2019

Evaluation of the difference in streamflow impacts in the Upper Platte River Basin due to water uses initiated prior to and after July 1, 1997

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INTRODUCTION

Nebraska Department of Natural Resources (NeDNR) and the Upper Platte River Basin Natural Resources Districts (NRDs) adopted the Basin-Wide Plan for Joint Integrated Water Resources Management of Overappropriated Portions of the Platte River Basin (BWP) and NRD-specific integrated management plans (IMPs) in 2009. Those plans contain a number of goals and objectives, including those related to supporting returning the basin to a fully appropriated condition. A key aspect of these goals and objectives is to identify the difference between the current and fully appropriated levels of development. As outlined in the Ground Water Management and Protection Act (Act), the IMPs shall identify the overall difference between the current and fully appropriated levels of development. This evaluation must consider four components: (1) cyclical supply, including drought; (2) the portion of the difference that is due to conservation measures; (3) the portion of the overall difference due to water uses initiated prior to July 1, 1997; and (4) the portion of the overall difference due to water uses initiated or expanded on or after July 1, 1997. Several publications have been developed to support evaluation of these components (see conservation measures study, Robust Review, INSIGHT analysis). This report specifically supports the evaluation of the portion of the overall difference due to water uses initiated prior to July 1, 1997. This is only one component of the identification of the overall difference between the current and fully appropriated levels of development and should not be construed as representative of the overall difference (See Appendix 1).

This evaluation provides summarized estimates of the streamflow impacts resulting from groundwater-only irrigated lands and municipal and industrial (M&I) uses developed through 2013. In the COHYST model, the estimates of streamflow impacts include temporary groundwater irrigation retirements expiring through 2023 within Central Platte NRD (CPNRD), Tri-Basin NRD (TBNRD), and Twin Platte NRD (TPNRD). In the WWUM model, land use and groundwater irrigation pumping data from 2009-2013 was repeated, and therefore, temporary groundwater irrigation retirements did not expire in North Platte NRD (NPNRD) and South Platte (SPNRD). An evaluation of the streamflow impacts resulting from gained and lost irrigated land, controls (allocations and transfers), M&I expansion and contraction, managed recharge, stream augmentation, and permitted uses initiated or expanded on or after July 1, 1997, within each NRD are provided in the Robust Review Report. The projections of future stream baseflow effects contained in this report will be reviewed and updated through the course of the second increment of planning, with future evaluations guiding any necessary refinements and modifications to the planning goals and objectives.

This evaluation represents the best data and information that are currently available for evaluating the portion of the overall difference due to water uses initiated prior to July 1, 1997, but is not inclusive of all water uses. Various modeling and data updates are expected to be completed in the second increment that may modify the results presented in this report. Many of the limitations associated with this analysis are presented in Robust Review Report Appendix 1. Examples of limitations associated with the analyses include:

1) Historical M&I pumping volumes were estimated and not quantified for NPNRD and SPNRD for this analysis prior to 1997;
2) 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;

3) Crop type data in the COHYST model area are held constant after 2010 based on the distribution available in 2010. The crop type data are repeated in the WWUM model area based on 2009-2013 land use data;
4) Conservation measures, primarily tillage practices, may not fully reflect present-day practices and associated water supply benefits;
5) Management actions implemented after 2013 are excluded, including N-CORPE operations and conjunctive management operations in CPNRD;
6) Water budget changes associated with modeled changes in on-field runoff have not been incorporated into the new depletions estimates;
7) Groundwater pumping in certain portions of the groundwater models is estimated and may be refined with the collection of measurement data;
8) Certain model areas exhibit dry cells that may limit the incorporation of pumping and recharge changes;
9) The regional nature of the models may not appropriately express the degree of connection between aquifers and streams for capturing smaller scale management actions;
10) Streamflow routing of runoff and diversions were not included and may warrant further evaluation of the impacts on results; and
11) 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 River Basin NRDs will continue to work to address these limitations through the second increment and update this review as these limitations are evaluated.

EVALUATION PROCEDURES AND DATA

This report provides the total depletions from 1950 or 1953, depending on model area, to 2063 due to groundwater-only and M&I pumping within the five Upper Platte River Basin NRDs. The depletions information is separated into depletions resulting from levels of groundwater-only development prior to 1997 and depletions from all groundwater-only development. To calculate the total baseflow depletions within each NRD, the baseflow of a groundwater model run with no groundwater-only irrigation or M&I pumping in each NRD (referred to as the **No GWO Run**) is compared to baseflow from a historical groundwater model run that includes all groundwater-only irrigation pumping and M&I pumping (referred to as the **Historical Run**). The documented Cooperative Hydrology Study (COHYST) 2010 integrated model and Western Water Use Management (WWUM) model were used as the basis for this analysis (See Appendix 2). Updates to the documented Watershed model portions of these models for the baseline in this analysis are documented in Appendix 2. Further documentation of the methods used to conduct the model simulations and summarize model results are contained in Appendix 2.

RESULTS

The results of this evaluation are limited to the effects on streams in the Platte River system, including the North Platte River, South Platte River, Lodgepole Creek, Platte River, and their perennial tributaries within the Overappropriated Basin (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 analyses of groundwater-only irrigation activities are limited to the five Upper Platte River Basin NRDs in the Overappropriated Basin. The impacts were determined based on pumping occurring within the entirety of each of the five NRDs that were evaluated.

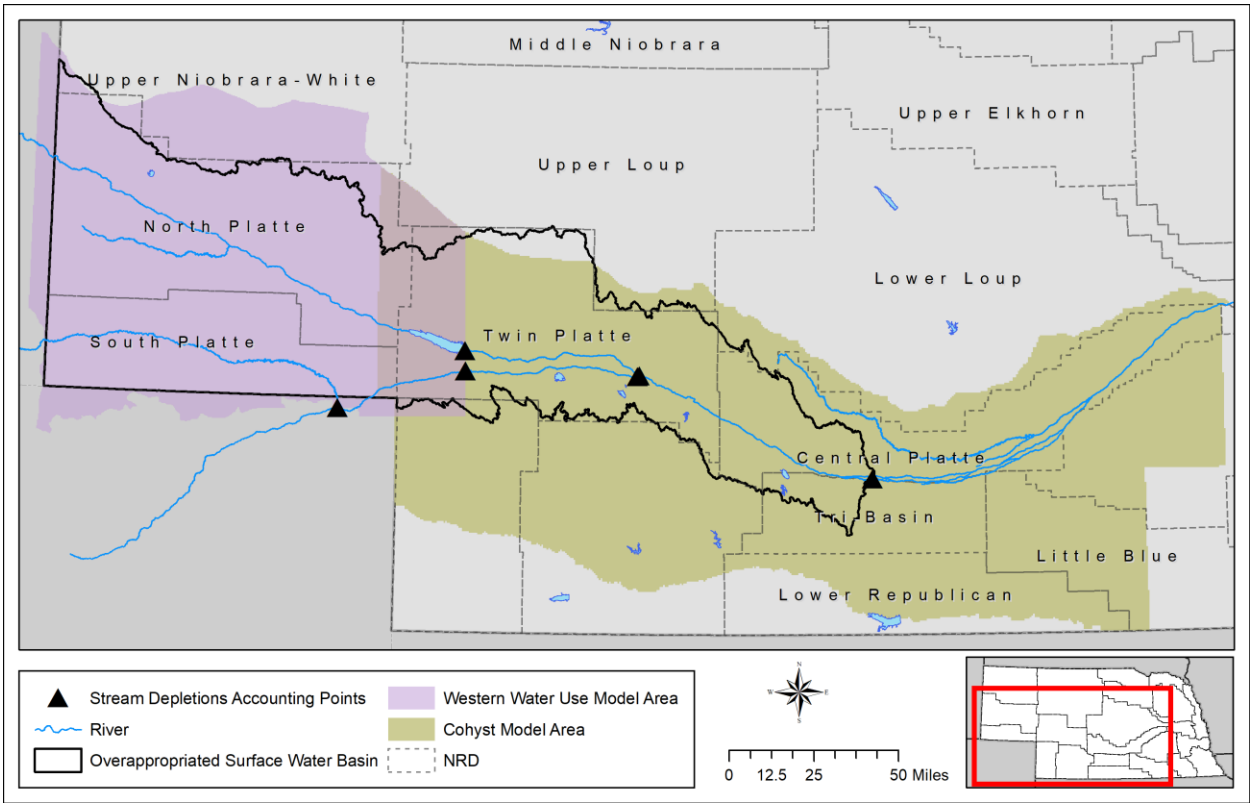

Figure 1. Upper Platte River Basin NRDs, Overappropriated Basin, accounting points, and model domains.

Table 2 illustrates the total number of groundwater-only irrigated acres within each NRD for the years 1997, 2005, 2013, and 2023. Acres values in the COHYST model area were maintained at constant levels after 2013, with the exception of temporary retirements that were reincorporated into subsequent years when the retirements terminated. All temporary retirements were reincorporated into the COHYST dataset until the retirement terminated. In the WWUM model area, acres values from 2009 to 2013 were repeated.

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. Tables 4-8 display water budget data for the period 2014-2063, including average values for recharge, groundwater irrigation pumping, M&I groundwater pumping, and net recharge within each NRD. The

average annual change in net recharge and change of M&I pumping by NRD for the period 2014 – 2063 accounts for all development of groundwater-only irrigation pumping and related changes in recharge and M&I pumping. The average change in 2014 – 2063 net recharge is based on 2013 land use conditions (with temporary retirements lapsing until 2023 in the COHYST model) with variable, but repeating, future climate conditions based on historical climate data. Negative values indicate net recharge has decreased due to the development of groundwater-only irrigation lands, and positive values indicate a net recharge increase due to the development of groundwater-only irrigation.

The results of the groundwater modeling evaluation of impacts on streamflow due to all groundwater-only and M&I pumping from 1950-2063 are summarized in Figures 2-10. The results of this groundwater modeling evaluation have been combined with the results from evaluations of post-1997 activities (2019 Upper Platte River Basin Robust Review) to determine the specific impacts resulting from activities established prior to 1997, and those established after 1997. 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 no groundwater-only nor M&I development) based on changes within each of the Upper Platte River Basin NRDs. Figure 11 shows the combined impact to streamflow due to changes in all five Upper Platte River Basin NRDs, relative to no groundwater-only nor M&I development. The four stream reaches within the Overappropriated Basin used in the analysis include: 1) Lodgepole Creek; 2) North Platte River; 3) South Platte River; and 4) Platte River between the North Platte and South Platte confluence and Elm Creek.

A variety of outcomes can be observed within this evaluation, in conjunction with the results of the Robust Review Report and other analyses. First, the results for NPNRD, SPNRD, and TBNRD show that depletions from the 1997 level of development are greater than current levels of depletions, indicating that streamflow impacts resulting from post-1997 depletions were fully mitigated as of 2013. Second, the total depletions due groundwater only-irrigation and M&I pumping for the entire Overappropriated Basin are estimated to be approximately 500,000 acre-feet by 2063. This estimate does not reflect additional management actions that have been implemented after 2013 or may be implemented in the second increment or other future increments. Third, the distribution of total depletions to streamflow indicates that approximately 25 percent of impacts are to the North Platte River, 24 percent of impacts are to the South Platte River, 7 percent of impacts are to Lodgepole Creek, and 44 percent of impacts are to the Platte River within the Overappropriated Basin.

SUMMARY

NeDNR and the Upper Platte River Basin NRDs have worked through the course of the first increment to implement action items outlined in each respective IMP. Those action items have included a variety of regulatory and non-regulatory management actions aimed at addressing depletions associated with post-1997 activities. This report provides a summary of the impacts associated with groundwater-only irrigation pumping and M&I pumping for current levels of development and for uses that existed prior to 1997. These results are only one of a number of components that will be used by NeDNR and NRDs in evaluating the overall difference between current and fully appropriated levels of development. Additionally, NeDNR and the Upper Platte River Basin NRDs will continue to update and review data sets and models that support updating this evaluation in the future.

STREAMFLOW DEPLETIONS FIGURES

North Platte NRD (NPNRD)

In Figure 2, the modeled streamflow impacts to the North Platte River from all groundwater-only irrigation and municipal and industrial development within NPNRD with offsetting management actions, including allocations, groundwater irrigated acres, retirements, and recharge projects on the North Platte River, are shown in orange. Also shown are the modeled streamflow impacts from all groundwater-only irrigation and municipal and industrial development prior to 1997 in blue.

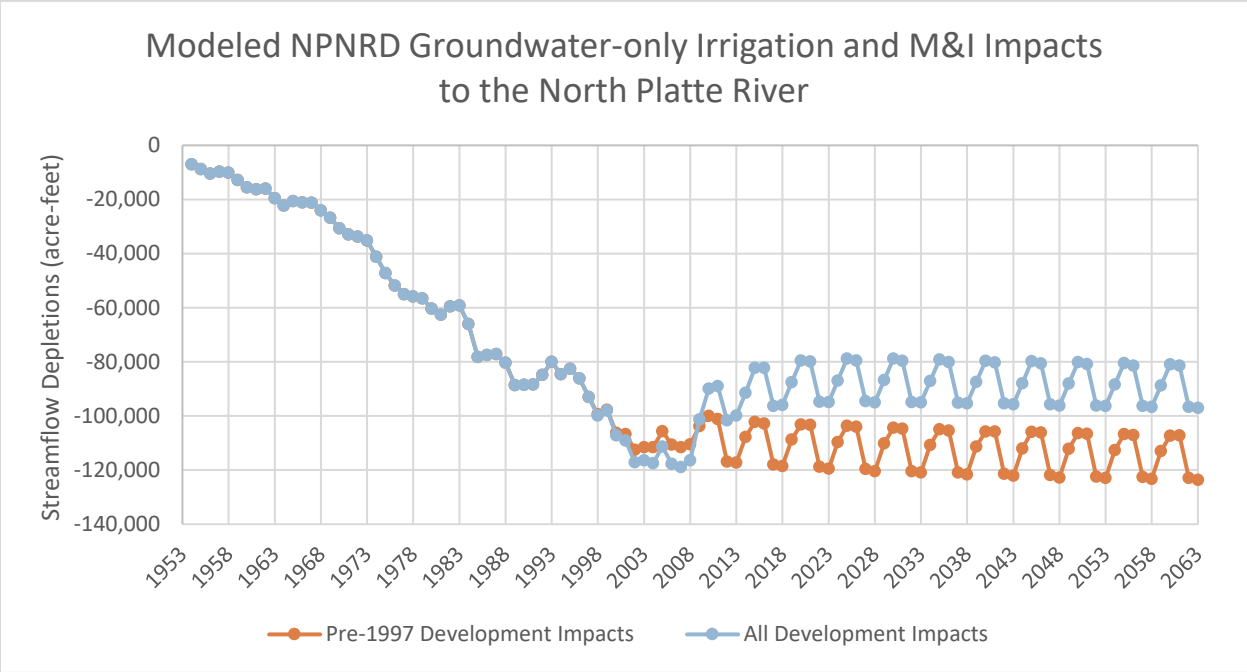

Figure 2. Modeled NPNRD streamflow impacts to the North Platte River from all groundwater-only irrigation and M&I development with offsetting management actions and the streamflow impacts from development pre-1997.

South Platte NRD (SPNRD)

In Figures 3, 4, and 5, the modeled streamflow impacts to the North Platte River, South Platte River, and Lodgepole Creek, respectively, from all groundwater-only irrigation and municipal and industrial development within SPNRD with offsetting management actions, including allocations, groundwater irrigated acres retirements, and recharge projects on the South Platte River, are shown in orange. Also shown are the modeled streamflow impacts from all groundwater-only irrigation and municipal and industrial development prior to 1997 in blue.

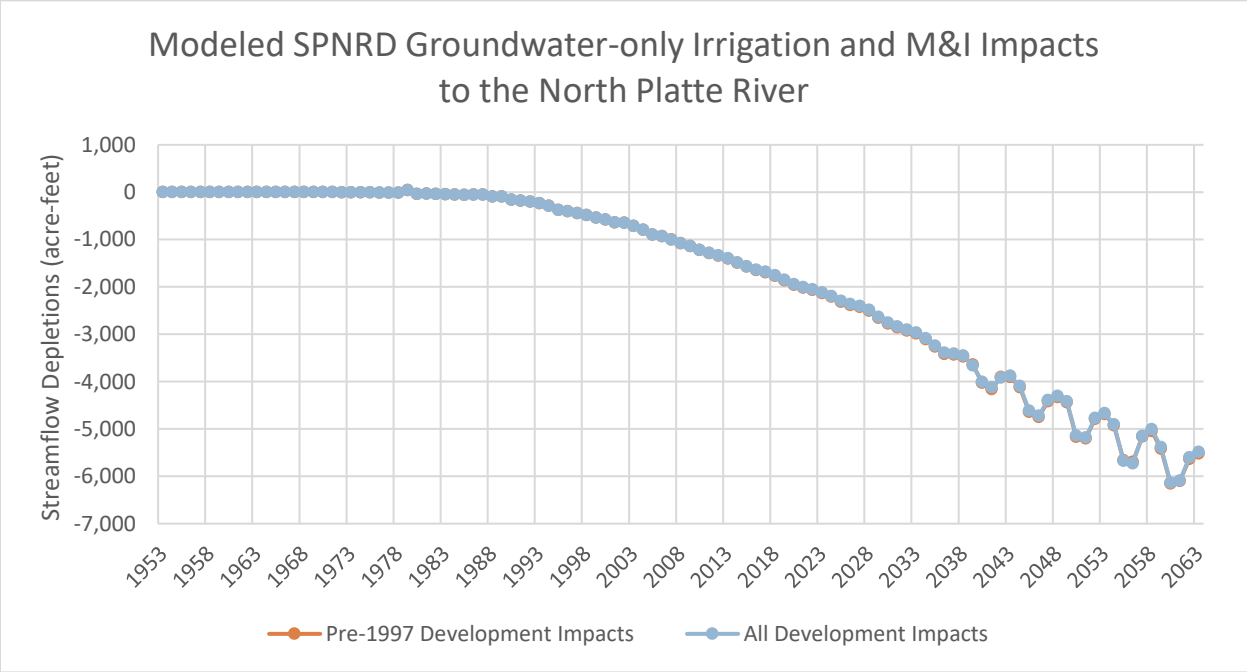

Figure 3. Modeled SPNRD streamflow impacts to the North Platte River from all groundwater-only irrigation and M&I development with offsetting management actions and the streamflow impacts from development pre-1997.

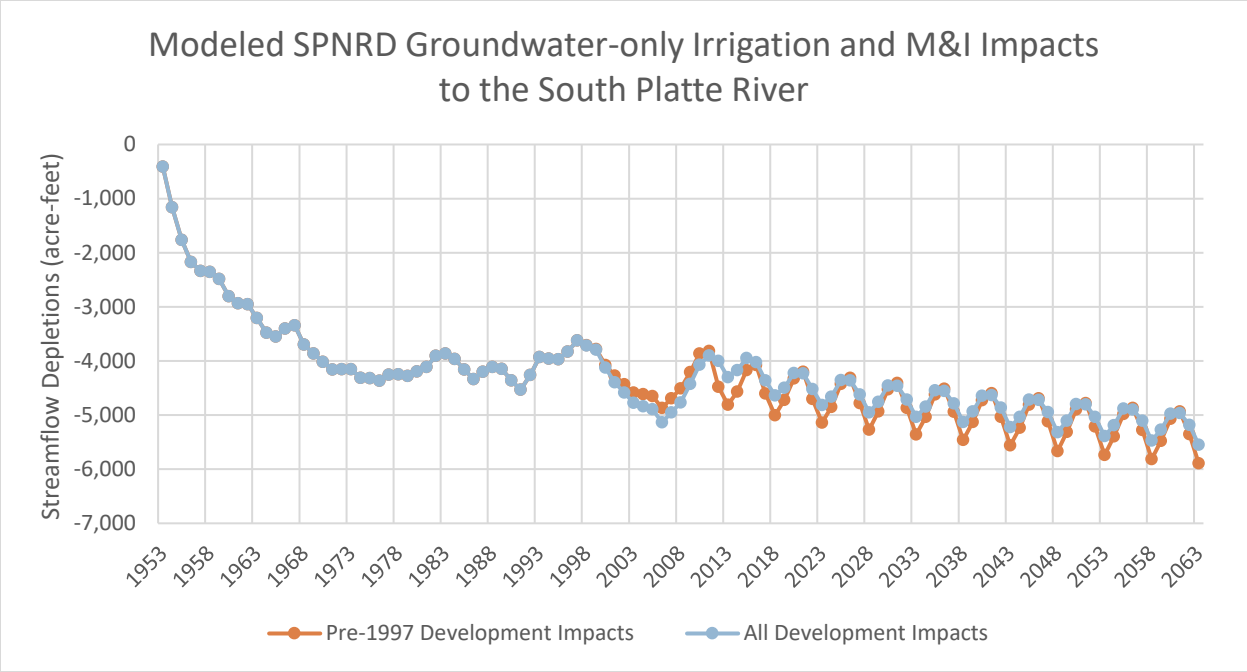

Figure 4. Modeled SPNRD streamflow impacts to the South Platte River from all groundwater-only irrigation and M&I development with offsetting management actions and the streamflow impacts from development pre-1997.

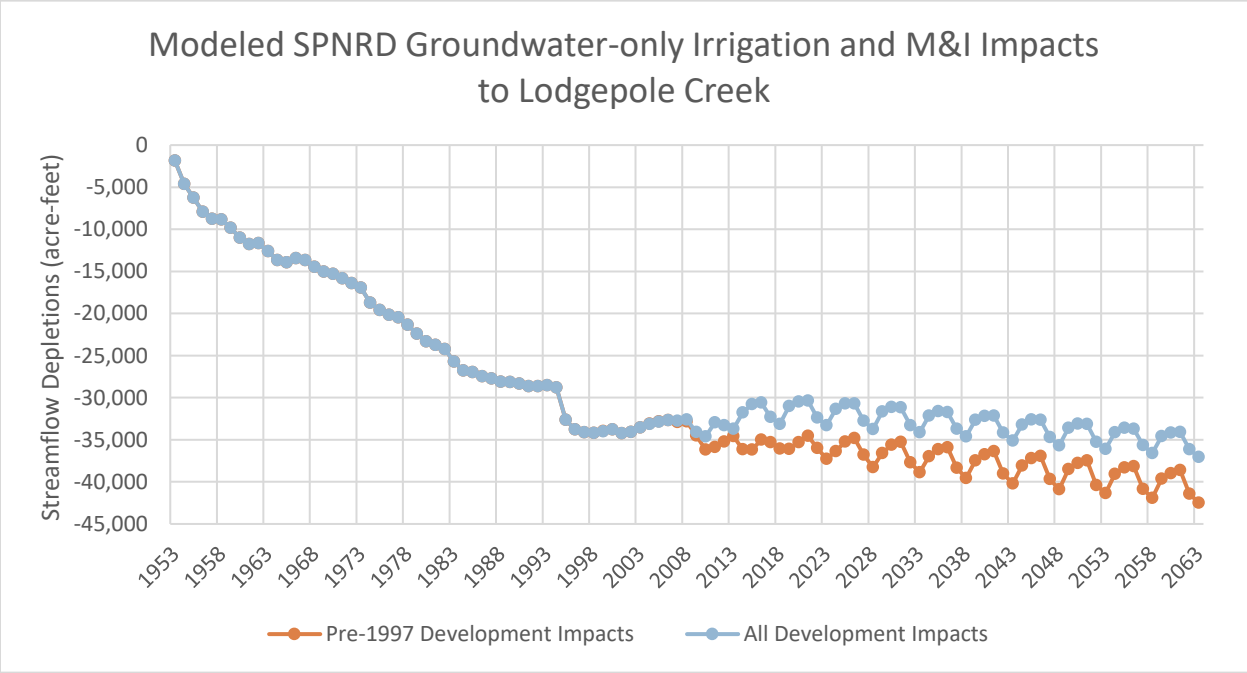

Figure 5. Modeled SPNRD streamflow impacts to Lodgepole Creek from all groundwater-only irrigation and M&I development with offsetting management actions and the streamflow impacts from development pre-1997.

Twin Platte NRD (TPNRD)

In Figure 6, 7, and 8, the modeled streamflow impacts to the South Platte River, North Platte River, and Platte River upstream of Elm Creek, respectively, from all groundwater-only irrigation and municipal and industrial development within TPNRD with offsetting management actions, including groundwater irrigated acres retirements and recharge projects on the South Platte River and Platte River upstream of Elm Creek, are shown in orange. Also shown are the modeled streamflow impacts from all groundwater-only irrigation and municipal and industrial development prior to 1997 in blue.

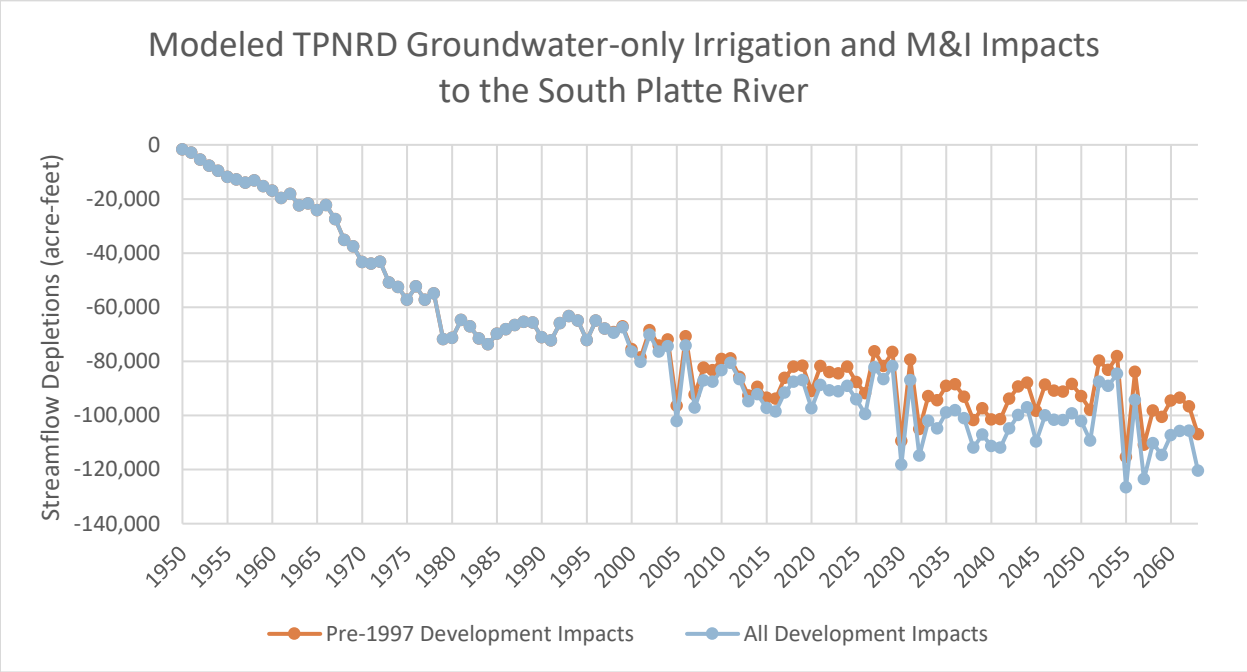

Figure 6: Modeled TPNRD streamflow impacts to the South Platte River from all groundwater-only irrigation and M&I development with offsetting management actions and the streamflow impacts from development pre-1997.

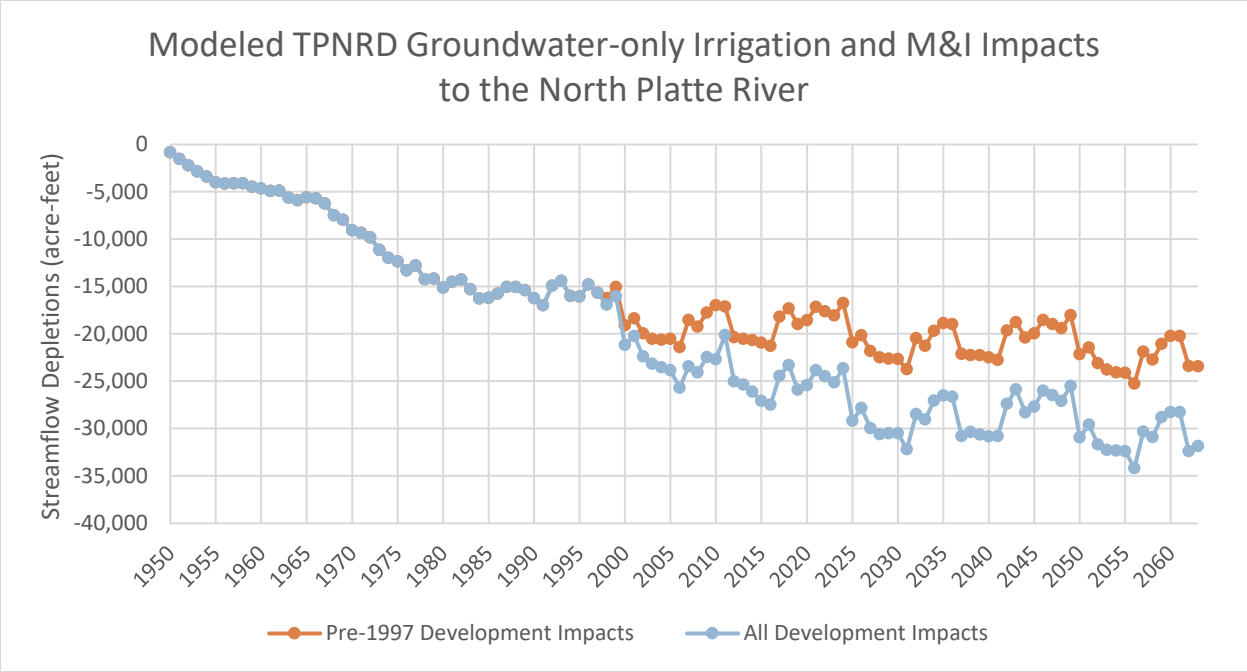

Figure 7: Modeled TPNRD streamflow impacts to the North Platte River from all groundwater-only irrigation and M&I development with offsetting management actions and the streamflow impacts from development pre-1997.

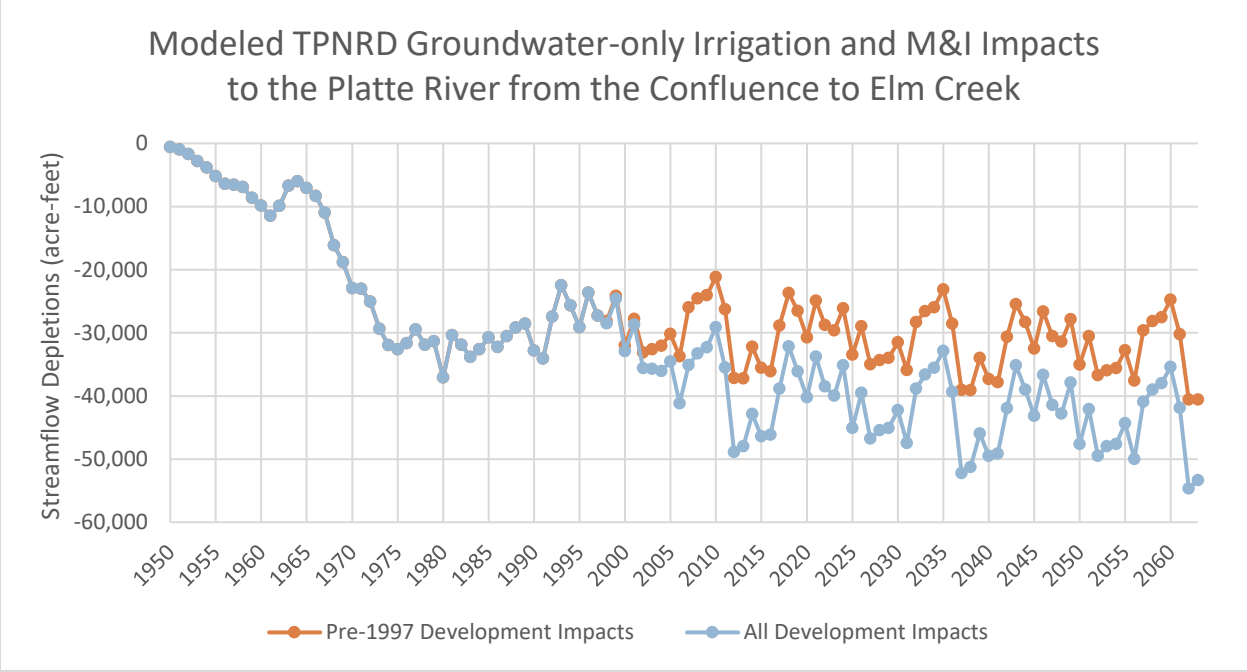

Figure 8: Modeled TPNRD streamflow impacts to the Platte River from the Confluence to Elm Creek from all groundwater-only irrigation and M&I development with offsetting management actions and the streamflow impacts from development pre-1997.

Central Platte NRD (CPNRD)

In Figure 9, the modeled streamflow impacts to the Platte River upstream of Elm Creek from all groundwater-only irrigation and municipal and industrial development within CPNRD with offsetting management actions, including groundwater irrigated acres retirements and recharge projects on the Platte River contracted by CPNRD, are shown in orange. Also shown are the modeled streamflow impacts from all groundwater-only irrigation and municipal and industrial development prior to 1997 in blue.

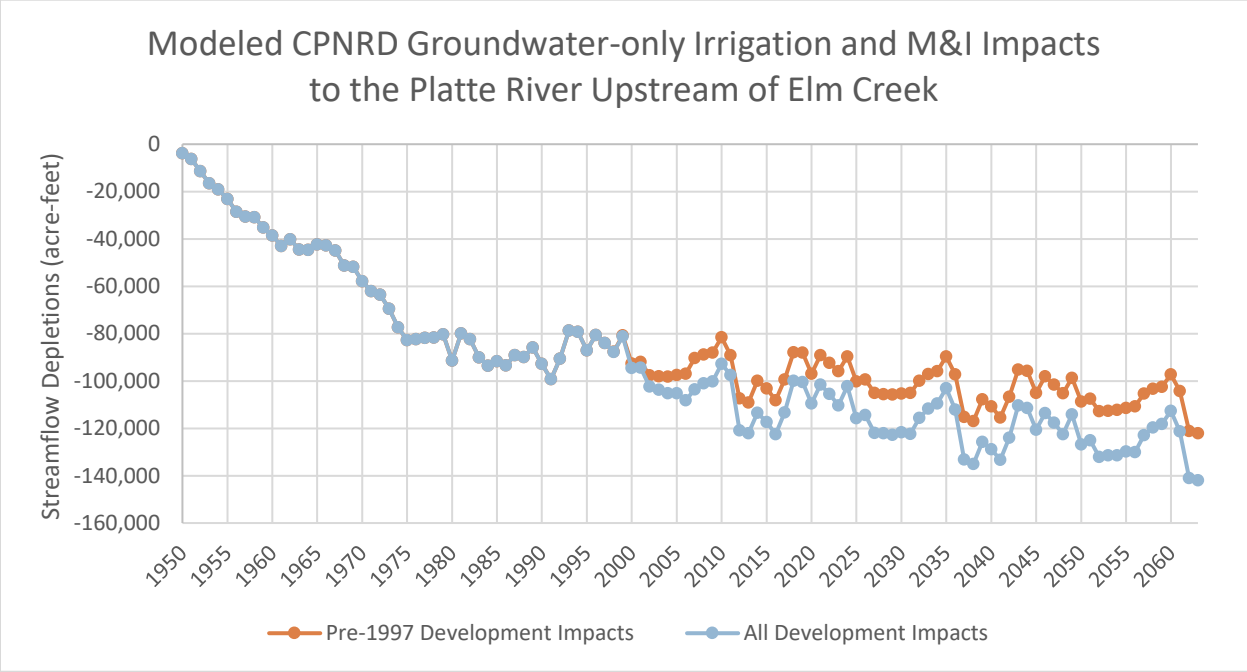

Figure 9: Modeled CPNRD streamflow impacts to the Platte River upstream of Elm Creek from all groundwater-only irrigation and M&I development with offsetting management actions and the streamflow impacts from development pre-1997.

Tri-Basin NRD (TBNRD)

In Figure 10, the modeled streamflow impacts to the Platte River upstream of Elm Creek from all groundwater-only irrigation and municipal and industrial development within TBNRD with offsetting management actions, including groundwater irrigated acres retirements, recharge projects on the Platte River contracted by TBNRD, and streamflow augmentation, are shown in orange. Also shown are the modeled streamflow impacts from all groundwater-only irrigation and municipal and industrial development prior to 1997 in blue.

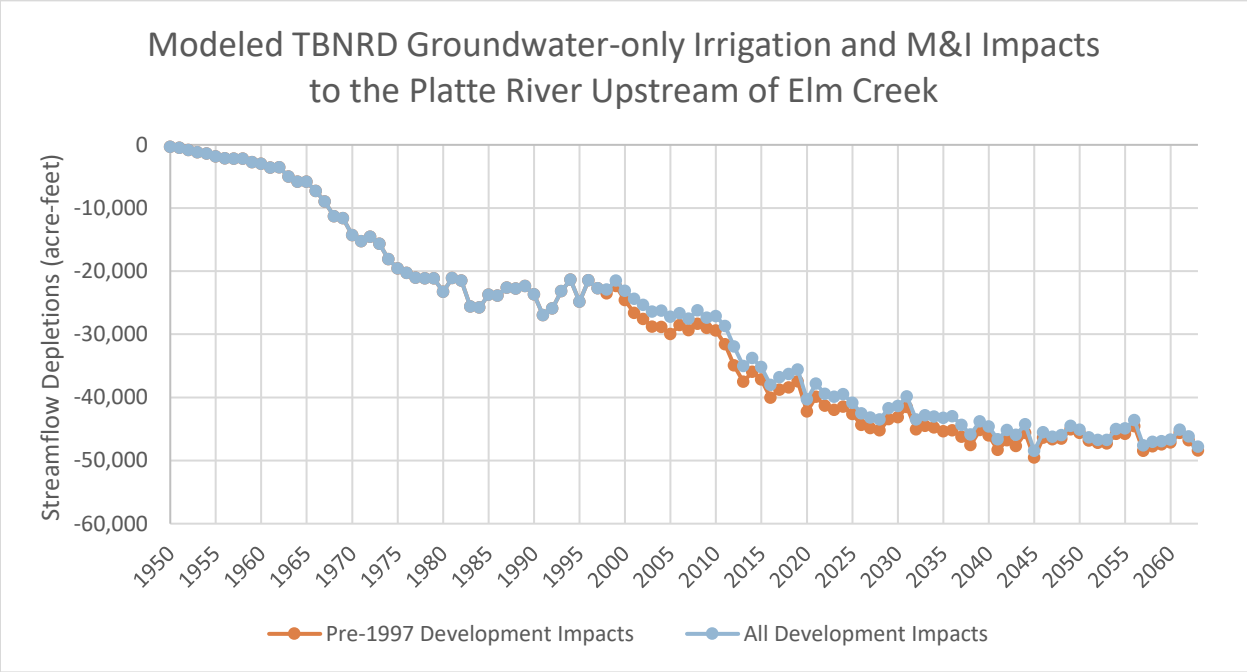

Figure 10: Modeled TBNRD streamflow impacts to the Platte River upstream of Elm Creek from all groundwater-only irrigation and M&I development with offsetting management actions and the streamflow impacts from development pre-1997.

Five Upper Platte River Basin NRDs

Figure 11 shows the modeled impacts to the Platte River upstream of Elm Creek from the five Upper Platte River Basin NRDs (including groundwater-only irrigation, municipal and industrial development, groundwater irrigated acres retirements, recharge projects, and streamflow augmentation).

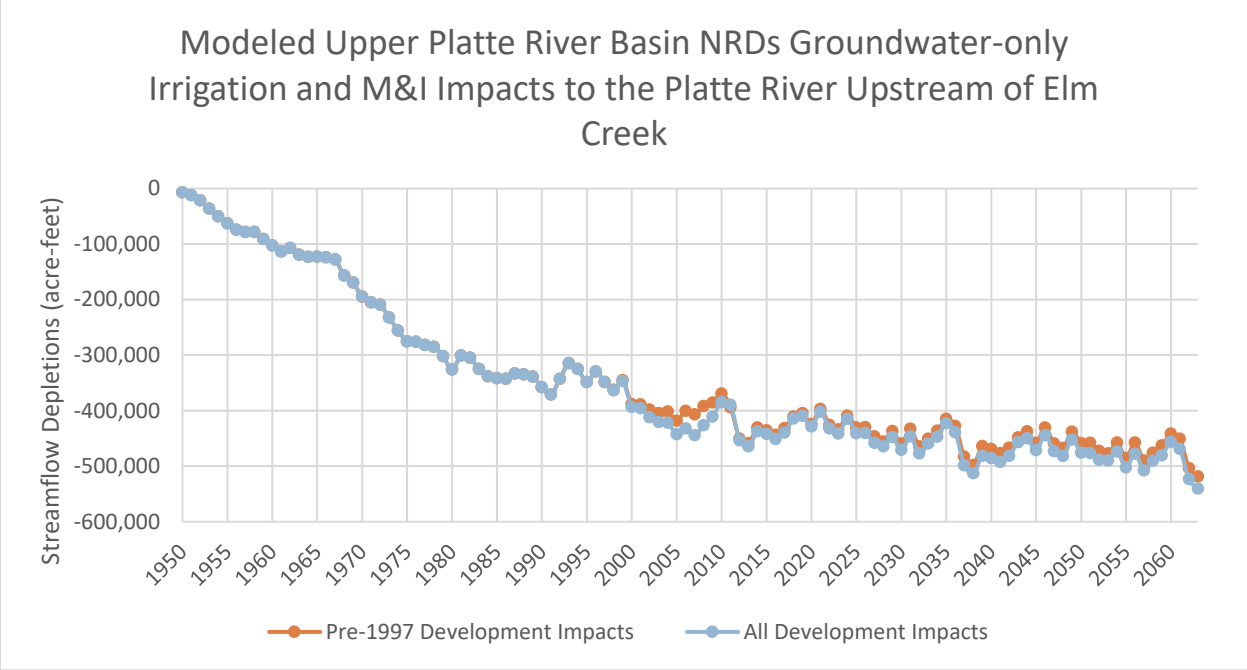

Figure 11: The five Upper Platte River Basin NRDs modeled streamflow impacts to the Platte River upstream of Elm Creek from all groundwater-only irrigation and M&I development with offsetting management actions and the streamflow impacts from development pre-1997.

STREAMFLOW DEPLETIONS TABLES

Table 1: Total groundwater-only irrigated acres for each of the Upper Platte River Basin NRDs used in this analysis, rounded to the nearest hundred acres.

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

Table 2: Average annual net recharge, irrigation groundwater pumping, municipal and industrial pumping, and net recharge (difference between recharge and groundwater pumping) within the entirety of NPNRD over 2014 to 2063 in acre-feet rounded to the nearest hundred.

NPNRD	HISTORICAL RUN (af)	NO GROUNDWATER-ONLY PUMPING RUN (af)	CHANGE DUE TO DEVELOPMENT (af)
AVERAGE RECHARGE	1,029,700	994,100	35,600
AVERAGE IRRIGATION GROUNDWATER PUMPING	198,800	53,800	145,000
MUNICIPAL AND INDUSTRIAL PUMPING	11,500	0	11,500
AVERAGE NET RECHARGE (Recharge - Groundwater Pumping)	819,400	940,300	-120,900

Table 3: Average annual net recharge, irrigation groundwater pumping, municipal and industrial pumping, and net recharge (difference between recharge and groundwater pumping) within the entirety of SPNRD over 2014 to 2063 in acre-feet rounded to the nearest hundred.

SPNRD	HISTORICAL RUN (af)	NO GROUNDWATER-ONLY PUMPING RUN (af)	CHANGE DUE TO DEVELOPMENT (af)
AVERAGE RECHARGE	160,200	136,100	24,100
AVERAGE IRRIGATION GROUNDWATER PUMPING	114,500	1,600	112,900
MUNICIPAL AND INDUSTRIAL PUMPING	3,600	0	3,600
AVERAGE NET RECHARGE (Recharge - Groundwater Pumping)	42,100	134,500	-92,400

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

TPNRD	HISTORICAL RUN (af)	NO GROUNDWATER-ONLY PUMPING RUN (af)	CHANGE DUE TO DEVELOPMENT (af)
AVERAGE RECHARGE	473,100	437,000	36,000
AVERAGE IRRIGATION GROUNDWATER PUMPING	358,600	37,800	320,800
MUNICIPAL AND INDUSTRIAL PUMPING	8,100	0	8,100
AVERAGE NET RECHARGE (Recharge - Groundwater Pumping)	106,400	399,200	-292,900

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

CPNRD	HISTORICAL RUN (af)	NO GROUNDWATER-ONLY PUMPING RUN (af)	CHANGE DUE TO DEVELOPMENT (af)
AVERAGE RECHARGE	646,200	559,000	87,200
AVERAGE IRRIGATION GROUNDWATER PUMPING	716,000	32,300	683,700
MUNICIPAL AND INDUSTRIAL PUMPING	22,300	0	22,300
AVERAGE NET RECHARGE (Recharge - Groundwater Pumping)	-92,100	526,700	-618,900

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

TBNRD	HISTORICAL RUN (af)	NO GROUNDWATER-ONLY PUMPING RUN (af)	CHANGE DUE TO DEVELOPMENT (af)
AVERAGE RECHARGE	287,300	248,100	39,200
AVERAGE IRRIGATION GROUNDWATER PUMPING	386,900	44,300	342,600
MUNICIPAL AND INDUSTRIAL PUMPING	3,200	0	3,200
AVERAGE NET RECHARGE (Recharge - Groundwater Pumping)	-102,800	203,900	-306,600

APPENDIX 1

Background on the Overall Difference between Current and Fully Appropriated Levels of Development

The Act (*Neb. Rev. Stat.* § 46-713 (3)), specifies that a basin, subbasin, or reach is fully appropriated if the current uses cause or will in the reasonably foreseeable future cause: 1) the surface water supply to be insufficient to sustain over the long term the beneficial or useful purposes for which existing natural-flow or storage appropriations were granted and the beneficial or useful purposes for which, at the time of approval, any existing instream appropriation was granted; 2) the streamflow to be insufficient to sustain over the long term the beneficial uses from wells constructed in aquifers dependent on recharge from the river or stream involved or 3) reduction in the flow of a river or stream sufficient to cause noncompliance by Nebraska with an interstate compact or decree, other formal state contract or agreement, or applicable state or federal laws.

The Act further defines that the overall difference between the current and fully appropriated levels of development to mean the extent to which existing uses of hydrologically connected surface water and ground water and conservation activities result in the water supply available for purposes identified in subsection (3) of section *Neb. Rev. Stat.* § 46-713 to be less than the water supply available if the river basin, subbasin, or reach had been determined to be fully appropriated in accordance with section *Neb. Rev. Stat.* § 46-714. This, in essence, suggests the overall difference between current and fully appropriated levels of development is determined through the rules and methods used by NeDNR to designate basins as fully appropriated.

The rules and methods used by NeDNR to designate a basin as fully appropriated in accordance with *Neb. Rev. Stat.* § 46-714 primarily rely on the evaluation of junior natural-flow surface water irrigation appropriations (see N.A.C. Title 457, Chapter 24 and Annual Evaluation of Availability of Hydrologically Connected Water Supplies, December 30, 2016). The rules further establish that in the event other natural-flow and storage appropriations need to be considered, NeDNR has the ability to utilize a standard of interference appropriate for the use in conducting its evaluation. Through the course of attempting to apply the rules and methods to the complexities of the Upper Platte River Basin, NeDNR and NRDs have agreed that further standards are necessary and have applied different methods (see INSIGHT, Preliminary Estimate of Historical Stream Flow Reductions in the Overappropriated Portion of the Platte River in Nebraska, 2009) were applied to support the assessments. These alternative methods remain flexible to NeDNR and the NRDs and may be refined in subsequent evaluations.

The technical evaluations described in this report, in conjunction with other supporting data, are ultimately used to establish appropriate IMP goals and objectives. The IMPs must contain clear goals and objectives with a purpose of sustaining a balance between ***water uses*** and ***water supplies*** so that the economic viability, social and environmental health, safety, and welfare of the river basin, subbasin, or reach can be achieved and maintained for both the near term and the long term (*Neb. Rev. Stat.* § 46-715 (2)). Understanding that water uses cannot exceed water supplies (natural-flow and storage supplies), a balance will likely exist each year in the overappropriated basin. However, ***water demand*** can exceed

water use when supplies are limited. Even if all water users have access to and are able to use water supplies, their total demand may not be met. It is important to review the distribution of the balance of water supply and water use among various water users to see which users might not be meeting their full demand. The distribution of water use among the different user groups in the basin and the degree to which the use meets the demand is what influences the economic viability, social and environmental health, safety, and welfare of the river basin. Therefore, establishing appropriate goals and objectives in the IMP requires careful consideration of this distribution, as well as the total water use and supply, in order to ensure that the balance recognizes the overall welfare of the basin.

APPENDIX 2

Model Documentation: COHYST and WWUM

I. Objective

The purpose of this modeling evaluation is to simulate depletions to streamflow from development of groundwater-only irrigated lands in each of the five Upper Platte River Basin NRDs.

For each NRD analysis, two model runs are necessary: a baseline simulation and an impact/scenario simulation. The baseline simulation is the representation of the historical condition. The scenario simulation is the representation of no groundwater only irrigated acres nor municipal and industrial (M&I) pumping. The difference between these two runs provides an estimate of the streamflow impacts from groundwater development.

The WWUM models were used for the NPNRD and SPNRD analyses. The simulation period for the WWUM analyses is 1953 to 2063. The COHYST models were used for the TPNRD, CPNRD, and TBNRD analyses. The simulation period for the COHYST analyses is 1950 to 2063.

II. Baseline Model Setup – Historical

The baseline WWUM and COHYST models used for this analysis were developed for the 2019 Upper Platte River Basin Robust Review. No additional changes were made to the baselines. The set-ups of the baselines are available in the Robust Review documentations for WWUM and COHYST separately (2019 Upper Platte River Basin Robust Review).

III. Scenario Setup – No groundwater-only pumping

The scenario for each of the five Upper Platte NRDs of NPNRD, SPNRD, TPNRD, CPNRD, and TBNRD is to represent no groundwater-only irrigation development and no M&I development (hereafter referred to as No GWO) as compared to the baseline that has historical groundwater-only irrigation and M&I conditions. This requires the scenario to be modified from the baseline during the scenario watershed model setup (land use and M&I pumping). Only the recharge files and well files change between the baseline and scenario all other MODFLOW package files maintain the same set up as the baseline.

1. Scenario Watershed Model Setup

There was one run of each of the watershed models (WWUM and COHYST) executed for the scenario simulation. The baseline inputs were modified by converting groundwater-only irrigated acres to dryland and not including M&I pumping. The TFG Memorandum Re: Robust Review COHYST area Model Runs, dated November 26, 2018, documents the COHYST Watershed model setup. The TFG Memorandum Re: October 2018 Update: Post 97 Analysis – Western Water Use Model (WWUM) Area, dated October 11, 2018, documents the WWUM Watershed model setup. The land use change and M&I pumping change was made for all areas of the model in a single watershed model run for each model, and the resulting pumping and recharge impacts were isolated by NRD management area in the scenario groundwater model setup. The watershed

results for the No GWO scenario were provided from TFG to DNR and include land use and water balance summaries and recharge (.rch) and pumping (.wel) MODFLOW groundwater model files.

2. Scenario Groundwater Model Setup

All scenario groundwater model data remained the same as in the baseline except watershed modeled recharge and pumping. Therefore, North Dry Creek pumping and excess flow recharge volumes were added to the scenarios pumping and recharge files, respectively, from the scenario watershed model output of each model, as applicable, which is described in the baseline models documentations (2019 Upper Platte River Basin Robust Review).

For each of the five NRD management area scenarios, the corresponding scenario recharge and pumping values were replaced in the baseline model for that management area with the baseline watershed model recharge and pumping values remaining the same for the other NRDs and remainder of the model area. The following table summarizes the five groundwater model run scenarios.

Table 1. Scenarios representing no groundwater irrigation and M&I pumping conditions for comparison to the baseline scenario representing historical development and management actions.

Scenario Management Area	Model Area	Scenario Description	Change to baseline pumping	Change to baseline watershed modeled recharge
NPNRD	WWUM	Historical without NPNRD GWO and M&I development	No GWO scenario pumping in NPNRD	No GWO scenario recharge in NPNRD
SPNRD	WWUM	Historical without SPNRD GWO and M&I development	No GWO scenario pumping in SPNRD	No GWO scenario recharge in SPNRD
TPNRD	COHYST	Historical without TPNRD GWO and M&I development	No GWO scenario pumping in TPNRD	No GWO scenario recharge in TPNRD
CPNRD	COHYST	Historical without CPNRD GWO and M&I development	No GWO scenario pumping in CPNRD	No GWO scenario recharge in CPNRD
TBNRD	COHYST	Historical without TBNRD GWO and M&I development	No GWO scenario pumping in TBNRD	No GWO scenario recharge in TBNRD

IV. Model Output and Post-processing

1. Watershed Model Outputs

The Watershed land use and water balance summaries were used to generate the summaries of acres by irrigation type and crop type. The accounting points and NRD area zone files described later in the groundwater model output post processing were used to create these reports. The following differences in the annual number of acres by irrigation source or crop type were used:

Groundwater-only developed acres = Historical/Baseline groundwater-only acres

The land use and water balance summaries were also used to QA/QC the pumping and recharge differences that were calculated in groundwater model post-processing.

2. Groundwater Model Outputs

a. Process model results by NRD zone

The cell-by-cell outputs of the groundwater model runs were processed through Zonebudget with a zone file representing the management areas, detailed in the following Zone files section of the Robust Review documentations (2019 Upper Platte River Basin Robust Review). The difference between the pumping and recharge between the scenario and the baseline were summarized annually and compared to the watershed model outputs for quality control.

b. Process model results by accounting zone

The cell-by-cell output of the groundwater model was run through ZoneBudget with a zone file representing the delineations of the stream accounting points. For the purpose of the report, the zones were combined to account for the North Platte River, South Platte River, and Platte River Upstream of Elm Creek, as further detailed in the Zone files section of the Robust Review documentations (2019 Upper Platte River Basin Robust Review). The stream leakage terms from the ZoneBudget outputs are summarized on an annual basis. Net stream leakage is calculated as the difference between the volumes of water that went from the aquifer to the stream and from the stream to the aquifer. The difference between the scenario and baseline net stream leakage are the scenario impacts. As calculated, negative impacts are depletions and positive impacts are accretions.

c. Pre and post 1997 development and management impacts

The results of this analysis provide an estimate of the streamflow impacts from all historical groundwater only irrigation and M&I pumping. To quantify the total impacts of the historical groundwater only irrigation and M&I pumping with the offsetting management actions, the results of this analysis were combined with the impacts of the augmentation and excess flow recharge management actions as calculated in the Robust Review. For further details on the Robust Review and calculation of the augmentation pumping and excess flow recharge impacts see the Robust Review documentation (2019 Upper Platte River Basin Robust Review). The post-1997 impacts quantified in the Robust Review, as described in the Robust Review documentation (2019 Upper Platte River Basin Robust Review), were subtracted from the No GWO results to obtain the pre-1997 development impacts.

V. Results

The acres changes, pumping and recharge differences, and resulting differences in stream leakage are summarized in five spreadsheets – one for each NRD/area. They are titled:

COHYST_RobRevResults_CPNRD.xlsx, COHYST_RobRevResults_TPNRD.xlsx, COHYST_RobRevResults_TBNRD.xlsx, WWUM_RobRevResults_NPNRD.xlsx and WWUM_RobRevResults_SPNRD.xlsx .

These files are available at: https://upjointplanning.nebraska.gov or by contacting NeDNR.

VI. Additional/Further Investigations

The results of this analysis are subject to the limitations of the modeling processes outlined in this and other model documentation. Further investigations may be necessary to test the assumptions of this analysis and to assess the impacts of other management actions. Below is a short list of further investigations that we recommend:

- The sensitivity of annual depletions resulting from different climate representations
- The sensitivity of depletions to different crop type conversions on groundwater-only irrigated acres historically and when converting between groundwater only to dryland
- The sensitivity of annual and accounting point depletions to including runoff and diversions and returns
- Updating conservation practices/more accurate representation of current farming practices
- Hydraulic conductivity and initial head sensitivity in the vicinity of Plum Creek