Republican River Basin-Wide Plan

Jointly developed by the Upper Republican, Middle Republican, Lower-Republican, and Tri-Basin Natural Resources Districts and the Nebraska Department of Natural Resources

2019

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1. Introduction

Section Overview

This section describes why the Republican River Basin-Wide Plan (Plan) was developed. It then compares this regional basin-wide plan with local Integrated Management Plans that have also been developed for this area, providing clarity about how these two types of plans relate to one another and work together to guide management of hydrologically connected surface water and groundwater. Finally, it outlines the planning process, including the parties who were involved in development of the Plan and their roles in the process.

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Effective Date and Time Frame of the Plan

The Republican River Basin-Wide Plan (Plan) became effective on March 1, 2019.

The time frame to implement this Plan is approximately 25 years, spanning from the effective date of the Plan to no later than April 17, 2044 (*Neb. Rev. Stat.* § 46-755(4)). A timeline to meet the goals and objectives of the Plan within this time frame is outlined in the "Plan Implementation Schedule" section, page 51.

Authority

Neb. Rev. Stat. § 46-755(1) requires a basin-wide plan when a basin includes three or more natural resources districts (NRDs) that have been or are required to develop an integrated water management plan (IMP) for at least eighty-five percent of the district. Because the Republican River Basin (Basin) meets these criteria, the NRDs within the

Basin must work together with each other and with the Nebraska Department of Natural Resources (NeDNR) to jointly develop and adopt a basin-wide plan for the areas of the Basin that have been determined to have hydrologically connected water supplies.

Background, Purpose, and Intent

This Plan is the result of a collaborative effort by NeDNR, Tri-Basin NRD, Lower Republican NRD, Middle Republican NRD, Upper Republican NRD, and the Republican River Basin-Wide Plan Stakeholder Advisory Committee (stakeholders). The Plan was initiated to fulfill the requirements of *Neb. Rev. Stat.* § 46-755, wherein NRDs and NeDNR are required to jointly develop and establish a plan to collaboratively manage hydrologically connected water resources with the Basin, as described above under "Authority."

The Plan's purpose is described by both a vision statement and a mission statement. A vision statement is a concise, forward-looking statement summarizing the desired end-state. The vision statement was developed with stakeholder input and adopted by a vote of the Stakeholder Advisory Committee.

Vision Statement for the Plan
"Waters responsibly used and the Republican River Basin is economically vibrant"

A plan's mission statement defines its purpose. NeDNR, the NRDs, and the stakeholders agreed that the plan's purpose is clearly defined in statute, so the adopted mission statement is based on the language found in *Neb. Rev. Stat.* § 46-755 (4)(a).

Mission Statement for the Plan
"To sustain a balance between water uses and water supplies so that the economic viability, social and environmental health, safety, and welfare of the Republican River Basin can be achieved and maintained for both the near term and long term."

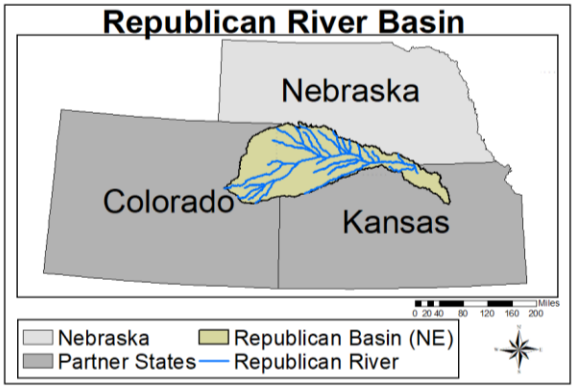

Figure 1.1. The Republican River Compact is an interstate agreement about how the water supplies of the Republican River Basin are shared by Nebraska, Kansas, and Colorado.

Statute also requires that this Plan "ensure that compliance with any interstate compact or decree or other formal state contract or agreement or applicable state or federal law is maintained" (*Neb. Rev. Stat.* § 46-755(4)(b)). Therefore, this Plan must ensure that Nebraska continues to comply with the Republican River Compact (Compact). The Compact (*Neb. Rev. Stat. Appendix* 1-106) is an interstate agreement between Colorado, Nebraska, and Kansas about how the water

supply of the Basin is to be shared among the three states (Figure 1.1).

For background information about the hydrology of the Republican River, see Appendix A, "Local Hydrology."

Integrated Management Plans and Basin-Wide Plan in the Basin

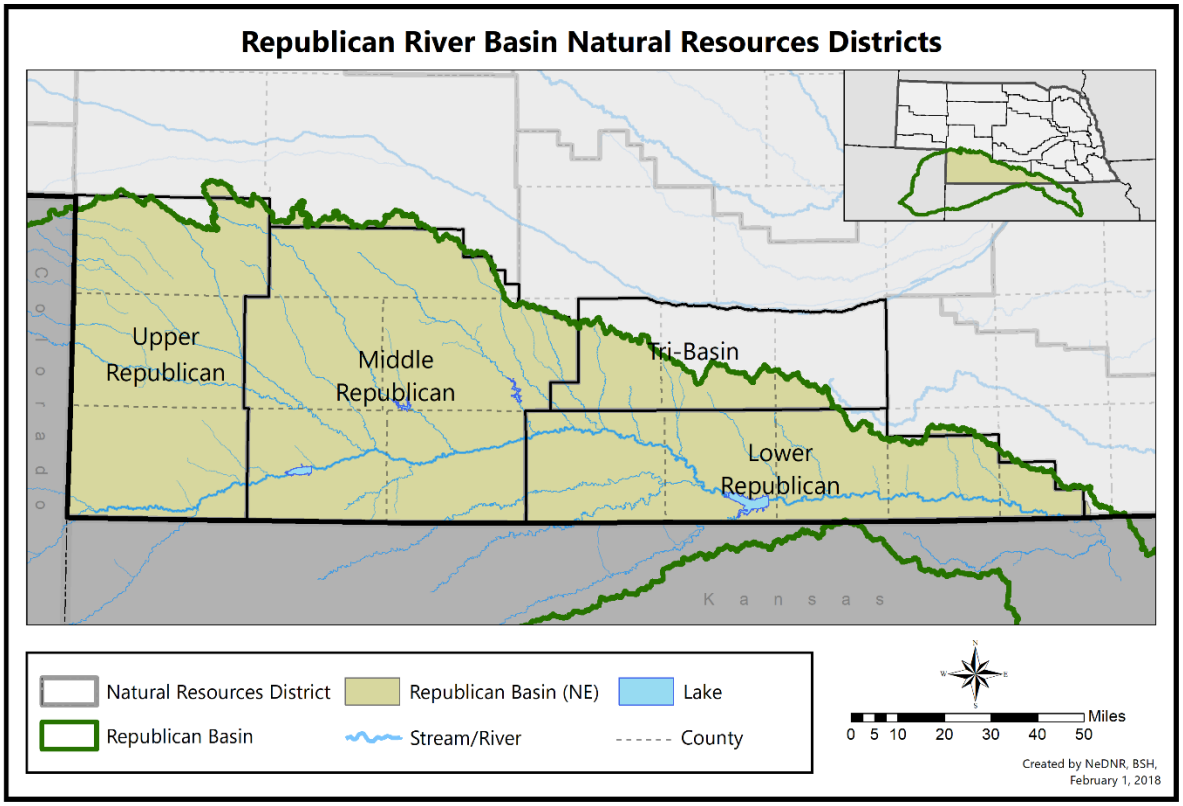

Figure 1.2. Four Natural Resources Districts comprise the majority of the Nebraska portion of the Republican River Basin, and are partners in the Republican River Basin-Wide Plan.

Collaborative integrated water management planning within this Basin occurs at both local (individual NRD) and regional (basin-wide) scales. Locally, each IMP is jointly developed and implemented by NeDNR and a single NRD. Under *Neb. Rev. Stat.* § 46-715, an IMP is required for each of the four NRDs in this Basin (Figure 1.2). Regionally, a basin-wide plan is jointly developed by NeDNR and multiple NRDs.

Broadly, the Basin's required IMPs and basin-wide plan support cooperation between NeDNR and the Basin's NRDs to ensure coordinated management of the Basin's hydrologically connected surface and groundwater supplies. Through the development and implementation of these planning processes, NeDNR, the NRDs, and local stakeholders foster better communication and collaboration concerning the Basin's water issues, which provides a foundation for more efficient, adaptable, and sustainable water management now and in years to come.

Many of the planning elements in individual required IMPs and this basin-wide plan are shared, but a few conceptual and practical differences exist. The two following subsections describe the background and unique role for each type of plan, as well as how the two types of plans work together to improve integrated water management in the Basin. These similarities and differences are summarized in Figure 1.3.

Integrated Management Plans

In 2004 the State Legislature passed LB 962, which required IMPs for NRDs designated as overappropriated or fully appropriated. The Upper Republican, Middle Republican, and Lower Republican NRDs initiated IMPs in 2005 and adopted their first generation IMPs in 2006. These plans have been updated several times since, and at the time of this Plan's adoption, each of these three IMPs is now in its fourth generation. The Tri-Basin NRD's IMP became effective in 2012. Through adaptive management, all of these IMPs will continue to be updated as needed.

As described in *Neb. Rev. Stat.* § 46-715, a required IMP must contain clear goals and objectives intended to protect existing uses and manage for new uses for a sustainable balance between water uses and water supplies. It must also include a map of the plan's geographic area (which must include the portion of the NRD determined by NeDNR to be hydrologically connected, but may include the entire NRD), at least one groundwater control, at least one surface water control, and a plan for monitoring and data collection. Management actions initiated through IMPs must also comply with federal and state laws and interstate compacts and agreements. In addition, NeDNR and the NRD consult with water users in the affected area and provide those water users with an opportunity to provide input during development of an IMP.

Each IMP is developed to uniquely suit the needs of the individual NRD, and thus monitoring protocols, actions, and controls are tailored to fit the differing goals and objectives of each plan.

The Republican River Basin-Wide Plan

In 2014, the Nebraska Legislature passed LB 1098, which called for the development of this basin-wide plan for the Republican River, because the Basin met the criteria described under "Authority" (page 4). The requirements for this Plan are described in *Neb. Rev. Stat.* § 46-755.

Like the individual IMPs, this basin-wide plan must contain goals and objectives; however, unlike IMPs, this basin-wide plan does not require groundwater or surface water controls. Basin-wide plans instead provide clear goals and objectives for the entire basin, to which the NRDs can then align the controls and actions of their IMPs to achieve. Similar to IMPs, this type of basin-wide plan must apply to at least the entire hydrologically connected area of the Basin, but may apply to the entire Basin.

Like IMPs, this type of basin-wide plan must include a plan for monitoring, data collection, and regular evaluation; however, *Neb. Rev. Stat.* § 46-755 specifies some unique additional requirements for this basin-wide plan: it must set forth a timeline to meet goals and objectives (not to exceed 30 years from April 17, 2014), as well as a schedule of intermediate target dates to track progress toward specified measurable

hydrologic objectives. In addition, every five years after adoption of this basin-wide plan, NeDNR and the NRDs must conduct a technical analysis of progress toward meeting the plan's goals and objectives.

Whereas NeDNR and the NRDs are required to consult with stakeholders during the development of an IMP, development of a required basin-wide plan must involve a much more rigorous process of consultation and collaboration with stakeholders that rely on water from the affected area. Statute requires that stakeholders be involved in formulating, evaluating, and recommending plan details, and that NeDNR and the NRDs work to reach agreement among all official participants. For additional information on information considered during the development of this Plan, see Appendix B.

Overall, basin-wide plans provide a more general framework than IMPs, focusing on regional, cross-boundary issues and opportunities such as those related to hydrologic connectivity and management strategies that cross the NRDs' borders. Basin-wide plans also provide opportunities for consistency among all of the Basin's NRDs by offering an umbrella framework for the individual IMPs. Individual IMPs must be consistent with the basin-wide plan, but may contain additional goals, objectives, and controls that are tailored to local conditions, management issues, and opportunities found within the specific NRD.

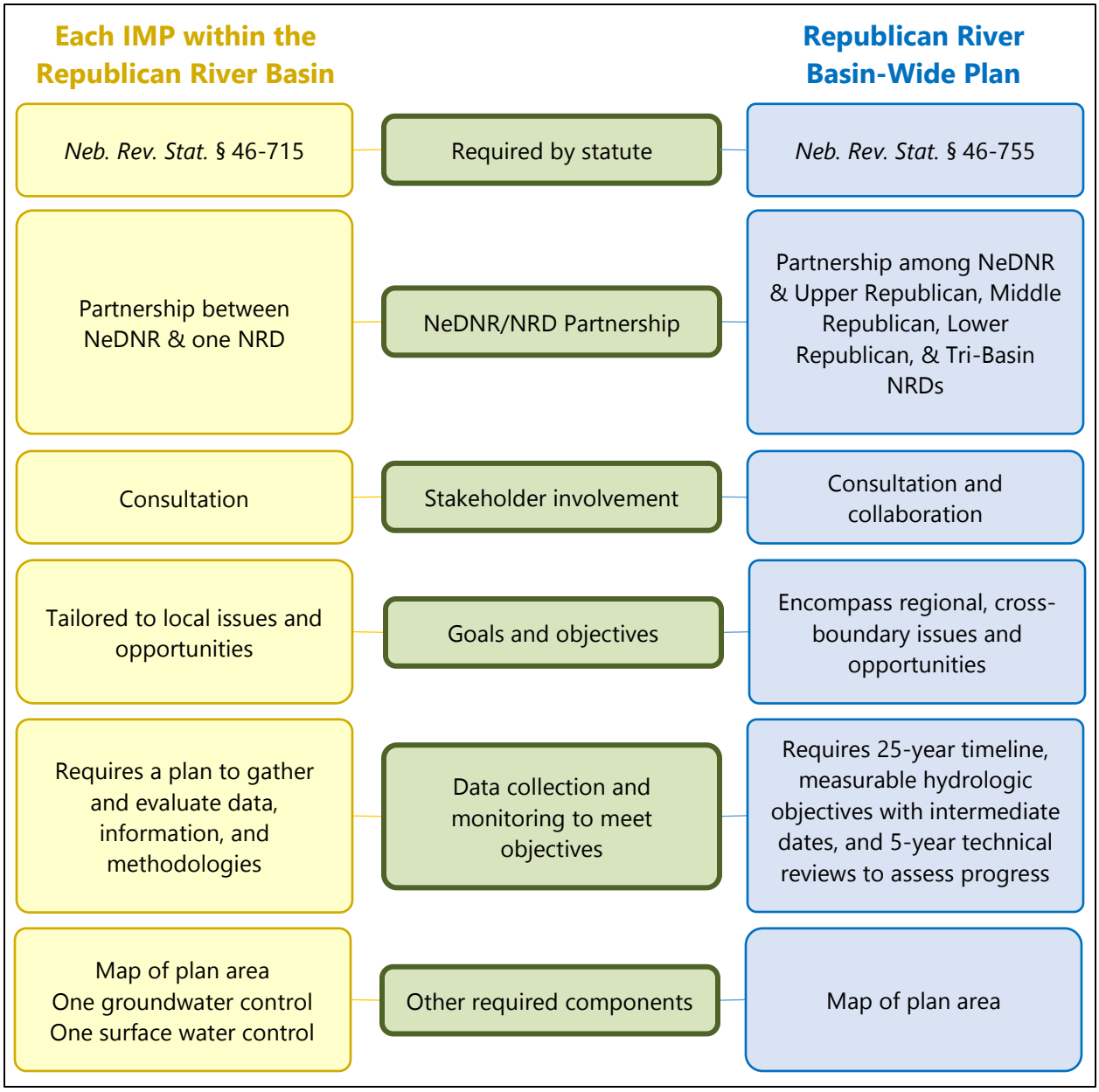

Figure 1.3. Comparison of IMPs developed by the Republican River NRDs and the Republican River Basin-Wide Plan.

Planning Process

Parties to the Plan

This Plan was jointly developed by NeDNR, Upper Republican NRD, Middle Republican NRD, Lower Republican NRD, Tri-Basin NRD, and the Plan's Stakeholder Advisory Committee.

The Plan was developed in consultation and collaboration with the representatives of irrigation districts, mutual irrigation

companies, reclamation districts, public power and irrigation districts, canal companies, groundwater users, range livestock owners, the Nebraska Game and Parks Commission, and municipalities that rely on water from the affected area, as required by statute (*Neb. Rev. Stat.* § 46-755 (5)(c)). The Stakeholder Advisory Committee additionally included representatives who self-identified as representing agribusiness, education, banking, general taxpayer, and conservation interests, as well as a representative of the US Bureau of Reclamation (Table 1.1).

Table 1.1. While registering to become members of the Stakeholder Advisory Committee, stakeholders indicated they were representing the following interests.

Self-identified interest in the Basin	Number of stakeholders*
Agribusiness	7
Banker	2
Conservationist	2
Education	3
Former NRD Staff	2
Groundwater user	19
Interested party	1
Irrigation district	3
Surface water irrigator	3
Irrigator	1
Municipalities	6
Nebraska Game and Parks Commission	1
Property tax payer	1
Public power district	1
Range livestock owner	7
Reclamation	1
Recreation	1

*Stakeholders were eligible to select more than one interest, so the total is larger than the number of stakeholders.

Stakeholder Selection

The US Bureau of Reclamation, Nebraska Game and Parks Commission, Frenchman-Cambridge Irrigation District, Frenchman Valley Irrigation District, Pioneer Irrigation District, Nebraska-Bostwick Irrigation District, and Central Nebraska Public Power and Irrigation District were invited, either in writing or verbally, to participate in the basin-wide planning process as members of Stakeholder Advisory Committee. These entities were asked to reply in writing if they chose to participate. Of these organizations, the US Bureau of Reclamation, Nebraska Game and Parks Commission, Frenchman-Cambridge Irrigation District, Nebraska-Bostwick Irrigation District, and Central Nebraska Public Power and Irrigation District each designated a representative to serve on the Plan's Stakeholder Advisory Committee.

In addition, NeDNR and the four NRDs published public stakeholder recruitment notices in local newspapers between July 27 and August 23, 2014. The NRDs published notices in 18 newspapers with local readership, and NeDNR published a notice in the Omaha World-Herald.

In response to these notices, members of the public who wanted to join the Stakeholder Advisory Committee had to indicate their interest in writing, either by submitting a letter or email to NeDNR or by filling out a form on NeDNR's website. Both residents of the Basin and individuals who lived outside the Basin, but who had a water interest in the Basin, were eligible to join (Figure 1.4). Examples of non-resident stakeholders include representatives of a state agency, a conservation organization, and agribusiness, as well as individuals from outside the Basin who own land within the Basin.

When indicating their interest in joining the Stakeholder Advisory Committee meeting, stakeholders were asked to self-identify their relevant interest to the Basin. These interests are listed in Table 1.1.

The initial deadline for stakeholders to indicate their intent to join the Stakeholder Advisory Committee was August 31, 2014. There were 28 respondents as of the initial deadline, and the response deadline was extended to February 13, 2015, to represent a wider range of stakeholder interests. At the start of Plan development, the Stakeholder Advisory Committee included 47 members. Five stakeholders resigned from the committee during Plan development, which left the Stakeholder Advisory Committee with 42 members to vote on the final draft of the Plan. The final stakeholders are listed in Appendix C, "Plan Development."

Planning Meetings

The development process for this Plan consisted of two types of meetings: stakeholder meetings and coordination meetings. These meetings began in January of 2015 with the first coordination meeting, and continued through mid-2018, typically alternating approximately every other month. A meeting schedule appears in Appendix C, "Plan Development."

Stakeholder meetings included NeDNR, the NRDs, and the Stakeholder Advisory Committee, with the majority of each meeting focused on stakeholder discussion and decision-making. Attendance at stakeholder meetings was voluntary. At coordination meetings, NeDNR and the NRDs came together to discuss Plan development progress, consider how to incorporate stakeholder feedback into the Plan, and plan the format of upcoming stakeholder meetings.

The core of Plan development occurred during the stakeholder meetings. For example, during stakeholder meetings, stakeholders identified their priorities for the Plan and identified their concerns about water management in the Basin. These identified priorities and concerns shaped the discussion topics for subsequent meetings, and the goals and objectives and many other details of the Plan grew out of those discussions. Stakeholders were also invited to provide written comments on draft Plan materials between meetings.

The purpose of the stakeholder process was to collaboratively develop a plan that suits the local needs of stakeholders and to ensure inclusion, while balancing water uses and water supply. The Plan's process specifically sought to reach agreement by setting each agenda based on previous stakeholder discussions. Per *Neb. Rev. Stat.* § 46-755 (5)(c), the objective of the planning process was to reach agreement on the Plan by all parties; a large majority of the stakeholders agreed to the Plan, but there wasn't total consensus among all members so the Plan was adopted by only NeDNR and the NRDs, as specified in statute. The stakeholders did reach agreement on 13 of 16 Plan sections, and for these 13 sections, NeDNR and the NRDs adopted language that is consistent with the language the stakeholders voted to approve. Almost all of the stakeholders present voted to approve the three remaining Plan sections (Plan Area, Plan Schedule, and Procedures for Addressing Conflicts), and for those three sections, NeDNR and the NRDs adopted language that was consistent with language that was most strongly supported by stakeholder votes.

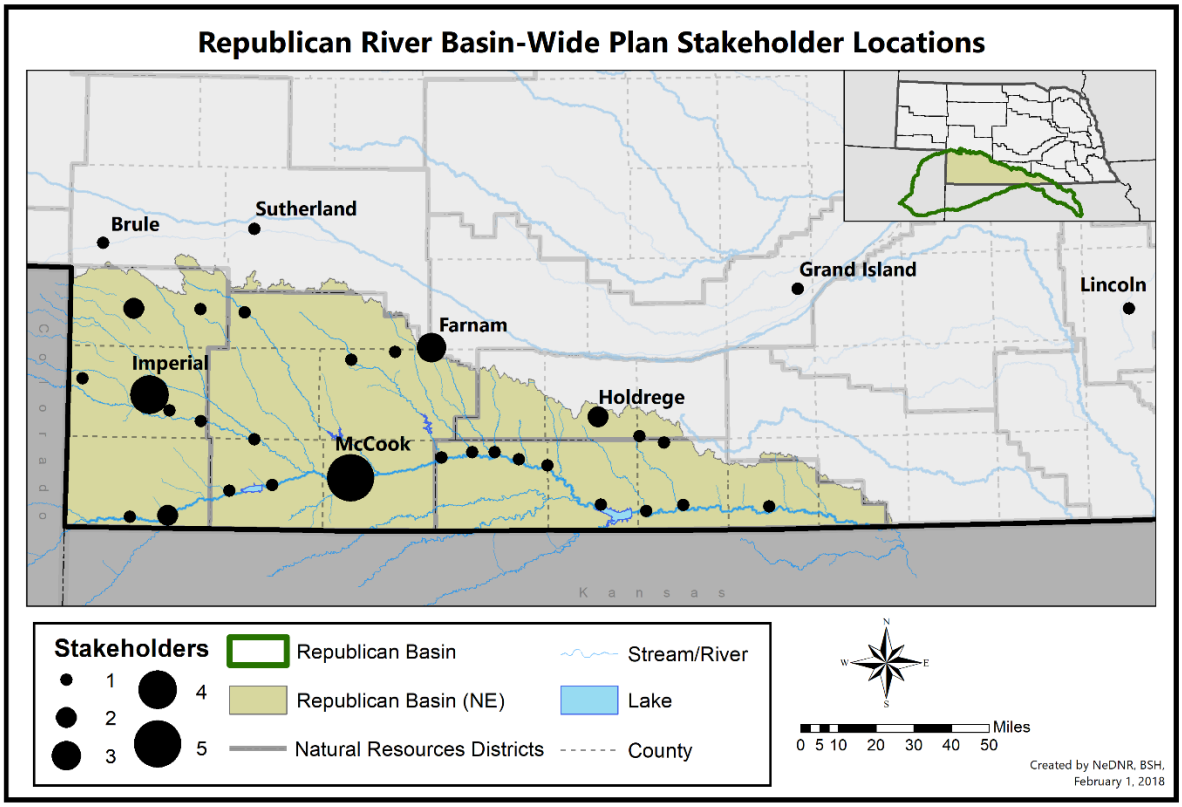

Figure 1.4. Locations of members of the Republican River Basin-Wide Plan's Stakeholder Advisory Council.

Responsibilities and Authorities of NeDNR and NRDs

NeDNR is responsible for permitting surface water rights for beneficial uses including storage, irrigation, hydropower, and instream flows. NeDNR registers wells, delineates hydrologically connected aquifers and flowing water, regulates dams, delineates floodplains, and provides technical and policy assistance. NeDNR also collaborates with all 23 NRDs to develop and manage integrated water management plans and basin-wide plans.

Among their statutory authorities, NRDs are responsible for local development, management, utilization, and conservation of groundwater and surface water. NRDs manage groundwater use permitting and monitor and regulate groundwater quality. The NRDs have the legal authority to regulate groundwater use within their boundaries to ensure that irrigated agriculture remains an important industry to Nebraska in accordance with *Neb. Rev. Stat.* §§ 46-701 and 46-704(3). Additionally, NRDs are authorized, along with the Nebraska Game and Parks Commission to hold instream water rights for fish, wildlife, and recreation, and the NRDs collaborate with NeDNR to develop and Implement integrated water management plans and basin-wide plans.

2. Goals and Objectives

Section Overview

The Goals and Objectives section of the Republican River Basin-Wide Plan (Plan) begins by listing the goals of the Plan. Then, the management actions that will be taken to achieve the Plan's goals and objectives are described in detail.

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List of Goals

The goals of the Plan are:

1. Maintain Nebraska's compliance with the Republican River Compact and applicable state laws
2. Maximize Nebraska's efficient and beneficial consumptive use of its portion of the water supply, increase certainty for long-range planning of water supplies to reduce the need for regulatory actions, and increase collaborative efforts among water management entities and stakeholders across the Basin
3. Positive public relations, including information sharing, within and outside the Basin
4. When possible, pursue projects that not only benefit water supplies and uses, but also create benefits for fish, wildlife, recreation, and conveyance within the Republican River Basin

Information about planned implementation of these goals can be found in the following locations of the Plan:

- A general timeline and framework for implementation is listed under "Management Activities to Achieve Goals and Objectives" (page 14).
- Following this general timeline and framework, each goal, objective, and action item is listed in a gray box, followed by a more detailed description of each one containing additional information and guidelines.
- The "Plan Implementation Schedule" section of the Plan (page 51) provides a quick reference listing all of the Plan's goals, objectives, and action items without additional description, as well as a detailed implementation schedule.

Management Activities to Achieve Goals and Objectives

The goals, objectives, and action items described on the following pages provide a framework for how the Plan will be carried out and what specific outcomes we hope to achieve.

Monitoring, reporting, and evaluation of the Plan's management activities follow the framework described in the Plan's "Monitoring" section (page 44), which can be summarized as:

1. Implementation of the goals, objectives, and action items of the Plan will follow the schedule indicated in the "Plan Implementation Schedule" section (page 51).
2. NeDNR and the NRDs will exchange data annually, as described under "Reporting" (page 45) and "Annual Meeting" (page 47), to assist with evaluation of Plan progress.
3. Progress toward each management activity will be evaluated as part of each five-year technical analysis, as described under "Five-Year Technical Analysis" (page 48).
4. If the evaluation of progress made toward any management activity indicates a need to revise this Plan, the resulting Plan modifications will be made following the procedures described under "Modifications to the Plan" (page 49).

The following pages list the objectives and action items associated with each of the Plan's goals, provide details about how each goal, objective, and action item will be implemented, and indicate how various goals, objectives, and action items relate to one another and to other parts of this Plan.

Goal 1. Maintain Nebraska's compliance with the Republican River Compact and applicable state laws

Goal 1, maintaining compliance with the Republican River Compact (Compact) and state laws, is an overarching goal for this Plan that must be considered throughout implementation of all other goals, objectives, and action items. Compliance with the Compact, including consistency with Compact accounting procedures, applies to the implementation of both this Plan and to the individual Integrated Management Plans (IMPs).

Objective 1.1 Coordinate basin-wide plan management actions with Nebraska's Compact compliance efforts and adherence to applicable state laws

This objective means that all actions of this Plan must be evaluated in the context of both Nebraska's obligations under the Compact and applicable Nebraska laws; therefore, the action items associated with this objective must be carried out any time an action is taken in pursuit of any other goal, objective, or action item found within this Plan. Action Item 1.1.1 and Action Item 1.1.2 provide details about how to coordinate management actions with Compact compliance and adherence to state laws.

Action Item 1.1.1 Review each basin-wide plan management action prior to implementation to ensure it does not negatively impact efforts to achieve Compact compliance in the most efficient and cost-effective way practicable while adhering to state laws

This action item specifies that before any management action may be taken under this Plan, NeDNR and the NRDs will evaluate the potential action to ensure that two criteria are satisfied: no negative impact on Nebraska's efforts to achieve Compact compliance in the most efficient and cost-effective way practicable, and adherence to state laws. This evaluation is described in more detail in the following paragraphs.

One criterion that must be satisfied under this action item is that each proposed management action will not negatively impact Nebraska's efforts to achieve compliance with the Compact in the most efficient and cost-effective way practicable. These efforts include any management actions undertaken by NeDNR or the NRDs for the purpose of Compact compliance in accordance with the joint Integrated Management Plan (IMP) for each NRD.

In situations where one aspect of a project would have a negative impact on Nebraska's efforts to achieve compliance and another aspect of the same project would have a positive impact, then the final evaluation of the project's impact on Compact compliance efforts described under this action item should consider the cumulative impacts of the project as a whole. For example, a management action that increases consumptive use of water might be expected to adversely impact Nebraska's Compact compliance efforts; however, if the same project includes a component that reduces consumptive use in another location in the Basin, the net effect might reduce overall consumptive use in the Basin, which would have a positive effect on Nebraska's Compact compliance efforts.

The other criterion that must be satisfied under this action item is that each proposed management action will adhere to all Nebraska's state laws. Examples of state laws to consider include, but are not limited to, the laws protecting existing surface water and groundwater users and laws related to permits required for water management projects.

Action Item 1.1.2 Implement appropriate offsets for any basin-wide plan action that would exceed Nebraska's allocation under the Compact

Under the Compact, Nebraska has an allocation that limits how much water from within the Basin can be used. This allocation varies each year with available water supplies and consumptive use within all three states that are a part of the Compact (Nebraska, Kansas, and Colorado). To comply with the terms of the Compact, Nebraska's net water use must remain within its allocation over specified averaging periods.

If any basin-wide plan action does cause Nebraska to exceed its allocation under the Compact, appropriate offsets will be implemented during the same accounting period, following the procedures detailed in the IMPs for the Basin's NRDs. In this context, offsets are actions that either reduce water use or increase water supply for the purpose of staying within Nebraska's Compact allocation.

Objective 1.2 Understand the effects of management actions for Compact compliance on water supplies for Nebraska's water users

The purpose of this objective is to ensure that, for any management actions undertaken for Compact compliance, the effects of those management actions on the water supplies available to Nebraska's existing surface water and groundwater users are understood.

Action Item 1.2.1 Qualitatively evaluate the net effect on water supplies of any management actions that are taken for Compact compliance

For any management action undertaken for the purposes of complying with the Compact, NeDNR or the NRDs will evaluate the effect of those actions on Nebraska's Compact allocation and balance and will also qualitatively evaluate the net effect of those management actions on the water supplies available to Nebraska's existing surface water and groundwater users. This information will be reported at each annual meeting as a generalized, qualitative description.

Objective 1.3 Assess progress toward meeting the goals and objectives of the Plan, and share the results of this assessment with the Public and the Nebraska Legislature

Statute requires that NeDNR and the NRDs assess progress toward meeting the goals and objectives of the Plan and that they share the results of this assessment with the public and the Legislature, as described in the action items for this objective.

Action Item 1.3.1 Within five years after the adoption of this Plan, and every five years thereafter, conduct a technical analysis of the actions taken to determine the progress toward meeting the goals and objectives of the Plan

NeDNR and the NRDs must conduct a technical analysis of the actions taken to determine progress toward meeting the goals and objectives of the plan, as described in *Neb. Rev. Stat.* § 46-755 (5)(d) and under "Five-Year Technical Analysis" (page 48).

Action Item 1.3.2 Evaluate progress toward each of the Plan's measurable hydrologic objectives at the intermediate dates specified in the Plan for each one

As required by *Neb. Rev. Stat.* § 46-755 (5)(b), this Plan includes measurable hydrologic objectives (MHOs) to help assess whether reasonable progress has been made toward the Plan's goals and objectives. The Plan's MHOs are listed

within Table 4.1 in the "Plan Implementation Schedule" section (page 51), along with the intermediate dates at which each will be evaluated and a description of the assessment that will be used to objectively evaluate progress toward each one. Evaluation of progress toward each MHO will take occur either annually or as part of each five-year technical analysis (Action Item 1.3.1), at the intervals indicated in Table 4.1. The results of these evaluations will be reported when NeDNR and the NRDs share the results of each five-year technical analysis with the public and the Legislature (Action Item 1.3.3), as described under "Evaluation of Progress" (page 48).

Action Item 1.3.3 Following each five-year technical analysis (Action Item 1.3.1), share the results of the analysis and any recommended Plan modifications with the public

Following each five-year technical analysis, NeDNR and the NRDs will share the results of the analysis and any recommended Plan modifications at a public meeting (*Neb. Rev. Stat.* § 46-755 (5)(d)). Details about the public meeting to be held for this purpose can be found under "Annual Meeting" (page 47).

If NeDNR and the NRDs recommend any Plan modifications as a result of this analysis, the procedures outlined under "Modifications to the Plan" (page 49) will be followed.

Action Item 1.3.4 Following each five-year technical analysis (Action Item 1.3.1) and any resulting modifications to the Plan, submit a report to the Legislature of the results of the analysis and progress made under the Plan

Following each five-year technical analysis and any resulting modifications to the Plan, NeDNR and the NRDs will issue a report to the Legislature summarizing the results of the analysis and progress toward the goals and objectives of the Plan (*Neb. Rev. Stat.* § 46-755 (5)(d)). Details about the required report to the Legislature can be found under "Report to the Legislature" (page 50).

Goal 2. Maximize Nebraska's efficient and beneficial consumptive use of its portion of the water supply, increase certainty for long-range planning of water supplies to reduce the need for regulatory actions, and increase collaborative efforts among water management entities and stakeholders across the Basin

Goal 2 is comprised of three distinct but related ambitions: to maximize Nebraska's efficient and beneficial consumptive use of its portion of the water supply, to increase certainty about the availability of water supplies for long-range planning to reduce the need for regulatory actions, and to increase collaboration within the Basin. The first part, "maximize Nebraska's efficient and beneficial consumptive use of its portion of the water supply," gives overall direction and focus to efforts to increase certainty and collaboration. Increasing certainty to reduce the need for regulation and increasing collaborative efforts are also related, as described in the next three paragraphs. They provide some background information about regulatory actions for Compact compliance and how the regulatory burden of Compact compliance has at times contributed to conflicts among the basin's water users. In addition, many of the action items focused on maximizing efficient and beneficial use and increasing certainty involve collaborative efforts.

Regulation for Compact compliance

To comply with the terms of the Compact, Nebraska's water use must remain within its allocation over specified averaging periods, as described on page 16. To assist with ensuring long-term Compact compliance, certain ongoing regulatory controls have been established for both groundwater and surface water in the IMP for each NRD, including groundwater allocations, certification of irrigated acres, moratoriums on new wells and new surface water permits, and metering of all wells and surface water diversions in the Basin.

In years designated by the State as Compact Call Years, Nebraska must take additional action to meet its Compact obligations by either reducing consumption or generating additional streamflow. These potential actions can be regulatory or non-regulatory and are outlined in the joint IMP for each NRD. For surface water, NeDNR may need to regulate and administer surface water in the Basin to ensure compliance. For groundwater, potential additional groundwater regulatory actions to ensure compliance for the Lower Republican, Middle Republican, and Upper Republican NRDs include establishing more restrictive, temporary allocations and curtailment of groundwater pumping within a designated portion of each NRD. The IMP for the Tri-Basin NRD also allows for additional regulatory actions as needed to maintain a hydrologically balanced condition (i.e., no net depletions to streamflow).

Uncertainty, conflict, and collaboration

Stakeholders have expressed that the potential for regulation, as was carried out in 2013 to ensure Compact compliance, has contributed to a perceived lack of certainty among surface water users. In addition, for most of the history of regulation of water rights in Nebraska, state legislation considered surface water and groundwater separately without recognizing that they are hydrologically connected resources that impact one another (Appendix D, "Relevant History of Groundwater and Surface Water Management.")

Together, these and other factors have contributed to a history of conflict between surface water and groundwater users in the Basin. This basin-wide planning process represents an opportunity to decrease conflict and increase collaboration among the Basin's water management entities and stakeholders, beginning with the exchange of ideas that has taken place at Stakeholder Advisory Committee meetings throughout Plan development and continuing through Plan implementation.

In the context of this goal's focus on increasing collaboration within the Basin, "water management entity" refers to any entity that makes independent decisions about water use within the Basin, and "stakeholder" refers to anyone with a water interest in the Basin. Therefore, collaborative efforts described in some of the objectives and action items under this goal might include, but are not limited to, the NRDs, NeDNR, irrigation districts, the Bureau of Reclamation, municipalities, and individual water users.

Objective 2.1 Understand the feasibility and potential impacts of Plan actions and establish a standard procedure for projects

This objective applies to all management actions taken in fulfillment of any of the Plan's action items. It establishes a mechanism for evaluating the feasibility and impacts of planned projects before carrying them out (Action Item 2.1.1), requires a summary of the previous years' evaluations within each Annual Report (Action Item 2.1.2), and sets forth a framework for implementing projects after a decision has been made to proceed (Action Item 2.1.3).

Action Item 2.1.1 For each planned new water management project in the Plan, evaluate hydrologic and regulatory feasibility and potential economic and environmental impacts

For each planned new water management project undertaken in fulfillment of any of the Plan's action items, the project proponent(s) will evaluate hydrologic and regulatory feasibility, potential economic impacts (including cost-benefit ratios),

and potential environmental impacts when deciding whether to move forward with a planned project.

If a previous evaluation or study of the feasibility and impacts of projects similar to a planned project already exists, the project proponent(s) will determine whether a new evaluation is necessary or the existing evaluation or study is sufficient.

As part of the evaluation of feasibility and impacts, the project proponent(s) will consider whether the project negatively impacts Nebraska's Compact compliance efforts and whether it adheres to applicable state laws, in accordance with Action Item 1.1.1.

As part of the evaluation for any potential interbasin transfer project (Action Item 2.2.2), any factors outlined in statute for the Director of Natural Resources' evaluation of interbasin transfer applications will be included in the evaluation of feasibility and impacts (as of the effective date of this plan, these factors are listed in *Neb. Rev. Stat.* § 46-289).

Action Item 2.1.2 For each project evaluated in accordance with Action Item 2.1.1 in a given year, include a summary of the evaluation in the annual report of that year's activities

If any projects were evaluated in a given year under Action Item 2.1.1, a summary of the results of the analyses of those projects will be included in the annual report of that year's activities. Additional information about the annual report can be found under "Reporting" (page 45).

Action Item 2.1.3 For projects that are feasible and beneficial, apply for necessary permits, establish new or utilize existing infrastructure, then begin operations

For each planned new water management project undertaken in fulfillment of any of the Plan's action items, it is recommended that Action Item 2.1.1 be completed before Action Item 2.1.3; however, for some projects, circumstances may not allow adequate time for Action Item 2.1.1 to be completed before implementation of the project. In that situation, the project proponents will, at a minimum, report on and discuss the considerations outlined in Action Item 2.1.1 at the annual meeting, allowing time for questions from the public.

Objective 2.2 Improve the efficiency of use, availability, and reliability of water supplies for current irrigators

During Plan development, irrigators identified multiple challenges to water supplies, such as improving the efficiency of use, availability, and reliability of water supplies.

The prior appropriation system has always allowed for senior surface water right holders to call out junior users when the available supply was not sufficient to meet all demands. The water supply of the Basin varies considerably from year to year, so a full supply has not always been available for all permitted surface water users. In addition, over recent decades, surface water users have faced the challenge of decreasing availability and reliability of surface water supplies. One cause of these decreases is groundwater pumping over time (Appendix A, "Local Hydrology"). There have been many other changes to the landscape that have also affected streamflow via reduced runoff[1]. The effects of conservation practices on streamflow will be studied during implementation of the Plan (Action Item 2.5.1).

For groundwater users, it can be difficult to know whether they will have sufficient water in dry years. Although groundwater is a more reliable and steady water source than surface water, groundwater users still depend on precipitation in addition to their groundwater allocations to fulfill the water needs of their crops. The action items associated with this objective focus on pursuing opportunities to improve efficiency of use, availability, and reliability of water supplies for both surface water and groundwater irrigators.

Action Item 2.2.1 Work with irrigation districts and individual groundwater and surface water irrigators to improve the efficiency of the Basin's surface water delivery systems and irrigation water use, when it is both feasible and beneficial to Nebraska's Compact accounting balance

This action item is focused on partnering with others on projects to improve efficiency; specifically, NeDNR and the NRDs will work with irrigation districts to identify opportunities to improve the efficiency of the Basin's surface water delivery systems and with individual groundwater and surface water irrigators to improve irrigation water use efficiency. Such improvements will only be undertaken as part of implementation of this Plan if it is both feasible and beneficial to Nebraska's Compact accounting balance to do so.

[1]Republican River Compact Settlement Conservation Subcommittee for the Republican River Compact Administration (2014). *Republican River Basin: Impacts of Non-Federal Reservoirs and Land Terracing on Basin Water Supplies*. Final Report.

Examples of the kinds of efforts of individual irrigators that NeDNR and the NRDs might support to increase efficiency and reliability of irrigation water use include, but are not limited to:

- Encouraging end gun removal and
- Incentivizing long-term reductions in water usage through increased efficiency.

Actions and opportunities related to this action item may be discussed by NeDNR and the NRDs as a group; however, decisions about which kinds of efficiency efforts to support within each NRD and how best to support them will remain within the existing authorities of NeDNR and each individual NRD.

Action Item 2.2.2 Participate in projects to improve the reliability, availability, and sustainability of water supplies in the Basin, which may include but are not limited to:

a. Voluntary reduction of irrigated acres (temporary or permanent)
b. Interbasin transfers
c. Conjunctive management projects such as aquifer recharge or streamflow augmentation

This action item is focused on projects to improve the reliability, availability, and sustainability of water supplies in the Basin.

For these projects, NeDNR and the NRDs may work with partners such as the US Bureau of Reclamation, irrigation districts, or private landowners to identify, evaluate, and operate potential new projects, as appropriate. In some cases, these other entities might own and operate suitable existing infrastructure for conjunctive management projects. Examples of existing infrastructure that might be suitable for this purpose include wellfields, canals, reservoirs, or small dams and terraces. For conjunctive management projects that utilize existing infrastructure owned and operated by other entities, NeDNR and the NRDs will always first pursue voluntary cooperation with the partner who owns and operates the existing infrastructure.

Details about some specific types of projects that may be undertaken to improve the reliability, availability, and sustainability of water supplies in the Basin follow.

Voluntary reduction of irrigated acres

Reduction of irrigated acres may be temporary, such as through participation in CREP or other incentive programs, or permanent, such as through conservation easements or buyout programs. Landowner participation in programs to reduce irrigated acres will be voluntary.

When it is necessary to prioritize an area of focus for acreage reductions, it is recommended that the agency or agencies involved may consider factors such as:

- Soil type,
- Proximity to stream,
- Canal leakage,
- Groundwater declines, and
- Return flows.

Interbasin transfers

The idea of interbasin transfers, or diverting available water to the Republican Basin from other basins during periods of high flows, has garnered much support from stakeholders throughout the Plan development process. The most likely basin to serve as a suitable basin of origin for an interbasin transfer project would be the Upper Platte River Basin in Nebraska, but other basins within and outside the state have also been suggested at times during Stakeholder Advisory Committee meetings. Interbasin transfers would benefit the Republican Basin by bringing additional water into the Basin and may also benefit the basin of origin (such as the Upper Platte Basin) by potentially reducing the impacts of flooding downstream of the diversion site.

Conjunctive management

Conjunctive management, or retiming water, refers to the combination of two categories of conjunctive management activities: storing water during periods when water is naturally abundant and using stored water during dry periods. Aquifer recharge and augmentation projects are listed within this action item as examples of potential conjunctive management projects and are discussed in further detail in the next several paragraphs. These are intended to be examples only; other types of conjunctive management activities are also permissible for fulfilling this objective.

Aquifer recharge projects fall within the category of conjunctive management activities related to storing excess water when it is available. Specifically, aquifer recharge projects encourage infiltration to recharge the underlying aquifer by

holding surface water in infrastructure such as canals, reservoirs, or terraces. Aquifer recharge projects undertaken to fulfill this action item include creating new infrastructure for the purposes of recharge, utilizing existing infrastructure for this purpose, or improving existing infrastructure to enhance its recharge capabilities. Large reservoirs and canals that existed within the Basin during Plan development are shown in Figure A.4 and Figure A.10.

In contrast to aquifer recharge projects, streamflow augmentation projects fall within the category of conjunctive management activities related to using stored water during dry periods. Specifically, augmentation projects involve enhancing streamflow by supplementing it with water from other sources, such as with groundwater pumped from an aquifer. The following three specific types of potential augmentation projects are described in more detail below:

- Augmentation to comply with the Compact and IMPs,
- Augmentation to provide a more reliable supply to surface water users, and
- Supplementation of existing surface water users' supplies with new groundwater wells.

Augmentation to comply with the Compact and IMPs

Augmentation projects that exist in the Basin during development of this Plan include N-CORPE, Rock Creek Augmentation Project, and the Turkey Creek Augmentation Project (Figure A.11). The Basin's current augmentation projects are intended to augment streamflow for the purposes of meeting Nebraska's Compact obligations and complying with the IMPs. Augmentation activities undertaken to fulfill this action item may make use of these existing augmentation facilities or may involve identifying and developing new potential augmentation projects.

Augmentation to provide a minimum reliable supply to surface water users

Groundwater irrigation is generally a more reliable source of water than surface water irrigation, because the aquifer is sheltered from the variations in weather and climate that cause surface water supplies to vary widely, both within a season and from year to year. In addition, surface water irrigators have experienced a decline in surface water availability over time (Figure D.2). During the Plan development process, stakeholders expressed concern that this decline, coupled with the natural variability and uncertainty of surface water supplies, has made it difficult for surface water users to plan in recent years.

Should one or more new augmentation projects be proposed for the purpose of providing surface water users with a minimum reliable surface water supply, or

should it be proposed that one or more existing augmentation projects be used for this purpose, NeDNR and the NRDs will determine the feasibility, including whether sufficient funding is available. In assessing proposed augmentation projects, NeDNR and the NRDs will seek input from surface water irrigation districts and surface water users. Based on the results of this feasibility study, the project proponent(s) may decide to move forward with one or more new or existing augmentation projects for this purpose, which would require agreement from the owners of the augmentation projects.

Supplementation of existing surface water users' supplies with new groundwater wells

Another option for increasing the reliability of surface water supplies would be to allow supplementation of existing surface water users' supplies with new groundwater wells. Some surface water-only acres are located in areas where it would be feasible to convert them to commingled acres if they were allowed to drill new wells and obtain new groundwater permits; however, there are currently moratoriums on new wells in most of the Basin. Because of this, allowing these surface water users to drill wells would require would require participating NRDs to grant variances from their well-permitting moratoriums. Any decisions about whether to grant a variance for this purpose would be made on a case-by-case basis and would take into account the impact on Nebraska's overall Compact Accounting balance. If any new depletions result from use of the new wells, they will need to be offset following the procedures outlined in the IMPs, in accordance with Action Item 1.1.2.

As noted above, aquifer recharge and augmentation are listed as examples of potential conjunctive management projects, not as an exhaustive list. Other types of conjunctive management projects may also be considered.

Objective 2.3 Provide opportunities for collaboration among the Basin's water users

This objective includes two opportunities for increasing collaboration among the Basin's water users: opportunities for discussion and information exchange at an annual public meeting (Action Item 2.3.1) and collaboration to address conflicts between water users that result from implementation of this Plan (Action Item 2.3.2).

Please note that in addition to the opportunities for collaboration outlined in the action items associated with Objective 2.3, many of the Plan's other objectives and action Items also contain opportunities for collaboration among the Basin's water users.

Action Item 2.3.1 Hold an annual public meeting to discuss Plan implementation and exchange information about the Basin

Information about the annual meeting can be found under "Annual Meeting" (page 47).

Action Item 2.3.2 Work cooperatively to investigate and address conflicts between water users resulting from implementation of this Plan by following the procedures for addressing conflicts that are outlined in this Plan

Conflicts between water users resulting from implementation of this Plan will be investigated and addressed following the "Procedures for Addressing Conflicts Resulting from Implementation of the Republican River Basin-Wide Plan" (Appendix E).

Objective 2.4 Promote conservation programs available to the water users in the Basin

NeDNR and the NRDs will collaborate to evaluate and promote existing and new water conservation programs related to the use of integrated water resources. These are programs that provide incentives to encourage voluntary modification by water users for the purposes of water conservation. Incentive programs include, but are not limited to, federal programs or programs authorized by state law. Some examples of this are programs that incentivize irrigated acreage reduction or best management practices.

The IMPs for all four NRDs already include guidelines for the establishment and implementation of incentive programs to reduce beneficial consumptive use of water within each NRD. This objective does not replace the existing incentive program guidelines contained in the four IMPs, nor does it require that all four NRDs implement exactly the same incentive programs.

Action Item 2.4.1 Work together to identify, investigate, and discuss existing and potential new water conservation programs

NeDNR and the NRDs will exchange information about and evaluate existing and potential new water conservation programs available to water users in the Basin. At a minimum, this will occur at annual meetings. NeDNR and the NRDs may also discuss water conservation programs between annual meetings, for example, as new opportunities are identified or as deadlines approach for a specific program.

Evaluation of each conservation program opportunity should include consideration of whether and how that conservation program might help advance progress toward the goals and objectives of this Plan.

For each conservation program opportunity that NeDNR and the NRDs agree might help advance progress toward the goals and objectives of this Plan, NeDNR and the NRDs should discuss whether to collaborate to promote such a program to water users, as described under Action Item 2.4.2.

Implementation and administration of conservation programs will remain the responsibility of individual NRDs and NeDNR, following existing guidelines found in each joint IMP.

Action Item 2.4.2 Collaborate to promote conservation program opportunities to the Basin's water users

If NeDNR and the NRDs agree that a specific conservation program opportunity might help advance progress toward the goals and objectives of this Plan (Action Item 2.4.1), NeDNR and the NRDs may determine that the program should be collaboratively promoted to users.

Potential opportunities for collaboration on the promotion of conservation programs include, but are not limited to:

- Collaborative development of educational materials about the program, such as written materials or presentations,
- Sharing or joint development of implementation tools such as forms or databases, or
- Joint applications for funding to support and promote conservation program opportunities.

Objective 2.5 Understand how various water management activities of independent decision-makers affect water supplies

NeDNR and the NRDs will improve their understanding of how various water management activities of independent decision-makers affect water supplies, as described in the following action items. Independent decision-makers in this context include any water management entities in the Basin other than NeDNR and the NRDs, such as producers, irrigation districts, municipalities, and other government agencies.

Action Item 2.5.1 Study the effects of conservation practices on streamflow, if feasible

NeDNR and the NRDs will study the effects of various agricultural conservation practices on streamflow, if and when enough funds and staff resources are available to make it feasible to do so. This includes, but is not limited to, an examination of how changes in conservation practices may have contributed to reduced runoff, as indicated in the description of Objective 2.2. The results of and recommendations based on the results of any such study will be shared with producers in the Basin. NeDNR and the NRDs may also use the results of this kind of study to inform discussion and promotion of conservation incentive programs (Objective 2.4).

Action Item 2.5.2 As part of each five-year technical analysis, analyze the future impacts to streamflow of past pumping to determine the lag time of these residual impacts

Streamflow depletions due to groundwater pumping are not immediate. The amount of time it takes for the effects of pumping to be realized in a stream depend on factors such as the distance of the well from the stream and the ease through which water can flow through the materials in the aquifer. Similarly, streamflow depletions due to groundwater pumping may continue long after pumping has stopped.

To fulfill this action item, NeDNR will use groundwater modeling to analyze future impacts of past groundwater pumping (i.e., the residual effects) by running a simulation to answer the question, "if groundwater pumping in the Basin were to stop completely, how long would it take streamflow to recover (i.e., return to a condition with no pumping-related stream depletions)?" This question explains what is meant in the action item language by "determine the lag time of these

residual impacts." Additionally, this simulation will provide information about the aquifer response. This action item will take place as part of each five-year technical analysis "Five-Year Technical Analysis" (page 48), and following the analysis, NeDNR and the NRDs will consider steps that could be taken to mitigate lag effects, if needed.

Action Item 2.5.3	Examine and attempt to estimate the quantity of all inputs and outputs affecting the water supply balance in a small watershed, and consider using the results of this pilot study to create water use and land use guidelines for producers and other land managers, incentivize participation in recommended practices, and determine the value of completing similar studies across the Basin

The purpose of this action item is first, to gain a better understanding of the potential benefits of using a complete water balance approach as a water management tool, and second, to support future management actions with the knowledge gained.

NeDNR and the NRDs will initiate a multi-year pilot study involving a water balance approach and groundwater/surface water modeling, with the purpose of examining and attempting to estimate the quantity of all inputs and outputs affecting the water supply balance in a watershed. The intent is to complete this evaluation within 10 years of this plan taking effect, provided that sufficient funding and staff resources are available to do so.

Examples of study objectives include, but are not limited to:

- Verification of precipitation and evapotranspiration,
- Verification of consumptive use in riparian areas, canals, dams, and of other water uses,
- Measurement of the impact of crop residue with the goal of improving residue management, and
- Collection of data that will be useful as the basis of an educational program for landowners to help them understand the impact they can have through water balance management.

The results of this study will be considered in the creation of water use and land use guidelines to educate producers and other land managers about the water management lessons learned from the pilot study. NeDNR and the NRDs will examine impacts of the water management actions studied. Results of such studies will be considered as NeDNR and NRDs consider whether to encourage

participation in certain management actions and how best to encourage those actions. Incentive programs are one option for encouraging participation.

In addition, based on the results of the initial study, NeDNR and the NRDs will make a recommendation regarding whether it would be valuable to conduct a similar study or studies in other locations across the Basin.

This action item is based on an idea proposed by a stakeholder during Plan development. This action item addresses the intent of the stakeholder's proposed study, but the methodology used to undertake this action item may differ from the originally proposed methodology, at the discretion of NeDNR and the NRDs. The original proposal is included for reference as Appendix F.

Objective 2.6 Evaluate the feasibility and potential outcomes of establishing water markets in the Basin

A water market is an economic platform for temporary or permanent trades of the rights to use water, where the price of water is determined dynamically by variable economic and market conditions. During Plan development, stakeholders expressed interest in the idea of trying a water market in the Basin for the purposes of exchanging water among groundwater and surface water users. Much is still unknown about the logistics, feasibility, and desirability of such water markets in the Basin; therefore, the purposes of this objective are to conduct a study and possibly initiate a pilot program to evaluate the feasibility and potential outcomes of establishing a water market or water markets within the Basin.

Nothing about this objective or its listed action items precludes NRDs or other entities from pursuing water markets in the Basin outside of this planning process.

This objective and its associated action items are based on an idea proposed by a stakeholder during Plan development. NeDNR, the NRDs, and the stakeholder who proposed the idea continued to discuss the idea during a coordination meeting, and this objective and action items resulted from that discussion. A summary of the discussion is included for reference as Appendix G.

Action Item 2.6.1 Cooperate in determining the feasibility of water markets in the Basin

This action item would include studying existing water markets, as well as working cooperatively with the US Bureau of Reclamation, water users, and irrigation districts, to evaluate the feasibility of water markets for surface water and

groundwater users in the Basin. This feasibility analysis will include such considerations as:

- Compact compliance obligations
- Program costs,
- Regulatory framework, and
- Water user interest.

The intent is to complete this evaluation within five years of this plan taking effect and to report on findings from the evaluation as part of the first five-year technical review, provided that sufficient funding and staff resources are available to do so.

If the conclusions from these efforts indicate that water markets in the Basin would be feasible, then NeDNR and the NRDs may choose to proceed with testing their conclusions in a pilot area (Action Item 2.6.2).

Action Item 2.6.2 Following the water markets feasibility analysis (Action Item 2.6.1), test conclusions through implementation of a water market program in a pilot area, if feasible

If the evaluation in Action Item 2.6.1 indicates that water markets in the Basin would be feasible, and if sufficient funding and staff resources are available to do so, then NeDNR and the NRDs will work cooperatively with the US Bureau of Reclamation, the Basin's irrigation districts, and water users in the Basin to conduct a water market pilot program within a portion of the Basin within the first 10 years of Plan implementation. The group of water users involved in developing a pilot program should be representative of water users in the pilot area, to the extent possible.

Factors to consider when determining the framework of the pilot program include, but are not limited to:

- The eligible geographic area
- Whether transfers of water rights from one subbasin to another will be allowed, and
- How stream depletion factors will affect transfers.

Objective 2.7 Support the NRDs in management of allocations for irrigation purposes and surface water irrigation districts in management of the allotment of their water supply

The Plan provides a framework to support the NRDs in management of allocations for irrigation purposes and surface water irrigation districts in management of the allotment of their water supply by periodically evaluating the groundwater allocation and surface water allotment systems as described in Action Item 2.7.1 and Action Item 2.7.2.

Action Item 2.7.1 Periodically evaluate, as part of each five-year technical analysis, the impact of the groundwater allocation and surface water allotment systems as a whole

As part of each five-year technical analysis ("Five-Year Technical Analysis," page 48), NeDNR and the NRDs will evaluate the impact of the groundwater allocation and surface water allotment systems as a whole. A synopsis of the current allocation system is provided in Appendix H.

Action Item 2.7.2 As needed, based on the evaluation described in Action Item 2.7.1, recommend changes or improvements to the groundwater allocation and/or surface water allotment systems

Based on the evaluation described in Action Item 2.7.1, NeDNR and the NRDs will determine whether to recommend changes or improvements to the groundwater allocation and surface water allotment systems. Whether or not to adopt the recommended changes or improvements remains within the authorities of each individual NRD or irrigation district.

Objective 2.8 Conserve water for future use during a drought

This objective relates to balancing storage water to maximize use in the long-term by conserving water when it is abundant so that it is available during times of scarcity.

Action Item 2.8.1 Organize and participate in a basin-wide drought planning exercise

NeDNR and the NRDs will organize and participate in a drought planning exercise for the Basin. A drought planning exercise is a workshop or other activity that brings together parties with expertise in various aspects of droughts to plan and prepare for managing drought. Some areas of focus for this exercise will be:

- Increasing understanding of the needs for and logistics of storing water for use during a drought,
- Evaluating existing and potential new management actions to determine the long-term availability trends that provide carry-over storage to meet crop-water needs during drought, and
- Developing metrics that could be used to evaluate whether conservation of water for future use during a drought is successful.

For the purposes of this action item, "storage" includes both surface water storage and aquifer storage. This exercise will support the evaluation of whether Plan revisions related to conserving water for a drought are needed (Action Item 2.8.2).

Action Item 2.8.2 Following the drought planning exercise (Action Item 2.8.1) evaluate whether to recommend any changes to the IMPs or this Plan related to conservation of water for future use during a drought

One outcome of the drought planning exercise will be to improve understanding of how this Plan or the IMPs might be able to be used as tools to help conserve water for future use during a drought. Following that exercise, NeDNR and the NRDs will evaluate whether to make any related changes to any of these plans. Some examples of the kinds of changes that could be made to this Plan include changes that would:

- Clarify how water will be conserved,
- Set specific targets for water storage, or
- Specify how to assess and measure conservation of water for future use.

For the purposes of this action item, "storage" includes both surface water storage and aquifer storage.

Goal 3. Positive public relations, including information sharing, within and outside the Basin

Goal 3 and its associated objectives and action items are focused on promoting positive public relations by improving information sharing about the Basin's water supplies and use as well as management efforts of the Basin's water users and managers, with both outside decision-makers and the Basin's water users.

Objective 3.1 Improve information sharing with decision-makers and the public about solutions formed within the Basin

The overarching focus of this objective is sharing information about the Basin's water management solutions, and the challenges those solutions are intended to address, with people who are not directly involved in developing or implementing those solutions. Sharing information with the Basin's water users is addressed separately in Objective 3.2. Part of Objective 3.1 is to improve information sharing about the Basin's water management solutions with decision-makers, especially those outside the Basin. This is because during Plan development, the Stakeholder Advisory Committee expressed concern that Legislators, the Governor's Office, and other decision-makers were unaware of many of the achievements, efforts, and overall progress that water users and managers in the Basin have already made toward addressing the Basin's water management challenges. Sharing information about implementation efforts with the general public is also part of Objective 3.1. The following action items provide details about how Objective 3.1 will be achieved.

Action Item 3.1.1 Use existing resources to share information about Basin progress and activities with outside entities

This action item specifies that outreach about Basin progress and activities will be undertaken using existing resources. Some examples of existing resources include NeDNR and the NRDs' staff, websites, and other outreach or education mechanisms.

Action Item 3.1.2 Educate civic leaders and the public on implementation efforts within the Basin

This action item clarifies that the "outside entities" mentioned in Action Item 3.1.1 include both civic leaders and the public. Some examples of civic leaders include the Legislature, the Governor's Office, and municipal leadership.

Some examples of potential topics for public relations campaigns or education about implementation efforts within the Basin and the challenges those solutions are intended to address are:

- Efficiency improvements,
- The NRDs' allocation systems and resulting successes,
- Other management activities and successes,
- Factors that have contributed to streamflow reduction in the Basin,
- Variations in groundwater management that reflect natural wet/dry cycles, and
- Realistic expectations for outcomes of projects and policy changes.

Action Item 3.1.3 Educate civic leaders and the public about the policies and institutional infrastructure that contribute to the development and implementation of solutions

Policies and institutional infrastructure have contributed and will continue to contribute to the development and implementation of water management solutions for Nebraska and this Basin. During Plan development, stakeholders expressed concern that civic leaders and the public may not be aware of what those policies and institutional infrastructure are, how they can contribute to effective water management, or how they differ from those of other states. Therefore, as part of plan implementation, efforts will be made to educate civic leaders and the public about how existing and new policies and institutional infrastructure contribute to the development and implementation of water management solutions for the Basin.

Examples of the types of policies and institutional infrastructure that could be addressed in outreach efforts include, but are not limited to:

- The NRD system,
- Correlative groundwater rights,
- Integrated Management Plans,
- The Republican River Basin-Wide Plan,

- The Republican River Compact,
- Other aspects of Nebraska's surface water and groundwater statutes, or
- Other NRD rules, regulations, and plans.

Action Item 3.1.4 Propose and support changes to laws, policies, and rules that would incentivize reduced water consumption

If NeDNR and the NRDs identify potential changes to federal or state laws, policies, or rules that would incentivize reduced water consumption, they will propose and support those changes, such as through communication with state or federal lawmakers (including Nebraska's federal delegation), policymakers, or rulemaking agencies. In addition, when appropriate, they will educate potential partner states, agencies, and organizations about their recommendations and seek their assistance in promoting the recommended changes.

A specific example proposed by a stakeholder during Plan development is to promote changes to the Farm Bill that would either incentivize farmers to either plant lower consumptive use crops or to fallow acres if doing so would reduce consumption. NeDNR and the NRDs will continue to examine and consider this proposal to better understand what specific changes can be made to the Farm Bill to incentivize reduced water consumption.

Some examples of methods to consider that might incentivize lower consumptive use crops include, but are not limited to:

- Amending the Federal Crop Insurance program to increase the Actual Production History (APH) on lower consumptive use crops on both dry and irrigated acres, as a way to lower the income risk of growing crops that will decrease water consumption, or
- Offering a higher crop insurance subsidy for crops that have a lower consumptive use, either through the Federal Crop Insurance Program or through other conservation programs, or
- Establishing an APH of lower consumptive use crops that currently lack an APH.

Objective 3.2 Improve information sharing with water users who are reliant on the Basin's water supplies

Objective 3.1 is focused on sharing information with outside entities, whereas Objective 3.2 is about sharing information internally, with the Basin's water users. The action items associated with Objective 3.2 describe multiple specific ways that information sharing within the Basin will be improved.

Action Item 3.2.1 Share data and information related to the Republican River Compact with the public in an easily accessible, user-friendly format

NeDNR and the NRDs already gather and share a considerable amount of data and information about Nebraska's water supplies and uses in the Basin with the states of Kansas and Colorado as part of the Republican River Compact Association's (RRCA's) annual data exchange process for the purposes of RRCA accounting. These data are currently available on the RRCA website; however, they are not easy to find and are not very user-friendly for users outside the RRCA. In accordance with Action Item 3.2.1, data and information related to the Compact will be shared with the public in a user-friendly format in an easily accessible, centralized location. Specific categories of RRCA data to be shared are listed under "Reporting" (page 45).

Action Item 3.2.2 Annually prepare and exchange reports containing data and information about water supplies and uses in the Basin, and make these reports publically accessible

As specified in Action Item 2.3.1, NeDNR and the NRDs will hold an annual public meeting to discuss Plan implementation and exchange information about the Basin, as described under "Annual Meeting" (page 47). For this meeting, NeDNR and the NRDs will exchange reports containing data and information about water supplies and uses in the Basin, management activities, and progress toward the goals, objectives, and action items of this Plan, as described under "Reporting" (page 45). Following the annual meeting, the reports exchanged will be made available to the public.

Action Item 3.2.3 Regularly communicate with the Plan's former Stakeholder Advisory Committee about implementation progress and potential Plan revisions

This action item specifies that after this Plan goes into effect, NeDNR and the NRDs will continue to communicate with the Plan's former Stakeholder Advisory Committee on a regular basis about Plan implementation progress and any potential revisions to the Plan. NeDNR and the NRDs will:

- Invite members of the former Stakeholder Advisory Committee to each annual meeting and five-year technical review meeting,
- Notify members of the former Stakeholder Advisory Committee of potential plan revisions, and
- Notify members of the former Stakeholder Advisory Committee when annual reports, five-year technical reviews, or other new reports related to implementation of this plan are published.

It is the responsibility of members who wish to receive these updates, or who wish to be removed from the contact list, to keep their contact information and preferences current by notifying NeDNR or their NRD of changes.

Additional information about meetings, reports, and the plan-revision process can be found in the "Monitoring" section of the Plan (page 44). Members of the Stakeholder Advisory Committee at the time of the committee's final vote are listed in Appendix C, "Plan Development."

Action Item 3.2.4 Encourage and support water users to share information about their management practice improvements with other water users and the public

Throughout implementation of this Plan, NeDNR and the NRDs will encourage and support water users to share information about their management practice improvements with other water users and the public. Various methods of implementation of this action item may be employed to fit specific circumstances. Examples of opportunities for individuals to share their successes with other water users include, but are not limited to:

- Articles for NeDNR or NRD newsletters, websites, or social media,
- Presentations or reports shared at the annual meeting to review implementation of this Plan,
- Presentations at annual water user conferences or other outreach events, or
- Coverage by external news media.

NeDNR and the NRDs will discuss opportunities to implement this action item at each annual meeting.

Goal 4. When possible, pursue projects that not only benefit water supplies and uses, but also create benefits for fish, wildlife, recreation, and conveyance within the Republican River Basin

During the development of this Plan, stakeholders expressed that it was important to them that this Plan provide benefits to fish, wildlife, recreation, and conveyance within the Basin. While these potential areas of benefit do not directly relate to integrated management of the Basin's water supplies and uses, there are likely to be opportunities for projects that can benefit fish, wildlife, or recreation while also benefiting water supplies and uses according to the Plan's other goals and their associated objectives and action items. The objectives and action items that fall under Goal 4 outline ways in which projects to manage water supplies and uses can provide additional benefits to the Basin's fish, wildlife, conveyance, and recreation.

It is important to note that for any action taken in fulfillment of any objective or action item under Goal 4 to benefit fish, wildlife, recreation, or conveyance, the action must also benefit water supplies and uses in fulfillment of one or more of the Plan's other goals, objectives, or action items. Actions that only benefit fish, wildlife, recreation, or conveyance without also benefiting hydrologically connected water supplies fall outside of the statutory authority of this Plan.

Objective 4.1 Where feasible and beneficial, protect and enhance fish and wildlife habitat and public outdoor recreational opportunities

NeDNR and the NRDs will pursue opportunities to protect and enhance wildlife habitat and outdoor recreation opportunities, if it is feasible and beneficial do to so as part of projects that also benefit water supply and use. Further details are given in the action items below.

Action Item 4.1.1 Partner with wildlife-focused organizations on projects that benefit the organizations' habitat and wildlife interests while also helping to fulfill other goals of this Plan

If it is feasible and beneficial to do so as part of actions taken to benefit water supply and use in fulfillment of this Plan's other goals, NeDNR and the NRDs will partner with wildlife-focused organizations on projects that benefit wildlife and their habitat. Some examples of wildlife and habitat-focused groups operating in Nebraska include:

- The Nebraska Game and Parks Commission,
- The US Fish and Wildlife Service,

- Ducks Unlimited,
- Audubon Nebraska,
- Rainwater Basin Joint Venture,
- The Nature Conservancy, and
- The Crane Trust.

The level of involvement of partner organizations may vary according to the needs and circumstances of each individual project, ranging from, for example, consultation on questions related to their area of expertise, to collaboration on project planning and design, to sharing project costs for projects that benefit the groups' wildlife and habitat-related interests.

Projects undertaken to fulfill this objective may involve establishing new or utilizing existing infrastructure. One example of a type of project that could benefit both the Basin's water supplies and wildlife habitat would be to use water diverted through an interbasin transfer project during periods of high flows to enhance wildlife habitat.

Action Item 4.1.2 Promote public recreation on the river, when doing so can also help to fulfill other goals of this Plan

If it is feasible and beneficial to do so as part of actions taken to benefit water supply and use in fulfillment of this Plan's other goals, NeDNR and the NRDs will promote public recreation on the river. Some examples of public recreation include recreational floating such as tubing, kayaking, and canoeing.

For promotion of public recreation, it may be beneficial for NeDNR and the NRDs to partner with organizations with an interest in public recreation, such as the Nebraska Game and Parks Commission or local river outfitters.

Action Item 4.1.3 Cooperate in projects to assess and restore riparian wetlands while also helping to fulfill other goals of this Plan

Riparian wetlands are wetlands located adjacent to streams, rivers, or lakes. NeDNR and the NRDs will participate in projects to assess and restore riparian wetlands if it is feasible and beneficial to do so as part of actions taken to benefit water supply and use in fulfillment of this Plan's other goals and objectives, such as for aquifer recharge (Action Item 2.2.2). As appropriate, they will do so in cooperation with organizations with interest and expertise in wetland restoration. Because of the wide-range of benefits wetlands provide, such as groundwater recharge, wildlife

habitat, flood control, and water quality, the primary focus of potential partner organizations for mutually beneficial wetland assessment and restoration projects also varies widely.

Action Item 4.1.3 includes two parts: wetland assessment and wetland restoration. Wetland assessment involves evaluating wetland condition and function. This may be done for many purposes, such as:

- To identify and inventory existing wetlands,
- To compare and prioritize wetlands for development and mitigation purposes, or
- To establish a baseline condition and then monitor changes in condition and function over time.

Wetland restoration involves rehabilitating the hydrology, plants, and soils of a degraded wetland or reestablishing a wetland that has been destroyed.

Objective 4.2 Where feasible and beneficial, reduce the effects of undesirable vegetation on water conveyance

NeDNR and the NRDs will pursue opportunities to reduce the effects of undesirable vegetation on water conveyance, if it is feasible and beneficial do to so as part of projects that also benefit water supply and use. Conveyance is the transport of water from one location to another. Further details are given in the action item below.

Action Item 4.2.1 Cooperate in removing undesirable vegetation impacting water conveyance and managing reinfestation

NeDNR and the NRDs will participate in projects to remove undesirable vegetation impacting water conveyance, if it is feasible and beneficial to do so as part of actions taken to benefit water supply and use in fulfillment of this Plan's other goals.

A summary providing background information about the relationship between removal of invasive vegetation and evapotranspiration is included as Appendix I. This information should be taken to consideration when considering projects involving riparian vegetation removal and management.

3. Monitoring

Section Overview

The "Monitoring" section includes information about how the Nebraska Department of Natural Resources (NeDNR) and the Upper Republican, Middle Republican, Lower Republican, and Tri-Basin Natural Resources Districts (NRDs) will share data and information and work together to monitor and evaluate progress toward the goals and objectives of the Plan. It also describes how NeDNR and the NRDs will use this information to assess the need for Plan modifications and lists procedures to follow if modifications are needed.

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Plan Schedule and Management Actions

As required by *Neb. Rev. Stat.* § 46-755 (5)(b), this Plan includes a schedule indicating the end date by which the goals and objectives are to be achieved and the management actions to be taken to achieve the goals and objectives. The Plan's goals, objectives and action items are listed within the Plan's "Plan Implementation Schedule" section (page 51) and described in detail with the "Goals and Objectives" section (page 13). The "Plan Implementation Schedule" section specifies a schedule for each action item and measurable hydrologic objective (MHO).

Reporting

Action Item 3.2.2 requires that NeDNR and the NRDs annually exchange reports on Plan progress. These reports will contain, but are not limited to, data and information about:

- Water supplies and uses in the Basin,
- Management activities, and
- Progress toward the goals, objectives, and action items of the Plan.

Annual reports will be exchanged by NeDNR and the NRDs at each annual meeting. Additional information about the annual meeting can be found under "Annual Meeting" (page 47). The reports exchanged will be made available to the public following the annual meeting. Members of the Plan's former Stakeholder Advisory Committee (Appendix C, "Plan Development") will be notified once annual reports have been published (Action Item 3.2.3).

The data on water supplies and uses in the Basin listed in Table 3.1 will be reported annually, either as part of the annual reports, or through a different medium such as the Plan's website. Not all listed data will be reported as part of the initial annual report, as it will take time for NeDNR and the NRDs to prepare each category of data for distribution. As such, NeDNR and the NRDs will gradually increase the number of items from this list reported on each year. Some data will take significantly longer to prepare for distribution than others.

During the Plan development process, stakeholders recommended reporting on more categories of data than are listed in Table 3.1. The items included in Table 3.1 are limited to data that are within NeDNR and the NRDs' statutory authority and that NeDNR and the NRDs believe can reasonably be collected using their available resources.

The list of data in Table 3.1 is subject to change through time as the result of changes in data needs or resources. In addition, as new projects are implemented as a result of this Plan, NeDNR and the NRDs will assess whether additional categories of data related to those new projects should be added to the reporting list.

In addition to the annual report, NeDNR and the NRDs will also report on Plan progress as part of the Annual Meeting (page 47), Five-Year Technical Analysis (page 48), and Report to the Legislature (page 50).

Table 3.1. Data on water supplies and uses in the Basin, to be gathered and reported annually. As described on page 45, NeDNR and the NRDs will gradually increase the number of items from this list reported on each year, as some of these data will take longer to prepare for distribution than others. These data may be reported on as part of the annual reports or through a different medium such as the Plan's website. As new projects are implemented as a result of this Plan, NeDNR and the NRDs will assess whether additional categories of data related to those new projects should be added to this reporting list. This list is subject to change as data needs and resources change over time.

Category	Data	Responsible Party
Allocations	Current allocations	NRDs
	Average annual use, relative to allocations	NRDs
Augmentation	Duration of pumping	NRDs
	Volume pumped	NRDs
Data needed to assess measurable hydrologic objectives (page 48)	Net groundwater depletions to streamflow, by NRD	NeDNR
	Groundwater levels by NRD	NRDs
	Dates of curtailment of groundwater pumping in Rapid Response Area for Compact compliance	NRDs
	Dates of surface water administration for Compact compliance	NeDNR
Interstate	Colorado CBCU	NeDNR
	Kansas CBCU	NeDNR
Landuse	Certified irrigated acres	NRDs
	Modeled commingled irrigated acres	NeDNR
	Modeled groundwater irrigated acres	NeDNR
	Modeled surface water irrigated acres	NeDNR
	Number of acres planted, by crop type, when available	NeDNR
Observation wells	Locations of wells being monitored	NeDNR and NRDs
	Number of wells being monitored	NeDNR and NRDs
Retirement programs	Conservation program acres	NeDNR and NRDs
	Permanent retired acres	NeDNR and NRDs
	Temporary retired acres	NeDNR and NRDs
Water balance	Annual canal recharge	NeDNR
	Annual precipitation	NeDNR
	Evaporation from reservoirs	NeDNR
	Field deliveries as percentage of water released from reservoirs for irrigation	NeDNR
	Groundwater CBCU	NeDNR
	Municipal and industrial CBCU	NeDNR
	Surface water CBCU	NeDNR
	Surface water storage	NeDNR

Annual Meeting

NeDNR and the NRDs will meet annually to discuss Plan implementation and exchange information about the Plan (Action Item 2.3.1). The Plan's former Stakeholder Advisory Committee (listed in Appendix C, "Plan Development") will be invited to the meeting (Action Item 3.2.3), and the meeting will be open to the public (Action Item 2.3.1). At a minimum, the agenda for each annual meeting will include the following elements.

1. Nebraska Open Meetings Act requirements
2. Exchange and discuss annual reports and data
3. Plan implementation progress
    a. Exchange and discuss annual reports and data ("Reporting," page 45)
    b. Progress toward goals and objectives of the Plan ("Plan Schedule and Management Actions", page 44).
    c. Delays due to resource limitations, if any ("Limitations," page 63)
    d. Qualitative summary of net effect of management actions taken for Compact compliance on water supplies, if any (Action Item 1.2.1)
    e. Summary of evaluation of feasibility and potential impacts of planned projects, if any (Action Item 2.1.2 and Action Item 2.1.3).
4. Collaboration
    a. Existing and potential new water conservation programs (Action Item 2.4.1)
    b. Information sharing about water user management practice improvements (Action Item 3.2.4)
        i. Informational presentations or reports from water users, if any
        ii. Future opportunities to encourage and support water users to share information about management practice improvements
    c. Conflicts Resulting from Implementation of the Plan, if any (Appendix E)
5. Technical analysis and recommended Plan modifications (if applicable, as described in "Five-Year Technical Analysis" (page 48)
    a. Results of technical analysis ("Five-Year Technical Analysis," page 48)
    b. Proposed Plan modifications, if any ("Modifications to the Plan," page 49)
    c. Report to the Legislature ("Report to the Legislature," page 50)
6. Public comment

Other agenda items will be included as needed.

Measurable Hydrologic Objectives

As required by *Neb. Rev. Stat.* § 46-755 (5)(b), this Plan includes measurable hydrologic objectives (MHOs) to help assess whether reasonable progress has been made toward the Plan's goals and objectives. The Plan's MHOs are listed under Action Item 1.3.2 and in Table 4.1 of the "Plan Implementation Schedule" section of the Plan (page 51), along with a description of the assessment that will be used to objectively evaluate progress toward each one and the intermediate dates at which each will be evaluated to determine whether it is being met.

Evaluation of Progress

Each MHO will be evaluated according to the assessment described in Table 4.1, either every five years or annually, as specified within the table. For those MHOs that will be evaluated every five years, that evaluation will coincide with the five-year technical analysis ("Five-Year Technical Analysis" (page 48)), and the results will be included in the report and presentation of the results of the technical analysis (Action Item 1.3.3; "Five-Year Technical Analysis" (page 48); "Report to the Legislature" (page 50)). For those MHOs that will be evaluated annually, the presentation and report of the results of the technical analysis will include a summary of the results of the annual evaluations from the time period included in the five-year technical analysis. The technical analysis will be conducted every five years beginning in 2023. The presentation of results to the public is expected to take place the same year as the analysis, and the report to the legislature will be submitted the following year ("Plan Implementation Schedule," page 51).

Process if MHO is Not Being Achieved

If NeDNR and the NRDs determine that one or more of the MHOs is not being achieved, they will determine what actions to take to achieve the MHOs in the future. If the NeDNR and the NRDs recommend any plan modifications as a result of this analysis, the procedures outlined under "Modifications to the Plan" (page 49) will be followed.

Five-Year Technical Analysis

NeDNR and the NRDs will conduct a technical analysis of actions taken to determine progress toward meeting the goals and objectives of the Plan (Action Item 1.3.1). This analysis must take place within five years after the adoption of this Plan and ever five years thereafter, as required by *Neb. Rev. Stat.* § 46-755 (d). NeDNR and the NRDs may conduct the analysis more frequently if needed.

The analysis will include an examination of:

- Available supplies, current uses (including Action Item 2.7.1), and changes in long-term water availability (including Action Item 2.5.2),
- The effects of conservation practices and natural causes, and
- The effects of the Plan in meeting the goal of sustaining a balance between water uses and water supplies, including whether the MHOs are being met (Action Item 1.3.2; "Evaluation of Progress," page 48).

The outcomes of any conflicts considered under the "Procedures for Addressing Conflicts Resulting from Implementation of the Republican River Basin-Wide Plan" (Appendix E) may be taken into account as part of the technical analysis to the extent that the conflicts evaluated relate to the topics examined in the analysis, which are listed in the previous paragraph.

Following the technical analysis, NeDNR and the NRDs will (*Neb. Rev. Stat.* § 46-755 (d)):

1. Determine whether the technical analysis indicates that modifications to the Plan are needed to meet the goals and objectives of the Plan ("Goals and Objectives," page 13),
2. Present the results of the technical analysis and any recommended modifications to the Plan at a public meeting ("Annual Meeting," page 47),
3. Modify the Plan following the procedures outlined in "Modifications to the Plan" (page 49), if modifications are needed, and then
4. Submit a report to the Legislature on the results of the technical analysis and progress on the Plan, as described under "Report to the Legislature" (page 50).

The technical analysis will be conducted every five years beginning in 2023. The presentation of results to the public is expected to take place the same year as the analysis, and the report to the legislature will be submitted the following year ("Plan Implementation Schedule," page 4).

Modifications to the Plan

The Plan may be modified if the technical analysis ("Five-Year Technical Analysis," page 48) determines that modifications to the Plan are needed to meet the goals and objectives of the Plan (*Neb. Rev. Stat.* § 46-755 (d)).

The procedures for modifying the Plan are (*Neb. Rev. Stat.* § 46-755 (d)):

1. Preceding modification of the Plan,
    a. Determine that the technical analysis indicates modifications are needed ("Five-Year Technical Analysis," page 48),
    b. Present the results of the technical analysis and recommended modifications to the Plan at a public meeting ("Annual Meeting," page 47), and
    c. Provide for at least a 30-day public comment period before holding a public hearing on the recommended modifications

2. Following modification of the Plan, a description of any modifications made will be included in the required report to the Legislature ("Report to the Legislature," page 50).

The Integrated Management Plans (IMP) for the NRDs within the Basin are tools that can be used to help implement the goals and objectives of the Basin-Wide Plan. NeDNR and the NRDs may choose to modify the IMPs, either instead of or in addition to the Basin-Wide Plan, if they determine that doing so would help achieve the goals and objectives of the Basin-Wide Plan. Consideration of any recommended changes to the IMPs will follow the established procedures for updating the IMPs. As of the effective date of the Plan, these procedures are described in *Neb. Rev. Stat.* §§ 46-715 to 46-718 and 46-719 (3).

Report to the Legislature

Following each technical analysis ("Five-Year Technical Analysis," page 48), and any resulting Plan modifications ("Modifications to the Plan," page 49), NeDNR and the NRDs will electronically submit a report to the Legislature (Action Item 1.3.4) that includes:

- The results of the technical analysis,
- Progress made under the Plan,
- Modifications made to the Plan, if any, and
- Any comments on the final, adopted Plan that have been submitted to NeDNR or the NRDs by any official participant or stakeholder.

4. Plan Implementation Schedule

Section Overview

As required by *Neb. Rev. Stat.* § 46-755 (5)(b), the Republican River Basin-Wide Plan (Plan) includes a schedule indicating the end date by which the goals and objectives are to be achieved and the management actions to be taken to achieve the goals and objectives. The Plan's goals, objectives and action items are described in detail with the "Goals and Objectives" section (page 13). Tables 4.1 through 4.4 in this Plan Implementation Schedule section specify a schedule for each action item.

Neb. Rev. Stat. § 46-755 (5)(b) also requires that the Plan include measurable hydrologic objectives (MHOs) to help assess whether reasonable progress has been made toward the Plan's goals and objectives. The MHOs will be evaluated as described under "Evaluation of Progress" (page 48). The Plan's MHOs are listed under Action Item 1.3.2 in Table 4.1.

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Measurable Hydrologic Objectives 53
Implementation schedule for Goal 2 56
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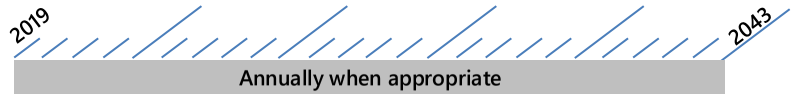
Implementation schedule for Goal 4 62

Table 4.1. Implementation schedule for Goal 1. Additional details about Goal 1 and its objectives and action items are described beginning on page 15. The Plan's MHOs ("Measurable Hydrologic Objectives," page 48) are included in this table as part of Action Item 1.3.2 and are indicated by a yellow background.

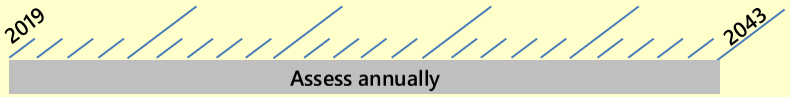
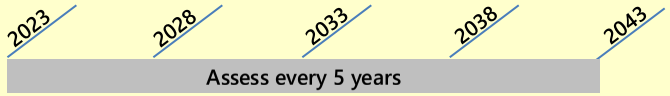
Goal 1: Maintain Nebraska's compliance with the Republican River Compact and applicable state laws				
Objective	***Plan language***			***Years in which addressed***
1.1.	**Coordinate basin-wide plan management actions with Nebraska's Compact compliance efforts and adherence to applicable state laws**			
	Action items	1.1.1.	Review each basin-wide plan management action prior to implementation to ensure it does not negatively impact efforts to achieve Compact compliance in the most efficient and cost-effective way practicable while adhering to state laws	
		1.1.2.	Implement appropriate offsets for any basin-wide plan action that would exceed Nebraska's allocation under the Compact	
1.2.	**Understand the effects of management actions for Compact compliance on water supplies for Nebraska's water users**			
	Action items	1.2.1.	Qualitatively evaluate the net effect on water supplies of any management actions that are taken for Compact compliance	
1.3.	**Assess progress toward meeting the goals and objectives of the Plan, and share the results of this assessment with the Public and the Nebraska Legislature**			
	Action items	1.3.1.	Within five years after the adoption of this Plan, and every five years thereafter, conduct a technical analysis of the actions taken to determine the progress toward meeting the goals and objectives of the Plan	

* From the effective date of this Plan ("Effective Date and Time Frame of the Plan," page 4)

(continued on next page)

** All Plan actions must be completed no later than April 17, 2044 ("Effective Date and Time Frame of the Plan," page 4)

(Table 4.1, continued from previous page)

Goal 1: Maintain Nebraska's compliance with the Republican River Compact and applicable state laws				
Objective	*Plan language*			*Years in which addressed*
1.3.	*Action items*	1.3.2.	Evaluate progress toward each of the Plan's measurable hydrologic objectives at the intermediate dates specified in the Plan for each one	As indicated for each MHO, below
		Measurable Hydrologic Objectives	**MHO A:** Maintain each NRD's net[2] groundwater depletions to streamflow within its portion of Nebraska's allowable groundwater depletions to streamflow **Assessment:** For the previous Compact averaging period (2 or 5 years, as determined by Compact accounting procedures), has each NRD's groundwater net depletions to streamflow for the RRCA model area, remained within its portion of Nebraska's allowable groundwater depletions to streamflow, as specified in the IMPs? **MHO is being achieved:** if assessment results in "yes" for NRDs	
			MHO B: Limit groundwater depletions to streamflow to a relatively constant level over the long-term both across the basin as a whole and within each NRD[3] **Assessment:** Before the first annual meeting, NeDNR and the NRDs will develop written procedures detailing this MHO analysis, which will be appended to the Plan.	

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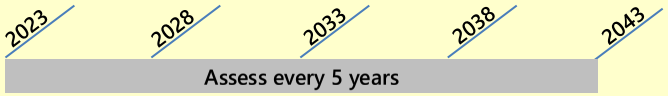
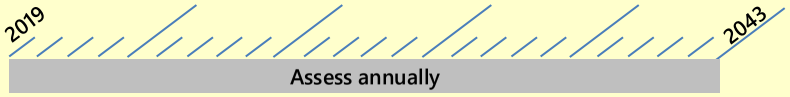
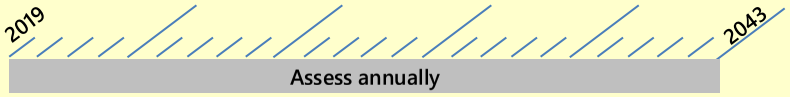
[2] For the purposes of MHO A, "net groundwater depletions to streamflow" does include augmentation

[3] For the purposes of MHO B, depletions to streamflow for Tri-Basin NRD and for the Basin as a whole will be evaluated as the net of groundwater depletions to streamflow plus the mound credit.

(Table 4.1, continued from previous page)

Goal 1: Maintain Nebraska's compliance with the Republican River Compact and applicable state laws				
Objective	*Plan language*			*Years in which addressed*
1.3.	*Action items*	*Measurable Hydrologic Objectives*	**MHO C:** Ensure there is always enough groundwater for all groundwater uses within the timeframe of this plan, either by stabilizing groundwater levels or managing declining groundwater levels **Assessment:** Before the first annual meeting, NeDNR and the NRDs will develop written procedures detailing this MHO analysis, which will be appended to the Plan.	
			MHO D: Continue existing and initiate new actions that reduce the need for special regulations in the Rapid Response Area for Compact compliance **Assessment:** During the previous year, has groundwater pumping within the Rapid Response Area of any NRD been curtailed to ensure Compact compliance? **MHO is being achieved:** if assessment results in "no" for all NRDs	
			MHO E: Continue existing and initiate new actions that reduce the need for administration of surface water use for Compact compliance **Assessment:** During the previous year, has surface water use within the Basin been administered to reduce surface water use to ensure Compact compliance? **MHO is being achieved:** if assessment results in "no"	

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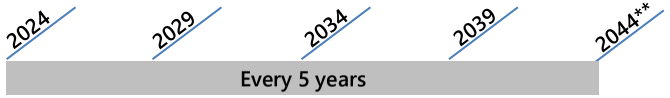
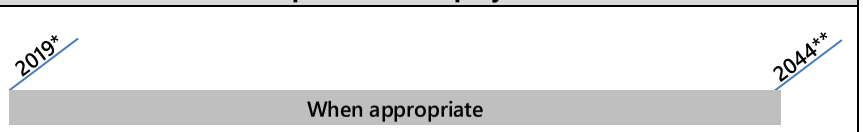
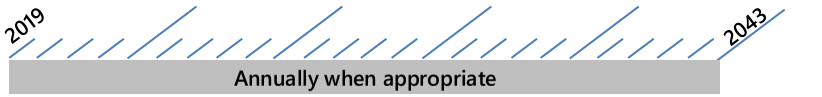
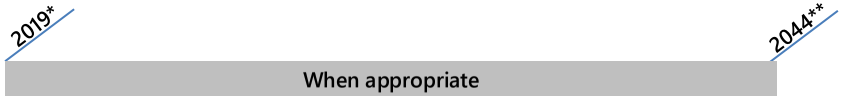
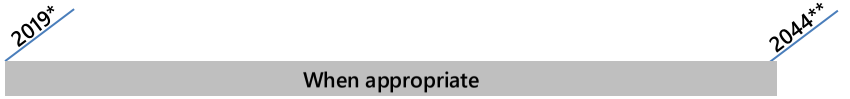
(Table 4.1, continued from previous page)

Goal 1: Maintain Nebraska's compliance with the Republican River Compact and applicable state laws				
Objective	*Plan language*			*Years in which addressed*
1.3.	*Action items*	1.3.3.	Following each five-year technical analysis (Action Item 1.3.1), share the results of the analysis and any recommended Plan modifications with the public	
		1.3.4.	Following each five-year technical analysis (Action Item 1.3.1) and any resulting modifications to the Plan, submit a report to the Legislature of the results of the analysis and progress made under the Plan	

** All Plan actions must be completed no later than April 17, 2044 ("Effective Date and Time Frame of the Plan," page 4)

Table 4.2. Implementation schedule for Goal 2. Additional details about Goal 2 and its objectives and action items are described beginning on page 19.

Goal 2: Maximize Nebraska's efficient and beneficial consumptive use of its portion of the water supply, increase certainty for long-range planning of water supplies to reduce the need for regulatory actions, and increase collaborative efforts among water management entities and stakeholders across the Basin				
Objective	***Plan language***			***Years in which addressed***
2.1.	**Understand the feasibility and potential impacts of Plan actions and establish a standard procedure for projects**			
	Action items	2.1.1.	For each planned new water management project in the Plan, evaluate hydrologic and regulatory feasibility and potential economic and environmental impacts	
		2.1.2.	For each project evaluated in accordance with Action Item 2.1.1 in a given year, include a summary of the evaluation in the annual report of that year's activities	
		2.1.3.	For projects that are feasible and beneficial, apply for necessary permits, establish new or utilize existing infrastructure, then begin operations	
2.2.	**Improve the efficiency of use, availability, and reliability of water supplies for current irrigators**			
	Action items	2.2.1.	Work with irrigation districts and individual groundwater and surface water irrigators to improve the efficiency of the Basin's surface water delivery systems and irrigation water use, when it is both feasible and beneficial to Nebraska's Compact accounting balance	

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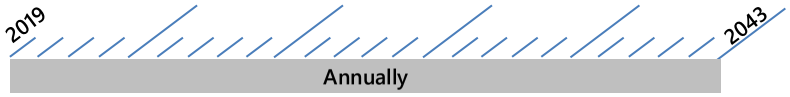
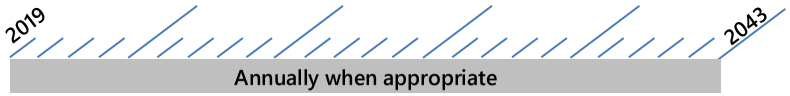
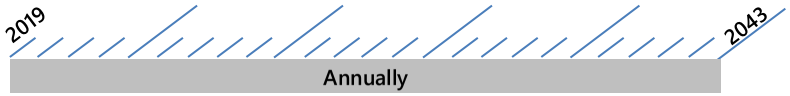
(Table 4.2, continued from previous page)

Goal 2: Maximize Nebraska's efficient and beneficial consumptive use of its portion of the water supply, increase certainty for long-range planning of water supplies to reduce the need for regulatory actions, and increase collaborative efforts among water management entities and stakeholders across the Basin

Objective	*Plan language*			*Years in which addressed*
2.2.	*Action items*	2.2.2.	Participate in projects to improve the reliability, availability, and sustainability of water supplies in the Basin, which may include but are not limited to: a. Voluntary reduction of irrigated acres (temporary or permanent) b. Interbasin transfers c. Conjunctive management projects such as aquifer recharge or streamflow augmentation	
2.3.	**Provide opportunities for collaboration among the Basin's water users**			
	Action items	2.3.1.	Hold an annual public meeting to discuss Plan implementation and exchange information about the Basin	
		2.3.2.	Work cooperatively to investigate and address conflicts between water users resulting from implementation of this Plan by following the procedures for addressing conflicts that are outlined in this Plan	
2.4.	**Promote conservation programs available to the water users in the Basin**			
	Action items	2.4.1.	Work together to identify, investigate, and discuss existing and potential new water conservation programs	

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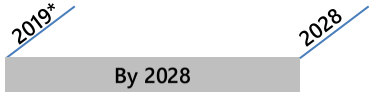
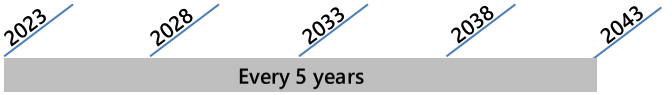
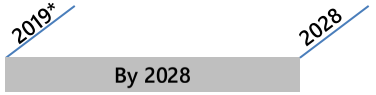
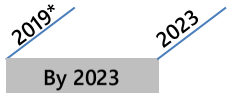
Goal 2: Maximize Nebraska's efficient and beneficial consumptive use of its portion of the water supply, increase certainty for long-range planning of water supplies to reduce the need for regulatory actions, and increase collaborative efforts among water management entities and stakeholders across the Basin

Objective	*Plan language*			*Years in which addressed*
2.4	*Action items*	2.4.2.	Collaborate to promote conservation program opportunities to the Basin's water users	
2.5.	**Understand how various water management activities of independent decision-makers affect water supplies**			
	Action items	2.5.1.	Study the effects of conservation practices on streamflow, if feasible	
		2.5.2.	As part of each five-year technical analysis, analyze the future impacts to streamflow of past pumping to determine the lag time of these residual impacts	
		2.5.3.	Examine and attempt to estimate the quantity of all inputs and outputs affecting the water supply balance in a small watershed, and consider using the results of this pilot study to create water use and land use guidelines for producers and other land managers, incentivize participation in recommended practices, and determine the value of completing similar studies across the Basin	
2.6.	**Evaluate the feasibility and potential outcomes of establishing water markets in the Basin**			
	Action items	2.6.1.	Cooperate in determining the feasibility of water markets in the Basin	

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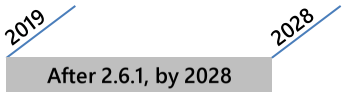
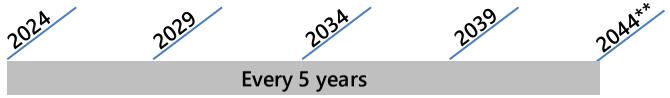
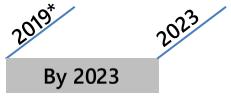
Goal 2: Maximize Nebraska's efficient and beneficial consumptive use of its portion of the water supply, increase certainty for long-range planning of water supplies to reduce the need for regulatory actions, and increase collaborative efforts among water management entities and stakeholders across the Basin				
Objective	*Plan language*			*Years in which addressed*
2.6.	*Action items*	2.6.2.	Following the water markets feasibility analysis (Action Item 2.6.1), test conclusions through implementation of a water market program in a pilot area, if feasible	
2.7.	**Support the NRDs in management of allocations for irrigation purposes and surface water irrigation districts in management of the allotment of their water supply**			
	Action items	2.7.1.	Periodically evaluate, as part of each five-year technical analysis, the impact of the groundwater allocation and surface water allotment systems as a whole	
	Action items	2.7.2.	As needed, based on the evaluation described in Action Item 2.7.1, recommend changes or improvements to the groundwater allocation and/or surface water allotment systems	
2.8.	**Conserve water for future use during a drought**			
	Action items	2.8.1.	Organize and participate in a basin-wide drought planning exercise	
	Action items	2.8.2.	Following the drought planning exercise (Action Item 2.8.1) evaluate whether to recommend any changes to the IMPs or this Plan related to conservation of water for future use during a drought	

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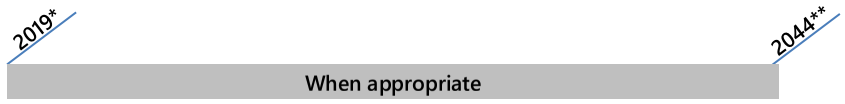
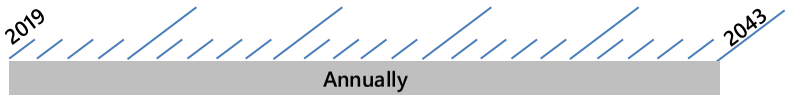
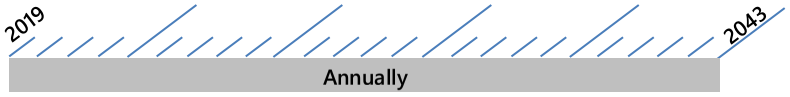
Table 4.3. Implementation schedule for Goal 3. Additional details about Goal 3 and its objectives and action items are described beginning on page 35.

Goal 3: Positive public relations, including information sharing, within and outside the Basin				
Objective	***Plan language***			***Years in which addressed***
3.1.	**Improve information sharing with decision-makers and the public about solutions formed within the Basin**			
	Action items	3.1.1.	Use existing resources to share information about Basin progress and activities with outside entities	
		3.1.2.	Educate civic leaders and the public on implementation efforts within the Basin	
		3.1.3.	Educate civic leaders and the public about the policies and institutional infrastructure that contribute to the development and implementation of solutions	
		3.1.4.	Propose and support changes to laws, policies, and rules that would incentivize reduced water consumption	
3.2.	**Improve information sharing with water users who are reliant on the Basin's water supplies**			
	Action items	3.2.1.	Share data and information related to the Republican River Compact with the public in an easily accessible, user-friendly format	
		3.2.2.	Annually prepare and exchange reports containing data and information about water supplies and uses in the Basin, and make these reports publically accessible	

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** All Plan actions must be completed no later than April 17, 2044 ("Effective Date and Time Frame of the Plan," page 4)

(Table 4.3, continued from previous page)

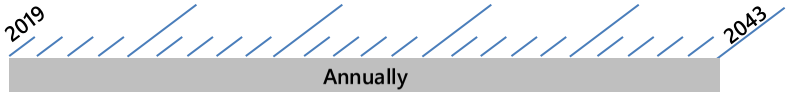
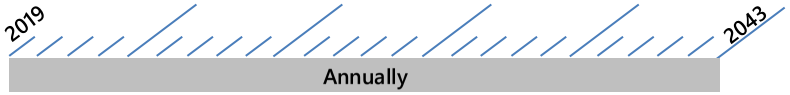
Goal 3: Positive public relations, including information sharing, within and outside the Basin				
Objective	***Plan language***			***Years in which addressed***
3.2.	***Action items***	3.2.3.	Regularly communicate with the Plan's former Stakeholder Advisory Committee about implementation progress and potential Plan revisions	
		3.2.4.	Encourage and support water users to share information about their management practice improvements with other water users and the public	

Table 4.4. Implementation schedule for Goal 4. Additional details about Goal 4 and its objectives and action items are described beginning on page 41.

Goal 4: When possible, pursue projects that not only benefit water supplies and uses, but also create benefits for fish, wildlife, recreation, and conveyance within the Republican River Basin				
Objective	***Plan language***			***Years in which addressed***
4.1.	**Where feasible and beneficial, protect and enhance fish and wildlife habitat and public outdoor recreational opportunities**			
	Action items	4.1.1.	Partner with wildlife-focused organizations on projects that benefit the organizations' habitat and wildlife interests while also helping to fulfill other goals of this Plan	2019* — When appropriate — 2044**
		4.1.2.	Promote public recreation on the river, when doing so can also help to fulfill other goals of this Plan	2019* — When appropriate — 2044**
		4.1.3.	Cooperate in projects to assess and restore riparian wetlands while also helping to fulfill other goals of this Plan	2019* — When appropriate — 2044**
4.2.	**Where feasible and beneficial, reduce the effects of undesirable vegetation on water conveyance**			
	Action item	4.2.1.	Cooperate in removing undesirable vegetation impacting water conveyance and managing reinfestation	2019* — When appropriate — 2044**

* From the effective date of this Plan ("Effective Date and Time Frame of the Plan," page 4)

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5. Funding

Section Overview

The Funding section of this plan establishes guidelines and limitations related to funding for carrying out the goals, objectives, and action items of the Republican River Basin-Wide Plan (Plan).

Guidelines

When possible, NeDNR and the NRDs will work together to pursue external funding or appropriate incentive programs to implement the goals, objectives, and action items of this Plan. The "Plan Area" section (page 64) describes where funding and studies may apply. Some existing potential funding sources are summarized in Table 5.1.

Table 5.1. Some existing funding sources to consider that could potentially support management actions related to implementation of this Plan.

Program	Administering agency or commission
CREP (Conservation Reserve Enhancement Program)	Farm Service Agency, US Department of Agriculture
EQIP (Environmental Quality Incentives Program)	Natural Resources Conservation Service, US Department of Agriculture
Natural Resources Districts' funding (e.g., occupation taxes and levies)	Natural Resources Districts
Nebraska Environmental Trust grants	Nebraska Environmental Trust
Water Conservation Field Services Grant	US Bureau of Reclamation
Water Resources Cash Fund	Nebraska Department of Natural Resources
WaterSMART Grants (Sustain and Manage America's Resources for Tomorrow)	US Bureau of Reclamation
Water Sustainability Fund	Nebraska Natural Resources Commission

Limitations

The ability of NeDNR and the NRDs to implement the goals, objectives, and action items for this Plan, including their ability to meet the implementation timeline and intermediate deadlines set forth herein, may be limited by the availability of resources, including (but not limited to) funding or staff resources.

If limited resources prohibit completion or initiation of a specific management action, or if they delay the ability of NeDNR or an NRD to complete a task by an established deadline, such limitations and delays will be discussed by NeDNR and the NRDs an Annual Meeting ("Annual Meeting", page 47). If such a delay results in the need for revisions to this Plan, the necessary revisions will be made following the procedures set forth in "Modifications to the Plan," (page 49).

6. Plan Area

Section Overview

This section describes the geographic area to which the Republican River Basin-Wide Plan (Plan) applies.

Plan Area

The Plan will examine and make recommendations for the entire Republican River Basin. Surface water funding and studies may apply specifically to the hydrologically connected area for surface water. Groundwater funding and studies may apply specifically to the hydrologically connected area for groundwater, the extent of which is defined by the Nebraska Department of Natural Resources (NeDNR) (as shown in Figure 6.1). During the time frame of the Plan, it may become necessary to revise the extent of the area where groundwater funding and studies may apply to remain consistent with updates to the extent of the hydrologically connected area defined by NeDNR. If future revisions to the Plan include the addition of controls, the geographic areas described above would also apply to those controls.

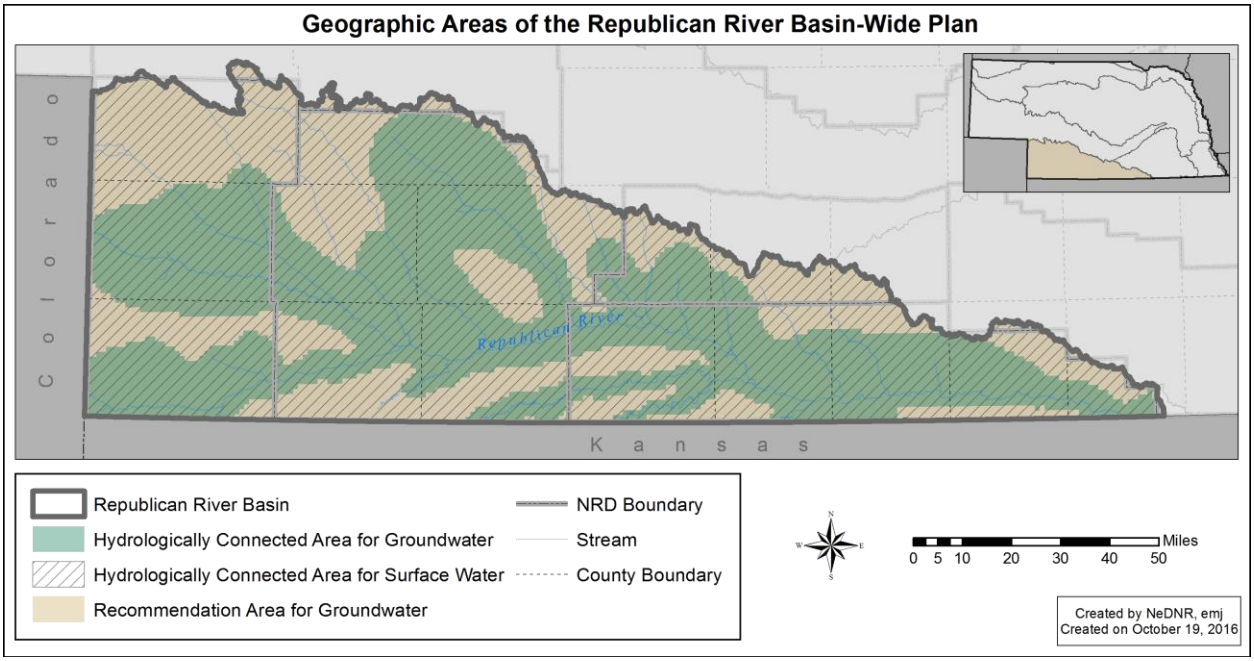

Figure 6.1. Geographic areas to which Plan actions related to groundwater and surface water apply. The hydrologically connected area for groundwater shown in this map is the area determined by NeDNR to be hydrologically connected according to NeDNR's 10/50 rule, as of the effective date of this plan.

7. Glossary

Acre-foot (af); *plural: acre-feet*
The volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot; equivalent to 325,851 gallons

Action item
A description of a specific task that NeDNR and the NRDs will undertake to achieve the goals and objectives

Allocation
1. A regulatory measure that stipulates the amount of water available to be used for irrigation, livestock or industrial purposes; or
2. A limit, determined by the RRCA, of how much water from within the Republican River Basin can be consumed by each state (Nebraska, Kansas, and Colorado)

Alluvial aquifer
An aquifer comprising unconsolidated sediments deposited by water, occurring adjacent to rivers or streams

Aquifer
An underground geological formation or structure of permeable rock or unconsolidated materials that stores and/or transmits water, such as to wells and springs

Augmentation
Supplementing or replacing surface water in a basin, subbasin, or reach through actions including, but not limited to, groundwater pumping and interbasin surface water transfers

Basin
See "watershed"; in the context of this Plan, "Basin" refers to the Republican River Basin

Basin of origin
For an interbasin transfer, the river basin in which the point or proposed point of diversion of water is located

Basin-wide plan
A plan developed between NeDNR and the NRDs within a river basin to jointly manage hydrologically connected surface water and groundwater in the basin to achieve and sustain a balance between water uses and water supplies for the long term

Beneficial consumptive use
The amount of surface water and/or groundwater that is consumed under appropriate and reasonably efficient practices to accomplish without waste the purposes for which the appropriation or other legally permitted use is lawfully made

Best management practices
Schedules of activities, maintenance procedures, and methods used for purposes of maximizing irrigation or other water use efficiency, to conserve or affect a savings of water, or to prevent or reduce present and future contamination of water

Compact
See "Republican River Compact"

Compact Call Year
A year in which NeDNR's analysis following the forecast procedures contained in the IMPs for the Upper, Middle, and Lower Republican NRDs indicate the potential for noncompliance with the Compact if sufficient management actions are not taken

Compact compliance
Adhering to the water use stipulations outlined in the Compact and the *Final Settlement Stipulation*

Computed Beneficial Consumptive Use (CBCU)
For purposes of Compact accounting, the streamflow depletion resulting from the activities of man that are specified in the *RRCA Accounting Procedures and Reporting Requirements*

Conjunctive management
Using surface water and groundwater in combination to improve water availability and reliability, primarily through conserving or changing the timing of the flow of existing water sources by shifting when and where it is stored; does not result in new sources of water

Conservation program
A program that provides financial or other incentives to encourage voluntary modification of farming and irrigation practices, industrial practices, or residential and commercial practices for the purposes of water conservation

Consumptive use
That portion of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment and does not return to a water resources system

Conveyance
The transport of water from one location to another

Cubic foot per second (cfs); *plural: cubic feet per second*
The flow rate or discharge equal to one cubic foot of water per second or about 7.5 gallons per second

Depletion
Reduction to streamflow that results from a use of either groundwater or surface water

Discharge
A hydrologic process where water moves from groundwater to surface water as part of the hydrologic cycle

End gun
A sprinkler located at the end of a center pivot irrigation system that is used to irrigate the portions of a field beyond the outermost span of the pivot

Evaporation
The process that transfers water from land surface to the atmosphere via energizing liquid water to water vapor

Evapotranspiration
The process that transfers water from land surface to the atmosphere as evaporation (or sublimation when below freezing) from open water, soil, and plant canopies and as transpiration by plants

Fully appropriated
A river basin, subbasin, or reach is designated by NeDNR as "fully appropriated" if it meets the conditions in *Neb. Rev. Stat.* § 46-713 (3)

Goal
A broad statement that defines what a group wants to accomplish and provides the context from which meaningful objectives and action items are developed

Groundwater
Water that occurs in or moves, seeps, filters, or percolates through ground under the surface of the land

Groundwater level
The elevation at which ground is wholly saturated with water

Groundwater mound
An area in which groundwater levels have increased significantly from pre-development levels, primarily due to canal seepage

High Plains Aquifer
An aquifer underlying parts of eight states: South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas, of which approximately two-thirds of the water underlies Nebraska

Hydrologically connected area
The area within which pumping of a ground water well for 50 years will deplete the river or a baseflow tributary thereof by at least 10 percent of the amount pumped in that time, as defined by NeDNR rules

Infiltration
The process by which water on the ground surface enters the soil

Integrated Management Plan (IMP)
A plan developed between NeDNR and an NRD to jointly manage hydrologically connected surface water and groundwater in a river basin, subbasin, or reach to achieve and sustain a balance between water uses and water supplies for the long term

Interbasin transfer
The diversion of water in one river basin and the transportation of such water to another river basin for storage or utilization for a beneficial purpose

Irrigated acreage retirement
The removal of cropland from irrigated crop production, either permanently or for a pre-determined number of years; the non-irrigated land use is usually either dryland cropland or grassland

Irrigation
The controlled application of water to land for the purpose of growing plants

Mainstem
The primary river within a basin; in the case of the Republican River Basin, the Republican River is the mainstem

Measurable hydrologic objective
A quantifiable target, related to the movement and distribution of water, used to evaluate the extent to which reasonable progress is made toward achieving the final goals and objectives of the Plan

Moratorium
In the context of groundwater and surface water rights, a legally authorized suspension of drilling of groundwater wells, development of additional irrigated cropland, or approval of new surface water appropriations

Natural resources district (NRD)
Local government entity of the State with broad responsibilities to protect Nebraska's natural resources within their subdivision; "NRDs" in this plan refers specifically to the Upper Republican, Middle Republican, Lower Republican, and Tri-Basin NRDs

Nebraska's allowable groundwater depletions
The maximum level of depletions to streamflow from groundwater pumping within the Nebraska portion of the Republican River Basin that can be allowed in any one year without exceeding the RRCA allocation over the appropriate averaging period

Objective
A statement that defines a specific outcome that a group seeks to accomplish in working toward a goal

Offset
A reduction in water use or an increase in water supply that corresponds with an increased use of water, for the purpose of balancing water uses and supplies; also referred to as mitigation

Ogallala Aquifer
A geologic formation of the High Plains Aquifer found within Nebraska

Rapid Response Area
An area designated in the IMPs and rules and regulations for the Upper, Middle, and Lower Republican NRDs in which additional groundwater regulations may be applied during a Compact Call Year if necessary to maintain compliance with the Compact

Recharge
A hydrologic process where water moves downward from surface water to groundwater aquifers, both naturally through the hydrologic cycle or through intentional or incidental seepage from streams, lakes and canals

Republican River Compact (Compact)
An agreement between Colorado, Kansas, and Nebraska that allocates consumption of the waters of the Republican River Basin among the three states

Republican River Compact Administration (RRCA)
The entity that administers the Republican River Compact; comprised of one member each from Colorado, Kansas, and Nebraska

Riparian
Positioned on or near the banks of a river, stream, or other body of water

RRCA groundwater model
The computer-based groundwater model developed under the provisions of the *Final Settlement Stipulation* of the Compact and subsequently adopted and revised through action of the RRCA

RRCA groundwater model boundary
The outer limits of the area analyzed using the RRCA groundwater model; this boundary is set by the RRCA and includes lands outside the Republican River surface water basin

Stakeholder Advisory Committee
The group of individuals with a water interest in the Basin that was formally assembled for the purpose of collaborating with NeDNR and the NRDs on the development of this Plan

Stream depletion factor
A measure of how much groundwater pumping at a specific location would deplete streamflow after a specified period of time

Streamflow
The discharge that occurs in a natural channel of a surface stream course

Subbasin
A portion of a river basin that is drained by a waterway

Surface water
Water that is on the Earth's surface, such as in a stream, river, lake, or reservoir

Surface water allotment systems
Within the context of the Plan, this refers to how the irrigation districts determine how water is shared among surface water users within each district

Transpiration
The process that transfers water from plants to the atmosphere, as vapor, from the leaves and stems

Tributary
A river or stream that is not the primary river within a watershed; in the Republican River Basin, all streams and rivers other than the Republican River itself are tributaries of the Republican River

Variance
An allowance of an exception to existing rules or regulations; for example, allowing an exception to a moratorium on new irrigated acres, new wells, or new surface water appropriations while providing adequate mitigations or transfers to assure that there is no net increase in depletions to the river or impacts to existing surface water or groundwater uses

Water market
An economic platform for temporary or permanent trades of the rights to use water, where the price of water is determined by variable economic and market conditions

Watershed
The area of land where all of the water that is under it or that drains off of it goes into the same place; synonymous with "basin

Wetland
An area of land saturated with water at or near the surface of the soil for all or part of the year, such as a swamp or a marsh

Appendix A. Local Hydrology

Section Overview

The hydrologic cycle and interactions of groundwater and surface water comprise an important part of the hydrology of the Republican River Basin (Basin). Because water management is the primary focus of the Republican River Basin-Wide Plan (Plan), it is important to know the concepts of how water moves through the Basin. This section begins with a basic discussion of Basin hydrology and then discusses precipitation, supplies, and uses in greater detail.

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Surface Water Supplies 73
Groundwater Supplies 76
Human Activities Relating to Basin Hydrology 80
Surface Water 81
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Basic Hydrological Principles of the Basin

Water moves between the sky, underground, and surface flows via a cycle known as the hydrologic (water) cycle (Figure A.1). A general understanding of basic water movement within the hydrologic cycle is needed to understand the Basin's hydrology.

Precipitation in the Basin can cycle in the following ways:

- Runoff into streams that feed into the Republican River
- Infiltration into the soil, eventually percolating into the aquifer
- Infiltration into the soil that eventually reaches the stream
- Infiltration into the soil and returned as vapor through plant transpiration
- Evaporation from the soil
- Evaporation from open waterbodies
- Consumptively used and removed from the system (primarily via agricultural harvest)

The water supply of the Republican River and its tributaries consists of groundwater baseflows and runoff of precipitation from the land surface into streams and rivers in the Basin. This is in contrast to river systems that are primarily supplied by mountain snow melt or baseflow. Different water sources lead to differing river characteristics. For example, the Republican River can display significant daily, seasonal, and annual variation because flows are significantly affected by recent rainfall.

Precipitation that infiltrates through the soil can reach the aquifer and be stored for long periods. This water, known as groundwater, is stored in interstitial spaces between sediment particles. Groundwater generally flows from areas of recharge (water moving into the aquifer) to areas of discharge (water moving out of the aquifer) via gravity. In locations where the water table (level of the "top" of the groundwater) is higher than stream elevation, water can flow from groundwater into surface water. Streams can lose surface water to groundwater recharge (losing stream) if the water table is lower than the stream elevation. If the water table is lower than the streambed, this is called a disconnected stream. This can occur naturally or because of aquifer overuse.

Precipitation that infiltrates the soil can be used by plants via root systems before the precipitation reaches the aquifer. Stomas on the outer layer of a plant must be open to photosynthesize. These pores lose water through a process known as transpiration.

Water can evaporate, and leave the system as vapor. Evaporation increases with temperature and wind speed, and with greater surface area.

Consumptive uses remove water from the local hydrologic system (Figure A.1). Consumptive use losses occur as evaporation from water bodies and land surfaces. In addition, evaporation and transpiration

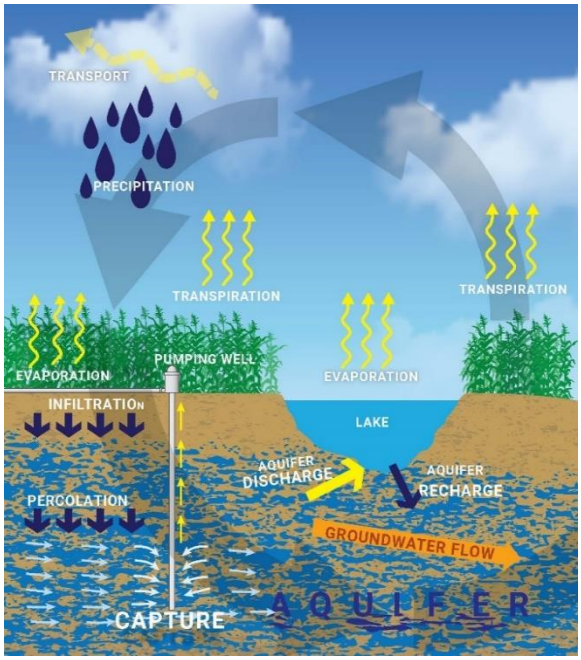

Figure A.1. A representation of the movement of water in a local hydrologic area. The movement of water (arrows) is driven by various above-ground and below-ground factors.

(evapotranspiration) by plants and the water contained in crops at the time they are removed from the field are considered other consumptive use losses.

Surface water in the Basin is hydrologically connected to the surrounding groundwater, but the interactions are difficult to observe and measure. To analyze the Basin hydrology, many variables need to be accounted for, including precipitation, soil type, land use, topography, water use, and geology. Computer models analyze and predict the influence of such variables.

Precipitation

It is important to analyze precipitation data from weather stations within the Basin because precipitation is a significant factor of groundwater replenishment and surface water flows. The majority of precipitation falls in the Basin during the months of May, June, and July. Precipitation can vary significantly among years (Figure A.2). Average annual precipitation varies across the Basin and increases from west to east. Among the weather stations in the Basin that are used to estimate precipitation in the RRCA model, the lowest average annual precipitation, 19", occurs in Wauneta (west), and the greatest, 26", occurs in Superior (east) based on 1918 through 2016 records (Figure A.3). Many factors influence recharge from precipitation including soil type, precipitation intensity, topography, and vegetative cover. Greater recharge occurs on coarse-textured soils compared with fine-textured soils given the same amount of precipitation, slope, and landuse.

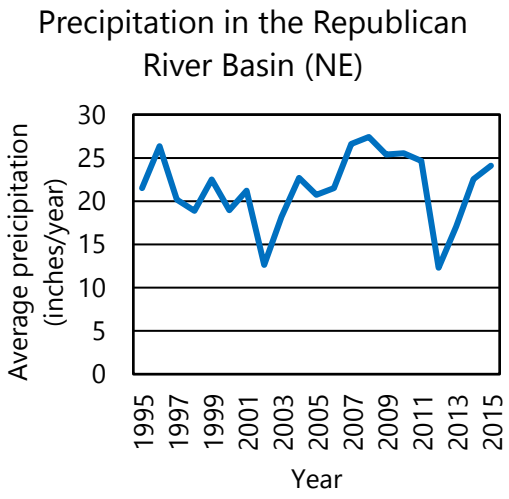

Figure A.2. Average annual precipitation for the Republican River Basin from weather stations used in the RRCA model with a full 98 years of data (1918-2016). Precipitation varies significantly among years.

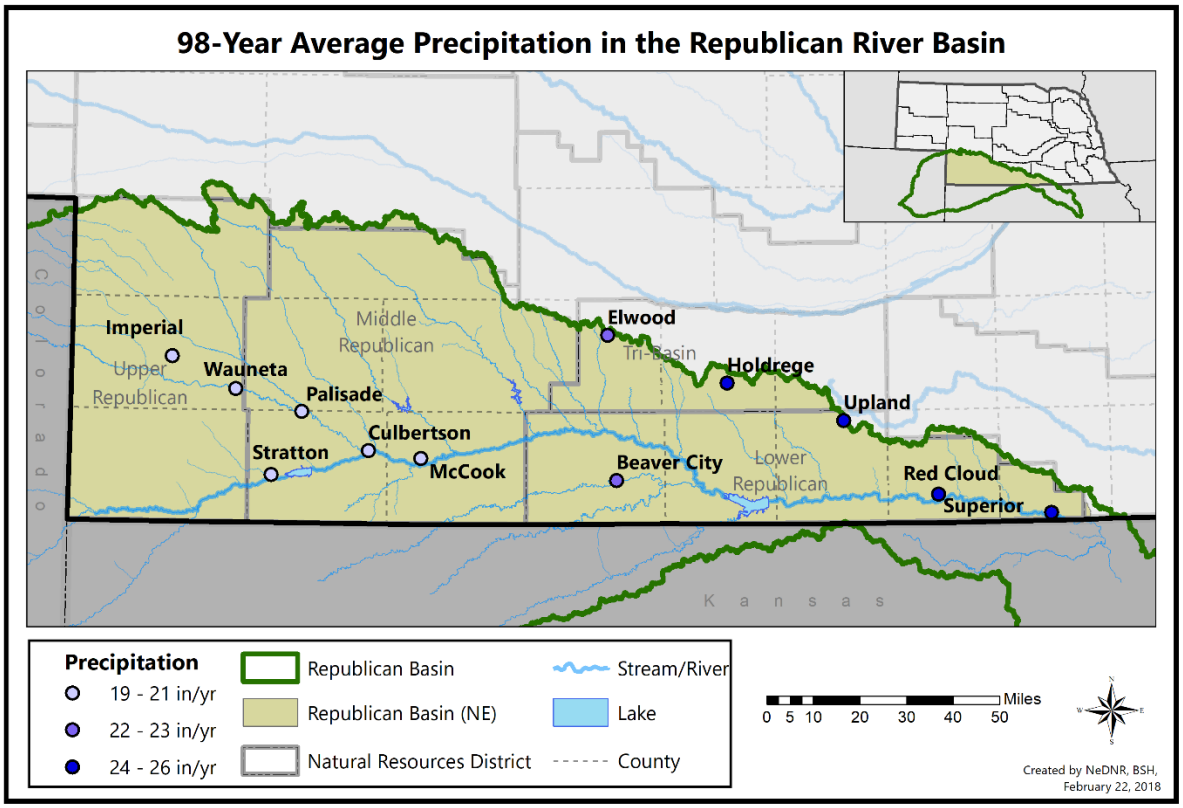

Figure A.3. Map of 98-year precipitation averages from weather stations in the Republican River Basin.

Surface Water Supplies

The mainstem of the Republican River forms at the junction of the North Fork of the Republican River and the Arikaree River near Haigler, Nebraska. The river flows in a generally eastern direction for approximately 445 miles before it joins the Smoky Hill River to form the Kansas River at Junction City, Kansas. The Basin encompasses approximately 24,900 square miles, of which about 7,700 square miles are in Colorado, 7,500 square miles are in Kansas, and 9,700 square miles are in Nebraska (Figure A.4). Its gradient ranges from about four to ten feet per mile. The channel width varies considerably, gradually widening downstream. There are many stream and canal gages throughout the Basin (Table A.1 and Figure A.5).

Important tributaries to the Republican River include:

- Frenchman Creek (River),
- Driftwood Creek,
- Red Willow Creek,
- Medicine Creek.
- Rock Creek,
- Driftwood Creek,
- Sappa Creek,
- Beaver Creek, and
- Buffalo Creek.

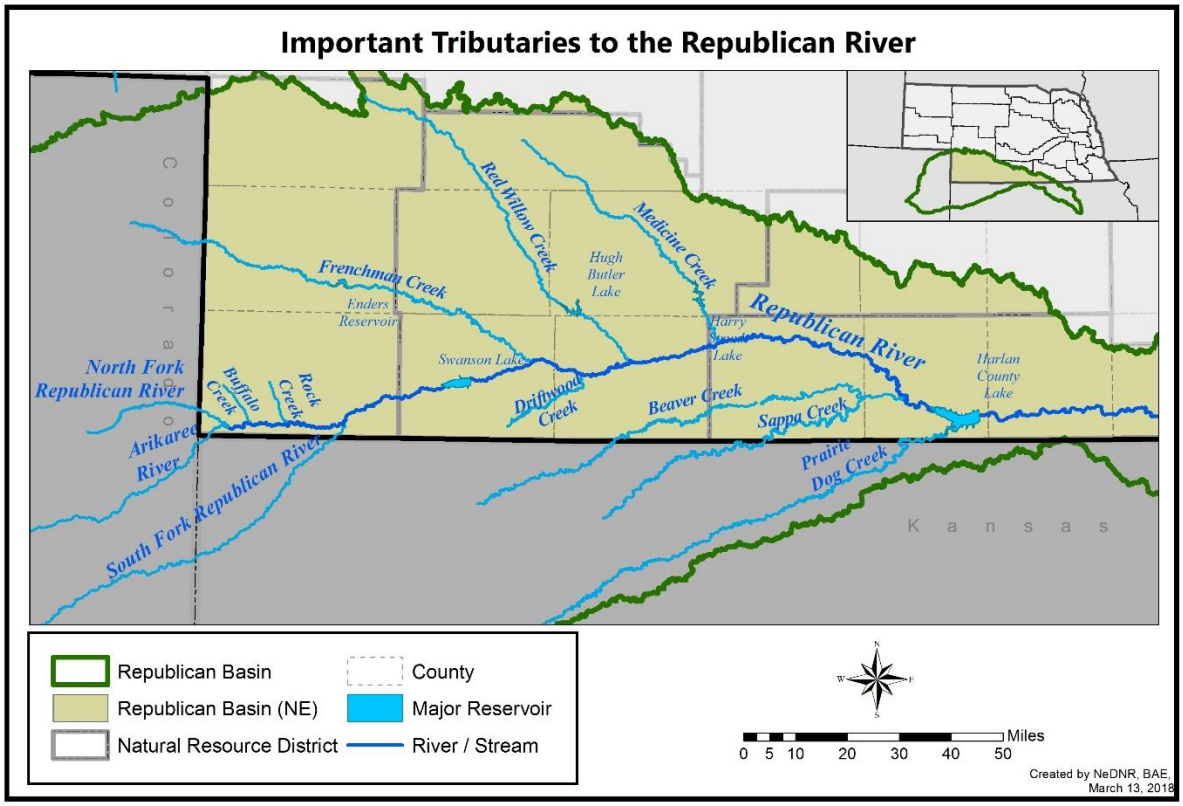

Figure A.4. Important tributaries and reservoirs to the Republican River.

Table A.1. Streamgages and measured canals within the Republican River Basin. Gages are monitored by either NeDNR (**bold)** or the US Geological Survey (USGS, *italics*).

Station Name - Owner	Station Number	Type
North Fork Republican River at CO-NE - USGS	06823000	Stream
Haigler Canal Spillback to Arikaree River - NeDNR	61500	Canal
Arikaree River at Haigler - USGS	06821500	Stream
Buffalo Creek near Haigler - USGS	06823500	Stream
Rock Creek at Parks - USGS	06824000	Stream
Republican River at Benkelman, NE - USGS	06824500	Stream
South Fork Republican River near Benkelman - USGS	06827500	Stream
Republican River at Stratton - USGS	06828500	Stream
Frenchman Creek near Imperial - NeDNR	6831500	Stream
Frenchman Creek near Enders - NeDNR	6832500	Stream
Frenchman Creek at Palisade - USGS	06834000	Stream
Stinking Water Creek near Palisade - NeDNR	6835000	Stream
Frenchman Creek at Culbertson - USGS	06835500	Stream
Driftwood Creek near McCook - USGS	06836500	Stream
Republican River at McCook - USGS	06837000	Stream
Red Willow Creek above Hugh Butler Lake - NeDNR	6837300	Stream
Red Willow Creek near Red Willow - USGS	06838000	Stream
Bartley Canal from Republican River - USGS	6000	Canal
Republican River at Hwy 47 Bridge, Cambridge, NE - NeDNR	6843400	Stream
Medicine Creek near Somerset - NeDNR	6838500	Stream
Medicine Creek near Curtis - NeDNR	6839970	Stream
Fox Creek at Curtis - NeDNR	6840000	Stream
Medicine Creek above Harry Strunk Lake - NeDNR	6841000	Stream
Medicine Creek below Harry Strunk Lake - NeDNR	6842500	Stream
Republican River at Cambridge - USGS	06843500	Stream
Muddy Creek at Furnas-Gosper County Line - NeDNR	224600	Stream
Muddy Creek at Arapahoe - NeDNR	6844000	Stream
Turkey Creek at Furnas-Gosper Co. Line - NeDNR	231700	Stream
Turkey Creek at Edison - NeDNR	6844210	Stream
Republican River near Orleans - USGS	06844500	Stream
Beaver Creek near Beaver City - USGS	06847000	Stream
Prairie Dog Creek near Woodruff KS - USGS	06848500	Stream
Sappa Creek near Stamford - USGS	06847500	Stream
Turkey Creek at Naponee - NeDNR	6850000	Stream
Center Creek at Franklin - NeDNR	6851000	Stream
Republican River at Riverton - NeDNR	6851090	Stream
Thompson Creek at Riverton - NeDNR	6851500	Stream
Elm Creek at Amboy - NeDNR	6852000	Stream
Republican River at Guide Rock NE - USGS	06853020	Stream
Courtland Canal at Nebraska-Kansas Stateline - USGS	06852500	Canal
Republican River- Hardy NE - USGS	06853500	Stream

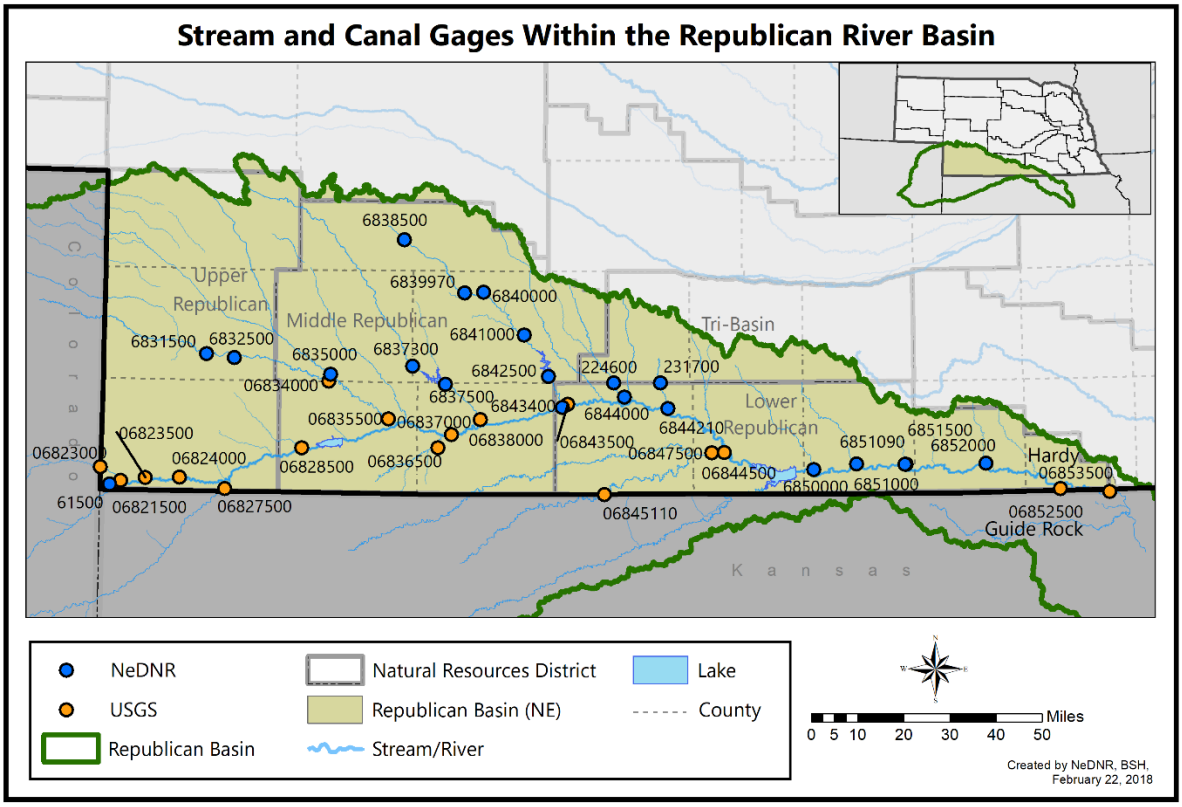

Figure A.5. Stream and canal gages within the Republican River Basin that collect data on surface water flows throughout the Basin.

Groundwater Supplies

Eighty-seven percent of the Basin overlies the High Plains aquifer (Figure A.6). The Ogallala geologic formation underlies all but the extreme southeastern edge of the Basin in Kansas. Water thickness in the Basin's portion of the aquifer ranges in thickness from a matter of inches in areas south of the Republican River valley to more than 400 feet on the northern edge of the basin.

The Ogallala Formation consists of beds of silt, sand, gravel, caliche, and clay, with considerable variability in the character of the formation within short vertical or horizontal distances. These variations are consistent with the fluvial environment in which the Ogallala was deposited. This environment was characterized by a series of braided streams carrying sediment eastward. Some of the sand and gravel deposits are weakly cemented into rocks by calcium carbonate, ranging from friable sandstone to relatively hard, ledge-forming limestone beds.

The High Plains Aquifer consists of the saturated parts of the Quaternary sediment deposits and the underlying Ogallala Formation. Depth to groundwater in the Republican Valley ranges from about two feet near the river to about 40 feet adjacent to the bluffs along the edge of the valley. In

the Frenchman River valley, the depth to water ranges from less than 10 feet to about 60 feet. The aquifer has defined basal and lateral limits, but usually has no confining upper boundary. This is known as an unconfined aquifer. Consequently, any change in the volume of the stored water coresponds to a change in the elevation of the water table.

Changes in the aquifer's water level result from an imbalance between discharge and recharge. Water-level declines can affect groundwater availability, surface water flow, and near-stream (riparian) habitat areas.[4] Seasonal water level fluctuations are due to variations in the amount and distribution of precipitation, temperature changes, and other factors that affect the amounts of groundwater recharge and discharge.

Discharge from the High Plains aquifer in the Basin primarily consists of groundwater withdrawals for irrigation but also includes groundwater withdrawals for public water supply and other uses; evapotranspiration where the water table is near land surface; and seepage to streams, springs, and other surface-water bodies where the watertable intersects the land surface.[5]

In general, the direction of groundwater flow in the Basin is west to east except in the vicinity of the Republican River and in the north-central portion of the Basin. Average groundwater flow velocities range from less than 50 to more than 200 feet per year.

In the extreme north-central portion of the Basin in Nebraska, there is a small amount of groundwater flow from the Republican River Basin north toward the Platte River Basin. In the northeast portion of the Republican River Basin, groundwater migrates south from the Platte River Basin via canal seepage in an area referred to as the "Groundwater Mound" because of artificially higher water elevations (Figure A.7).

[4] Alley, W.M., Reilly, T.E., and Franke, O.L. (1999). "Sustainability of ground-water resources." U.S. Geological Survey Circular 1186, 79 p. at http://pubs.usgs.gov/circ/circ1186/

[5] Maupin, M.A., and Barber, N.L. (2005). "Estimated withdrawals from principal aquifers in the United States, 2000." U.S. Geological Survey Circular 1279, 46 p. http://pubs.usgs.gov/circ/2005/1279/

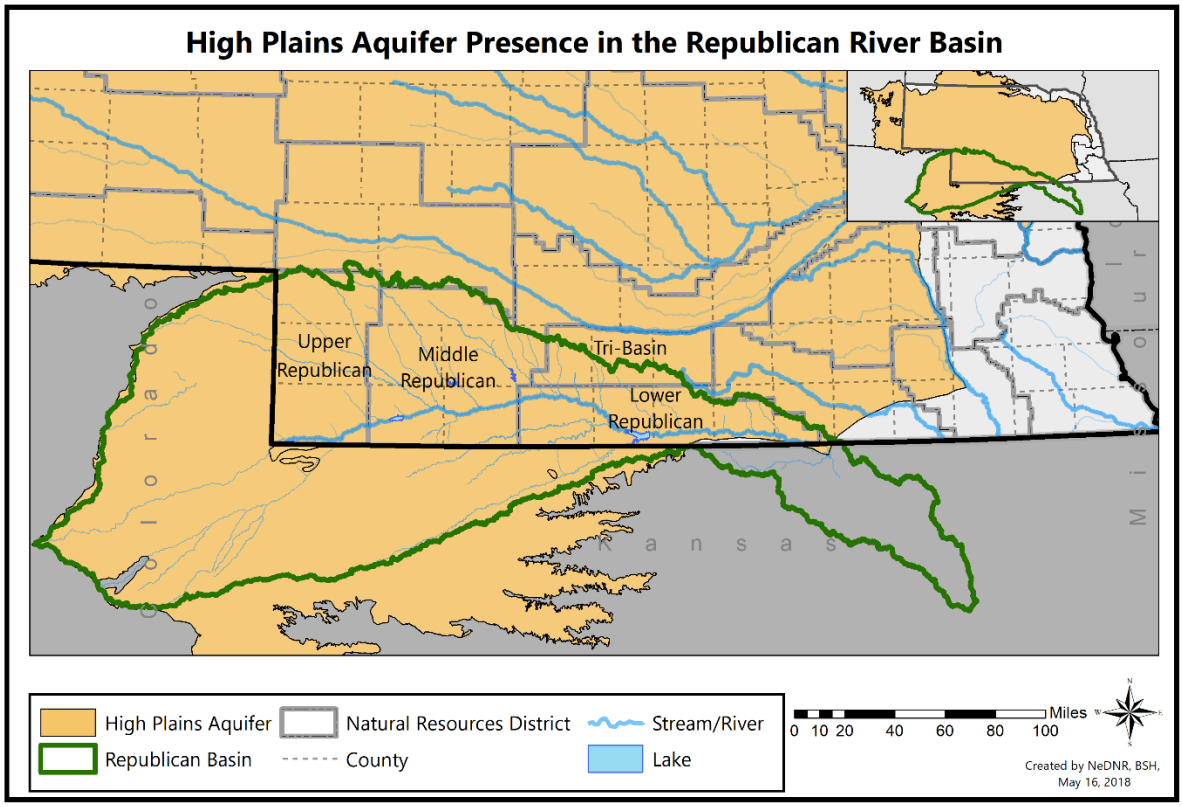

Figure A.6. Map of the High Plains Aquifer in the vicinity of the Republican River Basin. The majority of the Basin within Nebraska overlies the High Plains Aquifer. Other, local aquifers exist throughout Nebraska and the Republican River Basin.

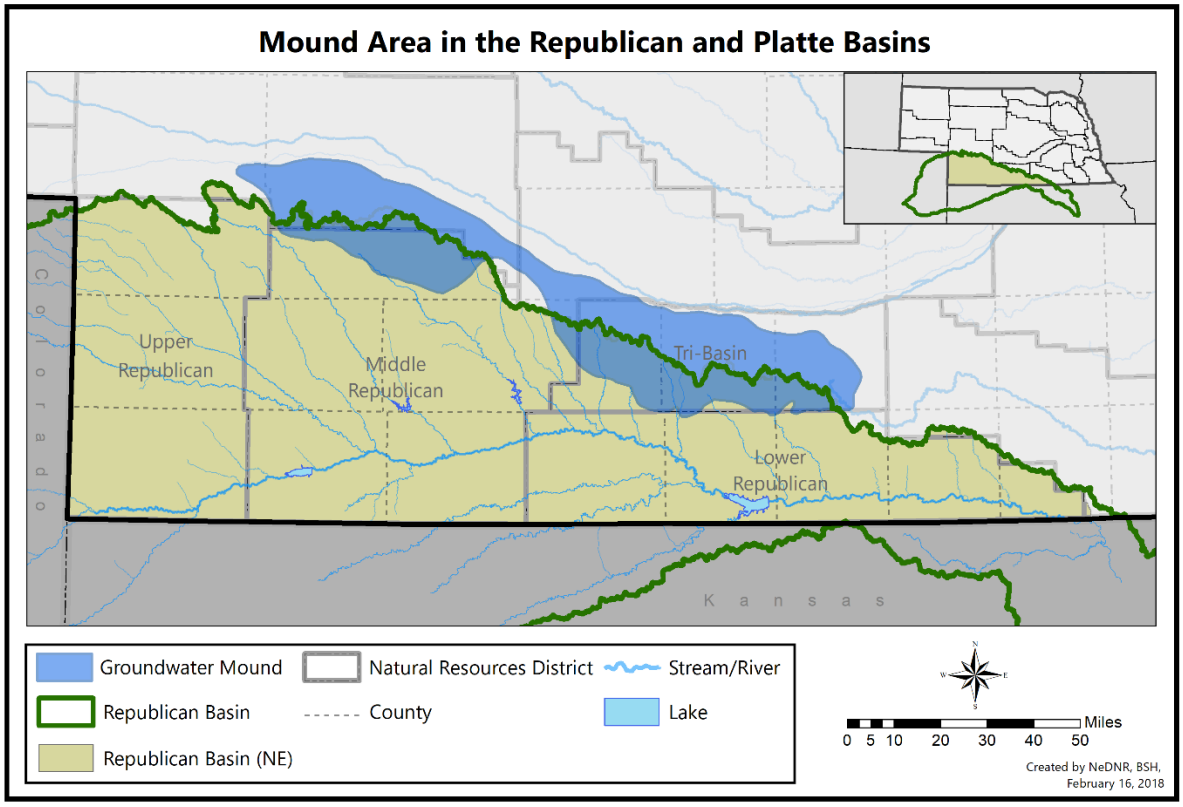

Figure A.7. Groundwater accretions, known as the Mound, originate from CNPPID and NPPD canals and cover much of the Middle Republican and Tri-Basin NRDs. In addition to providing groundwater for irrigation, accretions flow into the Republican and Platte Rivers.

Human Activities Relating to Basin Hydrology

The variability in precipitation within the Basin was long a barrier to living and farming within the Basin. A disastrous flood in the Basin in 1935 took the lives of 110 persons, damaged 274,615 acres of cropland, and killed over 20,500 livestock.[6] Devastating droughts in the 1890s and1930's caused economic hardship for the region. Two large flood events in June of 1947 and 1948, one of which crested at 27 feet above normal at the Medicine Creek dam site, caused significant damage (Figure A.8).

Figure A.8. June 24, 1947, flood of the Republican River on the border of Jewell County, KS, and Republic County, KS, near Hardy, Nebraska and Webber, Kansas, just south of Nebraska NE-8 on Kansas 1 Rd/CR-1 bridge over the Republican River. The normal flood state for the river is at the tree line in the foreground. By J.G. Connor (submitted to USGS by Steve Blanchard, OSW). USGS surface water photo gallery item 18, 09, Public Domain.

Following the drought of the 1930's and floods of the 1930's and 1940's, the Bureau of Reclamation and U.S. Army Corps of Engineers began constructing a series of dams and surface water irrigation networks intended to reduce flooding and to provide water for agriculture. The large Federal surface water irrigation projects came into use in the 1950's and 1960's.

By 1957, the Nebraska part of the projects was essentially complete, and the structures in Kansas were nearing completion.

The primary use of water in the Basin is for irrigation of agricultural crops. The primary crops grown are corn and soybeans, along with wheat and other small grains. Alfalfa and potatoes are also grown in the Basin. Most irrigable lands in the Basin are scattered on ridgetops throughout the Basin, along the Republican River valley, or on tablelands in Kearney, Phelps, Gosper, Perkins and Chase Counties. There are several active irrigation districts in the Basin. The two largest are Frenchman-Cambridge Irrigation District, with 45,669 irrigated acres, and the Nebraska Bostwick Irrigation District, with 22,446 irrigated acres. Including the irrigation districts, there are approximately 112,000 acres that may be irrigated with surface water in the Basin. Groundwater use is extensive, and groundwater pumping in the Basin removes water that might otherwise have flowed into the Republican River or its tributaries. The effect of the depletions is muted with distance (Figure A.9). There have also been changes to the landscape and agricultural practices over the years, such as small dams and terraces, that have affected streamflow via reduced runoff.[7]

[6] National Weather Service. "Republican River Flood of 1935 – The Aftermath." https://www.weather.gov/gld/1935flood-aftermath (Accessed July 27, 2018).

[7] Republican River Compact Settlement Conservation Subcommittee for the Republican River Compact Administration (2014). *Republican River Basin: Impacts of Non-Federal Reservoirs and Land Terracing on Basin Water Supplies*. Final Report.

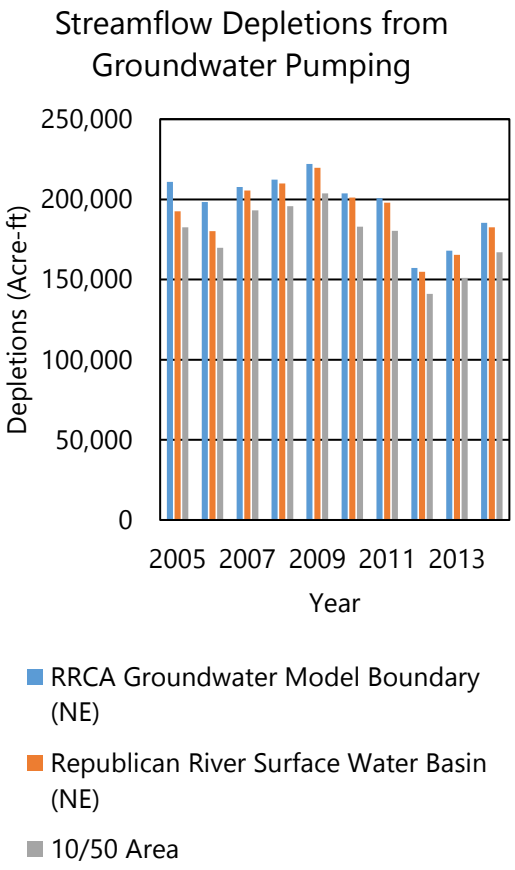

Figure A.9. Modeled depletions from groundwater pumping within three different boundaries of the Basin: the RRCA groundwater model boundary, the surface water basin, and the 10/50 area.

Surface Water

Surface water is stored, and may be released for irrigation projects, in seven federal reservoirs that are within the Basin upstream of where the Republican River crosses into Kansas. Within the State of Nebraska, the five Federal reservoirs (Swanson, Enders, Hugh Butler, Harry Strunk, and Harlan County Lake) are managed by the US Bureau of Reclamation, and hold water rights that are administered by the NeDNR (Figure A.4). The reservoirs, in addition to providing flood control, provide storage water to multiple irrigation districts including Frenchman-Valley, Hitchcock & Red Willow (H&RW), Frenchman Cambridge, and Nebraska Bostwick

The reservoirs and associated streams across which they are constructed are as follows, listed in downstream order:

1. Bonny Reservoir, South Fork of the Republican River, Colorado (In 2011, Colorado modified the dam so that it no longer stores water)
2. Swanson Lake, Mainstem of the Republican River, Nebraska
3. Enders Reservoir, Frenchman Creek, Nebraska
4. Hugh Butler Lake, Red Willow Creek, Nebraska
5. Harry Strunk Lake, Medicine Creek, Nebraska
6. Keith Sebelius Lake, Prairie Dog Creek, Kansas
7. Harlan County Lake, Mainstem of the Republican River, Nebraska
8. Lovewell Reservoir, Norway Creek, Kansas
9. Milford Lake, Mainstem of the Republican River, Kansas

Surface water irrigation projects (Figure A.10) that use both flowing surface water and water stored within the US Bureau of Reclamation's reservoirs are summarized in Table A.2. Other surface water permits not held by an irrigation district are summarized in Table A.3.

Table A.2. Number of acres irrigated by irrigation districts within the Republican River Basin. From NeDNR's surface water permitting database (as of August 9, 2018).

Surface Water Acres in the Republican River Basin	
Irrigation District	**Acres Permitted for Irrigation**
Frenchman Cambridge	45,669
Bostwick	22,455
H & RW	11,857
Frenchman Valley	9,323
Pioneer	1,900
Riverside	540
Total	91,744

Table A.3. Number of privately held appropriations and associated acres, by use, within the Republican River Basin. From NeDNR's surface water permitting database (as of August 9, 2018).

Surface Water Permits Not Held by an Irrigation District		
Use	**Number of Permits**	**Acres Permitted for Irrigation**
Irrigation	242	17,255
Power	1	-
Irrigation from Reservoir Only	11	678
Storage	189	-
Total	443	17,933

Surface water use grew at a steady pace until about 1956, when, at its peak, over 370,000 acre-feet (af) per year of surface water was applied for irrigation. Surface water acres fell from this peak and remained stable until the early 2000's when they began to drop again.

There are three surface water augmentation projects in the Basin: Nebraska Cooperative Republican Platte Enhance (N-CORPE), Rock Creek augmentation project, and the Turkey Creek augmentation project (Figure A.11). These projects were created in response to inconsistent surface water supplies in the Republican River in recent dry years, and are intended to augment streamflow for the purposes of meeting Nebraska's requirements under the Republican River Compact and complying with the Basin's Integrated Management Plans (IMPs). N-CORPE was created from a purchase by four NRDs of 19,500 acres (15,800 previously irrigated) along the Republican/Platte watershed divide in 2012. The Rock Creek augmentation project is operated by the Upper Republican NRD (URNRD) and augments surface flows to the Republican River to offset URNRD's depletions. The Rock Creek augmentation project was completed in early 2013. The Turkey Creek augmentation project was completed in early 2016 by Tri-Basin NRD (TBNRD). The Turkey Creek augmentation project is a tool to limit net depletions to streamflow to meet the requirements of TBNRD's IMP for the Republican River Basin. It has not yet been pumped to augment streamflow for this purpose.

Groundwater

Groundwater is the primary source of irrigation in the Nebraska portion of the Basin (Figure A.12). Groundwater irrigation via wells in the Basin increased significantly from just over 300 wells in 1950 to over 12,500 wells in 2014 (Figure A.13). Most growth occurred between 1970 and 2000, when the numbers of registered wells increased 343% from about 3,600 to over 12,500. In conjunction with the increase in registered wells, groundwater and commingled pumping increased from 2,056 af in 1950 to 415,944 af in 2014, with a peak of 913,270 af in 2002 within the RRCA groundwater model area. Groundwater levels in the Basin have responded to pumping with significant variation. Water-level changes

from 2002 to 2015 in the High Plains aquifer within the Basin, by well, ranged from a rise of 9.4 feet to a decline of 43.2 feet. The area-weighted, average water-level change from 2002 to 2015 in the Basin was a decline of 4.5 feet.

The natural resources districts in the Basin collect local data on acres irrigated by groundwater and set allocation limits on groundwater pumping.

Table A.4 summarizes acres by NRD.

Table A.4. Acres certified or permitted for irrigation, by NRD, in the Republican River Basin. The columns for groundwater acres and surface water acres both include commingled acres in their totals. Data on acres certified for groundwater irrigation were obtained from the Upper Republican, Middle Republican, Lower Republican, and Tri-Basin NRDs (2017 acres, as of August 6, 2018), and data on acres permitted for surface water irrigation were obtained from NeDNR's surface water permitting database (current acres, as of August 9, 2018). The acre totals listed include all acres that are certified or permitted for irrigation, including those that are enrolled in temporary retirement programs.

Acres Certified or Permitted for Irrigation in the Republican River Basin, by NRD		
NRD	**Acres Certified for Groundwater Irrigation**	**Acres Permitted for Surface Water Irrigation**
Upper Republican	432,759	4,393
Middle Republican	296,801	46,900
Lower Republican	320,208	57,362
Tri-Basin	189,992	795

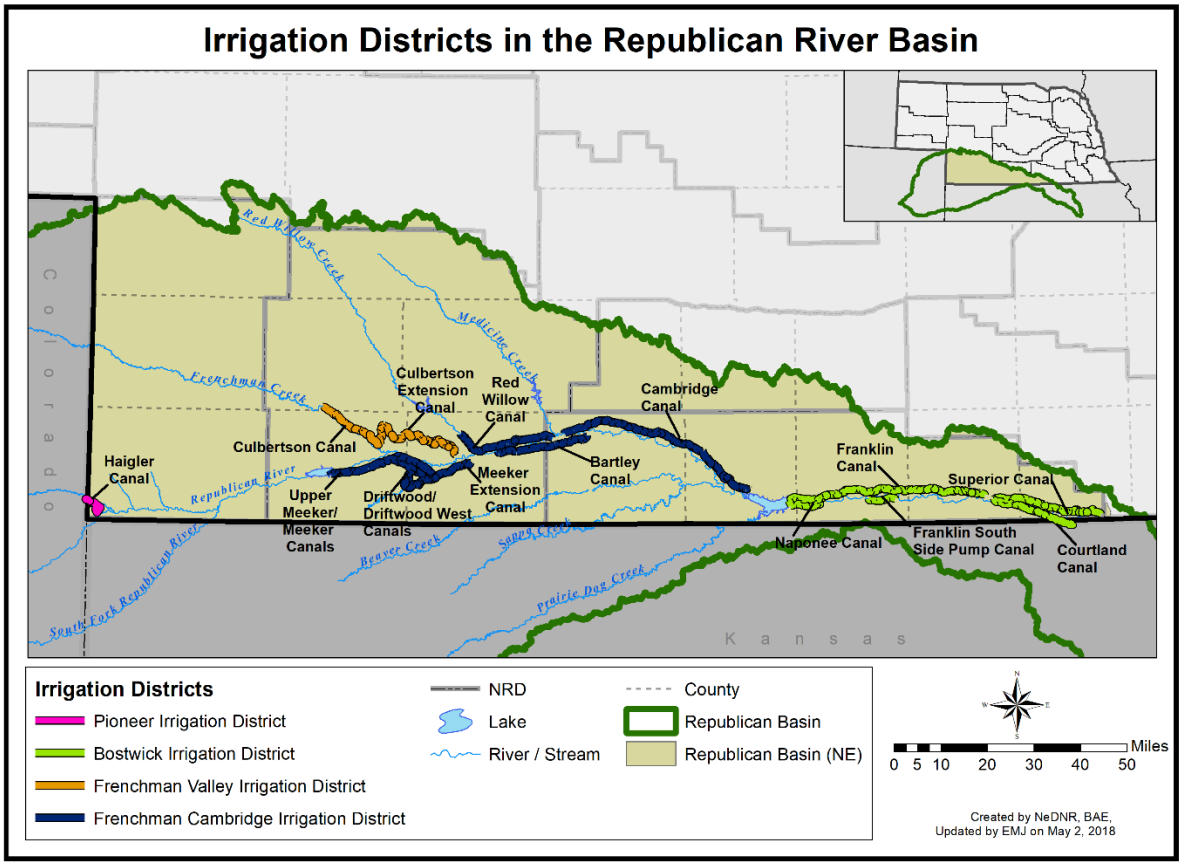

Figure A.10. Canals within the Nebraska portion of the Republican River Basin.

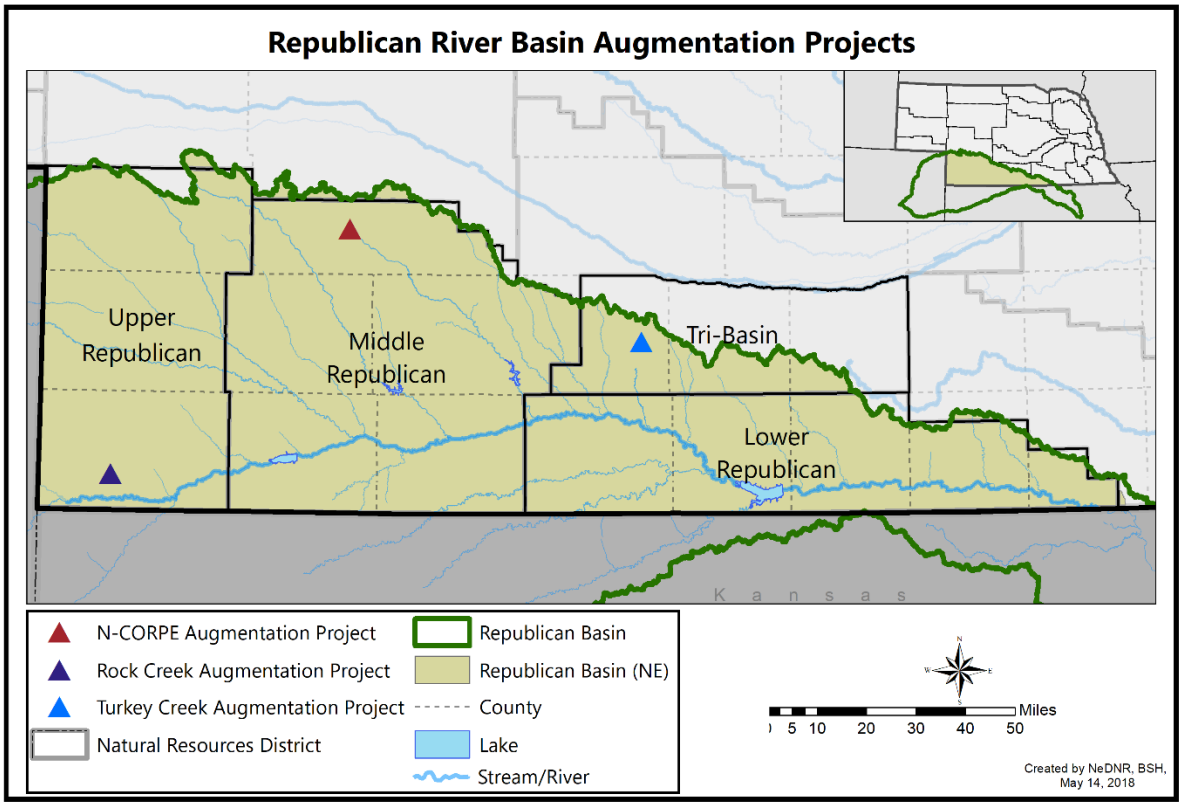

Figure A.11. Augmentation Projects within the Nebraska portion of the Republican River Basin.

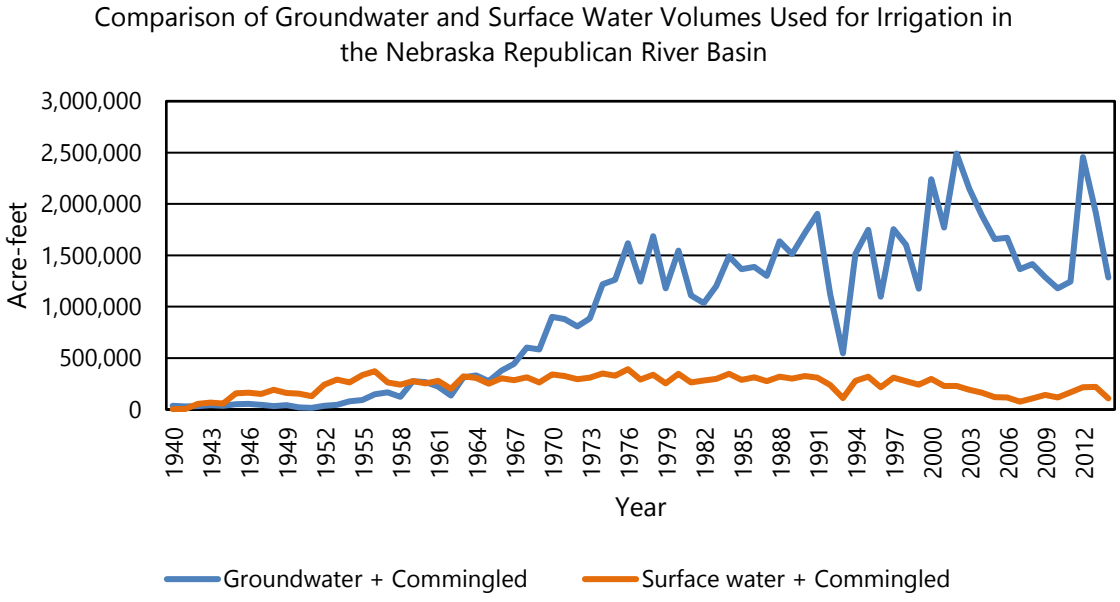

Figure A.12. Comparison of groundwater and surface water irrigation through time in the Republican River Basin. Since the early 1960's, groundwater has been the primary water source for irrigation in the Republican

River Basin. Data for this figure were provided by the Flatwater Group and encompass the Republican River Compact Administration groundwater model area for Nebraska.

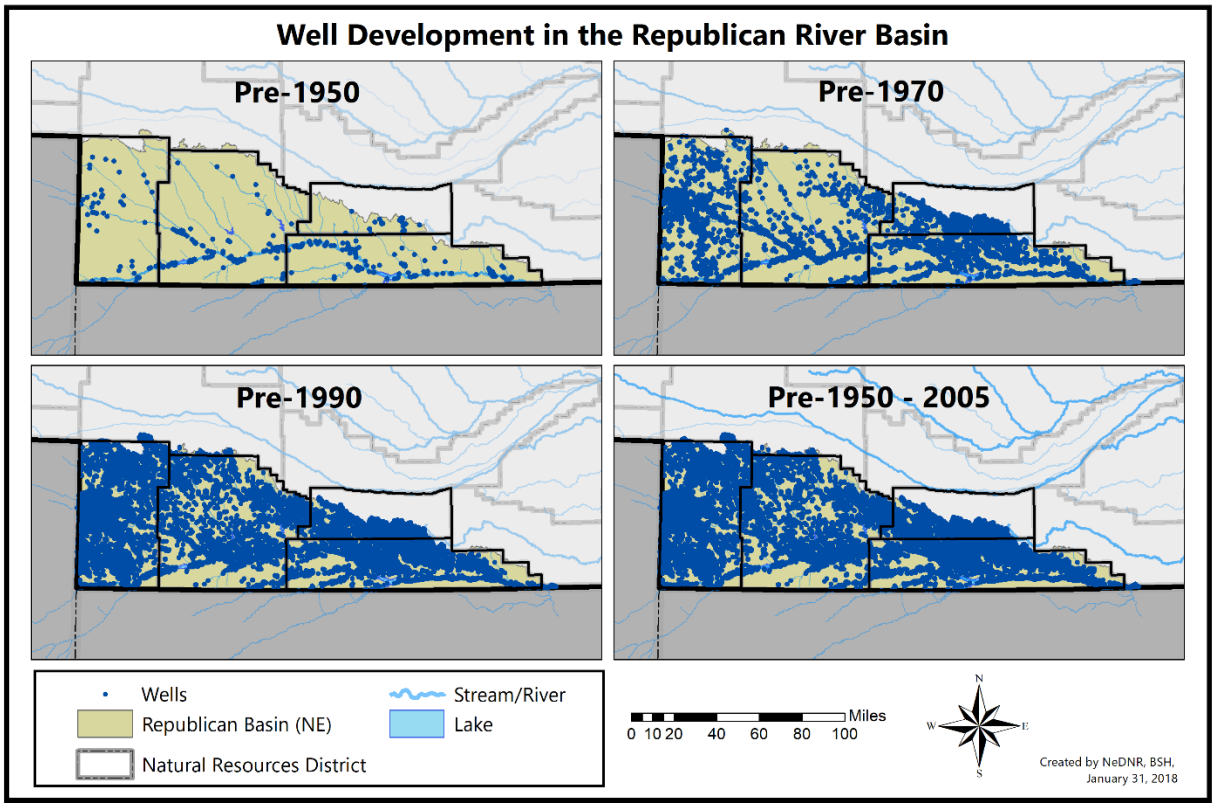

Figure A.13. Well development in the Republican Basin. Wells developed rapidly from 1950- 2005, from just over 300 wells in 1950 to over 12,500 wells in 2005.

Appendix B. Data and Information Used During Plan Development

Section Overview

The following types of scientific data and other information were considered during the development of the Plan, will be considered in the adoption of the Plan, or both pursuant to *Neb. Rev. Stat.* § 46-755 (5)(a).

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Hydrologic Considerations 87
Studies, Reports, and Presentations 88
Other 88

Hydrologic Considerations

Hydrologic data and records:

- Annual streamflow data
- NeDNR hydrographic reports
- Precipitation and weather stations
- Land use and irrigated acres
- Surface water use (canal diversions, field deliveries, small pumper diversions, surface water use reporting)
- Storage volumes in reservoirs
- Groundwater use (meter data and groundwater model data)
    - NRDs' certified acres records
    - NRDs' groundwater pumping records
- Stream depletions from groundwater pumping
- Computed Beneficial Consumptive Use (pursuant to the RRCA definition) of surface water use and groundwater use
- Surface water administration records
- Annual augmentation pumping numbers
- NeDNR and US Geological Survey streamgage records
- Crop irrigation requirement for corn across the basin
- Water level records and maps from NRDs, NeDNR, the University of Nebraska, the US Geological Survey, and the US Department of Homeland Security, including a comparison of modeled to actual groundwater level changes
- NeDNR INSIGHT data (supplies, demands, and water balance)
- Hydrogeologic conditions such as aquifer thickness and other groundwater reservoir information
- Dedicated observation wells' and other wells' groundwater level data

Studies, Reports, and Presentations

- Hydrologically connected area as determined by NeDNR (i.e., the 10/50 area) and other stream depletion zones
- The availability of supplemental water supplies, including opportunities for interbasin transfer or groundwater recharge
- Peer-reviewed literature on riparian phreatophyte evapotranspiration and removal
- Technical hydrologic reports from the University of Nebraska, the United States Geological Survey, and other publications
- Other studies related to the Basin
- Republican River Compact Model area
- US Bureau of Reclamation infrastructure
- MRNRD Medicine Creek Study
- Watershed Management Study

Other

- Stakeholder input
- Additional data on file with NRDs and NeDNR
- Previous definitions of sustainability for the Basin
- NeDNR registered well database
- NeDNR surface water database
- NeDNR dams database
- RRCA groundwater model and other groundwater models
- Introductory hydrologic science
- Current rules and regulations, groundwater management plans developed by the NRDs adopting the Plan
- Current and past Integrated Management Plans jointly developed by NeDNR and the NRDs adopting the Plan, and others
- Typical plan elements and terms
- Current groundwater and surface water controls for the Basin
- Past, present, and potential management actions, including but not limited to:
    - Water conservation incentive programs
    - Augmentation projects
    - Compact compliance management actions
    - Allocations
    - Recharge projects
    - Interbasin Transfer
- NeDNR's Order dated July 14, 2004, declaring formal moratoriums on all new surface water appropriations for the Republican River Basin, including all subbasins.
- NeDNR's Notice dated July 15, 2004, to all licensed water well contractors in Nebraska of the final determination that all of the Upper Republican NRD, Middle Republican NRD and

Lower Republican NRD are "fully appropriated" pursuant to *Neb. Rev. Stat.* §§ 46-713(4)(a) and (b) and placing immediate stays on new uses of surface water and ground water.

- NeDNR's Notices dated July 15, 2004, to the public and to the Lower Republican NRD; the Middle Republican NRD; and the Upper Republican NRD of the final determination that the Republican NRDs are "fully appropriated" and stays on new uses of surface water and groundwater have or will take effect.
- Republican River Compact, Final Settlement Stipulation, and Republican River Compact Administration (RRCA) Rules and Regulations, Accounting Procedures, and Resolutions in effect as of (the effective date of this Plan). Nebraska current and past statutes and rules related to water planning, including but not limited to:
- *Department of Natural Resources Rules for Surface Water, Nebraska Administrative Code Title 457*
- *Department of Natural Resources Rules for Groundwater, Nebraska Administrative Code Title 456*
- *Nebraska Revised Statutes*
    - *Neb. Rev. Stat. Appendix* 1-106, Republican River Compact
    - Applicable surface water statutes, *Chapter 46, Article 2*
    - Applicable groundwater statutes *Chapter 46, Article 6*
    - *Nebraska Ground Water Management and Protection Act, Neb. Rev. Stat.* §§ 46-701 to 46-756 (Reissue 2014 and Reissue 2016)

Appendix C. Plan Development

Section Overview

This section includes details about the process of developing the Republican River Basin-Wide Plan (Plan). Specifically, meeting dates and the names of stakeholders are listed. Additional information about the Plan development process is included in the Plan's Introduction.

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Members of the Stakeholder Advisory Committee....90
Plan Development Meeting Schedule....90
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Members of the Stakeholder Advisory Committee

At the end of Plan development, the Stakeholder Advisory Committee had 42 members, whose names are listed below. Members of this committee discussed and voted on the Plan during stakeholder meetings.

Jared Baker
Kurt Bernhardt
Brad Edgerton
Jerry Ehrke
Chris Flaming
Troy Fletcher
Josh Friesen
Jerda Garey Vickers
Mike George
Wayne Haarberg
Dale Helms
Dick Helms
William (Bill) Hoyt
Michael J. Kahrs
Max Kaiser
Curtis Kayton
Jim Kent
Bradly Knuth
Jerry Kuenning
Kent Lorens
Jeff Loschen
Gale Lush
Scott Lutz
Timothy McCoy
Cedric McDaniel
Ross Montgomery
Dan Nelsen
Dave Oxford
Roric Paulman
John Rundel
Nate Schneider
George Schortberger
Richard Siel
Kevin Slocum
Daniel Smith
Shad Stamm
Aaron Thompson
Ted Tietjen
Marcia Trompke
Dack Vesta
Tom Vickers
Todd Watson

Plan Development Meeting Schedule

Plan development meetings consisted of coordination meetings and Stakeholder Advisory Committee meetings (stakeholder meetings). At coordination meetings, the Nebraska Department of Natural Resources (NeDNR) and the Upper Republican, Middle Republican, Lower Republican, and Tri-Basin Natural Resources Districts (NRDs) met to plan stakeholder meetings. During stakeholder meetings, NeDNR, the NRDs, and stakeholders discussed the Plan and voted on Plan development. Meeting dates are listed in Table C.1.

Table C.1. Plan development meeting schedule.

Stakeholder Advisory Committee Meetings	Coordination Meetings
	January 27, 2015
	March 18, 2015
March 31, 2015	May 19, 2015
June 16, 2015	July 21, 2015
August 18, 2015	September 15, 2015
	November 17, 2015
January 19, 2016	February 16, 2016
March 15, 2016	April 19, 2016
June 21, 2016	July 19, 2016
August 16, 2016	September 20, 2016
	October 18, 2016
November 1, 2016	December 12, 2016
	February 21, 2017
March 21, 2017	April 18, 2017
	May 16, 2017
June 20, 2017	July 20, 2017
August 15, 2017	September 19, 2017
	October 24, 2017
November 30, 2017	
December 13, 2017	January 16, 2018
	February 27, 2018
	March 20, 2018
	April 12, 2018
June 1, 2018	
June 26, 2018	

Stakeholder Themes

During stakeholder meetings, numerous concepts were discussed that led to development of goals, objectives, and action items. Many other topics were discussed at individual meetings, but certain topics were repeatedly discussed by stakeholders across meetings that helped shape Plan goals, objectives, and action items. To the extent possible, these ideas have been grouped and are listed below in alphabetical order. The listed themes are those that were repeatedly discussed during stakeholder meetings. Their inclusion on this list indicates only that they were discussed, not that they were achieved during the planning process, and not that all stakeholders agreed with each listed item.

- Compact compliance
- Cooperation among stakeholders and agencies
- Economic viability of the Republican River Basin
- Equitability among users
- Farm Bill impacts on the Republican River Basin
- Government transparency

- Groundwater levels
- Importance of water for recreation, fish, and wildlife
- Regulatory measures through time and by water use
- Serving as a model for others of how a group can collaborate and come to agreement, as an aspiration for this planning process
- State law compliance
- Water markets
- Water supply and use
- Water sustainability or stability

Appendix D. Relevant History of Groundwater and Surface Water Management

Section Overview

The history of groundwater and surface water management can be divided into three main eras:

1. Independent Management of Groundwater and Surface Water - beginning in the late 1800's to 1970's
2. Water Planning and Policy Development - in the 1980's to 1990's
3. Collaborative Water Planning Process Implementation - from 1990's to today.

Following the descriptions of these eras are two figures showing the history of groundwater allocations (Figure D.1) and expected surface water deliveries (Figure D.2).

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Era of Collaborative Water Planning Process Implementation 96
Republican River NRD Allocation History figure 98
Republican River Irrigation District Delivery History figure 98

Era of Independent Management of Groundwater and Surface Water

Late 1800's

In Nebraska prior to 1895, a "Claim" for surface water rights was obtained beginning with a notice "posted" on a fence post.

This was valid until legislation was enacted on April 4, 1895, thus beginning the adoption of the doctrine of prior appropriation (first in time, first in right).

1900-1929

A process for canceling unused surface water appropriations was prescribed by statute.

The State Board of Irrigation became a part of the Department of Public Works.

The use of water of every natural stream within the state of Nebraska was dedicated to the people of the state for beneficial purposes, subject to provisions in the State Constitution.

1930's

The correlative use (shared use) doctrine was adopted for groundwater, as established through a Nebraska Supreme Court ruling.

The State Board of Irrigation changed to the Bureau of Irrigation, Water Power, and Drainage, and became a part of the Department of Roads and Irrigation.

1940-1959

Nebraska entered into the Republican River Compact with Kansas and Colorado.

The Department of Water Resources was created and took the place of the Bureau of Irrigation, Water Power, and Drainage.

Irrigation and other large capacity wells were required to be registered for the first time.

1960's

The Legislature passed laws to allow municipalities to apply for a permit from the Department of Water Resources to transfer groundwater off the overlying land.

The Legislature directed the State Soil and Water Conservation Commission to prepare a State Water Plan.

The first portions of the *State Water Plan* were published.

The Legislature created Natural Resources Districts, or NRDs, as multipurpose, locally elected management bodies.

1970's

The NRDs began operations.

The first *Ground Water Management Act* was passed into law.

The Legislature directed the primary responsibility for regulating groundwater to the NRDs.

The Upper Republican NRD became the first entity in Nebraska to regulate groundwater use via an allocation system (Figure D.1).

The Legislature prohibited state agencies from taking actions that jeopardize endangered species or their critical habitats.

At the request of the Legislature, the Natural Resources Commission and other state agencies issued a policy statement and work plan that recommended replacing the State Water Plan with a State Water Planning and Review Process.

Era of Water Planning and Policy Development

1980's

The Legislature authorized a State Water Planning and Review Process.

The Industrial Ground Water Regulatory Act was established which required a permit from the Department of Water Resources for anyone wanting to withdraw three thousand

or more acre-feet of groundwater per year for industrial purposes.

The Ground Water Management Act was revised to incorporate groundwater quality concerns and the title was changed to the Ground Water Management and Protection Act.

A new law allowed for transfer in location of use for surface water appropriations within the same basin.

A law was also passed allowing for appropriations for incidental and intentional underground water storage.

Permitting of new wells within a control area was changed to the authority of the NRDs.

A bill was passed that allowed for surface water appropriations for instream flows to protect recreation, fish and wildlife. Such applications could only be filed by the Nebraska Game and Parks Commission or an NRD.

Local groundwater management plans were required to be prepared by each NRD and submitted to the Department of Water Resources for review.

The Legislature further refined requirements of NRDs for local groundwater management plans.

1990's

The Legislature required the NRDs to expand their management plans to include protection of groundwater quality.

The Legislature required that all wells (including domestic and stock water wells) be registered with the Nebraska Department of Water Resources, as opposed to only large capacity wells.

The Legislature passed a law allowing public water suppliers to obtain surface water appropriations for induced groundwater recharge for public water supply wells located near streams.

Legislation was passed allowing a reduction of groundwater irrigated acreage in water management areas.

The Legislature passed a bill, which allowed the transfer of groundwater off the overlying land for irrigation purposes and for water withdrawn as part of a remediation plan, as required under the Environmental Protection Act, including the provision of water for domestic purposes.

Legislation was passed recognizing the connection between groundwater and surface water and initiated Joint Action Plans. This bill also eliminated Special Protection Areas and allowed for the formation of management areas for three purposes:

1. Water quantity
2. Water quality
3. Hydrologically connected surface and groundwater

The States of Nebraska, Wyoming, and Colorado and the U.S. Department of the Interior signed the Cooperative Agreement for Platte River Research and Other Efforts Relating to Endangered Species Habitats along the central Platte River, Nebraska.

Kansas filed an original action in the US Supreme Court against the State of Nebraska over the Republican River Compact.

Era of Collaborative Water Planning Process Implementation

2000- 2009

The Natural Resources Commission and the Department of Water Resources merged to create the present Department of Natural Resources (NeDNR).

Legislation was passed that allowed for transfers of groundwater off the overlying land for domestic purposes.

Nebraska, Colorado, and Kansas enter into the Final Settlement Stipulation (FSS) of the Republican River litigation in Kansas v. Nebraska and Colorado, initiated by Kansas in 1998.

The US Supreme Court approved the FSS.

The Basin NRDs initiated moratoriums on well development in their respective Districts

The Lower Republican and Middle Republican, NRDs initiated an allocation system in the Republican Basin (Figure D.1).

NeDNR implemented a moratorium on new surface water appropriations in the Republican River Basin.

Legislation was passed, which allowed for designation of areas as fully or overappropriated, required annual review of river basins, directed NRD/NeDNR joint adoption of Integrated Management Plans (IMPs) to address surface water and groundwater as a single resource in fully and over appropriated basins, and also converted Joint Action Plans to IMPs.

The Director of the Department of Natural Resources issued an "Order of Final Determination of River Basins, Subbasins, or Reaches as Fully Appropriated, and Describing Hydrologically Connected Geographic Area," which included the Republican River Basin.

Upper Republican, Middle Republican, and Lower Republican NRDs' first generation IMPs were adopted by NeDNR and the NRDs because these NRDs were deemed fully appropriated in 2004.

The Legislature established the Water Resources Cash Fund, required NeDNR to perform annual streamflow forecasts, empowered all NRDs to put an immediate temporary 180-day stay on new wells, and authorized Republican River Basin NRDs to use an occupation tax and River-Flow Enhancement Bonds.
The RRCA submitted disputes over compliance with the FSS to non-binding arbitration; the states executed an arbitration agreement, and non-binding arbitration began.

The Upper Republican, Middle Republican, and Lower Republican NRDs adopted updated IMPs, which included revisions to comply with changes to the Ground Water Management and Protection Act, particularly *Neb. Rev. Stat.* §§ 46-715, 46-716, 46-717, 46-718, and 46-720.

Following the conclusion of arbitration proceedings initiated by the RRCA in 2008, the arbitrator submitted the final report and findings to the states. Key among the arbitrator's findings was the conclusion that Nebraska likely needed to implement additional provisions in its IMPs to address periods of low water supplies.

2010-Present

Tri-Basin NRD implemented allocations in one township in Gosper County within the Republican River Basin for water quality purposes not related to integrated management (Figure D.1).

The Legislature allowed voluntary IMPs in areas that are not fully appropriated.

The Legislature authorized the use of an occupation tax in any NRD if it is written into its IMP.

Kansas filed an original action in the US Supreme Court against the State of Nebraska, alleging that it had been damaged by Nebraska's violation of the Compact in 2005 and 2006.

The Upper Republican and Middle Republican NRDs, together with NeDNR, adopted updated IMPs that included Compact Call Year information and protocols.

The US Supreme Court granted Kansas' motion and appointed a Special Master for Kansas v. Nebraska and Colorado to address the action filed by Kansas in 2010. Later, Nebraska filed a counterclaim seeking a change to the RRCA Accounting Procedures regarding imported water supply.

The Lower Republican NRD and NeDNR adopted an updated IMP that included Compact Call Year information and protocols.

The Legislature passed a law allowing transfers of non-consumptive use of water.

Tri-Basin NRD's first generation IMP for the Republican River Basin was adopted by NeDNR and Tri-Basin NRD.

The Special Master issued a report of findings and recommendations in Kansas v. Nebraska and Colorado related to the action filed by Kansas in 2010 and Nebraska's counterclaim filed in 2011.

The Legislature created the Water Sustainability Fund and required the Republican River Basin to develop a basin-wide plan.

The first voluntary Integrated Water Management Plans were jointly adopted.

The US Supreme Court issued an opinion in Kansas v. Nebraska and Colorado to conclude litigation related to the action filed by Kansas in 2010 and Nebraska's counterclaim filed in 2011, accepting the recommendations contained in the Special Master's report.

Upper Republican, Middle Republican, and Lower Republican NRDs, together with NeDNR, adopted updated, fourth generation IMPs.

A representative Stakeholder Advisory Committee was convened to advise during development of the Republican River Basin-Wide Plan, as described in the following subsections

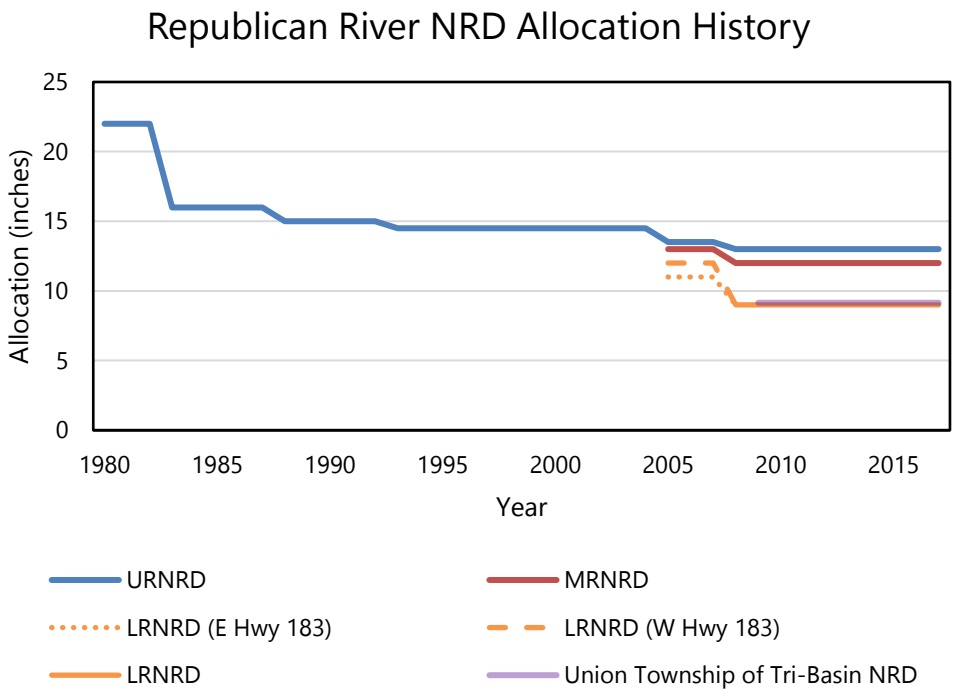

Figure D.1. Groundwater pumping allocation levels set by the Republican River Basin NRDs through time.

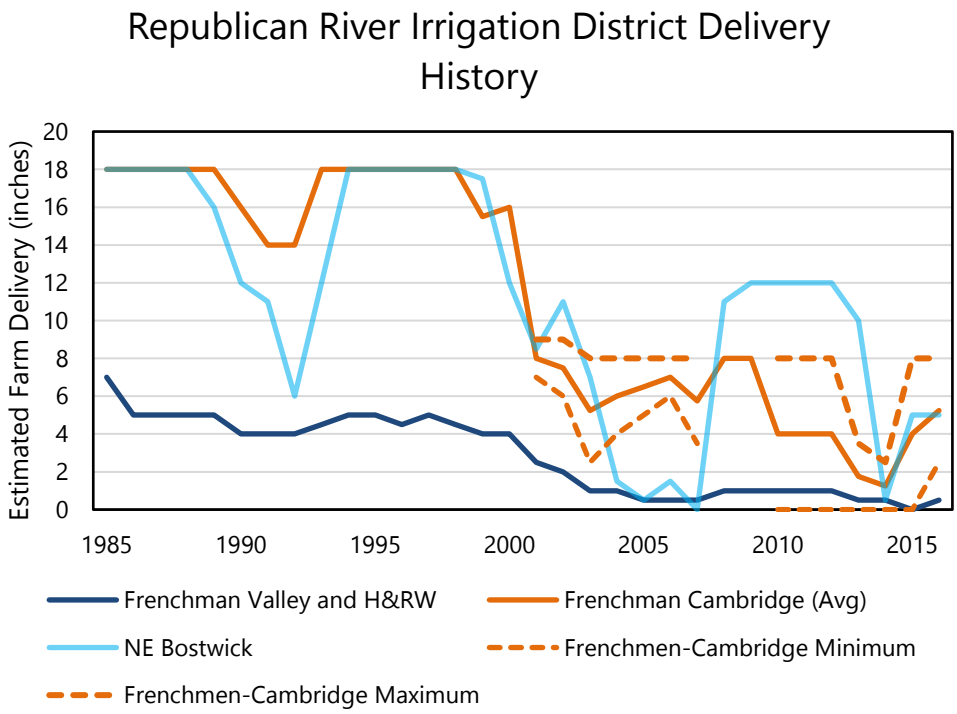

Figure D.2. Pre-season estimates of surface water delivery to landowners by irrigation districts in the Republican River Basin. Actual delivery may vary depending on numerous factors.

Appendix E. Procedures for Addressing Conflicts Resulting from Implementation of the Republican River Basin-Wide Plan

Section Overview

This document establishes procedures for addressing conflicts that arise among water users within the Republican River Basin of Nebraska (Basin) and that result from implementation of the Republican River Basin-Wide Plan (Plan). This appendix lists the procedures and describes their purpose and exclusions to them.

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Procedures 100
Initiate process 100
Investigate conflicts 101
Address conflicts 102

Purpose

This document establishes procedures for addressing conflicts that arise among water users within the Republican River Basin of Nebraska (Basin) and that result from implementation of the Republican River Basin-Wide Plan (Plan).

The Nebraska Department of Natural Resources (NeDNR), the Basin's natural resources districts (NRDs), and members of the Plan's Stakeholder Advisory Committee want to maintain local control over water management in the Basin to the extent possible. These procedures provide an opportunity to attempt to address certain conflicts locally, before resorting to lawsuits, the Interrelated Water Review Board, or other external conflict resolution processes.

In addition, including procedures to address conflicts as part of the Plan is consistent with the legislative intent of the Nebraska Ground Water Management and Protection Act:

> All involved natural resources districts, the department, and surface water project sponsors should cooperate and collaborate on the identification and implementation of management solutions to conflicts between ground water users and surface water appropriators or to water supply shortages in fully appropriated or overappropriated river basins, subbasins, and reaches (*Neb. Rev. Stat.* § 46-703 (6)).

This process might result in NeDNR and the NRDs deciding that revisions to the Plan are necessary, as described in further detail in the procedures below.

Exclusions

These procedures apply only to conflicts that result from implementation of the Plan.

These procedures will not be used to readdress prior conflicts that have already been litigated or addressed through other conflict resolution procedures.

The extent to which NeDNR and the NRDs can address conflicts via these procedures is limited to the statutory authorities of NeDNR and the NRDs.

These procedures do not apply to disagreements among NeDNR and the NRDs. *Neb. Rev. Stat.* § 46-755 (f) specifies that NeDNR and the NRDs may utilize the Interrelated Water Review Board process described in *Neb. Rev. Stat.* § 46-719 for disputes arising from developing and implementing this Plan.

Overview

These conflict resolution procedures can be summarized as:

1. Initiate process
2. Investigate conflicts
3. Address conflicts

The procedures for each of these steps are described in detail below.

Procedures

1. Initiate process

a. Any of the Basin's water users may initiate this process by sending a written request to the director of NeDNR or to the general manager of one of the NRDs. The request must be received by NeDNR or an NRD at least 60 days before an annual meeting in order to be placed on the agenda at that annual meeting ("Annual Meeting," page 47).

b. In their written request, the water user(s) initiating this process (requestor(s)) must include the following items:

   i. A description of the conflict

ii. A request to discuss their issues and concerns related to the conflict at the annual meeting

iii. An explanation of why they believe the conflict has resulted from implementation of the Plan

iv. Their proposed solution to the conflict

v. Whether they know of any potential adverse impacts to other water users that might result from their proposed solution, and if so, what those potential adverse impacts are

c. If NeDNR with concurrence from the NRDs determines that any of the required items listed in 1.b. above are missing from the written request, they will send the incomplete request back to the requestor(s) with a list of which required item(s) are missing. Returning an incomplete request to the requestor(s) will terminate these procedures, until and unless the requestor(s) submit a revised request that includes all required items.

d. If NeDNR with concurrence from the NRDs determines that all of the required items listed in 1.b. are included sufficiently within the written request, they will proceed to the next step.

e. Following this written request, and prior to the annual meeting, NeDNR and the NRDs will review the request to determine whether the conflict identified meets the criteria for consideration under these procedures: that it has resulted from implementation of the Plan, and that none of the stated exclusions apply.

f. Requestor(s) will receive a written response from NeDNR with concurrence from the NRDs to notify them about whether their issue meets criteria for consideration at the upcoming annual meeting. If NeDNR and the NRDs determine that the conflict or potential solutions may affect other water users, NeDNR and the NRDs will notify the affected water users of the written request and will request their participation in discussion of the conflict and potential solutions at the annual meeting.

g. Any written requests that have been made at least 60 days prior to the annual meeting will be posted to the website for the Plan before the meeting. In addition, NeDNR and the NRDs may use additional methods to notify other users potentially affected by the conflict or proposed solution about the upcoming discussion.

2. Investigate conflicts

a. During the annual meeting, the requestor(s) may present information about their conflict or issue. In addition, other water users or affected parties that would be affected by the conflict or a potential solution, may present information about potential adverse impacts to them.

This review will include:

i. Review of the application materials and other relevant background information,

ii. Discussion and evaluation of the proposed solution, and

iii. Discussion of other recommended solutions.

b. Following the annual meeting, NeDNR and the NRDs will evaluate the conflict and potential solutions. The potential adverse hydrologic, economic, and environmental impacts of any proposed change will be weighed against its potential beneficial hydrologic, economic, or environmental impacts under the 25-year time frame of the Plan. The evaluation will include, but is not limited to, consideration of:

i. The input previously provided by the Plan's former Stakeholder Advisory Committee during the initial Plan development process,

ii. Input provided during the annual meeting from all interested parties

iii. Additional input from affected water users or other knowledgeable parties during continued discussion after the annual meeting, if such input is requested by NeDNR and the NRDs

c. On a case-by-case basis, NeDNR and the NRDs may decide that a conflict should be evaluated by a subset of NeDNR and the NRDs. For example, location-specific conflicts might be evaluated by only NeDNR and the affected NRD(s), conflicts among only surface water users might be evaluated by only NeDNR, or conflicts among only groundwater users might be evaluated by only the NRDs.

3. Address conflicts

a. Following evaluation of the conflict, NeDNR and the NRDs will decide how to address the conflict identified. They may decide that no change or action is necessary. If they decide that a change or action is necessary, they are not limited to the proposed solution from the initial written request.

b. NeDNR with concurrence of the NRDs will submit to the requestor(s) a written description of how the conflict will be addressed.

c. If NeDNR and the NRDs determine, as a result of these procedures, that modifications to the Plan are needed to meet the goals and objectives of the Plan, modifications will be made following the established plan modification procedures ("Modifications to the Plan," page 49).

Appendix F. Watershed Management Presentation Materials

Section Overview

This appendix includes two handouts authored by stakeholder Ted Tietjen and shared with the Republican River Basin-Wide Plan (Plan) Stakeholder Advisory Committee. These handouts were included in the Plan to ensure a record of the original intent of Ted Tietjen's proposal. Ted Tiejen proposed a small-scale study of a HUC-12 watershed. The proposed study would obtain information with field-scale water accounting, and groundwater levels within the HUC-12 would be monitored before and after landowners were given data from the field-scale accounting. This proposal led to Action Item 2.5.3. The study will be carried out in accordance with Action Item 2.5.3 and not necessarily as described in the details of the proposal below.

Section Contents

"Why Watershed Management" handout from August 2017 stakeholder meeting 104
"Why Watershed Management" handout from November 2017 stakeholder meeting 113

Aug 15, 2017

Why Watershed Management

By Ted Tietjen

In the Republican River Basin, all water comes from precipitation including stream flow and filling the aquifer.
So the question is, "How do we best manage the water in a comprehensive way to maximize the benefits"?
It started with ditch irrigation and then dams were built to reduce flooding and to increase ditch irrigation. After that came groundwater irrigation using the aquifer as a reservoir.

A research paper "Damming the Prairie: Human alteration of the Great Plains River regimes", by Costigan & Daniels.

K.H. Costigan, M.D. Daniels / Journal of Hydrology 444–445 (2012) 90–99

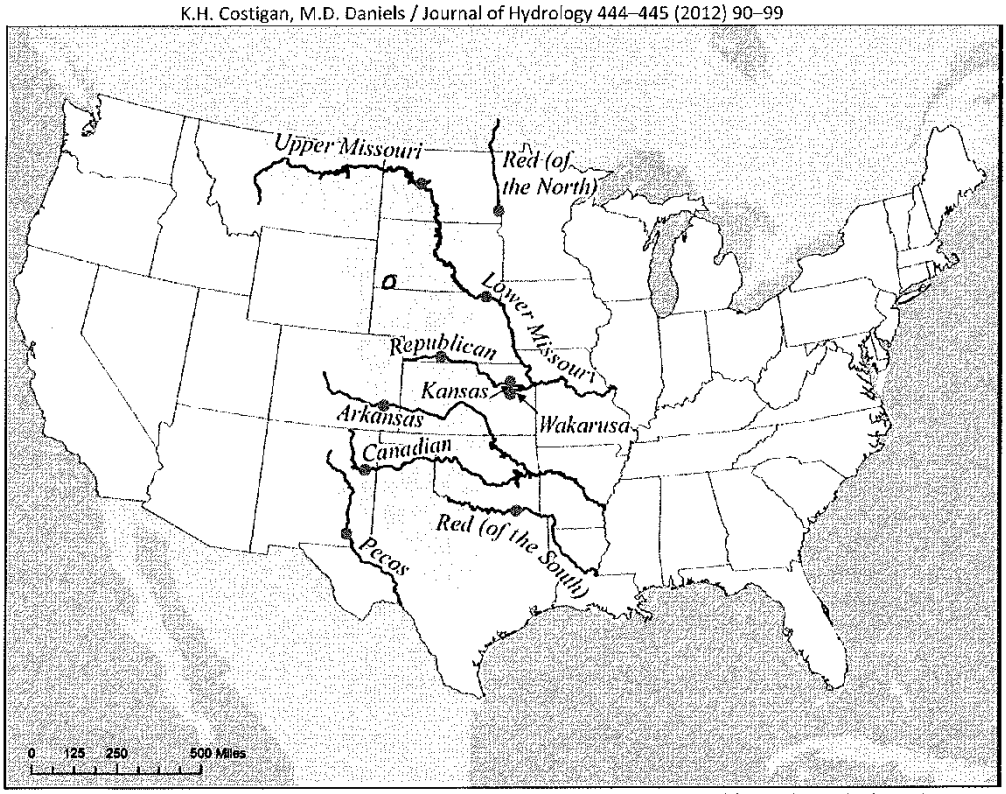


Fig. 1. Location of systems used for analysis, where gray circles indicate gage sites used for analysis. The boundary of the Great Plains USA is delineated in light gray.

The document; shows that stream flow in the Republican River was reduced by 65% after dams were built. Small livestock ponds, terraces and residue management are also negatively affecting stream flow. Later changes in tillage practices further changed the local hydrology.

Table 1
Characteristics of systems used in the analysis, is discharge in Cubic Meters Per Second

River	State	Dam Name	Mean Annual Pre Dam impact	Mean Annual after Dam impact	% Change
Arkansas	CO	John Martin	8.27	3.4	-59
Canadian	NM	Ute	9.66	1.19	-88
Kansas	KS	Tuttle-Milford	104.87	147.42	41
Lower Missouri	NE	Gavin's Point	727.18	735.11	1
Upper Missouri	MT	Garrison	624.1	624.39	0
Pecos	NM	Brantley	3.31	4.39	33
Red-North	ND	None	15.15	33.73	123
Red-South	TX	Dennison	137.25	138.13	1
Republican	NE	Harlan County	25.06	8.81	-65
Wakarusa	KS	Clinton Lake	5.32	7.62	44

These changes had a major impact on what the streams look like today. Unfortunately the riparian areas were taken over by undesirable vegetation such as: fragmentizes. Russian olive, Salt Cedar and Red Cedar trees are adding to the problem.

That leads to the next question?

Since 2007 two weed districts have been working to remove the undesirable vegetation from the flood plain and to restore the stream back to health. In addition NRCS has developed**: "The Stream Corridor Restoration"** manual to help in this effort and covers the following:
I. Background
II. Developing a Restoration Plan
III. Appling Restoration Principals

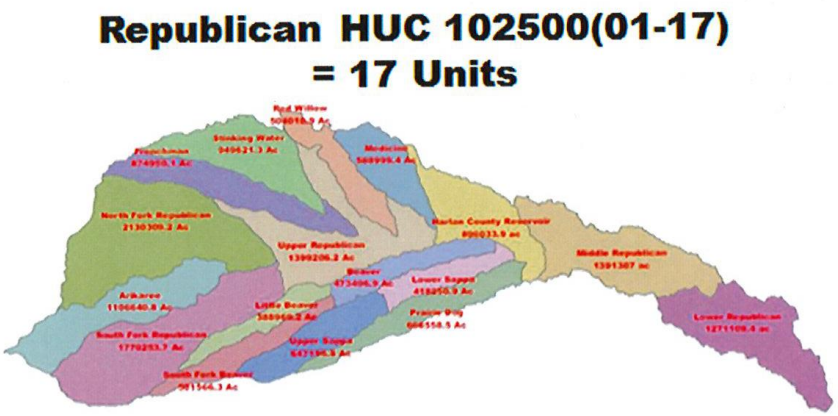
The manual is available through NRCS or online vendors.

For every action there is a reaction and sometime there are unintended consequences. "**The Stream Corridor Restoration**" training should be required for those that serve on NRD and Irrigation District boards to better understand how streams function.

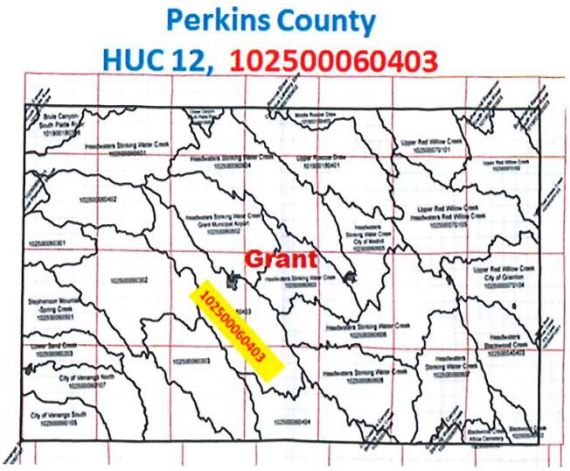
We have now laid the ground work for watershed management. Attached is an article by Frank Kwapnioski that explains how the water balance works in a watershed.

USGS has identified all watersheds in the US using Hydrologic Units that range in size from 1 through 12.
Example:
Missouri River is a HUC 10

The Republican River is a HUC 1025 and has identified 17 HUC watersheds.



A HUC 12 (102500060403) is south of Grant and happens to cover an enclosed watershed where no runoff comes in or out. It covers about a township in size.



Starting with a HUC 12 watershed the research can be quantified to show how much precipitation comes in and what happens to the water.
Some of the uses occur as:

Evaporation	Transpiration (from vegetation)
Aquifer recharge.	Municipal use.
Livestock and human consumption	Aquatic life
Wildlife	Recreation

Since agriculture is among the biggest suppliers as well as consumers of water it is only logical that we concentrate on those uses.

Examples:

Perkins County consumptive water use estimates for 2007

12-Aug-17 — **Perkins County , NE**

Average Rainfall 35.48 **Inches** 2007

Adams Lumber data

CROP	ACRES	Inches CONSUMPTION	Inches DEPLETION	Acre/Inches	Growing Season	Growing Season Precipitation
Irrigated Corn (150 bu/ac)	116500	22.0	6.9	1,036,442	April - Sept.	20.1
Irrigated Corn (200 bu/ac)	0	25.0	6.9	0	April - Sept.	20.1
Irrigated Corn (220 bu/ac)	0	27.0	4.9	0	April - Sept.	20.1
Irrigated Corn (240 bu/ac)	0	28.0	3.9	0	April - Sept.	20.1
Irr. Sugar Beets ("x" ton/ac)	1100	22.7	-0.5	-545	April - Sept.	20.1
Irr. Soybeans (50 bu/ac)	3100	23.0	5.9	45,553	May - Sept.	24.9
Irr. Soybeans (60 bu/ac)	0	24.0	7.9	0	May - Sept.	24.9
Irr. Soybeans (70 bu/ac)	0	25.5	6.1	0	May - Sept.	24.9
Irr. Sorghum ("x" bu/ac)	0	23.0	5.9	0	May - Sept.	24.9
Irr. Dry Edible Beans ("x" lbs/ac)	2200	22.0	9.9	32,778		
Irr. Potatoes ("x" tons/ac)	0	29.0	2.9	0		
Irrigated Alfalfa ("x" tons/ac)	1200	40.6	-5.7	-11,265		
Sunflowers ("x" lbs/ac)	2500	22.5	8.4	21,000		
Irrigated Wheat ("x" bu/ac)	16200	26.6	5.2	86,378	August - June	25.1
Irr. Small Grains (other)	0	26.6	5.2	0		
Dryland Corn (100 bu/ac)	62600	17.5	14.1	929,725	April - Sept.	21.6
Dryland Soybeans (45 bu/ac)	600	16.7	15.2	9,133	May - Sept.	20.5
Dryland Sorghum	200	17.6	14.2	2,866	April - Sept.	20.5
Wheat/Corn/Soybean/Wheat	0	17.5	14.4	0		
Dryland Edible Beans	0	16.7	15.2	0	May - Sept.	20.5
Dryland Alfalfa	500	19.2	12.7	6,356	March - Nov.	0.5
Dryland Wheat	111200	18.1	16.9	1,877,854	August - June	25.1
Summer Fallow Wheat	56155	9.4	22.5	1,241,268	August - June	25.1
Summer Fallow Wheat/Corn	0	11.0	21.0	0		25.5
Dryland Small Grains (Oats/Wild	0	15.0	12.9	0		
Conservation Reserve(CRP)	42319	21.1	10.5	459,849		
Other AG. Lands	993	16.6	15.3	15,225		
Range, Pasture, Grasses	92775	19.1	12.5	1,199,462	March - Oct.	22.0
Riparian Forest & Woodlands	1669	19.1	12.5	21,417	March - Oct.	22.0
Wetlands	126	51.0	-25.1	-2,409	Feb. - Oct.	22.0
Open Water	0	45.0	-16.1	0	N/A	
Waste Land	1042	19.0	12.9	12,475		
Buildings & Building Sites	2470	16.6	15.3	37,670	N/A	
Urban Land & towns	0	19.7	12.2	0	N/A	
Rural Roads (Unsurfaced)	9150	19.0	12.9	118,328	N/A	
Totals	**561,002**			**7,821,568**		

Representative Equivalent

7,821,568 A/inches

651,797 A/feet

Perkins County consumptive water use estimates for 2008

12-Aug-17		Perkins County NE					
Average Rainfall	18.77	Inches	2008				
Adams Lumber data							
CROP	ACRES	Inches CONSUMPTION	Inches UTILIZATION	Acre-Inches	Growing Season	Growing Season Precipitation	
Irrigated Corn (180 bu/ac)	0	33.0	-6.1	0	April - Sept.	12.6	
Irrigated Corn (200 bu/ac)	104500	33.0	-6.1	-647,182	April - Sept.	12.6	
Irrigated Corn (220 bu/ac)(Silage)	500	27.0	-10.1	-5,054	April - Sept.	12.6	
Irrigated Corn (240 bu/ac)	0	28.0	-11.1	0	April - Sept.	12.6	
Irr. Sugar Beets ('x' tons/ac)	1900	32.7	-13.5	-39,033	April - Sept.	12.6	
Irr. Soybeans (50 bu/ac)	0	33.0	-6.1	0	May - Sept.	11.5	
Irr. Soybeans (60 bu/ac)	15600	34.0	-7.1	-119,869	May - Sept.	11.5	
Irr. Soybeans (70 bu/ac)	0	35.5	-8.9	0	May - Sept.	11.5	
Irr. Sorghum ('x' bu/ac)	200	33.0	-6.1	-1,221	May - Sept.	11.5	
Irr. Dry Edible Beans ('x' lbs/ac)	6900	33.0	-6.1	-33,235			
Irr. Potatoes ('x' tons/ac)	0	29.0	-12.1	0			
Irrigated Alfalfa ('x' tons/ac)	2500	40.6	-23.7	-59,288			
Sunflowers ('x' lbs/ac)	2900	33.5	-6.6	-19,160			
Irrigated Wheat ('x' bu/ac)	10500	26.6	-9.7	-104,835	August - June	14.4	
Irr. Small Grains (other)	0	26.6	-9.7	0			
Dryland Corn (100 bu/ac)	49700	17.5	-0.9	-45,076	April - Sept.	12.6	
Dryland Soybeans (45 bu/ac)	500	16.7	0.2	104	May - Sept.	24.9	Representative Equivalent Use
Dryland Sorghum	0	17.6	-0.7	0	April - Sept.	24.9	-1,129,851 Ac/inche
Wheat/Corn/Soybean/Wheat	0	17.5	-0.6	0			-94,154 Ac/feet
Dryland Edible Beans	0	8.4	7.5	0	May - Sept.	11.5	
Dryland Alfalfa	500	19.2	-2.2	-1,154	March - Nov.	25.5	
Dryland Wheat	94400	19.2	-2.2	-217,781	August - June	14.4	
Summer Fallow	107562	9.5	7.1	762,937	August - June	14.4	
Summer Fallow Wheat/Corn	0	12.3	4.6	0			
Dryland Small Grains (Oats/Millet	0	15.0	-1.1	0			
Conservation Reserve(CRP)	41574	21.1	-4.2	-174,902			
Other AG. Lands (hay)	11200	16.6	0.3	3,282			
Range, Pasture, Grasses	57564	19.1	-2.2	-193,254	March - Oct.	22.0	
Riparian Forest & Woodlands	0	19.1	-2.2	0	March - Oct.	22.0	
Wetlands	156	51.0	-40.1	-7,460	Feb. - Oct.	23.6	
Open Water	0	45.0	-34.1	0	N/A		
Waste Land	4741	19.0	-2.1	-9,989			
Buildings & Building Sites	2453	16.6	0.3	726	N/A		
Urban Land & towns	5402	19.7	-2.8	-15,163	N/A		
Rural Roads (Unsurfaced)	9165	19.0	-2.1	-19,311	N/A		
Totals	561,077			(1,129,851)			

Precipitation varies so much from one year to the next that makes comprehensive water management a challenge.

Satellite imagery can also help to identify consumption in real time and then use the data to help to better manage our resources to maximize the benefits.

Understanding and encouraging residue management as a tool to reduce evaporation and increase soil recharge is a win-win opportunity.

Changing cropping systems to reduce consumptive water use including shorter season corn may reduce usage.

Summary

If we are going to solve the challenges before us, steps need to be taken to balance the water availability with the demand. Today our demand exceeds what is available, so we have to find the most beneficial uses of our water without destroying our economic and environmental base.

Water Balance as a Watershed Management Tool

Just as the better you understand a subject, the better you are likely able to explain it, the better you understand a situation, the better you are likely able to manage it. Water balance is a tool that helps us better understand the water situation. It can help us understand, within a specific area such as a watershed, where all the water comes from and how much there is as well as where it all goes. This type of inventory is critical when it comes to deciding what we can and want to do with the water and where its best value may lie.

Water budget, as an engineering tool, has been taught for years as a specific set of steps to systematically assess a reservoir site or other water supply project and determine firm yield. The only difference, and the thing that is unusual with this approach from a conventional water budget application, is generally the balance application and the fact that water budget has seldom been used for this purpose.

Since the water supply is not uniform and static another important feature of a water budget, as a tool, is that it can be adapted to assess any scale and time frame appropriate to the management needs. Not only can it assess the full extent of the record but also the duration, magnitude and frequency of any recurring cycles which helps quantify the extent of risk and opportunity available in a given situation.

When this information is known it can help determine the need for and extent of storage possible and necessary to meet the expected demands. Only after you fully understand and quantify the water supply and expected and agreed to demand can you then start to identify where; how much and what type of storage is necessary and appropriate to address supply variability and meet the water needs and firm yield requirements.

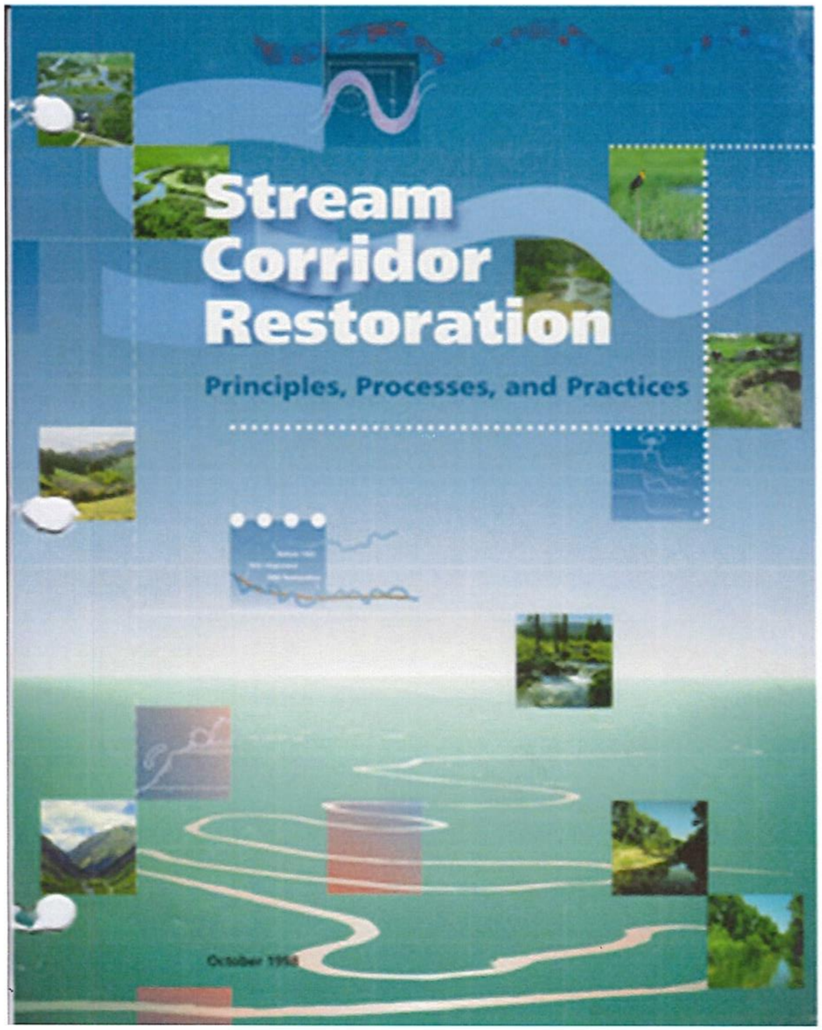
Although we have already developed some surface water storage, because of various reasons it is not likely to be expanded much more. Therefore, identification and development of the best and most effective ground water utilization will be critical with ground water storage management the most possible and adequate in scale.

There really is no other tool that has systematically, on a watershed basis, address these expectations. Water balance is a tool, not a silver bullet, that when applied with appropriate knowledge and judgment can be extremely efficient at optimizing water management at scale. The opportunity for water budget application has recently been significantly improved with the availability of both remote and direct ET estimating and measurement.

In the past, without these resources and the ability for consistent implementation of this type of tool in a comprehensive manner, most water management amounted to simply attempting to react to what nature provided without systematic quantification. This understanding, essentially a "Tragedy of the Commons" outcome, can help explain why, after almost 150 years of water management effort, Nebraska still has periods of water supply excess, water demand shortage and water conflicts.

All systems operate within specific physical limits that are generally a given and must be observed. Other possible constraints to addressing water management issues are financial and social or political but with the abundance of necessary data and effective tools we now have available, financial concerns should not be a real constraint to watershed management.

The extent of water development can be financially constrained but the assessment itself should not be. With a water budget tool, we have all the resources necessary to manage water in Nebraska to the degree we need to be extremely effective. This generally leaves only political and possibly statutory conditions as limits and if these remain as obstacles, then the problem is self-imposed.



The manual is available at NRCS offices or it can be ordered on line from a number of vendors

Why Watershed Management?

By Ted Tietjen
Nov 18, 2017

To: The Republican River Stakeholders
From Ted Tietjen

Why Watershed Management?

The Republican River Basin is trying to manage a basin that is suffering from the "Tragedy of The Commons"; where water demands exceed what's available and to comply with the Republican River Compact. It appears the Republican River Compact Administration has come up with a plan that should keep NE in compliance for a number of years. Unfortunately, the compact does not address the challenges we face in the state of NE. If during the growing season we would normally receive 30 plus inches rain per year, there would be no reason to meet as the availability would exceed demand.

The Natural Resource Districts where approved in 1969 by the NE Legislature and then implemented in 1972. The 23 districts were designed to represent watersheds as much possible along county lines. Correlative Rights relating to ground water management are also put in place. "Share and share alike" is the standard that can be used to further the "Tragedy of the Commons" or to use it as a tool to help solve some the challenges in over appropriated watersheds.

At the last stakeholders meeting in Aug a proposal was made to conduct a 4 to 5 year research project on a small Hydrologic Unit Code (HUC 12) to analyze the value in using water balance as a management tool. The committee requested that more detailed information be provided and then report back to the group for further consideration. Some of the concepts and opportunities this research could help identify and quantify are listed in the following bullets.

- Over the long term, the total average annual water supply or less is a limit and could be managed for consumption at similar to native consumption rates
- Anticipated water consumption amount distributions, per field, can be managed through crop selection to maximize land productivity.
- Each landowner determines how much water to consume on each of their fields based on their long-term average annual water supply
- Both surface and groundwater irrigation would be protected to help recapture and retime the average annual water supply in its most effective manner
- Irrigation can be used to maintain the expected consumption on only a portion of the land adequate to maintain a consumption verses supply balance
- Irrigation helps produce maximum benefits and address the variability of high and low precipitation periods
- This concept offers the opportunity to bring the local hydrologic system back to a native historic balance where sustainable aquifers and working streams can coexist
- Based on the landowner's specific production and conservation goals, any extra water conserved could either be further consumed by them or traded to other water interests

A HU12 located in Perkins County, NE was selected (number 10250006043) and comprises 33,459 acres. What is unique about this watershed is that it is an enclosed watershed. That means no water comes in or goes out of the watershed other than precipitation and a small amount of ground water flux at the boundary. This eliminated a lot of variables such as streams flowing in or out, large dams with a large surface water area and canals. Flood plains or riparian areas are not in the project either.

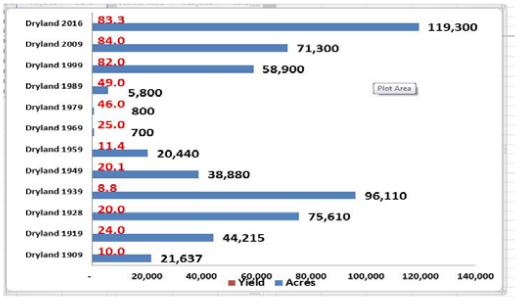
One of the challenges is that the underground aquifer does not follow the watershed. Since the aquifer water movement is very slow it isn't that hard to measure. This ground water flux could be assumed to be zero because it can operate in opposing directions in different parts of the boundary or it could be quantified with the model. The local NRD has enough information to measure it accurately so it should not present a problem.

One of the R & D objectives would be to identify recharge opportunities when the soil profile is already full and the area gets additional precipitation. Another opportunity would be when precipitation events exceed the water intake rate of the soil. These opportunities coupled with better residue management to reduce evaporation, elimination of undesirable vegetation and using cropping systems options to establish a baseline. Once the aquifer recharge baseline has been quantified and becomes measurable, ground water allocations and educational programs can be adjusted to meet the watersheds budgetary goals.

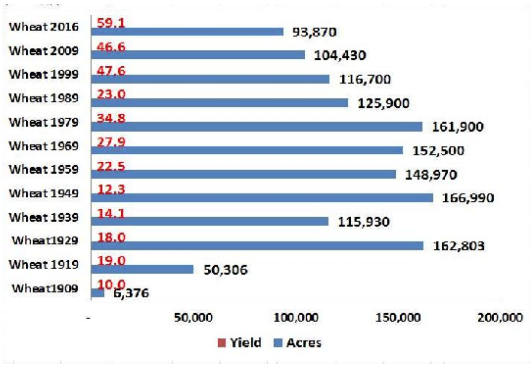
HUC 12 # 102500060403 in Perkins County, NE

As the data was being gathered for the presentation it became clear there was another strong factor influencing cropping systems that was driving water management was economics. It became very clear that economics was the factor and had a greater impact on what was happening and took precedence over everything else. Each grower's behavior also affected management strategies relating to their farming practices.

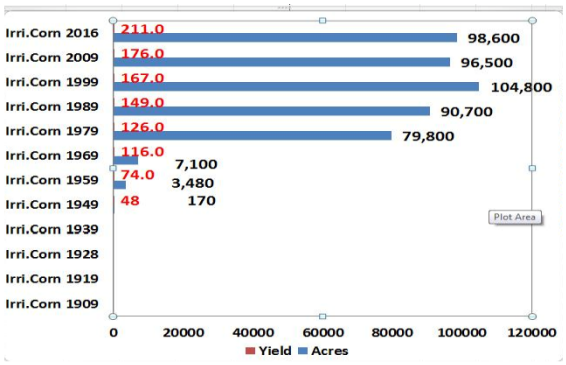
Before laying out the details for the HUC 12 in the R & D project it was decided to look at the cropping history in Perkins County from 1909 to 2016 for three crops, corn, wheat and soybeans. The information was derived from the NE Dept. of Ag Statistics



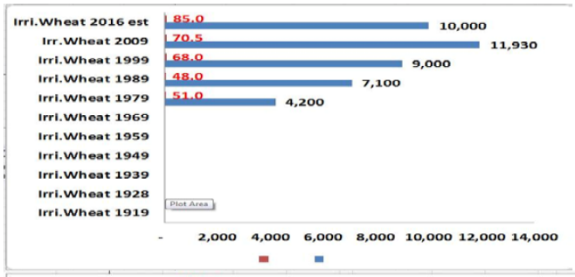
The bar graphs show how the corn cropping system changed. From 1909 to 1939 much of the corn was grown for the livestock. Then starting in the late forties summer fallowing before planting wheat became the norm and lasted until the early 90's when eco-fallow became more common. These eco-fallow acres were then planted to dryland corn rather than wheat as it produced more income due to higher yields and price. By 2016 Perkins County had more acres in dryland corn than wheat.



Wheat acres in 1909 were low because only 15% of the land had been broken out and the price was not attractive. By 1919 the acres jumped partly because of WWI and many more acres were being farmed. By 1928, 65 % of the acres in Perkins County were farmed and wheat became a major crop that surpassed the dryland corn acres. Summer fallow acres increased in the late 1940's as it increased yields and lasted till growers started using eco-fallow to save moisture and then switched to corn. New high yielding varieties came along in the 1990's and
Continued to increase, where 70 to 110Bu/A yields are not uncommon today.

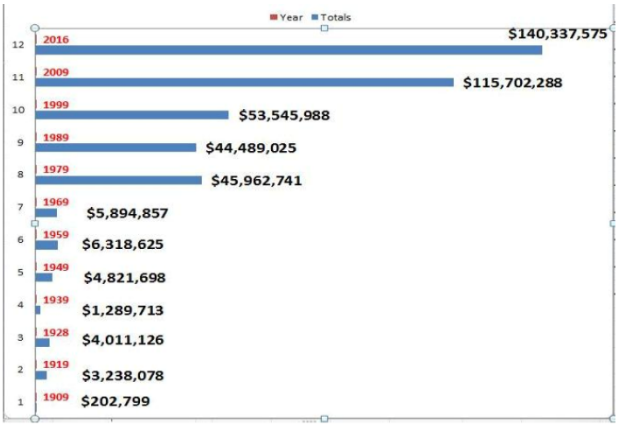


Irrigated corn acres came to the county in the 1950's with yields in the 75 to 80 Bu/A range. Center pivots became popular in the 1970's. At the same time hybrid corn varieties were increasing yields to 125 Bu/A. By **2016 the irrigate corn yields reached an average of 211 Bu/A. Irrigated corn acres kept increasing until a** moratorium on drilling irrigation wells was implemented in the 1970's.



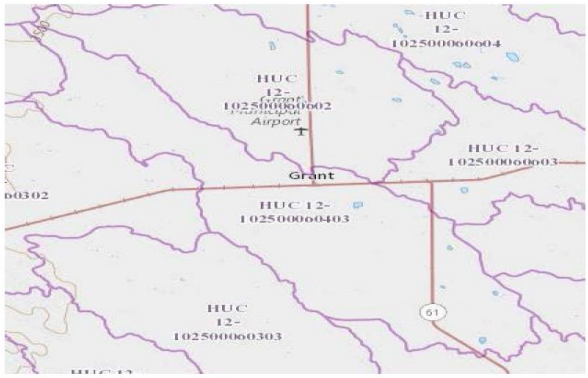
Some growers started irrigating wheat in the 1970's as center pivots became more common. New high yield varieties are still being grown in the crop rotations where yields above 80 Bu/A are common.

Soybean production under irrigation started in the 1970's and has grown because it fit well into the crop rotation. Yields have also increased from 30 to 70 Bu/A making it an income producing crop as well.



One can easily see how yield and price increases changed the revenue stream and how they impacted the decision making process. In 1909 when only 15 % of the land was broken out of sod only produced $202,799. WWI prices encouraged farmers to plant more acres. Steam engines and other innovations helped growers to expand their farmable acres in a very short period of time. Revenue from wheat and corn increased 160 % or $3,238,078 by 1919. By 1928 65% of the land in Perkins County was being farmed and increase wealth by another $773,048.

Increased revenue did not really take off until center pivot irrigation development took place. By 1979 the revenue from corn and wheat increased to $45,962,741. In 2016 corn, wheat and soybeans had a cash value of $140,337,575. We did not include other crops and livestock as the data was not available. It is not hard to see why economics is the driver and how we manage our resources.



We need to explain how USGS's Hydrologic Unit Code (HUC) 12, **#102500060403** units came about:
The numbers designate the following:
First two digits: **10** is in the Missouri River Basin
The Next two digits are: **1025**: designates the Republican River Basin
The next 4 digits are: **10250006**: Designates the Stinking Water.
The next 4 digits are: # **102500060403** and is the HUC 12 recommended for the project.

How was the data collected?

Both USGS: https://water.usgs.gov/GIS/huc/html or https://viewer.nationalmap.govadvanced-viewer and NRCS websites: https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx were used in the data gathering process.

Actual NRCS map with acres and crops grown in 2017 in **Section 11 & 12-10-38,** which includes part of **Grant**.

The watershed boundary is color coded in **Red.**
Irrigated land is **Yellow.**
Dry land is **Gray.**
Buildings and waste land is **Orange**

Acres of each crop grown in the HUC 12 in 2017 are as follows:

Irrigated crop acres

Corn	Wheat	Soybeans	Pinto's	Sudan	Irrigated Acres
6555	292	2592	393	195	10.027

Rain fed acres

Corn	Wheat	soybeans	sunflowers	Milo	Sudan	J Millet	Millet	Fallow	Rain fed Acres
7261	2608	98	207	186	913	530	262	3410	15,475

Pasture, buildings, roads and wasteland acres

Pasture	Grass	CRP	Shelter belts	Buildings/City	Roads/waste	Other Acres
5181	452	135	127	572	1629	7,957

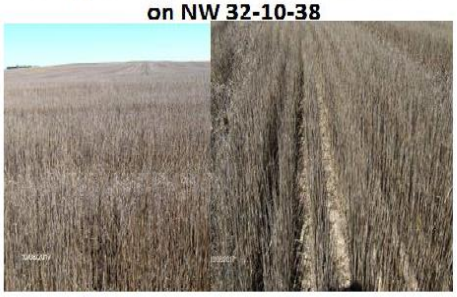
The acres in the HUC 12 watershed are: **Total Acres 33,459**

What did the crops look like?

Irrigated Corn 1n 2017 on E ½ 18-10-38

Irrigated Soybeans in 2017 on NE 19-10-38

Stripper Head Wheat Stubble in 2017 on NW 32-10-38



Tilled Dryland Summer Fallow in 2017 on NW 5-10-39

Chemical Fallow in 2017 on 14-11-40

Dryland Corn planted in Wheat stubble in 2017 on SW-5-10-39

Dryland Corn in 2017 on SE 35-11-40

Dryland Sunflowers in 2017 on SE-25-11-40

Dryland Japanese Millet in 2017 on SW 8-9-38

Dryland Sorghum Sudan 1n 2017 on NE-6-10-39

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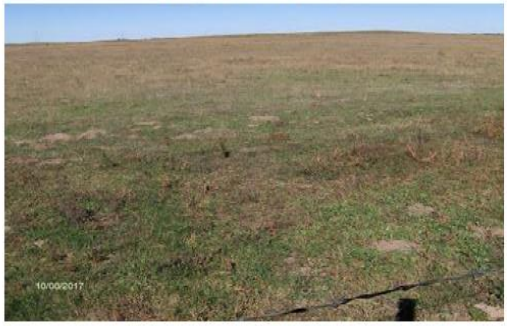
Dryland Sudan Bailed & planted to Wheat in 2017 on SE 25-9-39

Bailed Sudan in 2017 on SEC 36-11-40

Irrigated Sudan after wheat in 2017 on NW 12-9-39

Native Dryland Pasture in 2017 on SW 36-10-39



CRP Field in 2017 on SE 30-11-39

Center Pivot Corners in 2017 including CRP and Shelter Belts

Some observations

The soil moisture conditions in the fall of 2016 where very dry to a depth of five feet. Precipitation during the off season was very low and going into the spring the soil was still very dry prior to planting. The fields that were probed only had moisture to less than a foot. The April rains filled the soil from 3 ½ ft. to 4 ½ ft. depending on the WHC. Corn planted on soils with little residue ran out of moisture before the late July and early Aug rains came had a devastating effect on the yield potential. The September rains filled the soil profile. So we are starting with the soil profile that is full before off season precipitation. That means precipitation received during the off season will help recharge the aquifer provided it doesn't run off.

Fields that had the residue baled in 2016 and then planted to corn in 2017 had yields in the range of 20 to 40 Bu/A. Fields that had been corn in 2016 and then planted back to corn yielded in the 60-to 80 Bu range. Fields that were in wheat in 2016 and planted to corn yielded from 110 to 140 Bu/A.

Most of the fields that were summer fallowed in 2017 were tilled as chemical resistant weeds became such a problem.

What was learned?

Each field in the watershed showed that consumptive water use was quite different with each grower as their cropping systems management had different objectives. The previous year's residue management also played a major role in the following year's production, especially on dryland. Implementing watershed management will require getting a better understanding of why growers make the decisions they do. Real time data from an adequate weather station network, satellite consumptive water use, residue measurement, good information on soil texture and water holding capacity (WHC) in the top five feet and cropping plans that include Growing Degree Days (GDD) will be useful. The information can then be used in developing advanced watershed management strategies.

The first year would be used to develop a base line. In the second year, the project would start to implement what was learned. The third and fourth year would be used to measure the results. Hopefully the information could then be transferred to larger sub-basins. Sub-basins that have riparian areas with undesirable vegetation, dams and streams flowing in and out plus canal systems will require additional management strategies to maximize the beneficial use of water.

What are some of the benefits of watershed management?

There is enough data already to encourage better residue management; cutting three foot trenches in flat terraces and putting wood chips in them for aquifer recharge are already proven. The same concept works for storm water drainage systems and lagoons in fields. Unfortunately, some of the lagoon areas in farm fields may be classified as a wetland and the penalties for modification are very high.

Storm water study in Grant between the Railroad tracks and Highway in 2010

The proposed management model would embrace the concept that each landowner should quantify consumed water on his land, like native consumption, based on the average annual precipitation supply. Over time this concept could bring the hydrologic system back to a natural balance where sustainable aquifers and working streams can coexist. Both surface and groundwater irrigation would be protected to help retime the available water supply to maintain the expected consumption on portions of the property for maximum benefit and address the variability of high and low precipitation periods.

The consumptive use template used here came from earlier work by Frank Kwapnioski. The process demonstrated is currently workable but the consumption data and other assumptions will need better quantification that can be produced by and verified with this proposed research project.

Attached are two consumptive use tables showing water consumption in the HUC 12 with and without residue management. The 3.50-inch credit is based on information from an August 23, 2017 NE Farmer article, "Crop Residue Helps Prevent Unnecessary Water Losses" by Tyler Harris, where he quotes Steve Melvin on UNL research. The third sample of consumptive use is from the LT Farm on the E ½ 18-10-38 Acres, which includes each crop grown in 2017 and the defined 3.50-inch residue credit:

12-Nov-17			HUC 12 crops 2017			
Average Rainfall 2017	20.84	Inches	Precipitation in 2017			
Used LT Farm rain gauge	0	Residue benefit				
HUC 12, #102500060403	20.84					Growing
		Inches	Inches		Growing	Season
CROP	Acres	Consumption	Depletion	Acre/Inches	Season	Precip
Irrigated Corn (95 Rmor GDD)	0	23.2	-4.4	0	April - Sept.	16.5
Irrigated Corn (100 RM or GDD)	0	24.4	-5.6	0	April - Sept.	16.5
Irrigated Corn (105 RM or GDD)	0	25.6	-6.8	0	April - Sept.	16.5
Irrigated Corn (110 RM or GDD)	6555	26.8	-8.0	-52,728	April - Sept.	16.5
Irrigated Corn (115 RM or GDD)	0	28.0	-9.2	0	April - Sept.	16.5
Irr. Sugar Beets ("x" ton/ac)	0	32.7	-13.9	0	April - Sept.	16.5
Irr. Soybeans (50 bu/ac)	0	23.0	-4.2	0	May - Sept.	14.3
Irr. Soybeans (60 bu/ac)	2592	24.0	-5.2	-13,592	May - Sept.	14.3
Irr. Soybeans (70 bu/ac)	0	25.8	-7.0	0	May - Sept.	14.3
Irr. Sorghum ("x" bu/ac)	195	23.0	-4.2	-828	May - Sept.	14.3
Irr. Dry Edible Beans ("x" lbs/ac)	393	22.0	-3.2	-1,275		
Irr. Potatoes ("x" tons/ac)	0	29.0	-10.2			
Irrigated Alfalfa ("x" tons/ac)	0	40.6	-21.8	0		
Irr. Sunflowers ("x" lbs/ac)	0	23.5	-4.7			
Irrigated Wheat ("x" bu/ac)	293	26.6	-7.8	-2,298	August - June	9.4
Irr. Small Grains (other)	0	26.6	-7.8	0		
Dryland Corn (100 bu/ac)	7261	17.8	1.0	6,942	April - Sept.	16.5
Dryland Soybeans (45 bu/ac)	98	16.7	2.1	201	May - Sept.	14.3
Dryland Milo, Sudan & J Millet	1629	17.6	1.2	1,883	April - Sept.	16.5
Wheat/Corn/Soybean/Wheat	0	17.5	1.3	0		
Dryland Edible Beans	0	11.4	7.3	0	May - Sept.	14.3
Dryland Alfalfa	0	19.2	-0.4	0	March - Nov.	18.4
Dryland Wheat	2608	5.7	13.1	34,144	August - June	9.4
Summer Fallow Wheat	3410	15.6	3.2	10,762	August - June	9.4
Summer Fallow Wheat/Corn	0	7.8	10.9	0		
Dryland Small Grains (Oats/Millet	262	18.0	0.8	198		
Conservation Reserve(CRP)	135	21.1	-2.3			
Other AG. Lands, Sunflowers	207	16.6	2.2	446		
Range, Pasture, Grasses	5633	16.2	2.6	14,601	March - Oct.	18.0
Riparian Forest & Woodlands	127	47.0	-28.2	-3,587	March - Oct.	18.0
Wetlands	0	57.0	-38.2	0	Feb. - Oct.	18.0
Open Water	0	48.0	-29.2	0	Precipitation use is based	
Waste Land		19.0	-0.2		on no runoff	
Buildings & Building Sites	572	16.6	2.2	1,233	Representative Equivalent Net	
Urban Land & towns	0	19.7	-0.9	0	-4262	Acre inches
Rural Roads (Unsurfaced)	1490	19.0	-0.2	-364	-355	Acre feet
Totals	33,460			-4262		

12-Nov-17			HUC 12 crops 2017 # 102500060403			
Average Rainfall 2017	20.84	Inches	Precipitation in 2017			
Used LT Farm Rain Gauge	3.50	Residue benefit	Based on WCR&E data			
HUC 12, #102500060403	24.34					Growing
		Inches	Inches		Growing	Season
CROP	Acres	Consumption	Depletion	Acre/Inches	Season	Precip
Irrigated Corn (95 RM or GDD)	0	23.2	-1.3	0	April - Sept.	16.5
Irrigted Corn (100 RM or GDD)	0	24.4	-2.5	0	April - Sept.	16.5
Irrigated Corn (105 RM or GDD)	0	25.6	-3.7	0	April - Sept.	16.5
Irrigated Corn (110 RM or GDD)	6555	26.8	-4.9	-32,080	April - Sept.	16.5
Irrigated Corn (115 RM or GDD)	0	28.0	-6.1	0	April - Sept.	16.5
Irr. Sugar Beets ("x" ton/ac)	0	32.7	-10.8	0	April - Sept.	16.5
Irr. Soybeans (50 bu/ac)	0	23.0	-1.1	0	May - Sept.	14.3
Irr. Soybeans (60 bu/ac)	2592	24.0	-2.1	-5,428	May - Sept.	14.3
Irr. Soybeans (70 bu/ac)	0	25.8	-3.9	0	May - Sept.	14.3
Irr. Sorghum ("x" bu/ac)	195	23.0	-1.1	-213	May - Sept.	14.3
Irr. Dry Edible Beans ("x" lbs/ac)	393	22.0	-0.1	-37		
Irr. Potatoes ("x" tons/ac)	0	29.0	-7.1			
Irrigated Alfalfa ("x" tons/ac)	0	40.6	-18.7	0		
Irr. Sunflowers ("x" lbs/ac)	0	23.5	-1.6			
Irrigated Wheat ("x" bu/ac)	293	26.6	-4.7	-1,375	August - June	9.4
Irr. Small Grains (other)	0	26.6	-4.7	0		
Dryland Corn (100 bu/ac)	7261	17.8	4.1	29,814	April - Sept.	16.5
Dryland Soybeans (45 bu/ac)	98	16.7	5.2	510	May - Sept.	14.3
Dryland Milo, Sudan & J Millet	1629	17.6	4.3	7,014	April - Sept.	16.5
Wheat/Corn/Soybean/Wheat	0	17.5	4.4	0		
Dryland Edible Beans	0	11.4	10.5	0	May - Sept.	14.3
Dryland Alfalfa	0	19.2	2.7	0	March - Nov.	18.4
Dryland Wheat	2608	5.7	16.2	42,359	August - June	9.4
Summer Fallow Wheat	3410	15.6	6.3	21,503	August - June	9.4
Summer Fallow Wheat/Corn	0	7.8	14.1	0		
Dryland Small Grains (Oats/Millet	262	18.0	3.9	1,023		
Conservation Reserve(CRP)	135	21.1	-2.3	-316		
Other AG. Lands, Sunflowers	207	16.6	5.3	1,098		
Range, Pasture, Grasses	5633	16.2	2.6	14,601	March - Oct.	18.0
Riparian Forest & Woodlands	127	47.0	-28.2	-3,587	March - Oct.	18.0
Wetlands	0	57.0	-38.2	0	Feb. - Oct.	18.0
Open Water	0	48.0	-29.2	0	Preciptation use is based	
Waste Land		19.0	-0.2		on no runoff	
Buildings & Building Sites	572	16.6	2.2	1,233	Representative	Equivalent Net
Urban Land & towns	0	19.7	-0.9	0	75756	Acre inches
Rural Roads (Unsurfaced)	1490	19.0	-0.2	-364	6313	Acre feet
Totals	33,460			75,756		

Revised 11-12-17		LT Farms 2017 crop year			Field #: 18-1 through 18-5	
LT Farm weather station		20.84	rainfall for 2017			
Residue Management credit		3.5	Residue benefit, Based on WCR&E data			
		24.3				Growing
		Inches	Inches		Growing	Season
CROP	Acres	Consumption	Depletion	Acre/Inches	Season	Precip
Irrigated Corn (95 RM)	-	23.2	-1.3	0	April - Sept.	16.5
Irrigated Corn (100 RM)		24.4	-2.5	0	April - Sept.	16.5
Irrigated Corn (105 RM)	-	25.6	-3.7	0	April - Sept.	16.5
Irrigated Corn (110 RM)	120	26.8	-4.9	-589	April - Sept.	16.5
Irrigated Corn (115 RM)		28.0	-6.1	0	April - Sept.	16.5
Irr. Sugar Beets ("x" ton/ac)	-	32.7	-10.8	0	April - Sept.	16.5
Irr. Soybeans (50 bu/ac)	-	23.0	-1.1	0	May - Sept.	14.3
Irr. Soybeans (60 bu/ac)	-	24.0	-2.1	0	May - Sept.	14.3
Irr. Soybeans (70 bu/ac)	-	25.8	-3.9	0	May - Sept.	14.3
Irr. Sorghum ("x" bu/ac)	-	23.0	-1.1	0	May - Sept.	14.3
Irr. Dry Edible Beans ("x" lbs/ac)	-	22.0	-0.1	0		
Irr. Potatoes ("x" tons/ac)	-	29.0	-7.1	0		
Irrigated Alfalfa ("x" tons/ac)	-	40.6	-18.7	0		
Irr. Sunflowers ("x" lbs/ac)	-	23.5	-1.6	0		
Irrigated Wheat ("x" bu/ac)	-	26.6	-4.7	0	August - June	7.6
Irr. Small Grains (Millet/Oats)	-	26.6	-4.7	0		
Dryland Corn (100 bu/ac)	-	17.8	4.1	0	April - Sept.	16.5
Dryland Soybeans (45 bu/ac)	-	16.7	5.2	0	May - Sept.	14.3
Dryland Sorghum	-	17.6	4.3	0	April - Sept.	16.5
Dryland Sunflowers	-	17.5	4.4	0	April - Sept.	16.5
Dryland Edible Beans	-	11.4	10.5	0	May - Sept.	14.3
Dryland Alfalfa	-	19.2	2.7	0	March - Nov.	18.0
Dryland Wheat	-	4.5	17.4	0	August - June	7.6
Summer Fallow Wheat	-	15.6	6.3	0	August - June	7.6
Summer Fallow	81	7.4	14.5	1,171		
Dryland Small Grains (Millet/Oats	-	18.0	3.9	0		
Conservation Reserve(CRP)	-	21.1	0.8	0		
Other Ag Land	-	16.6	5.3	0		
Range, Pasture, Grasses	-	16.2	5.7	0	March - Oct.	18.0
Riparian Forest & Woodlands	-	47.0	-25.1	0	March - Oct.	18.0
Wetlands	-	57.0	-35.1	0	Feb. - Oct.	18.0
Open Water	-	48.0	-26.1	0	Precipitation used based	
Waste Land	3	19.0	2.9	9	on no run off	
Buildings & Building Sites	5	16.6	5.3	27	Representative	Equivalent Net
Urban Land & towns	-	19.7	2.2	0	617	Acre inches
Rural Roads (Unsurfaced)	-	19.0	2.9	0	51	Acre feet
Totals	209			617		

The first two spreadsheets above demonstrate how this concept can be applied to quantify the 2017 watershed precipitation verses consumption balance both without and with residue management. The remaining spreadsheet represents how the concept can be used to quantify precipitation verses consumption balance on an individual producer basis with adequate residue retention.

These examples apparently indicated that 2017 levels of irrigation could be sustainably implemented in this area with 2017 levels of precipitation, proper cropping and land use management. The total 2017 precipitation was about 58 KAF and the balance remainder for the watershed with total residue management is equal to 6.3 KAF or about 11% of surplus. A slightly larger remainder value of about 14% is calculated for the individual landowner example. However, all the values and assumption used in the above examples are based on current best understandings that should be further developed, improved and verified through this project.

This proposed management model provides tools (tables) so that each landowner can quantify the water consumed on their land based on their cropping patterns and their average annual precipitation supply. Sustainable aquifers and working streams would be possible based on approximating a native hydrologic system. Both surface and groundwater irrigation will be protected to help retime the available water supply and maintain the expected consumption on sustainable portions of the property for maximum benefit and also to address the variability of high and low precipitation periods.

I ask that the Republican River Stakeholders give serious consideration to this project and that it be approved. The next step would be to identify the base line in a watershed and then develop budgets to meet the desired goals and objectives. These goals and objectives would be developed in cooperation and input from the local NRD's, NE Department of Natural Resources, UNL and other interested parties.

Thank you for consideration.

Appendix G. Water Market Summary

Section Overview

Aaron Thompson, a member of the Stakeholder Advisory Committee, introduced the idea of establishing a water market in the Nebraska portion of the Republican River Basin (Basin) at the August 15, 2017, Stakeholder Advisory Committee meeting to explore the potential of such a market. Stakeholders commented that the market should be set up such that it would incentivize and encourage conservation with the intended outcome to reduce overall consumptive use.

At the September 19, 2017, coordination meeting with the natural resources districts (NRDs) and the Nebraska Department of Natural Resources (NeDNR), Aaron Thompson presented a draft proposal to the group. Proposal discussion followed on two "tracks."

- How the idea should be addressed in the Republican River Basin-Wide Plan (Plan)
- Determining the best way to move the idea forward

The remainder of this appendix is a summary of the discussion following the proposal. The ideas from this appendix informed Objective 2.6, Action Item 2.6.1, and Action Item 2.6.2. These action items will be carried out according to the text in the Goals and Objectives section of the Plan and not necessarily as described in the details below.

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Moving Forward

There is general agreement to approach the issue as a short term (within the first five years) action item. Given the schedule, there was concern that implementing a pilot and understanding the results would delay Plan completion considerably. It was agreed that including related action items in the plan would give them traction and support as it relates to possible funding applications (i.e., WaterSmart).

Further, the approach outlined here should not preclude a group of interested stakeholders in moving the idea forward as quickly as possible.

It is suggested that an independent group (a subset of the current stakeholder group possibly) begin work on development of a more detailed proposal.

There are some items that the coordination meeting attendees believe are essential to any program:

- The water market must be a truly cooperative, voluntary effort among groundwater users, surface water users, and state and federal partners
- The program supports water conservation
- Assumptions should be tested with a pilot program.

The goal of the feasibility work and pilot program implementation is to provide information to users about the risks and costs associated with the program. Users need to determine from the results of the pilot if the concept is good for them personally and for the basin as a whole. There is likely money available to support this effort. A joint application for WaterSmart funds between an irrigation district and an NRD with state and federal support is likely the best idea.

In terms of where to start, there are a number of questions to be answered. An understanding of current practices of buying/selling/trading water in the Basin will help guide or contribute ideas to water market feasibility efforts.

> The idea Aaron Thompson initially proposed during a stakeholder meeting can be summarized as: *Establish a pilot water market within the Basin. To simulate the entire Basin, it is suggested that the pilot have a 10:1 ratio of groundwater and surface water users. The pilot area will receive the same allocation. The pilot area will be allocating the supply not the shortage. To enter the "water exchange" or "water pool" a transaction cost will be paid by everyone in the exchange. Those in the exchange that do not have access to the entire allocation will be paid a stipend by the exchange. For example, if the allocation is 10" and someone only has an 8" supply the exchange will compensate the 2" difference with dollars or wet water. The exchange will then ask for willing buyers and sellers. Limits will be established on the amounts that can be bought and sold.*

Questions to Guide Initial Discussion

The questions below are intended to be a starting point for continuing discussion on program feasibility and program design:

1. Who holds the money and administers the program?
2. Who does the accounting?
3. How would the value of water be determined?
4. How would allocations be determined?
5. Can surface water allocation move to a groundwater user? Vice versa?
6. How does the water market system work with already established compact accounting procedures?
7. What is the appeal of the water market to a groundwater user?
8. Can it work as a surface water only market?

9. Is this really an opportunity to purchase offsets for a depletion? The offset of depletion appears to be the most marketable item. Should this be a market where people are basically buying offsets for depletion? It is simpler and may be a market some users would have an incentive to participate in.

The Prospect of a Pilot Program

A pilot program may be beneficial in testing the results of the feasibility study. The pilot could be either virtual or physical. In any case, the pilot should mirror the groundwater to surface water ratio of the Basin as a whole. A ratio of 10:1 groundwater to surface water users might be reasonably appropriate. Should the decision be to implement a pilot program, it would be helpful to have the pilot area within a single NRD.

The Red Willow Basin might be good pilot area candidate.

Other Resources

1. The Murray-Darling Basin in Australia is an example of a market of this kind, although it isn't clear that it covers both ground water and surface water. It may be a helpful template for developing the idea of a Water Market for the Republican Basin.
2. The Palo Verde, California groundwater/surface water system may also be a valuable example.
3. The Tucson/Phoenix, Arizona municipal water supply exchange might also have some relevant features.

Appendix H. 2018-2022 Allocation Summary

Section Overview

This appendix summarizes the natural resources districts' (NRDs') current allocations as of the effective date of the Republican River Basin-Wide Plan.

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Groundwater Allocations, Summarized

Republican NRDs' Allocations for Groundwater Irrigation Use[8]				
	2018-2022 Allocation Period			2018-2020 Allocation Period
	Upper Republican NRD	**Middle Republican NRD**	**Lower Republican NRD**	**Tri-Basin NRD (Allocations in effect ONLY in Phase 3 GQMA Union Twp)**
Total Allocation	65 Inches/Acre/5 Years	60 Inches/Acre/5 Years	45 Inches/Acre/5 Years	27 Inches/Acre/3 Years
Annual or Base Allocation	Allocation is over 5 Years, not annual	12 Inches/Acre/Year	9 Inches/Acre/Year	9 Inches/Acre/Year
Maximum Annual Use	65 Inches/Acre	60 Inches/Acre (15 Inches/Acre in a Compact Call Year)	45 Inches/Acre (13 Inches/Acre in a Compact Call Year)	27 Inches/Acre
Carry over amount that can be used in the following allocation period	7.5 Inches/Acre (Max)	12 Inches/Acre (Max)	9 Inches/Acre (Max)	9 Inches/Acre (Max)
Hard Cap	None	15 Inches/Acre/Year[9]	13 Inches/Acre/Year (in a Compact Call Year)	None
Pooling allowed?	Yes	Yes	Yes	Yes

[8] Information shown as provided by the NRDs
[9] MRNRD Rules do not use the term "hard cap"

Republican NRDs' Allocations for Groundwater Irrigation Use[8]				
	2018-2022 Allocation Period			2018-2020 Allocation Period
	Upper Republican NRD	**Middle Republican NRD**	**Lower Republican NRD**	**Tri-Basin NRD (Allocations in effect ONLY in Phase 3 GQMA Union Twp)**
How are the allocations affected by surface water use?	Allocations are not affected by surface water use. Irrigators may use their full groundwater allocation, regardless of any surface water use.	Allocations are not affected by surface water use. Irrigators may use their full groundwater allocation, regardless of any surface water use.	Allocations are not affected by surface water use. Irrigators may use their full groundwater allocation, regardless of any surface water use.	Allocations are not affected by surface water use. Irrigators may use their full groundwater allocation, regardless of any surface water use.
Special allocations for designated groundwater management areas? Or subbasins?	None	None	None	None
Rapid Response Area Allocations?	Not unless augmentation projects are insufficient to meet Compact obligations and Rapid Response Area allocations are needed. Allocations would depend upon projected Compact shortfalls.	None	See explanation below*	None
Penalty for exceeding allocation	For every inch of excess use, 2 inches of allocation lost for next allocation period.	See explanation below**	See penalty explanation below***	1.5 times the overuse amount
Penalty for exceeding carry over	2 inches carry-over deducted for every inch of carry-over used above 7.5 inches	For every inch of carry-over use in excess of 7.5" total during the allocation period, 2 inches of carry-over subtracted from remaining carry-over.	See penalty explanation below***	1.5 times the overuse amount

***Lower Republican NRD Rapid Response Area Allocations:**

During Non-Compact Call years, the Rapid Response Area has the same Allocation as the rest of the District. During a Compact Call Year, the Allocation shall be set at the maximum allowable that would not cause the District's depletions to streamflow to exceed the District's allowable Ground Water depletions after taking into consideration other actions and controls that the District would implement. As set forth in the IMP, DNR will perform all calculations relating to the District's forecasted allowable Ground Water depletions, forecasted depletions, and potential yield from implementing actions and controls.

****Middle Republican NRD Penalty for exceeding allocation:**

If an operator has exceeded his or her allocation, the allocation for the next allocation period shall be reduced by the number of acre inches, by which said allocation was exceeded in the prior period. A penalty of 1 inch for every inch over the first 3 inches and 2 inches for every inch over 3 inches of overuse will be applied.

Overuse of the adjusted base allocation during a Compact Call Year shall result in a penalty of 2 inches for every inch over the first 3 inches and 3 inches for every inch over 3 inches of overuse will be applied. This penalty will result in a correction to the remaining allocation following the compact call year. This penalty shall be in addition to the penalties imposed by 5-4.16 if the compact call year is the last year of an allocation period.

*****Lower Republican NRD Rule 3-2 Penalties:**

3-2.1. Unless otherwise provided, imposition of penalties shall be at the discretion of the Board and may include, but are not limited to:

(a) A reduction (in whole or in part) of a Person's Allocation of Ground Water;
(b) A reduction (in whole or in part) of a Person's Certified Irrigated Acres; and
(c) Decommissioning of Water Wells.

3-2.2. Where penalties are enumerated in the Rules and Regulations, the Board may impose additional penalties, up to and including a permanent forfeiture of Certified Irrigated Acres, and/or a permanent forfeiture of all future Allocations, under the following circumstances: (1) previous violations of any Rule or Regulation, (2) multiple violations of these Rules and Regulations, (3) engaging in willful and wanton misconduct, or (4) certification by the record owner to the District of the non-irrigation status of certain Certified Irrigated Acres in order to opt-out of an Occupation Tax levied by the District, which status is later found to be false in whole or in part.

3-2.3. Any Person who violates a cease and desist order issued by the District pursuant to *Neb. Rev. Stat.* § 46- 707(h) may be subject to a civil penalty assessed pursuant to *Neb. Rev. Stat.* § 46-745.

NRD Terminology, Defined

Allocation

Upper Republican NRD:
Water use allowed over a 5-year period on a per-acre basis.

Middle Republican NRD:
The total amount of ground water granted by the Board to a ground water user within the allocation period. For purposes of allocated certified irrigated acres within a certified irrigated tract, this amount includes the base allocation and the allowable carryover from the prior allocation period; *Neb. Rev. Stat.* § 46-706(15).

Lower Republican NRD:
Rule 2-2 (Allocation) As it relates to water use for irrigation purposes, means the allotment of a specified total number of acre-inches of irrigation water per certified irrigated acre assigned to that Regulated Water Well over the Allocation Period. As it relates to other purposes, the allotment of a determined quantity of Ground Water. Rule 2-4 (Base Allocation) An amount of Ground Water, in acre-inches, derived from dividing the Allocation by the Allocation Period.

Tri-Basin NRD:
Rule 8.5.2. Phase 3 GQMA (Union Twp.).

Carry-over

Upper Republican NRD:
Unused allocation from previous allocation periods.

Middle Republican NRD:
Any unused portion of an allocation as set by the Board that can be carried forward to the subsequent allocation period. Maximum carryover is equal to next base allocation

Lower Republican NRD:
Rule 2-9 (Carry-Forward) That part of an Allocation that is unused during the base Allocation Period, which may be credited to a subsequent Allocation Period in accordance with District Rules and Regulations.

Hard Cap

Middle Republican NRD:
With the designation of a Compact Call Year by the Nebraska Department of Natural Resources, the allocation for that calendar year will be restricted to 15 inches. (Note: The MRNRD does not call this a hard cap in their Rules and Regulations)

Pooling

Middle Republican NRD:
The common management of all or part of the certified acres and the associated allocation by two or more persons.

Lower Republican NRD:
Rule 2-43 (Pooling Agreement) An agreement approved by the District between two or more Landowners for the purpose of allocating ground water among the total combined Certified Irrigated Acres identified in such agreement. Rule 2-44 (Pooling Arrangement) An arrangement approved by the District by a single landowner to combine more than one tract of land under common ownership for the purpose of allocating Ground Water among the total combined Certified Irrigated Acres identified in the arrangement.

Tri-Basin NRD:
TBNRD Rules 8.5.7-8.5.7.15

Appendix I. Riparian Evapotranspiration and Removal of Invasive Vegetation

Section Overview

This document outlines efforts to control and remove invasive vegetation in the Republican River Basin (Basin) as it relates to Objective 4.2 of the Republican River Basin-Wide Plan (Plan) (page 43). Objective 4.2 and Action Item 4.2.1 of this Plan relate to removing undesirable riparian vegetation impacting water conveyance and managing reinfestation. This appendix provides background information about the relationship between removal of invasive vegetation and evapotranspiration, which should be considered as part of decisions related to the removal of invasive riparian vegetation from streams.

This appendix includes a summary of studies and other information about using removal of phreatophytic vegetation along streams (i.e., riparian vegetation) for water conservation. Phreatophytes are deep-rooted plants that obtain a portion of their supply from groundwater, and they comprise a large portion of riparian vegetation in the Basin. As such, phreatophytes have the ability to extract a large volume of water from groundwater. Removal of phreatophytic vegetation from riparian areas for water conservation should be assessed on a cost-benefit basis relative to other potential water conservation activities. This summary contains information about the costs and potential benefits of riparian vegetation removal.

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Brief Summary of Phreatophyte Studies

Phreatophytes are deep-rooted plants that obtain a portion of their water supply from groundwater. Phreatophytes comprise a large portion of riparian vegetation in the Basin. They include cottonwood, salt cedar, Russian olive, and phragmites. Due to the large role of riparian evapotranspiration (ET) in watershed-scale water budgets, phreatophytic vegetation removal is often proposed as a means of water conservation. The amount of water savings from phreatophytic vegetation removal depends on several factors, including:

- Transpiration rates of the vegetation removed,
- Depth of the groundwater table,
- Transpiration rates of the regrowth,
- Change in evaporation rate from microclimate changes, and
- Change in hydrologic conditions from ground cover removal and soil disturbances from the removal process.

In addition, the cost-benefit factor of vegetation removal and maintenance must be weighed against other water conservation activities. The following sections summarize relevant studies addressing these factors.

Phreatophyte Studies

Davenport et al.[10] found that while the mean evapotranspiration rate per unit leaf area is very similar for several phreatophytes, ET per unit land area can differ substantially based on the density of vegetation rather than species. For instance, the mean ET value for salt cedars in June was approximately 0.32 inches per day. Phreatophyte control application on salt cedars initially reduced ET by approximately 20 to 35 percent but the reduction was only 10 percent in the subsequent months in response to the understory growth. Culler et al.[11] reported that phreatophyte removal from river floodplains in Arizona reduced phreatophyte consumption of water from 43 inches per year by up to 19 inches per year; however, the reduction in transpiration did not translate into an increase in river flows as replacement vegetation was reestablished over the floodplain. Welder et al.[12] also documented a similarly low increase in river flows because replacement vegetation transpired an equivalent volume of water. Wilcox et al.[13] also found that conversion (removal) of salt cedars in riparian areas in favor of short-root vegetation may increase water yield by 1.5 to 3.1 inches per year in only small catchments.

Szilagyi et al.[14] estimated that in the Nebraska Sand Hills, the evapotranspiration rate of Ponderosa pines that are introduced to the area can exceed annual precipitation rate by 5 to 10 percent; however, it is also worth noting that the discussion of evapotranspiration should consider the

[10] Davenport, D. C., Anderson, J. E., Gay, L. W., Kynard, B. E., Bonde, E. K., Haga. R. M. (1979). "Phreatophyte evapotranspiration and its potential reduction without eradication." *Journal of Amer. Water Resources* 15, 5:1293-1300. doi:10.1111/j.1752-1688.1979.tb01128.x.

[11] Culler, R.C., Hanson, R. L., Myrick, R.M., Turner, R.M. and Kipple, F.P. (1982). "Evapotranspiration before and after clearing phreatophytes, Gila River floodplain, Graham Co., Arizona." U.S. Geological Survey, Professional Paper 655-P.

[12] Welder, G.E. (1988). "Hydrologic effects of phreatophyte control. Acme-Artesia reach of Pecos River, New Mexico" 167-82. U.S Geological Survey Water-Resources Investigation Report 87-4148.

[13] Wilcox, B. P., and T. L. Thurow (2006), "Emerging issues in rangeland ecohydrology: Vegetation change and the water cycle" *Rangeland Ecol. Manage*., 59, 220–224, doi:10.2111/05-090R1.1.

[14] Szilagyi, J., Zlotnik, V.A., Gates, J.B., Jozsa, J., (2011). "Mapping mean annual groundwater recharge in the Nebraska Sand Hills" *USA. Hydrogeol. J.* 19, 1503–1513. doi:10.1007/s10040-011-0769-3.

separate processes of evaporation and transpiration. The evaporation component will occur regardless of the presence of trees and may, in fact, be greater in grasses and open spaces than in the tree stands due to the shade provided by tree canopies. In a wetland, for example, Burba et al.[15] found that evapotranspiration rates were up to 17 percent lower than open water evaporation rates. Transpiration rates, on the other hand, have been documented to vary based on the depth to water table and the root depth of the species, which can provide access to water from deeper sources.

Transpiration Rates of Phreatophytes

Phreatophytic vegetation typically consumes more water than other terrestrial vegetation due to nearly constant access to water from the capillary fringe or saturated zone. The Nebraska Department of Natural Resources (Technical Report Number 2008-01) compiled annual consumptive water use volumes from various studies in the West and Midwest U.S. and Canada (Table I.1). Consideration must be given to the transpiration rate of the vegetation population proposed for removal and the potential vegetation regrowth at the site. Flowering rush, phragmites, and salt cedar are considered invasive species or noxious weeds with established populations in Nebraska. These species compete with and crowd out existing vegetation, form dense stands and use water while restricting streamflow in riparian areas (Nebraska Invasive Species Program website 2017). Water savings from the reduction of transpiration will depend on which species is present, the potential spread or encroachment of non-native, invasive species to the cleared area, and the continued maintenance of any population.

[15] Burba, G.G., Verma, S.B., Kim, J. (1999). "A comparative study of energy fluxes of three communities (*Phragmites australis, scirpus acutus*, and open water) in a prairie wetland ecosystem." *Wetlands*19:452-457.

Table I.1. Ranges of annual consumptive water use by common riparian and wetland vegetation, modified from Nebraska Department of Natural Resources.[16]

Common Name	Annual Consumptive Use (inches)
Arroweed	96
Cattail	35-198
Cottonwood	39.3-92.7
Bermuda Grass	28.8-73
Phragmites	7.2-30.71
Salt Grass	6.2-48.8
Rush	20.8-86.6
Russian Olive	18.6-114.6
Salt cedar (Tamarisk)	11.8-86
Willow	13.2-47.8
Riparian Woodland	13.2-22.4

Microclimate Changes due to Vegetation Removal

Woody vegetation and dense grass stands provide a significant amount of shade to the underlying surface, which reduces surface heat storage and energy available for surface evaporation from riparian areas. Potential water savings from complete removal of vegetation from riparian areas has been found to be offset by an increase in surface evaporation. Mykleby et al.[17] studied the removal of phragmites from a wetland field west of Arapahoe, Nebraska. Results of the study suggested that transpiration savings during the year following phragmites removal, prior to significant regrowth, was reduced by approximately 60 percent due to the increase in surface evaporation.

[16] Nebraska Department of Natural Resources (2008). "Assessment of resources available to quantify non-beneficial consumptive water use by riparian vegetation in Nebraska." Technical report number 2008-01. http://www.dnr.ne.gov/Media/iwm/PDF/RipET_FINAL_1208.pdf

[17] Mykleby, P.M., J.D. Lenters, G.J. Cutrell, K.S. Herrman, E. Istanbulluoglu, D.T. Scott, T.E. Twine, C.J. Kucharik, T. Awada, M.E. Soylu, B. Dong (2016). "Energy and water balance response of a vegetated wetland to herbicide treatment of invasive *Phragmites australis*." *Journal of Hydrology* 539: 290-303. http://www.limno.com/pdfs/2016_Mykleby_Lenters_Cutrell.pdf

Hydrological Alterations from Vegetation Removal

The physical structure of vegetation plays a large role in the hydrology and water flow within a riparian area. Huddle et al.[18] summarize several studies on the relationship between the physical structure of vegetation and water flow in riparian areas and found that vegetation impacts vary between and within geographic regions and stream types. The vegetation structure can obstruct, facilitate, or divert water flow. Changing the vegetation structure of a riparian area has been found to have a variety of effects, including flooding and erosion due to removal of woody species, increased water flow pattern heterogeneity from vegetation colonization after a disturbance of the native vegetation, and limited surface water infiltration and fine sediment trapping, sustaining moisture levels in the upper soil profile, from proliferation of dense herbaceous cover.

Cost Assessment of Phreatophyte Removal

Several economic variables should be taken into account when assessing the cost factor of phreatophyte removal (Table I.2).

Table I.2. The potential costs and benefits of phreatophyte removal.

Costs	Benefits
Physical removal	Woody harvest return
Maintenance of clearing	Consumptive water savings
Hydrologic alterations	Hydrologic alterations
Loss of ecosystem services	

A wide range of values can be found for each of these and should be assessed for each project. For example, the cost of salt cedar removal can vary from less than $50 to several thousand dollars per acre as summarized by Huddle et al.[18] (Table I.3).

[18] Huddle, J.A., T. Awada, D.L. Martin, X. Zhou, S.E. Pegg, S.J. Josiah (2011). "Do invasive riparian woody plants affect hydrology and ecosystem processes?" *Great Plains Res* 21:49–71. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=2143&context=greatplainsresearch

Table I.3. Summary of the cost of salt cedar removal by treatment type from various studies, modified from Huddle et al.[18]

Salt cedar Treatment Type	Cost (US$/acre)
Helicopter herbicide application	$68
Fixed-wing herbicide application	$56
Cut-stump and herbicide application	$1,059
Foliar herbicide application	$344
Cut and sprayed with imazapyr	$506 ± $2,499
Aerial spray of imazapyr with and without glyphosphate; burning	$174 ± $57
Individual cut and spray imazapyr	$1,599 ± $2,499
Individual herbicide application or mechanical grubbing	$40 ± $300
Large-scale control methods	$409 ± $186

Nebraska legislative dollars have been appropriated for weed management, and are awarded to projects in the Basin by Nebraska Department of Agriculture (Table I.4). These projects have also used additional funding sources.

Table I.4. Legislative funding for weed management in the Basin by fiscal year.

Fiscal Year	Legislative Funding (US$)
2007-2008	$1,420,228
2008-2009	$1,119,000
2009-2010	$1,000,000
2016-2017	$100,000
2017-2018	$93,500

The Twin Valley Weed Management Area has been coordinating removal of salt cedar, phragmites, and Canada thistle around Harlan County Dam and downstream along the Republican River since 2006. Approximately $1.2 million has been invested in aerial and terrestrial herbicide applications, taking place each fall. Merle Illian, Project Coordinator, observed an annual decrease in the phragmites population around the dam and along the river since the project began in 2006 until an apparent population rebound in 2016 (conversation, Illian, 2017).

Platte Valley Weed Management Area and PRRIP, which has used vegetation control as a means of increasing conveyance and ecological enhancement, estimates approximately $85 to 105 per acre for aerial control of phragmites over the last five years and $120 to almost $500 per acre for airboat and land-based control methods of phragmites (correspondence, Walters, 2017).

Conclusion

Phreatophytes have the ability to extract a large volume of water from groundwater. Removal of phreatophytic vegetation from riparian areas for water conservation should be assessed on a cost-benefit basis. Consideration should be given to the type of vegetation to be removed and the potential regrowth, the depth to groundwater table, removal and maintenance procedures, and potential microclimate, biological, and ecosystem alterations before project initiation.