Omaha World-Herald, March 13, 2009

NRDs say study shows water limits not needed on Platte

BY DAVID HENDEE
WORLD-HERALD STAFF WRITER

FREMONT, Neb. — Now it's on the desk of Nebraska's water czar.

Three months and four public hearings after Brian Dunnigan declared that demand for water in the lower Platte River basin was on the verge of outpacing supply, he now has 30 days to affirm his preliminary decision or change his mind.

If Dunnigan doesn't retreat, sweeping restrictions would be imposed on future water use across a third of Nebraska's landscape. The restrictions, proposed by the Nebraska Department of Natural Resources, would affect metropolitan Omaha and Lincoln in the east — where half of all Nebraskans live — and cattle feeders in the Sand Hills in the west.

A crowd of more than 300 farmers, irrigators, well-drillers and others sat in metal folding chairs on the hardwood basketball court at Fremont's City Auditorium for three hours at the final hearing to oppose the potential restrictions.

They brought emotion, but the key testimony designed to sway Dunnigan, who is the department's director, came from a study of the basin's water supply that was financed by nine natural resources districts.

"Please keep in mind that eastern Nebraska is different than western Nebraska," said Stan Staab, general manager of the Lower Elkhorn Natural Resources District in Norfolk.

The state already has imposed irrigation restrictions in much of the drier western half of the state in an attempt to restore stream flows and stop the decline of underground water.

The districts' study concluded that Dunnigan erred in his original determination.

The study, conducted by an Arizona environmental consulting firm, challenged the department's findings on the impact of irrigation wells on the Platte and how it computed the water needs of corn growers.

Urban Nebraskans also voiced concern.

Art Beccard, city engineer in Papillion, said the fast-growing Omaha suburb adds water service to 300 to 500 new users a year. The city pumps water from a well field on the bank of the Platte River south of Papillion.

If Dunnigan's designation holds, any additional water pulled from the basin would have to be offset by cutting use of basin water elsewhere.

Dunnigan did not attend the hearing. He was in Denver at a Republican River arbitration proceeding between Nebraska and Kansas.

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March 12, 2009

VIA HAND DELIVERY

Brian P. Dunnigan, P.E., Director
Nebraska Department of Natural Resources
301 Centennial Mall South, 4th Floor
Lincoln, NE 68509

Re: 2009 Annual Evaluation of Availability of Hydrologically Connected Water Supplies – Lower Platte River Basin

Dear Director Dunnigan:

On December 16, 2008, the Nebraska Department of Natural Resources ("DNR") issued a preliminary determination concluding that the Lower Platte River Basin ("Basin") is fully appropriated. *See 2009 Annual Evaluation of Availability of Hydrologically Connected Water Supplies*, DNR (Dec. 16, 2008) ("2009 Annual Evaluation"). Over the past several weeks, we have communicated and coordinated with you and your staff on behalf of and along with the following Natural Resources Districts ("NRD"): Lower Platte South NRD; Lower Platte North NRD; Upper Elkhorn NRD; Lower Elkhorn NRD; Upper Loup NRD; Lower Loup NRD; Papio-Missouri NRD, Upper Big Blue NRD; and Lower Niobrara NRD (collectively referred to as the "Basin NRDs").

Initially, we express our appreciation for DNR's transparency, professionalism, and partnership in working with the Basin NRDs to ensure that you have the best science available to make the final determination. It is because of this working relationship between DNR and the Basin NRDs that we are able to provide these substantive comments on the preliminary determination.

On behalf of the Basin NRDs, we are submitting comments concerning Chapter 7.0 of the 2009 Annual Evaluation, which constitutes DNR's preliminary determination that the Basin is fully appropriated. These comments consist of the following:

-Attachment A: *Technical Review of the Preliminary Fully Appropriated Determination in the Lower Platte River Basin*, Brown and Caldwell (March 12, 2009) ("B&C Technical Review");

-Attachment B: *Evaluation of Impacts to Days Needed to Meet 65/85 Requirements Under Various Scenarios*, Brown and Caldwell (March 12, 2009) (compare with Table 7-9, 2009 Annual Evaluation at 108);

-Attachment C: *Justification for the Minimal Irrigation Requirements Definition that is Incorporated in the Proposed Rule for Defining a Fully Appropriated Basin*, Dr. Ray Suppala (undated).

We ask that DNR include these materials in the administrative record and consider them in connection with developing the final decision on the availability of hydrologically connected water supplies in the Basin.

1. Summary of Preliminary Determination

The 2009 Annual Evaluation makes the preliminary determination that the Basin is fully appropriated upstream of the confluence with the Missouri River without the initiation of additional uses. According to the report, this determination is based on two factors: (1) "the current level of development will result in lag impacts such that the future water supply will be insufficient for junior surface water appropriations upstream of North Bend to satisfy the 65/85 rule completely;" and (2) "those same junior surface water appropriations are currently receiving less water than was available at the time the appropriations were granted (i.e., they have been eroded)." 2009 Annual Evaluation at 84; *id.* at 113.

2. The Legislature Gave the NRDs a Significant Role in Reviewing DNR's Preliminary Determinations.

Nebraska has faced many natural resources challenges in the past, and will continue to face similar challenges in the future. Our NRDs have a strong history of responding to our natural resources issues with local control and local solutions. Recognizing these abilities, and recognizing the partnership between the NRDs and DNR, the Legislature gave the NRDs a significant role in the fully and over appropriated determination process.

For example, the Legislature instructed the NRDs to "provide relevant data and information in their possession" to DNR for use in the annual determinations. The Legislature also set up a review system following a preliminary determination to assure the final determination is based on the best science. The NRDs, in partnership with DNR, are to play a significant role in this review:

> Within the time period between the dates of the preliminary and final determinations, the department and the affected natural resources districts shall consult with ... water users and stakeholders as deemed appropriate by the department or the natural resources districts.

Neb. Rev. Stat. § 46-714(4). The NRDs take this role very seriously, and appreciate the opportunity to work with DNR on these important issues.

3. Overview of Comments

The majority of these comments relate to the application of the 65/85 rule, which include both scientific and legal components. The Basin NRDs are concerned that the preliminary determination is not based on the best scientific data available and, in some cases, does not comply with the agency's regulations. For these reasons, explained in detail below, the preliminary determination is not legally defensible if adopted in its current form. The Basin NRDs recommend that DNR apply the best science consistent with the agency regulations to reach a final determination. Based upon the current information available to the Basin NRDs, a determination of not fully appropriated is the necessary conclusion utilizing the best science in accordance with the regulations.

4. Background on the 65/85 Rule.

DNR adopted the 65/85 rule at the culmination of the negotiated rule-making process, which included the Basin NRDs as stakeholders. 457 Neb. Admin. Code § 24.001.01A. The purpose of the rule is to assist DNR in evaluating the sufficiency of the hydrologically connected water supplies to meet the "then-current uses of hydrologically connected surface water and ground water." DNR describes the rule as follows:

> In short, the [65/85 rule] states that the surface water supply is deemed to be insufficient if, at current levels of development, the most junior right in the basin ... has been unable to divert sufficient surface water over the last twenty years to provide 85% of the amount of water a corn crop needs (the net corn crop irrigation requirement, or NCCIR) during the irrigation season (May 1 through September 30), or if the most junior irrigation right in a basin ... is unable to divert 65% of the amount of water a corn

> crop needs during the key growing period of July 1 through August 31.

2009 Annual Evaluation at 14.

To apply the rule, DNR must have the following information: (a) the hydrologically connected area; (b) current levels of development; (c) the most junior right in the basin; (d) the NCCIR for the most junior right; (e) the most junior right's ability or inability to divert over the last twenty years; (f) the current hydrologically connected water supply; and (g) the lag effect from existing groundwater pumping in the hydrologically connected area that will deplete the water supply within the next 25 years. If any of these inputs are incorrect, the conclusion will not be accurate.

5. Concerns Relating to the Application of the 65/85 Rule.

(a) The Regulations Limit Consideration of Impacts to Wells Inside the Hyrdologically Connected Area.

DNR's regulations provide that the sufficiency of a basin's water supply to meet demand will be determined based on "the current uses of *hydrologically connected* surface water and ground water." 457 Neb. Admin. Code § 24.001. In particular, the annual evaluation must consider "the impact of the lag effect from existing groundwater pumping *in the hydrologically connected area* that will deplete the water supply within the next 25 years." *Id.* at § 24.002.01A. Similarly, "[t]he projected future impacts from ground water wells to be included shall be the impacts from ground water wells located *in the hydrologically connected area* that will impact the water supply over the next 25 year period." *Id.* at § 24.002.01A.

The term "hydrologically connected area" is used consistently throughout the Nebraska Ground Water Management and Protection Act, Neb. Rev. Stat. § 46-701 to -753, and throughout DNR's regulations. The term is defined as "the area within which pumping of a well for 50 years will deplete the river or a base flow tributary thereof by at least 10% of the amount pumped in that time." 457 Neb. Admin. Code § 24.001.02. This definition establishes what is now commonly referred to at the "10/50 area."

The 2009 Annual Evaluation for the Basin included impacts from all wells in the Basin – not just those within the 10/50 area. This approach does not appear to be defensible under DNR's regulations, and should be amended prior to issuance of the final determination.

(b) The Regulations Identify "The Most Junior Appropriator" as the Trigger for the 65/85 Rule.

The 65/85 rule requires an evaluation of whether "the most junior irrigation right" will be able to meet the 65/85 rule. 457 Neb. Admin. Code § 24.001.01A. That section also refers to "the most junior surface water appropriator" and "the most junior surface water appropriation" as the right against which the 65/85 rule should be applied.

The 2009 Annual Evaluation for the Basin did not evaluate the 65/85 rule against "the most junior appropriator." Instead, it used "a junior surface water appropriation" above the North Bend gage. 2009 Annual Evaluation at 95. The right selected has a net corn crop irrigation requirement, or NCCIR, of 27.9 days annually to meet the 65% requirement from July to August. *See* Attachment B. In contrast, the NCCIR for the most junior appropriator in the Basin equates to 18.06 days to meeting the 65% requirement. *See* Attachment B and B&C Technical Review at 1-2.

The use of *a* junior – rather than the *most* junior – does not appear to be defensible under DNR's regulations, and should be amended prior to issuance of the final determination.

(c) Consideration of 10% Downtime Is Inconsistent With Regulations.

The 65/85 rule is based on the ability of the surface water user to divert enough water to meet the NCCIR. 457 Neb. Admin. Code § 24.001.01A. This rule, however, does not include an adjustment for downtime. The concept of downtime is that, although water is available for diversion, the user cannot irrigate because of some mechanical failure or other cause.

DNR added a 10% downtime assumption to its application of the 65/85 rule for the Basin. This assumption is inconsistent with the regulations, and is irrelevant to the evaluation of whether water is available for diversion. The evaluation should focus on whether water is available – not whether the appropriator's system is able to divert otherwise available water. Stated differently, a basin should not be declared fully appropriated based on mechanical failures. This preliminary determination was very sensitive to the downtime assumption and, all things being equal, the Basin would not be fully appropriated without that assumption. B&C Technical Review at 1-3.

6. Regulatory Concerns Relating to the Erosion Rule.

DNR adopted the erosion rule in 2006 through the negotiated rule-making process. That rule is intended to prevent a basin from becoming fully appropriated through the issuance of a new surface water right that could not meet the 65/85 rule when it was granted. As such, the rule's application is limited to those scenarios where, "at the time of the priority date of the most junior appropriation, the surface water appropriation could not have diverted surface water a sufficient number of days on average for the previous 20 years to satisfy the requirements of 001.01A," which is the 65/85 rule. 457 Neb. Admin. Code § 24.001.01C.

The application of the erosion rule in the 2009 annual evaluation is confusing. DNR applies the 65/85 rule in Section 7.7.1, and ultimately concludes that the 65/85 rule cannot be met based on future impacts from current uses. 2009 Annual Evaluation at 105. In the following section, then, DNR applies the erosion rule. 2009 Annual Evaluation at 108. Table 7-11 demonstrates that, at the time that the junior surface water appropriation DNR evaluated was granted, flows were sufficient to meet the 65/85 rule. Under the erosion rule, that is the end of the analysis.

Nevertheless, the report goes on to conclude that "the junior irrigation rights have been eroded." This conclusion is then used as a basis for the preliminary determination of fully appropriated. 2009 Annual Evaluation at 113 ("The designation is based on two factors. ... The second factor is that those same junior surface water appropriations are currently receiving less water than was available at the time the appropriations were granted (i.e., they have been eroded)"). Read without the rule, this conclusion appears to find the Basin fully appropriated through application of both the 65/85 and erosion rules as independent factors. But they are not independent tests; either the erosion rule or the 65/85 rule applies.

DNR should rework this analysis in future annual evaluations to avoid this confusion. The first step should be whether the 65/85 rule is satisfied. If it is not, the second step is to determine whether the 65/85 rule could be satisfied when the right was granted. If it could, then that is the end of the matter – the 65/85 rule applies and whether the appropriations have been eroded does not matter. If the 65/85 rule could not be satisfied when the right was granted, *then* the erosion rule applies and whether the right has been eroded is relevant.

7. The Annual Evaluations Must Use the Best Science.

DNR must "rely on the best scientific data, information, and methodologies readily available to ensure that the conclusions and results contained in the [annual] report are reliable." As discussed in the attached technical review by Brown and Caldwell, significant concerns exist regarding whether the preliminary determination for the Lower Platte River Basin meets this requirement.

One primary concern relates to the calculation of lag impacts and baseflow depletions from the Elkhorn Loup Model ("ELM"). Brown & Caldwell notes the importance of maintaining the distinction between the basic tool, the ELM, and simulations and runs made from the basic tool. This concern relates to the simulation DNR used, not to the tool. The tool remains the best science available to calculate the 10/50 area and streamflow depletions, but the tool must be used properly.

DNR relied on USGS's assumptions and methodology to calculate future streamflow depletions from current uses. USGS used 3.03 million acre-feet of pumping within the ELM area as the "current use" from which to predict future depletions. This assumption far exceeds the level of pumping needed for the 2.3 million acres currently irrigated in the ELM area.

Figure 16 of the ELM Phase 1 report depicts the estimated historic annual groundwater pumping for crop irrigation in the Elkhorn and Loup River Basins from 1940 to 2005. The highest estimated pumping in those 65 years occurred in 2002, at about 1.8 million acre-feet pumped from the entire ELM area. The estimates in Figure 16 exceed 1.5 million acre-feet only five times over that entire history. This information led DNR and the NRDs to make additional inquiries of USGS to explain its assumptions.

After reviewing information from USGS, the pumping assumption results from an apparent error in calculating the average effective precipitation. The average effective precipitation is important because it is used to calculate how much pumping is required to meet the weighted average crop water requirement of 25.1 inches for the ELM area. In other words, by subtracting the average effective precipitation from 25.1, one can calculate how many inches of pumping is needed to meet the weighted average crop requirement. USGS calculated the average effective precipitation for the ELM area to be 9.39 inches, causing a dramatic over-estimation of the required pumping. In reality, the ELM report data demonstrates an average effective precipitation of 19.14 inches from 1940 to 2005. Subtracting this average from 25.1 inches equals 5.96 inches of groundwater that would need to be pumped. Spread across the 2.3 million irrigated acres in the ELM area, this totals 1.15 million acre feet of pumping annually, compared with the 3.03 million acre feet of pumping used in the USGS simulation. B&C Technical Review at 3-1 to 3-4.

DNR adopted USGS's assumption of 3.03 million acre feet of pumping to calculate the streamflow depletions from the ELM area in the 2009 Annual Evaluation. This level of pumping in the ELM area does not reflect pumping from current conditions or current levels of development.

8. Conclusion.

The preliminary determination that the Lower Platte River Basin is fully appropriated is inconsistent with DNR's regulations and is not supported by the best scientific data, information, and methodologies readily available. The Basin NRDs appreciate the opportunity to provide these comments, and will continue working with DNR to assure the final determination is based on the best available science and is consistent with the regulations.

Sincerely,

FENNEMORE CRAIG, P.C.

Jaron Bromm

JABR
Enclosures

ATTACHMENT A

TECHNICAL REVIEW OF THE PRELIMINARY FULLY APPROPRIATED DETERMINATION IN THE LOWER PLATTE RIVER BASIN

Prepared for

Fennemore Craig, P.C.
Denver, Colorado

March 12, 2009

TECHNICAL REVIEW OF THE PRELIMINARY FULLY APPROPRIATED DETERMINATION IN THE LOWER PLATTE RIVER BASIN

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afd	acre-feet per day
afy	acre-feet per year
cfs	cubic feet per second
CALMIT	Center for Advanced Land Management Information Technologies
ELM	Elkhorn Loup Model
N.A.C.	Nebraska Administrative Code
NCCIR	Net Corn Crop Irrigation Requirements
NDNR	Nebraska Department of Natural Resources
NGWI	No Groundwater Irrigation
NRD	Natural Resources District
USGS	United States Geological Survey

1. REGULATORY

Brown and Caldwell reviewed the Nebraska Department of Natural Resources (NDNR) Rules for Surface Water (Nebraska Administrative Code [N.A.C.] Title 457, Chapter 24) and compared the regulations contained in these rules with the calculation procedures that were carried out for the 2009 Annual Evaluation of Availability of Hydrologically Connected Water Supplies ("2009 Annual Evaluation") (NDNR, 2008). This review was limited to NDNR's preliminary determination for the Lower Platte River Basin. Four primary issues were identified in the regulatory aspect of this review, and are discussed below.

This document sets forth the results of Brown and Caldwell's independent review of the Nebraska Department of Natural Resources 2009 Annual Evaluation of the Availability of Hydrologically Connected Water Supplies. During the course of this work, methods and models used by the USGS and used by the State of Nebraska were evaluated. Brown and Caldwell's review was based on compilation and interpretation of pre-existing information from third parties or the client, which information has not been independently verified by Brown and Caldwell unless explicitly stated herein.

1.1 Future Depletions from Groundwater Pumping in Hydrologically Connected Areas

It is clearly stated in 457 N.A.C. 24 that future streamflow depletions from current levels of groundwater development will be estimated for wells within hydrologically connected areas. References to estimating depletions for wells within hydrologically connected areas can be found in the first sentence of Paragraph 001, in the first sentence of Paragraph 001.01A, and in the last sentence of Paragraph 001.01A.

The geographic extent of hydrologically connected areas is defined in Paragraph 001.02 as the area within which a well pumped for 50 years will deplete the baseflow of a river or tributary by 10 percent of the amount pumped over that time, also referred to as the 10/50 area.

The 2009 Annual Evaluation included estimates of future lagged depletions from all current irrigation wells in the basin rather than only those wells within the 10/50 area. This resulted in estimating more future lagged depletions than what is prescribed in 457 N.A.C. 24. Future lagged depletions resulting from current well development that were estimated by the Elkhorn Loup Model (ELM) model and by the Jenkins method should have only included impacts from those wells located within the 10/50 area.

1.2 Most Junior Appropriator

It is clearly stated in 457 N.A.C. 24 that the 65/85 and erosion rules will be evaluated against the most junior irrigation right in the basin (for an explanation of the 65/85 and erosion rules, see NDNR, 2008). References to the most junior irrigation right are made in the first, fourth, and fifth sentence of Paragraph 001.01A, Paragraph 001.01B, and the first sentence of Paragraph 001.01C.

The 2009 Annual Evaluation used a junior irrigation right for its evaluation of the 65/85 and erosion rules that was not the most junior irrigation right. The junior irrigation right that was used (A-17900) is an active irrigation right that is junior to the priority date of the instream flow rights in the Platte River (November 30, 1993), and has the highest net corn crop irrigation requirement (NCCIR) of the junior irrigation rights in the Loup and Elkhorn Basins. This irrigation right has a priority date of August 3, 2000 and is used to irrigate approximately 32 acres in southeast Custer County (Figure 1). The NCCIR corresponding to this location is 10.52 inches. In the Loup Basin, there are 122 active irrigation rights junior to November 30, 1993. In the Elkhorn Basin, there are 65 active irrigation rights junior to November 30, 1993.

The most junior irrigation right in both the Loup and Elkhorn Basins is number A-18534 (Figure 1). This irrigation right has an appropriation date of September 4, 2007, and irrigates 132.8 acres in southwest Washington County. The location of this irrigation right corresponds to an NCCIR of approximately 6.8 inches. If this NCCIR were adopted, the number of days necessary to meet the 65/85 rule would be 18.06 and 23.62, respectively.

The most junior irrigation right in the Loup Basin is number A-18422 (Figure 1). It irrigates 65.1 acres in southeast Sherman County and has a priority date of September 15, 2006. The NCCIR corresponding to the location of this irrigation right is approximately 9.6 inches per year. If this value were adopted, the number of days necessary to meet the 65/85 rule would be 25.49 and 33.34, respectively.

1.3 Assumption of 80 Percent Efficiency

In the 2009 Annual Evaluation, the NCCIR for the junior water right is multiplied by 65 percent and 85 percent to calculate the number of days necessary to meet the July-August and seasonal requirements, respectively. These numbers are then divided by 0.8 to account for an assumed irrigation efficiency of 80 percent. The 2009 Annual Evaluation considers the resulting numbers to be gross irrigation amounts that are necessary to meet July-August and seasonal irrigation requirements. The NDNR adopted this calculation procedure based on a memorandum written by Dr. Ray Supalla (undated). Dr. Supalla's memorandum was written to document and to justify the 65/85 rule and its application to assessments of full appropriation.

Dr. Supalla's memorandum refers to the 65 percent and 85 percent as amounts of gross irrigation as a proportion of the NCCIR that is needed to meet July-August and seasonal irrigation requirements, respectively. It appears that NDNR misinterpreted the 65 percent and 85 percent as net irrigation requirements rather than gross irrigation requirements, which is why an adjustment for 80 percent irrigation efficiency was included in their calculation procedure. Dr. Supalla confirmed that the irrigation efficiency of 80 percent was included in the 65/85 multipliers (Supalla, personal communication, 2009). Because the 65 percent and 85 percent multipliers already incorporate an assumed irrigation efficiency of 80 percent, the additional irrigation efficiency adjustment over-estimates the number of days in the 65/85 calculation, adding 6 and 7 days, respectively.

1.4 Assumption of 10 Percent Downtime

In the 2009 Annual Evaluation, it is assumed that an irrigation system will be shut down for approximately 10 percent of the time when there is adequate streamflow to divert. The NDNR adopted the 10-percent downtime factor based on the memorandum written by Dr. Ray Supalla (undated).

The memo does not describe considerations that resulted in the 10-percent downtime assumption, although it is a rule of thumb that is used in irrigation system design. There are more detailed ways to evaluate or estimate downtime. Considerations of time necessary for repair and maintenance, and for load control, frequently factor in to more specific estimates of downtime. If irrigators are on load control or have extensive problems with system clogging and other frequent maintenance issues, then the 10-percent downtime assumption is probably realistic. However, Brown and Caldwell understands from conversations with Natural Resources Districts' (NRD's) staff that it is unlikely that there are many junior surface irrigators that are on load control. This makes sense because irrigators who are frequently shut down due to surface water administration will not likely subject themselves to additional shutdowns from load control. In addition, it seems probable that irrigators who are subject to shutdowns from surface water administration will save regular repair and maintenance activities for periods when they cannot irrigate because of a senior call.

The 2009 Annual Evaluation for the Lower Platte River Basin is sensitive to the downtime assumption; it adds 3 and 4 days, respectively, to the 65/85 calculation. Given the sensitivity of the 2009 Annual Evaluation to the downtime assumption, it should be reviewed with respect to the general irrigation practices in the Loup and Elkhorn Basins.

Findings:

- The 2009 Annual Evaluation considered impacts for wells outside of the 10/50 area.
- The 2009 Annual Evaluation assessed the 65/85 rule against an irrigator that is not the most junior irrigator in the basin.
- The 2009 Annual Evaluation used a calculation procedure that effectively adjusts for irrigation efficiency twice, and over-estimates the number of days required for the 65/85 rule.
- The 2009 Annual Evaluation assumes a 10-percent downtime assumption in the calculation of the number of days required to meet the 65/85 rule.

2. EVALUATION OF THE TECHNICAL TOOLS

2.1 Jenkins Method

2.1.1 Best Available Science

The NDNR relies on the Jenkins (1968) method as the best approach to calculate stream depletion for the purposes of determining the availability of hydrologically connected water supplies in regions where no numerical groundwater flow model exists. It is argued that the Jenkins method is especially useful when key hydrological data are unknown. Yet, this methodology is outdated, because it is based on overly simplistic assumptions leading to over-estimates of streamflow depletions. More recent and commonly applied analytical solutions provide much more realistic estimates. Thus, the Jenkins method for determining stream depletion factors is no longer the best available science.

The three main simplifying assumptions of the Jenkins method that consistently cause the overestimation of stream depletion at the basin scale are: (1) there is no groundwater recharge; (2) there is no constraint on water interchanges between groundwater and surface water due to diminished vertical hydraulic conductivity (conductance) of the streambed; and (3) the streambed fully penetrates the aquifer system. Newer analytical and semi-analytic methods require fewer assumptions.

The Jenkins method is essentially an overly conservative "end-member" solution for the quantification of streamflow depletion. It will always produce a higher estimate of streamflow depletion due to pumping relative to the more advanced analytical solutions developed by Hunt (1999) and Zlotnick (2004).

2.1.2 Other Sources of Groundwater Recharge

The Jenkins method assumes that the only source of groundwater to satisfy pumping within a basin is streamflow. As time increases, this solution assumes that stream depletions will eventually satisfy 100 percent of all groundwater pumping. However, both areal recharge and evapotranspiration also comprise portions of a groundwater basin water budget and are known to be additional sources of groundwater that can be captured by pumping. If these other components of the water budget are not negligible relative to the net loss of streamflow, then results from the Jenkins solution overestimate streamflow depletion (Chen and Shu, 2002). The magnitude of the errors in both the estimated extents of the 10/50 demarcations as well as the 25-year quantified volumes of future stream depletions can be significant when there is non-negligible recharge. This is the situation in the Lower Platte River Basin, as documented by the United States Geological Survey (USGS) in their description of the ELM water budget (Peterson et al., 2008).

One of the important features of groundwater systems in northeastern Nebraska is the ability for water-level recovery in years with high rainfall and reduced pumping. Such complexity is not accommodated by the Jenkins method. In other words, in a basin where groundwater is in connection with the surface water system, years with higher precipitation can restore groundwater levels that may have been reduced by drought and/or groundwater pumping back to pre-pumping conditions (Chen and Shu, 2002). This "restoration" of groundwater levels could lead to baseflow levels comparable to pre-depletion levels. The lack of consideration of the cyclicity and impacts of "wet" years or seasons will also cause the significant overestimation of the magnitude of streamflow depletion over time periods as large as 25 years. Powerful numerical models like MODFLOW can include (1) all sources of groundwater recharge, and (2) the natural variability in precipitation and recharge. In the absence of a suitable numerical model to calculate streamflow depletions, the best available science includes the more advanced analytical solutions that do not make the oversimplifying assumptions inherent in the Jenkins method.

2.1.3 Advanced Analytical Methods

The Jenkins method assumes that the stream unit is in full connection with the underlying aquifer system and fully penetrates it. It ignores the possibility of disconnection or limited connection between the stream and underlying aquifer system, even though this condition is present to some degree in practically all river systems. The use and application of the analytical solutions provided by Hunt (1999) and Zlotnik (2004) address these shortcomings of the Jenkins method through their inclusion of streambed conductivity values and consideration of the partial penetration of streams relative to the depth and thickness of typical well pumping intervals. Although these analytical solutions also neglect groundwater recharge and capture, they can be readily used in lieu of the overly simplistic Jenkins method to provide more realistic and accurate estimates of hydrologically connected areas and future streamflow depletion.

Analyses and graphs presented by Zlotnik and Tartakovsky (2005), the USGS (Reeves, 2008), and Butler et al., (1999) show that even the simplistic consideration of streambed conductivity and partial stream penetration, which are included in all recently derived analytical solutions, will always result in lower estimates of streamflow depletion as compared to the Jenkins method. In order to remove this overly conservative, mathematical bias with respect to streamflow depletion and be more representative of realistic stream and groundwater conditions, it is proposed that at a minimum the Hunt solution (Hunt, 1999) be used instead of the Jenkins method.

The data requirements and mathematical application of the Hunt solution are not time- or cost-prohibitive, and streambed conductivity estimates can readily be inferred from available field data, literature values, analogous systems, or commonly accepted horizontal to vertical conductivity ratios. Estimates of streambed conductance from work recently performed in the Blue River Basin and along Platte River would provide a data source to begin this process (Chen, personal communication, 2009). Even the inclusion of conservative estimates of streambed conductivity values would necessarily reduce the mathematical overestimation of streamflow depletion estimates from the use of the outdated Jenkins method.

2.2 Elkhorn-Loup Model

The evaluation of water supplies in the Loup and Elkhorn Basins was based on results from the Phase I ELM (Peterson et al., 2008). Modeling a region the size of the Loup and Elkhorn Basins is a formidable challenge given the complexity of the physical setting and the groundwater/surface water interactions. An appropriate scientific evaluation of the water resources within these basins requires a modeling tool with the power and flexibility to handle these complexities. This capability is provided by the numerical, finite difference, MODFLOW modeling package. In this respect then, the Phase I ELM represents an important step in evaluating the hydrologic response to pumping.

The ELM is being developed over a period of years through two additional phases of work that are designed to provide refinements to the model and to incorporate new hydrologic data that will be collected in the two basins. The present review of the Phase I ELM has identified a number of opportunities for improving the ELM in subsequent phases.

2.2.1 Calibration

To provide confidence in future predictions, the ELM must demonstrate the capability to predict the historical behavior of groundwater and surface water systems. The model in its present form has made progress in this respect. However, as shown in Figure 2, the simulated groundwater levels in the ELM do not satisfactorily capture the magnitudes of groundwater levels or temporal patterns of change. In addition, calibrating to water level change versus water level magnitude is not appropriate for the stated purpose of simulating baseflow, as it can lead to unacceptable errors in simulated groundwater levels. Errors in simulated groundwater levels will lead to errors in predicted inflows and outflows from the streams.

Clearly, a better calibration of groundwater conditions is required to be confident that the ELM is a valid representation of the actual hydrogeologic setting. This issue of calibration appears to be an important aspect of work planned for the follow-on phases of the ELM project.

2.2.2 Conceptual Model and Estimates of Baseflow

Mathematical models like ELM are built around what is known as a conceptual model, which provides a simplified understanding of how the hydrologic system works. For a model like ELM to be successful, the conceptual model needs to capture key details about the hydrologic system. One area where refinements to the ELM conceptual model are required relates to the present treatment of baseflow. The Phase I ELM uses ranges of baseflows (Figure 3) as part of the calibration exercise. Peterson et al. (2008) theorized that this single range of baseflows for various rivers can be used in the calibration of the pre-1940 simulation and the 1940-2005 simulations. Thus, the ELM model is calibrated with the implicit assumption that baseflows in 1940 and 2005 should be similar. This assumption is valid for upstream reaches rising in the sand hills but likely invalid for downstream reaches. To provide baseflows in 2005 that are comparable to those of 1940 required the addition of “additional recharge” that was almost identical to the irrigation pumpage. Beyond meeting the assumption of similar baseflow, there is little justification provided for the magnitude of the additional recharge. A revised conceptual model should treat variable baseflow in a more realistic manner.

The analysis of the impacts of pumping on baseflow from the ELM, shown on Figures 4 and 5, must be viewed as extremely preliminary. The issue is that the 1940-2005 simulation is being calibrated to provide some expected quantity of baseflow: the ELM inputs are being adjusted to finally produce a value of baseflow in the 1940-2005 simulation that fits the modeler’s conceptualization. Having obtained this final value of baseflow, it is not appropriate then to analyze the predictive baseflow estimates from the model as though they were independent variables.

Figure 6 displays baseflow from 1940 to 2033 for the case with no groundwater irrigation (NGWI). Note particularly the baseflow from 1940 to 2005, which increased by approximately 250,000 acre-feet per year (afy) over this period. This almost linear increase in baseflow appears to be an artifact of the model design rather than actual conditions in the natural system. Considering that precipitation has no statistically significant trend from 1940-2005, recharge should behave similarly. With no groundwater irrigation pumping, there is no reason to expect that the ELM should simulate an increase in baseflow of this magnitude.

The scope of the Phase I ELM study apparently precluded a detailed analysis of baseflow trends (Peterson et al., 2008, pg. 17). It will be essential in future phases of the ELM to look carefully and specifically at baseflow behavior both seasonally and interannually. The baseflow behavior of the streams in response to complex patterns of precipitation and pumping provides key data available to constrain the choice of parameter values during calibration. The simplified treatment of baseflow conditions in the Phase I ELM translates specifically into uncertainty with respect to the regulatory outcome of the predictive simulations. Clearly, a critical purpose of the modeling must be to understand how much water is flowing in the rivers under various conditions of recharge and pumping. With the present simplified conceptualization of baseflow behavior, estimates of baseflow, as well as baseflow depletion, are therefore highly speculative in this Phase I of the ELM project.

2.2.3 The Best Tool Available

The regulations emphasize the importance of employing the best science available to make decisions about the management of water resources in Nebraska. The difficulty in analyzing hydrologic systems of the size and complexity represented by the ELM cannot be overemphasized. By its very nature, numerical modeling is an iterative process moving from conceptualization, simulation, evaluation, to new data collection and back again (Domenico and Schwartz, 1998).

The ELM is a clear improvement over the Jenkins method for delineating the 10/50 area and calculating future streamflow depletions. These improvements are based on the fact that the ELM considers (1) streambed conductance, (2) other sources of recharge, (3) complex basin boundaries, and (4) fluctuations in recharge and pumping over time. Improvements planned in Phases II and III will refine the ELM and improve its value to the NDNR in performing their yearly assessments of hydrologically connected water supplies. In the interim, the ELM is the best available scientific tool for the Annual Evaluation, relative to any simplified analytical solutions.

Findings:

- The Hunt solution overcomes one of the major limitations of the Jenkins method and is readily available. It is a better scientific tool than the Jenkins method for the area outside of the ELM region.
- Numerical groundwater flow models are the best available science for calculating the 10/50 area and baseflow depletions. NDNR's decision to use the ELM is the correct selection of the best available tool.
- Improvements to the ELM model construction and calibration, as well as the refinements of the conceptual model and estimates of the various water budget components, will provide greater accuracy and reliability in future estimates of streamflow depletion.

3. LAG IMPACTS AND BASEFLOW DEPLETION – ELKHORN LOUP MODEL

This section addresses the assumptions and approach used by the NDNR to calculate 25-year lag impacts, or baseflow depletions, with the ELM. This section differs from the evaluation of the ELM as a tool (Section 2.2), as it is focused on the use of that tool to predict baseflow depletion in the future. In this discussion, the distinction between the numerical model itself (referred to as the ELM) and simulations that are run with this model (referred to as simulations, scenarios, or model runs) is important. Multiple scenarios were run with the ELM, incorporating a number of different timelines and assumptions about inputs.

The ELM was developed by the USGS and was completed in 2008 (Peterson et al., 2008). The USGS version of the model was calibrated through 2005. For purposes of the appropriation determination analysis, the ELM was updated by the NDNR to continue through 2006 and 2007 before transitioning to a predictive timeline beginning in 2008. In this update, the NDNR added 2006 and 2007 pumping and recharge estimates based on actual precipitation measurements. The predictive simulations to support the analysis of baseflow depletion begin in 2008 and end in 2033, accounting for 25 years of future conditions. (Note: the predictive simulation actually ended in 2047, but output from 2033 was used in the course of the 2009 Annual Evaluation.)

The approach used to calculate future baseflow depletion was to run the model with groundwater irrigation (Base Simulation) and without groundwater irrigation (NGWI Simulation), and calculate depletion by subtracting the respective baseflows. The NGWI Simulations are therefore the standard of comparison for baseflow depletion. The timeline for the NDNR simulations are shown in Table 3-1.

Table 3-1. Time Periods for the NDNR Simulations with the Elkhorn Loup Model

Simulation Period	Base Simulation	NGWI Simulation
1940 to 2007	Base thru Present Day	NGWI thru Present Day
2008 to 2047*	Base Predictive	NGWI Predictive

NDNR = Nebraska Department of Natural Resources
NGWI = No Groundwater Irrigation
**Output for the period from 2008 to 2033 was used for the 2009 Annual Evaluation.*

Input and output from model simulations performed by both the USGS and NDNR were examined during the course of this technical review. Two major concerns were identified with respect to (1) the pumping/recharge assumptions in the predictive simulations, and (2) the method of calculating the 25-year lag impacts by comparison with the NGWI simulation.

3.1 Pumping/Recharge Assumptions in the 25-Year Predictive Simulations

Large water budget changes occur in the Base Simulation runs between 2007 and 2008. This time period represents the transition from present-day conditions to predictive conditions. A summary of the MODFLOW-generated water budgets for the NDNR simulations that were used for the appropriation determination are provided as Appendix A. Comparing the cumulative budgets in Table A-1 for the Base Simulations (1940-2007 versus 2008-2047), the overall water budget drops from 5.1 to 4.8 million acre-feet because a net recharge approach was used to account for pumping. However, the net recharge for the predictive simulation time period was inconsistent with net recharge for the period from 1940 through 2007.

After review of the pumping and recharge inputs that were used to calculate the net values found in the 2008-2047 water budget, it was found that a total of 3.03 million acre-feet of groundwater pumping was assumed every year for all years in the predictive Base Simulation, whereas recharge inputs totaled 4.70 million afy. This assumed future rate of pumping is extremely high, particularly when compared with pumping assumptions for prior years, as shown on Figure 7. The highest rate of pumping in the historic period was approximately 1.8 million afy.

The method of calculating pumping for the predictive simulation was discussed with the USGS and NDNR. The future pumping was estimated based on 2005 irrigated acreage (Center for Advanced Land Management Information Technologies [CALMIT], 2007), the average effective precipitation for the growing season, and net crop irrigation requirements. Estimated 2005 acreage for each crop and the net crop water requirements are shown in Table 3-2. Groundwater pumping was calculated to be the difference between the average effective precipitation for the growing season and the crop requirements. A similar approach was reportedly used for groundwater pumping assumptions for 1940 through 2007.

Table 3-2. Estimated 2005 Acreage in the ELM Region and Crop Water Requirements Used in Calculating Pumping for Predictive Simulations

Crop	2005 Crop Acreage in the ELM Region	Percent of Total Acreage	Crop Water Requirement (Inches)
Corn	1,468,941	63.4%	25.5
Soybeans	633,948	27.4%	22.0
Sorghum	3,775	0.2%	20.5
Small grains	12,770	0.5%	17.0
Dry Edible beans	6,442	0.3%	15.5
Potatoes	762	0.0%	23.2
Alfalfa Hay	188,319	8.1%	33.5
Sunflower	1,272	0.1%	17.0
TOTAL	**2,316,230**	**100.0%**	**25.1***

**Weighted Average*

ELM = Elkhorn Loup Model

Total irrigated acreage from the CALMIT data was estimated to be 2.3 million acres (Peterson et al., 2008). Applying the irrigation pumping in the predictive simulation to this acreage results in an average of 15.7 inches of water. As the most prevalent crop within the model domain is corn, the 15.7 inches was compared to the NCCIR values developed using the CROPSIM model (Martin, 2005). The NCCIR values within the ELM region range from approximately 13.5 inches in the west down to 8 inches in the east (Figure 8), and are based on daily calculations of the soil water balance for the growing season, using the period from 1950 through 2004. A comparison of the ELM assumptions versus these NCCIR values in calculating future groundwater pumping is presented in Table 3-3.

Table 3-3. Comparison of the ELM Assumptions for Predictive Pumping versus Pumping Calculated Based on a Range of NCCIR

Source	Inches per Acre	Acres	Groundwater Pumping (afy)
ELM Assumption	15.7	2,316,230	3,030,401
NCCIR Low Value	8.0	2,316,230	1,544,153
NCCIR High Value	13.5	2,316,230	2,605,759

afy = acre-feet per year
ELM = Elkhorn Loup Model
NCCIR = Net Corn Crop Irrigation Requirement

The comparison in Table 3-3 presents a range of values for total groundwater pumping for the predictive streamflow depletion simulations, making a simplifying assumption that all crops are corn. These calculations do not account for the location of the irrigated lands; however, the CALMIT land use pattern shows that the distribution of irrigated lands in the ELM region are concentrated in the east, coinciding with the lower values of NCCIR.

The level of pumping assumed in the predictive simulation was estimated as a long-term average, which suggests that much greater levels of pumping could be expected immediately in the future. The maximum possible groundwater pumping would be approximately 4.85 million afy, corresponding to zero rainfall and total crop water requirements satisfied by groundwater. The estimate of 3.03 million afy is much larger than an average of the range of possible groundwater pumping scenarios, and appears to assume very dry conditions for all future years.

Spreadsheets, calculations, and numbers used in developing the pumping assumptions for the future predictive simulation were requested from and provided by the USGS. Figure 9 presents effective precipitation and groundwater-irrigated acreages assumed for the period from 1940 through 2005. The ramp-up in the number of acres under irrigation is evident on the top graph; the bottom graph normalizes the effective precipitation to depict the number of inches of effective precipitation by acre. The average effective precipitation for this historic period is 19.14 inches (note: precipitation values capped at 25.1 inches). Subtracting this average from the weighted crop requirement of 25.1 inches (Table 3-2) equals 5.96 inches of groundwater that would have to be pumped.

Figure 10 presents the effective precipitation in inches per year from the ELM (top graph), and the amount of groundwater in inches per year that would have to be pumped (bottom graph) to satisfy a net crop requirement of 25.1 inches for each year. The average of this historic groundwater demand is 5.96 inches (note: average calculation assumed zero groundwater pumping in years of precipitation higher than 25.1 inches). Also shown on this graph is the 15.7 inches that was used in the ELM for 25 years in the future, which is almost 10 inches higher than the average for the historic period.

The USGS provided the steps they took to calculate and estimate future groundwater pumping that resulted in 15.7 inches of demand. Instead of using the normalized groundwater demand in inches of water, the annual *volume* of effective precipitation that fell on the irrigated acreage was averaged from 1940 through 2005 and then applied to the present-day acreage. The effect of calculating an average based on the volume of effective precipitation can be illustrated using 1940 as an example: 132,038 acres were irrigated in 1940 using 123,366 acre-feet of groundwater. Applying 123,366 acre-feet to 2,316,230 acres currently under development results in less than 1 inch of water provided by precipitation, the rest would have to be pumped. This essentially was the calculation made for every year from 1940 through 2005. Because the volume of effective precipitation is highly dependent upon the number of acres, the calculation was skewed downward by the early time period with small numbers of acreage.

This mistake in calculating an average effective precipitation led to the over-estimate of future pumping. Using the annual average of 5.96 inches for the historic period and the 2005 irrigated acreage (2,316,230 acres), groundwater pumping for future simulations would be 1,150,394 afy.

An alternative approach to estimating future groundwater pumping would be using the NCCIR contours developed by Martin (2005). The daily soil water balance model developed to produce the NCCIR contours provides a solid basis for future predictions of groundwater demand during the growing season. Moreover, the NCCIR is the standard used for other elements of the Annual Evaluations, thus there is a good precedent for its use in the ELM simulations for the Elkhorn and Loup Basins as well.

Findings:

- Although the ELM is the best tool available, its use in a predictive sense requires a clear understanding of: (1) the limitations of the model in its preliminary state and (2) all assumptions regarding pumping and recharge that are used for the predictive simulations.
- An error was made in the methodology to calculate average groundwater pumping for the predictive simulations used in the 2009 Annual Evaluation. This error resulted in over-estimating groundwater pumping by a factor of three.

3.2 Calculating Lag Impacts Using the NGWI Simulation

The approach used to calculate lag impacts, or future streamflow depletions for 25 years, involved (1) using the ELM to simulate conditions both with groundwater irrigation (Base Simulation) and without groundwater irrigation (NGWI Simulation), and (2) calculating depletions by subtracting baseflows from each respective simulation (Table 3-1). The NGWI Simulations are therefore the standard of comparison for baseflow depletion.

In the upper reaches of the basins, within the sand hills, streamflow and by extension baseflow, is relatively consistent, varying little over time. Downstream of the sand hills, more variability is seen in stream hydrographs, reflecting the close relationship between baseflow and precipitation. Thus, one would expect alternating highs and lows in baseflow that mimic to some extent the precipitation patterns. One would not expect the system to reflect a steady increase in baseflow through time as that pattern would indicate a potential issue related to the magnitude of estimated recharge in the model input.

Figure 6 depicts the trends in baseflow in the NGWI Simulation from 1940 through 2033. Large increases in baseflow are observed from 1940 through 2004. Between 2004 and 2005, model assumptions and/or inputs change, and baseflow no longer increases at the previous rate although it does continue to rise. The lower graph in Figure 6 highlights the predictive simulation period in the NGWI Simulation, and shows the low but steadily increasing rate of baseflow from 2008 through 2033.

Because the NGWI Simulation is used as the point of comparison or “yardstick” to measure the impacts of irrigation on baseflow, a continuous rate of rise in a simulation that does not include pumping and recharge for irrigation is problematic. For the predictive period from 2008 to 2033, the increased baseflow amounts to 30.7 acre-feet/day (afd) or 15.5 cubic feet per second (cfs). In the context of the water budget for a regional model, this is not a significant amount; in the context of the appropriation determination and calculations of daily baseflow volumes available for irrigators, it is significant.

Because the changes in baseflow attributable to groundwater pumping for irrigation are derived from subtracting the NGWI Simulation baseflow from the Base Simulation baseflow in both 2008 and 2033, the additional 15.5 cfs of increased baseflow in the NGWI run shows up as additional streamflow depletion. This “augmentation” to the model-estimated, 25-year streamflow depletion is not due to groundwater pumping at all, but rather due solely to the simulated increase seen in baseflow over a time period when the NGWI Simulation should instead be showing relatively steady-state and non-changing conditions. The actual 25-year streamflow depletion estimate due to groundwater pumping should be determined solely from the consideration of the simulated baseflows from the predictive Base Simulation in 2008 and 2033. The method as it currently is being applied is artificially predicting too much streamflow depletion.

Findings:

- The NGWI Simulation, which is used as a point of comparison, introduces a 15.5-cfs bias into calculations of baseflow depletion.

4. LAG IMPACTS AND BASEFLOW DEPLETION – JENKINS METHOD

This section addresses the assumptions and approach used by the NDNR to calculate 25-year lag impacts, or baseflow depletions, outside of the ELM region using the Jenkins method. Apart from the issue of including wells located outside of the hydrologically connected area (Section 1.1), a discrepancy in the calculation of the baseflow depletions at the Louisville gage was identified.

Baseflow depletions at the Louisville gage were calculated to be 870 cfs after 25 years (NDNR, 2008). Of this amount, 25 cfs was attributed to regions outside of the ELM region, and was calculated using the Jenkins method. A review of the Geographic Information System files provided electronically with the 2009 Annual Evaluation revealed that approximately 121 wells *downstream* of the Louisville gage were included in the calculation of depletions at the gage. This downstream reach extends for approximately 15 river miles. The calculation of stream depletions caused by these wells was based on the distance to the closest downstream segment, not the distance back to the Louisville gage. This approach carries downstream impacts back to a point several miles upstream, over-estimates streamflow depletions, and, consequently, under-estimates the number of days available for diversion based on gage records.

Findings:

- Streamflow depletion calculations at the Louisville gage included wells in a 15-mile reach downstream of the gage location. These calculations used the distance to the closest stream segment instead of the distance back to the Louisville gage. This approach over-estimates streamflow depletions at the gage.

5. CONCLUSION

The Preliminary Determination of Fully Appropriated in the Lower Platte River Basin is not supported by the best science.

6. REFERENCES

Butler, J. J., M-S Tsou, V. A. Zlotnik and H. Huang, 1999. *Drawdown and Stream Depletion Produced by Pumping in the Vicinity of a Finite-Width Stream of Shallow Penetration.* Kansas Geological Survey, Open-File Report 1999-16.

Center for Advanced Land Management Information Technologies (CALMIT), 2007. *2005 Nebraska Land Use patterns: Lincoln, Nebraska Center for Advanced Land Management Information Technologies*, remote-sensing 1:100,000 scale.

Chen, X., and L. Shu, 2002. *Stream-Aquifer Interactions: Evaluation of Depletion Volume and Residual Effects from Ground Water Pumping.* Ground Water, 40(3), 284-290.

Domenico, P.A., and F.W. Schwartz, 1998. *Physical and Chemical Hydrogeology.* John Wiley & Sons, New York, 506 pp.

Hunt, B., 1999. *Unsteady Stream Depletion from Ground-Water Pumping.* Ground Water, 37(1), 98-102.

Jenkins, C.T., 1968. *Techniques for computing rate and volume of stream depletion by wells.* Ground Water 6(2), 37-46.

Martin, Derrel, 2005. *Net Irrigation Requirement.* A Summary of the CROPSIM Modeling Performed to Develop the Net Corn Crop Irrigation Requirements Map for the State of Nebraska.

Nebraska Department of Natural Resources (NDNR), 2008. *2009 Annual Evaluation of Availability of Hydrologically Connected Water Supplies.* December 16.

Peterson, S. M., J. S. Stanton, A. T. Saunders, and J. R. Bradley, 2008. *Simulation of Ground-Water Flow and Effects of Ground-Water Irrigation on Base Flow in the Elkhorn and Loup River Basins, Nebraska*, United States Geological Survey, Scientific Investigations Report 2008-5143.

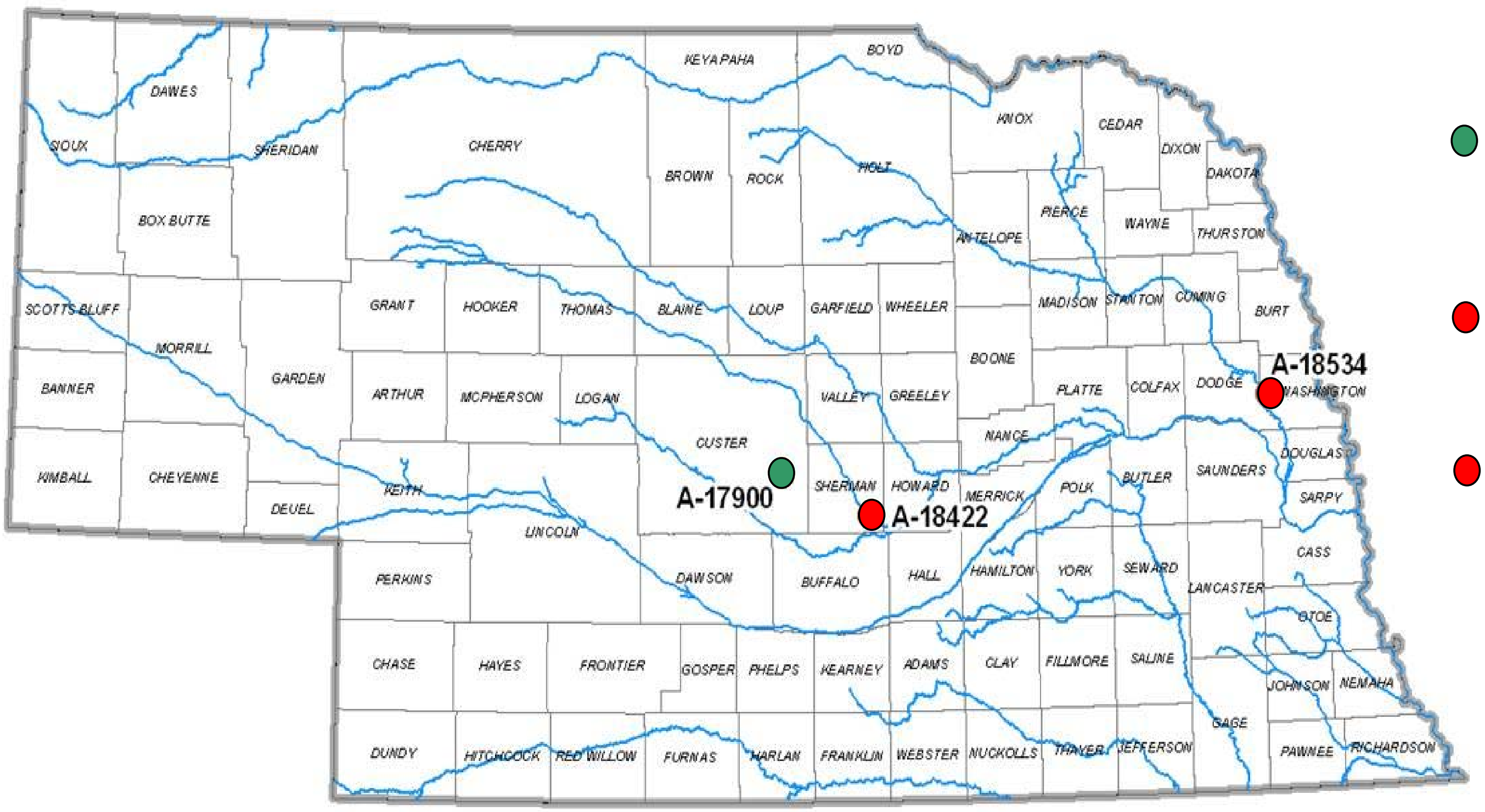
Reeves, H. W., 2008. STRMDEPL08, *An Extended Version of STRMDEPL with Additional Analytical Solutions to Calculate Streamflow Depletion by Nearby Pumping Wells.* United States Geological Survey, Open-File Report 2008-1166.

University of Nebraska-Lincoln, June 2007. *NebGuide G1328, Water Loss from Above-Canopy and In-Canopy Sprinklers.* http://www.ianrpubs.unl.edu/epublic/pages/index.jsp

University of Nebraska-Lincoln, May 2008. *NebGuide G1851, Minimum Center Pivot Design Capacities in Nebraska.* http://www.ianrpubs.unl.edu/epublic/pages/index.jsp

Zlotnik, V.A., 2004. *A Concept of Maximum Stream Depletion Rate for Leaky Aquifers in Alluvial Valleys*, Water Resources Research, 40: W06507.

Zlotnik, V.A. and D.M. Tartakovsky, 2005. *Stream Depletion by Groundwater Pumping from Leaky Aquifers*, submitted to Ground Water, 2005.



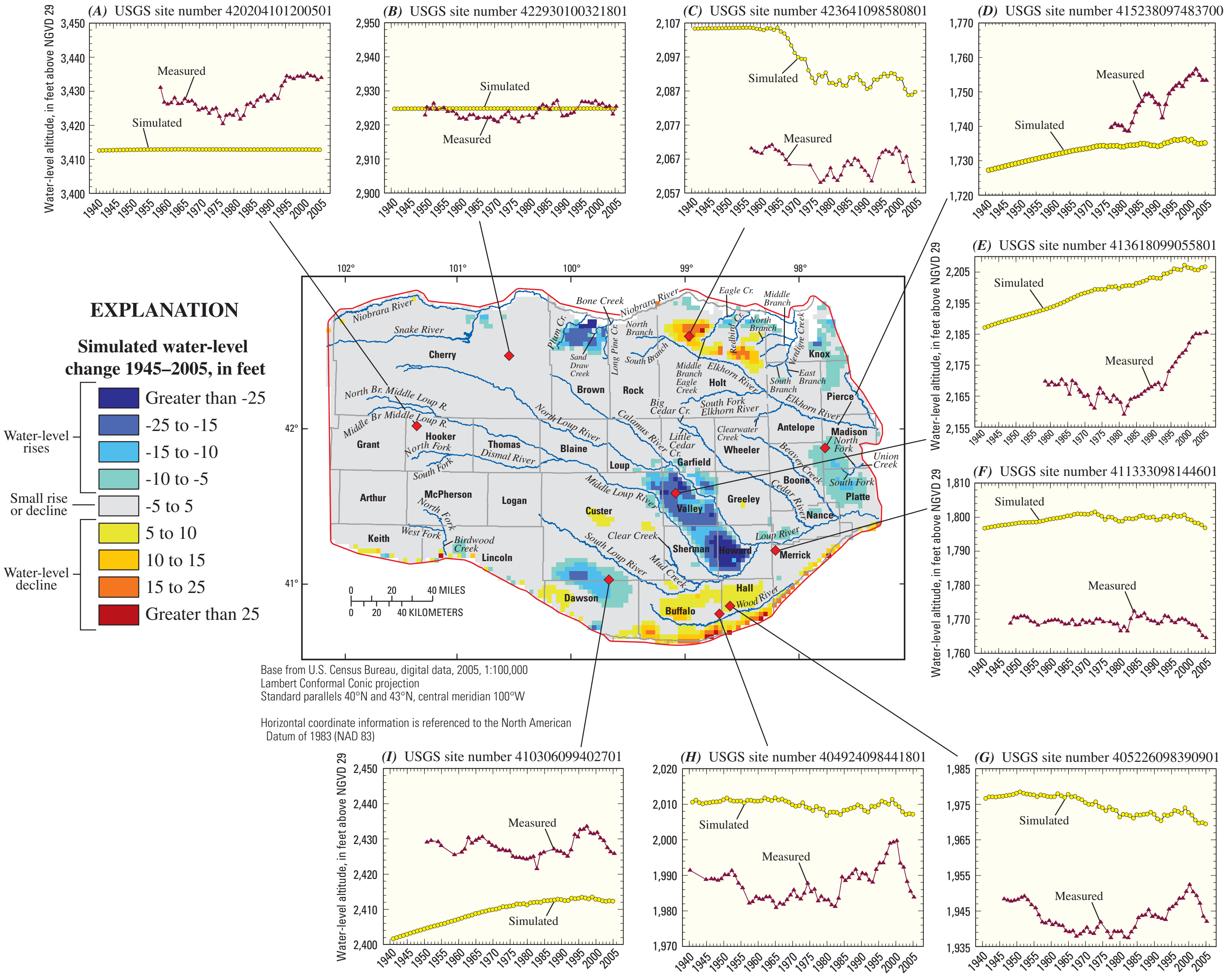
🟢 **A-17900**: Junior Irrigation Right used by NDNR in the 2009 Evaluation of Water supplies

🔴 **A-18534**: The Most Junior Irrigation Right in both the Loup and Elkhorn Basins

🔴 **A-18422**: The Most Junior Irrigation Right in the Loup Basin

FIGURE 1
MOST JUNIOR IRRIGATION WATER RIGHTS IN THE LOUP AND ELKHORN BASINS, NEBRASKA
LOWER PLATTE TECHNICAL REVIEW
FENNEMORE CRAIG

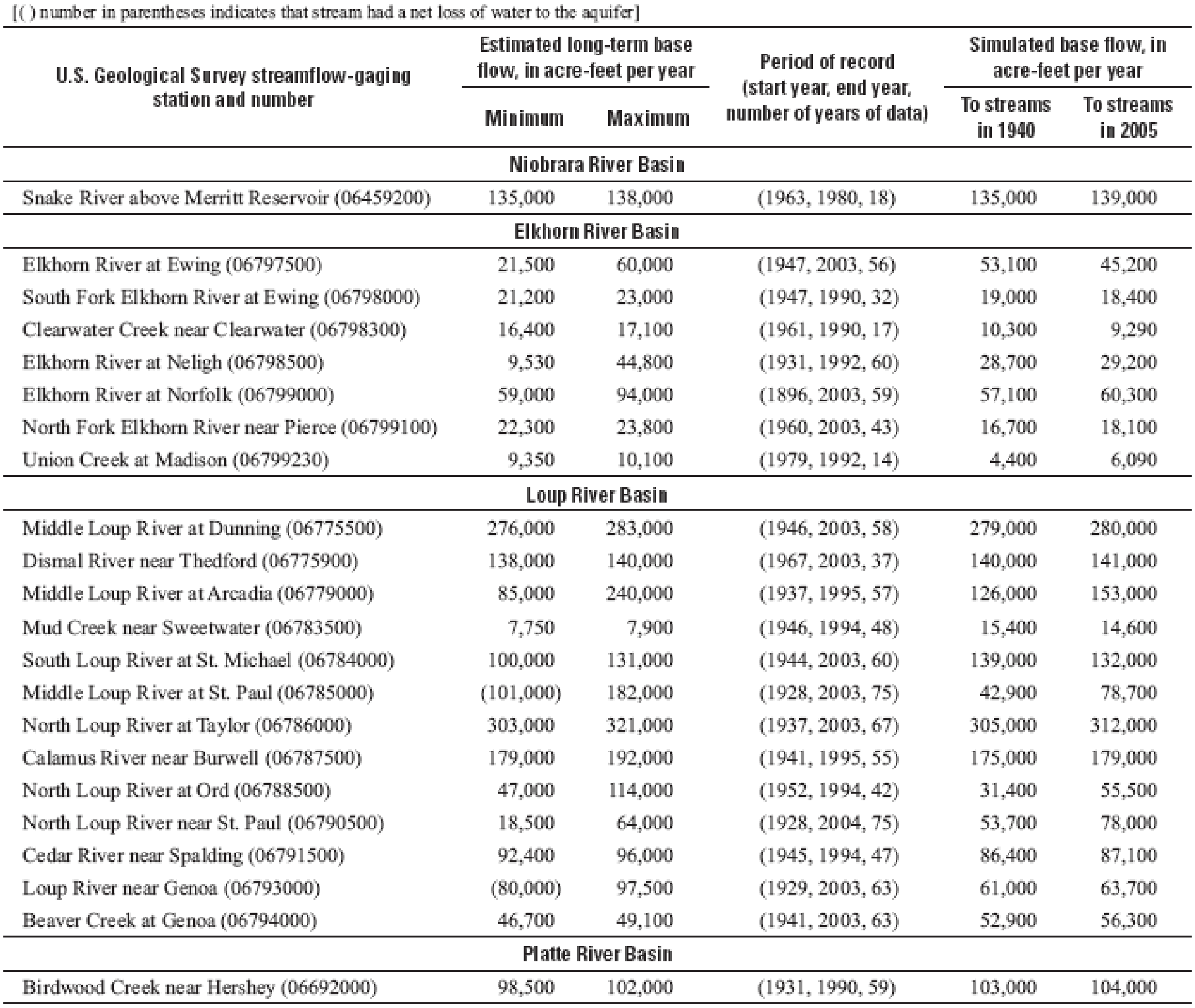
BROWN AND CALDWELL



Base from U.S. Census Bureau, digital data, 2005, 1:100,000
Lambert Conformal Conic projection
Standard parallels 40°N and 43°N, central meridian 100°W

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

FIGURE 2 - Calibration results for the 1940 through 2005 simulation, Elkhorn and Loup River Basins, Nebraska (Figure 25, Peterson, et al., 2008)



[( ) number in parentheses indicates that stream had a net loss of water to the aquifer]

U.S. Geological Survey streamflow-gaging station and number	Estimated long-term base flow, in acre-feet per year		Period of record (start year, end year, number of years of data)	Simulated base flow, in acre-feet per year	
	Minimum	Maximum		To streams in 1940	To streams in 2005
Niobrara River Basin					
Snake River above Merritt Reservoir (06459200)	135,000	138,000	(1963, 1980, 18)	135,000	139,000
Elkhorn River Basin					
Elkhorn River at Ewing (06797500)	21,500	60,000	(1947, 2003, 56)	53,100	45,200
South Fork Elkhorn River at Ewing (06798000)	21,200	23,000	(1947, 1990, 32)	19,000	18,400
Clearwater Creek near Clearwater (06798300)	16,400	17,100	(1961, 1990, 17)	10,300	9,290
Elkhorn River at Neligh (06798500)	9,530	44,800	(1931, 1992, 60)	28,700	29,200
Elkhorn River at Norfolk (06799000)	59,000	94,000	(1896, 2003, 59)	57,100	60,300
North Fork Elkhorn River near Pierce (06799100)	22,300	23,800	(1960, 2003, 43)	16,700	18,100
Union Creek at Madison (06799230)	9,350	10,100	(1979, 1992, 14)	4,400	6,090
Loup River Basin					
Middle Loup River at Dunning (06775500)	276,000	283,000	(1946, 2003, 58)	279,000	280,000
Dismal River near Thedford (06775900)	138,000	140,000	(1967, 2003, 37)	140,000	141,000
Middle Loup River at Arcadia (06779000)	85,000	240,000	(1937, 1995, 57)	126,000	153,000
Mud Creek near Sweetwater (06783500)	7,750	7,900	(1946, 1994, 48)	15,400	14,600
South Loup River at St. Michael (06784000)	100,000	131,000	(1944, 2003, 60)	139,000	132,000
Middle Loup River at St. Paul (06785000)	(101,000)	182,000	(1928, 2003, 75)	42,900	78,700
North Loup River at Taylor (06786000)	303,000	321,000	(1937, 2003, 67)	305,000	312,000
Calamus River near Burwell (06787500)	179,000	192,000	(1941, 1995, 55)	175,000	179,000
North Loup River at Ord (06788500)	47,000	114,000	(1952, 1994, 42)	31,400	55,500
North Loup River near St. Paul (06790500)	18,500	64,000	(1928, 2004, 75)	53,700	78,000
Cedar River near Spalding (06791500)	92,400	96,000	(1945, 1994, 47)	86,400	87,100
Loup River near Genoa (06793000)	(80,000)	97,500	(1929, 2003, 63)	61,000	63,700
Beaver Creek at Genoa (06794000)	46,700	49,100	(1941, 2003, 63)	52,900	56,300
Platte River Basin					
Birdwood Creek near Hershey (06692000)	98,500	102,000	(1931, 1990, 59)	103,000	104,000

FIGURE 3

Estimated Minimum and Maximum Baseflow Compared with Simulated 1940 and 2005 Baseflow, Elkhorn and Loup River Basins, Nebraska (Table 2 from Peterson et al., 2008)

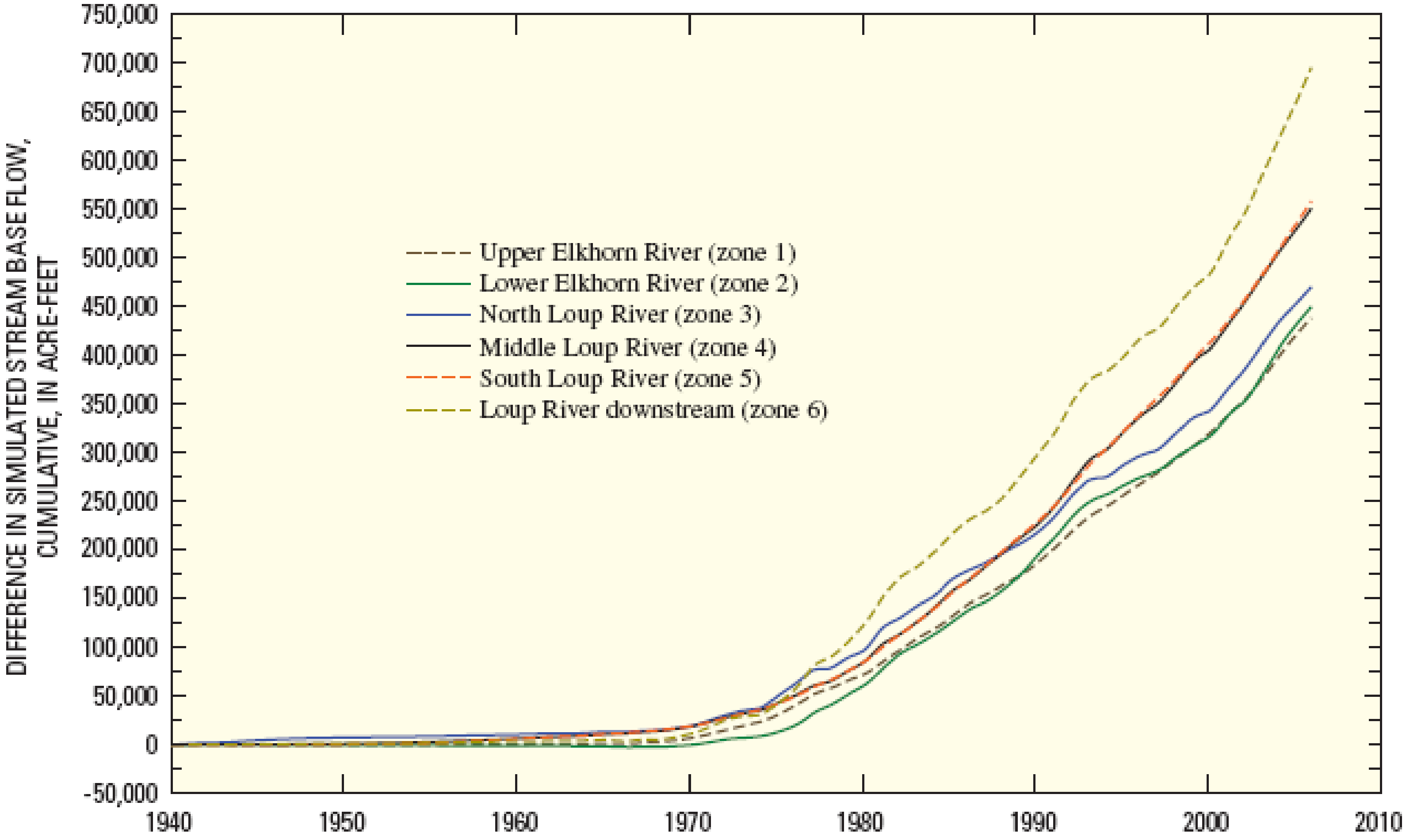


FIGURE 4 - Cumulative Effects of Groundwater Irrigation on Simulated Base Flow, Elkhorn and Loup River Basins, Nebraska, 1940 through 2005. (Figure 31 from Peterson, et al., 2008)

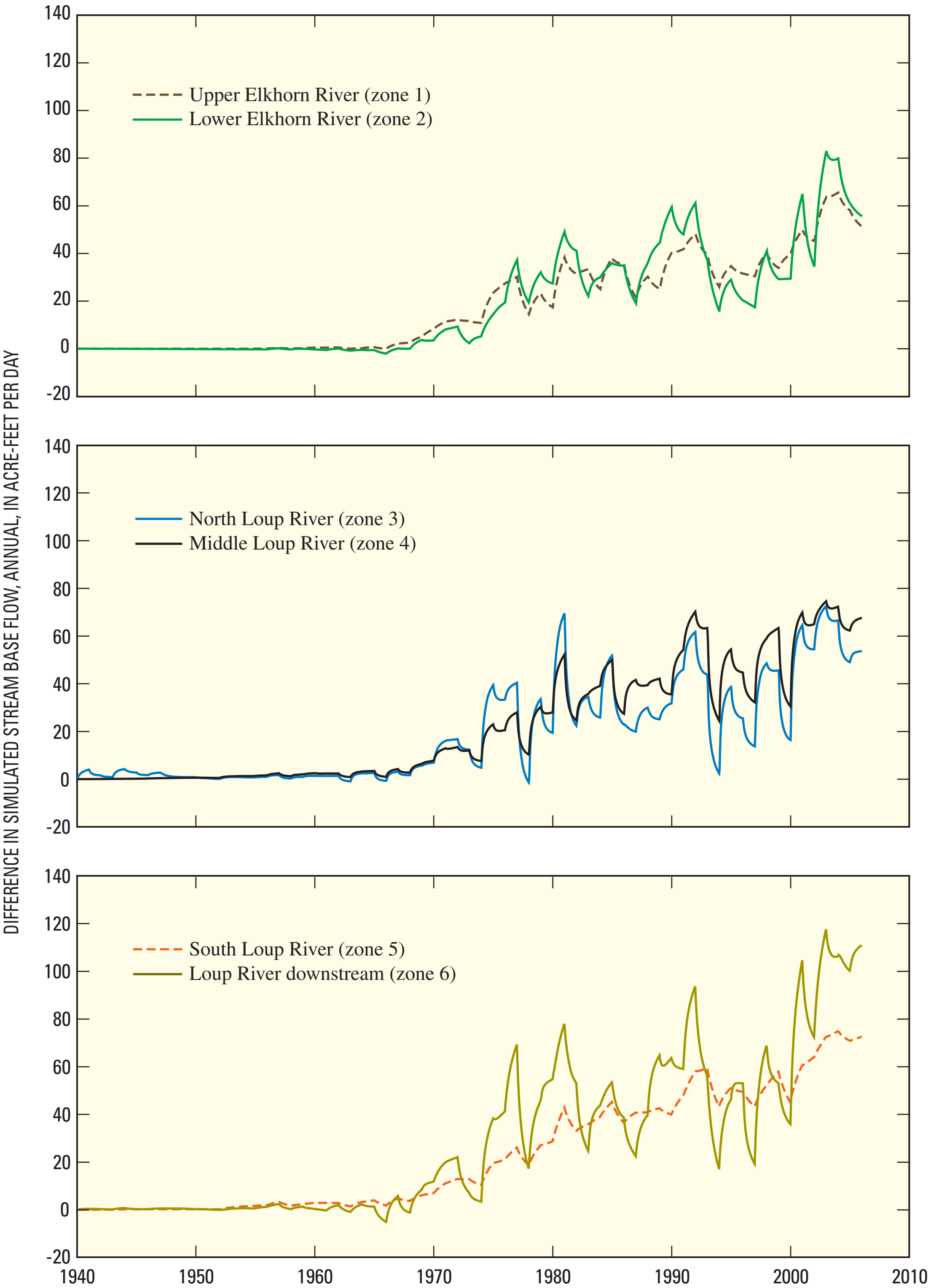


FIGURE 5 - Annual Rate of Effects of Groundwater Irrigation on Simulated Base Flow, Elkhorn and Loup River Basins, Nebraska, 1940 through 2005.
(Figure 32 from Peterson, et al., 2008)

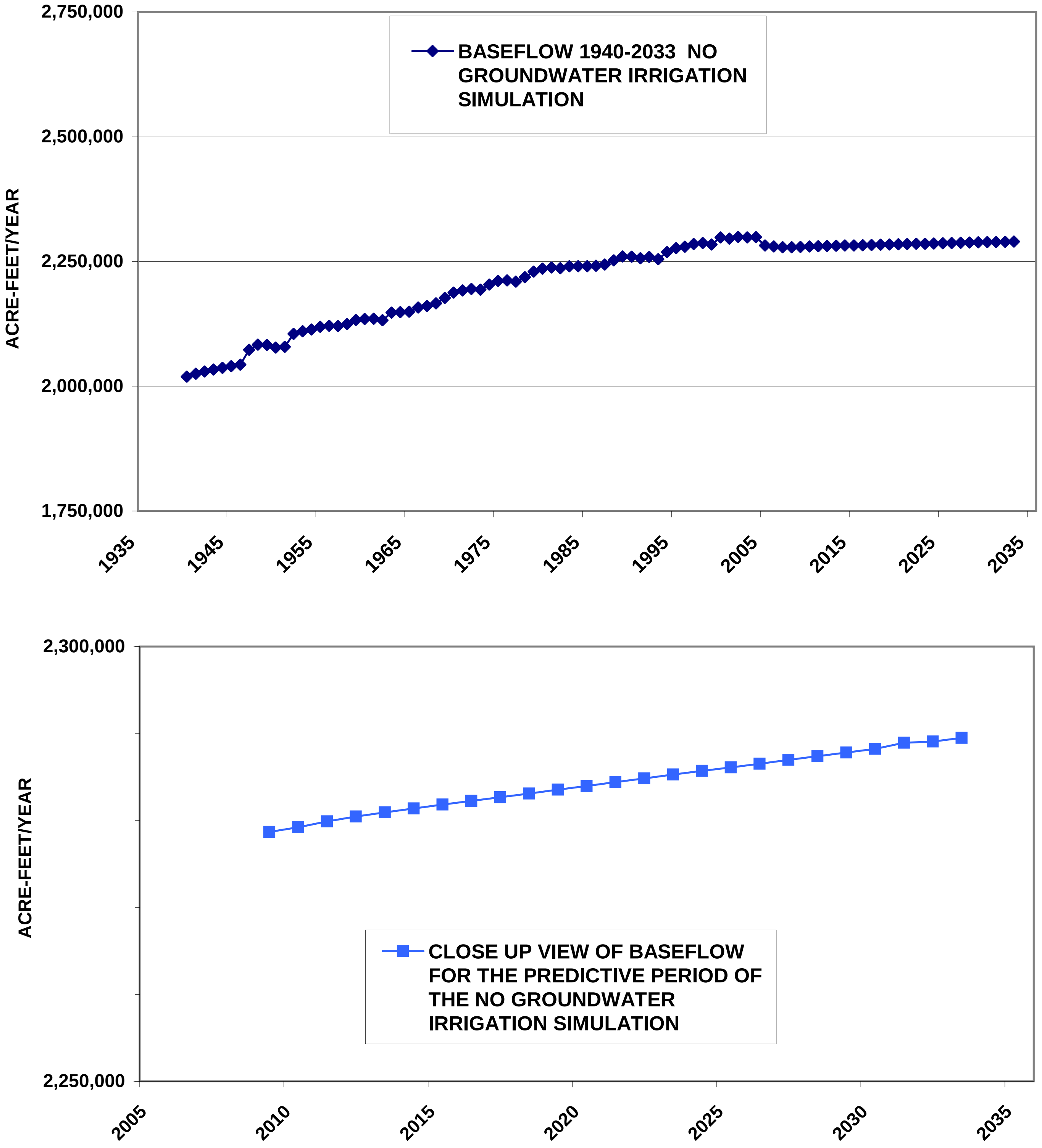


FIGURE 6
RISE IN BASEFLOW SIMULATED IN
THE NO GROUNDWATER IRRIGATION
SIMULATION 1940 - 2033

LOWER PLATTE TECHNICAL REVIEW
FENNEMORE CRAIG

BROWN AND
CALDWELL

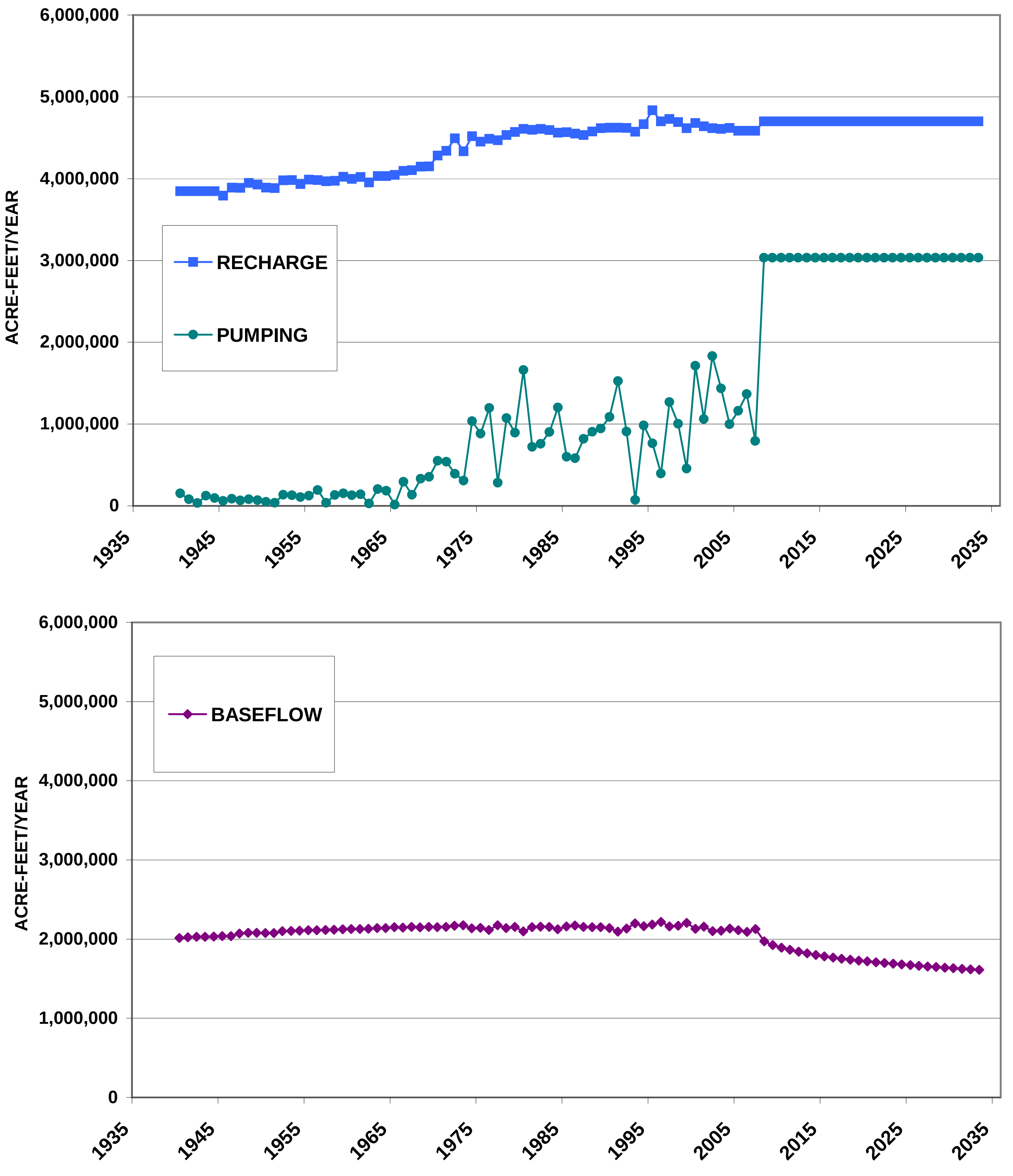


FIGURE 7
TOTAL PUMPING, TOTAL RECHARGE AND RESULTING BASEFLOW
BASE SIMULATION 1940 - 2033

LOWER PLATTE TECHNICAL REVIEW

FENNEMORE CRAIG

BROWN AND CALDWELL

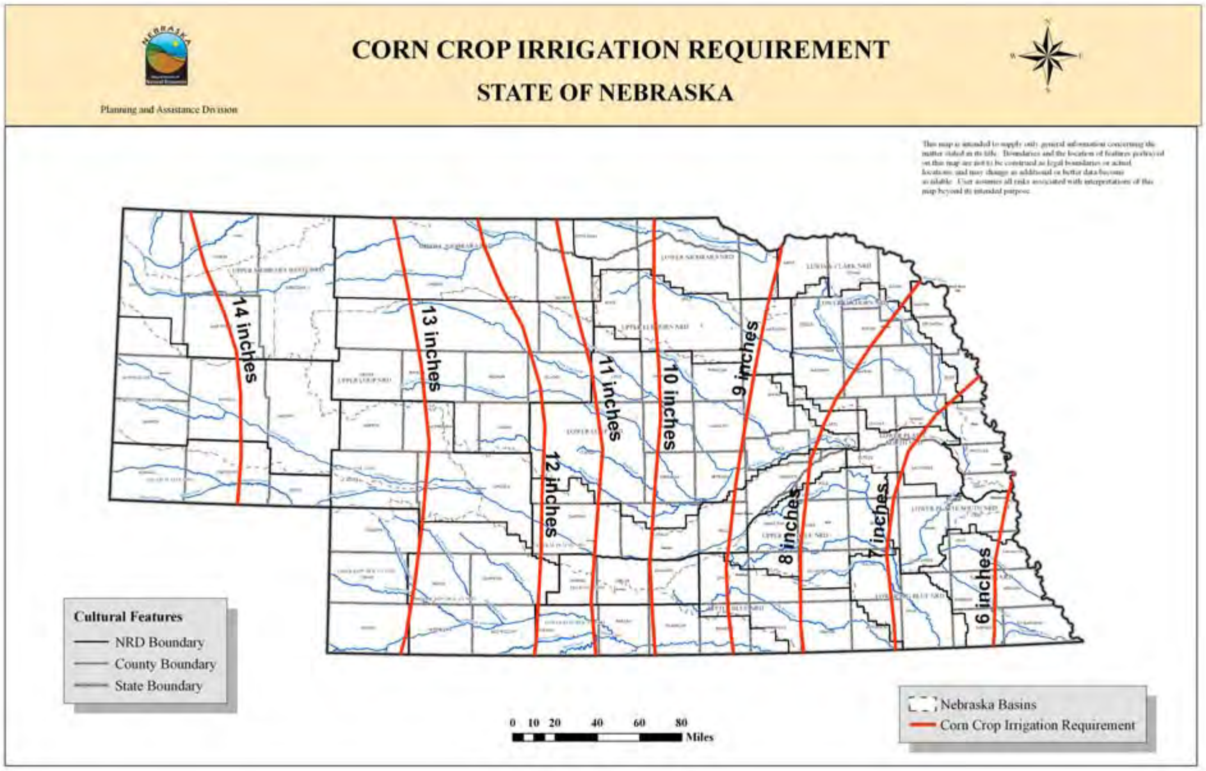
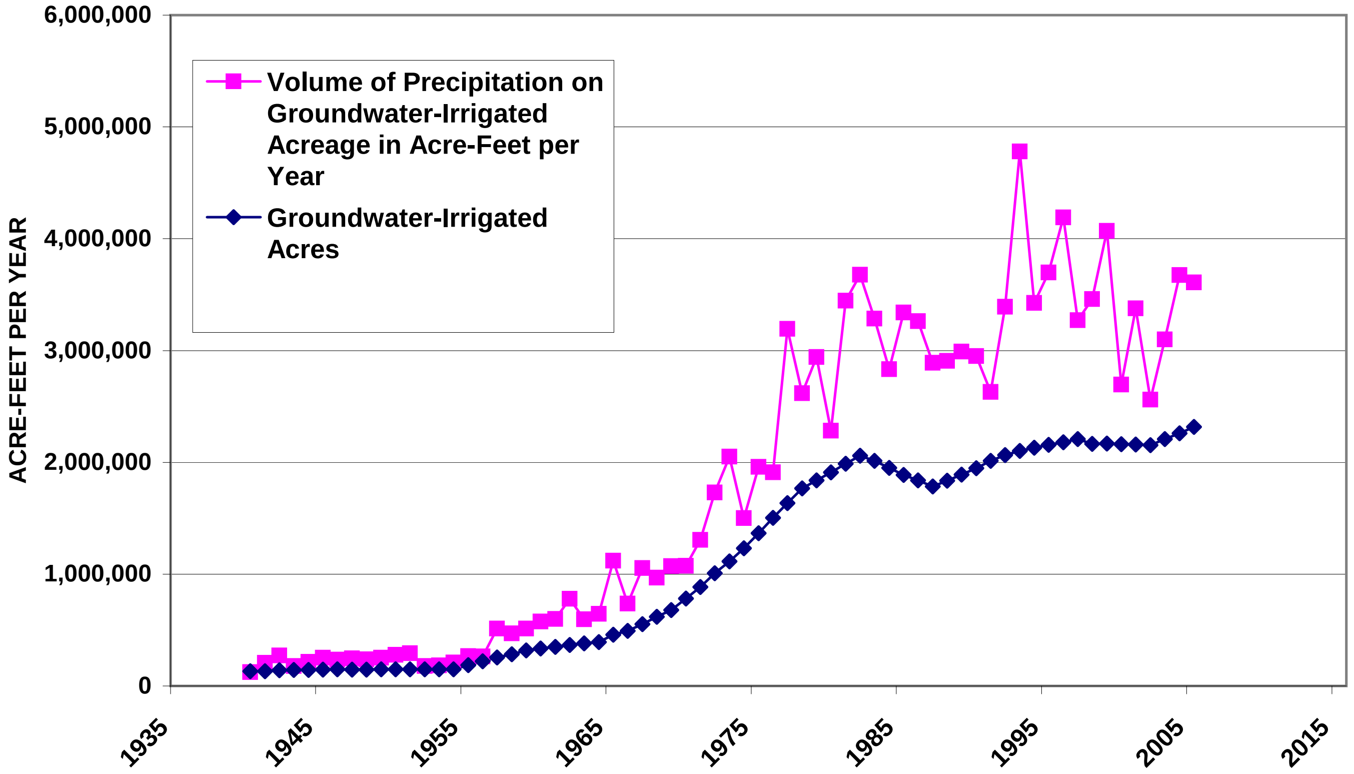
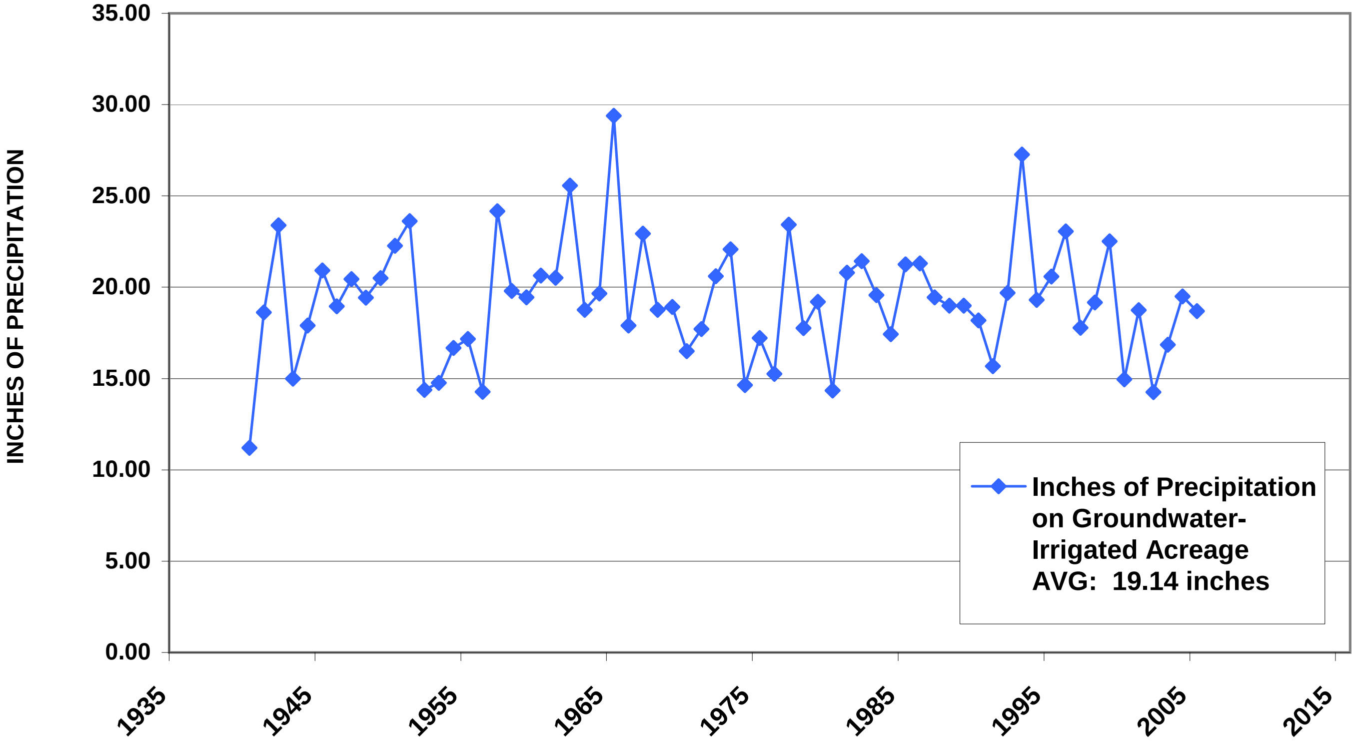


FIGURE 8 - Map of Net Irrigation Requirements (inches/year) for Corn Grown on Fine Sandy Loam (Figure 4 from Martin, 2005)



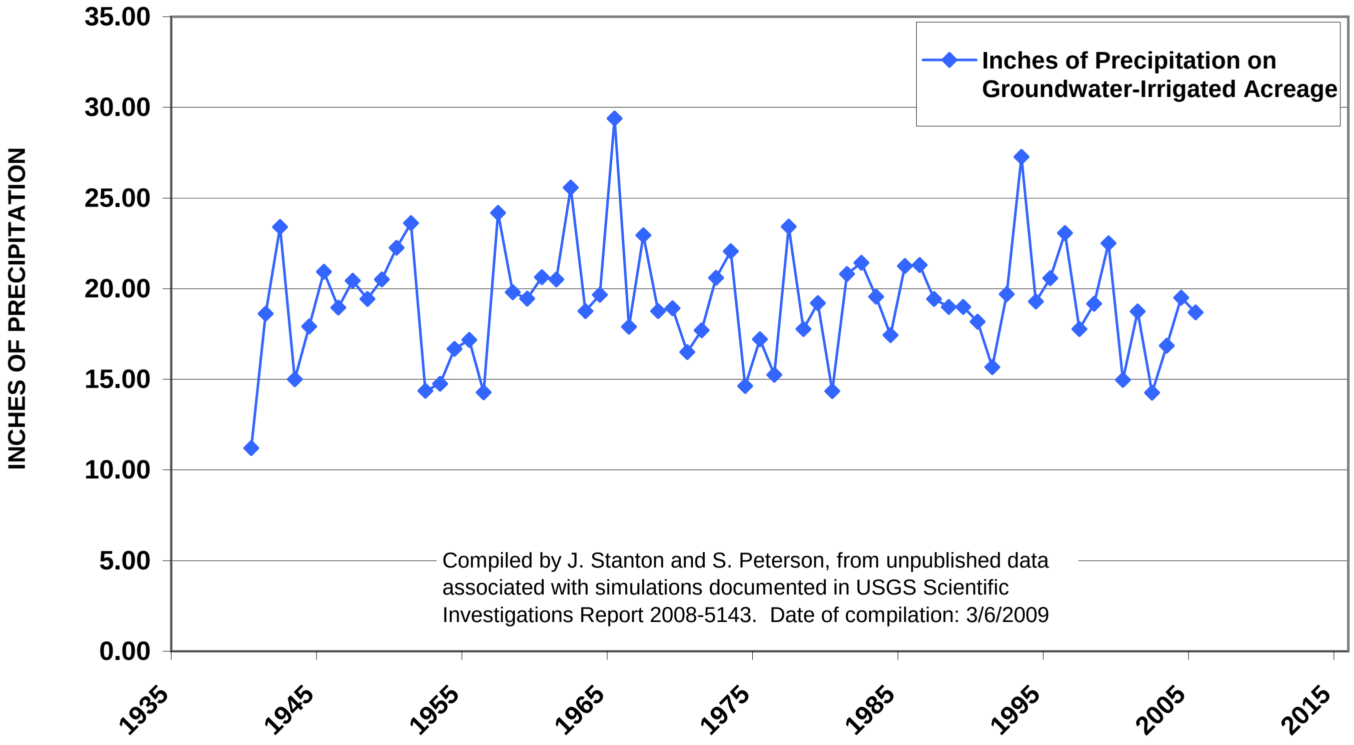


Compiled by J. Stanton and S. Peterson, from unpublished data associated with simulations documented in USGS Scientific Investigations Report 2008-5143. Date of compilation: 3/6/2009

BROWN AND CALDWELL

FIGURE 9
EFFECTIVE PRECIPITATION AND GROUNDWATER-IRRIGATED ACREAGE IN THE ELM 1940 - 2005

LOWER PLATTE TECHNICAL REVIEW
FENNEMORE CRAIG



Compiled by J. Stanton and S. Peterson, from unpublished data associated with simulations documented in USGS Scientific Investigations Report 2008-5143. Date of compilation: 3/6/2009

Annual Groundwater Pumping Calculation:
Net Crop Requirement of 25.1 inches *Minus* Effective Precipitation (Graph Above)

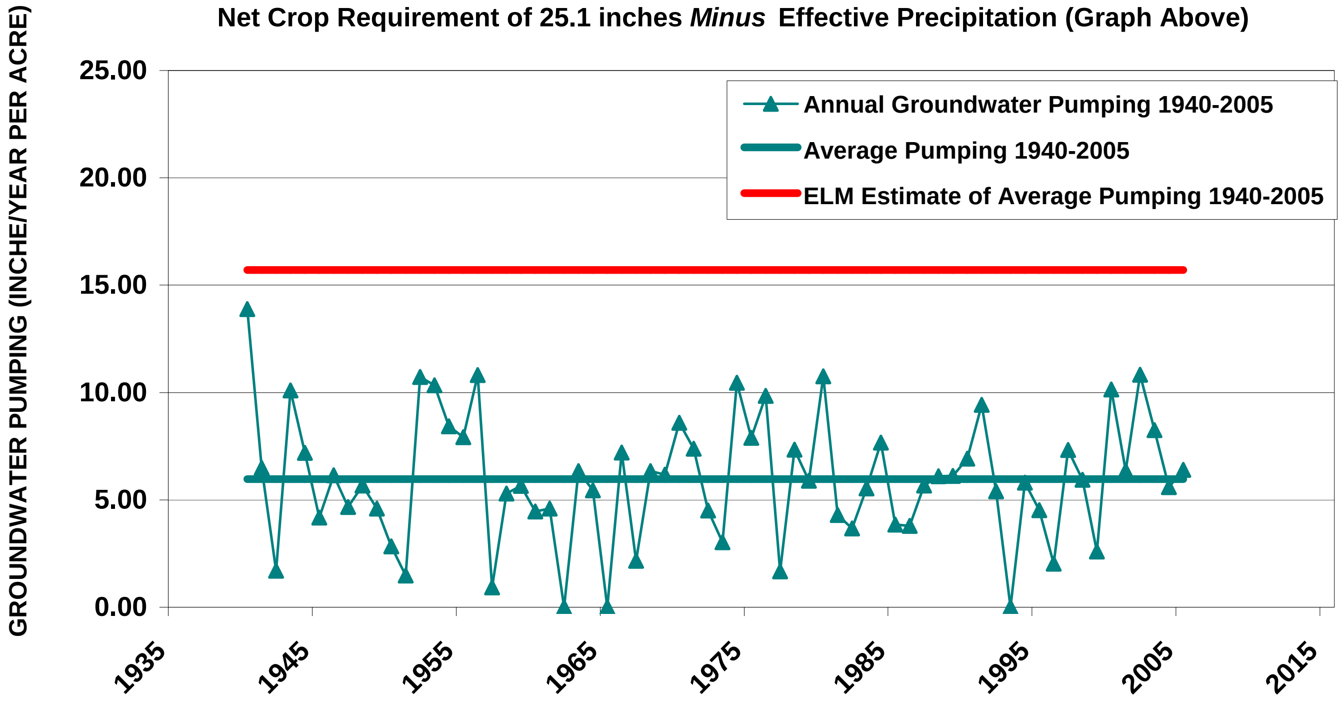


FIGURE 10
GROUNDWATER PUMPING BASED ON EFFECTIVE PRECIPITATION 1940 - 2005

LOWER PLATTE TECHNICAL REVIEW

FENNEMORE CRAIG

BROWN AND CALDWELL

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MODFLOW Water Budgets from the Nebraska Department of Natural Resources Simulations

TABLE A-1
MODFLOW WATER BUDGET SUMMARY
NEBRASKA DEPARTMENT OF NATURAL RESOURCES
BASE SIMULATIONS 1940 - 2047

	1940-2007		**2008-2047**		**2007**		**2047**	
	CUMULATIVE	**ANNUALIZED**	**CUMULATIVE**	**ANNUALIZED**				
IN:	**ft3**	**afy**	**ft3**	**afy**	**ft3/day**	**afy**	**ft3/day**	**afy**
STORAGE =	5.36E+11	181,102	2.14E+12	1,226,412	15,133,659	126,809	109761536	919,719
CONSTANT HEAD =	1.30451E+11	44,040	1.45066E+11	83,257	4,802,980	40,245	11218506	94,003
WELLS =	0	0		0	0	0		0
DRAINS =	0	0	0	0	0	0	0	0
ET =	0	0	0	0	0	0	0	0
HEAD DEP BOUNDS =	67273453568	22,712	63387013120	36,379	668,381	5,601	1039622.438	8,711
RECHARGE =	1.28E+13	4,307,446	4.99E+12	2,865,416	547,236,736	4,585,432	341728288	2,863,426
STREAM LEAKAGE =	1.5354E+12	518,352	9.7616E+11	560,239	61,325,988	513,866	66622344	558,245
TOTAL IN =	**1.50E+13**	**5,073,799**	**8.31E+12**	**4,771,694**	**629,167,744**	**5,271,952**	**530370304**	**4,444,104**
OUT:								

STORAGE =	6.59341E+11	222,594	73190244352	42,005	29,941,950	250,891	255912.5	2,144
CONSTANT HEAD =	9.41853E+11	317,970	3.59687E+11	206,432	39,393,200	330,085	21976596	184,147
WELLS =	1.6927E+12	571,457		0	94,485,320	791,716		0
DRAINS =	9.19264E+11	310,344	4.60756E+11	264,438	36,617,696	306,829	29154824	244,295
ET =	2.71E+12	913,716	1.31E+12	750,000	105,200,776	881,503	81801488	685,435
HEAD DEP BOUNDS =	2.76189E+11	93,242	1.60071E+11	91,868	8,493,130	71,166	8091636	67,802
RECHARGE =	0.00E+00	0	2.04E+12	1,170,455	0	0	137474976	1,151,937
STREAM LEAKAGE =	7.83E+12	2,644,189	3.91E+12	2,246,843	315,107,232	2,640,361	251667040	2,108,780
TOTAL OUT =	**1.50E+13**	**5,073,462**	**8.31E+12**	**4,772,039**	**629,239,296**	**5,272,551**	**530422464**	**4,444,541**
IN - OUT =	727,711,744	246	-603455488	-346	-71,552	-600	-52160	-437
PERCENT DISCREPANCY =	0		-0.01		0		-0.01	

ft3 = cubic feet

afy = acre-feet per year

TABLE A-2
MODFLOW WATER BUDGET SUMMARY
NEBRASKA DEPARTMENT OF NATURAL RESOURCES
NO GROUNDWATER IRRIGATION (NGWI) SIMULATIONS 1940 - 2047

	1940-2007		**2008-2047**		**2007**		**2047**	
	CUMULATIVE	**ANNUALIZED**	**CUMULATIVE**	**ANNUALIZED**				
IN:	**ft3**	**afy**	**ft3**	**afy**	**ft3/day**	**afy**	**ft3/day**	**afy**
STORAGE =	5.88E+10	19,855	8.06E+10	46,282	9,022,687	75,603	861,515	7,219
CONSTANT HEAD =	20176738304	6,812	7.76E+10	44,528	4,192,868	35,133	5,244,111	43,942
WELLS =	0	0	0	0	0	0	0	0
DRAINS =	0	0	0	0	0	0	0	0
ET =	0	0	0	0	0	0	0	0
HEAD DEP BOUNDS =	67159523328	22,673	6.02E+10	34,564	635,833	5,328	921,955	7,725
RECHARGE =	1.19E+13	4,010,358	6.98E+12	4,003,271	477,435,936	4,000,554	477,435,936	4,000,554
STREAM LEAKAGE =	1.5198E+12	513,085	8.76937E+11	503,293	60,287,208	505,161	59,910,368	502,004
TOTAL IN =	**1.37E+13**	**4,640,320**	**8.07E+12**	**4,631,944**	**551,574,528**	**4,621,779**	**544,373,888**	**4,561,443**
OUT:								

STORAGE =	84159664128	28,412	1.78878E+11	102,662	10,590,789	88,743	5,387,309	45,142
CONSTANT HEAD =	1.0233E+12	345,467	5.64735E+11	324,113	45,767,760	383,499	38,261,200	320,600
WELLS =	30982676480	10,460	1.82E+10	10,460	1,247,444	10,453	1,247,444	10,453
DRAINS =	36538013696	12,335	5.77968E+11	331,708	39,308,924	329,379	39,755,528	333,121
ET =	2.80E+12	945,180	1.70E+12	976,641	113,904,840	954,437	117,091,896	981,142
HEAD DEP BOUNDS =	77230387200	26,073	1.64991E+11	94,692	8,608,322	72,131	8,815,859	73,870
RECHARGE =	9.70E+06	3	1.29E+08	74	8,859	74	8,859	74
STREAM LEAKAGE =	7.99E+12	2,698,239	4.86E+12	2,792,068	332,231,168	2,783,847	333,834,176	2,797,279
TOTAL OUT =	**1.37E+13**	**4,639,983**	**8.07E+12**	**4,632,404**	**551,668,096**	**4,622,563**	**544,402,304**	**4,561,681**
IN - OUT =	1,095,761,920	370	-817364992	-469	**-93,568**	-784	-28416	-238
PERCENT DISCREPANCY =	0		-0.01		0		-0.01	

ft3 = cubic feet

afy = acre-feet per year

ATTACHMENT B

Evaluation of Impacts to Days Needed to Meet 65/85 Requirements Under Various Scenarios

	Number of Days to Meet 65 Rule	Number of Days to Meet 85 Rule
v. . 0 3 #	v1g0	l hgc
4 -	vcgc	l l gj
4 - # - # 3	v. gM	vhg1
4 - # - # j 3	D2gM	vMg

ATTACHMENT C

Justification for the Minimal Irrigation Requirement Definition that is Incorporated in the Proposed Rule for Defining a Fully Appropriated Basin[1]

The proposed rule defines a basin as fully appropriated if the amount of water available under a surface water irrigation water right is less than the amount required to produce an acceptable rate of return on a new irrigation investment. An analysis of the economics of irrigation found that under most Nebraska conditions the annual amount of applied irrigation water that was necessary for economic feasibility was about 85 percent of the consumptive irrigation requirement (CIR) for corn. Further consideration of crop water use found that the applied water requirement from July 1 to August 31 was at least 65 percent of the annual CIR.

Economic Analysis

The economic analysis upon which this rule was based assumed that new irrigation using surface water would most likely involve center pivots pumping directly from a river, that corn was the most likely crop because it now accounts for over 80 percent of all irrigated acres in Nebraska and that the minimum acceptable rate of return was 6.0 percent. The analysis was based on a 130 acre system requiring an investment of $70,000 exclusive of land costs. These and other key data inputs and assumptions are summarized in Table 1 for conditions in West Central Nebraska. Cost estimates were based on crop budgets published by the Nebraska Cooperative Extension Service. The corn price is a typical producer average for the last five years. The CIR and dryland ET estimates used in this example are mid-range values for the soil and climatic conditions found in West Central Nebraska. Crop yields were based on a combination of county averages published by the Nebraska Agricultural Statistics Service and yield trials conducted by Institute of Agricultural and Natural Resources, University of Nebraska–Lincoln.

The estimated dryland returns assumed that corn was the best dryland option in those areas where rainfall was high enough to generate dryland yields that resulted in at least a $40 net return to corn. If the net return to corn was less than $40, the best dryland option was assumed to be wheat or a wheat-corn-fallow rotation that produced a minimum net return of $40 per acre.

These inputs and assumptions were used to compute the average annual gross irrigation application that would be required to sustain a six percent rate of return on investment for a range of CIR levels that characterize Nebraska.[2] For example in a case where the CIR was 15

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[1] Prepared by Raymond J. Supalla, Professor of Agricultural and Natural Resource Economics, University of Nebraska–Lincoln.

[2] The CIR is defined for this analysis as the amount of water consumed by a fully watered crop that comes from irrigation. It is equal to total crop evapotranspiration (ET) less effective rainfall and is sometimes called the net irrigation requirement. The CIR divided by an efficiency parameter equals the gross irrigation requirement which is the amount of water that must be applied to the crop to meet the CIR. The efficiency parameter used in this analysis is called water use efficiency and is defined as the proportion of the gross irrigation amount that is consumed by the crop.

Table 1. Data Inputs and Assumptions for Economic Analysis

Data Inputs and Assumptions	
CIR for Corn, Inches/Acre	15
Dryland ET for Corn	16
Fully Watered Yield, Bushels Acre	215
Non-Irrigated Yield	60
Water Use Efficiency	0.8
Yield/Inch of ET (Corn)	12.5
Crop Price, $/Bushel	$2.35
Variable Irrigation Cost, $/Inch	$6.00
Irrigation Start-up Costs, $/System	$1,500
Variable Production Costs for Corn, $/Acre	$140
Yield Dependent Costs, $/Bushel	$0.50
Dryland ROVC, $/Acre	$40
Irrigation Investment, Center Pivot System	$70,000
Acres per System	130
Interest Rate, Decimal	0.06
Amortization Period (Years)	15

inches, the estimated minimum gross irrigation requirement (break-even point) was found to be 13 inches, which is 86 percent of the CIR (Table 2). This relationship between the CIR for corn and the minimum amount of water required to make irrigation economically feasible was found to be surprisingly consistent across the state, with the exception of Eastern Nebraska where rainfall is relatively high. In this area the CIR may be so small that the amount of gross irrigation required to justify an irrigation investment is more than 85 percent of the CIR. Results from the economic analysis suggest that a gross irrigation application of at least six inches is necessary to justify a sprinkler irrigation investment.

Computing the CIR

The CIR for corn varies primarily as a function of effective precipitation. In Nebraska it varies from less than 6 inches in Southeast Nebraska to over 20 inches in Northwest Nebraska. Estimates are available from several sources, including the Irrigation Guide published by the Natural Resources Conservation Service, U.S. Department of Agriculture (NRCS, USDA) and from the Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln (IANR, UNL). The estimates used in this analysis were provided by Derrel Martin, IANR, UNL based on results from a simulation model called CROPSIM.

Table 2. Example Break Even Analysis for a 130 Acre Center Pivot Irrigation Investment When the Consumptive Irrigation Requirement for Corn is 15 Inches

Inches Applied	Irrigated Yield Bu/Acre	Annual Net Return to Irrigation Investment $/Acre	Present Value of Net Returns to Irrigation Investment $/System	Present Value of Net Returns to Irrigation Irrigation Investment $/Acre
1	70	-68	-155,289	-1,195
2	80	-55	-139,227	-1,071
3	90	-42	-123,515	-950
4	100	-30	-108,170	-832
5	110	-18	-93,210	-717
6	119	-7	-78,657	-605
7	129	4	-64,533	-496
8	138	15	-50,867	-391
9	147	26	-37,690	-290
10	155	36	-25,039	-193
11	164	45	-12,959	-100
12	172	54	-1,504	-12
13	180	63	9,256	71
14	187	71	19,233	148
15	194	78	28,305	218
16	201	84	36,291	279
17	207	89	42,899	330
18	212	93	47,525	366

Temporal Distribution of the Seasonal Irrigation Requirement

Defining the minimum water supply that is necessary to justify an irrigation investment requires consideration of when the water is available during the season as well as the total amount available. Water timing requirements depend on the crop, the soil and the climate. In July and August crop water requirements are high, while rainfall and stream flows are low relative to earlier in the season. Therefore, the suggested procedures for defining a minimum water supply incorporate a minimum gross irrigation requirement for July and August as well as for the entire season. The proposed rule sets the July-August requirement at 65 percent of the seasonal CIR. This means for our example case that if we have a seasonal CIR of 15 inches, the minimum required gross irrigation application for the season is 12.75 inches (85 percent of 15) and the minimum for July and August is 9.75 inches (65 percent of 15). This insures that enough of the seasonal water supply is available during critical crop growth stages to produce the grain yield responses to water that are necessary to justify an irrigation investment.

Calculation of Stream Flow Requirement

The stream flow required to provide enough water to make irrigation economically feasible depends on the amount required at the field, the design flow rate, the losses if any between the stream and the field and an allowance for expected down time. The illustrative case depicted in Table 3 assumes: a design flow rate of 1 cfs per 70 acres, which is widely used when

Table 3. Conversion of Minimum Irrigation Requirement in Inches per Acre to Days of Required Stream Flow.

Assumptions and Data Inputs		Value
CIR, Inches per Acre		15
Water Use Efficiency, Proportion		0.8
Required Break-even Seasonal Field Delivery, Inches per Acre	15 x .85 =	12.75
Required Break-even July-August Delivery, Inches per Acre	15 X .65 =	9.75
Delivery Flow Rate, cfs	130*1/70	1.86
System Downtime Proportion		0.1
Days Required to Meet Break-even Seasonal Requirement*		42
Days Required to Meet Break-even July-August Requirement*		32
Total Seasonal Gross Irrigation Requirement, Inches per Acre**	15/.8 =	18.75
Days Required to Meet Total Seasonal Requirement	1.86cfs for 130 acres *1.98= 3.69 af/day/130 acres * 12 in/ft = .339 ac-in/ac per day Need 18.75 in/.339 = 55 day / .9 for down time = 61 days	61
Total July-August Gross Irrigation Requirement***	9.75/.8 = 12.2	12.2
Days Required to Meet Total July-August Requirement*	12.2in required/.339in/day = 35 day/.9 for down time = 40 days	40

* Inches per acre were converted to days required by dividing the total field volume required by the amount of water that could be delivered in a day at the design flow rate and assuming the system was down 10 percent of the time.

** The seasonal gross irrigation requirement was calculated by dividing the CIR by the water use efficiency.

*** The total July and August demand was assumed to be 65 percent of the seasonal gross irrigation requirement.

1. Red = ab additions

administering surface water rights in Nebraska; zero losses between the river and the field, which is equivalent to pumping directly from the river; and a system downtime factor of 10 percent. With these assumptions further irrigation development is likely to be economically feasible in a basin where the CIR for corn is 15 inches if a junior appropriator could divert water for a minimum of 42 days from May 1 to September 30, with 32 of these days occurring between July 1 and August 31.

The final question concerns how frequently this requirement must be met for irrigation to be considered economically feasible. Does it have to be met every year? To what extent does applying more than the minimum average requirement in good water supply years offset poor water supply years? This issue was analyzed for two example basins, the Elkhorn and the Loop. It was found that the break-even water requirement, when computed as a proportion of the average annual CIR as described in Table 1, 2 and 3, adequately reflected the economic implications of high and low flow years. What this finding means is that the 85 and 65 percent criteria can be applied to the historical flow regime to determine the economic feasibility of further irrigation development without regard to the annual variance in water availability.

In total this analysis suggests that if irrigation feasibility is used to determine if a basin is fully appropriated, then the following calculations are appropriate. First, determine the CIR for corn. Second, calculate the number of days that water must be available to a junior appropriator during the season (May to September) and during July and August before an irrigation investment is economically feasible. Third, calculate the number of water supply days required to meet the average annual full irrigation requirement for corn and the number of days required to meet the full requirement for July and August. Fourth, compute the number of days each year that water would have been available to a junior appropriator during the season and during July and August, using the appropriate historical period of record. Fifth, compute the average number of water supply days for the historical period using the observed number of days for each year or the number of days required for full irrigation, whichever is less. Sixth, if the results from step five are equal to or greater than the results from step two, irrigation can be considered economically feasible.