TO: PRRIP GOVERNANCE COMMITTEE
FROM: PRRIP EXECUTIVE DIRECTOR'S OFFICE
SUBJECT: SCORE RECOMMENDATION FOR ELWOOD RESERVOIR GROUNDWATER RECHARGE
DATE: AUGUST 27, 2019

The Program's Executive Director's Office (EDO) completed analyses and documentation for the scoring of the Elwood Reservoir Groundwater Recharge project in mid-2018. The Scoring Subcommittee was provided with materials to review and convened for conference calls to discuss and provide feedback to the EDO on July 26 and August 27, 2018. Draft documentation of the score analysis, including meeting minutes from the two conference calls, is provided in Exhibit A. The materials in Exhibit A are identical to the versions previously provided to the GC in September 2018. Additional documentation resulting from further review of the underlying groundwater modeling by the Program's EDO and the Nebraska Department of Natural Resources (DNR) is provided in Exhibit B.

<u>Elwood Reservoir Groundwater Recharge Project</u>
The Elwood Reservoir Groundwater Recharge project has operated since 2015 under a series of Water Service Agreements with the Central Nebraska Public Power and Irrigation District. The project diverts excess flows from the Platte River and pumps the water into Elwood Reservoir, where it seeps through porous soils to recharge the underlying groundwater aquifer. Recharged water returns to the Platte River over time through groundwater transport and baseflow accretion or interception by Plum Creek and delivery to the Platte River as surface water.

The Scoring Subcommittee recommended a score of 2,800 AFY for the Elwood Reservoir Groundwater Recharge project. This is based on a total available recharge capacity of 30,000 AF (total score of 5,600 AFY) and allocation of 50 percent to the Program. **The Scoring Subcommittee also recommends that the GC use Figure 5 in the Elwood scoring memo if it is necessary in the future to adjust the project score due to changes in available recharge capacity.**

<u>Further Review of Elwood Groundwater Modeling</u>
Following the completion of the draft score analysis for Elwood recharge, the Program's EDO worked with the Nebraska DNR to address a technical deficiency identified in one specific area of the underlying groundwater model. This effort involved a series of meetings between October 2018 and June 2019 and generated additional documentation to supplement the draft score memo. Both parties agreed to continue to assess and address the issue, and the Nebraska DNR agreed to move forward with the recommendation of the Scoring Subcommittee as a "provisional score," subject to future review and potential revision if deemed necessary due to modeling or operational changes.

EXHIBIT A

Elwood Reservoir Groundwater Recharge
Score Analysis Documentation

TO: PRRIP SCORING SUBCOMMITTEE
FROM: PRRIP EXECUTIVE DIRECTOR'S OFFICE
SUBJECT: ELWOOD RESERVOIR GROUNDWATER RECHARGE SCORING ANALYSIS
DATE: AUGUST 31, 2018

I. EXECUTIVE SUMMARY

The Platte River Recovery Implementation Program (PRRIP or Program) ad-hoc Scoring Subcommittee was formed to advance Water Action Plan (WAP) project scoring towards the Program's First Increment milestone of reducing shortages to U.S. Fish and Wildlife Service (USFWS) target flows by 50,000 to 70,000 acre-feet per year (AFY). The Scoring Subcommittee recommended a general methodology for calculating project score during the J-2 Regulating Reservoir score discussions, which the Program's Governance Committee (GC) accepted in 2010. The methodology was followed by the Scoring Subcommittee to score other WAP projects, including the Phelps County Canal Groundwater Recharge project and the Pathfinder Municipal Account Lease project. The Program's Executive Director's Office (EDO) provided technical assistance to the Scoring Subcommittee to score the Elwood Reservoir Groundwater Recharge project. The Program has been recharging water in Elwood Reservoir since 2015.

The Elwood Reservoir recharge project score analyses utilized the general methodology accepted by the GC in 2010 with additional assumptions made for this specific project. The lagged accretions reaching the Platte River from the recharge project were estimated using a site-specific unit response function developed for a locally recalibrated version of the COHYST numerical groundwater model. The analysis splits available excess flow between Program projects and other projects that use excess flows in the Central Nebraska Public Power and Irrigation District's (CNPPID) system.

During the scoring process, various alternatives described in this memorandum were considered for scoring the Elwood Reservoir recharge project. **The Scoring Subcommittee recommends a score for the Elwood Reservoir Groundwater Recharge project of 2,800 AFY for the Program.** The recommended score assumes a maximum recharge capacity of 30,000 AF, of which 50 percent (15,000 AF) is allocated to the Program[1]. **The Scoring Subcommittee also recommends that the GC use Figure 5 in this memorandum if it is necessary in the future to adjust the project score due to changes in available recharge capacity.**

II. INTRODUCTION

The Program's ad-hoc Scoring Subcommittee was originally formed in 2010 to advance discussions regarding scoring analyses for proposed WAP projects, at that time specifically for the J-2 Regulating Reservoirs project. The Program's EDO worked with the Scoring Subcommittee to develop a J-2 Regulating Reservoir Scoring Case Study[2]. Based on the findings

[1] The remaining Elwood Reservoir recharge capacity is allocated to the Nebraska Department of Natural Resources and the Tri-Basin Natural Resources District.
[2] "Water Action Plan Project Scoring Case Study: CNPPID Reregulating Reservoir" dated April 22, 2010 by the ED Office.

of the Case Study, the Scoring Subcommittee proposed a WAP project scoring methodology to the Governance Committee (GC)[3], and the GC approved the recommended methodology in June 2010[4]. The methodology approved by the GC was intended for use in future scoring of WAP projects to maintain consistency in project scoring. However, the Subcommittee and GC also recognized that additional assumptions and variations in the scoring methodology may need to be addressed on a case-by-case basis for other WAP projects.

To the extent possible, the EDO used the previously approved scoring methodology to complete preliminary scoring analyses for the Elwood Reservoir Groundwater Recharge Project. The EDO also identified additional scoring methodology questions requiring input from the Scoring Subcommittee specific to the current project. The purpose of this memorandum is to provide the Scoring Subcommittee with project scores using various alternatives, document the resolutions to questions pertaining to the scoring methodology, and document the Scoring Subcommittee's decisions regarding a recommendation for a final project score.

III. PROJECT DESCRIPTION

The following sections present an overview of Elwood Reservoir and its use for groundwater recharge by the Program.

A. Overview of Elwood Reservoir

Elwood Reservoir is a 37,800 acre-feet (AF) reservoir located in Gosper County, Nebraska, just north of the village of Elwood, Nebraska (see map in **Appendix A**). The reservoir was constructed in 1976 and is owned and operated by the Central Nebraska Public Power and Irrigation District (CNPPID) to augment irrigation supplies on the E-65 canal. It lies just south of the E-65 canal and is filled from the canal via the Carl T. Curtis Pump Station, which consists of three 300-horsepower pumps. The inflow rate into the reservoir depends on reservoir stage, with the pump efficiency decreasing as the reservoir stage increases and water has to be pumped to a higher elevation. When all three pumps are operating, inflows range from 275 cubic feet per second (cfs) at lower reservoir stages and about 170 cfs at higher stages. With only one pump operating the minimum inflow is 75 cfs. There are no substantial drainages that provide natural inflows into Elwood Reservoir. Releases from the reservoir flow by gravity back into the E-65 canal, and the reservoir does not release water to any natural surface water drainages. The reservoir has historically been filled in the spring and fall and released water for irrigation from May through September.

Elwood Reservoir typically operates between a maximum stage elevation of 2,607 feet, corresponding to a reservoir capacity of 37,800 AF, and the minimum operational stage of 2,567 feet as determined by the Carl T. Curtis Pump Station elevation and corresponding to a reservoir capacity of 12,100 AF. The 12,100 AF below the pump station elevation constitutes the reservoir's dead pool. While this water is not available for irrigation deliveries, water continues to seep out of the reservoir from the dead pool and it can be used for groundwater recharge

[3] Memo from Scoring Subcommittee to GC regarding "CNPPID Reregulating Reservoir Scoring Recommendation" dated May 12, 2010.
[4] See June 2010 GC Meeting Minutes.

purposes. The reservoir is unlined and the rate of seepage from the reservoir depends on the reservoir stage.

The only other inflows and outflows to or from Elwood Reservoir include precipitation, localized runoff, and evaporation. The nearest weather station to the Elwood Reservoir is located near Smithfield, NE, approximately 8 miles to the southeast. The station is part of the Automated Weather Data Network (AWDN) weather station network operated by the High Plains Regional Climate Center (HPRCC). The AWDN station has collected data since June 1995, including precipitation and reference evapotranspiration. Reference evapotranspiration is converted to free water evaporation by applying a factor of 0.91[5]. The annual average precipitation[6] and evaporation were determined over the June 1995 to March 2018 time period to include in the scoring calculations. While Elwood Reservoir does not receive any significant inflows from surface water tributaries, it will receive some localized runoff during precipitation events. The average monthly precipitation volume was increased by 10% to account for localized runoff based on an estimate of the localized drainage area. The average annual precipitation and runoff at the Smithfield AWDN weather station is 2.07 feet and the average annual free water evaporation is 4.82 feet. The net of these values (evaporation minus the sum of precipitation and localized runoff) is shown in **Figure 1** as the monthly average on a volumetric basis for the maximum area of Elwood Reservoir of 1,200 acres.

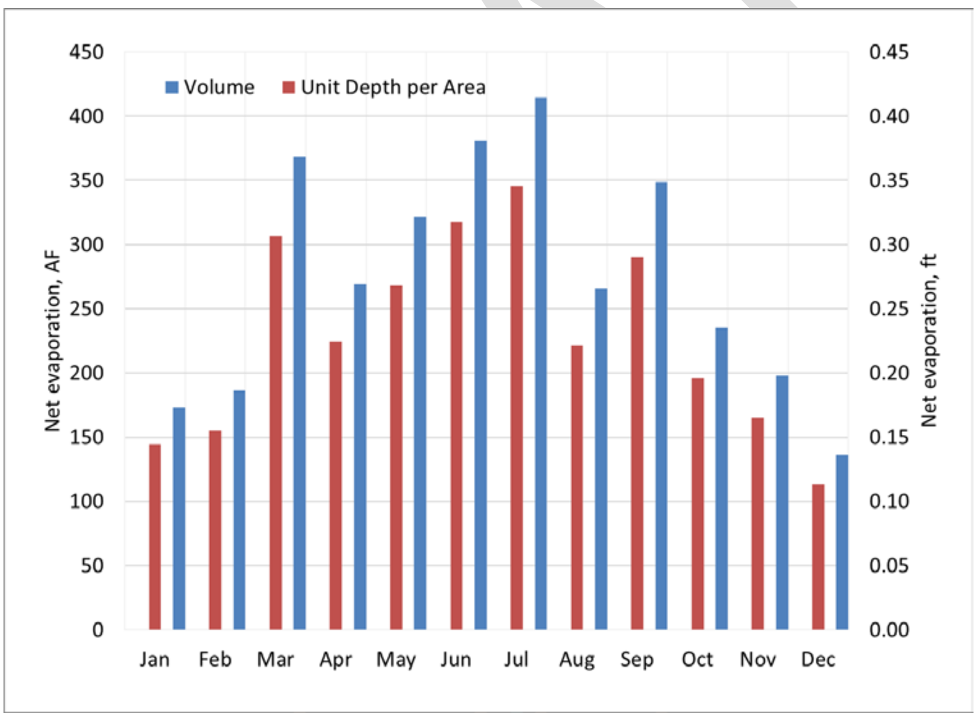

Figure 1. Maximum monthly net evaporation (=evaporation – precipitation) at the Smithfield, NE, AWDN weather station

[5] Funk Lagoon Water Action Plan Project Feasibility Report. 09/16/2015. Prepared by ED Office of the PRRIP. Draft for Review by the WAC.
[6] Tipping bucket style precipitation gages do not capture all solid (snow) precipitation, thus reported precipitation in winter months may be slightly lower than actually occurred.

B. Groundwater Recharge in Elwood Reservoir

Due to the reservoir's high seepage rates, the Program entered into a series of Water Service Agreements (WSAs) with CNPPID to divert excess flows into the Elwood Reservoir for intentional groundwater recharge beginning in 2015. The Program diverted a total of 29,400 AF into Elwood Reservoir for recharge through the end of 2017 under a series of temporary recharge permits from the Nebraska Department of Natural Resources (NDNR) that must be renewed annually. The most recent WSA and temporary recharge permit documents are included in **Appendices B1, B2 and B3**.

Over the past several years, the CNPPID has decreased its use of Elwood Reservoir for irrigation purposes from historical levels and expects this reduced usage to continue into the future[7]. This presents an opportunity for increased use of the reservoir for intentional groundwater recharge. The CNPPID currently expects to continue using the reservoir to provide approximately 9,000 AF of irrigation deliveries from June through August. The CNPPID plans to divert approximately 12,250 AF into the reservoir in April to allow for approximately 3,250 AF in losses that will occur between April and when the irrigation water has been fully released in August[8].

To deliver excess flows to the reservoir for groundwater recharge, excesses are captured at the Tri County Canal Diversion near North Platte, NE, and routed through the CNPPID canal system into the E-65 canal. Excess flows are then pumped into Elwood Reservoir via the Carl T. Curtis Pump Station. The stored excess flows seep into the aquifer below Elwood Reservoir over a period of months. The daily seepage rate depends on reservoir stage, with higher seepage rates occurring at higher stages and decreasing with reservoir stage. Seepage rates approach 120 AF/day when the reservoir is at its highest stage (2,607 ft, 37,800 AF) and decrease to 30 AF/day when the reservoir level is at or below its effective operational elevation. The average seepage rate from the reservoir is approximately 60 AF/day (30 cfs) over the typical operating range of the reservoir.

Elwood Reservoir lies near the groundwater divide between Republican River and the Platte River. The aquifer underlying the Elwood Reservoir is primarily made up of quaternary silts, sand and gravel with a hydraulic conductivity ranging from 20 to 100 feet per day[9]. Some of the water that seeps into the aquifer flows towards the Republican River while most of the water that seeps into the aquifer flows towards the Platte River, with about 76% of the water recharged in Elwood Reservoir eventually ending up in the Platte River. Water flowing to the Platte River can emerge as baseflow in the Platte River or may be intercepted by Plum Creek, a drainage that flows to the north of the reservoir, and flow to the Platte above ground. Recharge water travels slowly through the aquifer, with water beginning to arrive at Plum Creek approximately six months after it enters the aquifer or to the Platte as baseflow after about a year. Recharged water continues to slowly flow into Plum Creek and the Platte River for years after it is recharged.

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[7] Personal correspondence with Cory Steinke of the CNPPID on 3/22/2018

[8] Personal correspondence with Cory Steinke of the CNPPID on 3/22/2018

[9] Cannia, J., Woodward, D., and Cast, L. Cooperative Hydrology Study (COHYST) Hydrostratographic Units and Aquifer Characterization Report. 2/24/2006

The general assumptions used in the preliminary scoring analyses by the EDO are described in further detail in Section III. In addition, the EDO identified methodology issues requiring input from the Scoring Subcommittee, which are summarized in Sections IV and V.

IV. GENERAL METHODOLOGY

The EDO completed preliminary scoring analyses for the Elwood Reservoir Groundwater Recharge project, as shown in the map in **Appendix A**. The project score ultimately depends upon the Scoring Subcommittee's recommendations and GC approval.

The scoring analysis consists of two steps, a recharge analysis and a reduction of shortages to target flow analysis. The recharge analysis evaluates available excesses and Elwood Reservoir operations to determine the amount of water that can be recharged. The results of the recharge analysis are then used for the subsequent target flow deficit reduction analysis that lags groundwater returns to the river and routes them to Grand Island. The general scoring methodology and assumptions used for scoring of the Elwood Reservoir Groundwater Recharge project are listed in **Table 1**.

Table 1. Key Scoring Assumptions

Component	Data
Hydrology	OpStudy Adjusted Present Condition with Three State Projects (without pulse flows). EA flows included at Grand Island, but not available for recharge.
Analysis Period	1947-1994
Source of recharged water	Natural flows in excess of USFWS target flows (Excess flows)
Recharge Volume Time Step	Monthly (recharge operations)
Lagged Accretion Time Step	Monthly (reductions to shortages)
Excesses/Shortages Calculation	@ Grand Island
Target Flows	Appendix A-5, Column 4 or 8, depending on daily/monthly time step[10]
Routing	WMC Loss Model[11]
Accretion Modeling Method	Return flow curve developed from numerical model[12]

Various scoring assumptions were evaluated in the preliminary scoring analysis, resulting in a range of potential scores for the Scoring Subcommittee to consider. For the various alternatives, the EDO completed the preliminary scoring analyses using a monthly time step.

A. Reservoir Recharge Analysis

The first step in the Elwood Reservoir groundwater recharge project score analysis involves determining the volume of water that can be recharged in the reservoir on a monthly basis. Four

[10] Based on Column 4 or 8 of Appendix A-5 in Attachment 5 of the Program Document. Column 4 = target flows in "cfs" were used for the daily analysis. Column 8 = target flows in "average cfs" were summed on a monthly basis and converted to acre-feet as a monthly target flow volume in the scoring model.
[11] WMC Loss Model is referenced in the Water Management Study (2008) by Boyle Engineering Corporation.
[12] COHYST 2010 MODFLOW model with localized recalibration by Hahn Water Resources, ED Office Special Advisor.

factors determine the amount of water that can be delivered to the Elwood Reservoir for groundwater recharge, including the available excesses, the capacity of the pumps at the Carl T. Curtis pump station, the annual recharge capacity in Elwood Reservoir, and the storage space available in Elwood Reservoir.

1. Available excesses

The source of recharge water for this project is excess flows, or water in the Platte River at Grand Island that is in excess of the USFWS target flows. The Elwood Reservoir is fed by the E-65 canal which diverts water from the CNPPID's Tri-County Supply Canal just upstream of the Johnson Reservoir. Therefore, the scoring analysis only considered excess flows available within the CNPPID system as calculated at the J-2 Return. Similar to the Phelps County Canal Groundwater Recharge scoring analysis, hydrology from the OpStudy "Adjusted Present Condition with Three States Projects, without Pulse Flows" model run for 1947 to 1994 was used as the basis for the Elwood Reservoir Groundwater Recharge scoring analysis. Flows at the J-2 Return were used to determine the amount of water available to divert down the E-65 canal.

Flow contributions from Lake McConaughy Environmental Account (EA) releases were included when calculating excesses and shortages to target flows at Grand Island because EA water can influence the amount of shortage that needs to be met by other Program water projects. However, EA flows estimated to be present in the J-2 Return[13] were excluded from the excess flows available for recharge purposes, which is consistent with the Phelps County Canal scoring analysis. Excess flows identified at Grand Island also had to be physically available in the OpStudy modeling of the J-2 Return in order to be diverted into the E-65 Canal and Elwood Reservoir for recharge purposes. The groundwater recharge project was modeled using a monthly time step due to the delayed nature of groundwater return flows and accretion modeling considerations.

The determination of excess flows available for recharge is based on the greater of the USFWS target flows and instream flow rights held by Central Platte Natural Resources District and Nebraska Game and Parks Commission. A monthly summary of excesses and shortages to target flows at Grand Island is provided in **Appendix C**.

While it may be possible for the Elwood Reservoir groundwater recharge project to use other sources of water to recharge, such as water from the Lake McConaughy EA, the scoring analysis only considers excess flows. The amount of water to be recharged cannot exceed the amount of excess flows available at the E-65 canal.

2. Excess prioritization

Several projects along the CNPPID canal system compete for excess flows for groundwater recharge or other purposes. The Program has three WAP projects operating or in development along the CNPPID system to recharge excess flows, including the Phelps County Canal groundwater recharge project, the Cottonwood Ranch broad-scale recharge project, and the

[13] EA flow in the J2 Return is not an OpStudy output. Monthly values were estimated by subtracting the EA volume at Overton from the EA volume at Cozad. The difference was assumed to have been returned to the river through the J2 Return.

Elwood Reservoir groundwater recharge project. The NDNR and Tri-Basin Natural Resources District (NRD) also have contracts with the CNPPID for recharge in Elwood Reservoir. The CNPPID outlined its prioritization plan for delivery of excess flows to all of the projects along its canal system in Exhibit F of the WSA for delivery of water to Cottonwood Ranch, included in **Appendix B4**. In order to make deliveries to all of the excess flow projects, the Phelps County and E65 canals must divert a minimum of 30 cfs and 10 cfs, respectively. Any excess flows above these baseline diversions would be divided equally between projects, with the caveat that there must be enough excesses to meet the 75 cfs minimum pumping capacity to divert water into Elwood Reservoir.

3. Carl T. Curtis Pump Station Capacity

Another limitation on the amount of water that can be recharged in Elwood Reservoir is the amount of water that can be pumped into the reservoir. The Carl T. Curtis Pump Station is comprised of three pumps with a maximum capacity of 275 cfs. The scoring analysis assumed a daily pumping rate of 250 cfs to determine the total monthly volume of water that could physically be pumped into the reservoir for both recharge and irrigation purposes. This rate approximates the average pumping rate based on the reservoir stage in the scoring model. **Figure 2** below compares the range of constant pumping rates, from 150 cfs to 250 cfs with the average pumping rates based on reservoir stage and CNPPID's pump curve for three different diversion cap scenarios. In all cases, the rates are near or above 250 cfs, suggesting this constant value is an appropriate choice for the scoring model.

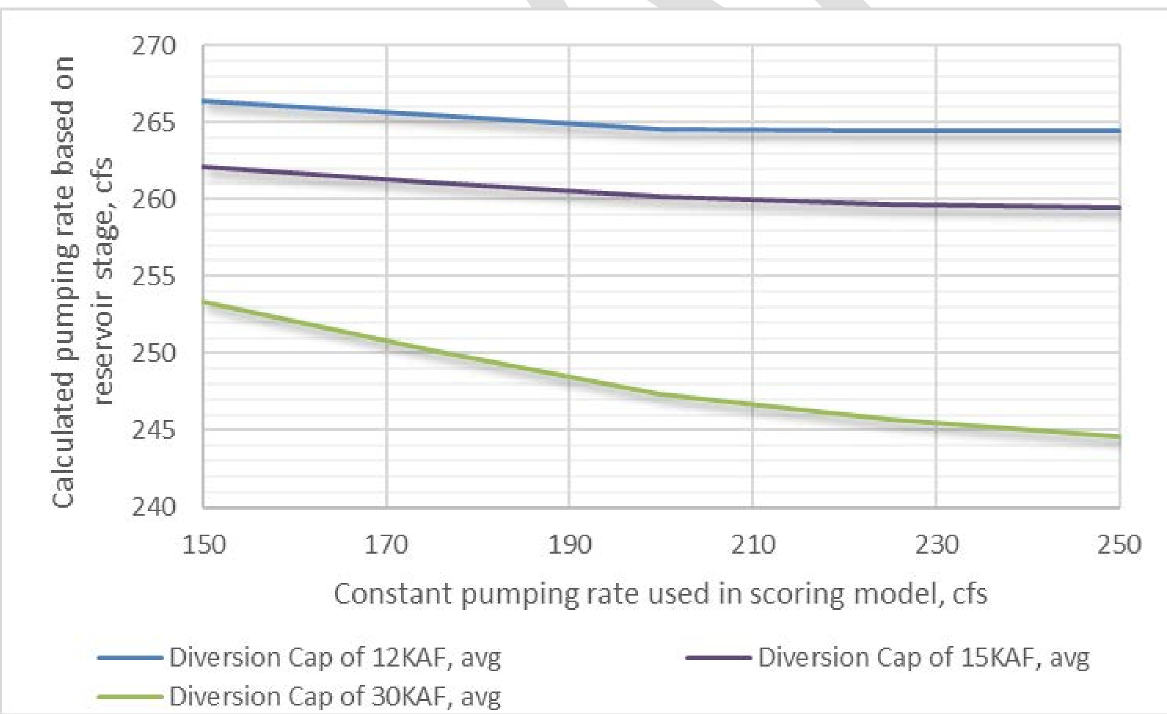


Figure 2. Calculated vs. constant pumping capacity

The pumping capacity for recharge is limited in months that the CNPPID pumps into the reservoir for irrigation purposes. Available space in the E-65 Canal also limits the amount of excess flows that can be diverted during the irrigation season. It is assumed that the canal is filled to the operational capacity of 350 cfs for irrigation from June through August and that no water is available to pump into Elwood Reservoir for Program recharge during those months.

4. Annual recharge diversion capacity

The temporary water service agreement between the Program and the CNPPID includes an annual cap on the volume of water that can be diverted for recharge into Elwood Reservoir. A cap of 8,000 AF was defined in the initial 2015 WSA and increased to 12,000 AF in January 2018 with an amendment (**Appendix B2**) to the October 2017 WSA (**Appendix B1**) between the Program and CNPPID for Elwood Reservoir recharge. The scoring analysis accounts for the cumulative annual recharge for each year and ensures that this does not exceed the annual recharge cap. A higher cap allows for a greater project score as more water can be recharged each year. The scoring analysis considers a range of annual recharge diversion caps, from 8,000 AF to 42,000 AF.

5. Storage Space available for recharge water

The amount of water that can be recharged in Elwood Reservoir is also constrained by how much storage space remains in the reservoir for any given month. While in the past the reservoir was filled in the spring and fall and used for irrigation deliveries throughout the summer, the CNPPID intends to reduce its use of the reservoir and only fill it in the spring. **Table 2** presents simulated likely future reservoir operations by CNPPID[14]. This scoring analysis repeats this expected reservoir operation scheme for every year to represent the CNPPID's use of the reservoir. The reservoir can only accommodate water for recharge if there is space in the reservoir in addition to that required by the CNPPID.

Table 2. Simulated CNPPID Annual Reservoir Operations, in thousands of acre-feet (KAF)

Month	Simulated CNPPID Elwood Inflows	Simulated CNPPID Elwood Releases	Simulated CNPPID Elwood Seepage	Simulated CNNPID Elwood Evap loss	Simulated CNPPID End of Month Storage
Jan	-	-	-	-	-
Feb	-	-	-	-	-
Mar	-	-	-	-	-
Apr	12.23	-	0.89	0.09	11.25
May	-	1.00	0.81	0.09	9.35
Jun	-	2.00	0.65	0.07	6.63
Jul	-	3.00	0.58	0.04	3.00
Aug	-	3.00	-	-	0.00
Sep	-	-	-	-	-
Oct	-	-	-	-	-
Nov	-	-	-	-	-
Dec	-	-	-	-	-
Annual Total	12.23	9.00	2.94	0.29	

[14] Based on personal correspondence with Cory Steinke of the CNPPID on 3/22/2018

In addition to the CNPPID's irrigation water storage in the reservoir, the storage space filled with water to be recharge from previous months factors into reservoir storage calculations. The end of month reservoir content is compared to the reservoir capacity as well as the upcoming space need by CNPPID for irrigation. The scoring analysis tracks the amount of CNPPID and recharge water present in the reservoir for each month and accounts for seepage from each pool of water as a share of the total volume. Seepage rates from the reservoir are determined using the loss curve for Elwood Reservoir provided by the CNPPID. The seepage rate depends on the reservoir elevation, as shown in **Figure 3** (note the inverted y-axis, with zero at the top and reservoir losses increasing downward).

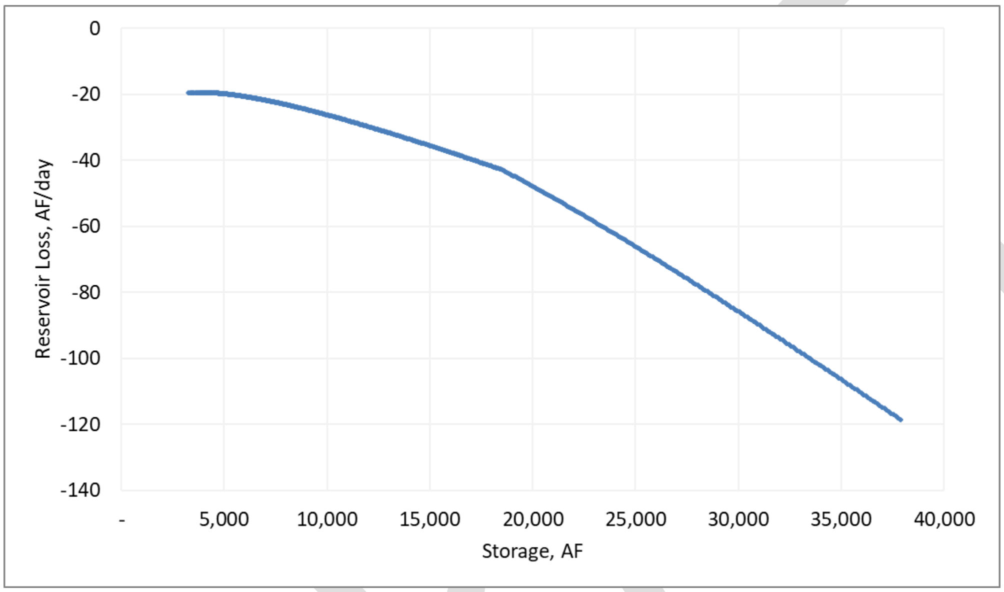


Figure 3. Elwood Reservoir Loss Curve (source: CNPPID)

6. Recharge analysis calculations

The calculations of water available for recharge take the limitations discussed above into account by identifying which of the four factors limits the amount of water that can be recharged in a given month. The calculation used in the analysis determines the minimum of the available excess flow, the monthly total pump capacity at the Carl T. Curtis Pump Station, the difference between the annual recharge cap and the current year's cumulative recharge, or the current month's available storage space. For example, if there are 5,000 AF of available excess flows in a given month but there is only 2,000 AF of available storage space in the reservoir, the volume of water diverted for recharge that month will be 2,000 AF. If a given month does not have any available excess flows, no water will be recharged for the month.

B. Reduction to Target Flow Shortages Analysis

Once the quantity of water to be recharged each month is calculated, the next steps in the scoring analysis are to calculate when and how much of this water arrives at the Platte River as "river accretions," route the accretions to Grand Island, and determine what portion of the accretions serve to reduce shortages to target flows.

1. Lagged accretions at the river

The recharge of the underlying aquifer that results from reservoir seepage eventually enhances flows in the Platte River, and is referred to as the “river accretion.” The timing of river accretions is dependent on aquifer characteristics, the distance between the point of recharge and the river, and the degree to which recharged water is intercepted by intervening surface water features such as Plum Creek. River accretions to the Platte River resulting from recharge in Elwood Reservoir were estimated using a return flow function developed using the MODFLOW groundwater model developed as part of the COHYST integrated model[15]. The return flow function was developed in conjunction with Hahn Water Resources (Special Advisor) and is described in further detail in **Appendix D**. The return flow function identified the percentage of recharged water that returns to the Platte River (either directly to the Platte or first to Plum Creek then to as surface flow to the Platte) on a monthly basis. Monthly volumes of recharged water were passed through the return flow function to determine the quantity and timings of river accretions for the scoring analysis. The return flow function is shown in **Figure 4**, with the total percentage of returns shown in red and the corresponding percentage of Platte River and Plum Creek returns shown in green and blue, respectively.

Groundwater drains lying between Elwood Reservoir and the Platte River may also intercept some of the recharged water; however, interception of recharged water by groundwater drains is not expected to have a significant impact on the timing or magnitude of water arriving at the Platte River considering the monthly timestep of the scoring analysis and the close proximity of groundwater drains to the Platte River.

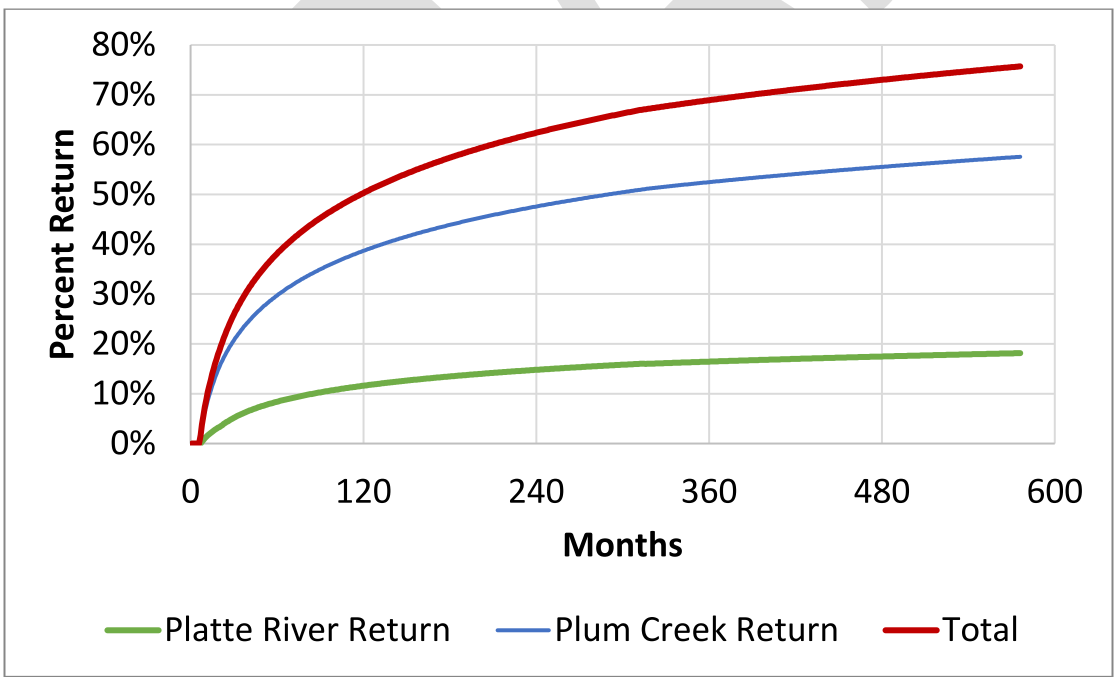


Figure 4. Return flow function for water recharged in Elwood Reservoir.

[15] COHYST 2010: A Total Water Budget Approach to Integrated Water Management in the Platte River Nebraska. June 2017. *cohyst.nebraska.gov*

The percent of water that returns to the Platte River via Plum Creek or directly to the Platte approaches 76%. The remaining 24% of recharged water eventually flows to the Republican River basin.

2. Routing of lagged accretions to Grand Island

The Elwood Reservoir groundwater recharge yield[16] accruing to the river was entered into the preliminary scoring model and routed to Grand Island using transit loss factors derived from the WMC Loss Model. As with the scoring of the Phelps County Canal Groundwater Recharge project, the WMC Loss Model was used to calculate the loss per mile for each month for water years 1975 – 2006. The transit losses were calculated for the Overton to Grand Island reach as all of the recharged water enters the river above Overton. The transit loss factors were applied to the river accretions to determine the volume of flow reaching Grand Island. On average, approximately 88% of recharge accretions reach Grand Island, or 12% per month is lost in a normal year due to routing. The percentage of water arriving at Grand Island was then averaged by month and year type as shown in **Table 3**.

Table 3. Average Percentage of River Accretions at Overton Reaching Grand Island, based on WMC Loss Model

Month	Wet Yr	Normal Yr	Dry Yr
Jan	89%	89%	85%
Feb	92%	93%	91%
Mar	98%	97%	95%
Apr	96%	97%	95%
May	97%	95%	94%
Jun	96%	93%	68%
Jul	96%	79%	41%
Aug	88%	77%	27%
Sep	84%	74%	36%
Oct	91%	84%	54%
Nov	92%	87%	74%
Dec	92%	88%	85%
Avg	**93%**	**88%**	**70%**

3. Reductions to target flow shortages

River accretions arriving at Grand Island are used in conjunction with monthly target flows (listed in Column 8 of Appendix A-5 of the Program Document, a monthly summary of excesses and shortages to target flows at Grand Island is provided in **Appendix C**) and the monthly river flow at Grand Island from the OpStudy Hydrology ("Adjusted Present Condition with Three States Projects, without Pulse Flows" model run for 1947 to 1994). River accretions arriving at Grand island when the Grand Island monthly flow volume is below the monthly target flow volume counted as reducing deficits while accretions arriving when Grand Island monthly flow

[16] The yield refers to the amount of recharge at the river. Note that the score is the portion of the yield routed to Grand Island that occurs during shortages to USFWS target flows.

volumes exceeded the monthly flow volume did not. The projects score is determined by summing the volume of river accretions that reduced deficits to target flows on an annual basis and averaging the annual totals over the 1947-1994 analysis period.

V. OTHER SCORING ASSUMPTIONS

The EDO requested that the Scoring Subcommittee review the assumptions and policy considerations outlined in this section and provide input to the EDO. The Scoring Subcommittee's recommendations were used to finalize the Elwood Reservoir groundwater recharge scoring analysis, and ultimately used to assign a final project score contribution towards meeting the Program's First Increment Water Objective. In addition, the methodology considerations addressed by the Subcommittee may be incorporated into the scoring of future WAP projects.

A. CNPPID Operations

The assumptions underlying the simulated CNPPID operations of Elwood Reservoir impact the storage space in the reservoir that is available for recharge use and thus the project score. The current simulated operational scheme does not vary from year to year to account for varying irrigation demands during wet or dry years. The operational scheme does not account for future increased or decreased use of the reservoir for irrigation purposes.

B. Sharing Water with Program Partners

As noted in the WAP, a Nebraska-based Program partner, such as Tri-Basin NRD, may use a portion of the river accretions resulting from groundwater recharge for addressing Nebraska New Depletion Plan (NNDP) requirements. Both the Tri-Basin NRD and the NDNR have entered into separate water service agreements with the CNPPID to recharge water in Elwood Reservoir, with their combined total recharge varying from less than 3,000 AF annually up to 15,000 AF, with an annual average of approximately 7,500 AF.

As use of Elwood Reservoir for groundwater recharge increases, the Program will work with its partners to develop an equitable approach to sharing the available space for groundwater recharge in the reservoir. This may take the form a joint water service agreement between the Program and its partners or separate agreements for each entity. If separate water service agreements are pursued, the annual recharge diversion cap will limit the amount of water the Program can recharge in the reservoir and ensure that other entities have access to available space in the reservoir. While the Program's current WSA with CNPPID for Elwood Reservoir groundwater recharge specifically caps billings to the Program at 12,000 AFY (without consent from the Program to exceed), the Scoring Subcommittee assumed 50 percent of the total recharge capacity is available to the Program.

C. Annual Recharge Diversion Cap

The annual cap on diversions for recharge set in the most recent water service agreement[17] with the CNPPID is 12,000 AF. However, the CNPPID intends to decrease its use of Elwood Reservoir for irrigation purposes, which may allow for future increases to the diversion cap. The

[17] Amendment No. 1 to the October 20, 2017 WSA, dated January 8, 2018

CNPPID currently estimates an annual 30,000 AF of space will be available for recharge water. The Program would split this volume with the NDNR and the Tri-Basin NRD, resulting in an annual diversion cap of 15,000 AF for the Program. Because this diversion cap may change as the CNPPID's use of Elwood evolves and the NDNR and Tri-Basin NDR refine their recharge needs, scoring analyses were performed using a range of diversion caps.

VI. ALTERNATIVES & SCORES

The EDO completed a scoring analysis based on the assumptions described in previous sections. A range of recharge diversion caps was evaluated as shown in **Figure 5**, which also shows the portion of the score (50 percent) that would be available for the Program to use for recharge.

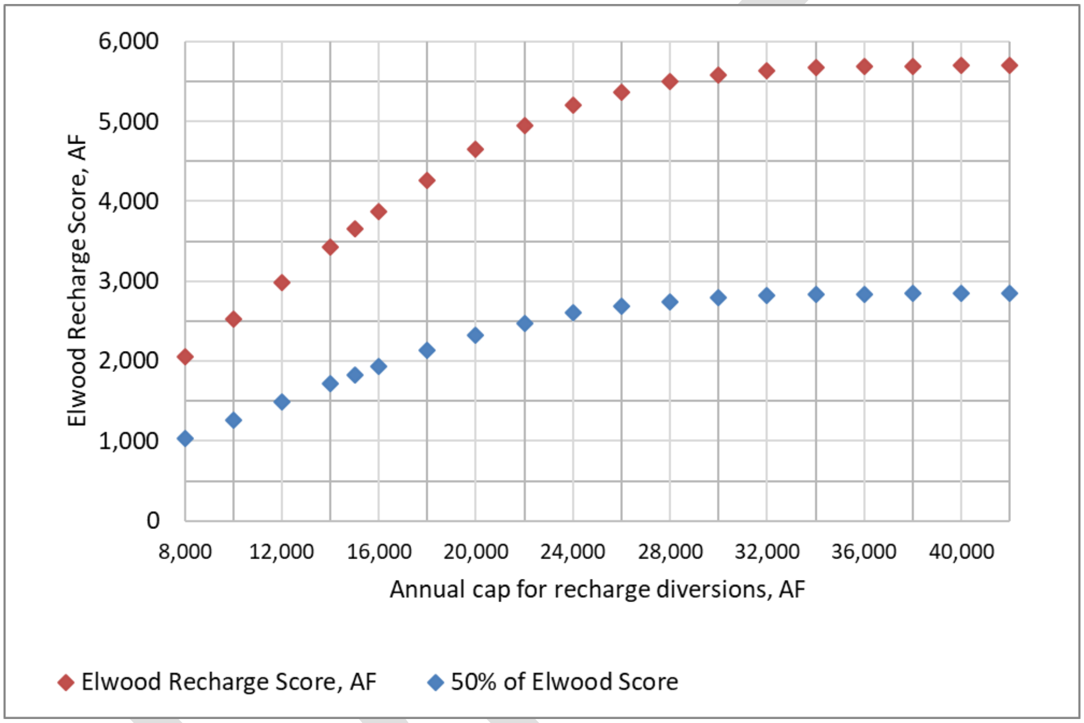


Figure 5. Elwood recharge diversion caps and corresponding project scores

The project score increases in a roughly linear fashion over the range of recharge diversion caps of 8,000 AF to 22,000 AF then flattens off at higher diversion caps. In this range, the recharge diversion cap has a direct relationship to project score, with higher caps resulting in higher scores. At higher recharge caps, the availability of excess flows becomes a limiting factor for the score.

Score estimates for select recharge cap are presented in **Table 4**; values shown represent the annual average over the 48-year analysis period for each scenario. These scenarios include the following: the current 12,000 AF (a total cap of 24,000 AF), a decrease of 4,000 AF to the previous diversion cap of 8,000 AF (a total cap of 16,000 AF), an increase of 3,000 AF to a cap of 15,000 AF (a total cap of 30,000 AF), and an increase of 8,000 AF to a cap of 20,000 AF (a total cap of 40,000). It is assumed that the Program would utilize half of the total annual recharge diversion cap while the remaining half would be used by the NDNR and the Tri-Basin NRD.

Table 4. Estimated Project Scores at Grand Island

Scenario	Total Annual Avg Recharged Volume (AF)	Program Annual Avg Recharged Volume (AF)	Total Score (AF)	Program Score (AF)
Recharge cap of 8,000 AF (total cap of 16,000 AF)	13,000	6,500	3,800	**1,900**
Current WSA: annual recharge diversion cap of 12,000 AF (a total cap of approximately 24,000 AF)	17,400	8,700	5,200	**2,600**
Recharge cap of 15,000 AF (total cap of 30,000 AF)	18,700	9,350	5,600	**2,800**
Recharge cap of 20,000 AF (total cap of 40,000)	19,100	9,550	5,700	**2,850**

Detailed score tables by month for annual recharge diversion caps corresponding to Table 4 are included in **Appendix E**. The difference between the diverted volume and the recharged volume is due to evaporation losses while recharged water is stored in Elwood Reservoir. The differences between the recharged volume and the returns to the river in **Table 4** are due in part to approximately 24% of the recharged water flowing to the Republican River basin (117,000 AF of the 480,000 AF recharged over the 48 year period) and in part because approximately 69,000 AF (14% of the 480,000 AF recharged over the 48 year period) of recharged water remains in storage at the end of the 48-year analysis period. The 69,000 AF in storage will eventually accrue to the Platte River over a longer time period.

VII. ADDITIONAL CONSIDERATIONS FOR DISCUSSION

The following additional considerations for the Elwood Reservoir groundwater recharge score analysis were addressed in discussions with the Scoring Subcommittee.

A. <u>Recapture of Recharged Water</u>

Of the water that is diverted into Elwood Reservoir for groundwater recharge, less than 30% returns to the river at times of shortage to target flows. Adding groundwater wells that pump recharged water back to the river could increase the project score in several ways. First, it would allow the Program to control when recharged water returns to the river to maximize the project's ability to reduce shortages to target flows. Pumping recharged water would also allow the Program to capture the 24% of recharged water that eventually flows to the Republican River basin. Additionally, the Program could access the large amount of recharged water that remains in storage (69,000 AF of recharged water remains in storage at the end of the 48-year analysis period) during especially dry time or times of greater shortages to target flows. The EDO reported that staff are beginning to evaluate options to develop networks of recapture wells to enhance several Program recharge projects on the south side of the Platte River, within the Tri-Basin NRD.

B. Lagged Accretions After the Study Period

During the July 26, 2018 (see minutes in **Appendix F**) conference call, the Scoring Subcommittee requested that the EDO evaluate options for dealing with lagged accretions that occur after the end of the 1947-1994 study period. The EDO reported back to the Scoring Subcommittee on August 27, 2018 (see minutes in **Appendix G**) with several alternatives for including lagged accretions that occur after the end of the 1947-1994 study period into the scoring model.

Approximately 69,000 AF of water remains in the aquifer and will eventually arrive at the Platte River after the end of the score model's analysis period. The Scoring Subcommittee discussed the merits of adding the lagged accretions back into the model and decided not to take this approach. Rather, it was noted that the lagged accretions may be the source water for future Program recapture well WAP projects. The Scoring Subcommittee said it would be more appropriate for the lagged accretions to be reflected in the scoring of recapture well projects than to simply incorporate the remaining volume mathematically into the Elwood recharge score.

The Elwood Reservoir recharge project score could also be modified in the future to account for a higher level of consistent returns after operations have continued for long enough to reach more of a steady state

C. Historical Elwood Reservoir Seepage

During the July 26, 2018 Scoring Subcommittee conference call (see minutes in **Appendix F**), it was requested that the EDO take a coarse look at historical Elwood Reservoir seepage and how differences between that and assumptions made in the score model could affect the project score. The EDO conducted an analysis that assumed that seepage and resulting baseflows from historic Elwood Reservoir operations from 1978 to 1994 were reflected in the OPSTUDY hydrology. The difference in historic baseflows and baseflows in the scoring model Elwood Reservoir operations were removed from the OPSTUDY hydrology. Removing baseflows resulted in decreasing excesses available for diversion and increasing shortages at Grand Island. The net result was a score increase of 900 AF for a recharge cap of 12,000 AF.

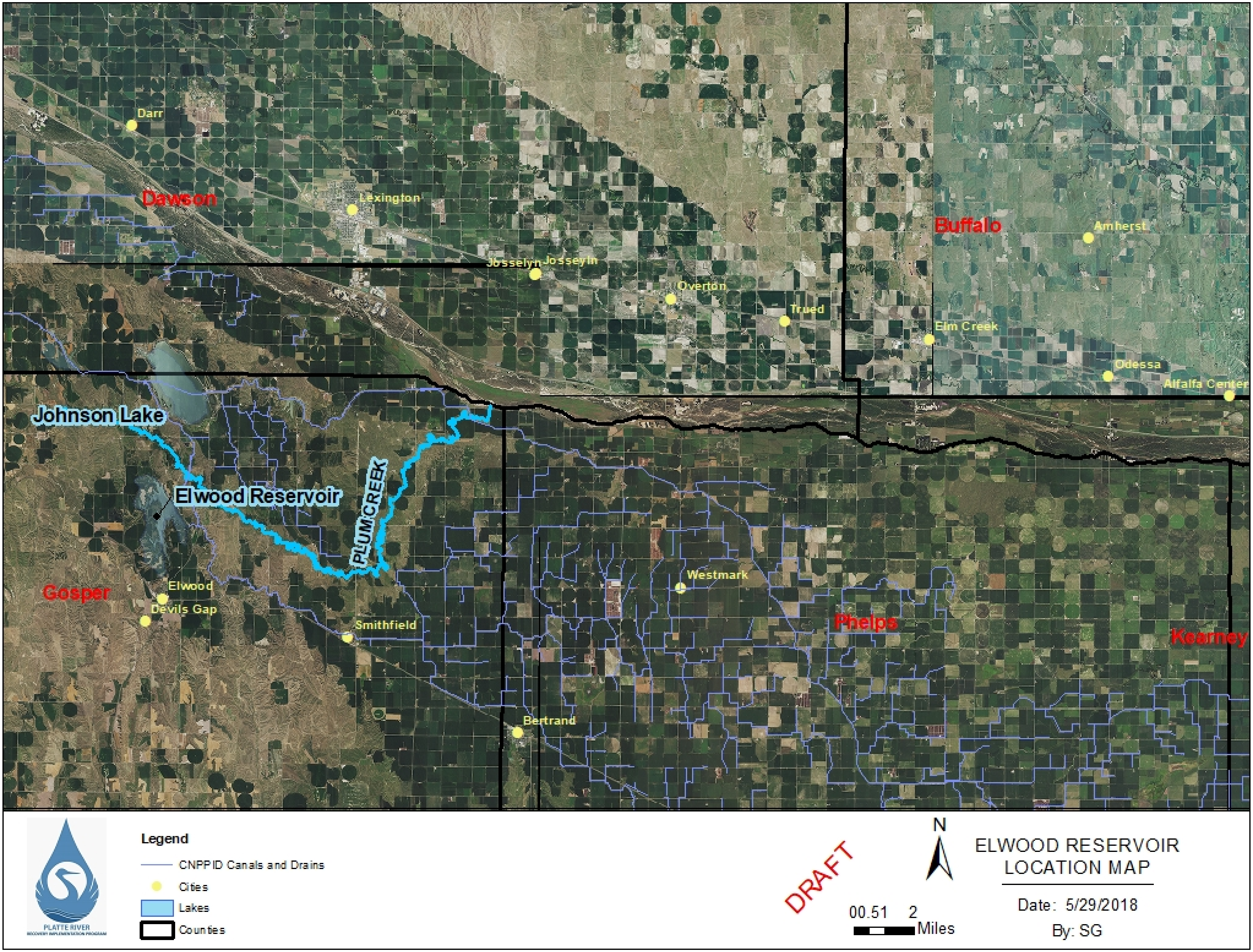
The Scoring Subcommittee discussed the issue in depth during the August 27, 2018 conference call (see minutes in **Appendix G**). It was agreed this issue is fundamentally a policy question in nature. It would reflect a departure from the existing scoring methodology and would have future implications as similar changes to the river's baseflow occur. The Scoring Subcommittee decided not to recommend to the governance committee a score that included adjustments to account for historical Elwood Reservoir seepage.

VIII. CONCLUSIONS

Based on current agreements and operations (12,000 AF recharge cap for the Program) and the assumptions outlined in this document, the Elwood Reservoir groundwater recharge project would have a score of 2,600 AFY. However, it is reasonably assumed that a total recharge capacity of 30,000 AF will be available in Elwood Reservoir, with 50 percent (15,000 AF) allocated to the Program. Per Figure 5 and Table 4, this would provide a total score of 5,600 AFY, or 2,800 AFY for the Program. **The Scoring Subcommittee recommends a score of 2,800 AFY for this project. The Scoring Subcommittee also recommends that the GC use Figure 5 in this memorandum if it is necessary in the future to adjust the project score due to changes in available recharge capacity.**

APPENDIX A

Elwood Reservoir Location Map


Darr
Dawson
Lexington
Buffalo
Amherst
Josselyn
Josseyln
Overton
Trued
Elm Creek
Odessa
Alfalfa Center
Johnson Lake
Elwood Reservoir
PLUM CREEK
Westmark
Elwood
Gosper
Devils Gap
Smithfield
Phelps
Kearney
Bertrand
Legend
CNPPID Canals and Drains
Cities
Lakes
Counties
PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM
DRAFT
N
0 0.5 1 2
Miles
ELWOOD RESERVOIR LOCATION MAP
Date: 5/29/2018
By: SG

APPENDIX B

B1. Water Service Agreement-Groundwater Recharge from Excess Flows Between The Central Nebraska Public Power and Irrigation District, Nebraska Community Foundation and Platte River Recovery Implementation Program.

October 20, 2017

B2. Amendment No. 1 to the Water Service Agreement-Groundwater Recharge from Excess Flows Between The Central Nebraska Public Power and Irrigation District, Nebraska Community Foundation and Platte River Recovery Implementation Program.

January 8, 2018

B3. State of Nebraska Department of Natural Resources. Approval of Application A-19559, Water Division 1-A.

September 25, 2017

B4. Exhibit F from DRAFT Water Service Agreement (for Diversion Project to Deliver Water from Phelps County Canal to Cottonwood Ranch).

Revision Date May 29, 2018

**WATER SERVICE AGREEMENT-
GROUNDWATER RECHARGE FROM EXCESS FLOWS BETWEEN
THE CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT,
NEBRASKA COMMUNITY FOUNDATION
AND
PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM**

THIS AGREEMENT made and entered into this 20th day of October, 2017, by and between **The Central Nebraska Public Power and Irrigation District**, a public corporation and political subdivision of the State of Nebraska, with its principal office located at 415 Lincoln Street, P.O. Box 740, Holdrege, NE 68949-0740, hereinafter referred to as "Central" and the **Nebraska Community Foundation** (representing all signatories to the Platte River Recovery Implementation Program), a Nebraska non-profit corporation, with its principal office located at 3833 South 14th Street, Lincoln, Nebraska 68502, and the **Platte River Recovery Implementation Program**, with its principal office located at 4111 4th Avenue, Suite 6, Kearney, Nebraska 68845 (hereinafter the Nebraska Community Foundation and Platte River Recovery Implementation Program are collectively referred to as "Platte Program" and the Nebraska Community Foundation is referred to individually as the "Foundation"). Central and the Platte Program may individually be referred to as "Party" and shall collectively be referred to herein as the "Parties."

WITNESSETH:

WHEREAS, Central is the owner of the Elwood Reservoir as shown on Exhibit A; and

WHEREAS, in August 2017 Central filed for an order from the Nebraska Department of Natural Resources (hereinafter "DNR") for a "Temporary Permit to Appropriate Water for Groundwater Recharge on the E65 Canal, Elwood Reservoir, and Cottonwood WPA" (hereinafter "Appropriation"); and

WHEREAS, the Foundation and the Platte Program desire Central to provide groundwater recharge in Elwood Reservoir for purposes of enhancing Platte River stream flows; and

WHEREAS, Central desires to provide such recharge services within the red highlighted areas shown in Exhibit A; and

WHEREAS, Central also has an agreement with the Tri-Basin Natural Resources District (Tri-Basin) and the State of Nebraska (State) for recharge services using Elwood Reservoir and the E65 Canal;

NOW, THEREFORE, IN CONSIDERATION of the mutual covenants and agreements herein contained and the terms and conditions hereinafter set forth, it is hereby covenanted and agreed:

1. WATER SERVICE.

a. During the term of this Agreement, Central will provide the Platte Program and Tri-Basin/State with groundwater recharge via seepage through the E65 Canal and Elwood Reservoir for the purposes described above. That part of the Total Amount Diverted that is pumped into Elwood Reservoir shall be divided into a 50% share to the Platte Program and a 50% share to Tri-Basin/State. The remainder of the Total Amount Diverted that is released into the E65 Canal shall be credited to Tri-Basin/State. The water billed to the Platte Program shall not exceed 8,000 acre feet unless agreed to by the Platte Program in writing. The Total Amount Diverted shall be measured by Central using the E65 Canal measuring flume located at milepost (MP) 2.8 (including water diverted and not available for recharge because of evaporation). The portion of the Total Amount Diverted that is delivered to Elwood Reservoir will be estimated using pump performance curves developed by Central and/or annubar measurements, with all remaining diversions passing the MP 2.8 flume considered diversions for the E65 Canal. The Total Amount Diverted will be adjusted, as appropriate, by subtracting any deliveries or releases made by Central from the E65 Canal, at the end of each subsequent quarter or billing period, and at the beginning of the next irrigation season. The non-irrigation season will begin when Central stops releasing water into sections of the E65 Canal for irrigation and end when Central begins releasing water into sections of the E65 Canal for irrigation, as determined by Central.

b. Central may make reasonable adjustments in the Total Amount Diverted and Elwood Reservoir diversions as necessary to account for similar operations from other water sources, or for other reasons as may be appropriate. Central shall consult with the Platte Program in making such adjustments. All data used by Central regarding the Total Amount Diverted and Elwood Reservoir diversion calculations shall be shared with the Platte Program.

c. Central may reduce or suspend groundwater recharge diversions under this Agreement for good cause, including but not limited to (a) maintenance or construction on the canal or Elwood Reservoir, (b) high groundwater levels, or (c) icing conditions, all as determined by Central.

d. The Parties shall have the right to terminate the diversions under this agreement, thus ending this agreement, by providing notice to the Parties by Wednesday of any week and diversions will cease on the next Sunday at midnight. The notice shall be provided via email to all Parties and include csteinke@cnppid.com.

2. WATER SERVICE CHARGES. The Foundation shall pay Central a Water Service Charge on a per acre-foot basis as specified in Exhibit B for the water service described above. All measurements made through Central's measuring device and pumping estimates into Elwood Reservoir, so recorded by Central operating personnel shall be considered final. Central shall invoice the Foundation for the water service charges quarterly. Payment shall be due within 60 days of invoice.

3. TERM. The term of this Agreement shall commence when this Agreement is signed by the Parties (the "Commencement Date"), and shall expire on December 31, 2019.

4. DATA SHARING. The Parties agree to share all hydraulic and hydrologic data collected in association with this Agreement.

5. WATER APPROPRIATIONS. The source of supply shall be water which is available pursuant to the Appropriation. The water service described herein shall be consistent with and limited to the terms and provisions of the Appropriation.

6. FORCE MAJEURE. Central shall not be liable for any delay or failure to perform its obligations under this Agreement caused by an event or condition beyond the reasonable control of, and without the fault or negligence of Central, including, without limitation, failure of facilities, flood, earthquake, storm, lightning, fire, severe cold or other weather event, epidemic, contamination, war, terrorist act, riot, civil disturbance, labor disturbance, accidents, sabotage, or restraint by court or restrictions by other public authority which delays or prevents performance (including but not limited to the adoption or change in any rule, policy, or regulation or environmental constraints imposed by federal, state or local governments), which Central could not reasonably have avoided by exercise of due diligence and foresight. Upon the occurrence of such an event or condition, the obligations of Central under this Agreement shall be excused and suspended without penalty or damages, provided that Central shall give the Foundation and the Platte Program prompt written notice describing the particulars of the occurrence or condition, the suspension of performance is of no greater scope and of no longer duration than is required by the event or condition, and Central proceeds with reasonable diligence to remedy its inability to perform and informs the Foundation and the Platte Program of the actions taken to remedy the consequences of the event or condition.

7. DEFAULT. If any Party to this Agreement fails to perform or otherwise breaches any of the terms of this Agreement, then such failure shall constitute a default. In the event of default by any Party, the non-defaulting Party/ies shall give written notice of the default to the defaulting Party. Following such written notice, the defaulting Party/ies may cure the default within thirty (30) days. Upon cure, this Agreement shall remain in full force and effect. If the defaulting Party/ies fails to cure, the non-defaulting Party/ies shall be entitled to any and all legal and equitable remedies except Central's total liability to the Foundation and the Platte Program for any loss or damage, including but not limited to special and consequential damages, arising out of or in connection with the performance of this Agreement shall not exceed either the amount of Water Service Charges paid by the Foundation and the Platte Program to Central pursuant to this Agreement or $50,000, whichever is less.

8. ENTIRE AGREEMENT. This Agreement contains the entire understanding of the Parties hereto with respect to the water service contemplated hereby and supersedes all prior agreements and understandings between the Parties with respect to such subject matter.

9. AMENDMENT. No amendment to this Agreement shall be valid unless it is in writing and signed by the Parties hereto.

10. BINDING EFFECT. This Agreement shall inure to the benefit of and be binding on the Parties, their successors and assigns. This Agreement may not be assigned by the Foundation or the Platte Program without the written consent of Central.

11. GOVERNING LAW. This Agreement shall be governed by and construed in accordance with the law of the State of Nebraska.

12. FUNDING. Should the Foundation or Platte Program determine that the anticipated source of funding will no longer be available, the Foundation or Platte Program will utilize the termination provisions in Section 1.d., to assure funding is available until diversions cease.

13. LAWS. In executing this Agreement, each Party shall be responsible for its compliance with all applicable state and federal laws.

IN WITNESS WHEREOF, the Parties hereto have executed this Agreement the date first stated above.

NEBRASKA COMMUNITY FOUNDATION,

By ______________________ 10/20/2017
Diane M. Wilson
Manager of Public/Private Partnerships

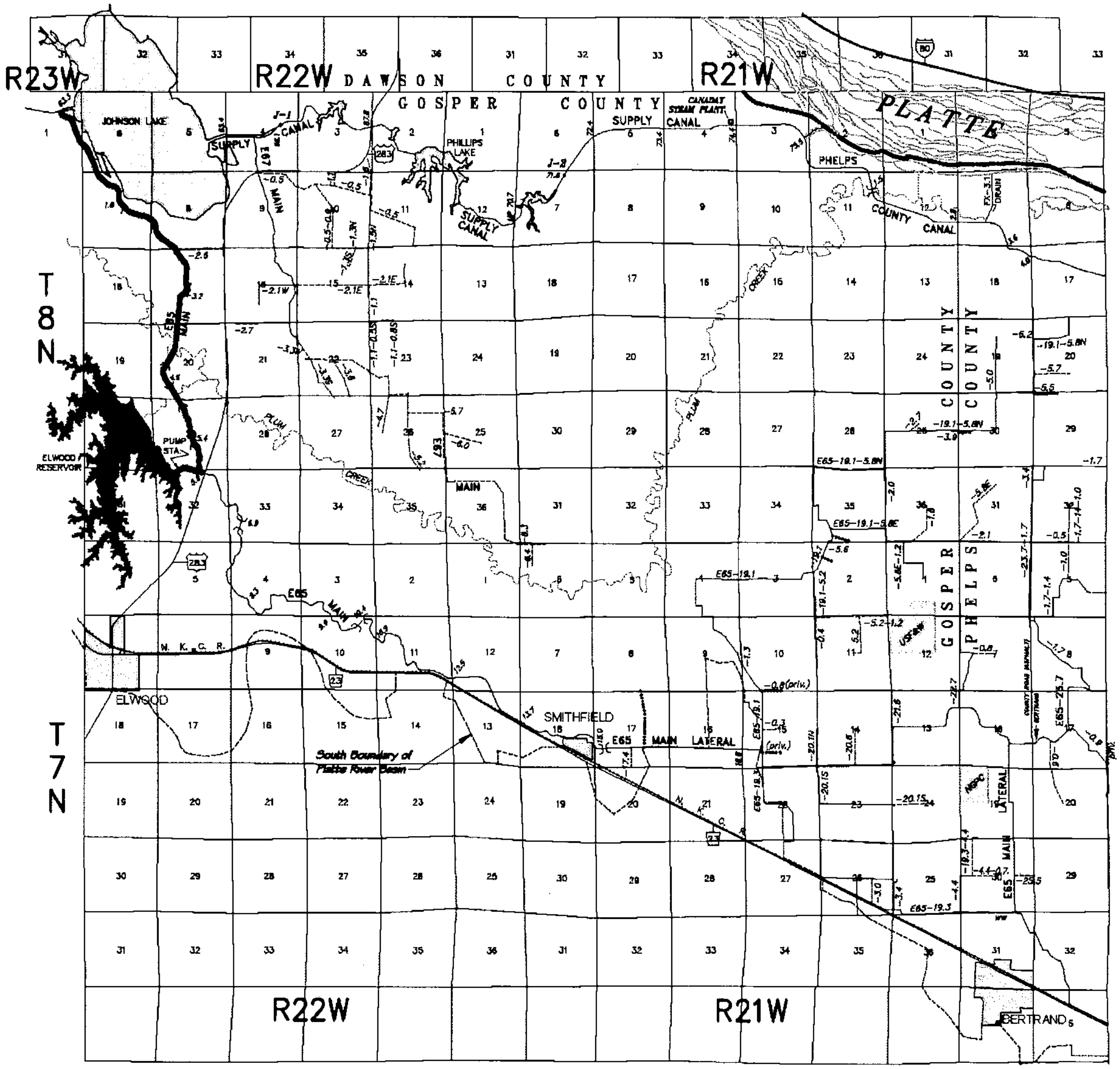
PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM – Office of the Executive Director

By ______________________ 10/19/17
Jerry F. Kenny, Ph.D.
Executive Director

THE CENTRAL NEBRASKA PUBLIC POWER AND
IRRIGATION DISTRICT,

By ______________________________

Don D. Kraus
General Manager



N

LEGEND

EXCESS FLOWS RECHARGE

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CENTRAL
Nebraska Public Power and Irrigation District
Holdrege, Nebraska

PLATTE RIVER EXCESS FLOWS FOR RECHARGE IN ELWOOD RESERVOIR, GOSPER COUNTY, NEBRASKA

DRAFTED BY	TMR	APPROVED	
SUBMITTED BY	DRF	BY	
SCALE	1"= 1.4 Mi.	DRAWING	
DATE	01/21/2015	NO.	RCHG_JAN2015

EXHIBIT B

Water Service Charges	
Elwood Reservoir Diversions	
Year	$ / Acre foot
2017	$45.68
2018	$47.05
2019	$48.46

AMENDMENT NO. 1 TO THE
WATER SERVICE AGREEMENT-
GROUNDWATER RECHARGE FROM EXCESS FLOWS BETWEEN
THE CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT,
NEBRASKA COMMUNITY FOUNDATION
AND
PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM

THIS AMENDMENT NO. 1 made and entered into this 8th day of January, 2018, by and between **The Central Nebraska Public Power and Irrigation District**, a public corporation and political subdivision of the State of Nebraska, with its principal office located at 415 Lincoln Street, P.O. Box 740, Holdrege, NE 68949-0740, hereinafter referred to as "Central" and the **Nebraska Community Foundation (representing all signatories to the Platte River Recovery Implementation Program)**, a Nebraska non-profit corporation, with its principal office located at 3833 South 14th Street, Lincoln, Nebraska 68502, hereinafter referred to as "Foundation," and the **Platte River Recovery Implementation Program**, with its principal office located at 4111 4th Avenue, Suite 6, Kearney, Nebraska 68845, hereinafter referred to as "Platte Program," (jointly referred to as "Parties" and individually as "Party."

WITNESSETH:

WHEREAS, Central is the owner of the Elwood Reservoir as shown on Exhibit A; and

WHEREAS, in August, 2017 Central filed for an order from the Nebraska Department of Natural Resources (hereinafter "DNR") granting a "Temporary Permit to Appropriate Water for Groundwater Recharge on the E65 Canal, Elwood Reservoir, and Cottonwood WPA" (hereinafter "Appropriation"); and

WHEREAS, the Foundation and the Platte Program desire for Central to provide groundwater recharge in Elwood Reservoir for purposes of enhancing Platte River stream flows; and

WHEREAS, on October 20, 2017 the Parties entered into a Water Service Agreement for Groundwater Recharge from Excess Flows using Elwood Reservoir;

WHEREAS, the Parties mutually desire to amend the terms and provisions of the Agreement by increasing the Total Amount Diverted from 8,000 acre feet to 12,000 acre feet.

NOW, THEREFORE, IN CONSIDERATION of the mutual covenants and agreements herein contained and the terms and conditions hereinafter set forth, it is hereby covenanted and agreed:

1. Section 1(a) of the Original Agreement is hereby amended to read as follows:

   During the term of this Agreement, Central will provide the Platte Program and Tri-Basin/State with groundwater recharge via seepage through the E65 Canal and Elwood Reservoir for the purposes described above. That part of the Total Amount Diverted that is pumped into Elwood Reservoir shall be divided into a 50% share to the Platte Program and a 50% share to Tri-Basin/State. The remainder of the Total Amount Diverted that is released into the E65 Canal shall be credited to Tri-Basin/State. The water billed to the Platte Program shall not exceed 12,000 acre feet unless agreed to by the Platte Program in writing. The Total Amount Diverted shall be measured by Central using the E65 Canal measuring flume located at milepost (MP) 2.8 (including water diverted and not available for recharge because of evaporation). The portion of the Total Amount Diverted that is delivered to Elwood

Reservoir will be estimated using pump performance curves developed by Central and/or annubar measurements, with all remaining diversions passing the MP 2.8 flume considered diversions for the E65 Canal. The Total Amount Diverted will be adjusted, as appropriate, by subtracting any deliveries or releases made by Central from the E65 Canal, at the end of each subsequent quarter or billing period, and at the beginning of the next irrigation season. The non-irrigation season will begin when Central stops releasing water into sections of the E65 Canal for irrigation and end when Central begins releasing water into sections of the E65 Canal for irrigation, as determined by Central.

2. In the event any terms and provisions of this Amendment are construed to conflict with the terms and provisions of the Original Agreement, the terms and provisions of this Amendment shall prevail. In all other respect, except as herein amended, the terms and provisions of the Original Agreement shall remain in full force and effect. This Amendment shall have the same force and effect as if incorporated in the Original Agreement, and shall take precedence thereover.

IN WITNESS WHEREOF, the Parties hereto have executed this Amendment No. 1 the date first stated above.

NEBRASKA COMMUNITY FOUNDATION,

By ______________________________
Diane M. Wilson
Chief Operating Officer/Chief Financial Officer

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM – Office of the Executive Director

By ______________________________
Jerry F. Kenny, Ph.D.
Executive Director

THE CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT,

By ______________________________
Don D. Kraus
General Manager

STATE OF NEBRASKA

DEPARTMENT OF NATURAL RESOURCES

APPROVAL OF APPLICATION A-19559

WATER DIVISION 1-A

BACKGROUND

1. On July 14, 2004, the Department of Natural Resources (Department) issued a formal moratorium on all new surface water appropriations in the Platte River Basin upstream of the confluence with the Loup River near Columbus, Nebraska. The moratorium included all tributary streams above the Loup River confluence including the North and South Platte Rivers and tributaries.

2. On September 11, 2009, a Basin-Wide Integrated Management Plan (BWIMP) for the overappropriated area of the Platte River Basin was adopted by order of the Department. The BWIMP was also adopted by the following NRDs: the North Platte NRD, the South Platte NRD, the Twin Platte NRD, the Central Platte NRD, and the Tri-Basin NRD. These NRDs are collectively referred to in the BWIMP as the "Platte River Basin NRDs." The individual integrated management plans referenced in the next paragraph are required to be in conformance with the goals and objectives of the BWIMP.

3. On August 13, 2009, the initial integrated management plans (IMPs) were adopted by order of the Department, pursuant to *Neb. Rev. Stat.* § 46-718(2) for the following natural resources districts (NRDs): the North Platte NRD, the South Platte NRD, the Twin Platte NRD, the Central Platte NRD, and the Tri-Basin NRD. There have been subsequent revisions to the IMPs. As part of the surface water controls adopted by the Department pursuant to *Neb. Rev. Stat.* § 46-716(1)(b), the moratorium on issuing new surface water appropriations was continued.

4. On January 1, 2007, work officially commenced on the Platte River Recovery and Implementation Program (PRRIP or Program). PRRIP's goals include reducing shortages to U.S. Fish and Wildlife Service target flows and providing additional land habitat for endangered species in the Lexington to Chapman reach of the Platte River. In order to meet these goals, each signatory to PRRIP has adopted depletions plans to address the mitigation of the adverse impacts of water-related activities on streamflows in the Platte River. The State of Nebraska, through the Department will utilize the integrated management process to achieve the goals of PRRIP (BWIMP and IMPs).

5. On August 21, 2017, The Central Nebraska Public Power and Irrigation District (CNPPID) filed in the Department petition VAR-6281 for Leave to File or Consider an Application for a Permit to Appropriate Water within a Moratorium Area or Stay Area. The petition requests leave to file an application for a temporary permit to appropriate water for the purpose of groundwater recharge via the E65 Canal, Elwood Reservoir, Cottonwood Waterfowl Production Area (WPA), Linder WPA, and Victor Lakes WPA.

6. On September 6, 2017, the Department granted leave to file an application for a permit to appropriate water by approving petition VAR-6281.

7. On September 11, 2017, CNPPID filed in the Department application A-19559 for a temporary permit to appropriate water for the purpose of groundwater recharge through the E65 Canal system, Elwood Reservoir, Cottonwood Waterfowl Production Area (WPA), Linder WPA, and Victor Lakes WPA. The application proposes to divert water from the Platte River at the headgate of the applicant's Tri-County Canal located in Section 08, Township 13 North, Range 29 West of the 6th P.M. in Lincoln County, which then connects to the E65 Canal, Elwood Reservoir, Cottonwood WPA, Linder WPA, and Victor Lakes WPA.

8. Temporary permits may not be granted for a term of more than one year.

9. For the purposes of this order "Desired Minimum Discharge" (DMD) describes the water parameter that will be used to determine whether, and to what extent diversion may occur for projects such as that proposed under A-19559. Table A (see attached) lists the DMD values for the Platte River, measured in cubic feet per second at the Grand Island stream gage, for specific time periods. The magnitude of these flows differs according to the PRRIP's designation of dry, normal or wet hydrologic conditions, derived from the USFWS's recommendations for species flows and annual pulse flows and found in the PRRIP Water Plan Reference Materials Attachment 5, Section 11, Appendix A-5. These flow values also include instream flow appropriations which must also be met in order for unappropriated water to be considered available for possible diversion.

CONCLUSIONS:

1. Construction of the E65 Canal, Elwood Reservoir, Cottonwood WPA, Linder WPA, and Victor Lakes WPA have been completed.

2. Applicant has demonstrated there may be unappropriated water in the Platte River. It is anticipated there may be water available for diversion for some periods under this application in the future.

3. The purpose of this application is to recharge the groundwater aquifer in order to mitigate stream depletions from groundwater pumping and increase baseflow into local streams, which are goals of the Basin-Wide Plan (BWP) and Integrated Management Plans (IMPs). Accretions to streamflow that may occur as a result of recharge under this appropriation will be considered as beneficial if they are achieving the goals of the BWP and IMPs. Secondarily, the BWP and IMPs provide support for Nebraska's participation in the PRRIP. Nebraska is a party to the PRRIP and in part, Nebraska will achieve its commitments under the PRRIP through implementation of Water Action Plan projects. Diversions under A-19559 may be used for PRRIP purposes, if available water is not needed for other BWP and IMP purposes. Any diversions under this application must not be to the detriment of achieving the goals of the BWP and IMPs in the most effective manner as determined by the Department.

4. Diversions would occur under the proposed project during the non-irrigation season or under conditions such that no adverse impacts to existing water users are expected.

5. This diversion project is expected to be operated in accordance with the goals and objectives of the BWP and IMPs. As stated above, Nebraska has committed to achieve its obligations to the PRRIP. Therefore, under Nebraska's current commitment to the PRRIP the project shall only divert water when U.S. Fish and Wildlife Service target flows are exceeded or such requirement is waived by the Department. As such, this project will not require an offset for the purpose of ensuring that these target flows are met.

6. The diversion of water for aquifer recharge is beneficial, there may be unappropriated water available, and the application is in the public interest. Therefore it should be approved.

ORDER

IT IS HEREBY ORDERED that application A-19559 is APPROVED subject to the following conditions:

1. The source of water is the Platte River.

2. The water diverted under this permit shall be used for the purpose of groundwater recharge in support of the BWP and IMPs via the existing E65 Canal, Elwood Reservoir, Cottonwood WPA, Linder WPA, and Victor Lakes WPA.

3. If water is available according to the conditions of this Order and not required for use in achieving the goals of the BWP or IMPs, then the Department may allow diversion for groundwater recharge for PRRIP purposes.

4. The priority date is September 11, 2017.

5. When the specified conditions of this appropriation are met, water may be diverted, at a maximum rate of 350 cubic feet per second, into the headgate of the Tri-County Canal located in Section 08, Township 13 North, Range 29 West of the 6th P.M. in Lincoln County, and the same water less transit losses allowed to flow into and through E65 Canal system, Elwood Reservoir, Cottonwood WPA, Linder WPA, and Victor Lakes WPA.

6. If a relinquishment is not submitted first, then A-19559 will EXPIRE one year from the date of this Order and appropriation A-19559 will be CANCELLED without further action by the Department as of that date.

7. The term "Desired Minimum Discharge" (DMD) is quantitatively defined in Table A and is attached to and hereby incorporated into the conditions of this Order. Only those flows in excess of the DMD shall be considered to be available to be diverted. These target flows are specified in **Table A** on page 6. The project will utilize only previously unappropriated available water.

8. In order to ensure compliance with the BWP and IMPs, the Department imposes the following hydrologic and administrative conditions, to determine whether, and in what quantity, water may be available for diversion:

   A. No diversion under this appropriation may occur unless the previous day's twenty-four-hour average flow of the Platte River, as measured at the Grand Island stream gage or other Department-specified gage, is in excess of the DMD. This requirement may be waived if written permission is granted by the Department.

   B. The current hydrologic condition of wet, normal or dry, as designated by PRRIP, shall determine the appropriate DMD value from Table A.

   C. If the amount of streamflow in excess of the designated DMD is less than the maximum diversion permitted under this appropriation, as described in condition 7 above, then only that amount of streamflow in excess of the DMD may be diverted unless waived by written permission of the Department.

9. Prior to diversion under appropriation A-19559, appropriator must coordinate with the Department's field office in charge of water administration to confirm during regular business hours that conditions are met.

10. The appropriator shall contact the Bridgeport field office during regular business hours a minimum of 24 hours prior to the anticipated change in purpose of diversions from irrigation under other appropriations to groundwater recharge under this appropriation, or from groundwater recharge under A-19559 to irrigation. When such change in purpose of diversions should occur, accurate measurement of diversions and duration of diversion shall be documented by the appropriator.

11. The Department reserves the right to make adjustments to the amounts and measurement location(s) listed in Table A.

12. The water diverted under A-19559 through the Tri-County Canal, E65 Canal, Elwood Reservoir, Cottonwood WPA, Linder WPA, or Victor Lakes WPA may not be used for direct irrigation by CNPPID's customers. Any water diverted for the purpose authorized under this permit that does not seep into the groundwater aquifer shall be returned to the river at established spills and drains.

13. Within six months after the final date of diversion under this temporary permit, the appropriator shall file a map that depicts where the water was routed, and will provide in-depth quantitative analysis to the Department of the recharge achieved by utilizing the E65 Canal, Elwood Reservoir, Cottonwood WPA, Linder WPA, and Victor Lakes WPA, including all data provided for any contractual arrangements between CNPPID, the Department or other persons.

14. The appropriator must comply with all relevant statutes.

ADDITIONAL INFORMATION

Failure to comply with all laws and regulations pertaining to surface water appropriations, any orders issued by the Director of the Department of Natural Resources, or the provisions of this Approval may result in the cancellation of the appropriation, temporary closing of the appropriation, administrative penalty, criminal prosecution, or any combination thereof.

This appropriation is not a guarantee that water will be available. Nebraska law gives priority to senior appropriations.

DEPARTMENT OF NATURAL RESOURCES

September 25, 2017

Gordon W. Fassett, P.E., Director

The applicant and any person with sufficient legal interest who has been or may be substantially affected by this order may request a contested case hearing in accordance with the *Neb. Admin. Procedures Act* §§ 84-901 et. seq. RRS and the Department's *Rules of Practice and Procedure Title 454 Neb. Admin. Code* Chapter 7. The request must be received by the Department at its Lincoln office (Nebraska State Office Building, 4th Floor, 301 Centennial Mall South, P.O. Box 94676, Lincoln, Nebraska 68509-4676) within 30 days of the date of the order and be accompanied by a filing fee of $10.

A copy of this approval was posted on the Department's website and provided to the Department's field offices in Bridgeport and North Platte, Nebraska. A copy of this approval was mailed on September 25, 2017, to the following:

Don Kraus, P.E., General Manager
The Central Nebraska Public Power and Irrigation District
P.O. Box 740
Holdrege, Nebraska 68949-0740

Table A - Desired Minimum Discharge of the Platte River in cfs

Measured at the Grand Island Stream Gage Relevant to Appropriation A-19559

Period	**PRRIP Target Flows Grand Island**		
	Wet*	**Normal***	**Dry***
January 1 - January 31	1,000	1,000	600
February 1 - February 14	1,800	1,800	1,200
February 15 - February 28	3,350	3,350	2,250
March 1 - March 15	3,350	3,350	2,250
March 16 - March 22	1,800	1,800	1,200
March 23 - March 31	2,400	2,400	1,700
April 1 - April 14	2,400	2,400	1,700
April 15 - May 3	2,400	2,400	1,700
May 4 - May 10	2,400	2,400	1,700
May 11- May 19	1,200	1,200	800
May 20 - May 31	3,700	3,400	800
June 1 - June 20	3,700	3,400	**1,000****
June 21 - June 23	1,200	1,200	**1,000****
June 24 - July 31	1,200	1,200	**1,000****
August 1 - August 22	1,200	1,200	800
August 23 - August 31	1,200	1,200	800
September 1 - September 15	1,200	1,200	800
September 16 - September 30	1,000	1,000	600
October 1 - October 11	2,400	1,800	**1,350****
October 12 - November 10	2,400	1,800	**1,500****
November 11 - November 15	2,400	1,800	1,300
November 16 - December 31	1,000	1,000	600

* The current Hydrologic Condition, (Wet Normal or Dry) determined by PRRIP can be found at: *http://platteriverprogram.org/PubsAndData/Pages/CurrentHydrologicCondition.aspx*

**Represents the minimum discharge required by instream flow appropriation, which is greater than PRRIP Target Flows, and senior to A-19559

EXHIBIT F

Excess Flow Diversion Sharing

Central currently has multiple projects that utilize Excess Flows. Those projects include: E65 Canal Recharge, Phelps Canal Recharge, Elwood Reservoir Recharge, Cottonwood Ranch Recharge, and Waterfowl Production Area (WPA) Recharge. There are 5 WPAs on the E65 and Phelps Canals. The Phelps Canal (down to MP 13.3) and the E65 Canal (down to MP 5.9) (hereinafter "Base Recharge Projects") must get the first water in order to deliver to the remaining projects. Once diversions for the Base Recharge Projects are covered, Central will equally share any remaining Excess Flows among the current/future projects.

General Sharing Principle:

Total available Excess Flows – flows for Base Recharge Projects = Remaining Excess Flows
Project share = Remaining Excess Flows / number of projects

Example:

130 cfs of Excess Flows available
Flows for Base Recharge Projects
Phelps Canal to MP 13.3 - 30 cfs
E65 Canal to MP 5.9 - 10 cfs
130 cfs – 40 cfs (Base Recharge Projects) = 90 cfs remaining
Three projects (Cottonwood Ranch, Elwood Reservoir, WPAs) = 33.3 % share of remaining water
90 cfs / 3 = 30 cfs/project

Distribution:

Base Recharge Projects

Phelps Canal to MP 13.3 - 30 cfs
E65 Canal to MP 5.9 – 10 cfs

Initial Distribution
Cottonwood Ranch – 30 cfs
Elwood Reservoir – 30 cfs
WPAs – 30 cfs

Limitations
Elwood Reservoir minimum diversion of 75 cfs

Final Distribution
Cottonwood Ranch – 45cfs
WPAs – 45 cfs

Measuring Points:

E65 Canal MP 2.8 – Measures total E65 flow
Elwood Reservoir Flowmeter – Measures Elwood Reservoir flows
E65 MP 5.9 –Calculated flow for projects downstream of MP 5.9
Phelps Canal MP 1.6 Flume – Measures total Phelps Canal flow
Cottonwood Ranch Flow Meter- Measures Cottonwood Ranch flow
Phelps Canal MP 13.3 – Measures flow for projects downstream of MP 13.3

Limitations:

Elwood Reservoir pumps require a minimum of 75 cfs to be operational.
WPA diversions will experience transportation losses to each site and may make diversions to those projects inefficient at low flows.
E65 and Phelps Canal maintenance may limit certain project diversions capabilities.
Ice conditions may limit or prohibit diversion of Excess Flows
Each project share may be moved to another project if mutually agreed to by water service agreement signatories

APPENDIX C

Monthly Summary of Excess and Shortage to Target Flows at Grand Island

APPENDIX C, TABLE 1:
EXCESSES AND SHORTAGES AT GRAND ISLAND USING MONTHLY OPSTUDY HYDROLOGY

Values in KAF. Positive values represent excesses, negative values represent shortages.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr Type
1947	52.7	3.5	-10.3	14.8	-1.3	85.2	237.1	-24.0	-17.5	-5.5	41.4	66.5	Normal
1948	61.4	23.6	117.8	-13.3	-10.4	-87.0	-23.3	-39.8	-51.3	-49.1	-10.2	18.7	Normal
1949	16.1	-48.6	36.7	42.6	-14.4	120.8	109.2	-24.3	-16.9	1.3	26.1	20.8	Wet
1950	42.7	19.8	-10.7	-28.6	-1.9	-87.2	5.2	-27.0	-9.4	37.7	-5.2	23.7	Normal
1951	23.3	-16.1	-73.2	-28.3	-22.2	-4.5	40.1	-27.4	163.4	24.8	46.6	54.9	Wet
1952	70.8	36.6	79.0	61.8	-22.1	-86.7	-15.1	-24.2	-17.4	-81.7	-23.7	42.7	Wet
1953	101.4	16.5	10.7	37.3	81.7	12.5	-18.0	-6.8	-11.9	-34.6	19.1	40.6	Dry
1954	39.3	29.7	-34.6	-24.7	57.2	-6.4	-29.6	-10.0	-9.3	-46.5	-7.9	16.2	Dry
1955	17.9	-34.6	-32.5	-55.3	-24.5	-5.0	-18.0	-21.4	-18.0	-77.0	-31.0	2.5	Dry
1956	21.4	-46.0	-71.6	-61.6	-12.9	-32.3	-24.8	-26.7	-17.1	-67.1	-32.7	2.2	Dry
1957	-16.0	-39.0	-59.4	-28.1	86.3	150.0	22.0	-8.1	6.3	6.1	22.3	35.3	Dry
1958	45.6	-56.2	-27.9	2.0	23.1	8.2	38.8	-24.2	-17.6	-16.3	-7.6	19.9	Normal
1959	13.7	-14.0	41.8	41.3	56.1	12.5	-5.5	-21.1	-27.8	-14.1	32.9	46.0	Dry
1960	14.3	-30.1	29.4	-2.3	-26.8	-55.7	-23.4	-42.7	-24.0	-53.3	-10.1	13.3	Normal
1961	50.5	6.3	-14.7	-5.9	53.3	66.3	0.0	-16.2	-36.1	-19.4	39.3	34.9	Dry
1962	23.5	0.1	18.5	-43.5	-82.2	52.6	24.7	-12.1	-35.6	-35.8	-5.8	7.0	Normal
1963	28.6	60.0	21.0	5.5	62.7	12.3	-38.0	-33.9	-13.7	-15.0	15.2	17.1	Dry
1964	45.8	-18.6	-15.3	16.9	34.2	-7.9	-21.2	-23.2	-29.4	-43.5	-14.9	6.9	Dry
1965	-13.8	-88.9	-77.9	-43.6	-81.2	35.1	143.4	-28.5	69.1	32.3	26.0	61.9	Wet
1966	16.3	4.2	-9.5	-9.1	-38.0	-107.4	-39.5	-44.9	-58.2	-47.1	-10.9	-1.7	Normal
1967	10.7	-54.8	-84.8	-76.3	-81.8	165.9	95.5	-33.9	-35.5	-39.1	-4.2	8.3	Normal
1968	32.9	-37.8	-72.3	-37.6	-77.3	-87.2	-24.2	-20.9	-35.6	-45.0	6.2	-3.0	Normal
1969	23.7	-40.9	8.4	-23.1	-1.4	-25.4	100.0	-24.3	-17.8	-14.9	39.4	63.9	Normal
1970	53.8	25.9	-32.5	13.3	-22.2	-60.7	34.2	-24.2	-17.7	-51.5	-9.6	-6.9	Wet
1971	15.0	-24.7	-27.9	-1.3	-22.2	240.0	42.3	-24.5	-17.6	-32.6	50.0	60.9	Wet
1972	3.5	24.6	-9.5	-20.4	-22.5	-86.7	-24.9	-14.3	-35.5	-60.0	-5.4	23.6	Wet
1973	67.7	17.1	-19.3	81.1	588.1	517.3	-0.4	-24.0	19.7	191.3	130.7	139.7	Wet
1974	144.6	98.6	28.5	208.4	-19.3	-70.4	-23.6	-41.0	-17.6	-36.2	-10.4	3.1	Wet
1975	31.0	-44.3	-56.7	-38.5	-1.4	-39.9	-23.3	-35.5	-35.6	-35.6	-0.2	67.4	Normal
1976	64.6	32.5	1.2	12.7	81.6	0.0	-24.1	-26.7	-25.8	-38.3	-14.8	3.6	Dry
1977	-26.2	-74.5	-82.5	-11.8	-22.5	-89.2	-23.6	-34.6	-38.0	-34.9	-5.3	5.9	Normal
1978	-16.9	-71.1	47.5	-21.8	-14.9	-87.0	-48.7	-44.0	-39.0	-78.2	-43.0	-27.3	Normal
1979	-25.0	-90.7	-8.8	-26.6	-26.3	55.7	63.2	-23.6	-17.6	-47.5	2.0	74.4	Normal
1980	31.7	12.6	37.0	-4.7	294.5	199.8	-24.9	-24.6	-17.7	-39.0	-35.0	2.4	Wet
1981	24.1	-38.0	-32.6	-29.9	0.9	9.0	-8.3	4.3	-11.9	-38.3	-2.2	15.1	Dry
1982	-13.7	-71.3	-88.7	-55.7	-62.5	-87.0	-23.8	-42.7	-36.1	-16.2	-20.7	20.2	Normal
1983	61.6	8.7	-11.2	38.6	310.2	954.5	652.9	-24.0	5.3	154.8	63.7	63.3	Wet
1984	196.0	157.3	102.3	325.5	842.3	548.7	103.6	-24.0	30.2	64.4	140.7	134.2	Wet
1985	64.1	68.9	33.7	86.1	-16.7	-39.0	-25.3	-27.3	27.9	-5.7	-6.0	55.5	Wet
1986	96.3	29.7	-9.7	27.7	31.1	163.3	-18.7	-24.6	14.5	15.7	38.3	89.0	Wet
1987	70.8	15.9	77.5	128.5	2.8	73.6	35.3	-24.4	16.1	0.8	35.4	42.8	Wet
1988	47.3	54.9	-10.2	-18.2	-1.4	-99.1	2.2	-30.4	-17.7	-26.2	1.6	19.2	Normal
1989	17.0	-60.2	-60.4	-68.2	-45.5	-96.2	6.1	-47.5	36.7	-50.3	-24.8	-28.4	Normal
1990	46.3	-57.5	-70.4	-72.2	-42.1	-86.8	-50.1	-46.7	-43.9	-93.8	-49.5	-34.6	Normal
1991	5.6	-4.8	-34.3	-51.9	0.6	36.6	-17.4	-23.9	-21.1	-52.8	-7.9	13.3	Dry
1992	2.0	-68.3	-83.7	-94.9	-115.6	-131.3	-18.6	-73.8	-65.5	-59.5	-37.8	0.6	Normal
1993	7.6	-84.0	89.9	-44.1	-103.2	-87.4	108.7	7.0	12.8	-54.5	-23.8	7.4	Wet
1994	-8.1	-75.7	-32.0	-39.4	-27.5	-105.8	15.6	-37.4	-34.7	-59.7	-10.8	-3.1	Normal

Based on monthly OpStudy hydrology and target flows from Appendix A-5 Column 8 in Attachment 5 of the Program Document.

APPENDIX D

Memorandum: Analysis of Return Flows Associated with Seepage from Elwood Reservoir

Hahn Water Resources (Revised May 18, 2018)

MEMORANDUM (revised 05/18/2018)

May 18, 2018

TO: Seth Turner
Kevin Werbylo
Scott Griebling
Jason Farnsworth
Platte River Recovery Implementation Program (Program)

FROM: William Hahn
Hahn Water Resources

SUBJECT: Analysis of Return Flows Associated with Seepage from Elwood Reservoir

Introduction

The Program purchases water from the Central Nebraska Public Power and Irrigation District (CNPPID) for delivery to Elwood Reservoir via CNPPID's E-65 Canal. All water delivered to the reservoir is pumped via the Carl T. Curtis Pump Station. Subject to other calls for the water, the water is typically available to the Program during times of excesses to target flows. Elwood Reservoir occupies about 1,200 surface acres and is operated by CNPPID. The reservoir became operational in 1976. The main physical features in the vicinity of the reservoir are shown in **Figure 1**.

Elwood is a leaky reservoir. Elwood Reservoir losses range from about 10 to 60 cubic feet per second (cfs) and that these losses are a function of reservoir stage (CNPPID, 2018, Elwood Tracking Spreadsheet 1-16-2017). The relationship between reservoir stage and the rate of loss is shown in **Figure 2**. The Program's goal is to have water delivered to Elwood for groundwater recharge, recognizing that some of the water that seeps from the reservoir will return to the Platte River during times of shortage to target flows.

Water stored in Elwood Reservoir can leave the reservoir along the following pathways:

- Build-up of groundwater storage
- Accretions to groundwater and return to the Platte River via the subsurface
- Accretions to groundwater and return to the Republican River via the subsurface
- Accretions to groundwater and interception by Plum Creek and discharge to the Platte River
- Accretions to groundwater and interception by tributaries and drains and discharge to the Republican River

- Direct evaporation from the reservoir's water surface and transpiration by plants residing along the shoreline (ET)
- Gravity discharge and/or pumping through the Carl T. Curtis pump station.

Water that is stored in Elwood Reservoir can enter the reservoir along the following pathways:

- Direct runoff
- Precipitation on the reservoir's surface
- Pumping from the E-65 canal.

The goal of this study was to evaluate the timing and relative proportions of water moving along these pathways. A cursory analysis of precipitation and ET indicated that these terms were approximately equal on an annual basis, and that for purposes of this investigation, their omission from the reservoir's water balance would not have a material impact on the timing and disposition of reservoir losses. The timing and quantities of water returning to the Platte River via subsurface flow and through interception by Plum Creek were of particular interest, as both of these returns are potentially of benefit to the Program in reducing shortages to target flows. For purposes of this study, it is assumed that water intercepted by Plum Creek can be counted as an immediate gain to the Platte River. This is a reasonable assumption given that the travel time for seepage water to reach the Platte River once it has been intercepted by Plum Creek is a matter of days.

This investigation was performed under the direction of Bill Hahn of Hahn Water Resources, LLC (HWR). Hahn serves as a Special Advisor to the Program. Scott Griebling of the EDO assisted in the execution and review of the work. The work described herein relied on the current version (as of November 2017) of the COHYST Groundwater Model. Hayden Strickland of Ecological Resource Consultants, Inc. (ERC) performed a major portion of the work involving the COHYST Model, including parameter adjustments, checks on calibration, model execution, and compilation of model results, under contract to HWR.

The results of this investigation consist primarily of an analysis of the timing and location of return flows originating as seepage from Elwood Reservoir. These results will be used by the EDO in scoring of the project. In this case, scoring involves a comparison of the timing and quantity of return flows reaching the Platte River with the timing of shortages to US Fish and Wildlife Service defined target flows in the Platte River. The scoring analysis will be performed by the EDO and addressed in a separate document. Return flows are herein defined as water that has seeped from the reservoir that: has been intercepted by a stream such as Plum Creek; water that has traveled through the groundwater system and re-emerged in a river (Platte or Republican); and water that has entered groundwater storage.

There are multiple references herein to the "COHYST Model". The full implementation of the COHYST Model consists of three integrated models: a) Surface Water Model; b) Groundwater Model, and; c) Watershed Model. For purposes of this memorandum, all references to the COHYST Model refer to the groundwater model, unless indicated otherwise. The version of

COHYST used for the analysis described herein (as of November 2017) is considered to be the final, fully calibrated form of the model.

There was a previous attempt to estimate the timing and pathways for seepage from Elwood Reservoir to reach the Platte River. This work was done jointly by HWR and EDO staff (2015, unpublished work by EDO staff and HWR). That work relied on several COHYST Model simulations performed by the Nebraska Department of Water Resources (NDNR). As such, the results were based on an earlier, interim version of the COHYST Model. The scope of that investigation was somewhat limited – as a result, the simulations did not allow for a complete accounting of the disposition of water seeping from the reservoir.

Background

The Program began purchasing water for delivery to Elwood Reservoir in May 2015. Water is purchased from CNPPID for delivery to Elwood via CNPPID's E-65 Canal. CNPPID maintains an accounting of water delivered to the reservoir for the multiple accounts. The Program is one of several of these "accounts" representing water stored in the reservoir.

At this time, CNPPID accounting for reservoir content considers multiple inflow and outflow terms. The single largest inflow to the reservoir is water that is pumped through the Carl T. Curtis pump station from the E-65 canal. There are no tributaries or streams of significant size draining into the reservoir. In terms of CNPPID accounting, losses represent the sum of water leaving the reservoir as ET and seepage and entering the reservoir as precipitation and direct runoff. Given that ET and precipitation are in approximate balance, and that contributions from surface runoff are considered negligible, losses in this case may be assumed to represent water that seeps from the reservoir and then enters the groundwater system. CNPPID employs a stage vs. loss relationship in determining day-to-day losses from the reservoir. That relationship is shown in **Figure 2**.

Plum Creek passes along the embankment of Elwood Reservoir. There is a gaging station on Plum Creek known as Plum Creek near Smithfield. While the records are intermittent, there is clear evidence of a change in the flow regime of Plum Creek coincident with the construction and filling of Elwood Reservoir which was completed around 1976. **Figure 3a** shows the long-term record of the average daily discharge of Plum Creek. **Figure 3b** shows a partial record of the average daily discharge during the period 1996 through 2002. The long-term record (Figure 3a) shows that prior to 1976, Plum Creek discharge frequently dropped to zero or near zero, whereas the discharge rarely dropped below 10 cubic feet per second (cfs) after 1976, implying consistent baseflow accretions from Elwood seepage.

Changes and Recalibration of the COHYST Model

The COHYST Groundwater Model is a regional model covering an estimated 35,000 square miles, of which about 20,000 square miles are part of the model's active domain. It is based on MODFLOW, a groundwater modeling tool developed by the U.S. Geological Survey. The model includes a number of tributary streams and drains, including Plum Creek. The COHYST

Model is a monthly model (stresses such as pumping or recharge are represented as being constanct over a one-month period). It simulates a period of about 26 years, starting in October 1979 and running through December 2005. There are two time-steps for each stress period.

As a regional model, the COHYST Model is considered to be reasonably well calibrated (COHYST Model Documentation, 2013, Appendix 7H). However, as is sometimes the case with regional models, calibration efforts tend to focus on the regional scale and may be less rigorous at the local scale. Where the regional model is applied at a local scale, it is appropriate to evaluate the quality of calibration at a local scale and where appropriate, modify the model to improve calibration.

The quality of model calibration in the area of Plum Creek was reviewed prior to use of the model in predicting return flows from Elwood Reservoir losses. The published calibration results (**Figure 4**) suggested that the COHYST Model was under-predicting the response of discharge in Plum Creek to losses from Elwood. On average, it appeared that the model was under predicting flows in Plum Creek by about 10 to 15 cfs. However, the current investigation (the subject of this report) relied on two important sources of information on flow in Plum Creek, only one of which appears to have been considered in the development of the COHYST model. The first source consisted of flow measurements from a rated section at a stream gage operated intermittently beginning in 1946 known as Plum Creek near Smithfield, or the Smithfield gage. The data for this gage appear to have been used as a calibration target by the developers of the COHYST Model, although we were unable to identify the records used in generating the “estimated” flow record shown in **Figure 4**. A second source of information consisted of a set of measurements (17 measurements of discharge at 6 locations along Plum Creek including Plum Creek near Smithfield) made in the course of one year (US Geological Survey, 2004, Water Resource Data Nebraska, 2004). The locations of the measurement points are shown in **Figure 5a**. The station numbered 4 on the figure coincides with the Smithfield gage. The principal value in the gain/loss study is that it identifies the relative gains in flow along Plum Creek, beginning at a location just upstream of where Plum Creek passes Elwood Reservoir. The survey shows significant gains in the reach of Plum Creek where it passes Elwood. The survey also shows that there are no reaches along Plum Creek that experience losses of water between Elwood Reservoir and the confluence of Plum Creek with the Platte River. **Figure 5b** shows the average discharge for each of the six stations based on 17 measurements at each station during 2004.

In comparing COHYST Model predictions of flow in Plum Creek with the aforementioned data sources, we concluded that the COHYST Model predictions of flow in Plum Creek at station 1 (**Figure 5**) were reasonable, i.e. discharge of about 1 to 2 cfs in the reach of Plum Creek above Elwood Reservoir. However, we concluded that the COHYST Model was under-predicting the gains between station 1 and station 4. The COHYST Model predicted this reach of Plum Creek to be both gaining and losing, but with a net gain that was substantially less than the target gain of about 8 to 10 cfs. Also, the COHYST Model was predicting the reach of Plum Creek between Station 4 and Station 6 to be a net losing reach, whereas the measurements of discharge indicated this reach is a gaining reach.

The final “solution” in evaluating the timing and location of losses and return flows from Elwood Reservoir involved several refinements to the COHYST model. The refinements were required in order to improve the model’s calibration and the reasonableness of the model’s predictions. Throughout this process, we evaluated the agreement between observed groundwater levels and model predictions of water levels, with the intent of preserving, as best possible the quality of the model’s calibration to water levels.

This process involved step-by-step testing of different changes to the model and an evaluation of the impact of those changes on the quality of the model’s calibration and the reasonableness of the results. Some of these changes resulted in model responses that appeared to improve the overall quality of the model’s predictions, whereas others resulted in some unexpected model behavior and no improvement to the model’s predictions. Despite the fact that some of these tests were judged to be failures (in terms of the overall goals of the model refinement process), a record of the types of tests that were attempted may be useful if there are subsequent efforts to further refine the model. The results of these tests may also inform decisions as to the need to refine the model for general use and decisions to make further changes to the model elsewhere in the model’s domain.

Plum Creek Elevations

The first set of model adjustments that were attempted were intended to improve calibration of the model in terms of its predictions of flow in Plum Creek and the gains and losses that occur in Plum Creek beginning with the segment of the creek immediately north of Elwood Reservoir and extending to the confluence of Plum Creek and the South Channel of the Platte River.

The model’s predictions of the relative gains and losses that take place between a stream and the underlying groundwater system are dependent on, and sometimes highly sensitive to, the difference between surface water levels in the stream and the underlying groundwater levels. In this case it appeared that differences in levels of as little as a few feet might have significant impacts on the model’s predictions of gains and losses. Given the relatively coarse cell size of the model, and the relative coarseness of data for the stream’s surface elevation, depth, and the elevation of the predicted groundwater table, the initial test consisted of lowering the streambed elevation (as it is represented in the model) by one to several feet over relatively short reaches of the stream. However, rather than having the expected result of producing changes in stream gains and losses, this change resulted in the model failing to converge. Also, the convergence failure occurred in cells several miles from Plum Creek, far removed from the location of the changes. Repeated attempts to introduce small changes in streambed elevations all resulted in convergence failures. Accordingly, this method of improving model calibration was abandoned. There were no further attempts to resolve the model convergence issues, although these issues may by symptomatic of more significant instabilities within the model.

Hydraulic Conductivity

Ultimately, a change in the value of hydraulic conductivity (from 80 feet per day (ft/d) to 55 ft/d) for a region of the model that included Elwood Reservoir provided a significantly improved agreement between observed stream gains and model predictions of stream gains in the reach between Stations 1 and 4. The region for which this change was made was pre-defined, i.e. this was one of many regions delineated by the COHYST modeling team. We found the lower value of hydraulic conductivity to be more or less consistent with reported values of specific capacity in this area (specific capacity is often used to infer values of hydraulic conductivity). The change in hydraulic conductivity did not appear to compromise the quality of the model's calibration to water levels. Additional discussion of this change is provided in **Attachment 1** to this memorandum.

Plum Creek Below Smithfield Gage

Although the model continues to predict slight losses in streamflow in Plum Creek in the reach between the Smithfield gage (Station 4) and the junction of Plum Creek with the Platte River (Station 6), there were no attempts to improve or otherwise change the model's calibration for this reach of Plum Creek. There were several reasons for this decision. We observed large swings in the model's predictions of gains and losses along the length of the channel in this reach. Some of these changes may be related to topography crossed by the stream – Plum Creek traverse an upland area before descending through a relatively steep escarpment whereupon the topography transitions to a relatively flat floodplain. These rapid changes in elevation may not be fully and accurately reflected in the model's representation of topography or stream bed elevation. Further, these rapid changes in surface elevation may be mirrored to some degree by rapid changes in the groundwater table through this area, again a condition that may not be fully captured in the model. Also, in making refinements to the model for the lower segment of Plum Creek, there is some risk that the effects of changes made in and near Plum Creek could propagate beyond the immediate area and might cause changes in the model's representation of the Platte River as well, and unnecessarily complicate the calibration process. Accordingly, it was decided not to attempt any improvements to model calibration through this reach of Plum Creek (Smithfield gage to the Platte River). For purposes of quantifying gains and losses related to seepage from Elwood Reservoir, gains and losses in Plum Creek are taken to be those measured at the Smithfield gage.

Total Gains and Losses (Plum Creek plus Platte River)

Gains and losses of the Platte River as related to seepage from Elwood Reservoir are taken to be the sum of gains and losses for two segments of the Platte River (essentially the North Channel and the South Channel) lying north of the area drained by Plum Creek. Detailed mapping of these segments is shown in **Figure 6**. The full measure of gains related to seepage from Elwood Reservoir is taken as the sum of gains in Plum Creek (as calculated at the Smithfield gage) plus the gains in reaches 1 and 2 of the Platte River (**Figure 6**). As discussed earlier, the gain/loss patterns in the lower reach of Plum Creek as predicted by the model are erratic and were not subject to any attempts at refinement in this project. The gain/loss patterns of the Platte River's south channel in the reach immediately below the point at which Plum Creek enters the river are similarly erratic. Fortunately, a general measure of the total of gains and losses (Platte River plus Plum Creek) can be obtained by looking at the total of the gains and losses at the upstream end of reach 4 (**Figure 6**). This location theoretically measures the total of the gains and losses of the Platte River plus the gains and losses of Plum Creek. The sum of the gains and losses reported at this location in response to simulated losses from Elwood Reservoir are in close agreement with the total obtained by summing the gains for reaches 1 and 2 of the Platte River and those of Plum Creek.

Platte River Split Channel

Figure 7 shows the predicted groundwater level rise following 26 years of recharge at Elwood Reservoir. The gains estimated for Reach 1 of the Platte River (South Channel) appeared as if they could have been underestimated by the model, given that this reach is immediately north of and within an area of direct influence of groundwater level rise (mounding) associated with seepage from Elwood Reservoir (**Figure 7**). A closer inspection of the model package used to represent the Platte River through this area revealed that the model represents the river as occurring in two distinct channels. More importantly, the model is configured in such a way that all flow moving down river was being routed to the north channel. In such a case, groundwater levels beneath the river might be expected to be consistently higher in the north channel and lower in the south channel. It is therefore conceivable that river gains might be underestimated for the south channel, as the amount of rise in the water table needed to trigger river gains would be larger than if the channel were constantly flowing. This was considered to be a potentially important consequence of the routing scheme in the model. In order to test this possibility, the routing aspect of the stream package was modified to allow 50% of the up-river flow to be routed to the south channel. This change had no discernable impact on the gains calculated for Reach 1 (south channel) and therefore the stream package was returned to its original setting (all flow diverted to the north channel). Whereas river conditions in this reach do not appear to exert a strong influence on gains, there is strong evidence of a seasonality to gains and losses. It appears that gains from Elwood Reservoir seepage increase significantly during the irrigation season. This is likely related to a broad scale rise in water levels during the irrigation season. In such a case, any additional rise in groundwater levels such as would be caused by seepage from Elwood Reservoir would cause a more immediate increase in gains in the river at times when groundwater levels are high.

Analysis of Timing and Location of Return Flows

Return flows are herein defined as water that originates as leakage from Elwood Reservoir and subsequently accumulates in groundwater storage, travels by subsurface flow to either the Republican or Platte Rivers, or is intercepted by tributaries and/or drains. The COHYST Model was run twice – once as a baseline simulation and once as an impact simulation, as a way to investigate the timing and distribution of return flows. Groundwater responses for the impact simulation were generated by introducing a recharge impulse in Elwood Reservoir. The recharge impulse was modeled by adding 10 wells, each recharging 1 cfs. The wells were distributed one per cell over 10 model cells coinciding approximately with the footprint of the reservoir. All other stresses remained unchanged. There was no attempt to apportion the recharge according to the portion of a cell actually occupied by water. This simplification is reasonable, given the fact that there is no available information on differences in the rate of loss across the reservoir bottom. Also, this simplification likely has minimal impact on the accuracy of the model predictions.

The timing and distribution of return flows for a 10 cfs recharge condition were evaluated by comparing the impact scenario with the baseline scenario. Impacts (gains) to Plum Creek were determined by extracting model predictions of flow in Plum Creek at a location in the model coinciding with the Smithfield gage. Impacts (gains) to the Platte River were determined by summing the predicted changes in gains/losses for two stream reaches (Reaches 1 and 2) used to represent the Platte River near where Plum Creek enters the river (see **Figure 6**). For purposes of this exercise, the slight gains and losses predicted to occur in the reach of Plum Creek between Station 4 and Station 6 are ignored. The model prediction of an increase in losses in this reach is likely an artifact of a calibration that predicts this as a losing reach, whereas flow observations consistently indicate this to be a reach of slight gains.

The model predicts that there are no increases in discharge of any of the tributaries and drains within the Republican River basin. Spot-checking of elevations specified in the model for various tributaries and drains suggests that the elevations as specified in the model are reasonable. However, in comparing the predicted rise in water table with these specified elevations it can be seen that the water level rise is insufficient to cause any interception of groundwater flow by surface tributaries and drains. Similarly, the model predicts no change in flow within the Republican River itself. This is likely a result of the long time required for changes originating at Elwood Reservoir to reach the Republican River (the distance from Elwood Reservoir to the Republican River is about three times the distance from Elwood Reservoir to the Platte River).

A sensitivity test was done to investigate the effects of a significant increase in leakage from Elwood Reservoir. In particular, we were interested to know whether a significant increase in recharge might raise groundwater levels to a point where tributaries and drains in the Republican Basin would begin to intercept the raised groundwater table. The test consisted of a recharge impulse of 30 cfs (i.e. 30 cfs of recharge above historical rates). The tributaries and drains in the Republican River basin remained dry and failed to intercept the raised groundwater table. Similarly, there were no increases in flow in the Republican River in response to the increase in recharge.

Figure 8 shows the model's prediction of gains for the Platte River (Reaches 1 and 2 separately, and total for the river) and Plum Creek in response to 10 cfs of continuous recharge at Elwood Reservoir. The figure also shows the rate of movement of water into groundwater storage. In effect, the movement of groundwater into storage is a measure of the build-up of water levels (growth of a groundwater mound). The broad swings in gains to the Platte River and movement of groundwater into storage appear to be seasonal, and related to the changes in groundwater levels between irrigation and non-irrigation seasons.

Figure 9 shows the effect of applying a "smoothing" function to the predictions in Figure 8 as well as an attempt to extend the predictions from 26 years (as produced by COHYST) to 48 years (for consistency with the 48-year hydrology used in project scoring). **Figure 9** reflects a recognition that estimated gains will approach a steady-state value as the change in groundwater storage approaches zero.

The curve-fitting process involved in generating **Figures 8 and 9** introduces a small (less than ten percent) error in the separate terms. Whereas the sum of the gains to the Platte, the gains to Plum Creek, and the movement of water into storage should always sum to 10 cfs (the amount of water added to the system), there are times when this is not the case and the terms sum to greater than 10 cfs. This "error" term is distributed on a proportional basis, reducing both of the gain terms and the flow to storage proportionately. This yields a conservative estimate of the gains realized in response to recharge. **Figure 10** shows the adjusted estimates of gains and movement of water to groundwater storage.

Assuming a continuous delivery of water to Elwood Reservoir at a constant rate of delivery, **Table 1** shows the approximate percentage of return flows by location in increments of 10-years through the 48-year hydrologic study period.

Table 1. Percentage Distribution of Return Flows for Continuous Recharge at Elwood Reservoir

Site of Return Flows	Elapsed Time (years)				
	10 Years	20 Years	30 Years	40 Years	48 Years
Platte River	11%	15%	16%	17%	18%
Plum Creek	39%	48%	53%	56%	58%
Total Returns	50%	63%	69%	73%	76%
Water to Groundwater Storage	50%	37%	31%	27%	24%

The Program began accepting delivery of water to Elwood Reservoir in May of 2015. The total amount of water delivered to the reservoir is reported by the Program to be 29,188 acre-feet (AF) through December 31, 2017. The total loss/recharge during this same period is estimated to be about 21,000 AF (estimated based on average loss of 72% as reflected in CNPPID Elwood Tracking Spreadsheet, 1-16-2017). The water has been delivered to the reservoir intermittently, for periods of several days to a month at a time.

It is possible to make a very approximate accounting of the disposition of the losses incurred while the delivered water has been in storage. If it is assumed that the rate loss of water during the period of storage has been continuous and uniform, this translates to an average loss rate of about 11 cfs over the period May 2015 through December 2017. With these assumptions, the disposition of losses from the reservoir can be estimated as of December 2017. They are approximately as follows:

Table 2. Approximate Disposition of Program Water Delivered to Elwood Reservoir in the period May 2015 through December 2017

Total Program Water Delivered to Elwood Reservoir (AF)	Total Loss of Program Water Delivered to Elwood Reservoir (AF)	Water Returned to the Platte R. via Subsurface Flow (AF)	Water Returned to the Platte R. via Plum Ck. (AF)	Water to Groundwater Storage (AF)
29,200	21,000	600	2,300	18,100

Note: Estimates are approximate and for illustration only. Values rounded and assume losses occur at a uniform rate over time. Actual loss rates vary over time. Modeling of variability in loss rates would provide more precise estimates of returns (locations and amounts).

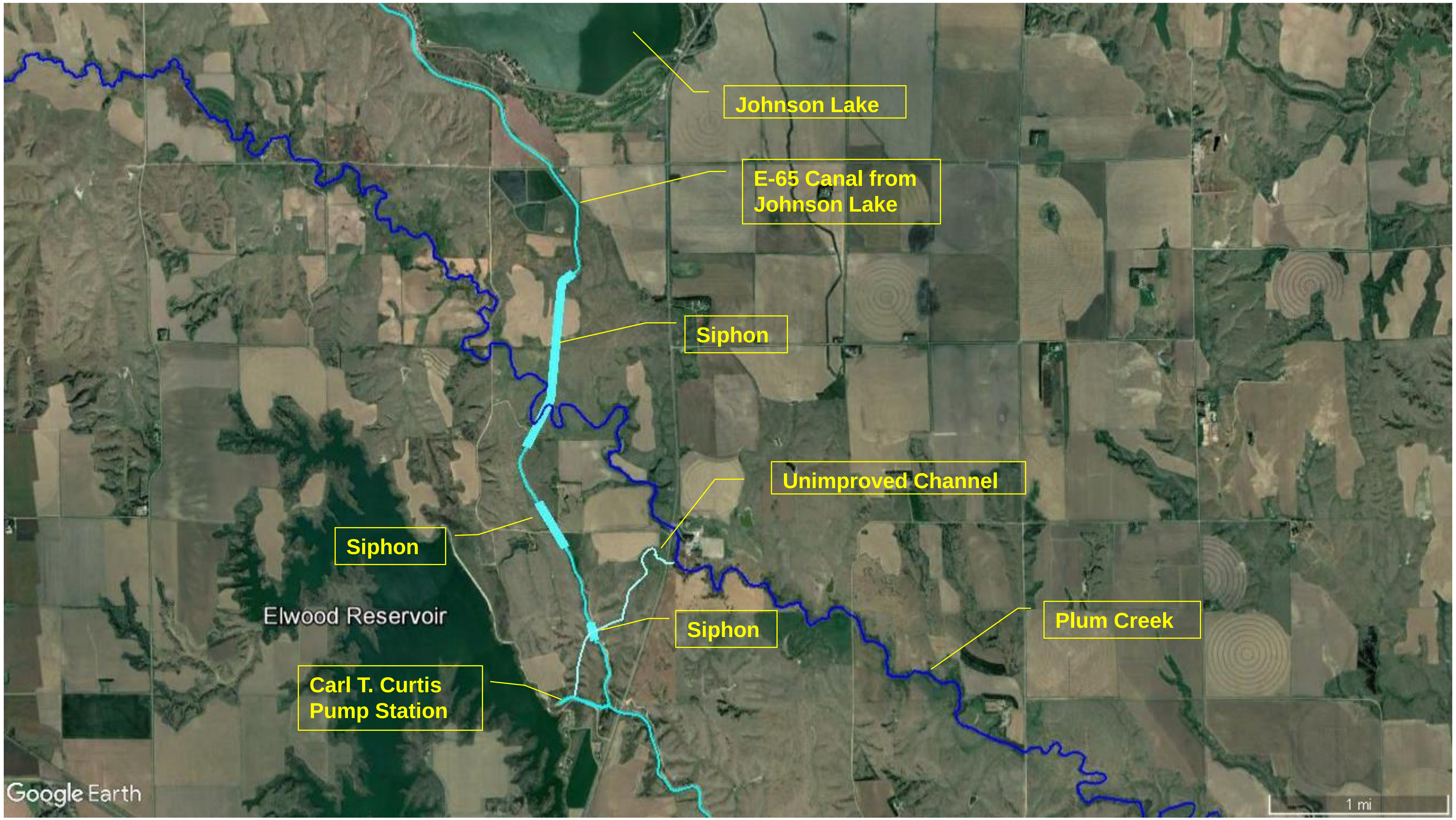
The difference between water delivered to the reservoir (29,200 AF) and the losses (21,000 AF) represents water that is in reservoir storage.

As can be seen in the above table, Program deliveries to Elwood Reservoir have contributed a significant amount of water to groundwater storage in the first several years of recharge (over 18,000 AF). This water may be available to the Program depending on the Program's legal rights to recover the recharged water. One measure of the "efficiency" of the Program's delivery of water to the reservoir is the ratio of return flows generated by the delivery to the total water delivered to the reservoir. In this case, efficiency of the project could be improved by recovering water that is lost from the reservoir and subsequently accumulates in groundwater storage.

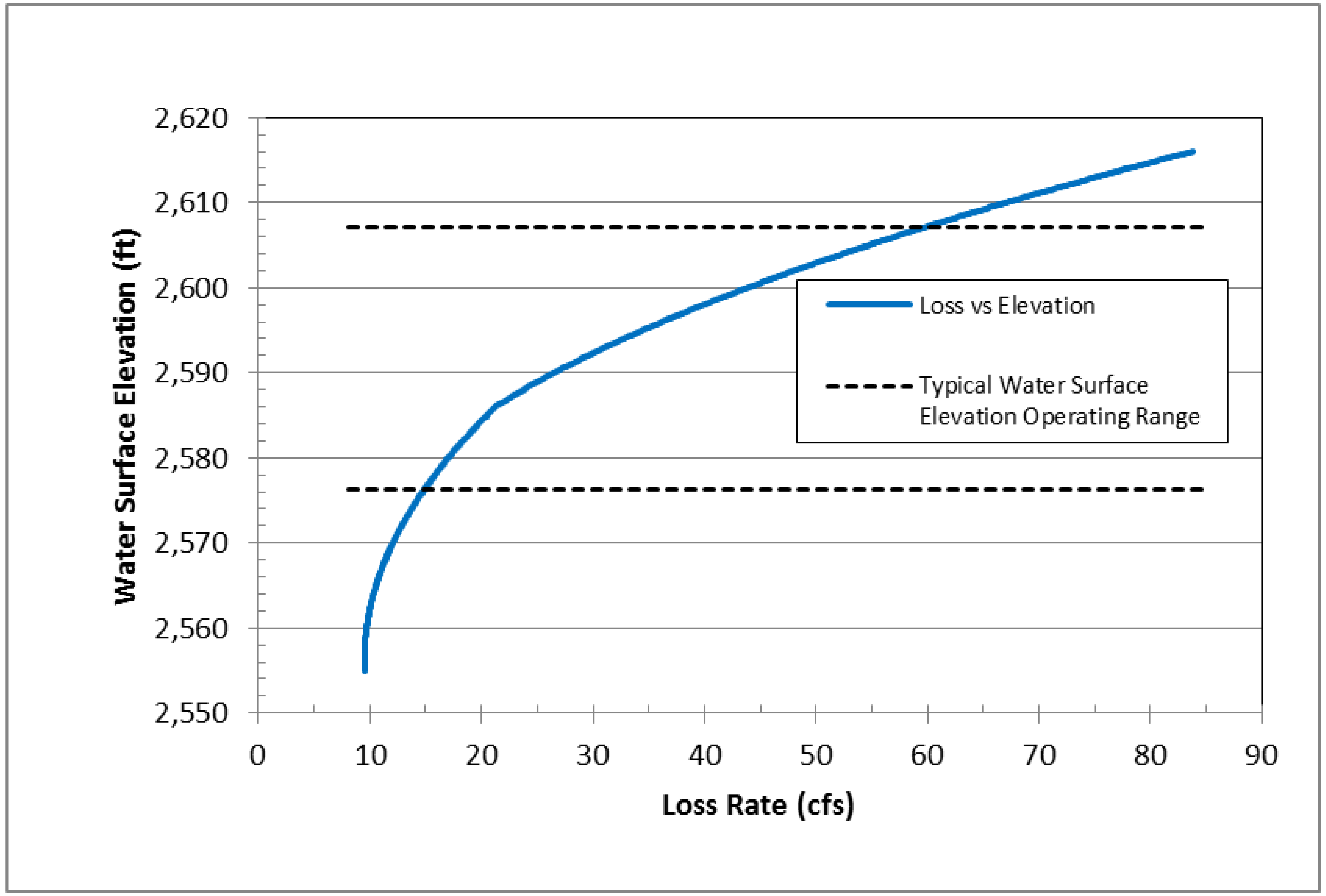
We have not made a rigorous study of the final disposition of water that is moving into groundwater storage. Groundwater contours in the area of the reservoir and contours of the build-up of water levels that will accompany delivery of water to the reservoir all suggest that in time, about one-half of the water moving into groundwater storage will emerge in the Republican River Basin and half will emerge in the Platte River Basin.

List of Figures

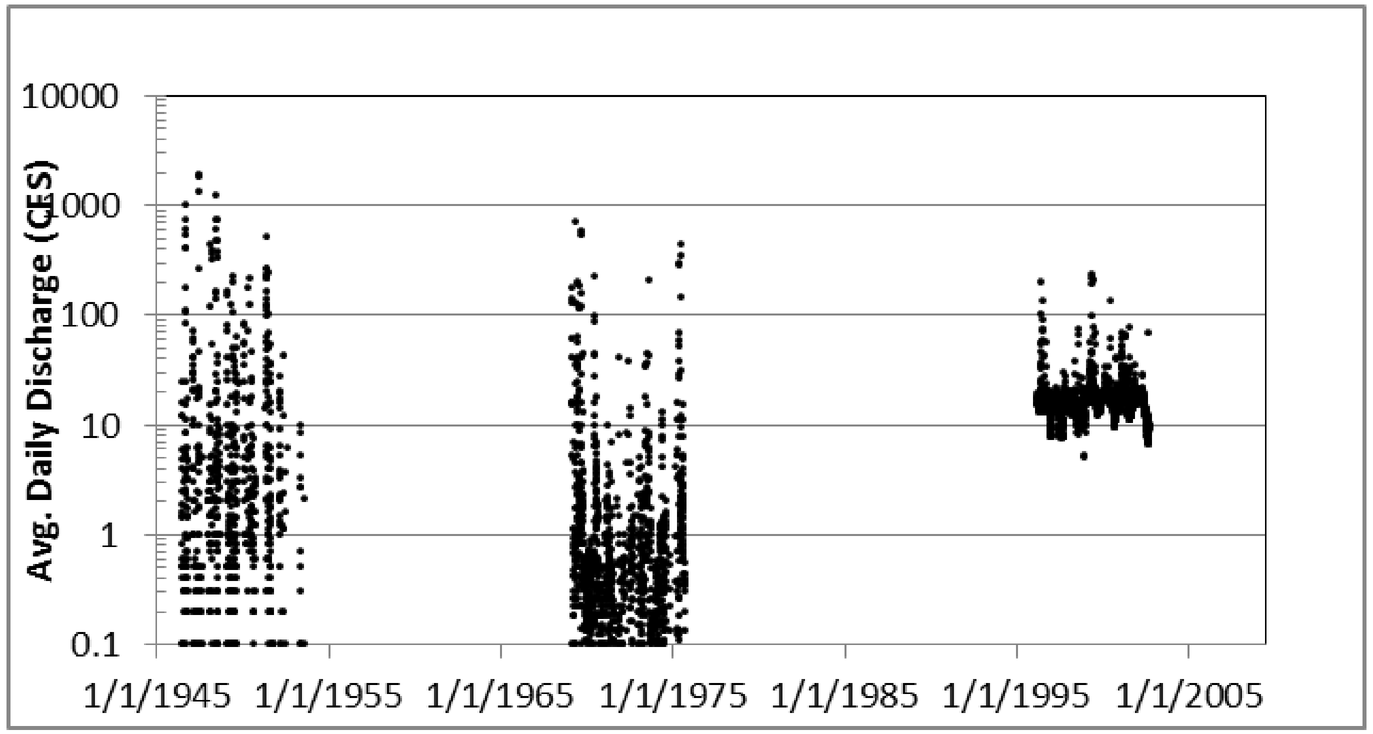
List of Attachments



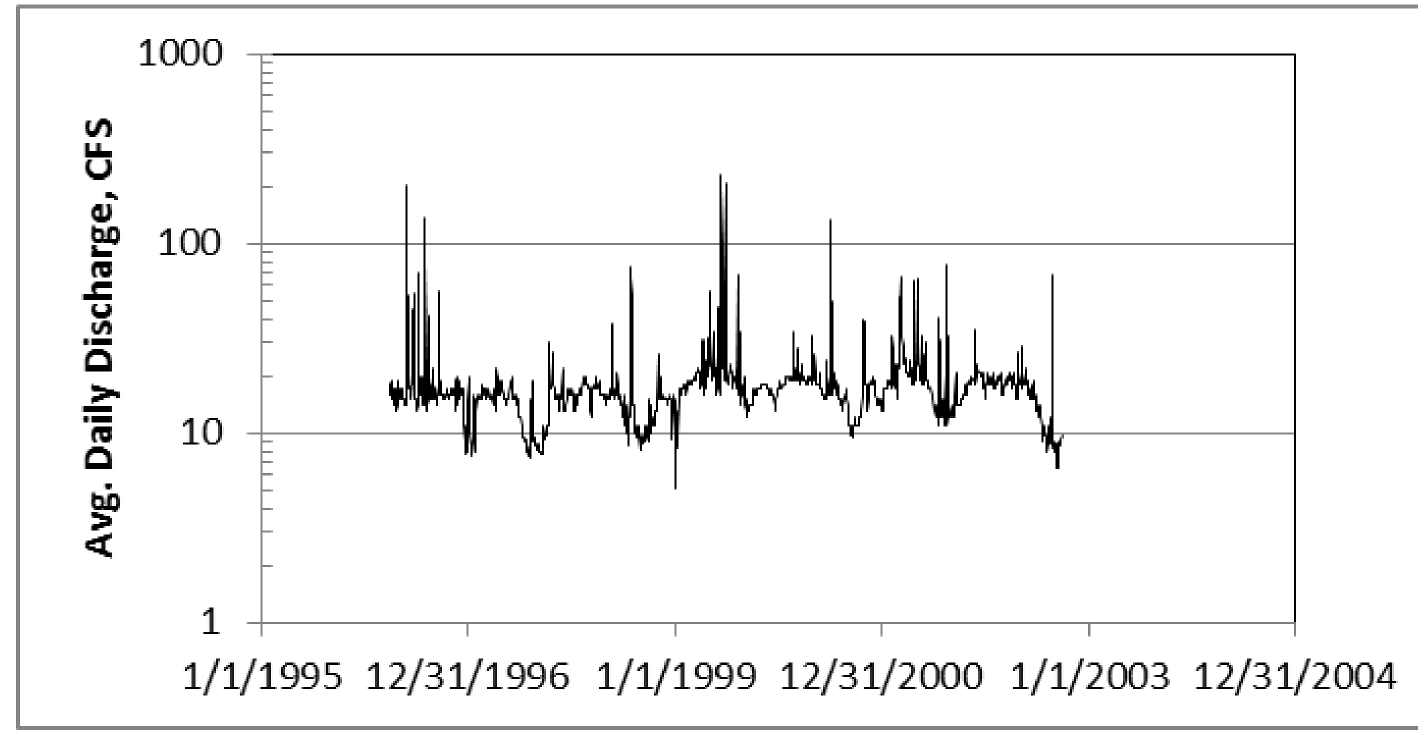
01/19/2018	Elwood Reservoir Project Area	Figure 1
HA-801	Elwood Reservoir Seepage and Return Flow Analysis	



	01/19/2018	Elwood Reservoir Loss Rate vs. Water Surface Elevation	Figure 2
	HA-801	Elwood Reservoir Seepage and Return Flow Analysis	

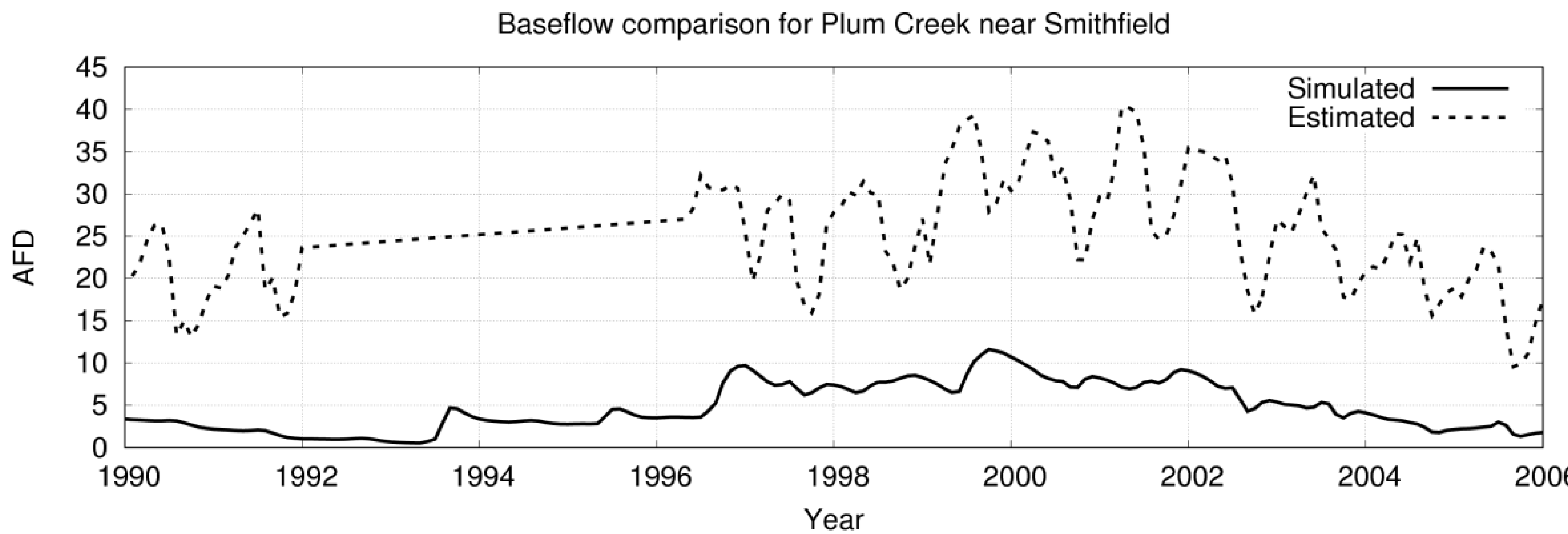


3a. Long-term Record



3b. Recent Record

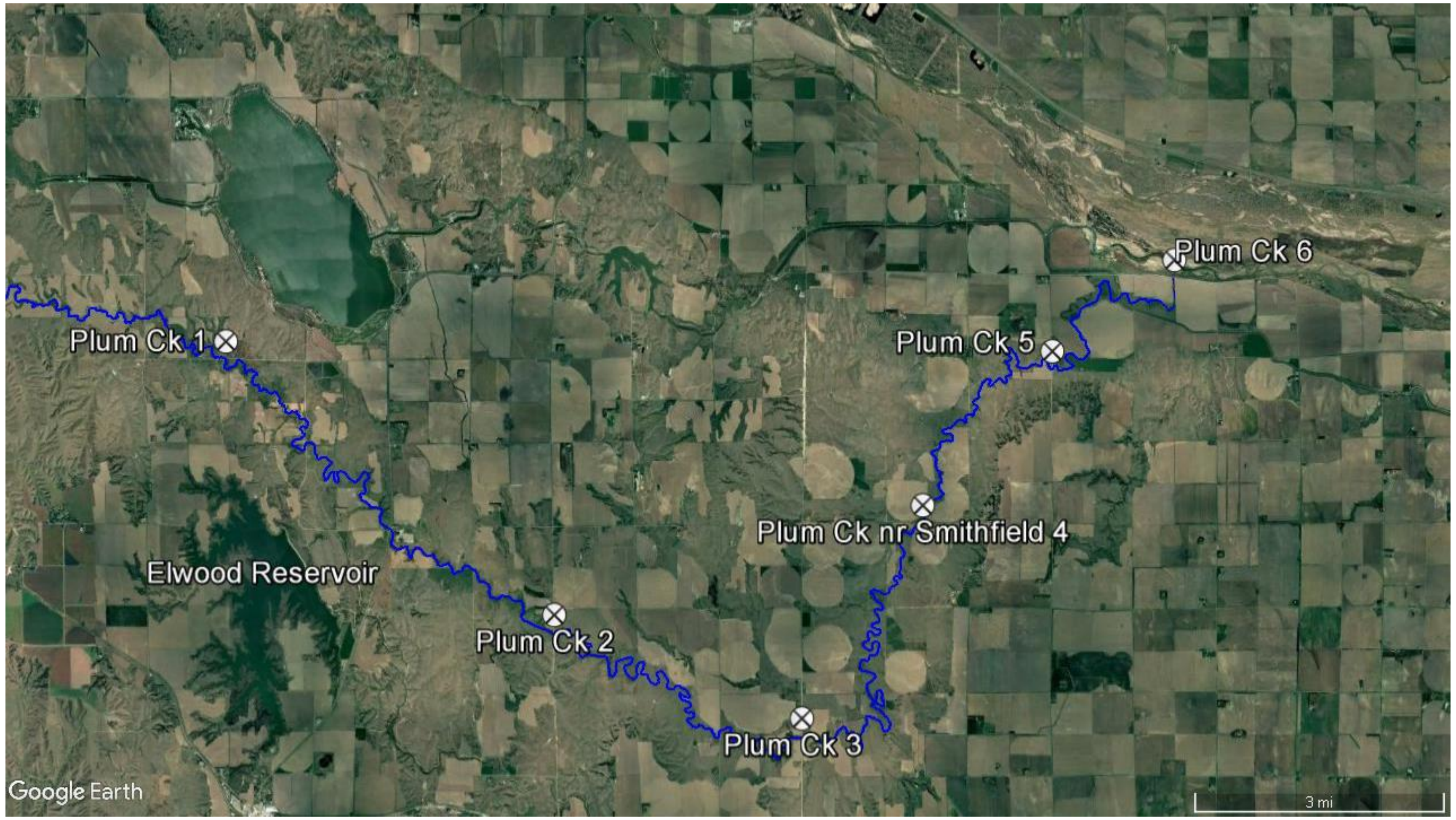
	01/19/2018	Average Daily Discharge Plum Creek Near Smithfield	Figure 3
	HA-801	Elwood Reservoir Seepage and Return Flow Analysis	



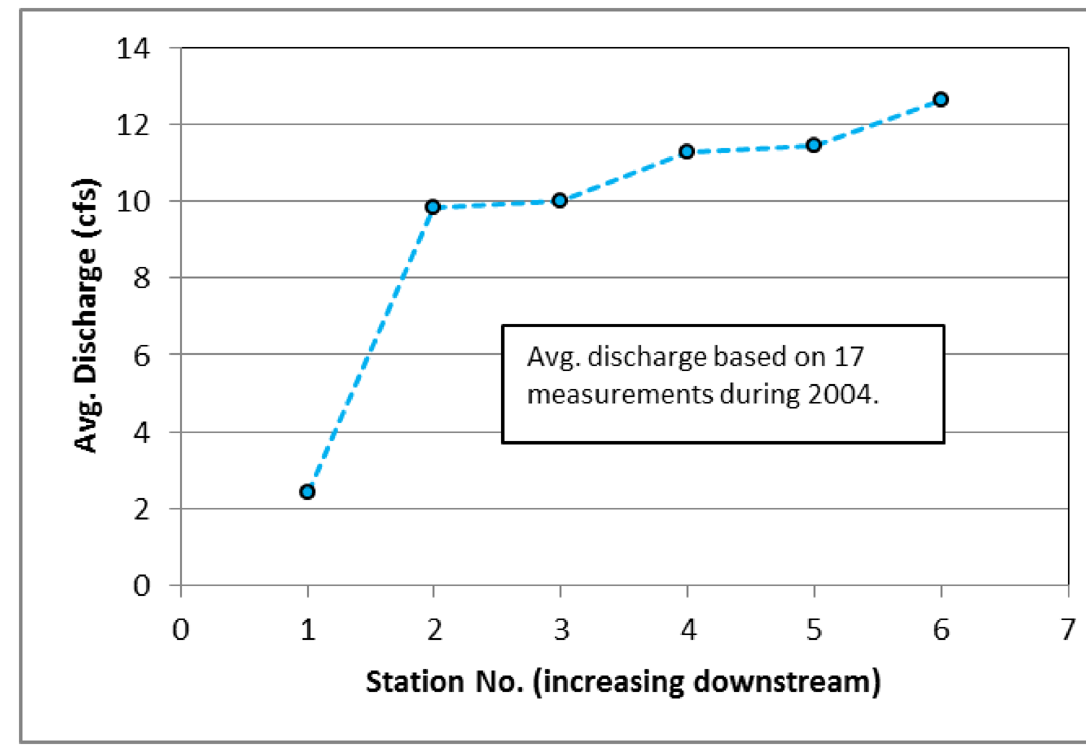
Simulated gains are much lower than observed. For all previous models the simulated values were higher than observed. This may be related to other problems in the Phelps County area.

Source: Presentation by Lee Wilson and Associates 2/7/2017

	01/19/2018	Plum Creek Calibration in the COHYST Model	Figure 4
	HA-801	Elwood Reservoir Seepage and Return Flow Analysis	

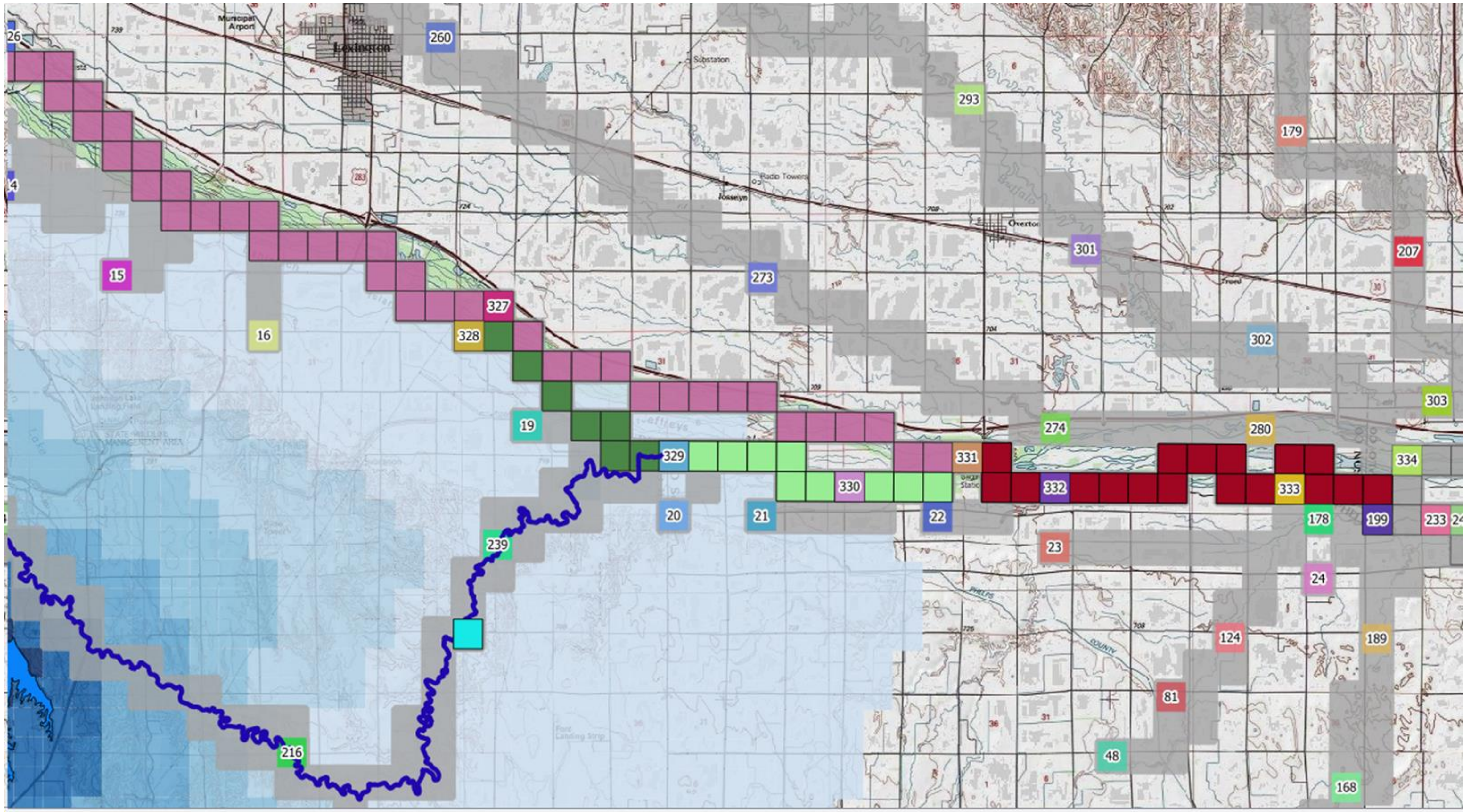


5a. Discharge measurement locations



5b. Average measured discharge

	01/19/2018	Locations of Discharge Measurements in Plum Creek	Figure 5
	HA-801	Elwood Reservoir Seepage and Return Flow Analysis	



Reach 1 Reach 2 Reach 4

Figure from ERC, 2017

	01/19/2018	Model Representation of Stream Reaches for Plum Creek and Platte River	Figure 6
	HA-801	Elwood Reservoir Seepage and Return Flow Analysis	

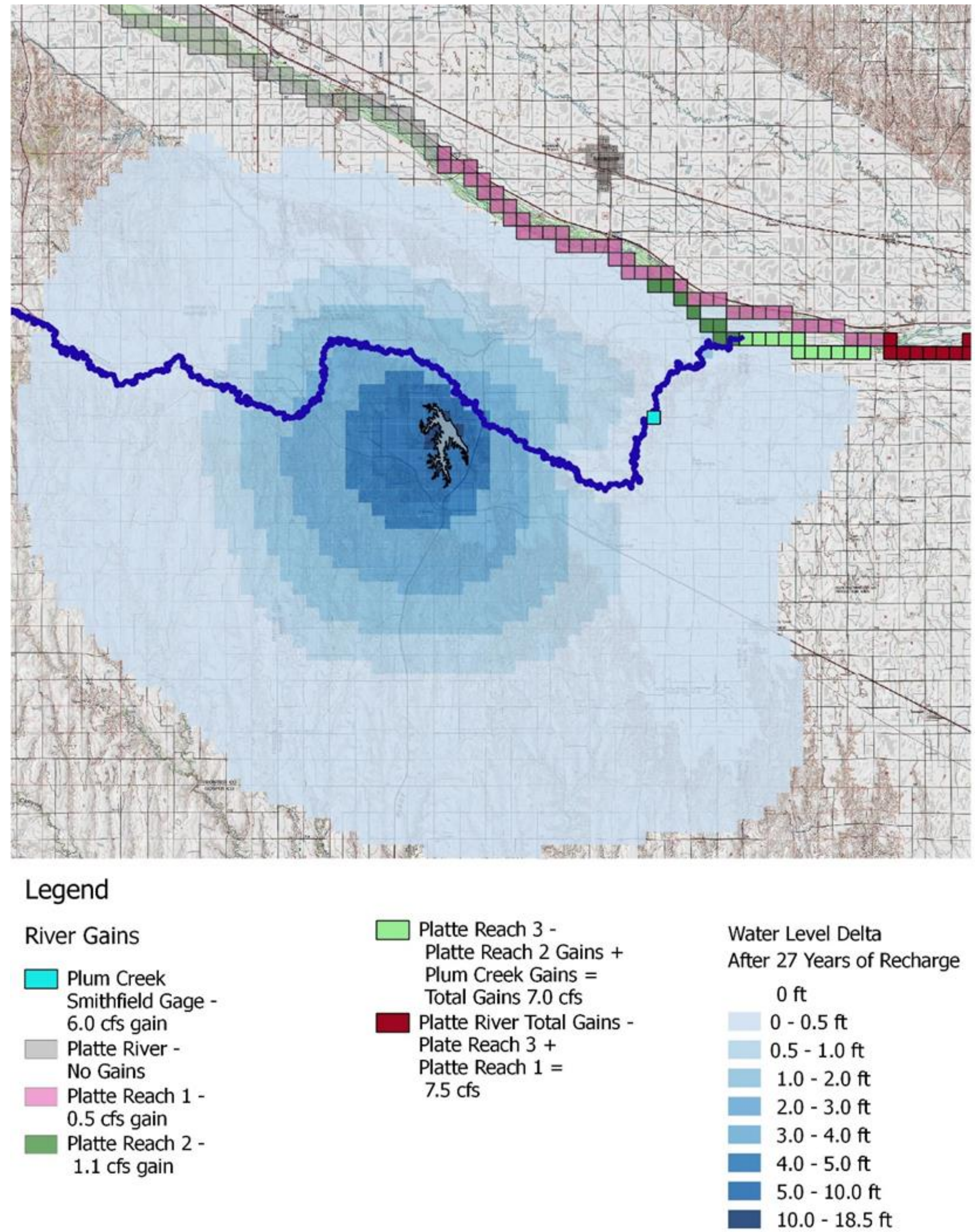
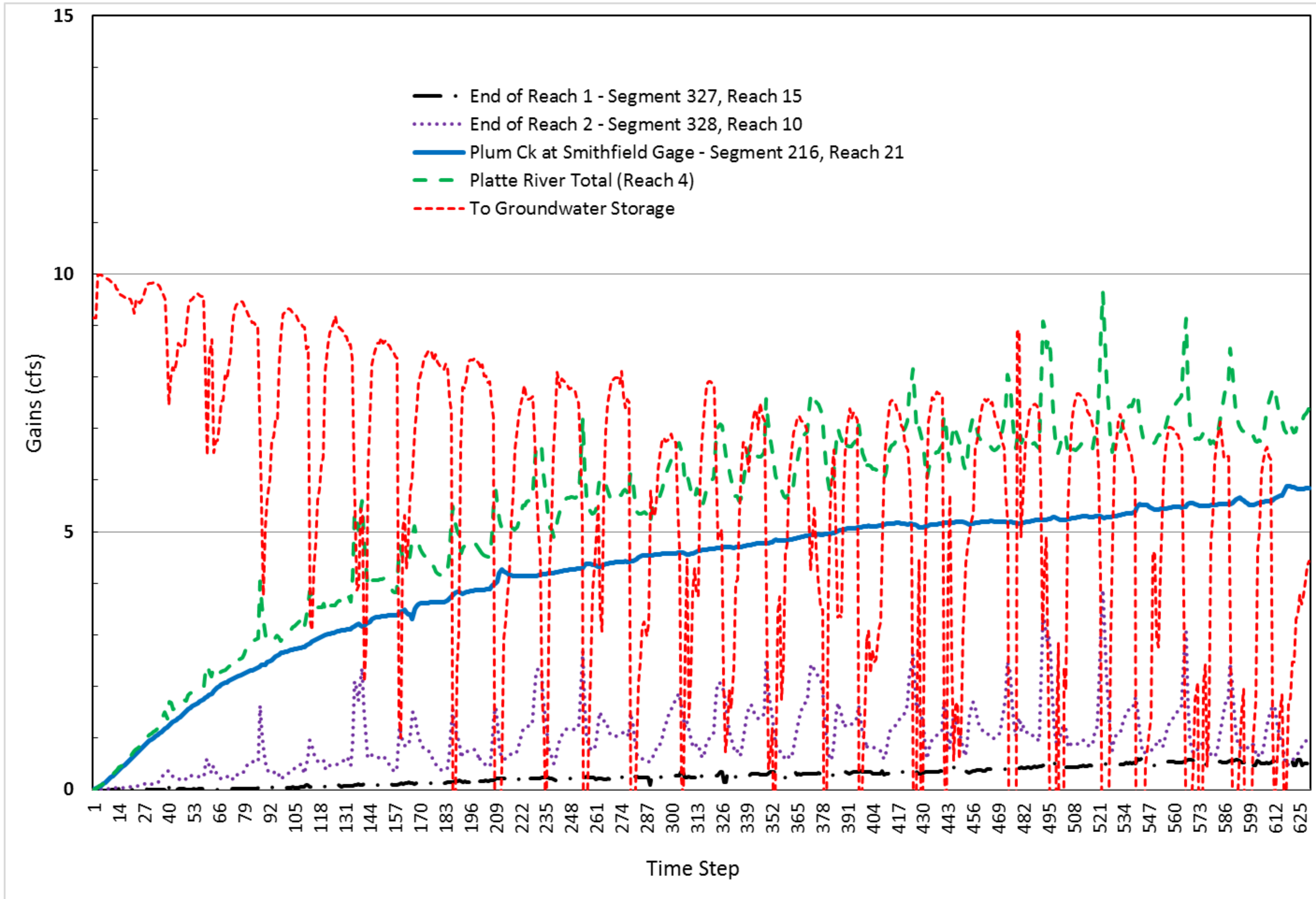
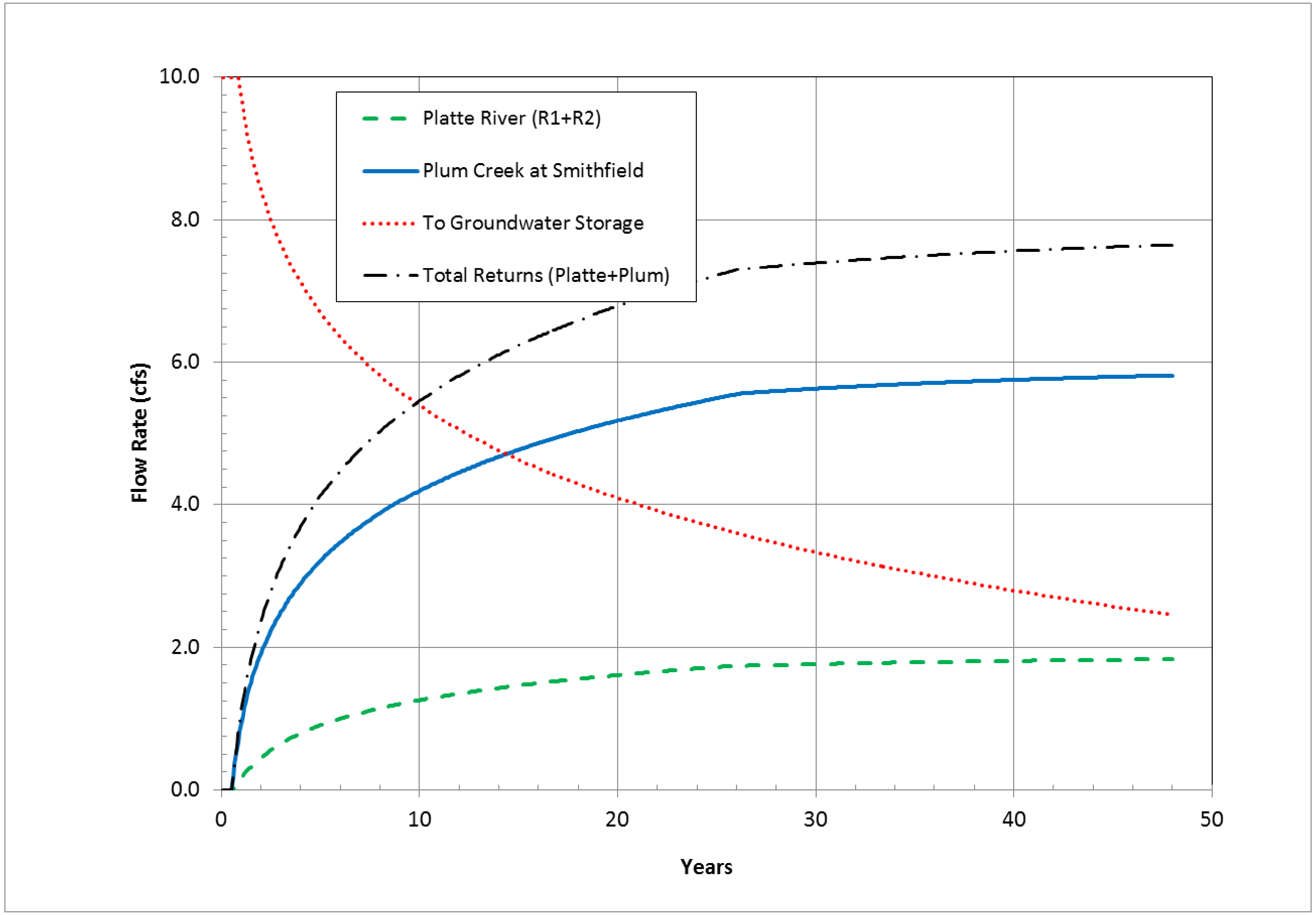


Figure from ERC, 2017

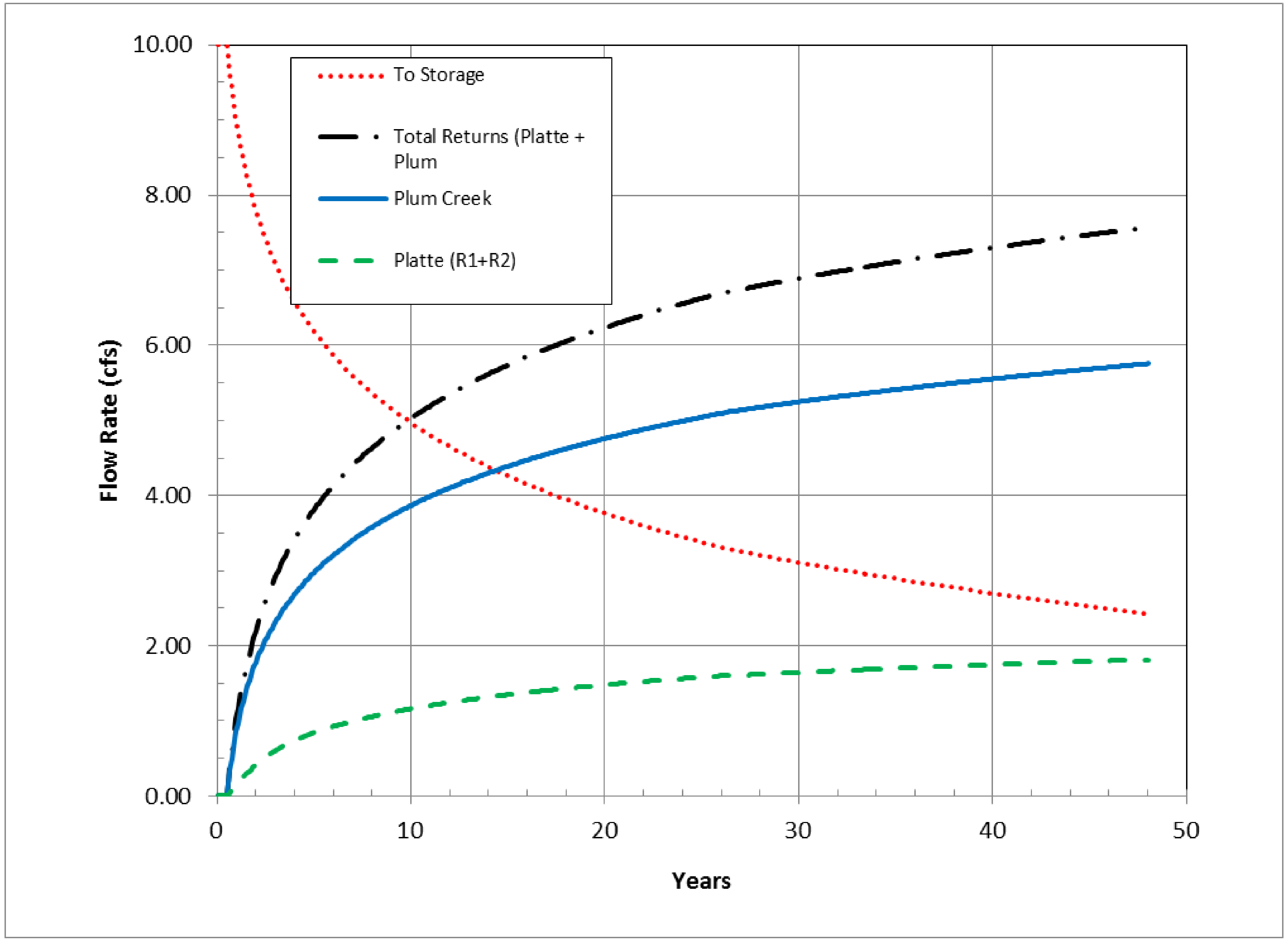
	01/19/2018	Predicted Water Level Rise Following 26 Years of Recharge	Figure 7
	HA-801	Elwood Reservoir Seepage and Return Flow Analysis	



	01/19/2018	Model Prediction of Change in Flow for 10 CFS Recharge at Elwood Reservoir	Figure 8
	HA-801	Elwood Reservoir Seepage and Return Flow Analysis	



	01/19/2018	48-Year Return Flows and Flows to Groundwater Storage for 10 CFS Recharge (unadjusted)	Figure 9
	HA-801	Elwood Reservoir Seepage and Return Flow Analysis	



	01/19/2018	48-Year Return Flows and Flows to Groundwater Storage for 10 CFS Recharge (adjusted)	Figure 10
	HA-801	Elwood Reservoir Seepage and Return Flow Analysis	

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Technical Memorandum

Date: December 12, 2017

To: William Hahn, Hahn Water Resources, LLC

From: Hayden Strickland, Ecological Resource Consultants, Inc.

Re: COHYST Model Results – Elwood Seepage

Ecological Resource Consultants, Inc. (ERC) was retained by Hahn Water Resources (HWR) to evaluate the impacts of Elwood Reservoir Seepage on flows in Plum Creek and nearby sections of the North Platte River. This memorandum presents the results of that analysis.

HWR requested ERC perform four tasks including:

1) **Develop Baseline model run** – Under this task ERC worked with HWR to develop a baseline model for evaluating the impact of Elwood Reservoir seepage on flows in Plum Creek and the Platte River. As part of this task, ERC and HWR concluded that the hydraulic conductivity around Elwood Reservoir and south-southeast of Elwood Reservoir was likely too high at its calibrated rate of approximately 80 ft/day. This was revised to a value of 55 ft/day based on nearby well specific capacity values and matches to Plum Creek flow data collected by HWR at 4 locations (PC-1 to PC 3 and the Smithfield Gage), beginning at a location just upstream of Elwood Reservoir and extending downstream to the Smithfield gage along Plum Creek. Figure 1 shows an overview of the Elwood Reservoir area, Plum Creek, and the location of the changed hydraulic conductivity values. This model run is the baseline model run and is what all other model runs are compared to.

2) **Model 10 cfs of recharge at Elwood reservoir** – Under this task, ERC modeled 10 cfs of recharge utilizing 10 injection wells each pumping 1 cfs for the duration of the model simulation period. These wells were placed in the cells currently used by the COHYST model to simulate recharge as shown below in Figure 2. The stream flows at the Smithfield gage on Plum Creek were then extracted for this scneario run and compared to the flows at the Smitfiled gage for the base case (Figure 3).

3) **Test non-linearity of recharge** – Under this task, ERC modeled f 30 cfs of recharge at 10 Elwood Reservoir cells by modeling 10 injection wells each injecting 3 cfs for the entire modeling period. As with Task 2, the wells per placed in the cells shown in Figure 2, and the stream flows at the Smithfield gage on Plum Creek were then extracted for this scneario run and compared to the flows at the Smitfiled gage for the base case (Figure 3). Under the 10 cfs scenario, approximatley 6 cfs reached Plum Creek after 27 years. Under the 30 cfs scenario, this amount increases by a factor of 3, indicating the model continues to operate in a linear fashion despite the increased recharge rate.

Figure 1- Overview of Elwood Reservoir and Plum Creek Area

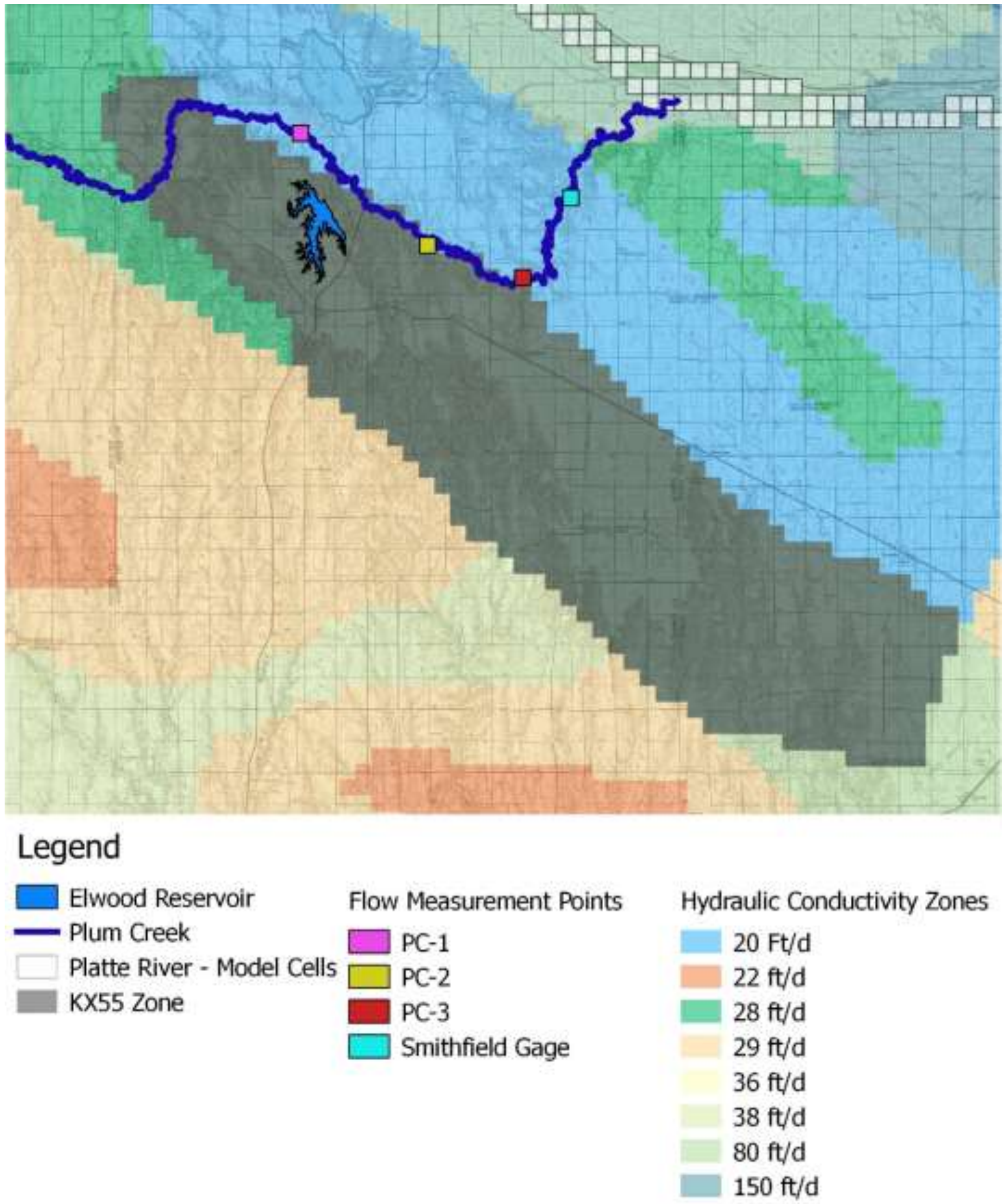


Figure 2 – Location of cells used to simulate recharge at Elwood Reservoir.

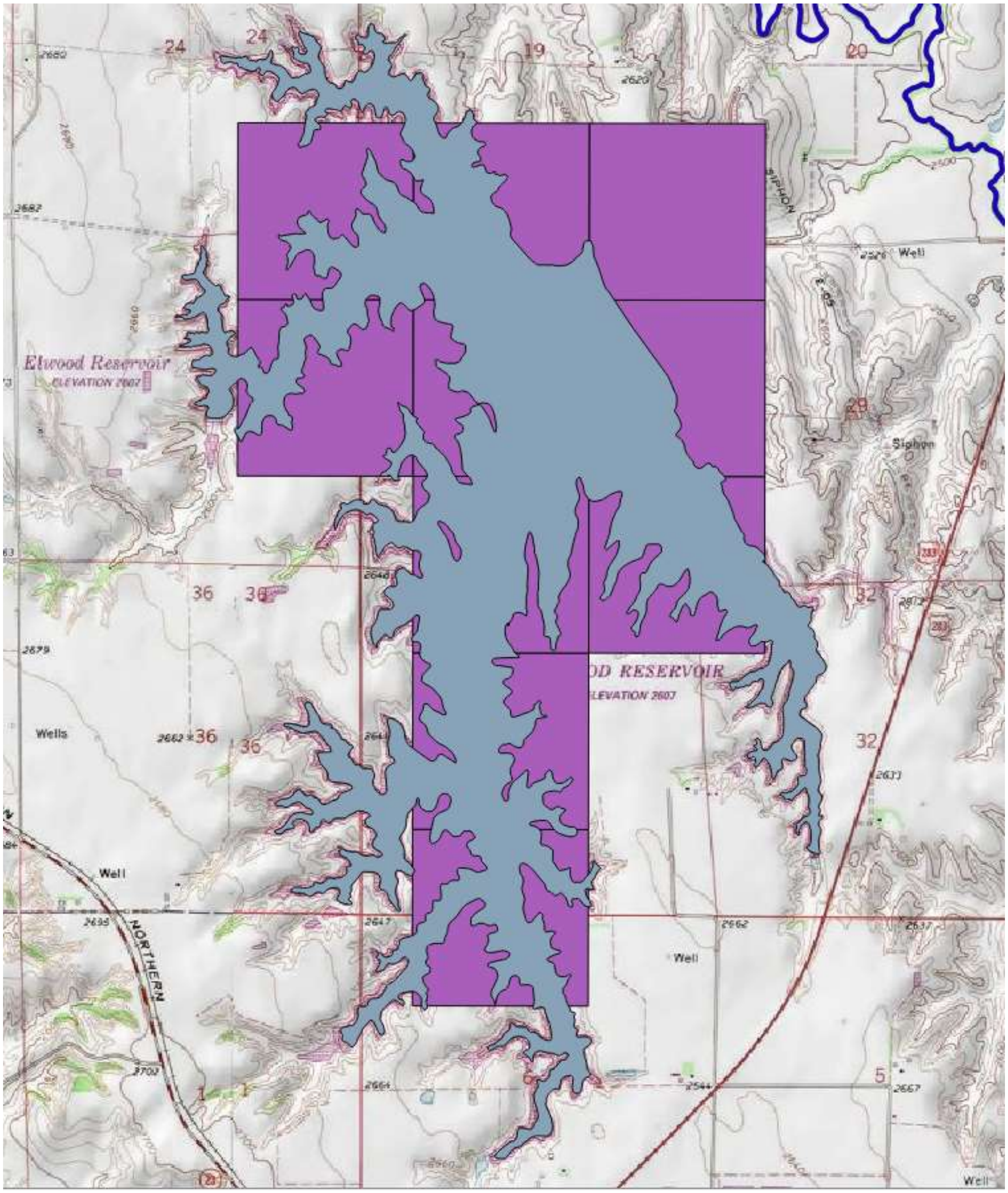
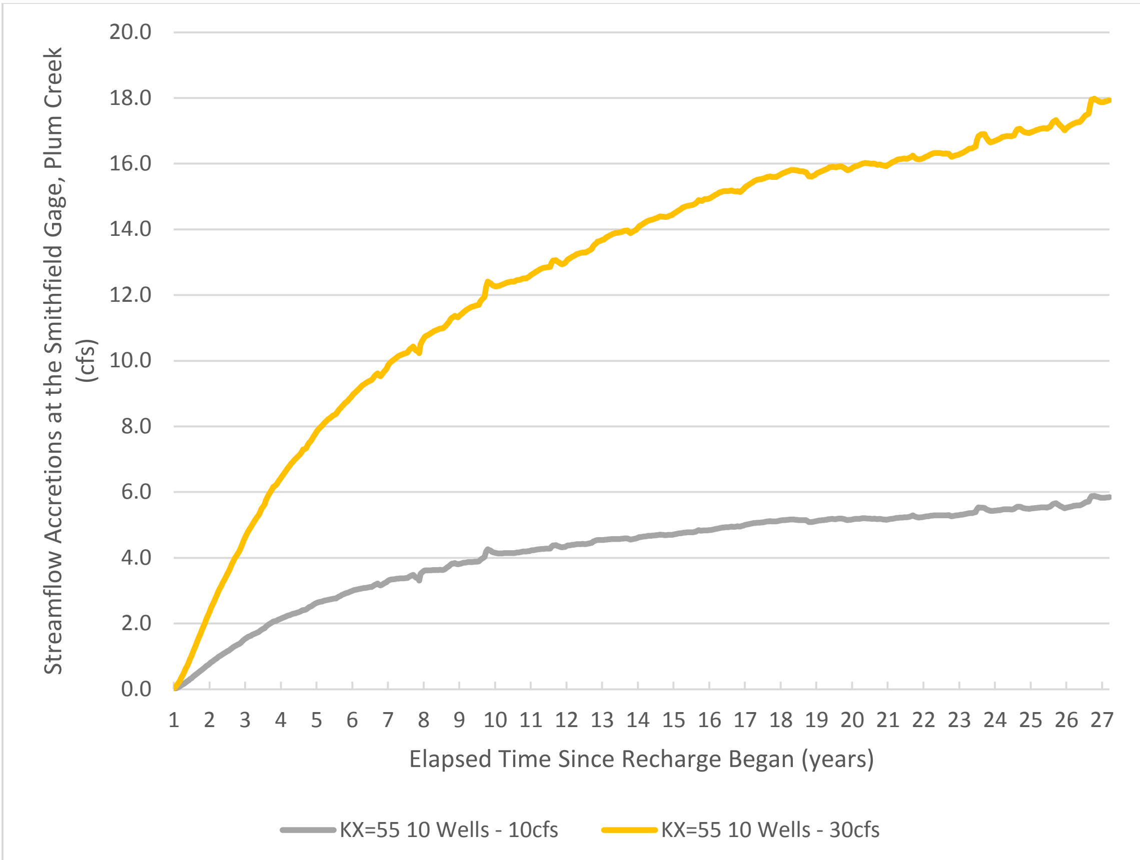


Figure 3- Streamflow accretions at the Smithfield gage caused by recharge of 10 and 30 cfs at Elwood Reservoir.



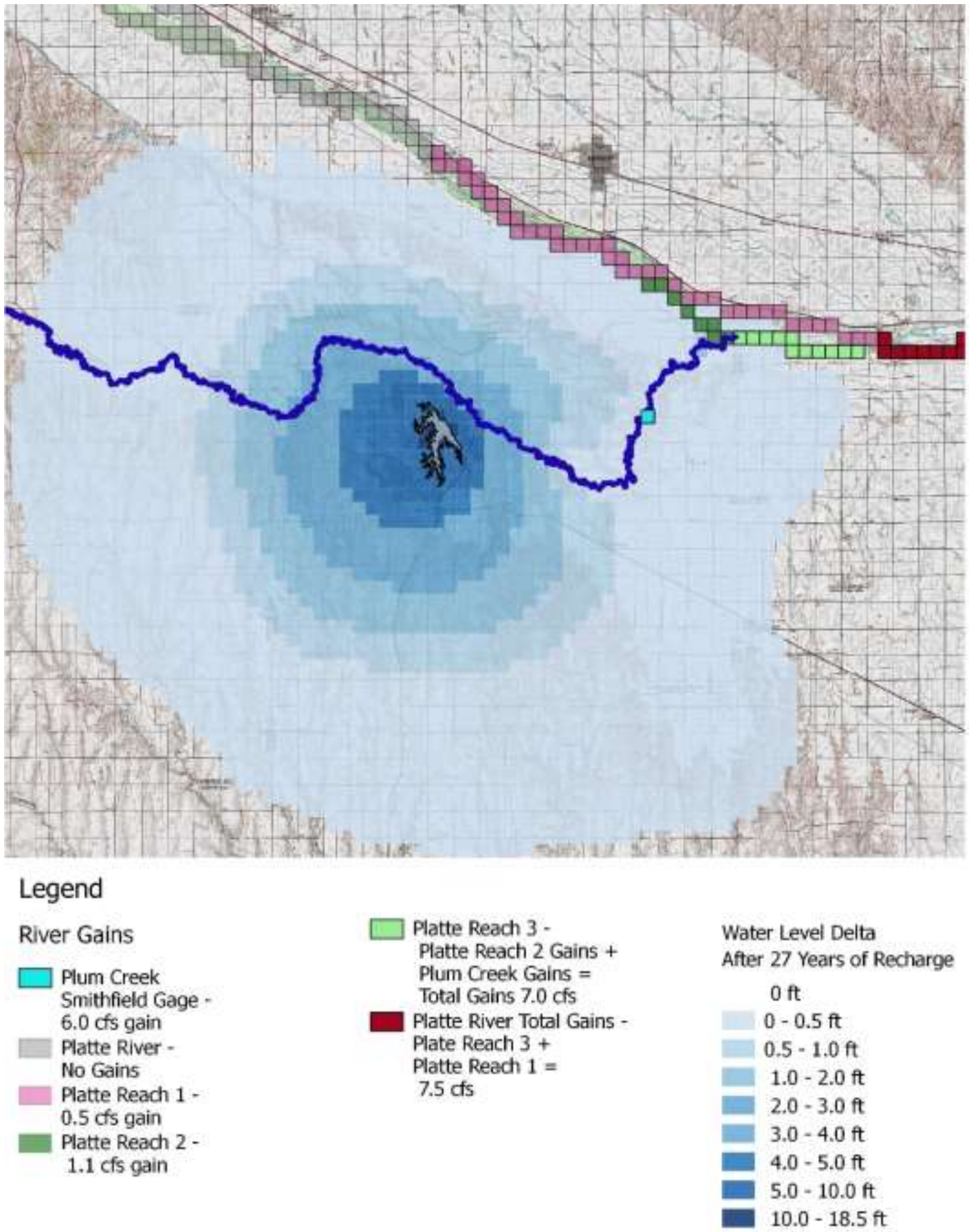
4) **Extract data to be used to generate response functions for returns to Plum Creek and the Platte River for 10 cfs of recharge** – Under this task ERC evaluated the impact of the 10 cfs recharge amount on flows in Plum Creek at the confluence with the south channel of the Platte River and gains to the Platte river directly. The first step in this process was to determine the extent of impacts to aquifer water levels as shown in Figure 4. As this figure shows, the change in water levels between the baseline model and the 10 cfs scenario model extends to portions of the Platte River upstream of Plum Creek. Based on this, ERC extracted the stream flows for the points shown in Figure 4 for both the baseline and scenario run. The difference between these values represents the net impacts to Plum Creek and the Platte River caused by 10 cfs of recharge at Elwood Reservoir. Table 1 presents the total stream gain by reach after 27 years of recharge.

Table 1 – Summary of stream gains after 27 years of recharge at Elwood Reservoir (10 cfs)

Reach	Description	Streamflow Gains (cfs)
Platte River 1	Upgradient and North Channel [1)]	0.5
Platte River 2	South Channel	1.1
Plum Creek – Smithfield Gage	Gains at the Smithfield Gage on Plum Creek above the Confluence	5.9
Platte River 3	Total Gains in the S Channel blw. the Plum Creek Confluence [1)]	7.0
Total Gains to Platte River	Gains calculated in the Platte River after the confluence of North and South Channel [2)]	7.5

Notes: 1) Platte Reach 2 gains + Plum Creek Smithfield Gage gains
2) Platte Reacj 3 gains + Platte River 1 gains

Figure 4- Water level impact and stream impact reaches.



APPENDIX E

Score Summary Tables

Appendix E
Score Analysis - Recharge Diversion Cap of 8,000 (16,000 AF total cap, 50% credited to the Program)

Table E-1: Score at Grand Island (AF).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1947	0	0	0	0	0	0	0	15	21	32	0	0	68
1948	0	0	0	57	58	59	59	65	69	86	96	0	549
1949	0	105	0	0	114	0	0	112	114	0	0	0	445
1950	0	0	155	154	151	148	0	137	138	0	174	0	1,058
1951	0	182	194	189	189	186	0	185	0	0	0	0	1,126
1952	0	0	0	0	213	209	217	207	201	226	231	0	1,503
1953	0	0	0	0	0	0	101	70	94	144	0	0	408
1954	0	0	249	247	0	173	108	74	100	152	213	0	1,314
1955	0	255	263	260	255	183	112	75	100	151	209	0	1,862
1956	0	248	255	253	248	178	110	75	100	152	211	0	1,830
1957	237	253	261	259	0	0	0	72	0	0	0	0	1,083
1958	0	249	261	0	0	0	0	226	224	261	275	0	1,496
1959	0	285	0	0	0	0	124	83	112	173	0	0	777
1960	0	300	0	308	300	292	250	243	239	279	294	0	2,506
1961	0	0	314	312	0	0	0	93	124	188	0	0	1,031
1962	0	0	0	327	319	0	0	267	261	301	314	0	1,789
1963	0	0	0	0	0	0	143	97	129	196	0	0	565
1964	0	328	338	0	0	235	145	99	131	199	277	0	1,751
1965	326	336	356	346	346	0	0	305	0	0	0	0	2,015
1966	0	0	309	313	312	308	270	268	262	302	315	319	2,979
1967	0	329	342	337	329	0	0	264	253	285	290	0	2,428
1968	0	298	310	306	299	292	256	254	249	287	0	304	2,857
1969	0	314	0	324	316	308	0	267	261	301	0	0	2,091
1970	0	0	347	0	339	334	0	319	307	340	345	344	2,675
1971	0	340	360	351	351	0	0	318	301	328	0	0	2,350
1972	0	0	339	330	334	333	333	315	307	344	353	0	2,988
1973	0	0	374	0	0	0	200	346	0	0	0	0	920
1974	0	0	0	0	381	374	380	355	340	375	381	0	2,586
1975	0	377	391	385	375	365	317	312	303	348	100	0	3,273
1976	0	0	0	0	0	0	164	112	149	225	313	0	963
1977	368	382	396	391	380	370	313	300	286	320	324	0	3,829
1978	319	331	0	340	332	323	275	265	258	297	309	313	3,362
1979	312	325	340	337	330	0	0	264	252	282	0	0	2,441
1980	0	0	0	304	0	0	325	314	309	348	359	0	1,959
1981	0	357	369	367	0	0	160	0	146	221	308	0	1,929
1982	363	377	391	386	376	366	310	298	285	318	323	0	3,793
1983	0	0	348	0	0	0	0	340	0	0	0	0	687
1984	0	0	0	0	0	0	0	369	0	0	0	0	369
1985	0	0	0	0	403	395	401	375	0	395	400	0	2,369
1986	0	0	417	0	0	0	403	376	0	0	0	0	1,196
1987	0	0	0	0	0	0	0	379	0	0	0	0	379
1988	0	0	416	410	400	389	0	333	324	372	0	0	2,644
1989	0	403	419	413	403	391	0	326	0	358	369	371	3,452
1990	0	383	401	398	392	383	335	333	326	375	390	395	4,111
1991	0	402	415	411	0	0	174	115	150	220	299	0	2,186
1992	0	358	373	368	360	353	301	291	279	313	318	0	3,313
1993	0	327	0	339	341	338	0	0	0	328	334	0	2,007
1994	321	335	351	348	341	334	0	274	262	293	298	297	3,454
Avg	47	170	209	206	193	159	131	220	162	211	175	49	1,933

Appendix E
Score Analysis - Recharge Diversion Cap of 12,000 (24,000 AF total cap, 50% credited to the Program)

Table E-2: Score at Grand Island (AF).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1947	0	0	0	0	0	0	0	15	21	33	0	0	70
1948	0	0	0	63	67	71	74	87	99	128	145	0	733
1949	0	163	0	0	172	0	0	165	167	0	0	0	668
1950	0	0	234	231	226	221	0	202	203	0	254	0	1,571
1951	0	265	279	274	277	273	0	267	0	0	0	0	1,635
1952	0	0	0	0	311	307	316	302	295	335	346	0	2,213
1953	0	0	0	0	0	0	150	103	139	215	0	0	607
1954	0	0	379	373	0	262	162	111	149	227	316	0	1,978
1955	0	378	386	381	371	267	165	112	149	225	312	0	2,746
1956	0	370	379	374	365	260	159	108	143	214	297	0	2,669
1957	331	352	361	357	0	0	0	98	0	0	0	0	1,498
1958	0	326	340	0	0	0	0	296	292	337	352	0	1,944
1959	0	363	0	0	0	0	165	112	152	235	0	0	1,026
1960	0	412	0	420	415	410	357	350	344	398	416	0	3,521
1961	0	0	438	432	0	0	0	128	170	256	0	0	1,423
1962	0	0	0	437	432	0	0	367	360	417	436	0	2,449
1963	0	0	0	0	0	0	194	133	179	272	0	0	778
1964	0	459	471	0	0	326	200	135	180	272	379	0	2,421
1965	447	459	484	470	469	0	0	410	0	0	0	0	2,738
1966	0	0	412	423	427	425	372	368	360	413	429	434	4,063
1967	0	446	462	455	442	0	0	351	336	377	385	0	3,253
1968	0	394	409	403	392	382	332	327	319	365	0	383	3,707
1969	0	395	0	406	396	386	0	329	322	372	0	0	2,607
1970	0	0	430	0	422	418	0	406	394	441	453	455	3,419
1971	0	453	479	465	465	0	0	418	395	430	0	0	3,104
1972	0	0	442	430	439	441	445	418	403	449	457	0	3,923
1973	0	0	479	0	0	0	200	449	0	0	0	0	1,128
1974	0	0	0	0	528	522	527	492	473	524	535	0	3,601
1975	0	532	550	540	524	508	438	429	415	473	100	0	4,509
1976	0	0	0	0	0	0	219	150	201	306	427	0	1,304
1977	508	526	544	535	519	503	425	407	388	434	441	0	5,230
1978	434	449	0	458	446	433	366	352	341	391	406	410	4,485
1979	409	425	443	438	428	0	0	340	325	363	0	0	3,169
1980	0	0	0	389	0	0	407	391	384	432	444	0	2,447
1981	0	443	457	454	0	0	197	0	178	268	372	0	2,369
1982	438	454	471	465	453	444	379	367	352	399	409	0	4,631
1983	0	0	443	0	0	0	0	422	0	0	0	0	865
1984	0	0	0	0	0	0	0	468	0	0	0	0	468
1985	0	0	0	0	535	525	531	498	0	533	544	0	3,165
1986	0	0	571	0	0	0	550	514	0	0	0	0	1,635
1987	0	0	0	0	0	0	0	524	0	0	0	0	524
1988	0	0	589	580	564	547	0	466	455	521	0	0	3,722
1989	0	563	582	572	556	540	0	454	0	498	514	517	4,797
1990	0	532	561	564	557	545	472	463	450	513	531	536	5,724
1991	0	542	557	550	0	0	231	152	198	292	395	0	2,917
1992	0	473	491	484	472	461	392	378	362	406	413	0	4,332
1993	0	424	0	438	440	435	0	0	0	419	426	0	2,582
1994	410	428	450	449	442	434	0	358	344	387	395	396	4,492
Avg	62	230	283	277	261	216	176	296	217	283	236	65	2,601

Appendix E
Score Analysis - Recharge Diversion Cap of 15,000 (30,000 AF total cap, 50% credited to the Program)

Table E-3: Score at Grand Island (AF).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1947	0	0	0	0	0	0	0	15	21	33	0	0	70
1948	0	0	0	63	70	78	82	95	105	135	152	0	780
1949	0	169	0	0	177	0	0	192	192	0	0	0	730
1950	0	0	255	251	255	261	0	234	231	0	284	0	1,770
1951	0	292	306	308	320	328	0	317	0	0	0	0	1,872
1952	0	0	0	0	378	385	393	368	354	395	404	0	2,677
1953	0	0	0	0	0	0	174	119	159	244	0	0	695
1954	0	0	419	413	0	304	189	128	170	257	357	0	2,237
1955	0	422	431	423	412	297	184	124	166	249	346	0	3,053
1956	0	409	419	413	402	287	175	118	156	234	323	0	2,936
1957	360	383	392	388	0	0	0	106	0	0	0	0	1,629
1958	0	351	366	0	0	0	0	324	318	366	382	0	2,106
1959	0	391	0	0	0	0	176	120	162	249	0	0	1,098
1960	0	435	0	443	443	443	387	380	372	429	447	0	3,778
1961	0	0	468	462	0	0	0	135	180	270	0	0	1,515
1962	0	0	0	460	458	0	0	392	384	444	462	0	2,600
1963	0	0	0	0	0	0	204	139	187	285	0	0	816
1964	0	479	492	0	0	346	213	144	191	289	402	0	2,554
1965	474	487	513	498	496	0	0	433	0	0	0	0	2,900
1966	0	0	436	449	459	461	404	397	387	443	459	463	4,358
1967	0	476	492	484	470	0	0	373	356	400	408	0	3,459
1968	0	417	433	426	415	404	351	345	336	384	0	402	3,914
1969	0	415	0	427	416	405	0	344	337	388	0	0	2,732
1970	0	0	448	0	444	445	0	430	416	464	475	477	3,599
1971	0	474	500	486	486	0	0	436	412	448	0	0	3,242
1972	0	0	461	447	456	465	474	445	429	475	484	0	4,136
1973	0	0	505	0	0	0	200	471	0	0	0	0	1,176
1974	0	0	0	0	563	563	568	527	504	558	567	0	3,850
1975	0	561	579	568	551	534	460	449	434	495	100	0	4,731
1976	0	0	0	0	0	0	232	158	211	320	447	0	1,368
1977	530	548	567	558	541	524	442	424	404	452	459	0	5,449
1978	452	467	0	476	464	450	381	366	354	406	421	425	4,663
1979	424	441	459	454	444	0	0	352	337	376	0	0	3,286
1980	0	0	0	404	0	0	421	403	396	445	457	0	2,526
1981	0	456	471	467	0	0	202	0	182	275	382	0	2,435
1982	449	466	484	477	465	456	389	376	361	409	419	0	4,751
1983	0	0	455	0	0	0	0	432	0	0	0	0	887
1984	0	0	0	0	0	0	0	491	0	0	0	0	491
1985	0	0	0	0	581	575	580	540	0	572	581	0	3,430
1986	0	0	616	0	0	0	615	571	0	0	0	0	1,802
1987	0	0	0	0	0	0	0	590	0	0	0	0	590
1988	0	0	649	646	639	629	0	530	514	585	0	0	4,192
1989	0	623	642	630	611	599	0	508	0	560	578	582	5,333
1990	0	598	630	632	623	610	526	514	497	565	583	587	6,367
1991	0	593	609	601	0	0	251	166	216	317	429	0	3,181
1992	0	514	533	525	511	498	424	409	391	438	446	0	4,689
1993	0	458	0	473	475	468	0	0	0	449	456	0	2,778
1994	438	457	481	479	472	463	0	384	369	417	427	428	4,815
Avg	65	245	302	296	281	235	190	319	233	303	253	70	2,793

Appendix E
Score Analysis - Recharge Diversion Cap of 20,000 (40,000 AF total cap, 50% credited to the Program)

Table E-4: Score at Grand Island (AF).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1947	0	0	0	0	0	0	0	15	21	33	0	0	70
1948	0	0	0	63	73	90	94	106	115	145	162	0	848
1949	0	177	0	0	184	0	0	198	198	0	0	0	757
1950	0	0	260	255	260	269	0	241	238	0	291	0	1,812
1951	0	298	312	314	326	334	0	322	0	0	0	0	1,906
1952	0	0	0	0	382	389	397	372	358	399	407	0	2,703
1953	0	0	0	0	0	0	175	119	160	245	0	0	700
1954	0	0	422	415	0	306	190	128	171	259	358	0	2,250
1955	0	424	433	426	414	299	185	125	166	251	347	0	3,068
1956	0	411	421	415	404	288	176	118	157	235	325	0	2,949
1957	361	384	394	389	0	0	0	107	0	0	0	0	1,636
1958	0	353	368	0	0	0	0	330	323	373	388	0	2,134
1959	0	398	0	0	0	0	179	121	164	252	0	0	1,113
1960	0	439	0	447	448	450	394	387	378	436	453	0	3,832
1961	0	0	474	468	0	0	0	137	182	273	0	0	1,534
1962	0	0	0	465	462	0	0	399	390	451	469	0	2,636
1963	0	0	0	0	0	0	207	141	189	288	0	0	825
1964	0	484	497	0	0	356	221	149	197	299	415	0	2,617
1965	489	502	528	512	511	0	0	445	0	0	0	0	2,987
1966	0	0	447	460	470	475	416	409	398	455	472	476	4,477
1967	0	488	504	496	482	0	0	381	364	409	417	0	3,542
1968	0	427	442	435	424	413	358	352	342	391	0	410	3,994
1969	0	423	0	434	424	412	0	349	342	394	0	0	2,778
1970	0	0	454	0	453	464	0	449	432	482	492	493	3,720
1971	0	489	515	500	500	0	0	447	422	459	0	0	3,333
1972	0	0	471	457	466	476	487	458	440	487	495	0	4,239
1973	0	0	516	0	0	0	200	480	0	0	0	0	1,196
1974	0	0	0	0	574	578	584	542	517	571	579	0	3,945
1975	0	572	591	579	562	544	468	457	442	503	100	0	4,818
1976	0	0	0	0	0	0	236	160	214	325	453	0	1,389
1977	537	556	575	566	550	531	448	429	409	458	465	0	5,525
1978	458	474	0	483	470	456	386	371	359	411	426	431	4,726
1979	430	447	465	460	450	0	0	357	341	381	0	0	3,329
1980	0	0	0	409	0	0	426	408	400	449	462	0	2,555
1981	0	461	476	472	0	0	204	0	184	278	385	0	2,459
1982	453	470	488	481	469	460	393	380	365	412	423	0	4,795
1983	0	0	459	0	0	0	0	435	0	0	0	0	894
1984	0	0	0	0	0	0	0	512	0	0	0	0	512
1985	0	0	0	0	606	608	614	569	0	598	607	0	3,601
1986	0	0	638	0	0	0	643	596	0	0	0	0	1,877
1987	0	0	0	0	0	0	0	616	0	0	0	0	616
1988	0	0	671	667	660	655	0	552	534	607	0	0	4,345
1989	0	644	664	650	631	618	0	523	0	576	594	598	5,495
1990	0	614	646	648	639	625	538	525	508	578	596	600	6,516
1991	0	605	622	614	0	0	257	169	220	324	438	0	3,248
1992	0	525	544	536	522	509	433	417	399	447	455	0	4,788
1993	0	468	0	482	485	478	0	0	0	458	465	0	2,835
1994	446	466	490	488	481	472	0	390	375	424	434	436	4,901
Avg	66	250	308	302	287	241	194	327	238	309	258	72	2,851

APPENDIX F

Scoring Subcommittee Conference Call Minutes (July 26, 2018)

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM
GC Scoring Subcommittee Meeting Minutes
Conference Call
July 26, 2018

Meeting Attendees

Scoring Subcommittee

State of Colorado
Jojo La – Member
Brian MacPherson

State of Wyoming
Bryan Clerkin - Member
Jeff Cowley – Alternate

State of Nebraska
Jessie Strom – Member

U.S. Fish and Wildlife Service
Tom Econopouly – Member

U.S. Bureau of Reclamation
Brock Merrill – Member

Downstream Water Users
Mike Drain – Chair
Brian Barels - Member
Jeff Shafer – Alternate
Brandi Flyr - Member
Cory Steinke

Colorado Water Users
Jon Altenhofen – Member
Luke Shawcross - Alternate

Upper Platte Water Users
n/a

Environmental Groups
n/a

Executive Director's Office (EDO)
Courtney Black
Scott Griebling
Bill Hahn (Special Advisor)
Seth Turner
Kevin Werbylo

<u>Welcome and Administrative:</u> *Mike Drain, 2016 Chair and Seth Turner, EDO*
Introductions were made. It was noted that there were several new members on the Scoring Subcommittee.

Barels nominated Drain as Chair, seconded by Altenhofen, unanimous approval.

<u>Project Scoring Discussion</u>
Overview: *Seth Turner, EDO*
Turner gave a brief slide presentation that covered the following: Program water goals; three initial state projects; definition of scoring; approved WAP project scores; project scoring process; key scoring assumptions; and the EDO scoring work plan for 2018.

Drain, Barels, and Altenhofen have been involved in activities associated with the Platte River Cooperative Agreement and the Program since the mid-1990s and collectively provided some background information for the benefit of new Scoring Subcommittee members. They explained that scoring model assumptions are intended to maintain consistency with OpStudy analyses for the Platte River EIS, scoring of the three initial state projects, and so forth.

La noted that the J-2 Regulating Reservoirs project was scored using a daily time step and asked whether there are differences in score results when using a daily vs. monthly time step. Griebling explained the differences in calculating excess flows on daily and monthly time steps. Drain added that nearly all models at the time of the Cooperative Agreement and Program development were monthly time step; for scoring, monthly is default, daily is an option.

Cowley asked why the model study period used for scoring stops in 1994. Turner noted the simulation period for OpStudy hydrology was 1947-1994; and that the end date was recent at the time of the Cooperative Agreement in 1997. Drain added that initial meetings of what led to the Cooperative Agreement were held in 1994 and that using this study period keeps Program analyses consistent across time.

In response to a question from Barels, it was clarified that target flows, shortages, and excesses are evaluated at Grand Island. It was also noted that project scores are reduced if the project benefits only a portion of the Program's associated habitat reach below Overton, NE.

Elwood Reservoir Groundwater Recharge: *Scott Griebling and Seth Turner, EDO*
Griebling began with an overview of the Elwood scoring analysis: the EDO evaluated the availability of excess flows within the CNPPID system, then inflows to Elwood. A unit response function was developed using the regional COHYST groundwater model. In order to more accurately simulate the local area around Elwood Reservoir, adjustments to the hydraulic conductivity were made based on observations from nearby wells. Altenhofen suggested adding a flowchart to the score memo to illustrate the "if statements" in the analysis process. Altenhofen asked about power interference; Drain said it is factored into the price of water diverted into Elwood for recharge.

<u>Possible impacts of changes from historical Elwood operations</u>

It was noted that Elwood Reservoir is already used for irrigation, which has an incidental seepage component for which the Program cannot claim score credit. Scoring also cannot assume the full capacity of the reservoir is available for intentional groundwater recharge.

Altenhofen commented that this project is different from previously scored projects. We need to understand Elwood baseline operations since 1976, how Elwood historically affected the river with seepage and accretions, then how CNPPID has and will change operations from historical, and how this may affect the score. The extensive discussion that followed is summarized below.

Drain provided a brief history of Elwood Reservoir, which came online in 1976: historically the reservoir was filled in the fall, lost water to seepage over the winter, and then was topped off again in the spring. Irrigation practices were less efficient in the 1970s and 1980s. In the early 1990s, CNPPID adopted new target operations (circa 1994-1995), including not topping off the reservoir in the fall. Altenhofen noted that those changes took place after the end of the model study period.

Griebling and Drain said the Program's use of Elwood for recharge is the *result* of changes to CNPPID's operations that were already ongoing. Drain didn't think the Program needs to account for operational changes that CNPPID implemented, over which the Program has no control. La inquired about the source of the CNPPID operations represented in Table 2 of the memo. Griebling described what the table shows and said it was based on conversations with Steinke to approximate future Elwood operations. Altenhofen asked if this is representative of operations since the early 1990s. Drain said no, efficiencies have continued to improve since then, the operations shown in Table 2 are more reflective of the present. Drain added that the question is what volume is available to the Program above what CNPPID needs to irrigate, since there is no Program benefit from seepage associated with CNPPID operations.

Steinke described CNPPID's future plans for Elwood: CNPPID is looking for ways to eliminate the need to use Elwood for irrigation. It is not efficient for irrigation, and they are getting to a point at which the reservoir will not be needed for that purpose. If the Program, state, and Tri-Basin NRD were not using Elwood for recharge, CNPPID would probably find ways to not use the reservoir at all.

Altenhofen reiterated the need to evaluate CNPPID's seepage from Elwood prior to the Program recharge project, specifically for the period 1977-1994. Drain again disagreed, noting different sources of water for the different operations, Lake McConaughy for irrigation, excess flows for recharge. Econopouly agreed on the need to see an analysis of historical seepage from Elwood for the period 1977-1994. Flyr asked about the level of effort required for this analysis. Griebling said the EDO could make some assumptions and come up with an answer. Drain didn't think the EDO needed to do this but would go along if a majority of the Scoring Subcommittee thinks the EDO should take a rough cut at how changes in historical operations change the score based on historical vs. current returns. La also wanted to know how the score might be affected.

Griebling said this might set a precedent for changing a score based on changes in operations. Barels expressed concern that, from a policy perspective, evaluating historical effects of Elwood seepage could change flows at Grand Island, which could then change the score for every project in context of new flows. This is not within the scope of Program scoring, given time, funding constraints, etc. Altenhofen and Drain agreed that any policy issues should be addressed by the GC, not the Scoring Subcommittee.

<u>Other potential uses of Elwood Reservoir</u>

Drain noted that other uses of Elwood Reservoir are being considered, including the proposed Platte-Republican diversion project, which could take excess flows and store them temporarily in Elwood. Drain asserted that water would not be available for the transbasin project if there were Platte Basin uses needing that water. The Program would always have priority over any transbasin diversion, and Elwood capacity would only be available for that purpose if the Program had already been offered the opportunity and declined. Strom confirmed that these descriptions of the Platte-Republican diversion project are accurate.

Projects are scored based on the capacity to reduce shortages and the assumption that the Program takes advantage of such opportunities. The score wouldn't be reduced for something else that might happen. In the case of a transbasin diversion, the Program would always have priority.

<u>Capacities of the E-65 Canal and the Carl T. Curtis Pump Station</u>

Altenhofen asked if the Program gets credit for seepage from E-65; Griebling said no. Diversions into the E-65 Canal are measured in a flume at Mile Post 2.8. From there it is another 3 miles to the pump station into Elwood. The canal is mostly lined from the headgate to the flume. Downstream of the flume there are ~1.5 miles of siphons, therefore there is little seepage from E-65 upstream of Elwood. The Program only gets credit for what goes into Elwood; Tri-Basin and the state pay for and get credit for recharge water that remains in the E-65 canal past Elwood Reservoir.

The capacity of E-65 is 350 cfs, which is filled for irrigation during June-July-August. Drain recommended that the EDO discuss with Steinke to better understand canal capacity limitations during the irrigation season, then update the analysis accordingly.

La asked about the pump station capacity that conveys water from the E-65 Canal into Elwood, noting that with a maximum pumping rate of 275 cfs, the 250 cfs used for the analysis seems to be too high. Griebling explained the assumptions made in selecting that pumping rate. Steinke also said the rate is high, since 250 cfs is only possible at lower reservoir volumes. Shawcross asked if a pump curve could be added into the analysis spreadsheet to make the pumping rate more dynamic. Drain said the EDO should also discuss the pumping rate with Steinke.

Strom asked about the assumption of 10 percent localized runoff into the reservoir. Griebling said it was mostly an educated guess, since there is not much drainage area surrounding the reservoir. Drain added that since Elwood is pumped storage, it sits at the top of its own watershed. Whether it's 0 percent or 20 percent probably doesn't matter.

<u>Returns to Platte vs Republican</u>

Shawcross noted that page 4 of the memo says that 80 percent of seepage returns to the Platte River and 20 percent to the Republican River and asked where that water shows up in the Republican. Hahn said the model doesn't actually show "wet" water in the Republican River during the simulation period, but it is still migrating through the aquifer and may eventually get there.

Barels said NDNR should look at this split, make sure there is consistency between models. Hahn replied that Jesse Bradley of NDNR weighed in on this issue at a WAC meeting and said the state was seeing similar results. Strom concurred. Drain added that the 50 percent to each basin seen in other analyses was an outdated number from an old NCCW analysis.

Barels asked where the water returned in the Platte Basin. Hahn said some is intercepted by Plum Creek and returns as surface water. The balance returns as accretions over a fairly broad area, but all above Overton.

<u>Lag effects and long-term return flows</u>

Shawcross asked if the groundwater modeling should have a warm up period, perhaps 15 years prior to 1947, so that the scoring better reflects a steady state return. There was discussion of lag effects and drawn-out return flows that continue long after the end of the study period. Altenhofen asked how the Phelps recharge score analysis dealt with this issue. Hahn said Phelps acts differently because it is much closer to the river and return times are much quicker. Hahn noted that some of those delayed returns could be accelerated by adding recapture wells. It was recommended that the EDO further investigate this issue.

<u>Effects of recharge cap</u>

Drain noted Table 4 on page 13 of the memo, which clearly shows that the recharge cap has a significant effect on score. Based on discussions with Steinke, CNPPID could comfortably assume 24,000-30,000 AF of available capacity above CNPPID irrigation needs. Assuming the Program gets 50 percent of that capacity, a cap in the range of 12,000-15,000 AF could be considered for this analysis. Drain added that if the state and Tri-Basin don't use the other 50 percent of recharge capacity, it may be available to the Program.

The score memo already presents a range of potential scores using different caps. A possible recommendation to the GC would be to use the table and associated curve and assign a score based on the contract between CNPPID and the Program. If the cap was increased from its current 12,000 AF, the score could increase to an already known value.

Action Items for the EDO

- The Elwood recharge analysis is referred back to the EDO to address the following:

  1. Coarse look at lost seepage from CNPPID changes in Elwood irrigation operations.
  2. Re-evaluate based on irrigation season canal capacity
  3. Proper pumping capacity
  4. Options for lag effect (how to account for additional recharge occurring after the end of the 48-year study period)

  Items #1 and #4 are to provide options for comparison. Items #2 and #3 need to be discussed with Steinke, incorporated into revised analysis.

- Specific memo edits:
  - Add flowchart of "if statements" in analysis process
  - Add legend to Figure 1
  - Clarify text to indicate that USFWS and NGPC target flows are not combined, but the higher is used.

- Send preliminary analysis and documentation of Pathfinder Municipal Account lease score update for review by Scoring Subcommittee.

- Set up doodle poll for next Scoring Subcommittee conference call to discuss both Elwood and Pathfinder.

APPENDIX G

Scoring Subcommittee Conference Call Minutes (August 27, 2018)

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM
GC Scoring Subcommittee Meeting Minutes
Conference Call
August 27, 2018

Meeting Attendees

<u>**Scoring Subcommittee**</u>

State of Colorado
Jojo La – Member
Brian MacPherson

State of Wyoming
Bryan Clerkin - Member
Jeff Cowley – Alternate

State of Nebraska
Jessie Strom – Member

U.S. Fish and Wildlife Service
Tom Econopouly – Member

U.S. Bureau of Reclamation
Brock Merrill – Member

Downstream Water Users
Mike Drain – Chair
Brian Barels - Member
Jeff Shafer – Alternate
Brandi Flyr - Member
Cory Steinke

Colorado Water Users
Jon Altenhofen – Member
Luke Shawcross - Member

Upper Platte Water Users
Dennis Strauch - Member

Environmental Groups
n/a

<u>**Executive Director's Office (EDO)**</u>
Jason Farnsworth, ED
Scott Griebling
Bill Hahn (Special Advisor)
Seth Turner
Kevin Werbylo

Welcome and Administrative: *Mike Drain, 2016 Chair and Seth Turner, EDO*
Introductions were made. There were no agenda modifications. Turner noted that past Scoring Subcommittee minutes did not indicate a need to formally approve minutes of the July 26 conference call. No comments on the July 26 minutes were offered over the phone. Turner requested submittal of any comments by email by the end of the week (August 31).

Elwood Reservoir Groundwater Recharge: *Scott Griebling and Seth Turner, EDO*
Turner introduced the revisions to the Elwood recharge score analysis, noting that the EDO would first address the specific revisions to the pumping rate and irrigation season diversions requested by the Subcommittee during the previous call on July 26, to be followed by discussion of additional issues raised during the previous call.

Discussion of Elwood pumping rate sensitivity and irrigation season diversions
Griebling explained the EDO's approach to evaluating pumping rate sensitivity, showing Figure 2 from the revised memo. The EDO tested a range of fixed pumping rates and calculated variable pumping rates based on Elwood end-of-month storage. In nearly all cases tested, the average of variable pumping rates exceeded the 250 cfs pumping rate originally assumed for the analysis, with the exception of a diversion cap of 30,000 AF, in which case the average pumping rate dropped slightly below 250 cfs. **Drain asserted that the analysis suggested no reason to change the assumed 250 cfs pumping rate. There were no objections from the committee.**

Griebling also explained that the analysis was revised to allow no diversions for recharge during June, July, and August, when the full capacity of the E-65 canal is used for irrigation deliveries. Slides (appended to these minutes) showing Table 4 and Figure 5 (score vs recharge capacity) from the revised Elwood score memo were presented. Score results were reduced slightly but not much.

Discussion of Elwood historical seepage effects
Griebling explained that the EDO sought to address an issue raised by Altenhofen during the July 26 call, namely "How would the project score change if Elwood's historical seepage wasn't present in the scoring model's hydrology?" Elwood Reservoir came online in 1978; from 1978-1994, the reservoir operated at higher levels, which resulted in higher seepage and more return flows to the river (i.e., higher baseflows in the river). Drain noted that even during that period, Elwood operations were variable.

Griebling said an underlying assumption of this analysis is that OpStudy hydrology for Grand Island has the higher seepage signal embedded, based on model representation of past Elwood operations. In contrast, the score model operates Elwood at lower levels, resulting in less seepage and lower return flows, and in turn, greater shortages at Grand Island. A figure was presented to illustrate estimated seepage under the two scenarios. The difference was subtracted from OpStudy Grand Island flows, and the modified flows were run through the score model. The greater shortages resulted in an increased score of about 900 AF (for the base scenario with a 12,000 AF recharge cap).

Griebling noted a few considerations: (1) this approach represents a departure from previous scoring methodology; (2) other projects would potentially need to be rescored using this same methodology for consistency; and (3) changing the scoring model to account for Elwood operational changes unrelated to the Program sets a precedent for additional rescoring of all WAP projects with future operational changes.

Drain commented that the result of the analysis was surprising, with an increase of 900 AF representing roughly one-third of the estimated score. Griebling said greater shortages inherently lead to a higher score. Drain expressed continued skepticism about making any changes based on this analysis but said that would ultimately be a policy decision for the GC to make. The analysis suggests that there is benefit to the Program to encourage actions that result in reduced baseflows, which is exactly the opposite of what we want to happen. Many other things can result in baseflow changes, such as improved irrigation efficiency (center pivots vs gated pipe, lining canals, etc.).

Barels suggested that those examples were not the same as the Elwood operational changes, since the analysis shows how Elwood will operate moving forward, which seems appropriate to consider. Drain said that Elwood operations were already changing independent of the Program; CNPPID is weaning off of Elwood, and that creates the opportunity for the Program to use the reservoir for recharge. Griebling clarified that this historical analysis undertaken by the EDO does not reflect changing reservoir operations, but changes to the baseflow in the river. There was some discussion of OpStudy hydrology.

Econopouly asked if Program recharge operations put more water in the river relative to 1997 levels. Drain thought not, by example comparing 1993 operations vs 2023 with Program recharge. There would have been more seepage, more water going to the river in the 1990s. However, that ignores other factors such as changes in supply; historical operations relied on Lake McConaughy water, whereas current recharge operations utilize available excess flows. Econopouly noted this as another reason to score conservatively and not unnecessarily increase the score.

Altenhofen commented that the key factor is that Elwood operational changes are unrelated to the Program. Any changes to scoring would be a GC policy decision but based on recent conversations, Colorado stakeholders seem to be OK with current score policies and procedures. Altenhofen said he would be OK with a score of 3,000 AF.

Drain again asked the committee if there is a policy issue that should be raised with the GC. Drain, Merrill, Altenhofen agreed that there was no need to do so. Barels said we should not deviate from current GC policies. No committee members offered a contrary position.

Flyr inquired about the significance of a 900 AF score increase and the degree of error in the stated score numbers. There was some discussion; Turner clarified that score values are 48-year averages based on the model analyses.

La asked how the preceding discussion was to be documented. **Drain recommended documentation in these minutes, including the presentation slides, instead of a separate memo or addendum to the Elwood scoring memo. Barels suggested including a couple summary paragraphs in the score memo. There were no objections to this approach from committee members.**

Discussion of lag effects (tail wrapping)

Griebling described different scenarios considered to address lagged accretions that occur after the end of the scoring study period. Figures (see slides appended to these minutes) were shown and described, including potential scores that could result from these approaches. Other considerations were noted, since this would represent another departure from previous scoring methodologies. Drain added that this is primarily an issue due to the distance from Elwood to the river, compared to the much shorter distance from Phelps to the river, and asked if we should consider an alternative approach of calculating the score from the mid-1960s to 1994 rather than 1947-1994.

La asked if taking this approach would affect other projects, Griebling said potentially, as this would be a different approach than what was done for Phelps recharge scoring. Drain asked if the calculated results from tail wrapping would have the potential to discount future scores of proposed recapture wells. The EDO said it would. Barels said this is another policy issue, but maybe better to rely on recapture wells instead of calculations to increase score. Drain asked about the potential to revisit the score in the future; Econopouly was comfortable with that, if needed.

Drain directed the EDO to again document this discussion in these minutes, with a conclusion that we should not add in the lagged accretions occurring outside of the model study period. Barels, Econopouly, and Altenhofen agreed. There were no objections from other committee members. Drain said to continue with the score analysis as is and document this discussion in the score memo.

Discussion of score recommendation

Drain noted, based on Figure 5 in the Elwood score memo, that there are differences in the score if the cap is 12,000 AF vs half of 24,000 AF. Should the score be based on the Program considered in isolation or the Program getting half of the maximum recharge capacity collectively available to the Program, the state, and Tri-Basin NRD? Griebling said we assume the overall cap is somewhere between 28,000 AF and 32,000 AF. Farnsworth read from the WSA: excess flows are diverted, divided 50/50 between Program and other parties, Program not to be billed for more than 12,000 AF without written approval from the Program.

Steinke confirmed that after CNPPID takes its necessary space in Elwood, there is the potential for up to 30,000 AF total capacity for recharge. Drain recommended the approach of determining score based on the Program getting 50% of the 30,000 AF capacity, with the recognition that the Program would have to pay more (beyond 12,000 AF) to achieve the full score. Based on the curve in Figure 5 of the memo, a cap of 30,000 AF would result in a total score of about 5,600 AF, or 2,800 AF for the Program.

Extensive discussion followed. Strom noted that the state has a contract for up to 13,500 AF of recharge annually. Barels suggested that the contract limit of 12,000 AF needed to be taken into consideration. Drain recommended using the curve in Figure 5 as the basis for the score, providing a mechanism for the GC to make future revisions if needed. There was discussion of whether the Program might regularly get more than 50%, but Steinke said the state and Tri-Basin are likely to fully use their half of the recharge capacity. Drain offered another suggestion of splitting the difference of the scores with a total cap of 30,000 AF and a total cap of 24,000 AF, which would mean a score of 2,700 AF for the Program. The discussion continued, and Farnsworth countered that the Program doesn't want to be paying for water that isn't scored. Farnsworth recommended going ahead with the score corresponding to half of a capacity of 30,000 AF, since that's what CNPPID thinks is a reasonable expectation of the total recharge cap. The Program and CNPPID could work to amend the current WSA accordingly.

Drain made a definitive recommendation for the GC to use the Figure 5 curve for assigning score and making future adjustments if needed. EDO will revise the figure to note that the curve as shown is for all Elwood recharge users and will add a 50% curve for the Program. Econopouly clarified that this would mean a Program score corresponding to half the score for a total recharge cap of 30,000 AF. Altenhofen and Econopouly agreed with the premise of Drain's recommendation.

Barels asked if this meant 30,000 AF of excess flows were available every year. Drain and Griebling clarified that the analysis considers both available recharge capacity and excess flow availability; more space in the reservoir can be added, but cannot create more excesses, which is why the score vs. capacity curve flattens.

With no objections, the Scoring Subcommittee recommended a score of 2,800 AF based on half of the score with a 30,000 AF cap (5,600 AF), per the score vs. capacity curve in Figure 5 of the score memo.

Pathfinder Municipal Account Lease: *Scott Griebling and Seth Turner, EDO*

Griebling explained that the original score analysis for the Pathfinder Municipal Account lease project assumed releases of 4,800 AF annually. Table 1 in the score update memo (see appended slides as well) shows that additional water has been available in most years over the 2012-2018 operational period for the project. The EDO evaluated three possible scenarios: (1) an additional 4,800 AF is available in all wet years only; (2) an additional 4,800 AF is available in all wet years and half of normal years; and (3) an additional 4,800 AF is available in all wet and normal years.

Drain asked if there is any guidance on how frequently the Program can expect to get extra water. Turner said the updated score analysis was reviewed by Wyoming, with recommendations from different personnel of either Scenario 2 or Scenario 3. Econopouly had previously inquired about the possibility of simply calculating a firm yield value to use in the score update, and there was some additional discussion of this point. Turner noted that the 9,600 AF maximum delivery is based on the firm yield for the 20,000 AF Municipal Account, as defined in earlier Program documents. Barels asked if Wyoming could contract for the full 9,600 AF; Clerkin said no because there are other obligations to Wyoming municipal water users who haven't needed the water.

Drain said that because the Program has gotten extra water in at least some normal years, that rules out Scenario 1, and since the Program is not getting the full extra 4,800 AF in all normal years, that seems to rule out Scenario 3, leaving Scenario 2 as the best approach. Committee discussion of Scenario 2 and Scenario 3 continued. Clerkin said the average account balance over 2012-2018 has been about 8,800 AF. The Program didn't take extra water in 2012, 2013, and 2016; if that had happened, the average account balance would've been reduced to about 6,400 AF. Based on further evaluation, Clerkin said Scenario 3 seems reasonable.

Drain suggested splitting the difference between Scenarios 2 and 3. Econopouly expressed a preference for a more conservative score approach. Farnsworth noted that Scenario 2 assumes all or nothing in normal years, but this year shows that is not necessarily the case since the Program is getting less than 4,800 AF additional water, but not zero. Farnsworth added that this project is notable for actually outperforming its original score.

Drain proposed averaging the mathematical scores of Scenario 2 (5,940 AF) and Scenario 3 (6,760 AF), then rounding to the next hundred. Farnsworth and Altenhofen agreed with this approach. Barels agreed with the logic of averaging Scenarios 2 and 3 but dissented from rounding up to 6,400 AF. Clerkin suggested continuing to look at the project yield every year, keeping open the option for future score revisions based on operations.

Drain and Altenhofen proposed an unrounded score of 6,350 AF. Econopouly said that was good.

With no objections from the committee, Drain recommended a score of 6,350 AF based on the mathematical average of Scenarios 2 and 3, with continued monitoring to see if the score needs to be revisited again in the future.

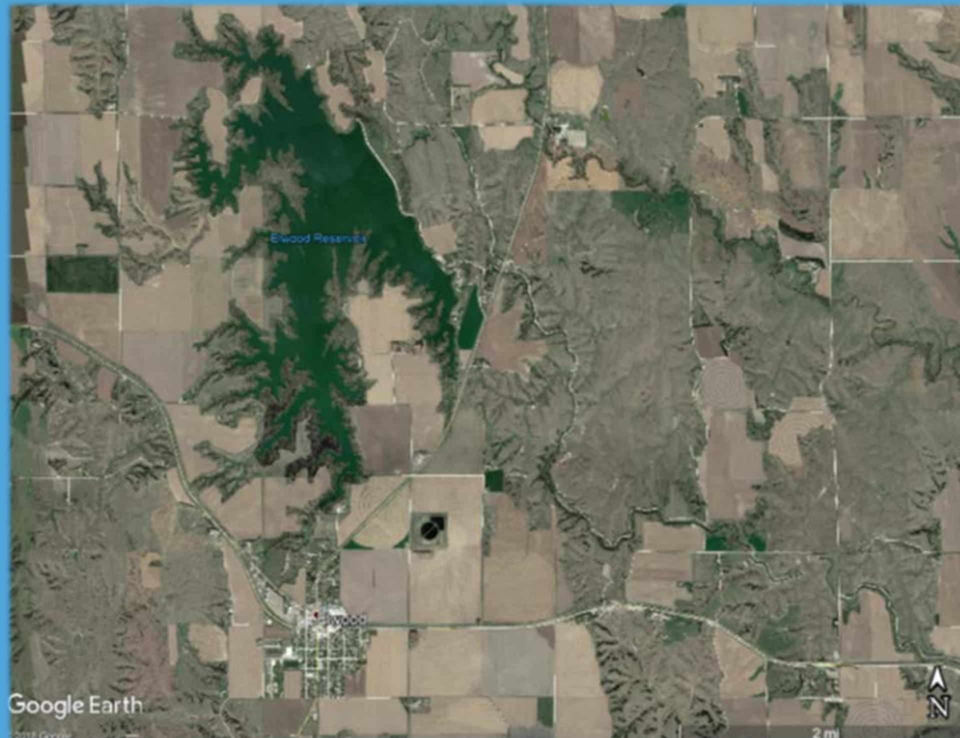
Additional Business: *Mike Drain, Chair*
None

Decisions and Action Items

- Scoring Subcommittee decisions pertaining to Elwood Reservoir groundwater recharge:
  - The assumed pumping rate of 250 cfs is appropriate.
  - The prohibition of June-July-August recharge diversions via the E-65 Canal as incorporated in the analysis is appropriate.
  - The discussion regarding Elwood Reservoir historical seepage and effects on score is to be documented by the EDO in these minutes, with slides presented during the conference call appended, and briefly summarized in the score memo. No policy consideration will be referred to the GC.
  - The discussion of "tail wrapping" to account for lagged accretions beyond the study period is to be documented by the EDO in these minutes, along with appended slides, and briefly summarized in the score memo. No further changes to the score analysis were proposed, and no policy considerations will be referred to the GC.
  - Score is to be based on the score vs. capacity curve (Figure 5 in the memo), with revisions as noted in these minutes. The score for the Program will be 50% of the total score associated with a reasonably assumed maximum recharge capacity of 30,000 AF. **The Scoring Subcommittee recommends a score of 2,800 AF for the Elwood Reservoir groundwater recharge project.**

- Scoring Subcommittee decisions pertaining to the Pathfinder Municipal Account lease:
  - **A revised score of 6,350 AF is recommended based on the mathematical average of scores calculated for Scenario 2 and Scenario 3, as defined in the score update memo. This is an increase of 2,350 AF over the original score of 4,000 AF.**
  - The EDO will continue to monitor operations of the Pathfinder Municipal Account lease to determine if the score should be revisited again in the future.

- The EDO will prepare meeting minutes, make necessary revisions to the two score memos, and recirculate to the Scoring Subcommittee no later than Thursday August 30. The Scoring Subcommittee will provide any final comments on the documentation, preferably by Friday September 7. However, since the Scoring Subcommittee has made formal score recommendations to the GC as noted above, it is not imperative for the documentation to be absolutely final prior to the September 11-12 GC meeting.

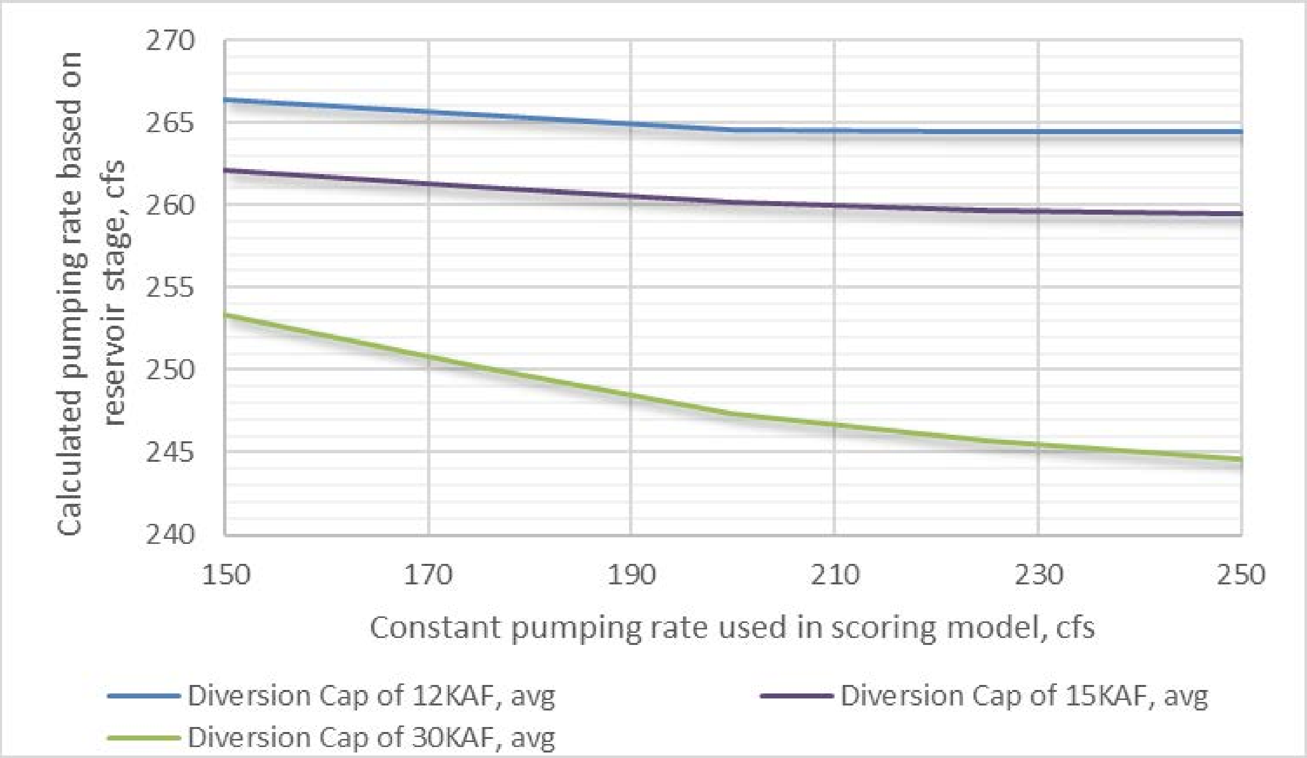


PLATTE RIVER
RECOVERY IMPLEMENTATION PROGRAM

Scoring Subcommittee Conference Call

August 27, 2018

Pumping Rate Sensitivity



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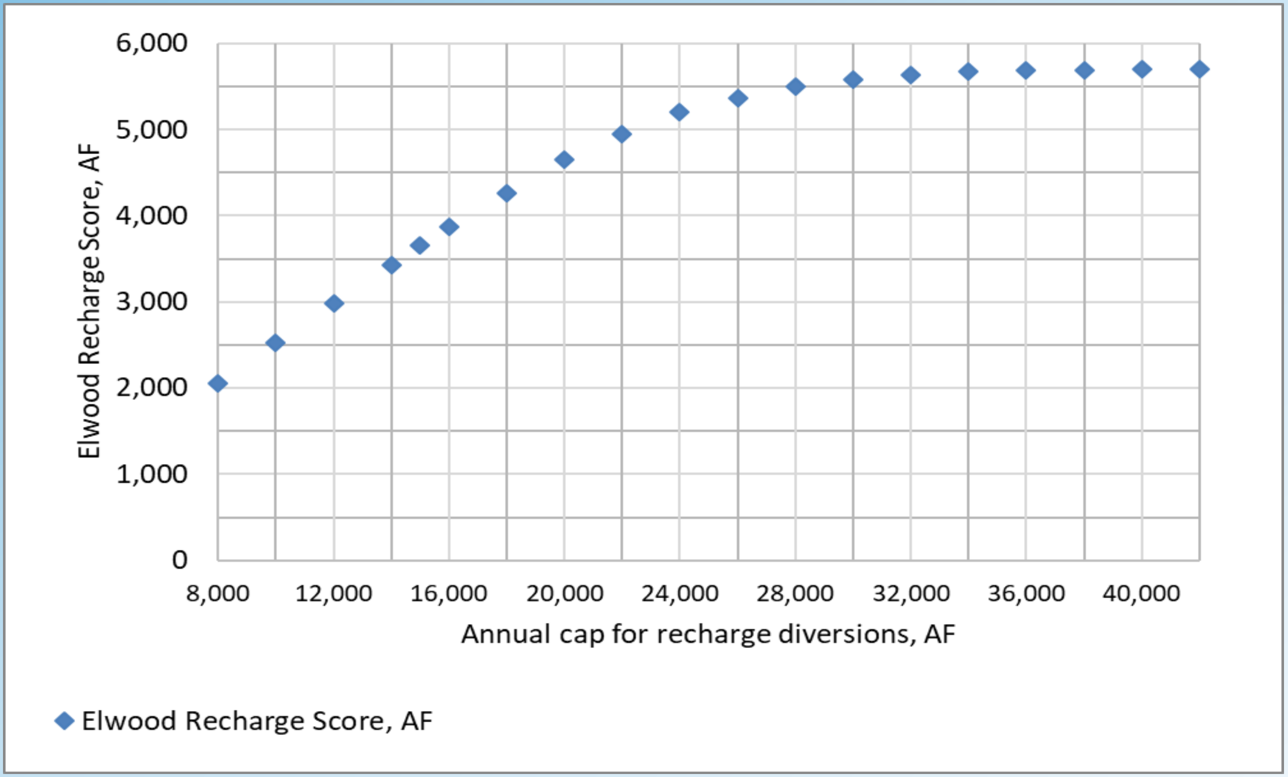
Revised Elwood Score Results (250 cfs pumping rate, no June-July-August recharge diversions)

Scenario	Annual Avg Diverted Volume (AF)	Annual Avg Recharged Volume (AF)	Annual Avg Returns to the River (AF)	Score (AF)
Recharge cap of 8,000 AF	7,400	6,900	4,200	2,100
Base Scenario: annual recharge diversion cap of 12,000 AF	**10,900**	**10,000**	**6,100**	**3,000**
Recharge cap of 15,000 AF	13,500	12,300	7,500	3,700
Recharge cap of 20,000 AF	17,000	15,600	9,600	4,700
Recharge cap of 26,000 AF	19,700	18,000	11,100	5,400

PLATTE RIVER
RECOVERY IMPLEMENTATION PROGRAM

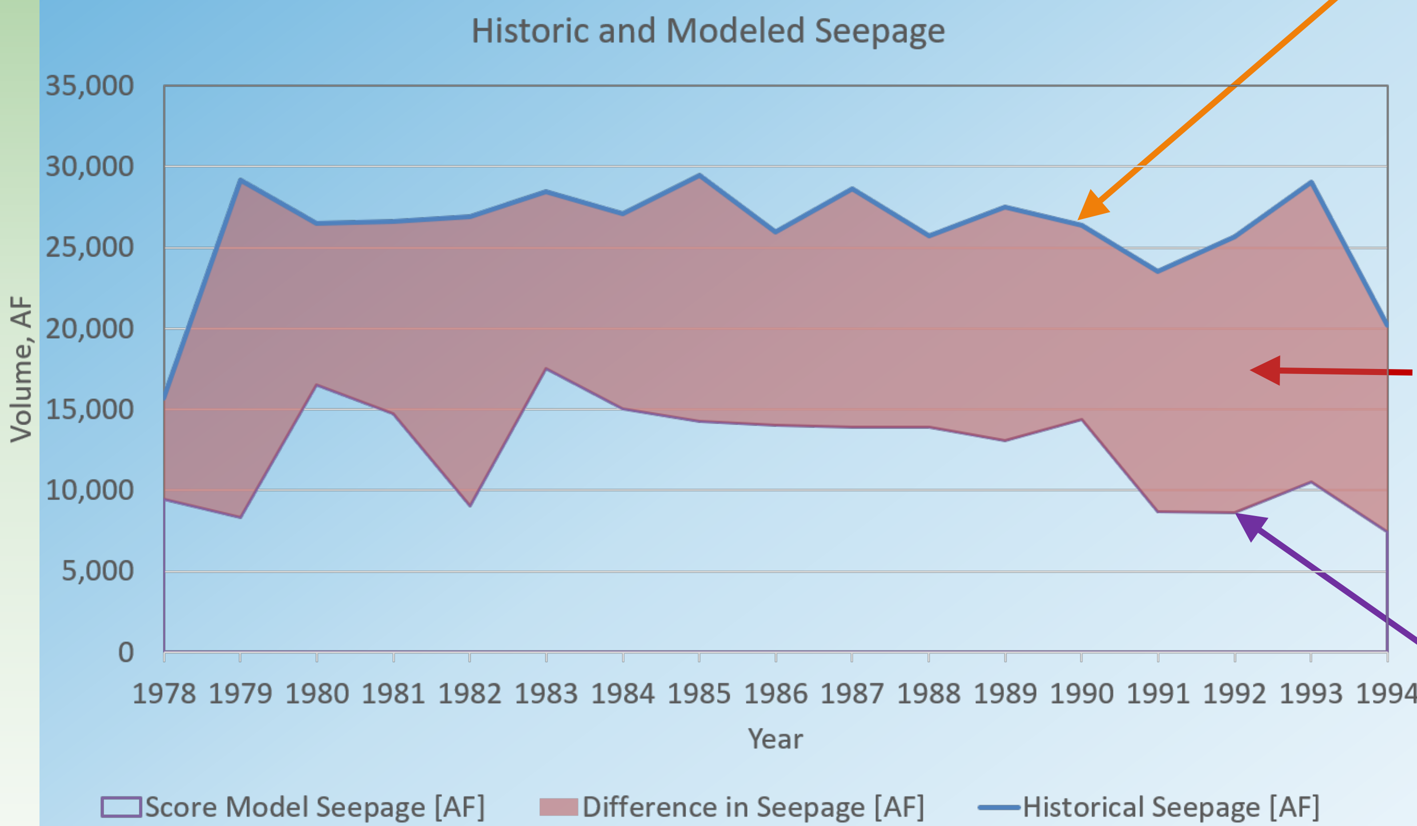
Revised Elwood Score Curve (250 cfs pumping rate, no June-July-August recharge diversions)



How would the project score change if Elwood’s historic seepage wasn’t present in the scoring model’s hydrology?

Historic vs. Modeled Seepage

Greater historic seepage due to more water in Elwood Reservoir



Difference in seepage

Less seepage in scoring model due to less water in Elwood Reservoir

PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM

Assumptions made in the analysis

- OPSTUDY hydrology captures the effects of historic Elwood Reservoir operations from 1978-1994
- Thus, the OPSTUDY hydrology INCLUDES higher Platte River baseflows caused by historic Elwood Reservoir seepage
- To evaluate the impact of the lower Elwood Reservoir operations reflected in the scoring model, baseflow must be LOWERED to account for less seepage from Elwood Reservoir

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RECOVERY IMPLEMENTATION PROGRAM

Current Score Model

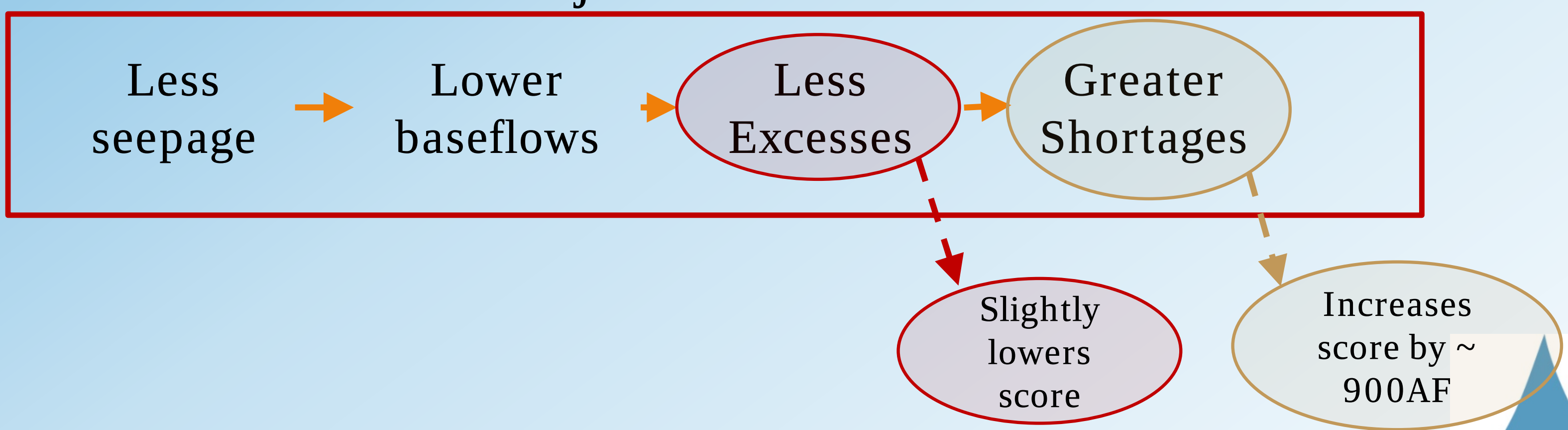
Greater seepage → Higher baseflows → Greater Excesses → Less Shortages

Adjusted Score Model

Less seepage → Lower baseflows → Less Excesses → Greater Shortages

Current Score Model

Adjusted Score Model



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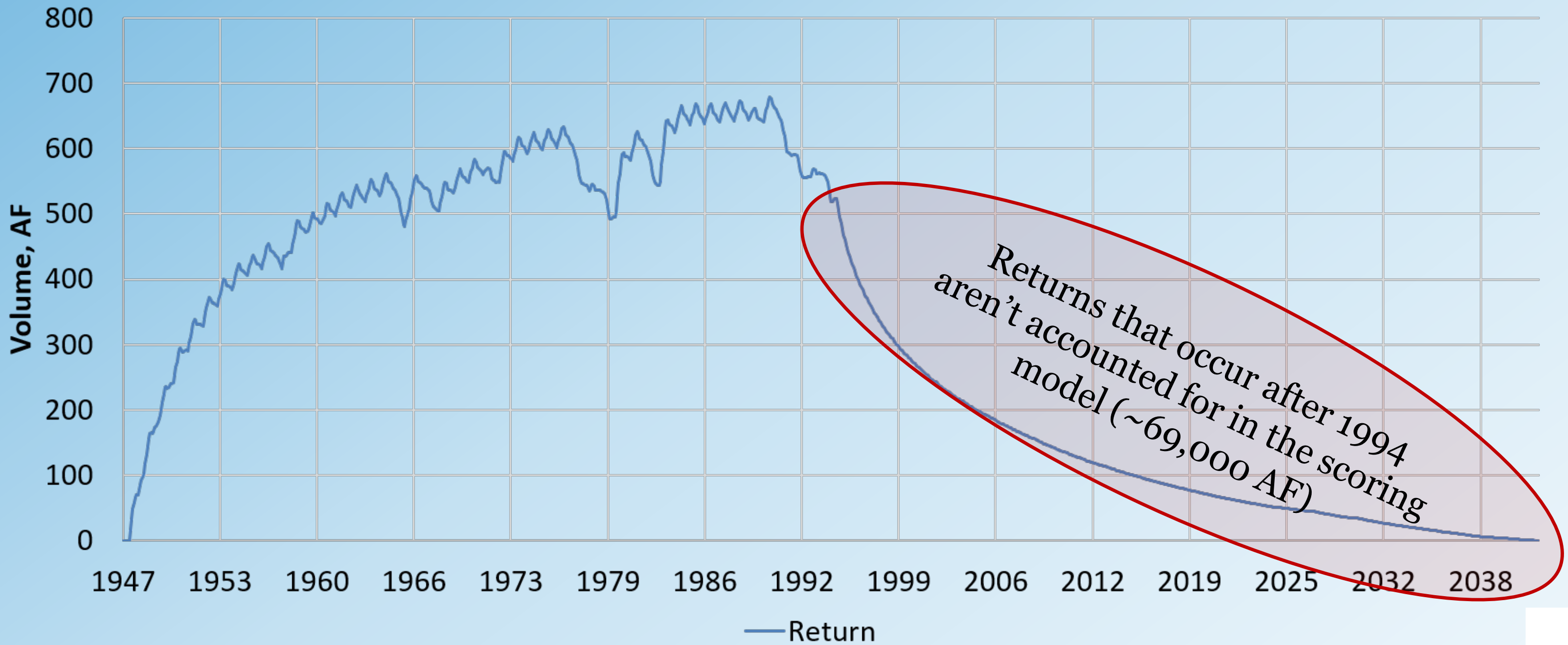
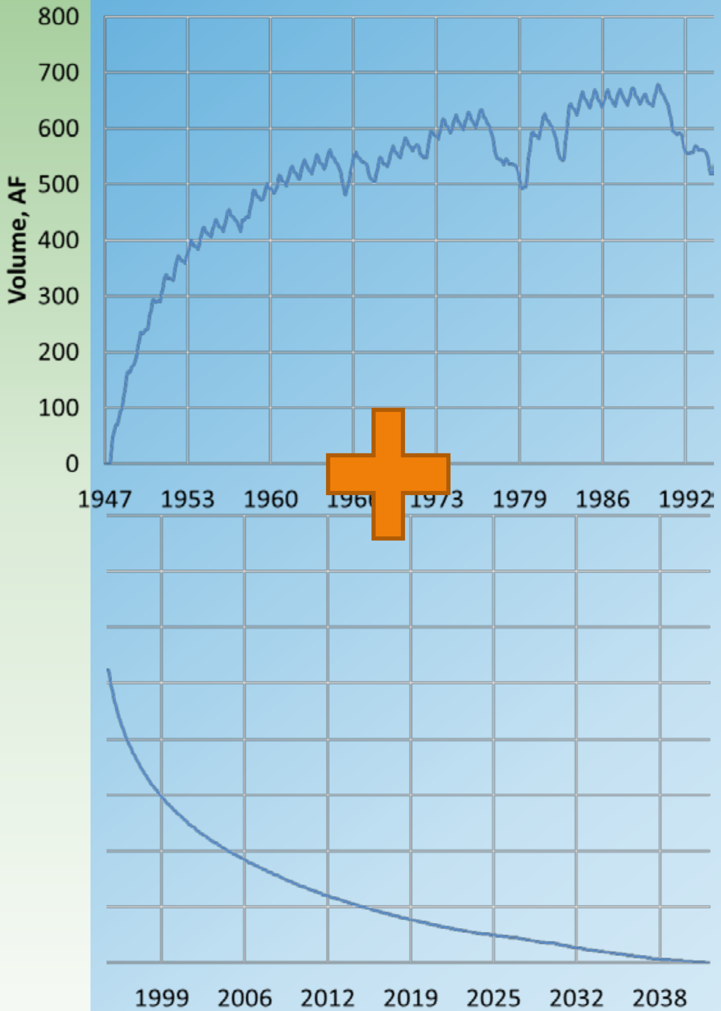
A Few Considerations…

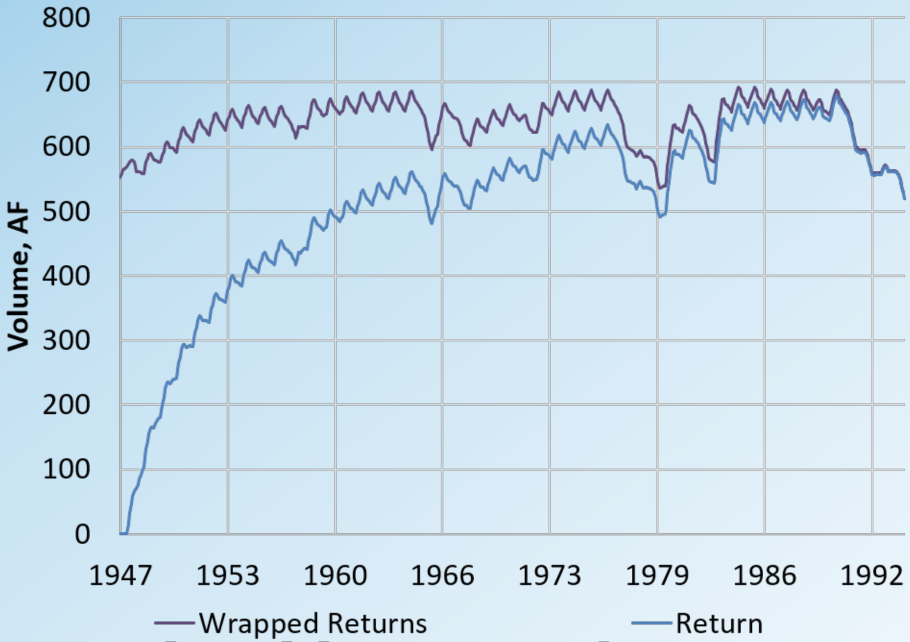
- This approach represents a departure from previous scoring methodology
- Other projects would need to be rescored using this same methodology for consistency
- Changing the scoring model to account for Elwood operational changes sets the stage for additional rescoring of all WAP projects with future operational changes

PLATTE RIVER
RECOVERY IMPLEMENTATION PROGRAM

Wrapping lagged returns

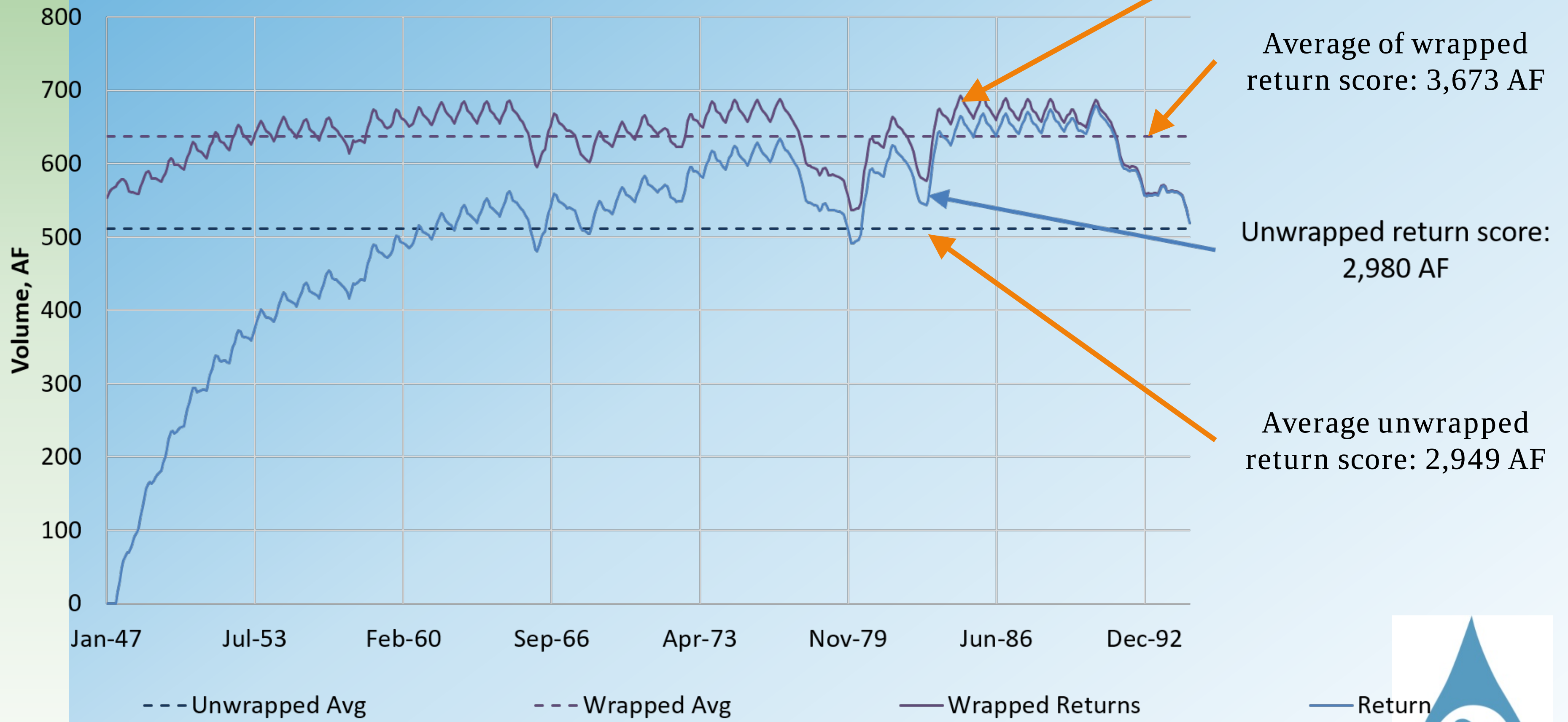






Simply add returns that occur from 1995 onwards to the existing returns, beginning in 1947?

Or take the average of the unwrapped seepage?
Or the wrapped seepage?



A Few Considerations…

- This approach represents a departure from previous scoring methodology
- The Phelps Canal Recharge project would likely need to be rescored using this same methodology for consistency
- Future recharge projects would likely need to be scored using this same methodology

PLATTE RIVER
RECOVERY IMPLEMENTATION PROGRAM

Pathfinder Municipal Account Lease

Year	Year type	Lease amount (AF)
2012	Normal	4,800
2013	Normal	4,800
2014	Normal	9,600
2015	Wet	9,600
2016	Wet	4,800 (declined additional 4,800)
2017	Wet	9,600
2018	Normal	8,100

PLATTE RIVER
RECOVERY IMPLEMENTATION PROGRAM

Pathfinder Release Scenarios, 1947-1994

- **Scenario 1 (additional 4,800 AF available in wet years only):**
  - Wet years release = 9,600 AF
  - Normal and Dry years release = 4,800 AF
  - Wet years account for 16 of 48 years (33 percent)
- **Scenario 2 (additional 4,800 AF available in wet years and half of normal years):**
  - Wet years and every other Normal year release = 9,600 AF
  - Dry years and the remaining Normal years release = 4,800 AF
  - Additional water is available 26 of the 48 years (54 percent)
- **Scenario 3 (additional 4,800 AF available in all wet and normal years):**
  - Wet and Normal years release = 9,600 AF
  - Dry years release = 4,800 AF is released.
  - Wet and normal years account for 36 out of 48 years (75 percent)

Updated Pathfinder Muni Account Scores

Scenarios	Score [AFY]
Scenario 0 (4,800 AFY in all years)	3,940
Scenario 1 (9,600 AFY 33% of the time: wet year only)	5,270
Scenario 2 (9,600 AFY 54% of the time: wet years & every other normal year)	5,940
Scenario 3 (9,600 AFY 75% of the time: wet & normal years)	6,760

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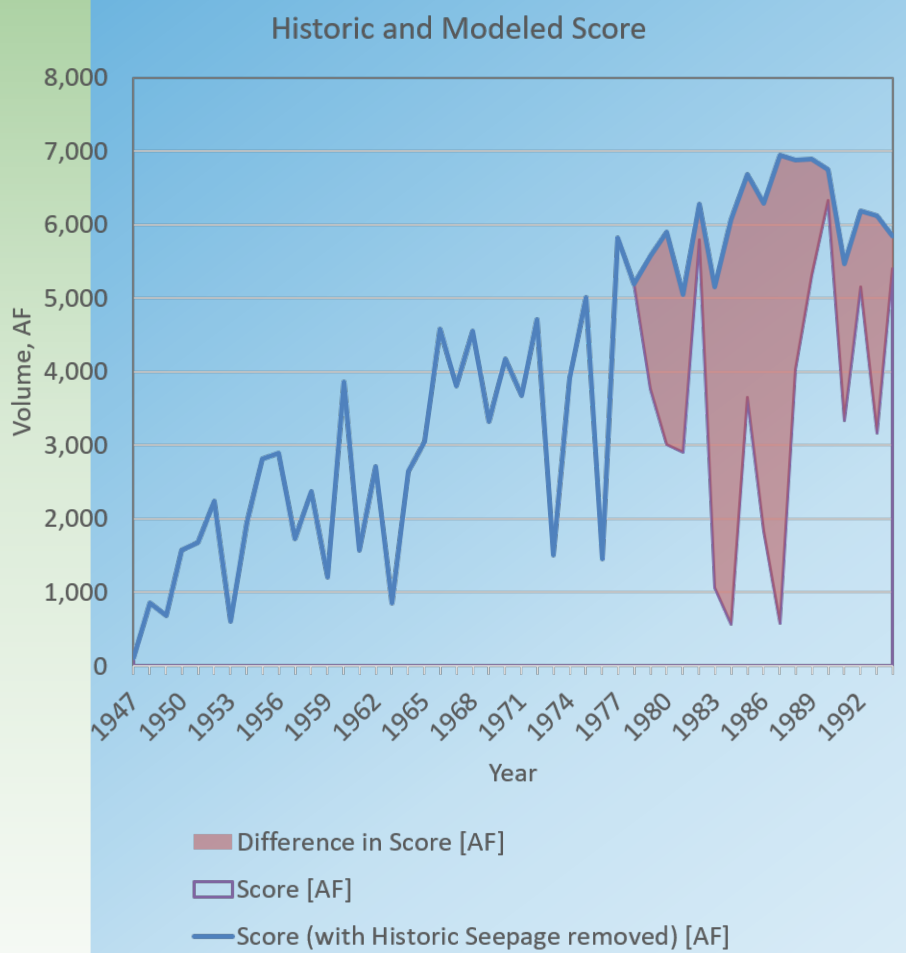
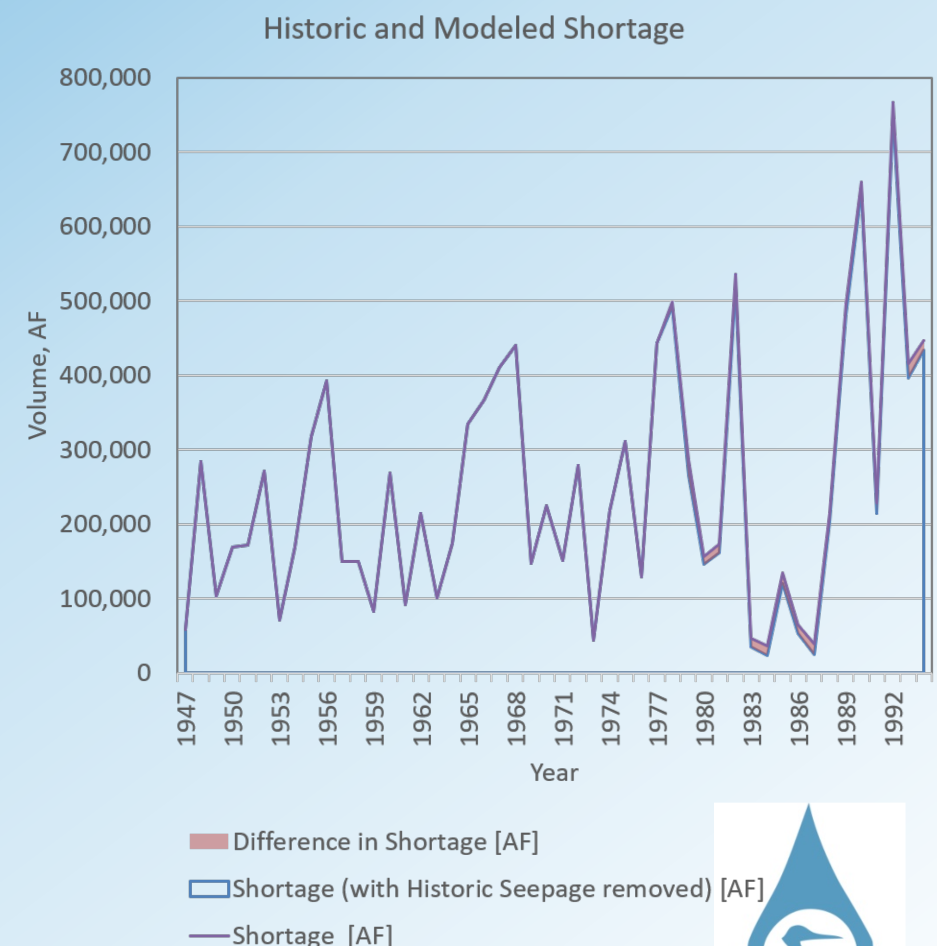
Additional Elwood Seepage Analysis Figures





PLATTE RIVER
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EXHIBIT B

Program Use of the COHYST Model in the Elwood Reservoir Groundwater Recharge Analysis
(PRRIP EDO, August 28, 2018)

Technical questions on "PRRIP Use of the COHYST model in the Elwood Reservoir Groundwater Recharge Analysis"
(Nebraska DNR, April 18, 2019)

Accounting for Elwood Recharge Returns Using the COHYST Groundwater Model
(PRRIP EDO, May 31, 2019)

TO: DON KRAUS, MEMBER, PLATTE RIVER RECOVERY IMPLENTATION PROGRAM GOVERNANCE COMMITTEE

JENNIFER SCHELLPEPPER, WATER PLANNING DIVISION MANAGER, NEBRASKA DEPARTMENT OF NATURAL RESOURCES (NDNR)

FROM: JASON FARNSWORTH, EXECUTIVE DIRECTOR, PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM (PROGRAM)

SUBJECT: PROGRAM USE OF THE COHYST MODEL IN THE ELWOOD RESERVOIR GROUNDWATER RECHARGE ANALYSIS

DATE: AUGUST 28, 2018

Don and Jennifer,

This memorandum is in response to your emails of August 27, 2018 in which you inquire about the Program's use of the COHYST Model in the analysis of our water projects, changes that may have been made to the model to facilitate these analyses, the degree to which we have documented such changes, and the extent of the coordination between the Program and the COHYST sponsors. For purposes of this discussion, my reference to the COHYST Model concerns only the groundwater component of the model.

As a general rule, our goal in using the COHYST Model is to apply the model without change wherever possible. However, we recognize that the COHYST Model is a regional model and that there may be instances in dealing with projects at a more refined scale where changes to the model may be appropriate. In such cases, our goal is to implement the fewest number of changes that are appropriate, while minimizing the overall impact on the model. Our intent is also to document such changes.

Thus far, our only use of the COHYST Model in the analysis of a Program Water Action Plan water projects was in our investigation of the Elwood Reservoir groundwater recharge project. We determined that the COHYST Model would benefit from some localized changes to improve its representation of Plum Creek, a key hydrologic feature in the vicinity of Elwood Reservoir. These changes are documented in the attached memorandum (Hahn Water Resources, May 18 2018). The attached document was made available to members of the PRRIP Water Action Committee (WAC) earlier this year. While minor, we believe that changes to the COHYST Model made in connection with our investigation of Elwood Reservoir improve the model's predictive capabilities in the area of Elwood Reservoir.

The Program does not have a formal process for communicating with other sponsors of COHYST on matters such as this. The changes we made were communicated informally to several members of the COHYST technical team during the course of our work. The Program anticipates using the groundwater portion of the COHYST model in a similar fashion to develop response functions for other recharge projects and will keep the COHYST sponsor's group informed as this work progresses.

DATE: April 18, 2019

TO: EDO

FROM: NeDNR

SUBJECT: Technical questions on "PRRIP Use of the COHYST model in the Elwood Reservoir Groundwater Recharge Analysis"

MEMORANDUM

The Department had a brief technical discussion with EDO representatives on October 15, 2018, and obtained model files from EDO. The Department has attempted to recreate the response curve and document any differences from our methodologies or gaps in the documentation or our understanding, and any related questions that have arisen. This memo provides our questions for EDO regarding the Elwood accretions curves used in conjunction with the scoring methodology and presents some of our initial findings in attempting to recreate this information. These are broken down into two categories: 1) EDO's change to the COHYST model and 2) EDO's methodology of processing model results to create a streamflow response curve to Elwood recharge.

EDO's Change to the COHYST Model Conductivities

Description:

EDO lowered the conductivity in an area including Elwood Reservoir and extending to the southeast from 80 ft/day to 55 ft/day for the described purpose of maintaining Plum Creek as a gaining stream.

Gordon W. "Jeff" Fassett, P.E., Director
Department of Natural Resources
301 Centennial Mall South
P.O. Box 94676
Lincoln, Nebraska 68509
OFFICE 402-471-2363
FAX 402-471-2900
dnr.nebraska.gov

Impact Assessment:

We did not find a significant change in the direction of the Plum Creek stream to aquifer interaction resulting from the conductivity modification (Figure 1).

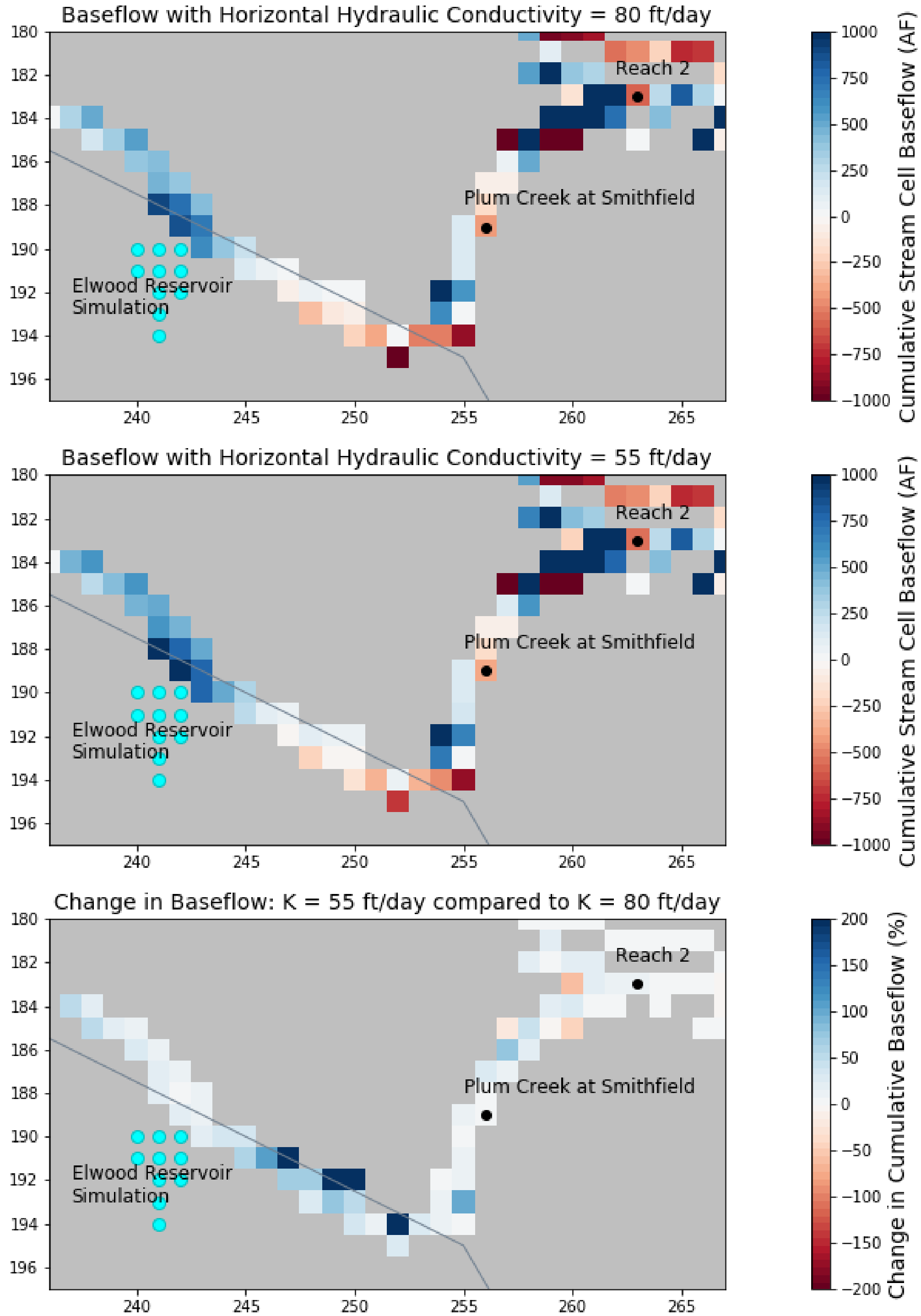

Figure 1. Cumulative baseline (no added Elwood recharge) baseflow from the documented COHYST model (k=80) and EDO model (k=55). Negative values represent a losing stream, positive values represent a gaining stream.

The cumulative change in streamflow resulting from the conductivity change appears to be minimal. Using the documented COHYST model (k = 80 ft/day in the Elwood zone) as the baseline, adding 10 cfs of recharge to the Elwood cells results in 37.2% accretion to the Platte River at Elm Creek after 26.25 years. Using the EDO modified model (k = 55 ft/day in the Elwood zone) as the baseline, adding 10 cfs of recharge to the Elwood cells results in 40.7% accretion to the Platte River at Elm Creek after 26.25 years.

The timing of the accretions is affected by the conductivity change (Figure 2). The accretions with the COHYST model do not occur until later in the simulation, but then occur at a greater magnitude through the rest of the simulation. As shown in an example pulse-flow scenario, this is likely due to the groundwater mound along Plum Creek and the Platte River taking longer to build since the conductivity is greater in the opposite direction of the stream than EDO's model (Figure 3).

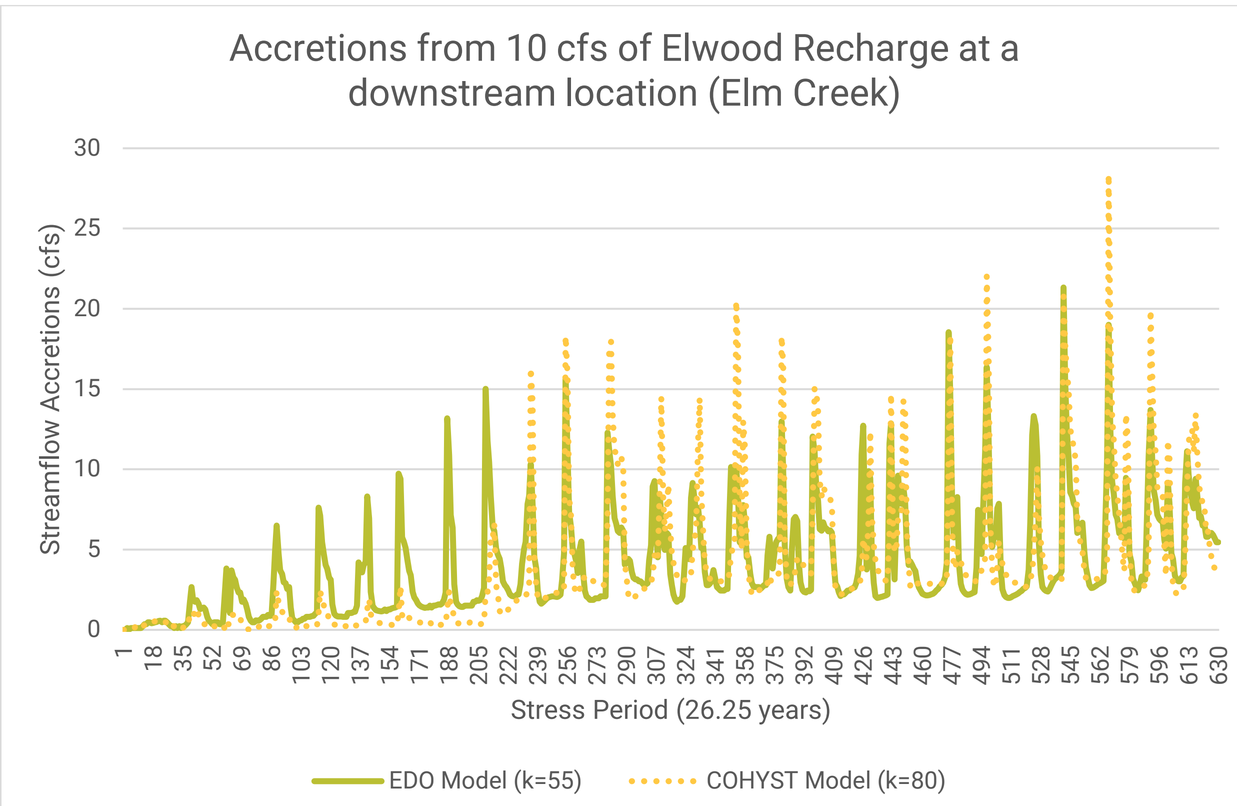

Figure 2. Time series of accretions to streamflow at a downstream location from adding 10 cfs of recharge from Elwood using the documented COHYST model or EDO Elwood model.

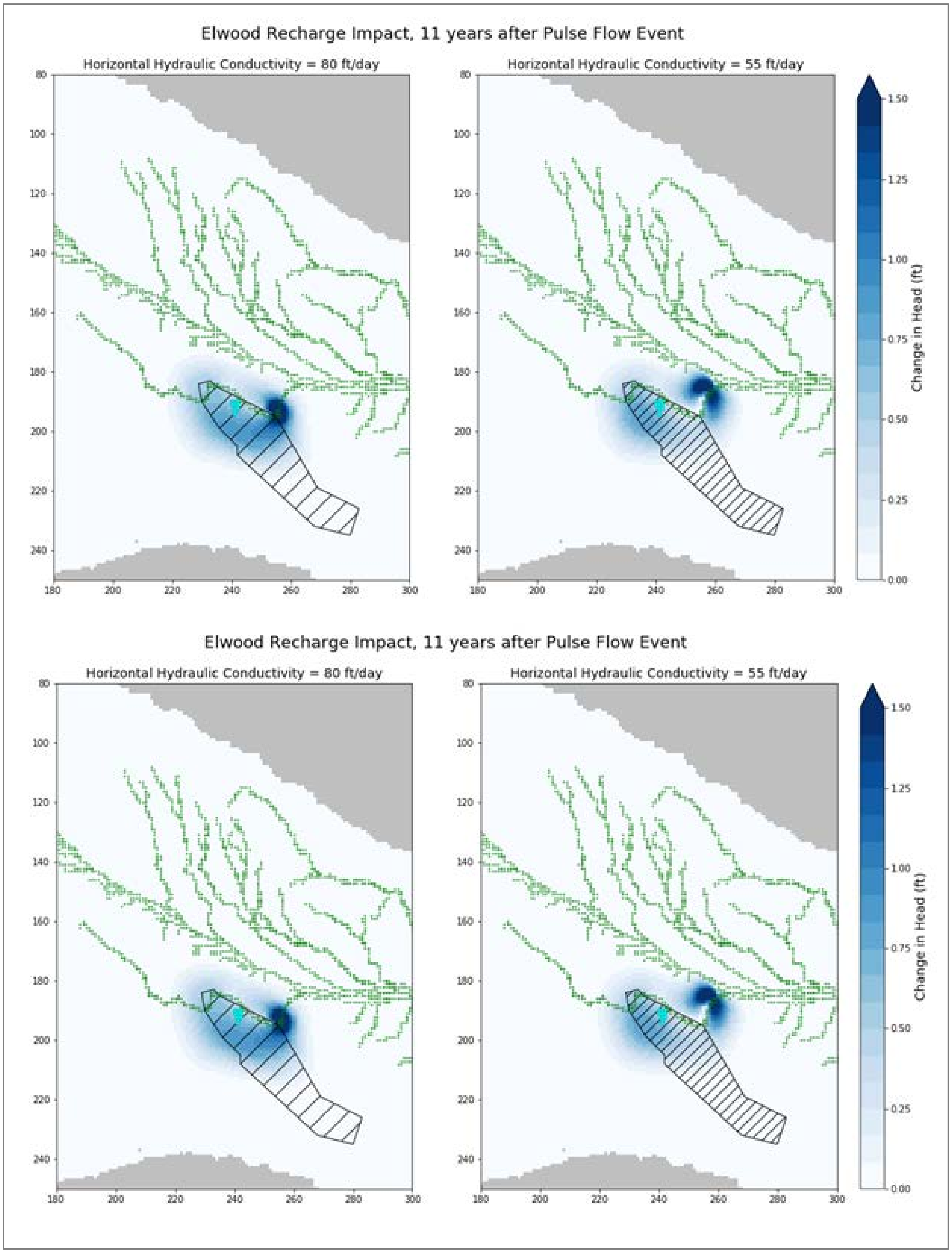

Figure 3. Change in modeled groundwater head 11 years and 35 years after a simulated Elwood Recharge pulse flow event using an extension of the documented COHYST model and an extension of the COHYST model with the EDO Elwood model LPF file.

Follow-up Questions for Discussion Regarding Model Changes:

EDO's described change in horizontal conductivity was a straightforward change in a single model parameter. We would like to verify that this was the only change made to the documented COHYST model. The Department would also like to review with EDO staff how the calibrated groundwater levels were affected by this change.

EDO's Methodology of Processing Model Results to Streamflow Accretions

Description:

Based on EDO's documentation, our assumption has been that to calculate accretions, EDO summed outflows from Platte River Reach 1 (Segment 327, Reach 15), Platte River Reach 2 (Segment 328, Reach 10), and Plum Creek at Smithfield (Segment 216, Reach 21). This is different from methodologies used by the Department, which summarizes accretions to all stream cells upstream of Elm Creek and Chapman. Outflows at Reach 4 identified by EDO (assumed Segment 332, Reach 1) would yield similar results to the Department's accounting methodology for Elwood recharge events. According to EDO's documentation, this accounting was used to allow only "gaining reaches" to be included in the final results, but clarification of this accounting methodology would likely assist in understanding the broader purpose of the changes and the resulting differences in the methodologies.

Impact Assessment:

Impact from Elwood accretions occur downstream of the combined locations of Reach 1, Reach 2, and Plum Creek at Smithfield, therefore different results are obtained than when using Reach 4 or upstream of Elm Creek (Figure 4). This accounting difference may be a larger factor in the accretions curve differences than the differences that exist between the COHYST Model results and EDO model results.

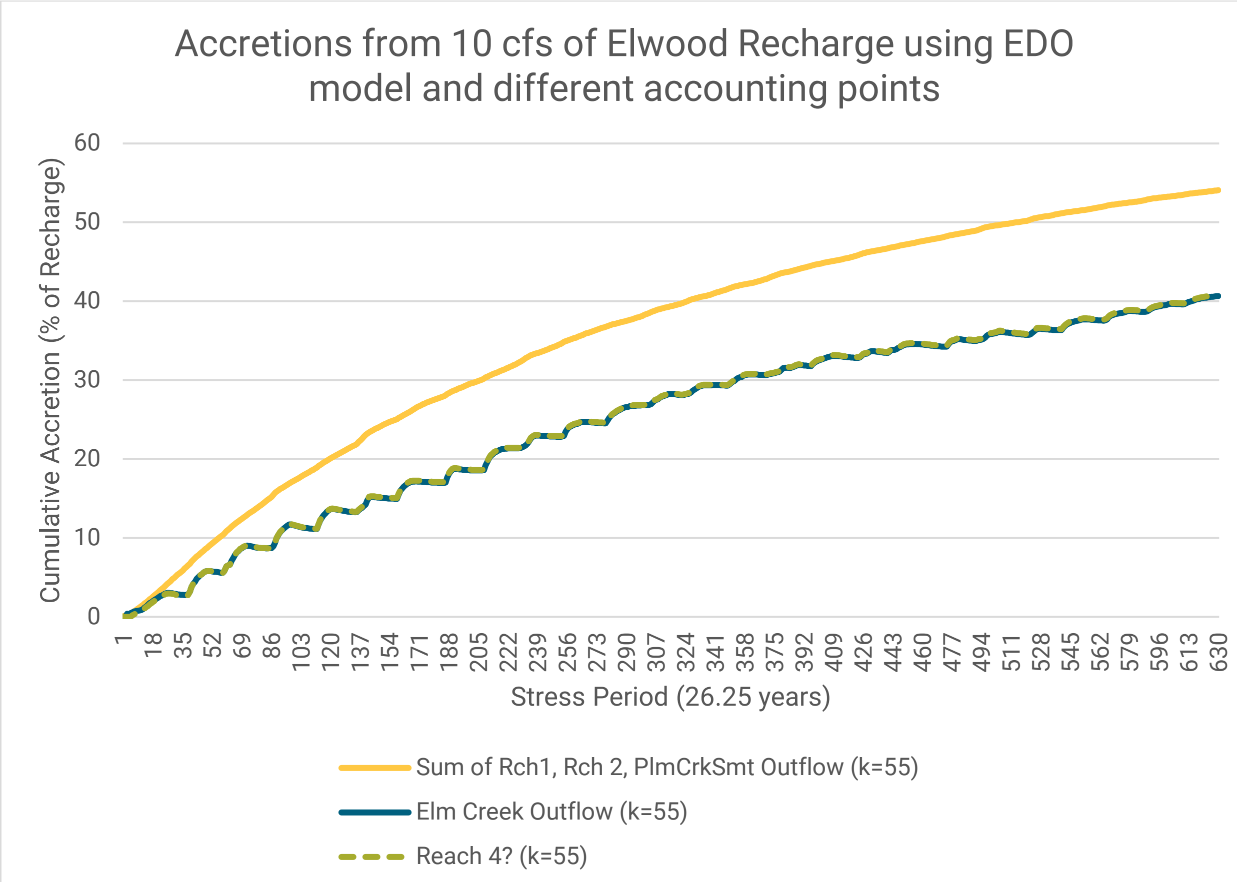

Figure 4. Time series of accretions to streamflow from adding 10 cfs of recharge from Elwood using the EDO Elwood model with three different methods of accounting. The sum of outflows Reach 1, Reach 2, and Plum Creek at Smithfield (yellow line) is assumed to be what EDO used. The Elm Creek outflow is similar to what NeDNR might use (blue line).

Follow Up Questions for Discussion:

1. Which reaches were summed to determine the total returns to the Platte River?
   a. Why were they chosen? Why were other reaches excluded?
   b. How is the chosen method consistent with the conceptual understanding of what is happening within the water balance of the model and of the actual river-aquifer system?
   c. Additionally, the documentation describes the processing of the accretions calculations as smoothing, curve-fitting, and extending. It seems that a logarithmic fit with a forecast was applied. Why was this approach preferable to using the direct model outputs?
2. How were the modeled accretions processed into the final response curve?
   a. What were the smoothing or curve-fitting procedures?
   b. How was the curve extended?
   c. Is the error adjustment because of the curve-fitting and/or the segment subsetting?

The Department would appreciate the opportunity to further discuss these questions with EDO staff and work collaboratively to develop a common understanding of the complexities of modeling aquifer/stream interactions in this area with the desired goal of having a common representation for this project and future activities occurring in this area.

TO: NEBRASKA DEPARTMENT OF NATURAL RESOURCES

FROM: THE EXECUTIVE DIRECTORS OFFICE OF THE PLATTE RIVER RECOVERY IMPLEMENTATION PROGRAM

SUBJECT: ACCOUNTING FOR ELWOOD RECHARGE RETURNS USING THE COHYST GROUNDWATER MODEL

DATE: MAY 31, 2019

I. INTRODUCTION

This memo provides additional information on the methodology used by the Executive Director's office (EDO) of the Platte River Recover Program (Program) to account for returns to the Platte River from modeled groundwater recharge meant to simulate seepage from Elwood Reservoir to the nearby groundwater aquifer (Elwood recharge). Additional documentation of the Elwood Reservoir recharge analysis is available from the report titled "PRRIP Use of the COHYST Model in the Elwood Reservoir Groundwater Recharge Analysis" (Project Report, included as **Attachment A**).

II. TYPICAL ACCOUNTING METHODOLOGY

The goal of the Elwood Reservoir groundwater recharge project is to increase flows in the Platte River by allowing water in Elwood Reservoir to enter the groundwater and flow through the aquifer to the river. Streamflow accretions caused by the Elwood recharge arrive at the Platte River in two ways: as baseflow directly into the Platte River and as baseflow into Plum Creek that then flows down Plum Creek into the Platte River. These baseflow accretions are caused by increases in aquifer levels as a result of Elwood recharge. **Figure 1** shows the ground water level impact from Elwood recharge, with the light blue area of influence indicating the extent of water level rises in the aquifer as a result of the 27 years of continuous recharge of 10 cfs at Elwood Reservoir[1]. The portion of Plum Creek and the Platte River that fall within the light blue area are impacted by Elwood recharge.

One approach for accounting for the accretions to the Platte River from Elwood recharge would be to pick a location on the Platte River downstream of the areas impacted by Elwood recharge. Increases in streamflow at this downstream location would reflect the total increases in streamflow from Plum Creek and the Platte River. Based on the area of impact, a logical location to choose to account for accretions to the Platte River and Plum Creek caused by Elwood recharge would be below the confluence of the north and south channels of the Platte River. This corresponds to the cells highlighted in dark red in **Figure 1** and reach F in the line diagram shown in **Figure 2**.

[1] The use of 10cfs is further described in the Project Report

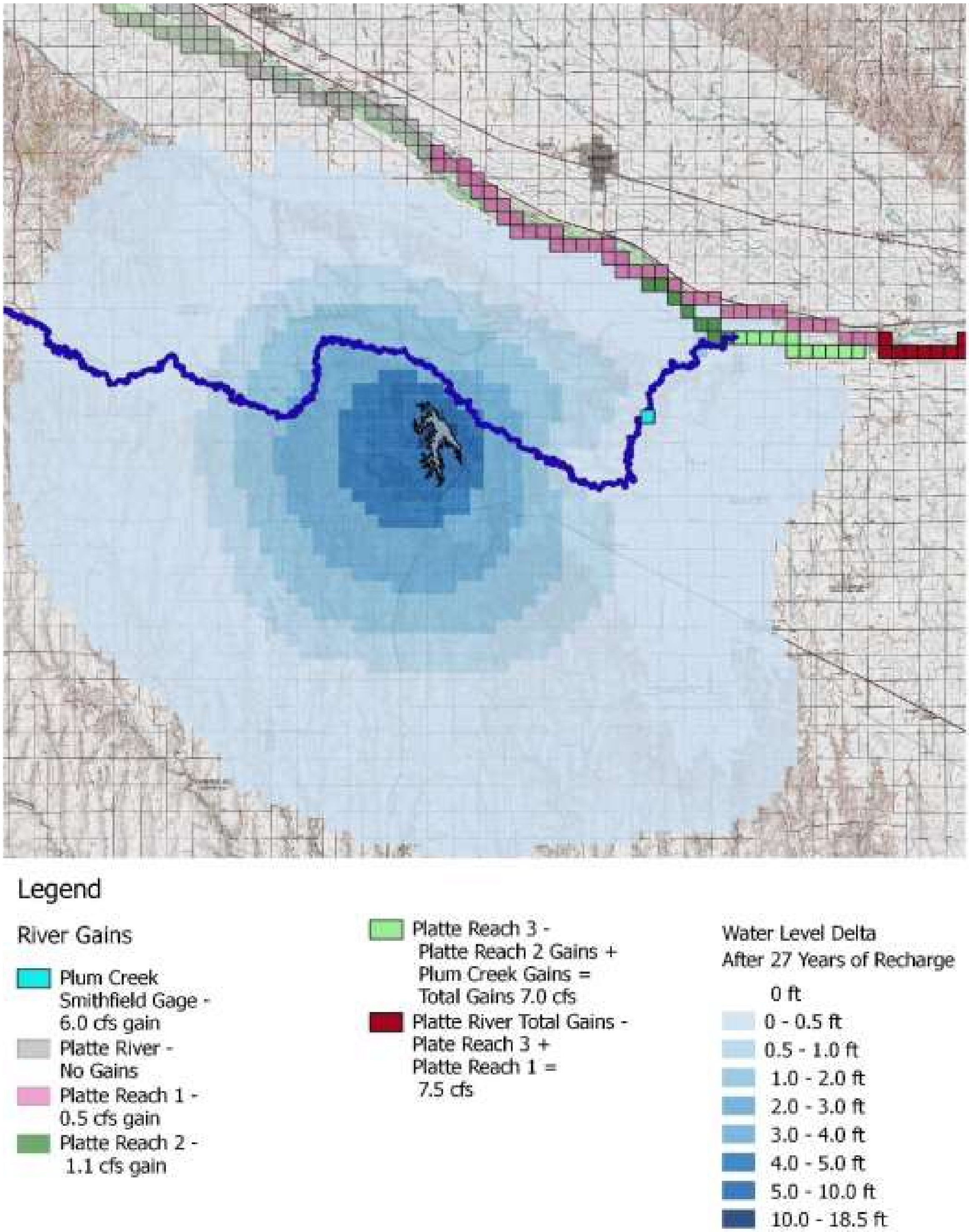

Figure 1. Water level impact and stream reaches (From the Project Report)[2]

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[2] The river gains in this figure do not exactly match the values presented in the rest of this memo as they reflect and average of the last few timesteps in the model while the values presented in this memo are for the last timestep in the model.

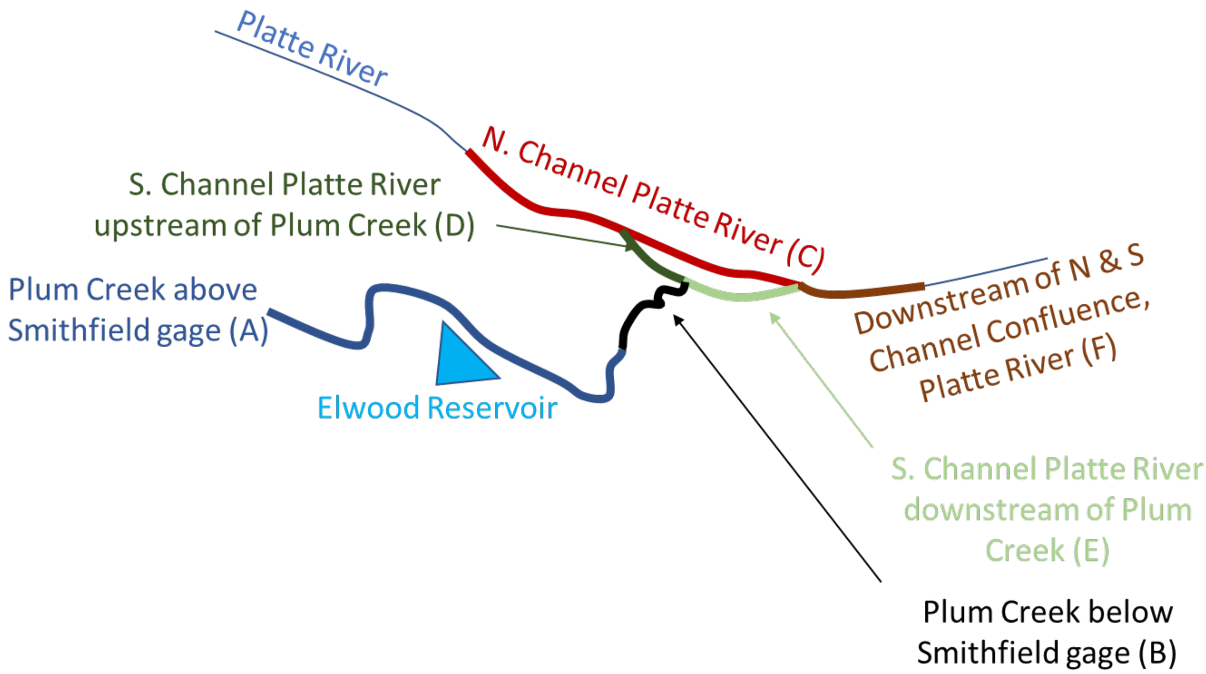

Figure 2. Line diagram of Platte River and Plum Creek reaches, Elwood Reservoir, and the Smithfield Gage (labels A through F correspond to **Table 1**)

Increases in streamflow in the Platte River below the confluence of the north and south channels (reach F in **Figure 2**) should match the sum of increases in streamflow from the north channel of the Platte River (reach C), the south channel of the Platte River upstream of Plum Creek (reach D), the south channel of the Platte River downstream of the Plum Creek (reach B), Plum Creek above the Smithfield gage (reach A), and Plum Creek below the Smithfield gage (reach B). **Table 1** shows the gains in each of these reaches for the last timestep of the model run.

Table 1. Recharge gains to the Platte River by reach in the final timestep of the model, with gains shown as the change in streamflow between the base model run and the recharge model run

	Reach	**Stream Segment & reach**	**Change in Streamflow (cfs)**
A	Plum Creek above the Smithfield Gage	216, 27	5.9
B	Plum Creek below the Smithfield Gage	239, 20	3.8
C	North channel of the Platte River	327, 15	0.4
D	South channel of the Platte River, above Plum Creek	328, 10	1.3
E	South channel of the Platte River, below Plum Creek	329, 8	5.3
F	Downstream of the confluence of the north and south channels of the Platte River	331, 1	5.8
Expected value downstream of the confluence of the north and south channels of the Platte River (A + C + D)			7.6

As seen in **Table 1**, the streamflow increases in reach F of 5.8 cfs do not match the sum of streamflow increases in the upstream reaches (A + C + D) of 7.6 cfs. If the method of using a downstream reach (reach F) to account for Elwood accretions is used, it results in only 76% of the expected returns showing up in the Platte River (5.8 cfs / 7.6 cfs = 76%). We would expect to see a steady increase in streamflow increases moving from upstream to downstream in both the Platte River and in Plum Creek as a result of increased aquifer heads from Elwood recharge. Instead, the model shows a reduction of streamflow increases of 2.1 cfs between the upper reach of Plum Creek (reach A, 5.9 cfs) and the lower reach of Plum Creek (reach B, 3.8 cfs). This does not match real world observations of Plum Creek which indicate that the creek gains from its upper reaches to its confluence with the Platte River. We evaluated how the lower reach of Plum Creek is simulated in the model and discovered several issues.

III. ISSUES WITH PLUM CREEK

The COHYST model appears to improperly route water through the lower portion of Plum Creek from the Smithfield gage to the south channel of the Platte River. The model shows this segment of Plum Creek behaving in an erratic fashion, as seen in **Table 2** and **Figure 3** which tabulates the changes in streamflow for each reach of this segment. The gains are calculated as the flow into the cell from the Elwood Recharge run minus the flow into the cell in the base model run, thus providing the change to streamflow as a result of the Elwood Recharge. Between reaches 4 and 5, the change in streamflow drops from 6.0 cfs to 4.0 cfs. Between reaches 9 and 10, the change in streamflow drops from 5.5 cfs to 0 cfs. Overall, the reach shows the change in streamflow to decrease from 5.9 cfs in reach 1 to 3.8 cfs in reach 20. This behavior does not make sense on an intuitive level and there is not a reality-based explanation for why this portion of Plum Creek would behave in this fashion. Apart from the recorded measurements at the Smithfield gage, discharge measurements at other locations are extremely limited. Nonetheless these measurements show on average a gain in Plum Creek in the segment between the Smithfield gage and the junction with the Platte River of about 13 percent. The EDO staff and Bill Hahn have observed this segment of Plum Creek in person and have never observed it to suddenly lose large amounts of flow. Additionally, the staff of the Tri-Basin Natural Resources District (TBNRD) cannot recall Plum Creek ever going dry below the Smithfield gage[3]. The model should at a minimum route the 5.9 cfs of increased streamflow seen in reach 1of the segment down to the Platte River without any losses. If the model were to adequately capture the observed behavior of Plum Creek, it would likely show additional increases in streamflow as water is routed down the segment, with the amount of increased streamflow reaching the south channel of the Platte River greater than 5.9 cfs.

[3] Personal communication between EDO Staff and TBNRD staff

Table 2. Plum Creek change in streamflow (Base model run subtracted from the Recharge model run) for the final timestep in the model

Segment	Reach	Row	Column	Streambed Conductance (ft^2/day)	Change in Streamflow (cfs)
239	1	187	258	1,274	5.9
239	2	186	258	26,683	6.0
239	3	187	258	1,626	6.0
239	4	187	259	1,626	6.0
239	5	186	259	27,202	4.0
239	6	187	259	1,577	4.0
239	7	186	259	29,064	5.3
239	8	186	260	24,599	5.4
239	9	186	261	26,683	5.5
239	10	185	261	28,191	0.0
239	11	185	260	30,485	0.4
239	12	185	261	29,280	2.6
239	13	184	261	28,191	1.8
239	14	185	261	29,064	4.3
239	15	185	262	24,599	4.4
239	16	184	262	26,683	4.1
239	17	185	262	24,599	4.2
239	18	185	263	21,138	4.2
239	19	184	263	19,691	4.0
239	20	184	264	19,690	3.8

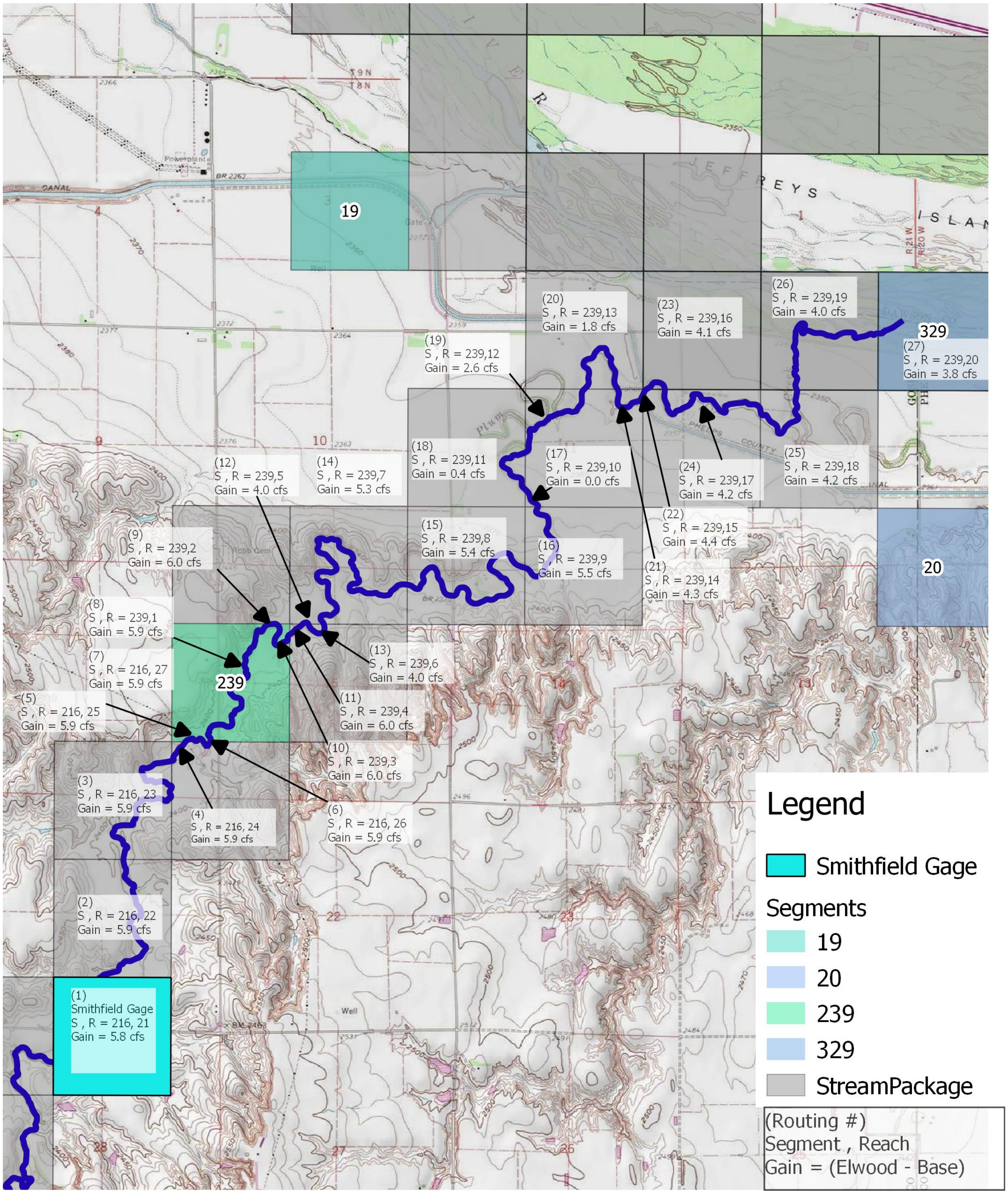

Figure 3. Plum Creek Stream Package – Gains due to Elwood Recharge

The poor functionality of the lower segment of Plum Creek is thought to be related to several factors, including inconsistent streambed conductance values, an irregular routing of the Creek from cell to cell, and the sudden addition of runoff.

Streambed Conductance

The streambed conductance term for each reach of the lower segment is shown in **Table 2**. Comparing reach 1 and 2, 4 and 5, and 6 and 7 shows a change in streambed conductance of an order of magnitude. The streambed conductance term is expressed as:

Streambed Conductance = (K*L*W)/M

Where:
K=hydraulic conductivity of the streambed material
L=length of the stream in the cell
W=the width of the stream
and
M=the streambed thickness.

The physical geometry and streambed material (and by extension the hydraulic conductivity) of Plum Creek remains consistent through this reach. The variations in streambed conductance cannot be explained by changes in stream lengths, as the large values do not necessarily correspond to larger stream lengths depicted in **Figure 3**. The streambed conductance term in the model does not reflect this consistency causing the model to yield poor results in this segment.

Irregular Stream Routing

In addition to the inconsistent streambed conductance, the model routes the lower segment of Plum Creek through multiple model cells, as seen in **Table 2** and **Figure 3**. For example, the model cell in row 187 column 258 contains reaches 1 and 3 and the cell in row 185 column 261 contains reaches 10, 12, and 14. This happens when flow in Plum Creek enters a cell, then leaves the cell only to return back to the cell at a downstream location. The stream package also overlaps reaches when one segment ends and second begins. This irregular routing scheme is a relic of the automated process used to build the streamflow routing (SFR) package in MODFLOW. We are unsure how this routing scheme might affect the accuracy of the model's calculation of stream gains and losses.

Sudden Addition of Runoff

A review of the stream package indicates that the runoff from watershed zone 12 is input into the top of reach 239 (see page 1050 of the full COHYST documentation). This addition of flows results in higher stream stage, and thus the potential for increased losses from the stream to the aquifer. **Figure 4** shows the stream stage in the Plum Creek for the base model run from the Smithfield gage down to segment 239, reach 1. The stream stage in segment 239 differs significantly from the upstream reaches. The sudden addition of runoff does not capture the behavior of the natural system and we suspect it may contribute to instability in the model's predictions of gains and losses through this segment.

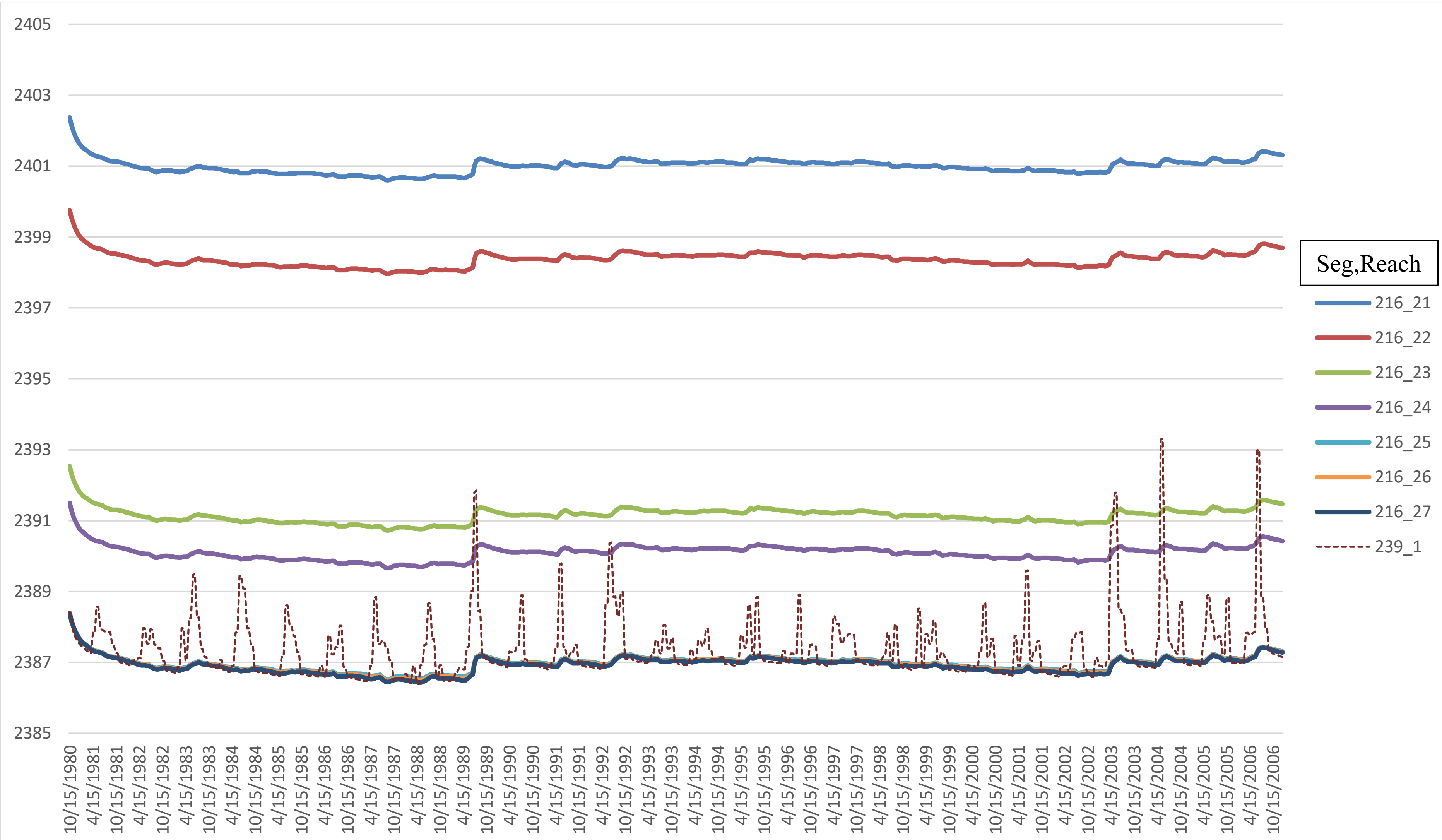

Figure 4. Stream Stage in Plum Creek at various reaches – Base Model.

IV. ACCOUNTING METHODS USED FOR THE ELWOOD ANALYSIS

Based on the model's poor representation of the lower segment of Plum Creek, the EDO concluded this segment of Plum Creek should be excluded from the accounting. To account for returns in Plum Creek from Elwood Reservoir recharge, the EDO used the returns in the upper segment of Plum Creek at the Smithfield gage (segment 216, reach 27). These were added to the returns in the north channel of the Platte River and the south channel of the Platte River above Plum Creek. Returns from Elwood recharge to the Platte River were calculated as the sum of returns in Plum Creek at Smithfield (segment 216, reach 21, 5.8 cfs), returns in the south channel of the Platte River above the confluence with Plum Creek (segment 328, reach 10, 1.1 cfs), and returns in the north channel of the Platte River above the confluence with the south channel (segment 327, reach 15, 0.5 cfs) for a total return to the Platte River of 7.5 cfs. The EDO believes this to be a conservative approach to accounting because it does not include any returns from the lower portion of Plum Creek or the lower portion of the south channel of the Platte below Plum Creek. The EDO chose to exclude these returns as we could not determine a clear method for calculating them from the modeled data.

The accounting approach reflects a concerted effort to match the model results with the observed behavior of the system. The COHYST model was developed as a regional model with the understanding that it could be used to evaluate localized project impacts and that doing so may require small modifications to the regional model. Based on our review of the COHYST model documentation we judged the area around Plum Creek as poorly calibrated. The EDO believes its accounting approach appropriately captures the behavior of the physical system.

V. ALTERNATIVES CONSIDERED

One alternative to the accounting methodology described above would be to attempt to fix the lower segment of Plum Creek in the model. This would likely involve re-routing Plum Creek so it only passed through each model cell once and adjusting the streambed conductance terms throughout the segment to ensure they consistently reflect the physical system. The EDO determined this level of effort was outside of the scope of the Elwood Recharge scoring process. Further, the EDO could not be certain that such changes would necessarily resolve the calibration issues in the Plum Creek area. In the case where calibration issues were resolved, the EDO believes that a revised accounting (accounting for gains at a downriver reach of the Platte River would yield similar results than the accounting process described above.

ATTACHMENT A

PRRIP Use of the COHYST Model in the Elwood Reservoir Groundwater Recharge Analysis