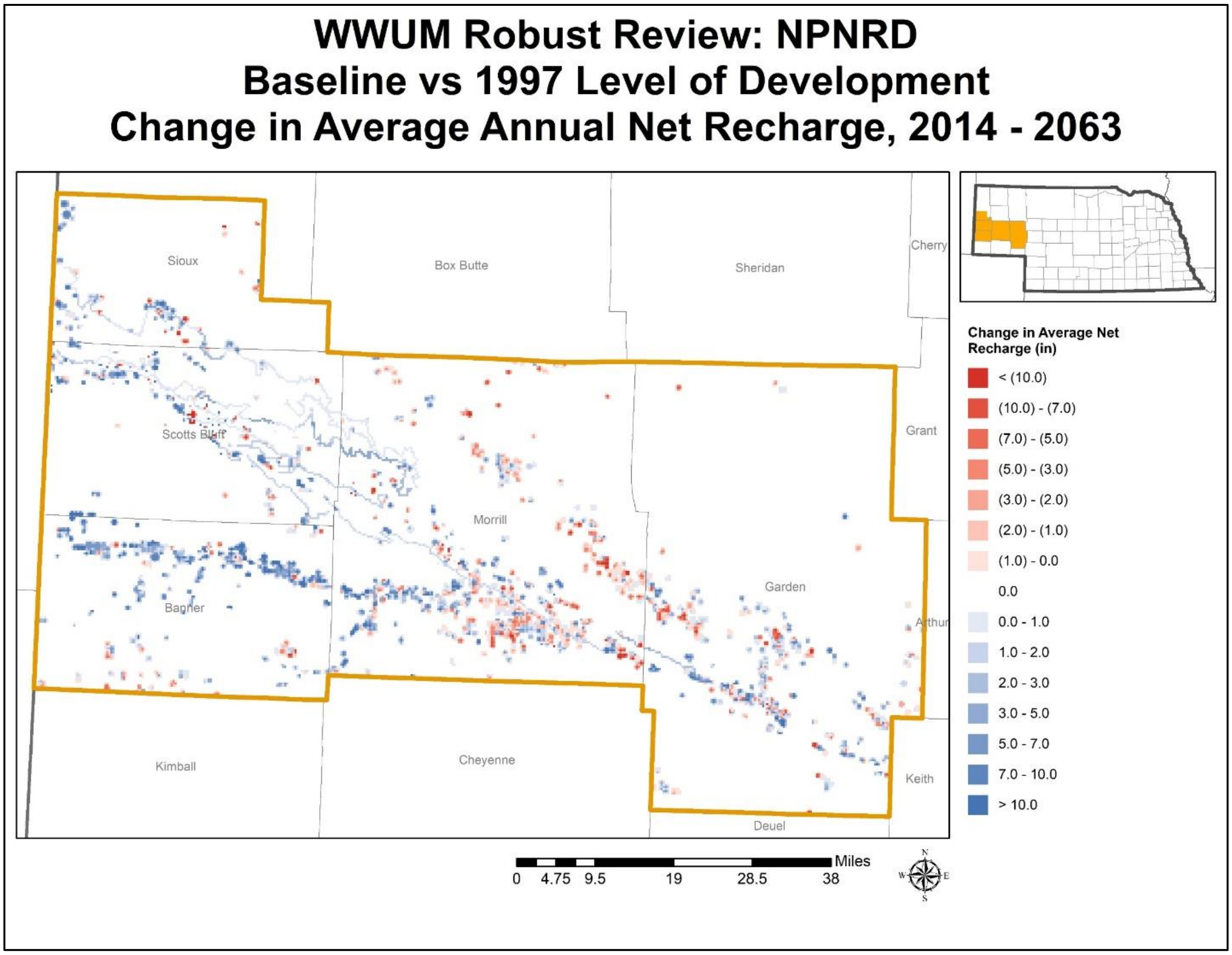

Figure 2. Historical Run minus 1997 Development Run. Change in average net recharge including change in M&I pumping from 2014 – 2063 within NPNRD.

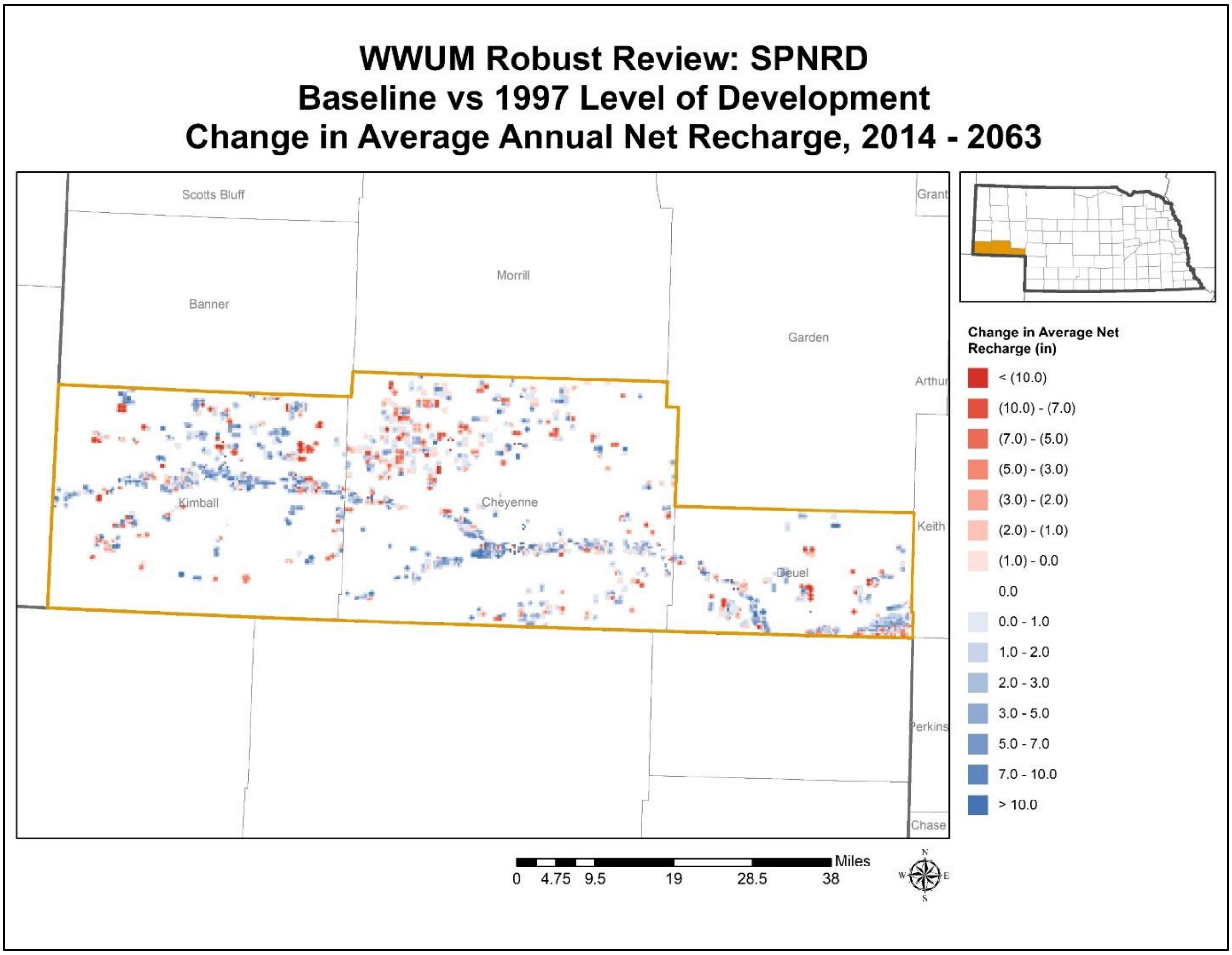

Figure 3. Historical Run minus 1997 Development Run. Change in average net recharge including change in M&I pumping from 2014 – 2063 within SPNRD.

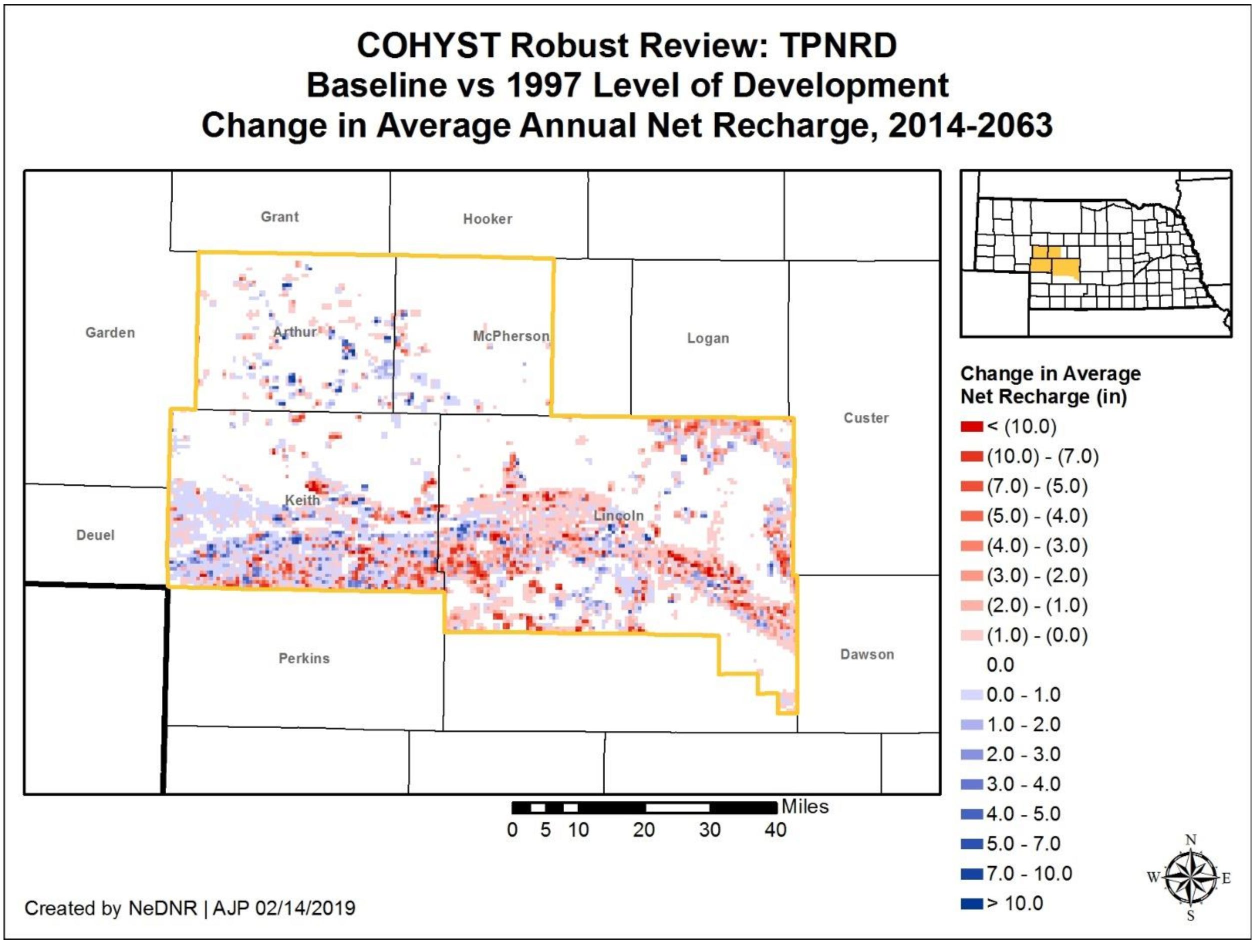

Figure 4. Historical Run minus 1997 Development Run. Change in average net recharge including change in M&I pumping from 2014 – 2063 within TPNRD.

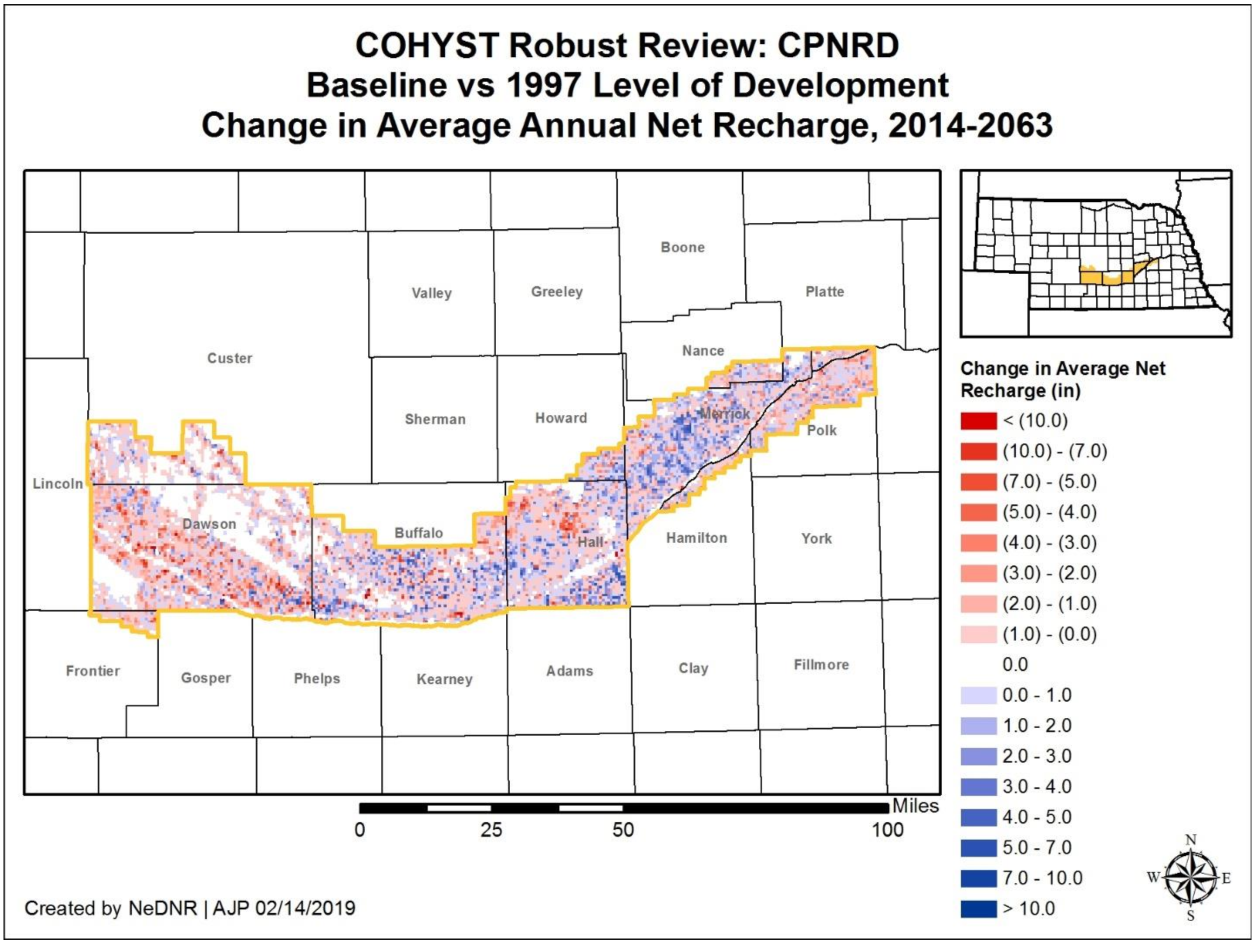

Figure 5. Historical Run minus 1997 Development Run. Change in average net recharge including change in M&I pumping from 2014 – 2063 within CPNRD.

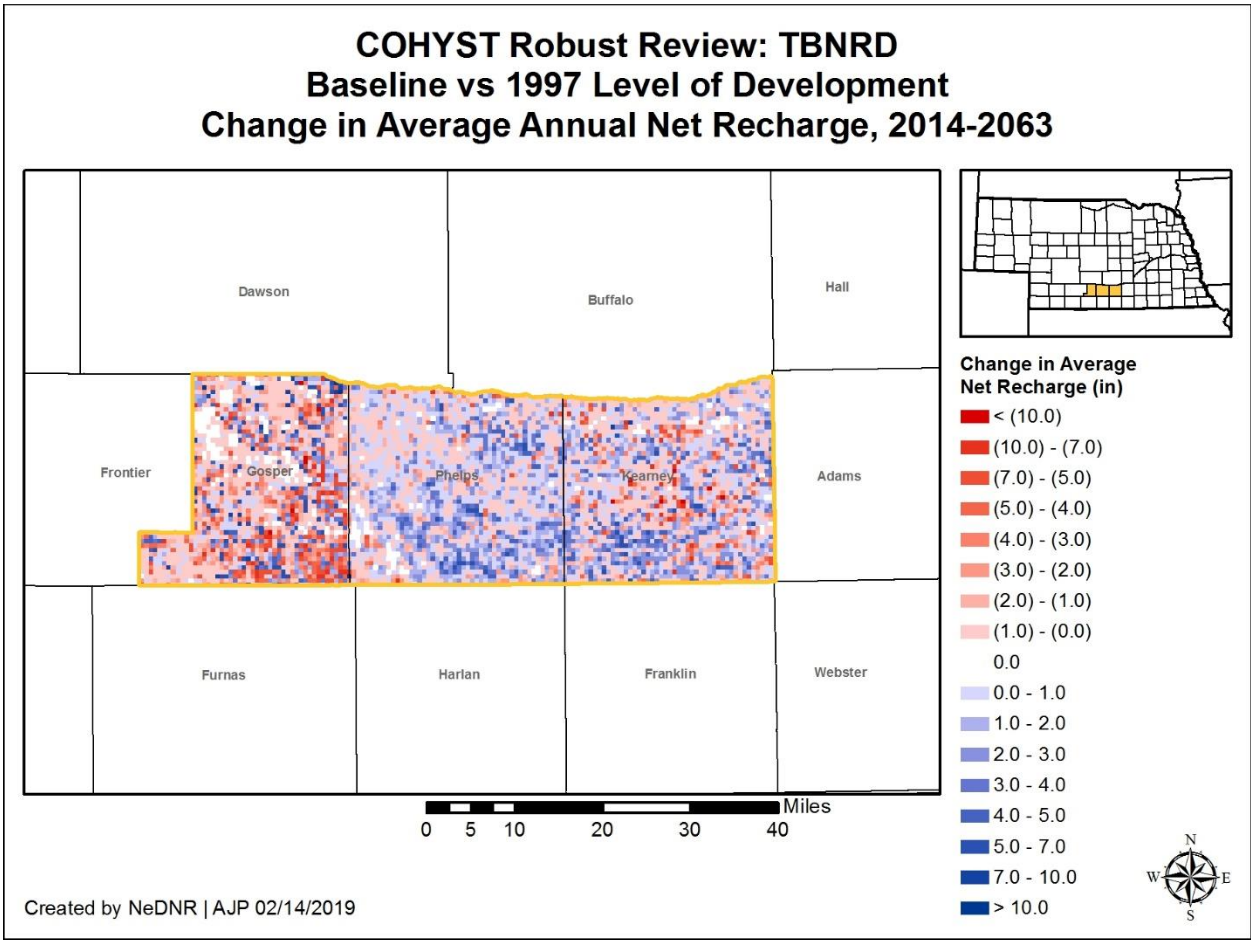

Figure 6. Historical Run minus 1997 Development Run. Change in average net recharge including change in M&I pumping from 2014 – 2063 within TBNRD.

STREAMFLOW DEPLETIONS FIGURES

North Platte NRD (NPNRD)

In Figure 7, the modeled post-1997 impacts to the North Platte River from groundwater-only irrigation and municipal and industrial development within the NPNRD are shown. Data shown in this figure also includes depletions-offsetting management actions including: allocations, groundwater irrigated acres retirements, and recharge projects on the North Platte River.

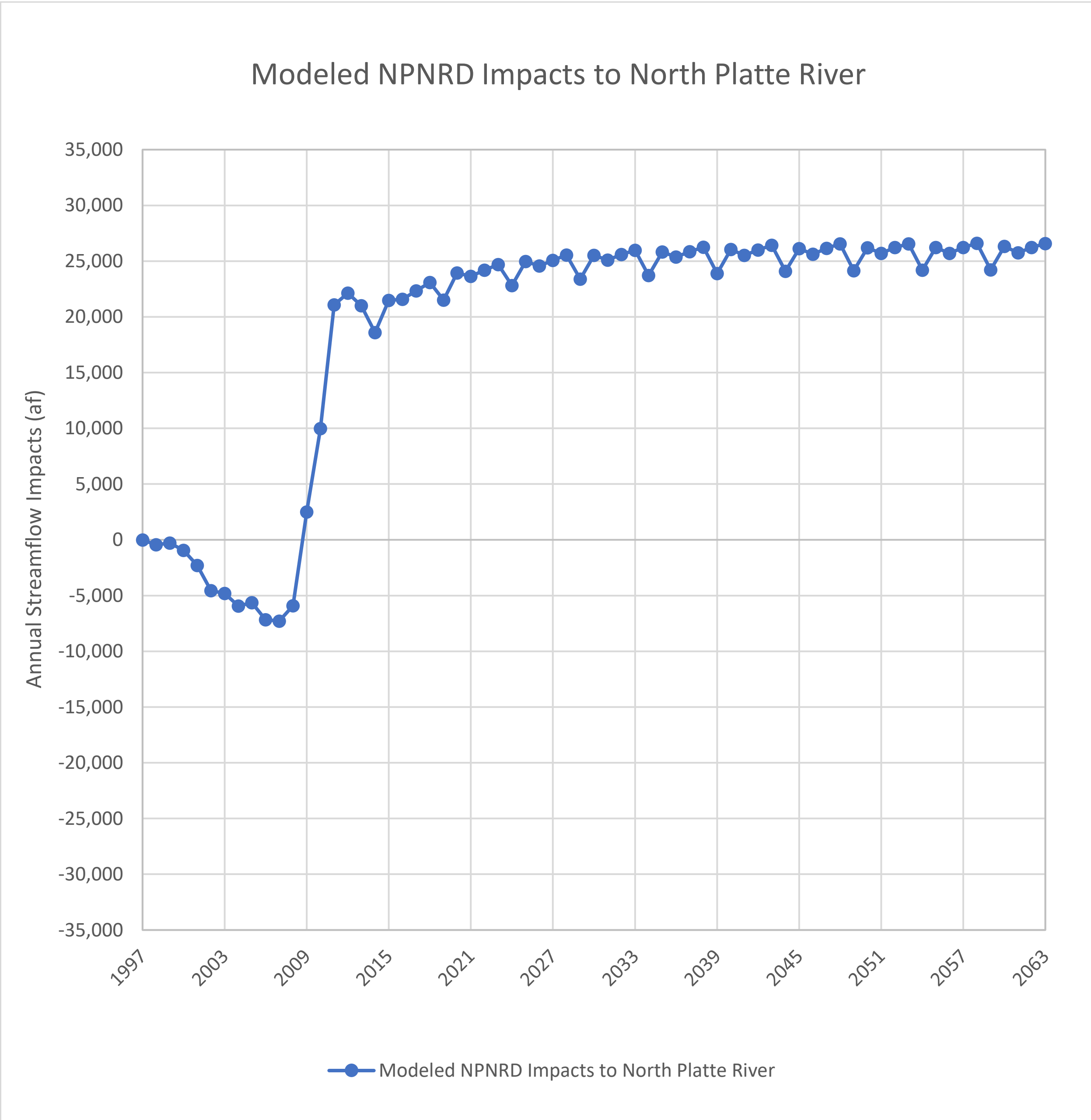

Figure 7. Modeled NPNRD post-1997 impacts to the North Platte River.

Figure 8 displays the same modeled post-1997 impacts of NPNRD to the North Platte River as that found in Figure 7 (including groundwater-only irrigation, municipal and industrial development, allocations, groundwater irrigated acres retirements, and recharge projects on the North Platte River), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend. The inset in Figure 8 shows the same data at a smaller scale.

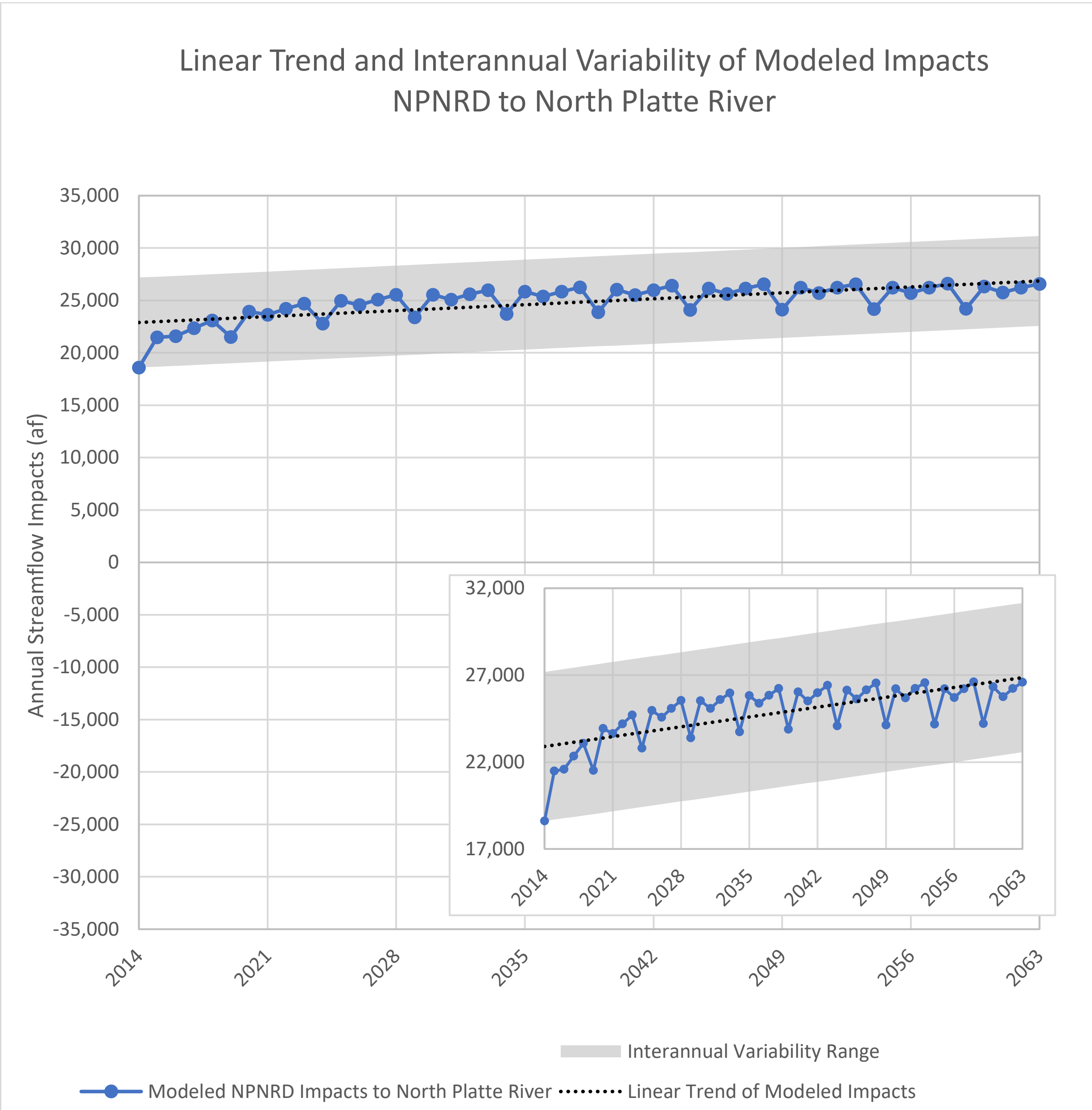

Figure 8. Modeled NPNRD post-1997 impacts to the North Platte River, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

South Platte NRD (SPNRD)

In Figure 9, the modeled post-1997 impacts to the North Platte River, South Platte River, and Lodgepole Creek from groundwater-only irrigation and municipal and industrial development within SPNRD are shown. Data shown in this figure also includes depletions-offsetting management actions including: allocations, groundwater irrigated acres retirements, and recharge projects on the South Platte River. The inset in Figure 9 shows the same data at a smaller scale.

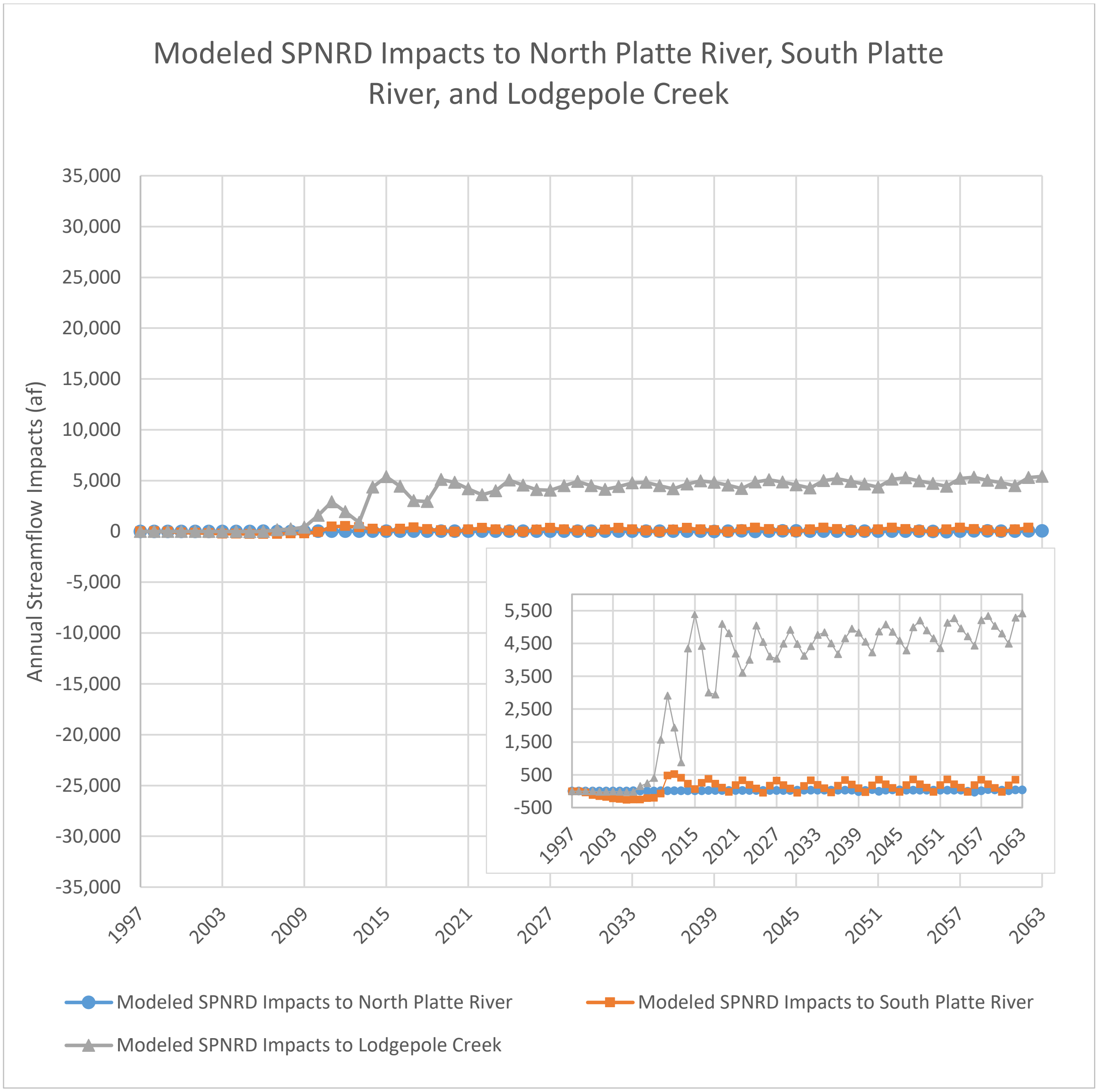

Figure 9. Modeled SPNRD post-1997 impacts to the North Platte River, South Platte River, and Lodgepole Creek.

Figure 10 displays the same modeled post-1997 impacts of SPNRD to the North Platte River as that found in Figure 9 (including groundwater-only irrigation, municipal and industrial development, allocations, and groundwater irrigated acres retirements), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend. The inset in Figure 10 shows the same data at a smaller scale.

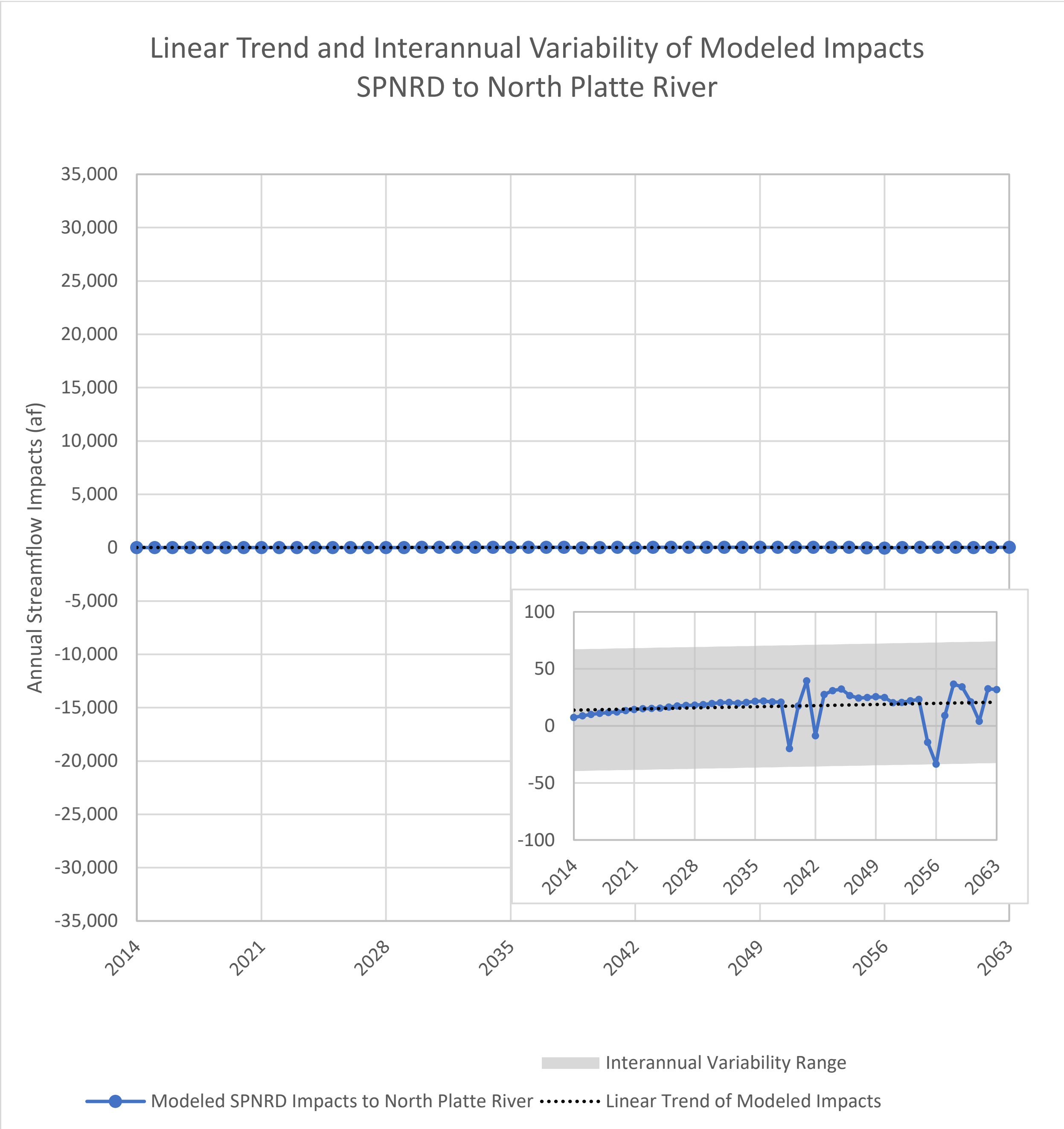

Figure 10. Modeled SPNRD post-1997 impacts to the North Platte River, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

Figure 11 displays the same modeled post-1997 impacts of SPNRD to the South Platte River that were seen in Figure 9 (including groundwater-only irrigation, municipal and industrial development, allocations, groundwater irrigated acres retirements, and recharge projects on the South Platte River), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend. The inset in Figure 11 shows the same data at a smaller scale.

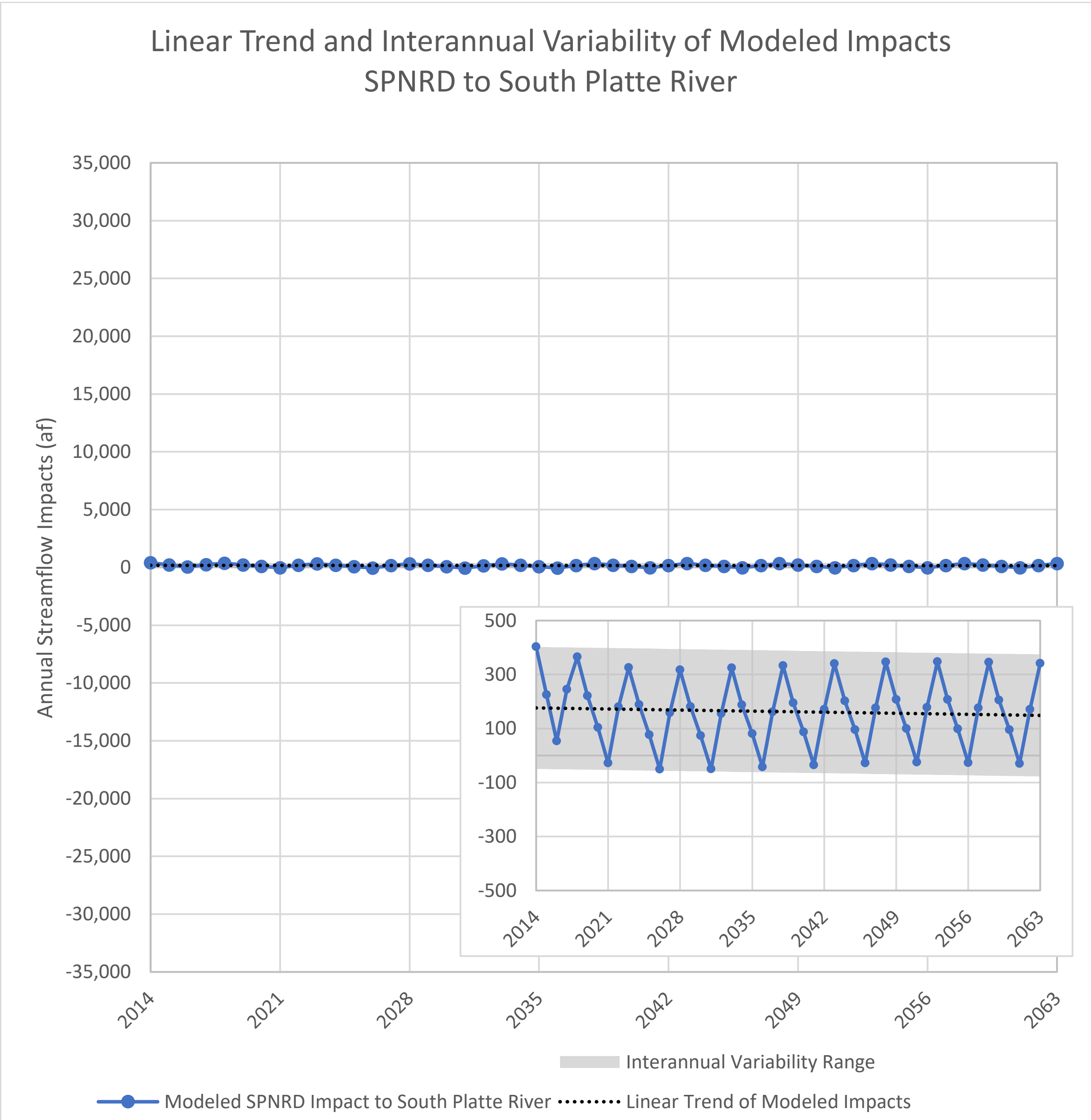

Figure 11. Modeled SPNRD post-1997 impacts to the South Platte River, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

Figure 12 displays the same modeled post-1997 impacts of SPNRD to Lodgepole Creek that were seen in Figure 9 (including groundwater-only irrigation, municipal and industrial development, allocations, and groundwater irrigated acres retirements), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend. The inset in Figure 12 shows the same data at a smaller scale.

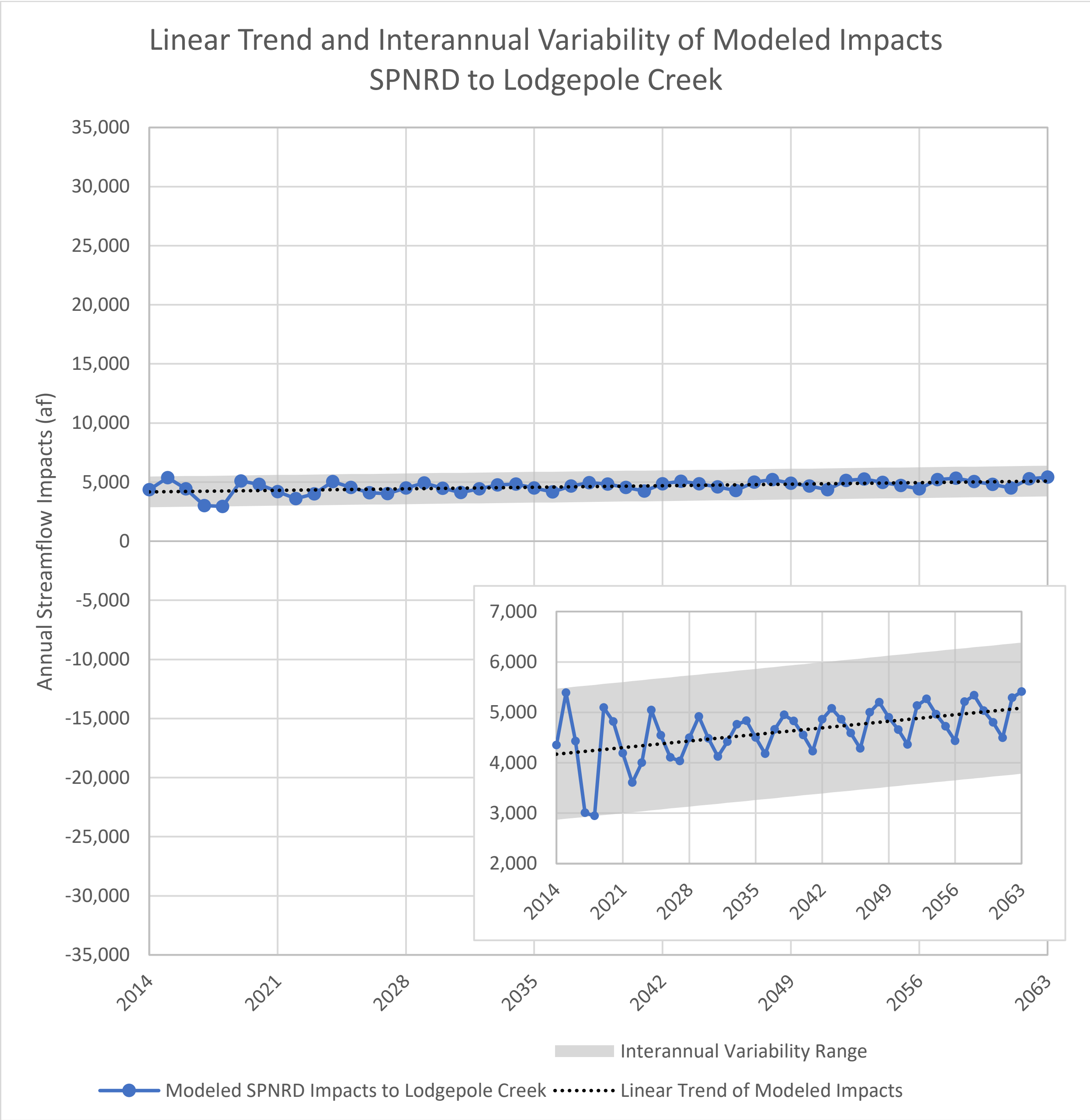

Figure 12: Modeled SPNRD post-1997 impacts to Lodgepole Creek, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

Twin Platte NRD (TPNRD)

In Figure 13, the modeled post-1997 impacts to the South Platte River, North Platte River, and the Platte River upstream of Elm Creek from groundwater-only irrigation and municipal and industrial development within TPNRD are shown. Data shown in this figure also includes depletions-offsetting management actions, including groundwater irrigated acres retirements and recharge projects on the South Platte River and Platte River upstream of Elm Creek. The inset in Figure 13 shows the same data at a smaller scale.

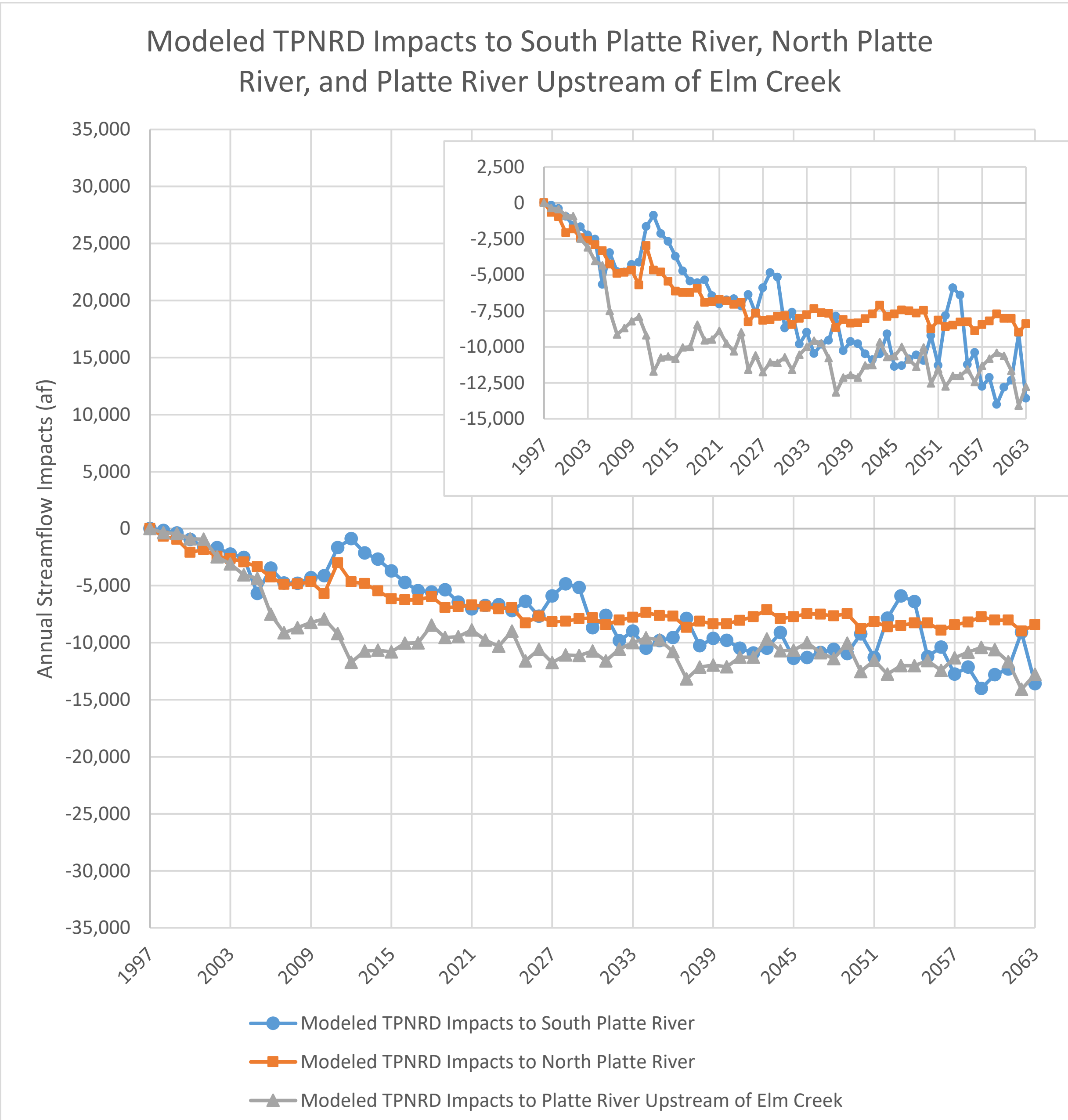

Figure 13: Modeled TPNRD post-1997 impacts to the South Platte River, North Platte River, and Platte River upstream of Elm Creek.

Figure 14 displays the same modeled post-1997 impacts of TPNRD to the South Platte River as that found in Figure 13 (including groundwater only irrigation, municipal and industrial development, groundwater irrigated acres retirements, and recharge projects on Western Canal), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend. The inset in figure 14 is the same data at a smaller scale.

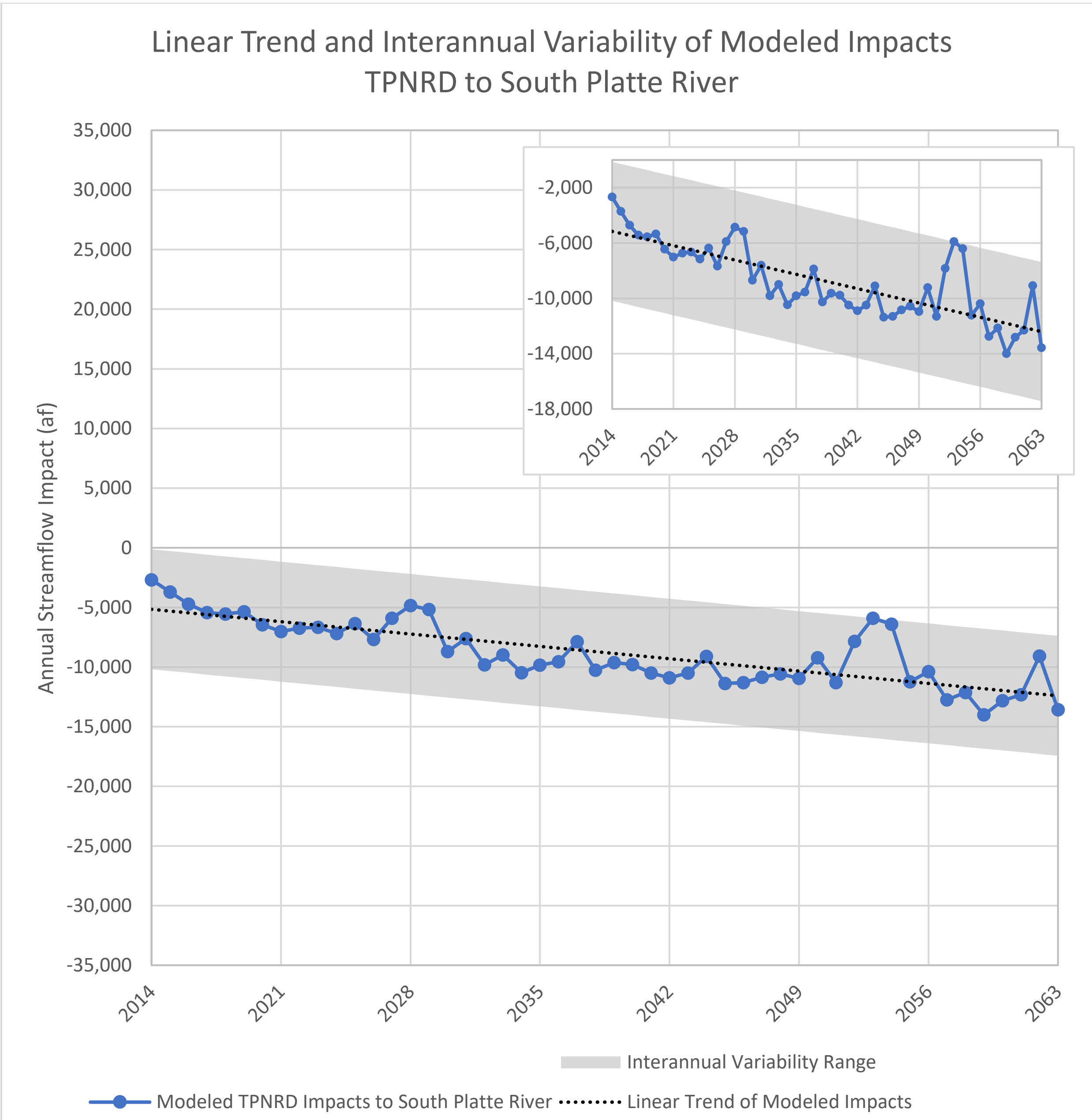

Figure 14: Modeled TPNRD post-1997 impacts to the South Platte River, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

Figure 15 displays the same modeled post-1997 impacts of TPNRD to the North Platte River as that found in Figure 13 (including groundwater-only irrigation, municipal and industrial development, groundwater irrigated acres retirements, and recharge projects on Keith Lincoln Canal, North Platte Canal, Paxton Hershey Canal, and Suburban canal), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend. The inset in figure 15 shows the same data at a smaller scale.

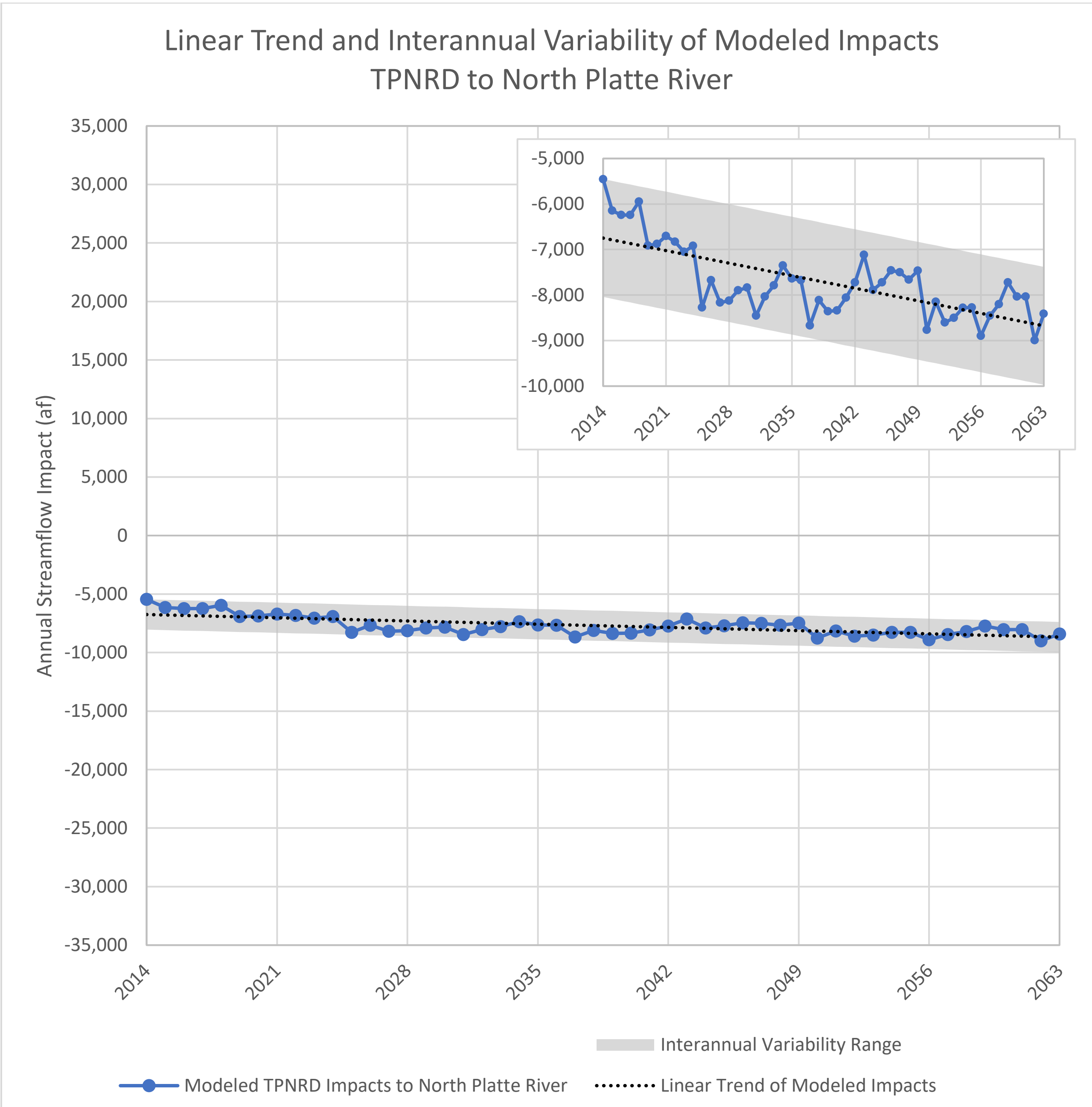

Figure 15: Modeled TPNRD post-1997 impacts to the North Platte River, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

Figure 16 displays the same modeled post-1997 impacts of TPNRD to the Platte River upstream of Elm Creek as that found in Figure 13 (including groundwater only irrigation, municipal and industrial development, and groundwater irrigated acres retirements), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend. The inset in Figure 16 shows the same data at a smaller scale.

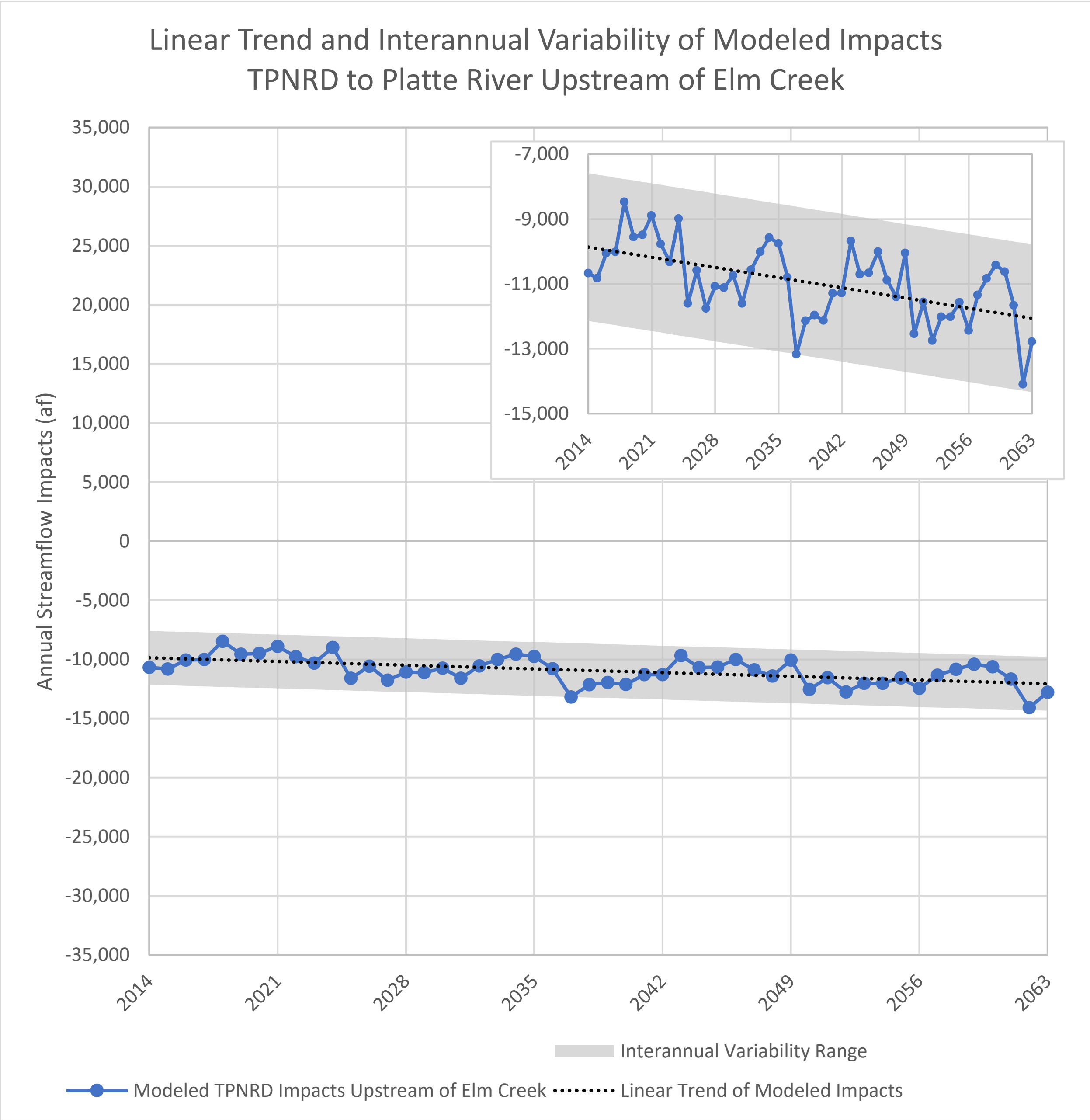

Figure 16: Modeled TPNRD post-1997 impacts to the Platte River upstream of Elm Creek, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

Central Platte NRD (CPNRD)

In Figure 17, the modeled post-1997 impacts to the Platte River upstream of Elm Creek, and between Elm Creek and Chapman, from groundwater-only irrigation and municipal and industrial development within CPNRD are shown. Data shown in this figure also includes depletions-offsetting management actions, including groundwater irrigated acres retirements and recharge projects on the Platte River contracted by CPNRD.

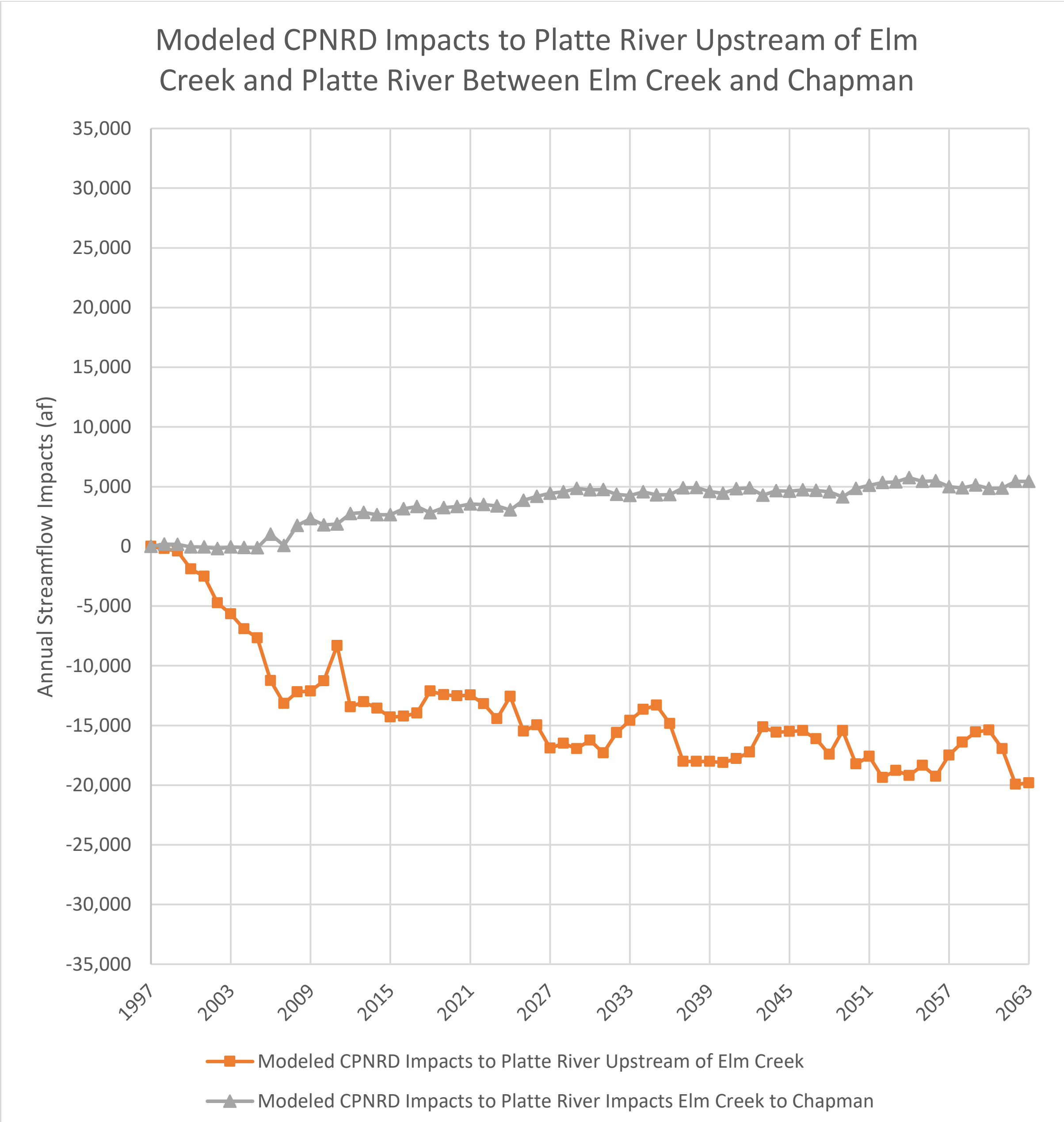

Figure 17: Modeled CPNRD post-1997 impacts to the Platte River Upstream of Elm Creek and the Platte River between Elm Creek and Chapman.

Figure 18 displays the same modeled post-1997 impacts of CPNRD to the Platte River upstream of Elm Creek as that found in Figure 17 (including groundwater-only irrigation, municipal and industrial development, groundwater irrigated acres retirements, and recharge projects on the Platte River contracted by CPNRD), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend. The inset in Figure 18 shows the same data at a smaller scale.

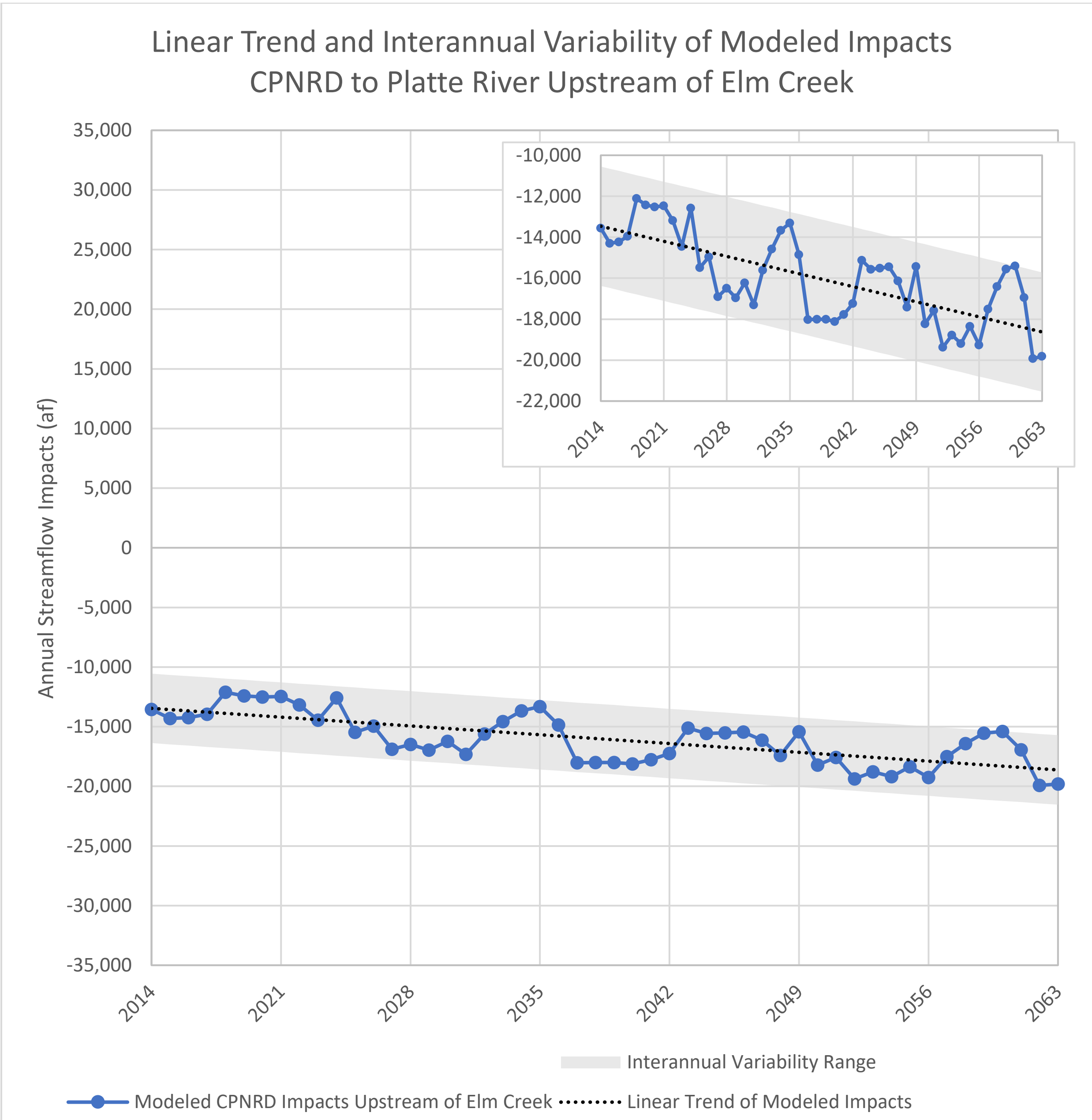

Figure 18: Modeled CPNRD post-1997 impacts to the Platte River upstream of Elm Creek, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

Figure 19 displays the same modeled post-1997 impacts to the Platte River between Elm Creek and Chapman as that found in Figure 17 (including groundwater-only irrigation, municipal and industrial development, groundwater irrigated acres retirements, and recharge projects on the Platte River contracted by CPNRD), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend. The inset in Figure 19 shows the same data at a smaller scale.

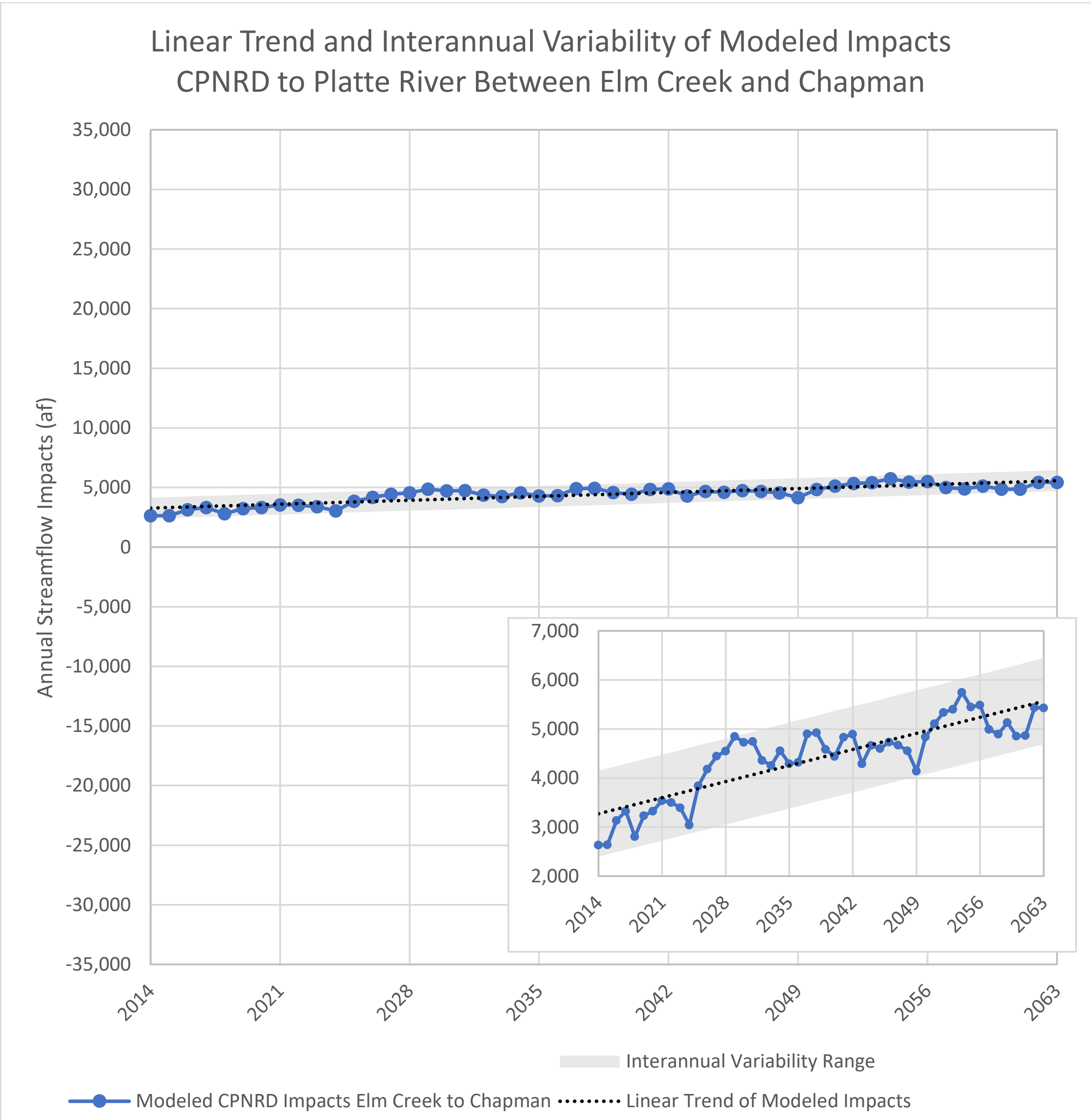

Figure 19: Modeled CPNRD post-1997 impacts to the Platte River between Elm Creek and Chapman, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

Tri-Basin NRD (TBNRD)

In Figure 20, the modeled post-1997 impacts to the Platte River upstream of Elm Creek, and between Elm Creek and Chapman, from groundwater-only irrigation and municipal and industrial development within TBNRD are shown. Data shown in this figure also includes depletions-offsetting management actions, including groundwater irrigated acres retirements, recharge projects on the Platte River contracted by TBNRD, and streamflow augmentation.

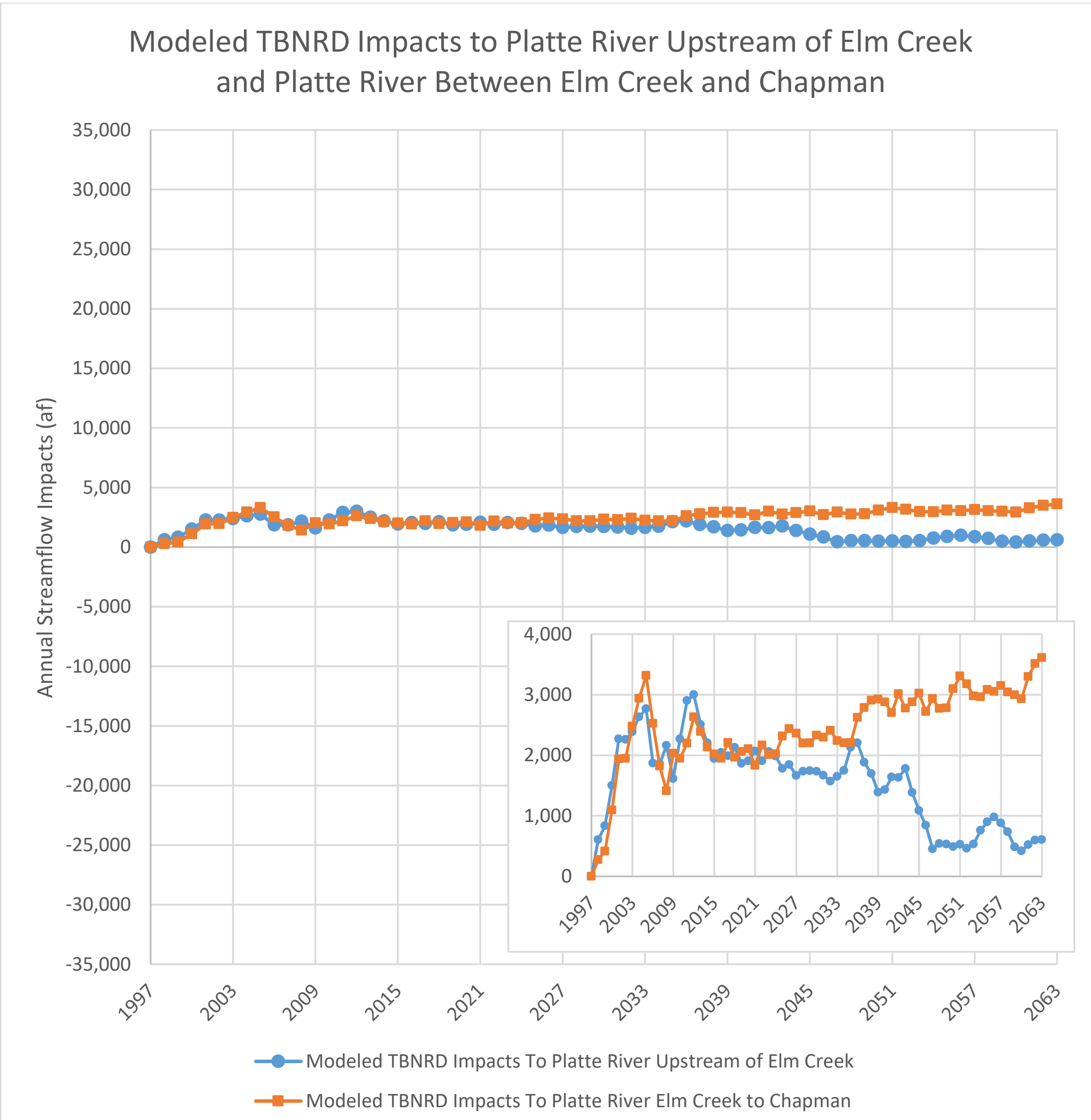

Figure 20: Modeled TBNRD post-1997 impacts to the Platte River upstream of Elm Creek and the Platte River between Elm Creek and Chapman.

Figure 21 displays the same modeled post-1997 impacts of TBNRD to the Platte River upstream of Elm Creek as that found in Figure 20 (including groundwater-only irrigation, municipal and industrial development, groundwater irrigated acres retirements, and recharge projects on the Platte River contracted by TBNRD), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

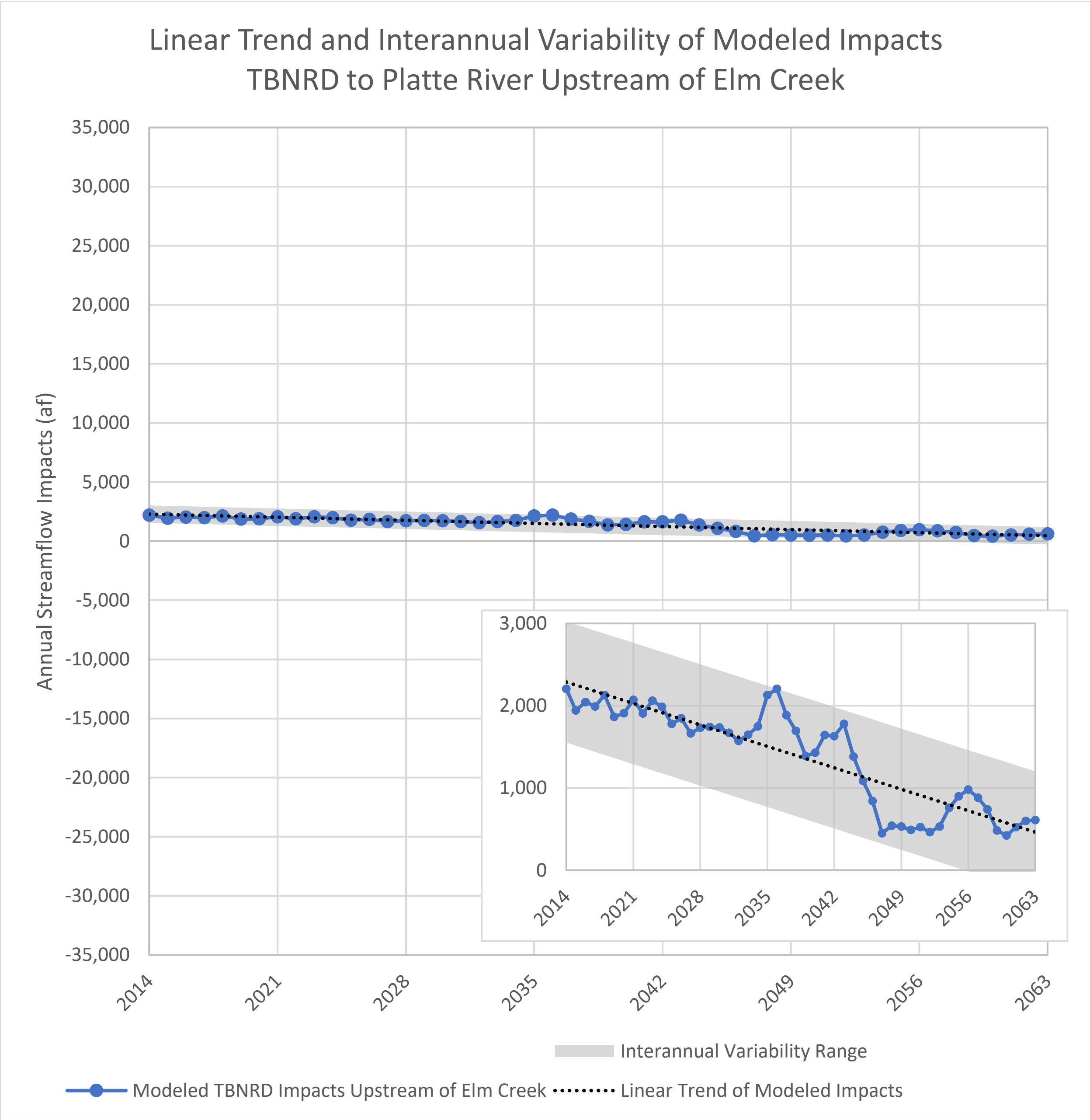

Figure 21: Modeled TBNRD post-1997 impacts to the Platte River upstream of Elm Creek, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

Figure 22 displays the same modeled post-1997 impacts of TBNRD to the Platte River between Elm Creek and Chapman (including groundwater-only irrigation, municipal and industrial development, groundwater irrigated acres retirements, recharge projects on the Platte River contracted by TBNRD, and streamflow augmentation), with the addition of the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

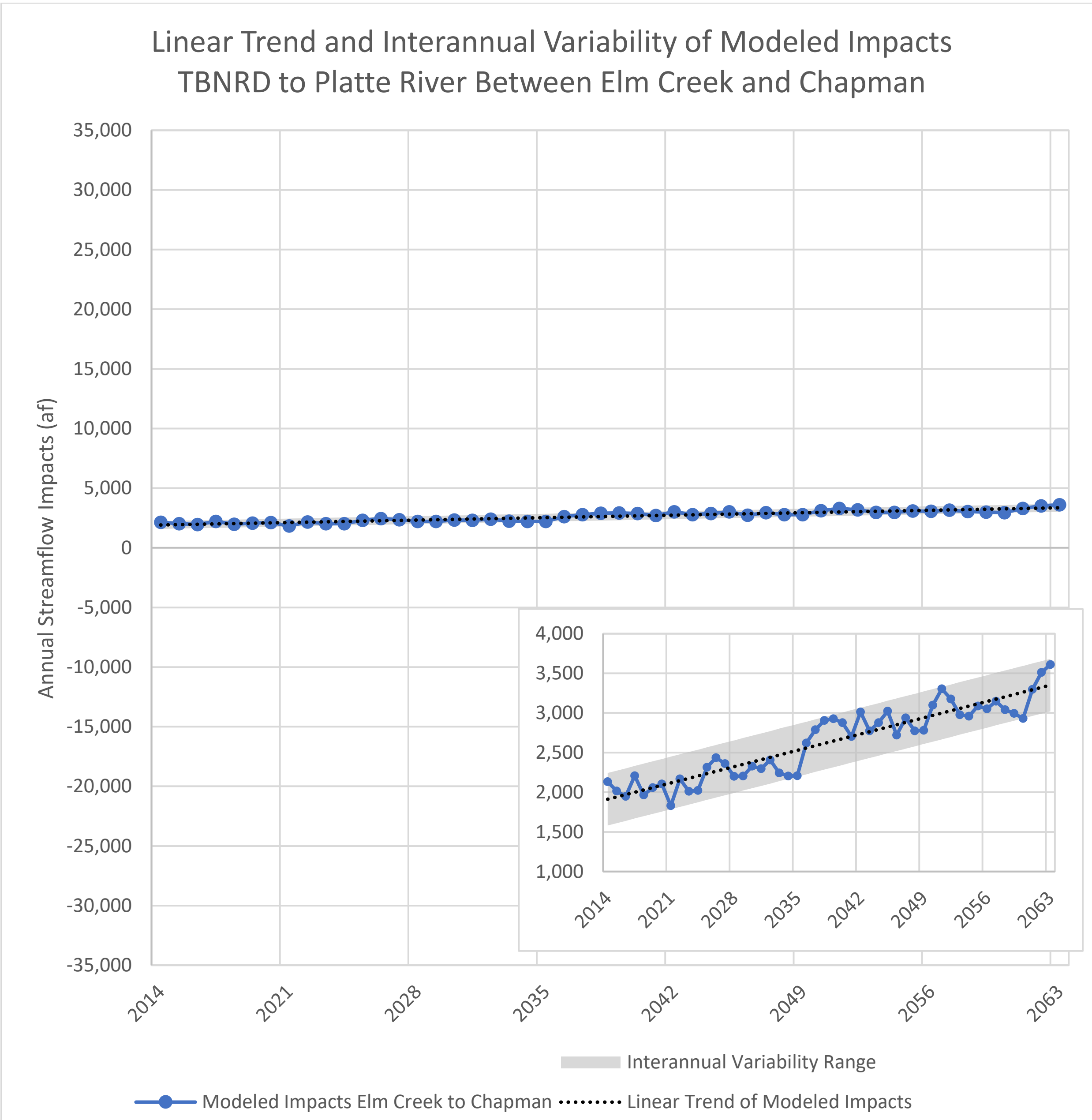

Figure 22: Modeled TBNRD post-1997 impacts to the Platte River between Elm Creek and Chapman, the linear trend line of the modeled impacts from 2014-2063, and the inter-annual variability range of modeled impacts across the trend.

Area Outside of the Five Upper Platte Basin NRDs

Figure 23 shows the modeled post-1997 impacts to the Platte River upstream of Chapman from groundwater-only irrigation and municipal and industrial development that occurred outside of the five Upper Platte Basin NRDs, but still within the model area.

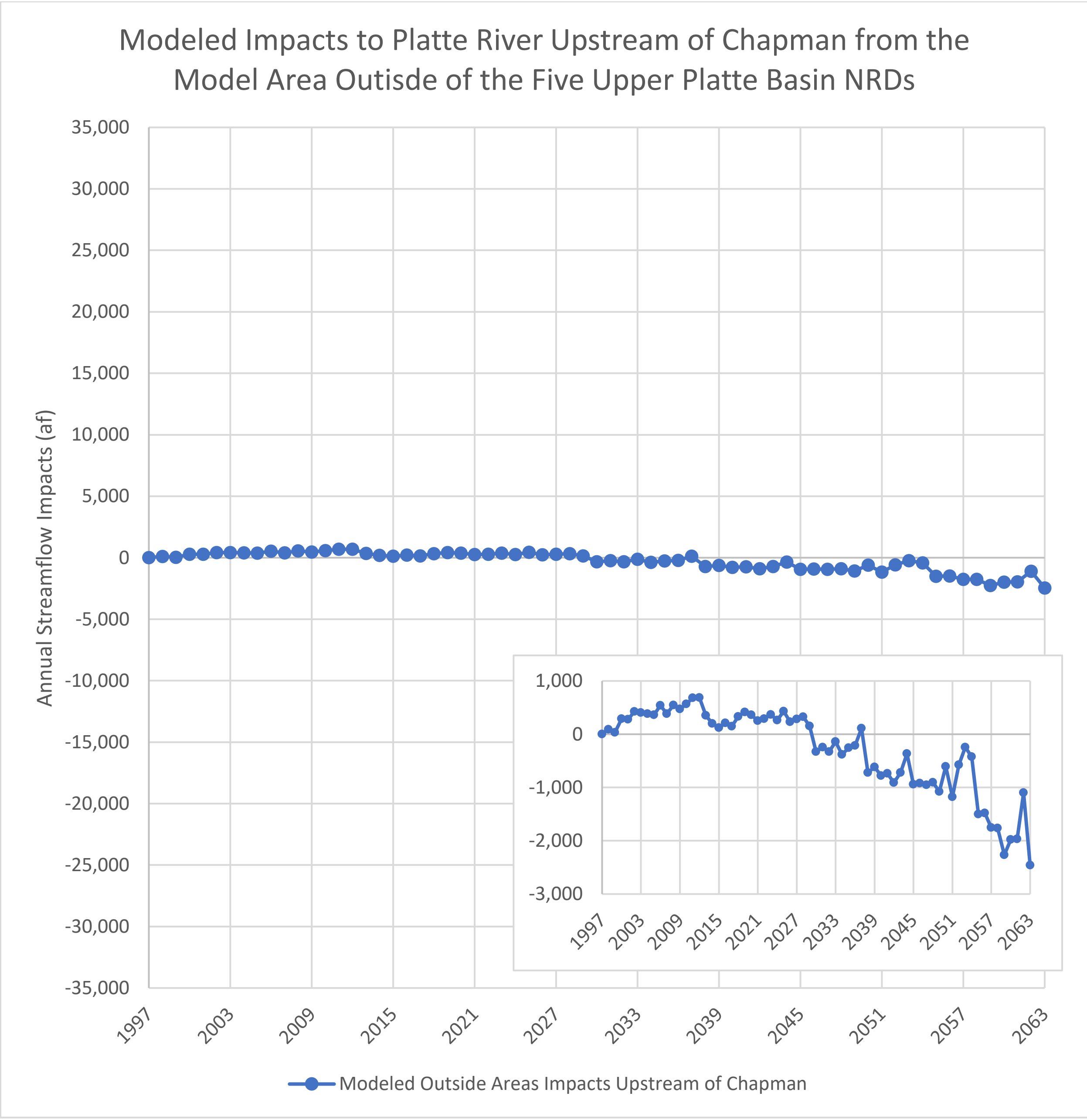

Figure 23: Modeled post-1997 impacts to the Platte River upstream of Chapman from the model area outside of the five Upper Platte Basin NRDs.

Five Upper Platte Basin NRDs and Total Model Area

Figure 24 shows the modeled post-1997 impacts to the Platte River upstream of Elm Creek from the five Upper Platte Basin NRDs (including groundwater-only irrigation, municipal and industrial development, groundwater irrigated acres retirements, recharge projects, and streamflow augmentation).

Also displayed in Figure 24 are the modeled post-1997 impacts (including groundwater-only irrigation, municipal and industrial development, groundwater irrigated acres retirements, recharge projects, and streamflow augmentation) to the Platte River upstream of Chapman from the entire model area, which includes but is not limited to, the area represented by the five Upper Platte Basin NRDs.

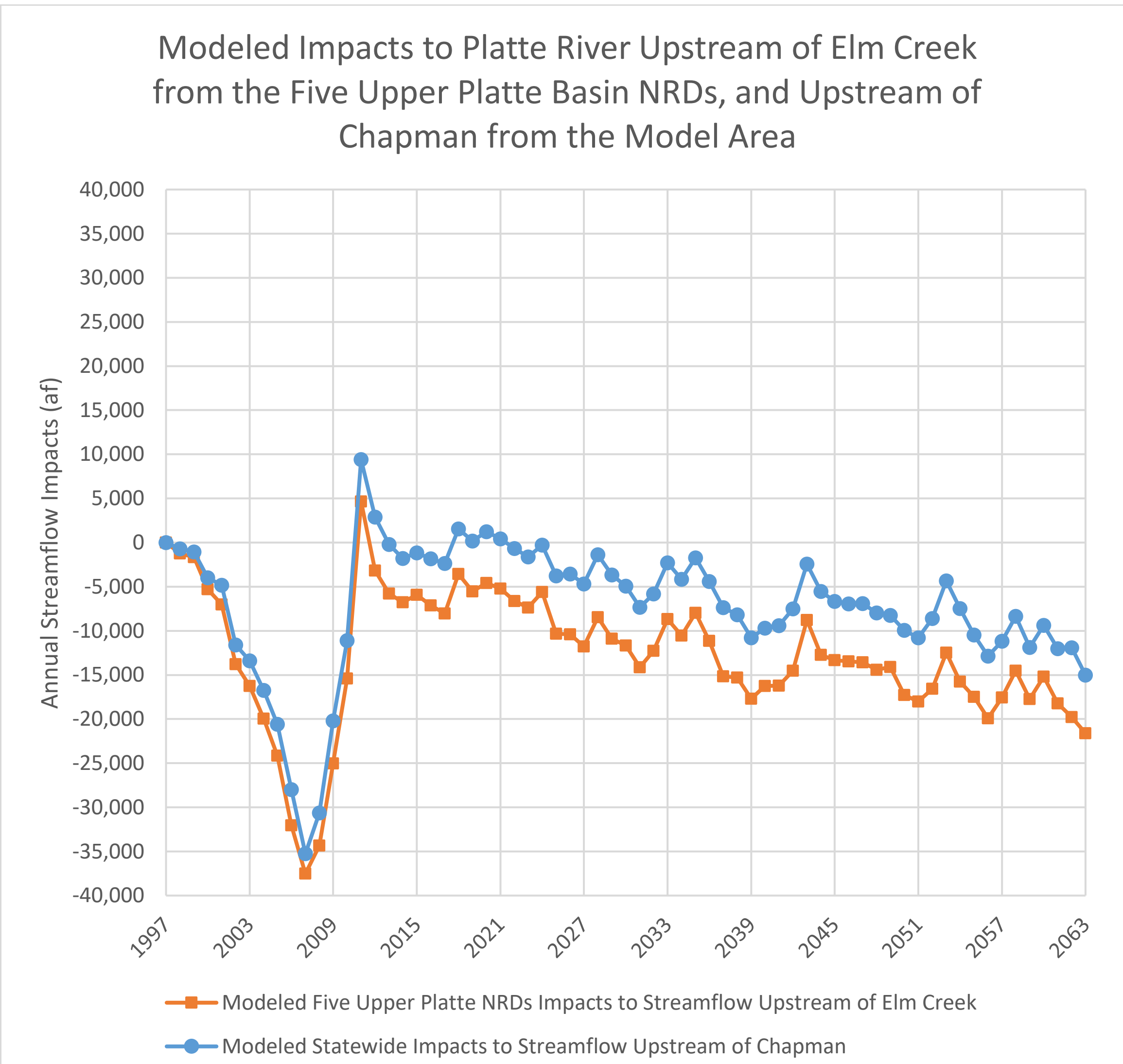

Figure 24: Modeled post-1997 impacts to the Platte River upstream of Elm Creek from the five Upper Platte Basin NRDs. Also, the modeled post-1997 impacts to the Platte River upstream of Chapman from the entire model area, including the Upper Platte Basin NRDs.

TABLES

Table 1: Net effect through 2019 of depletions and accretions. Values previously reported to PRRIP on April 21, 2017.

YEAR	NET EFFECT OF PERMITTED ACTIVITIES (af)	DEPLETIVE EFFECT FROM OTHER ACTIVITIES (af)	ACCRETIVE EFFECT FROM MITIGATION MEASURES (af)	TOTAL NET EFFECT (af)
2016	730	-20,400	23,710	4,040
2017	730	-20,800	23,540	3,470
2018	720	-21,300	23,080	2,500
2019	710	-21,600	22,980	2,090

Table 2: Total groundwater-only irrigated acres for each of the Upper Platte Basin NRDs and the Other NRDs within the model area used in the Robust Review analyses, rounded to the nearest hundred acres. Land use acres were held constant after 2023.

YEAR	NPNRD (acres)	SPNRD (acres)	TPNRD (acres)	CPNRD (acres)	TBNRD (acres)	OTHER NRDS (acres)
1997	134,400	103,800	205,700	817,300	406,600	1,590,400
2005	140,300	120,300	250,500	887,400	422,400	1,915,000
2013	131,100	119,000	263,100	902,200	461,300	2,055,700
2023	131,100	119,000	263,800	902,900	461,600	2,055,700

Table 3. Change in total groundwater-only irrigated acres for each of the Upper Platte NRDs and the Other NRDs within the model area used in the Robust Review analyses, rounded to the nearest hundred acres. Land use acres were held constant after 2023.

YEAR	NPNRD (acres)	SPNRD (acres)	TPNRD (acres)	CPNRD (acres)	TBNRD (acres)	OTHER NRDS (acres)
2005	5,900	16,500	44,800	70,100	15,900	324,700
2013	-3,400	15,300	57,500	84,900	54,700	465,300
2023	-3,400	15,300	58,100	85,700	55,000	465,300

Table 4: Average annual net recharge, irrigation groundwater pumping, net recharge (difference between recharge and irrigation groundwater pumping), and municipal and industrial pumping within NPNRD over 2014 to 2063 in acre-feet rounded to the nearest hundred.

NPNRD	HISTORICAL RUN (af)	1997 DEVELOPMENT RUN (af)	CHANGE DUE TO POST-1997 DEVELOPMENT (af)
AVERAGE RECHARGE	1,029,700	1,025,000	4,700
AVERAGE IRRIGATION GROUNDWATER PUMPING	198,900	233,500	-34,500
AVERAGE NET RECHARGE (Recharge - Irrigation Groundwater Pumping)	830,700	791,500	39,300
MUNICIPAL AND INDUSTRIAL PUMPING	11,500	14,100	-2,600

Table 5: Average annual net recharge, irrigation groundwater pumping, net recharge (difference between recharge and irrigation groundwater pumping), and municipal and industrial pumping within SPNRD over 2014 to 2063 in acre-feet rounded to the nearest hundred.

SPNRD	**HISTORICAL RUN** (af)	**1997 DEVELOPMENT RUN** (af)	**CHANGE DUE TO POST-1997 DEVELOPMENT** (af)
AVERAGE RECHARGE	160,200	157,300	3,000
AVERAGE IRRIGATION GROUNDWATER PUMPING	114,500	127,300	-12,800
AVERAGE NET RECHARGE (Recharge - Irrigation Groundwater Pumping)	45,700	29,900	15,700
MUNICIPAL AND INDUSTRIAL PUMPING	3,600	4,000	-400

Table 6: Average annual net recharge, irrigation groundwater pumping, net recharge (difference between recharge and irrigation groundwater pumping), and municipal and industrial pumping within TPNRD over 2014 to 2063 in acre-feet rounded to the nearest hundred.

TPNRD	**HISTORICAL RUN** (af)	**1997 DEVELOPMENT RUN** (af)	**CHANGE DUE TO POST-1997 DEVELOPMENT** (af)
AVERAGE RECHARGE	473,000	463,200	9,900
AVERAGE IRRIGATION GROUNDWATER PUMPING	358,600	293,600	64,900
AVERAGE NET RECHARGE (Recharge - Irrigation Groundwater Pumping)	114,500	169,500	-55,000
MUNICIPAL AND INDUSTRIAL PUMPING	8,100	6,700	1,400

Table 7: Average annual net recharge, irrigation groundwater pumping, net recharge (difference between recharge and irrigation groundwater pumping), and municipal and industrial pumping within CPNRD over 2014 to 2063 in acre-feet rounded to the nearest hundred.

CPNRD	**HISTORICAL RUN** (af)	**1997 DEVELOPMENT RUN** (af)	**CHANGE DUE TO POST-1997 DEVELOPMENT** (af)
AVERAGE RECHARGE	646,200	607,300	38,900
AVERAGE IRRIGATION GROUNDWATER PUMPING	716,000	664,300	51,700
AVERAGE NET RECHARGE (Recharge - Irrigation Groundwater Pumping)	-69,800	-56,900	-12,900
MUNICIPAL AND INDUSTRIAL PUMPING	22,300	18,400	3,900

Table 8: Average annual net recharge, irrigation groundwater pumping, net recharge (difference between recharge and irrigation groundwater pumping), and municipal and industrial pumping within TBNRD over 2014 to 2063 in acre-feet rounded to the nearest hundred.

TBNRD	**HISTORICAL RUN** (af)	**1997 DEVELOPMENT RUN** (af)	**CHANGE DUE TO POST-1997 DEVELOPMENT** (af)
AVERAGE RECHARGE	287,300	252,700	34,600
AVERAGE IRRIGATION GROUNDWATER PUMPING	386,900	362,400	24,500
AVERAGE NET RECHARGE (Recharge - Irrigation Groundwater Pumping)	-99,600	-109,700	10,100
MUNICIPAL AND INDUSTRIAL PUMPING	3,200	2,500	700

Table 9: Trend in modeled post-1997 streamflow impacts for 2019 to 2029 from groundwater-only irrigation development after 1997, expansion of municipal and industrial uses after 1997, and management activities through 2013 in NPNRD.

YEAR	**NPNRD IMPACT ON NORTH PLATTE RIVER** (af)
2019	23,300
2020	23,400
2021	23,500
2022	23,500
2023	23,600
2024	23,700
2025	23,800
2026	23,900
2027	23,900
2028	24,000
2029	24,100

The modeled impacts and inter-annual variability range about the trend presented in Table 9 are displayed in Figure 8.

Table 10: Trend in modeled post-1997 streamflow impacts for 2019 to 2029 from groundwater-only irrigation development after 1997, expansion of municipal and industrial uses after 1997, and management activities through 2013 in SPNRD.

YEAR	SPNRD IMPACT ON SOUTH PLATTE RIVER (af)	SPNRD IMPACT ON LODGEPOLE CREEK (af)	SPNRD IMPACT ON NORTH PLATTE RIVER (af)
2019	200	4,300	0
2020	200	4,300	0
2021	200	4,300	0
2022	200	4,300	0
2023	200	4,300	0
2024	200	4,400	0
2025	200	4,400	0
2026	200	4,400	0
2027	200	4,400	0
2028	200	4,400	0
2029	200	4,500	0

The modeled impacts and inter-annual variability range about the trend presented in Table 10 are displayed in Figures 10-12.

Table 11: Trend in modeled post-1997 streamflow impacts for 2019 to 2029 from groundwater-only irrigation development after 1997, expansion of municipal and industrial uses after 1997, and management activities through 2013 in TPNRD.

YEAR	TPNRD IMPACT ON SOUTH PLATTE RIVER (af)	TPNRD IMPACT ON NORTH PLATTE RIVER (af)	TPNRD IMPACT ON PLATTE RIVER UPSTREAM OF ELM CREEK (af)
2019	-5,900	-6,900	-10,100
2020	-6,000	-7,000	-10,100
2021	-6,200	-7,000	-10,200
2022	-6,300	-7,100	-10,200
2023	-6,500	-7,100	-10,300
2024	-6,600	-7,100	-10,300
2025	-6,800	-7,200	-10,400
2026	-6,900	-7,200	-10,400
2027	-7,100	-7,300	-10,400
2028	-7,200	-7,300	-10,500
2029	-7,400	-7,300	-10,500

The modeled impacts and inter-annual variability range about the trend presented in Table 11 are displayed in Figures 14-16.

Table 12: Trend in modeled post-1997 streamflow impacts for 2019 to 2029 from groundwater-only irrigation development after 1997, expansion of municipal and industrial uses after 1997, and management activities through 2013 in CPNRD.

YEAR	CPNRD IMPACT ON PLATTE RIVER UPSTREAM OF ELM CREEK (af)	CPNRD IMPACT ON PLATTE RIVER BETWEEN ELM CREEK AND CHAPMAN (af)
2019	-14,000	3,500
2020	-14,100	3,600
2021	-14,200	3,600
2022	-14,300	3,600
2023	-14,400	3,700
2024	-14,500	3,700
2025	-14,600	3,800
2026	-14,700	3,800
2027	-14,800	3,900
2028	-14,900	3,900
2029	-15,000	4,000

The modeled impacts and inter-annual variability range about the trend presented in Table 12 are displayed in Figures 18 and 19.

Table 13: Trend in modeled post-1997 streamflow impacts for 2019 to 2029 from groundwater-only irrigation development after 1997, expansion of municipal and industrial uses after 1997, and management activities through 2013 in TBNRD.

YEAR	TBNRD IMPACT ON PLATTE RIVER UPSTREAM OF ELM CREEK (af)	TBNRD IMPACT ON PLATTE RIVER ELM CREEK TO CHAPMAN (af)
2019	2,100	2,100
2020	2,100	2,100
2021	2,000	2,100
2022	2,000	2,100
2023	2,000	2,200
2024	1,900	2,200
2025	1,900	2,200
2026	1,800	2,300
2027	1,800	2,300
2028	1,800	2,300
2029	1,700	2,400

The modeled impacts and inter-annual variability range about the trend presented in Table 13 are displayed in Figures 21 and 22.

Table 14: Trend in modeled post-1997 streamflow impacts for 2019 to 2029 for areas outside of the five Upper Platte Basin Natural Resources Districts (other NRDs), but still within the model area.

YEAR	OTHER NRDS' IMPACT ON PLATTE RIVER UPSTREAM OF CHAPMAN (af)
2019	400
2020	300
2021	300
2022	300
2023	200
2024	200
2025	100
2026	100
2027	0
2028	0
2029	-100

Table 15: Summarized trended robust review results for the five Upper Platte Basin NRDs by stream segment for 2019 -2029 (second IMP increment).

YEAR	NORTH PLATTE RIVER (af)	SOUTH PLATTE RIVER (af)	LODGEPOLE CREEK (af)	PLATTE RIVER BETWEEN NORTH AND SOUTH PLATTE CONFLUENCE AND ELM CREEK (af)	PLATTE RIVER ELM CREEK TO CHAPMAN (af)	TOTAL UPSTREAM OF ELM CREEK (af)	TOTAL UPSTREAM OF CHAPMAN (af)
2019	16,400	-5,700	4,300	-22,000	5,600	-7,100	-1,500
2020	16,400	-5,900	4,300	-22,200	5,600	-7,300	-1,700
2021	16,500	-6,000	4,300	-22,400	5,700	-7,600	-1,900
2022	16,500	-6,200	4,300	-22,500	5,800	-7,900	-2,100
2023	16,500	-6,300	4,300	-22,700	5,900	-8,200	-2,300
2024	16,600	-6,500	4,400	-22,900	5,900	-8,400	-2,500
2025	16,600	-6,600	4,400	-23,100	6,000	-8,700	-2,700
2026	16,700	-6,800	4,400	-23,300	6,100	-9,000	-2,900
2027	16,700	-6,900	4,400	-23,500	6,200	-9,300	-3,100
2028	16,700	-7,100	4,400	-23,700	6,300	-9,600	-3,300
2029	16,800	-7,200	4,500	-23,900	6,300	-9,800	-3,500

The summary in Table 15 does not include any new management actions implemented subsequent to 2013, including Nebraska's participation in the J-2 Water Action Plan Project.