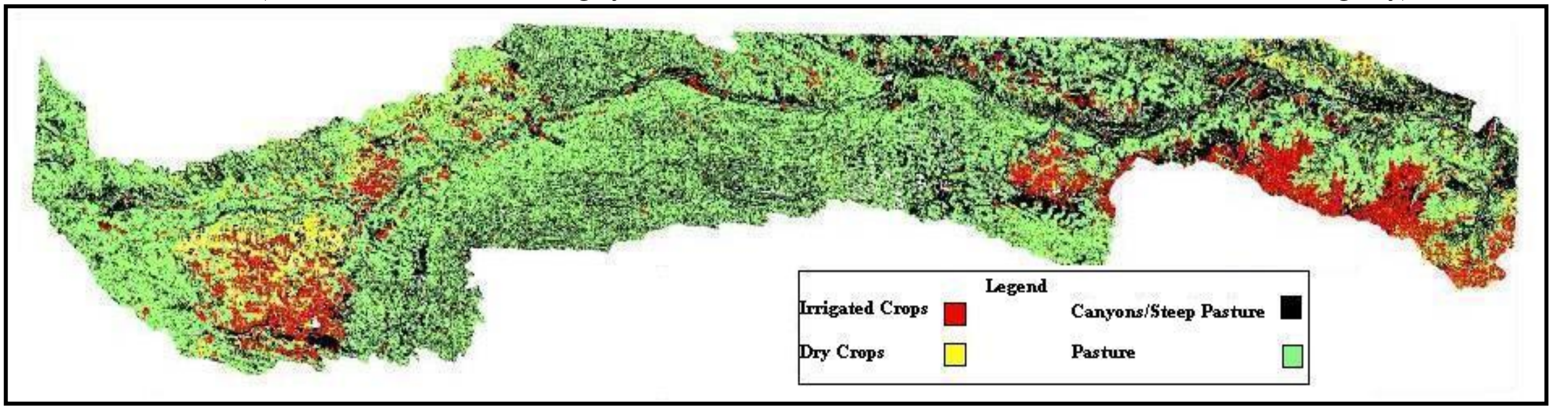
Final Research Report (December 7, 2010)

The Extent and Value of Agricultural, Municipal, and Industrial Water Use in the Niobrara Basin

Land Cover and Irrigation across the Niobrara Basin

(CALMIT, 2005 Satellite Imagery Classifications across Common Land Units of the Farm Service Agency)



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The Objectives and Focus of this Research Project:

Provide Nebraska public officials and Niobrara River Basin stakeholders with objective and accurate information on the current and potential extent and value of out-of-stream ground/surface water resources across the Niobrara Basin.

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Disclaimer

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EXECUTIVE SUMMARY

Municipal and Industrial Water Uses

Water consumption for either municipal needs (drinking water) or industrial activities in the Niobrara Basin is low and unlikely to increase in the coming decades. This is a result of declining population levels across the Basin combined with sufficient current drinking water supplies, and the fact that no new ethanol plants are likely to be constructed due to existing plants and the relatively low level of total corn production in the Basin.

Hydro-electricity generation at the Spencer Dam by Nebraska Public Power District (NPPD) is characterized by historical water right of 1.4 million acre-feet per year and an average use (water flowing through turbines) of 874,000 acre-feet per year. Four alternative estimates exist for the value of water used for this hydro-electric generation. A consultant working on behalf of agricultural landowners litigating against the NPPD estimated $0.32/acre-foot based on peak water flow levels from 1996 and gross electricity prices from 2007. The NPPD itself estimated these values to be $1.09/acre-foot, but in a recent settlement offer agreed to charge irrigators only $0.80/acre-foot. This current report estimates values to be either $0.48/acre-foot based on dividing gross electricity revenues in 2007 by the quantity water rights owned by the NPPD, or $0.57/acre-foot based on dividing 2007 revenues by actual 2007 water flows.

Current and Potential Irrigated Agriculture

Based on data provided by individual Natural Resource Districts (NRDs) in the Basin who manage groundwater resources, and by the Nebraska Department of Natural Resources (NDNR) which manages surface water resources, along with the use of a year 2005 satellite imagery-based land cover GIS database developed by the Center for Advanced Land Management Information Technologies (CALMIT), there are approximately 794,500 irrigated acres across the Basin. Around 70% of this irrigation (554,000 acres) is located in areas deemed 'fully appropriated' by the NDNR. Basin-wide 84% of the irrigation is associated with groundwater sources versus 81% in the fully appropriated areas.

Future (potential) irrigation development was estimated by identifying currently non-irrigated land with similar bio-physical characteristics as nearby irrigated land and is 106,000 acres which is 13.3% more than current irrigation acreage. However, many well informed stakeholders in the Basin feel that very little potential irrigation development exists. Around 64% of this GIS-estimated potential irrigation is located in 'fully appropriated areas and 65% are associated with groundwater supplies, versus 45% with surface water resources, and 10% with dual supplies.

The Economic Value of Irrigation

Surface water irrigation in the Mirage Flats Irrigation District (Box Butte Reservoir) which uses an average of 10,220 acre-feet of water annually, is characterized by high inefficiency (water loss during delivery) at a cost to irrigators of between $25 and $40 per acre-foot received. In the Ainsworth Irrigation District (using water from Merritt Reservoir), an average of 75,629 acre-feet of water is diverted for irrigation annually at a cost of $31 to $36 per acre-foot received.

Hedonic price modeling (multiple regression analyses based on GIS classifications of 896 agricultural land sale transactions across the Basin from 2000 to 2008), was shown to be an accurate and reliable approach to quantify the economic value of irrigation in specific market segments. Basin-wide hedonic-based marginal irrigation values are $827/acre which corresponds to values of $62 per year or $67 per acre-foot of water utilized by irrigators per year.

These irrigation values varied substantially across the seven NRD-based market segments (ranging from $412 to $916 per acre or $31 to $74 per acre per year). The contribution that irrigation (measured by marginal prices) makes to total irrigated land sale values was on average 63% across the entire basin and ranged from 51% to 89% in particular NRD market segments. As expected, higher contributory percentages were found in relatively drier market segments with greater irrigation needs. Basin-wide, current irrigation has an economic value of $44 million per year or $29.4 million per year in the fully appropriated areas.

Comparing Alternative Water Use Values in the Basin

Basin-wide, the value of irrigation as measured by buyers' willingness to pay for it is about twice as high as what surface irrigators are actually paying for delivered surface water. In the Ainsworth Irrigation District, irrigators pay between $31 and $36 per acre-foot for delivered water while the marginal price of irrigation water in that market segment (Middle Niobrara/South) is $74 per acre-foot. In the Mirage Flats Irrigation District irrigators pay between $25 and $40 per acre-foot of delivered water while the marginal price of irrigation in that market segment (Upper Niobrara-White/South) is $54 per acre-foot.

Average annual irrigation values based on imputed market prices and water allocations within each NRD are $67 per acre-foot of water used. This value is substantially higher than the water values associated with Spencer Dam hydro-electricity generation ($0.32 to $1.09 per acre-foot).

Under the assumption that 25% of groundwater irrigation (and all surface irrigation) in areas of the Basin upstream of Spencer Dam would return to the River if not used for irrigation, its value is $7.7 million per year which is 19% lower than in-stream flow values (recreational floating and hydro-electricity generation which were previously estimated to be $9.5 million per year). Assuming a 50% return rate for groundwater irrigation, irrigated agriculture is valued at $11.9 million (25% higher than in-stream flow values). Assuming a 75% return rate, irrigated agriculture is $17.5 million (84% higher than in-stream flow values). However, if the geographical focus of these irrigated agriculture versus in-stream flow values is limited only to the middle Niobrara NRD (the area immediately surrounding and upstream of the evaluated in-stream flow activities), than irrigated agriculture has an estimated value that is from 21% to 48% lower than in-stream flow values (depending on assumed groundwater return rates).

In addition to the uncertainty of actual groundwater return rates in the Basin, a major limitation to such comparisons of irrigated agricultural values to in-stream flow values is that recreational activates other than floating the NSR portion of the River, as well as option and existence values which residents statewide may place on Niobrara River flows, and various fishery, wildlife, ecological values associated with such flows have not yet been estimated and included in the comparisons.

1. INTRODUCTION

Background

The Niobrara River Basin extends 486 miles across Nebraska from Wyoming in the west to the confluence of the Missouri River in the east (Figure 1.1) and encompasses 7.6 million acres of pasture/grazing/livestock production, wet meadows, and both dry and irrigated cropland production from both ground and surface water sources. The upper section of the National Scenic River portion of the Niobrara River located in the middle of the Watershed near Valentine, NE, is heavily used for recreational floating from June to August, and these recreational flows are dependent on both overland stream and groundwater flows and therefore are influenced by out-of-stream water uses.

In May 2006, the Nebraska Game and Parks Commission (NGPC) commissioners directed their staff to develop in-stream flow recommendations for fish, wildlife, and recreation resource needs associated with the Niobrara River. This resulted in the NGPC undertaking several hydrologic, recreation, and fisheries studies.

In January 2008, the Nebraska Department of Natural Resources (NDNR) declared most of the Niobrara Basin to be ‘fully appropriated’ limiting additional (future) permits for groundwater water rights (NDNR, 2008). The three primary Natural Resource Districts (NRDs) in the Basin (the Upper Niobrara-White, the Middle Niobrara, and the Lower Niobrara) and two adjacent but partially affected NRDs (the Upper Elkhorn and the Upper Loup) are quantifying existing groundwater irrigation use as part of required integrated management plans for groundwater within their districts while the NDNR continues to manage surface water irrigation permits.

Figure 1.1 Location Map of the Niobrara Basin

Nebraska in-stream flow laws and regulations (*Statute 46-2,116)* specify that an in-stream appropriation must be in the public interest on the basis of: 1) The economic, social, and environmental value of the in-stream use or uses including, but not limited to, recreation, fish and wildlife, induced recharge for municipal water systems, and water quality maintenance; and 2) The economic, social, and environmental value of reasonably foreseeable alternative out-of-stream uses of water that will be foregone or accorded junior status if the appropriation is granted. This second criteria, out-of-stream utilization of water and its resulting economic value, is the focus of this present study.

Prior to the initiation of this study it was determined through discussions with public officials and stakeholders throughout the Niobrara Basin that the primary non-recreation based water uses in the Niobrara Basin are irrigated agriculture (both from ground and surface water sources), hydro-electricity generation (by the Nebraska Public Power District at Spencer Dam), a single major industrial usage in the form of an ethanol plant in Ainsworth, and finally, municipal water systems supply for a relatively small number of residents in the largest cities and towns across the Basin (Valentine, Chadron, O'Neill, and Alliance).

A recent relevant development in the Basin is the NPPD subjugation of junior appropriators. In 2006 NPPD met with the Department of Natural Resources regarding the diminishing flow of the Niobrara River which was negatively effecting power production at Spencer Hydro-Power Plant. In 2007, for the first time in 50 years, NPPD attempted to exercise its right as a senior appropriator to have junior appropriators with a preferred use designation (crop irrigators) pay for foregone power production due to reduced flow. Several lawsuits have been filed on behalf of different irrigators challenging NPPD's call for water (on whether it should be allowed, the time frame, and the valuation of charges). As of May 2010, all cases have decided in favor of NPPD.

It was also expected that irrigated agriculture is the out-of-stream water utilization with the greatest likelihood of continuing and/or expanding in the coming years in the Basin, particularly if the fully-appropriated designation that is now in place was ever lifted and/or if new water supplies and/or rights were to become available to landowners.

Such irrigated cropland expansion would require the conversion of either existing (dry) cropland or suitable pasture land using either groundwater sources (i.e. well pumping) or from surface water diversions. Potential surface water-based irrigated cropland developments would most likely be associated with pumping water directly from rivers or streams (i.e. the Niobrara or one of its many tributaries) or diverted directly from Merritt Reservoir (associated with the Ainsworth Irrigation District). However, irrigation expansion would not likely be derived from Box Butte Reservoir (associated with the Mirage Flats Irrigation District) which in the last decade has suffered from low water levels and inconsistent irrigation deliveries.

This study quantifies the extent and economic value of both current and potential (i.e. future) agricultural, municipal, and industrial water uses in specific parts of the Niobrara Basin using a variety of approaches and data sources. Analyses of municipal, industrial and hydro-electric-based water uses are determined primarily on secondary (already existing) analyses and reports. In contrast, both current and potential (future) irrigated water usage and its associated economic values are estimated through more complex and elaborate approaches including geographic information system-based (GIS) analyses of land coverage data integrated with a variety of data including well, river and reservoir locations, land productivity indices, and real estate transaction data.

Efforts to quantify the extent and value of irrigated agriculture is conducted within seven different geographical sub-regions of the Niobrara Basin with relatively homogenous land productivity and irrigation supply factors, watershed delineations, and NRD administrative boundaries. The seven sub-regions include the areas north and south of the Niobrara River within the three major Natural Resource Districts (NRDs) in the Basin, and the Upper Elkhorn NRD. Irrigation within the relatively small section of the he Upper Loup NRD which is in the Niobrara Basin is combined with the adjacent Middle Niobrara South NRD segment.

Finally, it should be noted that this study makes estimates of the extent and value of both groundwater and surface irrigation and considered together. Surface irrigation could be in the form of irrigators pumping water directly from a stream or river and/or irrigators who are members of the two reservoir-based surface water irrigation districts in the Niobrara Basin: the Ainsworth Irrigation District located within the Middle Niobrara NRD which utilizes surface irrigation supplied via canals from the Snake River (Merritt Reservoir) and the Mirage Flats Irrigation District which receives water via canals from the Box Butte Reservoir in the Upper Niobrara-White NRD and which is north of Niobrara River. If water was not stored in these reservoirs for the purposes of irrigation, it would otherwise flow directly into the Niobrara River.

Study Objectives

This study has two primary objectives: 1) Evaluate and describe the primary out-of-stream and industrial water users across the Niobrara Basin; 2) Estimate the extent (water usage) and the economic values associated with these water uses both now and in the future.

Based on prior knowledge of the Basin, the study concentrates on the following water uses: municipal and industrial uses (drinking water supplies and ethanol plants), ground and surface water irrigated agriculture, and hydro-electric generation (at Spencer Dam by the Nebraska Public Power District).

These tasks are accomplished through the collection of secondary data sources (reviews of previous studies and reports), through primary data collection efforts (contacting water use managers from both the private and public sector), through GIS analyses (quantifying current and potential irrigation), and finally through analyses of real estate transaction data (to quantify irrigation values).

This information is intended to provide the NGPC, state policy makers, and other interested stakeholders with objective and accurate data regarding the current and potential (i.e. future) value of water consumption of both ground and surface water resources across the Niobrara Basin. Such information is considered critical to the goal of maximizing the societal benefits of water resources in the Niobrara Basin for the joint benefits of both local and statewide stakeholders.

2. MUNICIPAL AND INDUSTRIAL WATER USES AND VALUES

Municipal Water Supply Uses and Future Needs

Municipal water supply information was collected from the Nebraska USGS Water Science Center and from personal interviews with city managers and/or water treatment managers of the four largest municipalities in the Niobrara Basin (Valentine, Chadron, O'Neill, and Alliance). [1]

Population trends for each Niobrara NRD region were obtained from the U.S. Census Bureau for counties within the Niobrara Basin in order to evaluate current and future demand for municipal drinking.

Population in the Niobrara Basin has declined in the last decade particularly in the Lower Niobrara NRD. Beginning in 2000 and ending in 2008, the Lower Niobrara NRD has lost 13% of its population. The Upper Niobrara-White and Middle Niobrara districts have each lost 10% during the same period. The largest nominal population loss occurred in the Upper Niobrara-White NRD which experiences a reduction of 2,568 people over this time period.[2]

Most of the sources for municipal water uses in the basin are from groundwater. A survey of the four largest municipalities in the basin revealed that only one (Chadron in the Upper Niobrara-White NRD) received a portion (30%) of its potable water from a surface water source.[3] Valentine, O'Neill, and Alliance, Nebraska use ground water exclusively as do most other small municipalities in the Basin. Rural residents in the Basin receive their potable water from private groundwater wells.[4]

Barring a drastic change in population trends and/or water source preference, residential potable water use will not put additional strain on surface water resources. As the population in the region declines, potable water demands should remain constant or mirror population trends. Moreover, current ground water supplies are meeting municipal and rural potable water demands and the quality of ground water is such that it typically does not need treatment. Thus, it is unlikely that municipalities would choose surface water over ground water if ground water supplies are available.

Current and Potential Use of Water by Ethanol Plants

Personal discussion with NRD managers and agricultural producers in the summer of 2008 determined that ethanol plants were the only relevant industrial user of water (actual or potential) in the Niobrara Basin other than hydro-electricity production by the Nebraska Public Power District (NPPD) at Spencer Dam. Information regarding factors influencing the location and feasibility of ethanol plants in Nebraska were obtained and evaluated based on documents and reports from the Nebraska Ethanol Board.[5]

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[1] http://ne.water.usgs.gov/wudatasw.html.
[2] Data from the US Census Bureau online at http://quickfacts.census.gov/qfd/states/31000.html and the Nebraska NRD website at http://www.nrdnet.org/.
[3] http://www.chadron-nebraska.com/public-works/water--sewer.html.
[4] PER: Valentine and O'Neill Nebraska City Managers.
[5] http://www.ne-ethanol.org/industry/ethplants.htm.

Financial statements from the ethanol plant located in Atkinson, Nebraska, and owned by NEDAK Ethanol LLC were evaluated. Currently this is the only ethanol plant in the Niobrara Basin. Finally, statewide data on corn production by county was obtained from the USDA National Agricultural Statistical Service (www.nass.usda.gov) and used to evaluate whether corn production in the Niobrara Basin is sufficient enough to result in the construction of additional ethanol plants in the region.

A typical small capacity ethanol plant, such as the one near Atkinson, Nebraska, has an estimated annual grind of 17 million bushels. The Upper Niobrara-White NRD combined county production in 2007 was 15.1 million bushels of corn. The total corn production of the Middle Niobrara, including portions of Cherry County Nebraska not within the borders of the Middle Niobrara NRD, was 10.8 million bushels in 2007. The Lower Niobrara NRD has had the highest production which, in 2007, was 51.8 million bushels.[6] Most corn production in the Lower Niobrara NRD is attributed to Holt County which mostly resides in the Upper Elkhorn NRD. An ethanol plant currently operates in Atkinson located in Holt County.

The profitability of ethanol plants in Nebraska is a function of crude oil prices, corn price per bushel, and plant efficiency (Perrin and Roberts, 2009). Site selection is also important in ensuring plant sustainability. Access to major highways and/or rail appears to be a key site selection consideration as well as proximity to cultivated corn crops. This is especially true for small capacity ethanol plants where profit margins may be slim and average transportation costs may be considerable.

High construction costs and miscellaneous expenses add to the overall risk of ethanol plant investments. The Atkinson plant is situated in the highest corn production county (Holt), in the Niobrara Basin with adequate access to highways and a rail line in O'Neill. Thus, the Atkinson plant may represent a "best case scenario" for a production plant in any Niobrara NRD. The financial statements of NEDAK Ethanol LLC show that overall costs to bring their Atkinson plant online were $111.6 million. Total profits for the most recent reported two years were losses of $1.47 million and $4.75 million in 2007 and 2008, respectively.[7]

The likelihood of any new ethanol plants emerging and sustaining operations in any of the three Niobrara Natural Resource Districts is low considering high potential transportation costs coupled with the risky nature of the ethanol industry. This is especially true in the Upper Niobrara-White and Middle Niobrara districts where combined corn production is not enough to sustain a small capacity ethanol plant in either district. The probability in the Lower Niobrara district is higher however the existence of the Atkinson plant decreases the likelihood. Although rising future corn prices may lead to an increase in corn production in the Niobrara Region, an increase in production as a result of rising prices would not entice ethanol expansion.

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[6] Data for annual corn production per county from the National Agricultural Statistical Service www.nass.usda.gov.
[7] NEDAK Ethanol, LLC Notes to condensed Financial Statements September 2009.

NPPD Hydro-Electricity Generation at Spencer Dam

Background

The Spencer Dam and hydro-electricity generating plant is located in Holt County in the Lower Niobrara NRD. Construction of the dam was completed in 1927 with an originally planned economic life of 100 years. The dam foundation is soil with a storage capacity of approximately 16,487 acre-feet and a maximum discharge of 0.46 acre-feet of water per second. The plant has two generators with a maximum capacity of 3,000 kilowatt hours.[8] Maximum generation at Spencer Hydro occurred in 1957 when the plant generated 15,059 MWh of electricity. In the last 20 years the maximum power generation occurred in 1996 when Spencer Hydro generated 14,848 MWh of electricity.

In March 2007, NPPD exercised their senior water priority rights for the first time in over 50 years through a request for water administration to the NDNR. NPPD claimed that reduced flow along the Niobrara River had resulted in reduced output and required just compensation for the foregone revenues. It is important to note that under Nebraska statutory law for surface water appropriation,

> "…… the one first in time is first in right.[9] However, [priority of appropriation shall give the better right as between those using the water for the same purposes, but when the waters of any natural stream are not sufficient for the use of all those desiring the use of the same, those using the water for domestic purposes shall have the preference over those claiming it for any other purpose, and those using the water for agricultural purposes shall have the preference over those using the same for manufacturing purposes.[10] No inferior right to the use of the waters of this state shall be acquired by a superior right without just compensation therefore to the inferior user. The just compensation paid to those using water for power purposes shall not be greater than the cost of replacing the power which would be generated in the plant or plants of the power user by the water so acquired."[11]

On May 1, 2007, 400 surface water irrigators were issued regulating/closing notices by the NDNR. Those who entered an agreement with NPPD were allowed to resume irrigation. Approximately 65 irrigators entered the new subordination agreement with NPPD at an NPPD set price of .70 dollars per acre-feet[12]

On May 10, 2007, a lawsuit was filed with the U.S. District Court on behalf of the surface water irrigators receiving cease and desist notices. For the duration of the lawsuit, the cease water use orders were lifted. The lawsuit was dismissed by the U.S. District Court judge and the cease irrigation orders were re-instated. Surface water irrigators with rights that dated post-rights granted to NPPD were told they must pay NPPD or stop using the water. When the water flows increased, the cease and desist orders were again lifted but a warning was issued that should

[8] http://www.nppd.com.
[9] Neb. Rev. Stat. § 46-203.
[10] NPPD's Spencer Hydro falls under the description of manufacturing use.
[11] Neb. Rev. Stat. § 70-669.
[12] Presentation at the University of Nebraska Lincoln Water Center by Tom Wilmoth available online at: watercenter.unl.edu/WaterConference/2009WLPS/PPTs/WilmothTom.pdf.

flows again decrease, the cease use would be re-issued.[13] In April 2009, the 8th U.S. Circuit Court of Appeals remanded the case back to the district court. The final ruling of the case between Keating et al. (Surface Water Irrigators) and NPPD was in favor of NPPD in that the irrigators must stop using the water or pay NPPD the stated price.[14]

The quantity of water used by NPPD for hydro-electricity generation at the Spencer Dam in the lower section of the Niobrara Basin was determined by a review of two affidavits submitted as part of the above mentioned law suit as well as by analyses of stream flow measurements from the USGS River Gage (No. 06465500) at Verdel, Nebraska.

The first case between Gerald J. Keating et al. and The Nebraska Public Power District (Case No. 07-3056) focuses on water use based upon current rights held by NPPD's Spencer Hydro. Each permit states the amount of water reserved for NPPD and combining the permits gives the total quantity of water allotted to the Hydro Power Plant. The second affidavit is from the case between Jack Bond and Joe Mcclaren Ranch LLC, and The Nebraska Public Power District (Case No. CI07-45).

Through the Nebraska Department of Natural Resources which manages surface water rights in the state, NPPD possesses three surface water appropriation permits defined as follows:

> "….Permit A-359 is dated September 12, 1896, and was originally issued for Minnechaduza Creek but was transferred to the Spencer Dam in 1996. It permits the use of 35 cubic feet of water per second. Permit A-1725 was approved in 1925 prior to the 1927 construction of the first Spencer Dam, which was later destroyed by ice in 1935 and reconstructed around 1940. It permits the use of 1450 cubic feet of water per second. The third permit, A-3574, was approved on June 8, 1942, and allows for the use of 550 cubic feet of water per second from the Niobrara River. Both the A-1725 and A-3574 permits state that the grants are made subject to Nebraska irrigation laws which give preference to water appropriators who use the water for domestic and agricultural uses over those who use the water for manufacturing and power purposes."[15]

Based on this definition, NPPD water rights for hydro-electric production at Spencer Dam are 2035 cubic feet per second or 1,473,272 acre feet per year.[16]

Another method for determining water use for hydro-electricity generation at Spencer Dam is actual use (as measured by stream flow gages). According to an affidavit in the previously mentioned court case (#CI07-45), a consultant on behalf of irrigators reported that total annual flow in 1996 as per the government stream gage was 1,740,377 acre feet

The Value of Water Associated Hydro-Electricity Production at Spencer Dam

Estimates of the value of water for hydro-electricity production at Spencer Dam by both sides of the recent irrigator-NPPD lawsuit are first reported and evaluated. Then some additional values

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[13] United States Court of Appeals for the 8th Circuit Case No. 07-3056.
[14] Document #186 Case: 7:07-cv-05011-LES-FG3 Filed:5/12/10.
[15] United States Court of Appeals for the Eighth Circuit Case No. 07-305 pg 3.
[16] 1 acre feet of water=43,560 cubic feet of water. Acre feet per year becomes acre feet per second annualized.

are estimated based on data reported by the litigators and defendants combined with additional river flow data obtained by the USGS.

A consultant working on behalf of the landowner/irrigators in their lawsuit against NPPD calculated the value of water on an acre-foot basis by dividing gross sales by water flows.[17] Gross energy sales of $564,224 were based on energy production in 1996 (14,848 MWh) valued at year 2006 wholesale prices of $38 per MWh. The water flows were based on 2009 water flows at the Verdel, NE gage station (1,740,377 acre feet).[18] This resulted in a valuation of water of $0.32 per acre feet. These analyses and affidavits did not explain or justify why multi-year averages of water flows, hydro-electricity generation, and prices were used to estimate hydro-production values.

For this report, two alternative valuations of water associated with the production of hydroelectricity at Spencer Dam were undertaken. First, NPPD reported gross revenues from hydro-electricity generation in 2007 from Spencer Hydro ($700,000)[19] was divided by water flows at the Verdel gage in that same year (1,224,313 acre-feet)[20] which generates a value estimate of $0.57 per acre-foot. Second, this same year's gross revenue figure was divided by actual water rights held by the NPPD (1,473,272 acre-feet) resulting in a value estimate of $0.48 per acre-foot. Ideally such analyses should utilize average (10-year) gross revenue and flow data but the required annual hydro-electric generation data at Spencer Dam could not be accessed.

According to Resolution No. 09-17 from the minutes of the NPPD Board of Directors meeting on February 12-13, 2009, the compensatory rate for water is to be $0.80 per acre-feet[21] NPPD reports however, the actual cost of water based upon foregone power production is $1.09 per acre-feet. The values are calculated from market-based power projections prepared by NPPD's planning department. They are based upon water that actually passes through the generators, (873,777 acre-feet) and future estimates of power costs.[22] Thus, NPPD's calculation method is similar to the gross revenue of this report. However, since it uses water flow through the turbine rather than rights held or river flows, the denominator is smaller which increases the per acre-feet value. Readers are invited to review to Appendix A of this report to see more details on the NPPD approach used to value water used for hydro-electric generation at Spencer Dam.[23]

[17] Affidavit of David L. Sunding, Ph.D. Case No. CI07-45 In the County Court of Boyd County, Nebraska.
[18] United States Court of Appeals for the Eighth Circuit Case No. 07-305 pg. 3
[19] From court filing before Riley, Gruender, and Shepherd, Circuit Judges and from NPPD's Annual Report
[20] Flow data from USGS stream gage near Verdel Nebraska http://waterdata.usgs.gov/ne/nwis/uv?06465500.
[21] Minutes of Regular Meeting of the Board of Directors of Nebraska Public Power District, February 12-13 2009.
[22] Correspondence with Brian Barels NPPD Water Resource Manager.
[23] Case No. 08-03 County Court of Boyd County, Nebraska. Lon Keim and Lon Breiner vs. Nebraska Public Power District.

3. THE EXTENT AND NATURE OF CURRENT IRRIGATION

Irrigation Acreage Estimates from NRDs and the NDNR

Each of the five Natural Resource Districts (NRDs) in the Niobrara Basin were provided their most current estimates of certified groundwater acreage within their boundaries and estimates of surface water irrigation. Estimates were requested for the entire boundaries of NRDs and within areas deemed fully appropriated by the Nebraska Department of Natural Resources (NDNR) in 2008. As well, the NRDs with land areas both south and north of the Niobrara River were requested to estimate irrigation acreage by such designations.

The NDNR provided their most current summary of irrigated acres under surface water permits within each NRD in the basin. Each permit has a project map that delineates the land where surface water may be applied. The permit allows for the use of water at a specific place for a specific beneficial purpose, but it may not be exercised every year. It is likely that some irrigators have both surface and groundwater irrigation sources which could result in the over counting of total irrigated acres.

As well, to identify the extent of surface water irrigation acreage within the Mirage Flats and Ainsworth Irrigation Districts, historical irrigation acreage statistics were requested from these districts and the Bureau of Reclamation. The Mirage Flats Irrigation District in the Upper Niobrara-White NRD receives water from Box-Butte Reservoir on the Niobrara River. Many of the irrigators in this District supplement surface irrigation water with groundwater pumping. The details of Mirage Flats are evaluated in Chapter 5. Based on this it is estimated that the District uses (diverts) an average of 10,200 acre-feet of water annually to irrigate approximately 5,000 acres. The Ainsworth Irrigation District in the Middle Niobrara NRD which receives water from Merritt Reservoir on the Snake River (a tributary to the Niobrara River) is also evaluated in detail in Chapter 5. It uses (diverts) on average 75,629 acre-feet of water per year to irrigate approximately 31,000 acres of land.

The approaches used by several of the NRDs to certify (estimate) irrigation acreage within their boundaries is summarized in Appendix B of this report. These approaches relied on secondary data sources (county tax assessor records and information from the Farm Service Agency of the USDA) and the mapping of irrigation field boundaries using GIS technologies.
The Upper Loup NRD also used GIS approaches to quantify irrigation acreage. The Upper Elkhorn NRD did not formerly certify and place into a GIS database irrigation acreage but instead made informal (ballpark) estimates of irrigation acreage based on irrigation acres on county tax rolls (for fully appropriated areas) and by assuming 122 acres of irrigation for each registered irrigation well in non-fully appropriated areas. The Lower Niobrara NRD did not report specific methodologies used to certify their irrigation estimates and such estimates were only provided for fully-appropriated areas.

In cases of known (i.e. reported) overlaps between groundwater and surface irrigation acres (termed combination irrigation acres), these combination values are subtracted from irrigation acreage totals (groundwater irrigation acres plus surface water irrigation acres) to avoid double counting.

It is important to point out that the estimates of irrigation acreage contained in this Report may need to be revised and/or changed over time because certified irrigation acreage estimates by the different NRDs were just recently completed and are in many cases noted as ‘preliminary estimates’. As well, some irrigators may stop irrigating certain land parcels in the coming years and/or switch supply sources (groundwater versus surface water) in cases of irrigators having both types of irrigation rights.

The resulting reported irrigation estimates broken down by whether they are groundwater or surface water based and by the entire basin versus fully appropriated areas are summarized in each NRD in Table 3.1.

Table 3.1. Irrigation Acreage Estimates As Reported by NRDs and the NDNR*

	Total Irrigation Acreage	Surface Irrigation	Groundwater Irrigation
Upper Niobrara-White NRD (All)	276,985	27,400	249,585
Upper Niobrara-White (Fully App)	273,569	27,400	246,169
Middle Niobrara (All)	134,428	48,800	85,628
Middle Niobrara (Fully App)	132,295	48,800	83,495
Lower Niobrara (All)	Not Reported	Not Reported	Not Reported
Lower Niobrara (Fully App)	106,200	16,200	90,000
Upper Elkhorn (All)	135,598	16,821	118,777
Upper Elkhorn (Fully App. Only)	40,484	14,170	26,314
Upper Loup (All)	1,446	0	1,446
Upper Loup (Fully App. Only)	1,446	0	1,446

** Individual NRDs reported groundwater irrigation estimates and in some cases surface water irrigation estimates while the NDNR only reported surface irrigation estimates.*

Additional GIS-Based Estimates of Irrigation Acreage (CALMIT 2005).

A Geographic Information System (GIS) approach was used to quantify irrigation acreage across the Niobrara Basin (the watershed boundary) to verify the accuracy of the above NRD/NDNR reported irrigation estimates, and to generate irrigation estimates for areas not reported by NRDs (in particular, the non-fully appropriated portion of the Lower Niobrara NRD and areas within particular NRDs north and south of the Niobrara River).

Another advantage of having a GIS-based irrigation acreage data set is that it allows irrigation acreage to be evaluated in conjunction with other GIS data (land characteristics and water supply conditions in order to more fully evaluate the nature of irrigated agriculture as well as to estimate potential (future) irrigation development (which is the focus of Chapter 4).

The GIS irrigation database relied upon in this study is referred to as CALMIT (2005). It was created by the Center for Advance Land Management Information Technologies (CALMIT) at the University of Nebraska-Lincoln and is summarized basin-wide in Figures 3.1 and 3.2. It is a land use cover database derived from both supervised and unsupervised classifications of multi-temporal Landsat satellite images at a 30 meter spatial resolution (Dappen, Merchant, Ratcliffe and Robbins 2007). Land use classifications include pasture, hay, irrigated cropland, wetlands and wet meadows, water, forests, etc.). It appears the approaches used to classify irrigated cropland in this database closely followed the methods used in the 2001 delineation of land use and cover for COHYST in other parts of the state (Dappen and Merchant 2003).

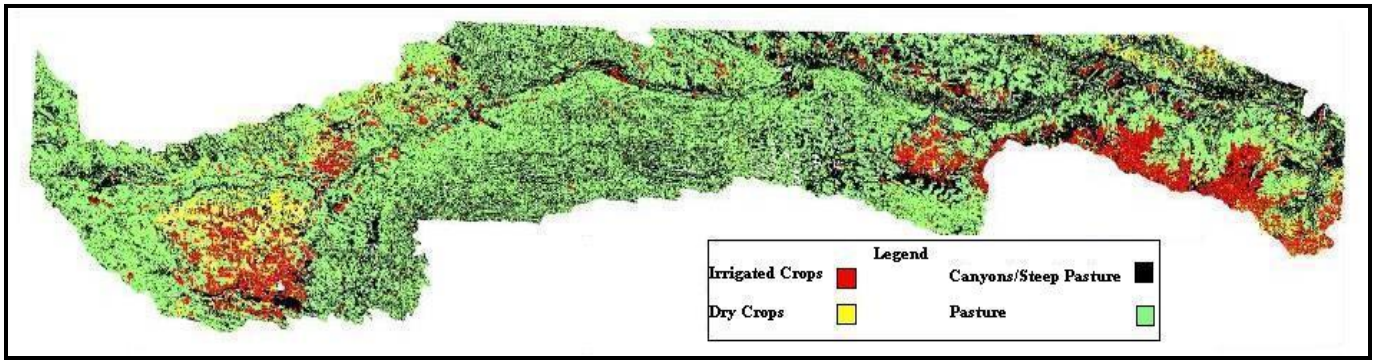

Figure 3.1. CALMIT 2005-Based Land Cover and Irrigation across the Niobrara Basin

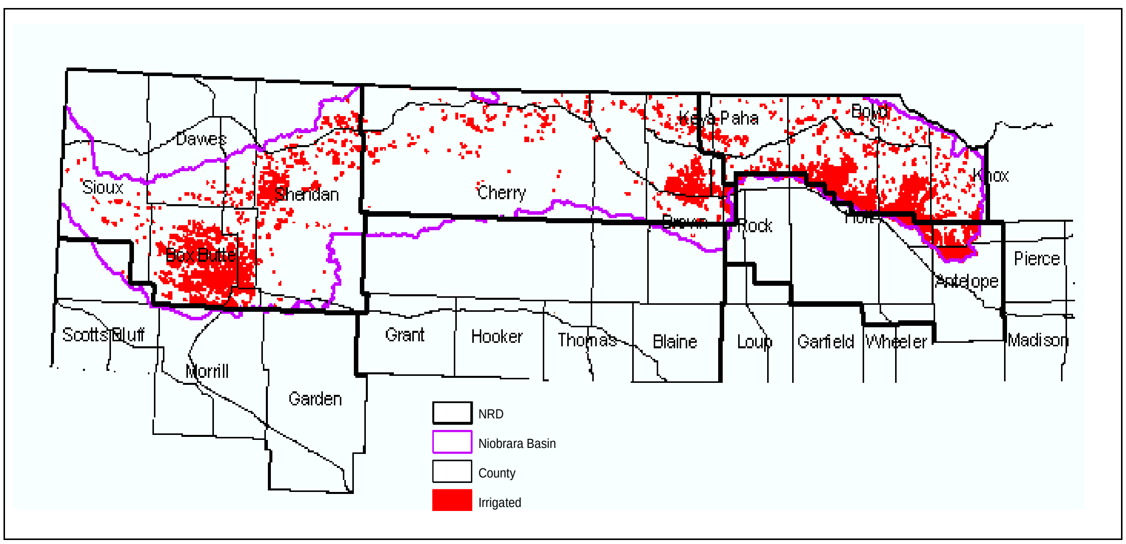

Figure 3.2 CALMIT (2005) Irrigation Acreage across the Basin and by Counties

The accuracy of CALMIT (2005) irrigation acreage estimates were assessed simply by comparing differences between CALMIT (2005) irrigation acres and those reported by each of the NRDs and the NDNR. From the outset, the NDNR and NRD reported estimates of irrigation are considered superior (more accurate than the CALMIT-based estimates because they are more up-to-date (made in 2009 and 2010) whereas the CALMIT estimates are based on 2005 data); and they are made by local natural resource professionals using a variety of different (and often cross-referenced) data sources including irrigation permit databases, landowners surveys, field checks, air photos, and often CALMIT 2005 and/or other GIS data.

Current (2009-2010) groundwater irrigation acres, as reported by the Upper Niobrara-White, Middle Niobrara, and Lower Niobrara NRDs, are summarized in Line 1 of Table 3.2. The Upper Niobrara-White and Middle Niobrara NRDs reported irrigation for all of their administrative areas, whereas the Lower Niobrara NRD only reported irrigation acreage for their fully appropriated areas.

The Upper Elkhorn NRD only reported irrigation acreage estimates based on the assumption that each registered irrigation well in the Niobrara Basin portion of their NRD was associated with 122 acres of irrigation (resulting in a total of 81,750 irrigated acres). Since this estimate is not considered as accurate as actual CALMIT (2005) irrigation classification data, it is not compared to CALMIT (2005) irrigation acreage estimates. Instead, CALMIT-based irrigation estimates in the Upper Elkhorn NRD are adjusted by the same parameters that were used to obtain GIS-based estimates in the nearby Lower Niobrara NRD, which has fairly similar land use conditions.

Surface water irrigation estimates made by the NDNR (via email correspondence with Mike Thompson in December of 2009) are reported on line 2 of the table while combined (total) irrigation acre estimates are reported in line 3. The CALMIT (2005) irrigation estimates, as shown in Figure 3.1 (along with other land cover classification across the entire Niobrara Basin) and reported on line 4 of the table, are followed by calculations of their accuracy on a percentage basis as compared to NRD and NDNR reported estimates which again are considered the most accurate available.

Table 3.2. Comparisons of NRD/NDNR Reported Irrigation Acreage Estimates with CALMIT (2005) Based Estimates

	Upper Niobrara-White	Middle Niobrara	Lower Niobrara (Fully Appropriated Areas Only)
Groundwater Acres	249,585	85,628	90,000
Surface Water Acres	27,400	48,800	16,200
Total Irrigated Acres	276,985	134,428	106,200
CALMIT (2005) Irrigated Acres	233,997	102,210	89, 541
CALMIT (2005) Accuracy	16% Under	24% Under	16% Under

Basin-wide, CALMIT (2005) under-estimated actual irrigation by 18% (16% in the Lower Niobrara and Upper Elkhorn NRDs, 24% in the Middle Niobrara NRD, and 17% in the Upper Niobrara-White NRD).

It is not known if these CALMIT 2005 under-estimates are a result of the estimates being based on five-year-old satellite imagery data (i.e. whether new irrigation development has occurred since 2005) or whether they are simply less precise than the NRD-based estimates many of which are based on ‘ground-truthing’ using physical inspections and/or through the use of global positioning system coordinates, and actual irrigation/well permit data. A third explanation for the under-estimation of irrigation acreage by CALMIT 2005 is that not all of the NDNR reported surface irrigation acres may be irrigated every year, and/or some irrigators switching to groundwater sources without informing the NDNR.

To estimate irrigation acreage in the entire Lower Niobrara Basin (since only irrigation in fully appropriated areas was reported by the NRD), the CALMIT irrigation estimates were increased by 16% resulting in an estimate of 246,065 irrigated acres for the entire Lower Niobrara NRD (37,500 acres of surface irrigation and 208,466 acres of groundwater irrigation).

Therefore, basin-wide it is estimated that there are 794,522 irrigated acres of which 70% (553,994 acres) are located in fully appropriated areas. And most (83% or 663,902 acres) of the irrigation is based on groundwater sources. Finally most of the irrigation occurs in the Upper Niobrara-White and Lower Niobrara NRDs (and 35% and 31% of all irrigation, respectively).

The relative amount of groundwater, surface and total irrigation in the different NRDs in the Basin are summarized in Figure 3.3 and Table 3.3. Basin-wide 84% of all irrigation is groundwater based and 81% of all fully appropriated irrigation is groundwater based. Most (49%) of the fully appropriated irrigation acreage in the Basin occurs in the Upper Niobrara-White NRD, followed by the Lower Niobrara NRD (with 19% of all fully appropriated irrigation).

Finally, 84% of all irrigation Basin-Wide is from groundwater sources and this ranges from 90% in the Upper Niobrara-White NRD to 64% in the Middle Niobrara NRD. In fully appropriated areas the percentage of irrigation from groundwater sources is 81% Basin-wide, 90% in the Upper Niobrara-White NRD, 63% in the Middle Niobrara NRD, 85% in the Lower Niobrara, NRD, 65% in the Upper Elkhorn NRD, and 100^ in the Upper Loup NRD.

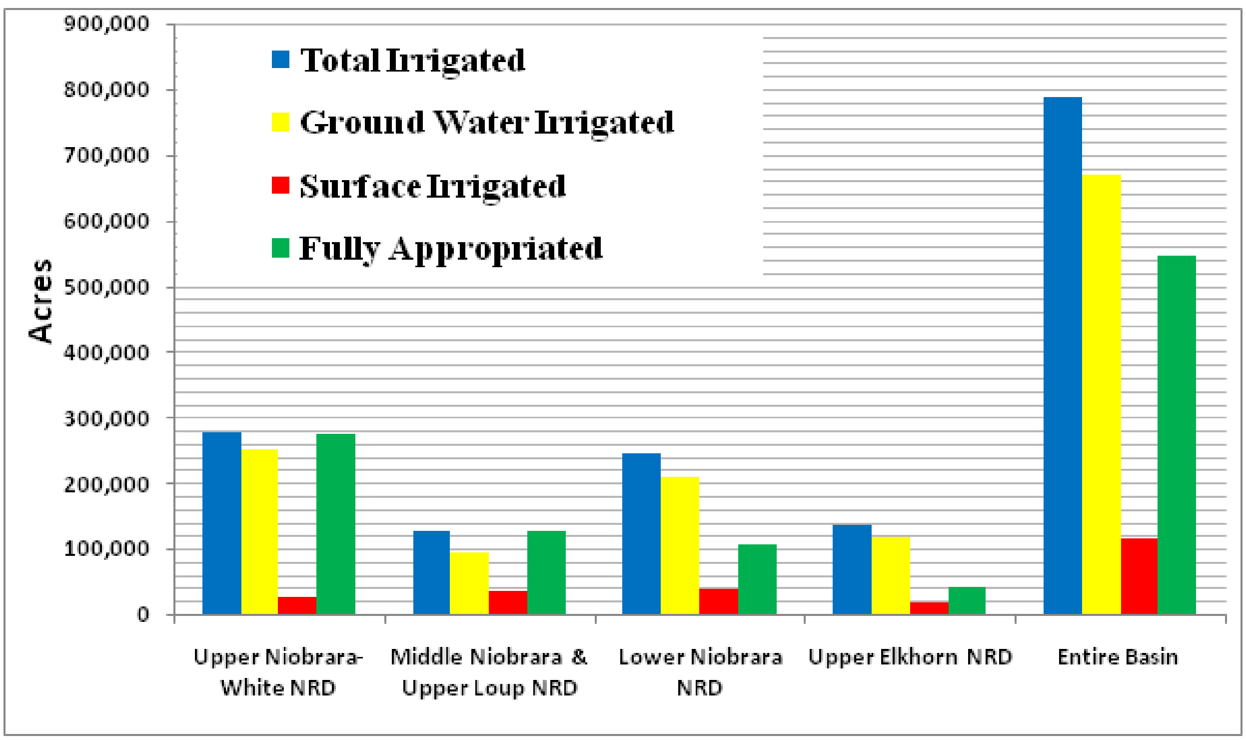

Figure 3.3. The Extent and Type of Irrigation Acreage Within and Across NRDs

Table 3.3 Relative Irrigation Acreage (% of Basin-Wide Irrigation) Across NRDs by Fully Appropriated Status and Irrigation Type (Groundwater versus Surface)

	Upper Niobrara-White		Middle Niobrara & Upper Loup		Lower Niobrara		Upper Elkhorn	
	All	FA	All	FA	All	FA	All	FA
All Irrigation	35%	49%	17%	24%	31%	19%	17%	7%
Surface Irrigation	21%	21%	37%	37%	29%	12%	13%	11%
Groundwater Irrigation	38%	55%	13%	19%	31%	20%	18%	6%

Finally, irrigation estimates were solicited from NRDs for specific market segments defined as North/South of Niobrara River designations within the Upper, Middle, and Lower NRDs. These North/South irrigation estimates were estimated for the Lower Niobrara NRD using the CAMIT 2005 database. The Middle Niobrara South segment includes the Upper Loup NRD portion of the Niobrara River. Such classifications were not done for the Upper Elkhorn NRD since all of it is south of the Niobrara River. These market segment irrigation acreage classifications are summarized in Table 3.4 and used later for valuing irrigation in specific market segments of the Basin.

Table 3.4 Irrigation Acreage Estimates for North/South Market Segments within NRDs

	All Irrigated Acres	Fully Appropriated Irrigation Acres
Upper Niobrara-White/North	84,561	83,405
Upper Niobrara-White/South	192,424	190,164
Middle Niobrara/North	36,934	35,934
Middle Niobrara/South & Upper Loup	98,940	97,807
Lower Niobrara/North	31,652	27,612
Lower Niobrara/South	214,413	78,588

The Characteristics of Irrigated Land

The mean levels of soil productivity associated within irrigated parcels (Common Land Unit as defined by the Farm Service Agency) that are at least 68% irrigated were compared to those of dry cropland and pastureland across the Niobrara Basin in Table 3.5. These soil productivity measures including SRPG (soil rating for plant growth as reported by SSURGO digital soils survey of the Natural Resource Conservation Service), average field slope based on digital elevation model (DEM) data compiled by the NDNR, and two measures of irrigation water availability: distances to active irrigation wells and the pumping capacity measured in gallons per minute (GPM) of wells closest to particular parcels.

These results clearly confirm widely held assumptions that irrigated parcels are less steeply sloped, have higher soil productivity, and much better access to water supplies than pasture land. As well, irrigated cropland has much better access to water supplies and is less steeply sloped than dry cropland which otherwise has similar soil productivity measures.

Table 3.5 Parcel Level Productivity Characteristics by Irrigation Status

Productivity Condition	Irrigated Parcels	Dry Cropland	Pasture
Slope	1.53	2.19	4.6
SRPG (soil rating for plant growth)	43.1	46.7	32.3
% Parcel that is wet/marsh	0.20%	0.30%	2.60%
% Parcels within 1.5 miles of An active irrigation well	96%	81%	63%
Gallons Per Minute of Closest Well	576	40	26

Estimates of the Quantity of Water Used by Irrigation

Total water usage associated with irrigation in the Basin were estimated by multiplying groundwater and non-irrigation district-based surface irrigation acreage estimates by irrigation needs based on grown corn (acre-feet of water per acre) plus actual surface water diversions associated with surface irrigation in the Mirage Flats and Ainsworth Irrigation Districts (10,200 acre-feet and 75,600 acre-feet, respectively).

Water needs for all irrigated acres were estimated based on average annual precipitation from the National Weather Service Forecast Office and corn plant usage data from the University of Nebraska-Lincoln and waterclaim.org (Yonts 2002).[24] Corn plant usage is based upon the amount of water each plant requires for maximum yield. Monthly county precipitation aggregates were taken and then averaged between the counties comprising each Niobrara NRD region to create Table 3.6.[25] Corn was specifically used in this estimate since it comprises the largest percentage of cultivated crop production in the district. As expected irrigation needs (water usage) is higher in the more western (and drier) Upper Niobrara-White NRD. Irrigation needs in the Upper Elkhorn NRD were assumed to be identical to the nearby Lower Niobrara NRD (11.2 inches per year). The average (mean) water usage across the entre Basin is 13 inches per acre (or 1.08 acre feet of water per acre of land). This means that on average, the amount of water needed to irrigate currently irrigated acres is 8% higher than actual irrigated acres.

[24] Evapotransporation map of Nebraska at www.waterclaim.org. and weather data Online at: http://www.nws.noaa.gov/climate/index.php?wfo=gid.
[25] NRD Average Monthly Precipitation is the simple average of all the counties that lie solely, or in part, within the borders of the Each Niobrara NRD.

Table 3.6 Estimated Irrigation Needs (Water Usage) by NRD

NRD	Corn Usage*	Seasonal Precipitation**	Estimated Irrigation needs (in Inches)***	Estimated Irrigation Need Per Acre (in Acre Feet)
Upper Niobrara White	28.75	12.75	16	1.25
Middle Niobrara	27.25	15.35	11.9	.99
Lower Niobrara	29.5	18.27	11.23	.94

*Corn Usage = Average amount of water in inches used by crop
**Seasonal Precipitation = Aggregate precipitation quantity in inches during the entire growing season
***Expected Irrigation in Inches= Net amount of additional need in inches

Table 3.7 summarizes ground and surface irrigation acreage estimates within NRDs while excluding irrigation acreage within the Mirage Flats and Ainsworth Irrigation Districts, estimated water usage (irrigation acres multiplied by acre-feet water needs from Table 3.5), water usage in the Mirage Flats and Ainsworth Irrigation Districts (in acre-feet) and finally, total irrigation water usage (likely water usage plus Irrigation District usage). Basin-wide, approximately 877,062 acre-feet of water is used annually (or 649,800 acre-feet in fully appropriated areas).

Table 3.7 Estimated Water Use From Current Irrigation Across the Niobrara Basin

NRD	Ground and Surface Irrigation Acres[1]	Estimated Water Use[2]	Acre-Feet Used in Irrigation Districts	Total Irrigation Water Usage
Upper Niobrara-White	265,315	331,644	10,200	341,844
Upper Niobrara-White (Fully Appropriated Areas)	261,899	327,374	10,200	337,574
Middle Niobrara & Upper Loup	101,874	100,855	75,600	176,455
Middle Niobrara & Upper Loup (Fully Appropriated Areas)	99,741	98,744	75,600	174,344
Lower Niobrara & Upper Elkhorn	381,663	358,763	0	358,763
Lower Niobrara & Upper Elkhorn (Fully Appropriated Areas)	146,684	137,883	0	137,883
Entire Basin				877,062
Entire Basin (Fully Appropriated Areas)				649,800

1. Excluding surface irrigation acreage within the Mirage Flats and Ainsworth Irrigation Districts.
2. Based on multiplying irrigated acres by required acre-feet per acre of corn production as calculated in Table 3.5.

4. FUTURE (POTENTIAL) IRRIGATION DEVELOPMENT

Future (potential) irrigated cropland development across the different NRDs of the Niobrara Basin was estimated through a GIS analysis of the previously described irrigation classifications based on the CALMIT 2005 database. It required classifying whether or not non-irrigated land parcels have similar bio-physical characteristics as irrigated parcels, and hence could potentially be developed for irrigation in the future.

The unit of analysis for actual and potential irrigation parcels is common land unit (CLU) as produced in GIS coverage by the USDA Farm Service Agency (FSA). CLU boundaries are used by the FSA for conducting business with landowners and agricultural producers and for the most part accurately represent actively managed agricultural production units. Most often they are sized at 80, 160, 320 and 640 acres, although pastureland-based CLU's are often much larger. CLU's are considered the best available representation of land parcels owned and/or managed by individual landowners and farm producers.

Land characteristics were quantified through spatial overlays, and summarized for each discrete CLU parcel. Land characteristics for this study included: the CALMIT 2005 land cover database, hydrologic data (river/streams and groundwater wells as compiled by the NE Department of Natural Resources),[26] soils information from the Natural Resources Conservation Service's (NRCS) SSURGO database, and field slope measurement derived from 30 meter digital elevation models (DEMS) obtained from the USGS National Elevation Dataset (NED).

The specific procedures used to estimate the irrigation potential status of land parcels throughout the Basin are summarized below in chronological order.

First, all public lands were removed from the CLU database. Second, already irrigated parcels were removed. These were CLU parcels that were 68% or more irrigated and totaled 653,163 acres (which represents 786,943 irrigated acres when the basin-wide under-estimation calibration of 17% is applied).

It is therefore assumed that land (approximately 6.9 million acres in the basin) currently used for pasture/grazing could potentially be converted to irrigated cropland if it contained similar physical characteristics to existing irrigated cropland parcels. It is also important to note that for this irrigation development to occur, much of the basin would have to have its fully appropriated status removed.

Next a determination was made regarding whether non-irrigated CLU parcels had similar bio-physical (i.e. productivity) characteristics as those of observed irrigated parcels. Selection criteria included; SRPG (soil rating for plant growth produced by the NRCS), average field slope (from a USGS digital elevation model); the extent of wetlands and/or marshy areas within parcels based on CALMIT 2005 data (with lower levels preferred for irrigated-based agricultural production); and whether parcels were within half a mile of a well that pumps at least 500 gallons per minute, or is within 1 mile of a perennial stream or river.

[26] The NE NDNR Well Database can be accessed at: http://NDNRdata.NDNR.ne.gov/wellssql/.

To improve the accuracy of such classifications, the above selection criteria were made within each of the previously seven agricultural production market segments in the Basin (i.e. the north/south designations of the three primary NRDs in the Basin and Upper Elkhorn NRD (which is entirely south of the Niobrara River.

A parcel is considered to have the potential for irrigation development when each of the physical traits evaluated are within the lower (or upper) limits of the inter-quartile range of the observed values of nearby irrigated CLU parcels (within the same NRD-based market segment classification). The inter-quartile range (IQR) is a statistical measure of dispersion of a mean value and represents the mid-spread of the middle 50% of a population. In contrast, a standard deviation represents 68.3% of the dispersion of a variable from its mean. The IQR range is used in this study because it is a more conservative and statistically robust measure of dispersion than a standard deviation. However, to evaluate the sensitivity potential irrigation estimates of the use of IQR versus a standard deviation measure, potential irrigation estimate values based on both measures are calculated and reported.

The selection of either a lower or upper IQR (or standard deviation) limit is predicated by whether the physical characteristic being evaluated has a minimum or maximum limiting effect. For example, if a mean SRPG (soil productivity) value for irrigated parcels within a particular NRD was 42 and the corresponding IQR was 6, this would indicate that SRPG values greater than or equal to 38 would be considered feasible for irrigation development or alternatively, that the bottom 25 quartile of low SRPG parcels (those with mean values below 38) are excluded. In contrast, irrigated parcels with a mean field slope value of 2.8 and an IQR of 0.8, would indicate that only parcels with mean slope values of less than 2.2 would be considered feasible for irrigation development (i.e. the upper quartile of slopes are excluded).

Finally, to be considered for irrigation potential parcels must not have extensive marsh and wetland areas defined as being less than 15% and based on the CALMIT 2005 data. The 15% criteria used in an early analysis indicated that no irrigation occurred on parcels with more than 15% marsh and wetlands within their fields.

The resulting limits of bio-physical characteristics necessary for irrigation development in different market segments of the Basin are summarized in Table 4.1.

Table 4.1 Minimum/Maximum Productivity Criteria for Determining if Non-Irrigated Parcels Could Potentially be Irrigated.

Area	SRPG	Slope
Ainsworth Irrigation District	>47	<1.4
Upper Niobrara-White NRD/North	>40	<2.4
Upper Niobrara-White NRD/South	>38	<2.2
Middle Niobrara NRD/North	>28	<2.3
Middle Niobrara NRD/South	>26	<2.0
Lower Niobrara NRD/North	>36	<2.8
Lower Niobrara NRD/South	>33	<1.8
Upper Elkhorn	>34	<2.1

Note that the values of productivity criteria, particularly SRPG and slope vary across the different NRD areas. For example, minimum SRPG criteria values range from greater than 26 in the Middle Niobrara/South of the river to 47 (Ainsworth Irrigation District) while maximum slope values range from 2.8 (Lower Niobrara NRD/North of the river) to 1.4 (Ainsworth Irrigation District). The effect of this productivity filtering criteria was to reduce the potential pool of land with irrigation potential to approximately 450,000 acres.

Land parcels were only considered to have a feasible water supply for irrigation development if a parcel was within half a mile of an existing irrigation well with a pumping capacity of at least 500 gpm, or alternatively, if a parcel was within one mile of a surface water resource (a reservoir, canal, or a river/stream classified by the NDNR as being perennial). GIS intersect and near operations were used to quantify the above water supply criteria associated with individual CLU parcels.

Applying the water supply criteria restrictions resulted in an estimate of 156,000 acres of potential irrigation. In other words, only about 34% of all land with acceptable productivity measures (i.e. SRPG, slope, and without extensive marsh/wetland areas, all of which when combined would allow irrigation development), actually have a feasible (i.e. likely) water supply required for irrigation.

In Figure 4.1, the locations of the 156,000 acres of potential irrigation acreage are depicted in green while current irrigation is shown in red. As expected, actual and potential irrigation areas are generally in close proximity to each other. However, this potential irrigation acreage would likely only result in 129,500 acres of actual irrigation (assuming that corners of fields under pivot irrigation systems are not irrigated).

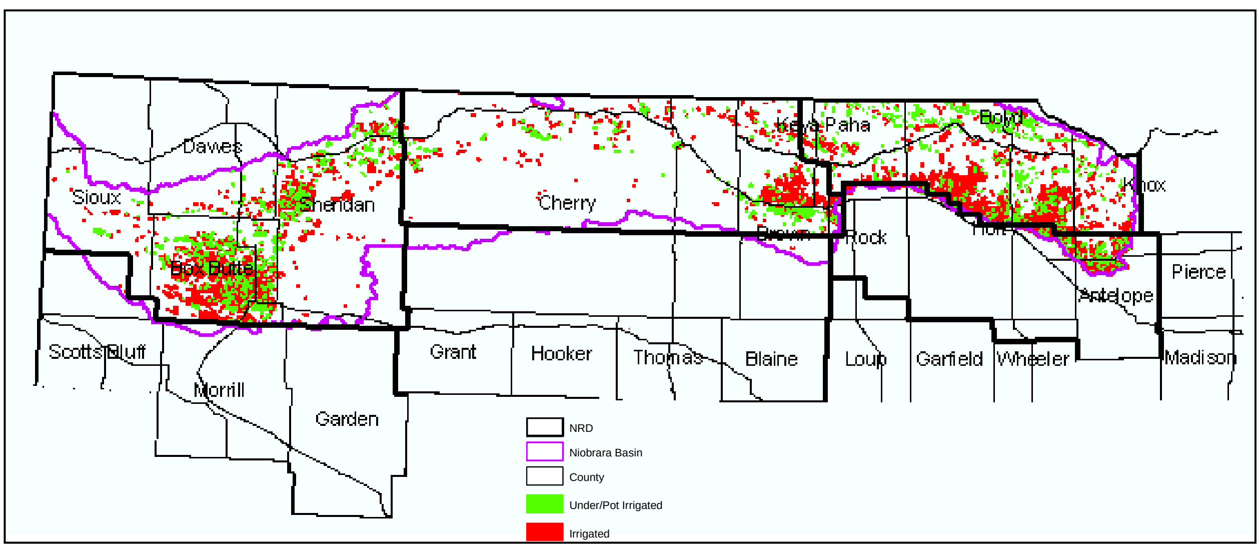

Figure 4.1 Estimates of Actual, Under-Estimated, and Potential Irrigation Acreage.

However, it is very important to note that this GIS-based 129,500 acres of potential irrigation acreage actually represent a mix of previously under-estimated current irrigation acreage and potential irrigation acreage. This is due to the fact that the 17% under-estimation of irrigation by CALMIT 2005 was accounted for numerically when making current irrigation estimates, but these adjustments were only made to numerical/tabular data and not to the CALMIT 2005 GIS coverage (as it is not known where these missing irrigation parcels were actually located).

Therefore, applying the reverse calibration adjustments to these estimates of potential/under-estimated irrigation acreage is necessary (on average 18% across the entire basin), the resulting estimate of potential irrigation acreage then becomes 108,000 acres which is about 14% of estimated current irrigation acreage. Assuming 13 inches of irrigation per acre each season this corresponds to 116,640 acre-feet of irrigation per year.

These potential irrigation estimates should be considered high-end or maximum potential irrigation acreage estimates because there is no guarantee that water sources are available on these parcels. As well, some may make the argument that all of the landowners in the Basin who wanted to develop their land for irrigation could have done so well in advance of the fully appropriated designations being implemented and therefore the potential for new irrigation developments is closer to zero. This view has been shared with the author by several NRD managers, local producers and other elected officials and stakeholders. Since economic and political situations can change causing people to reconsider how their land is utilized (i.e. early ethanol production), this report simply addresses a scenario in which potentially irrigated ground is re-assessed for use. Future research efforts that refine these estimates of potential irrigation based on interviews with irrigation developers and /or the estimation of irrigation development profit models are warranted.

Estimates of potential irrigation development within the entire, fully appropriated and non-fully appropriated areas of each NRD are summarized in Table 4.2. From this it can be seen that Upper Niobrara-White NRD has 45% of the estimated potential irrigation development acreage within its boundary and most of this occurs south of the river. Upper Niobrara White contains 52% of all potential irrigation development contained within fully appropriated areas, followed by the Middle Niobrara NRD with 30%. Finally, potential irrigation in non-fully appropriated areas (which is still allowable) is feasible only in the Lower Niobrara or Upper Elkhorn NRDs.

Table 4.2 Potential/Future Irrigation Acreage Developments across Market Segments (Based on land with similar characteristics as nearby irrigated land)

Area	Potential Irrigation Acres	Percent of Potential Irrigation in Fully Appropriated Areas
Upper Niobrara-White/North	17,280 (16%)	100%
Upper Niobrara-White/South	31,320 (29%)	99%
Middle Niobrara/North	3,240 (3%)	100%
Middle Niobrara/South (including Upper Loup)	11,880 (11%)	99%
Lower Niobrara/North	17,289 (16%)	47%
Lower Niobrara/South	18,360 (17%)	22%
Upper Elkhorn	8,640 (8%)	4%
Entire Basin	108,000 (100%)	64%

Finally, the question of where future (potential) irrigation development would obtain its water is summarized in Table 4.3, which reports the percentage of all potential irrigation acres with access to ground, surface, or combined water sources. Basin-wide, 65% of potential irrigation is associated with groundwater sources, versus 45% with surface water, and 10% with both (i.e. either source). The area with the highest percentage of potential irrigation associated with groundwater is the upper Elkhorn NRD (93%) and the area with the greatest amount of irrigation development associated with surface water is the Lower Niobrara NRD, north of the River.

Table 4.3 Likely Water Sources of Potential Irrigation Development across the Basin

Areas	Percent of Acres with Groundwater Supplies	Percent of Acres with Surface Water Supplies	Percent of Acres with Both Water Supplies
Upper Niobrara-White/North	78%	36%	14%
Upper Niobrara-White/South	86%	19%	5%
Middle Niobrara/North	67%	35%	3%
Middle Niobrara/South	71%	60%	31%
Lower Niobrara/North	5%	97%	2%
Lower Niobrara/South	59%	51%	10%
Upper Elkhorn	93%	20%	13%
Entire Basin	65%	45%	10%

5. THE VALUE OF SURFACE WATER FOR IRRIGATION BASED ON EXISTING CONTRACTS

Current irrigated acreage estimates were compiled for each irrigation district. Estimated surface irrigated acreage for Mirage Flats is given at the Mirage Flats Irrigation District website (http://www.mfid.org) and at the Great Plains Bureau of Reclamation website. Information was confirmed via personal interview with Mirage Flats district manager, Todd Orton.[27]

Estimates for the Ainsworth Irrigation District for surface irrigated acreage comes from the Bureau of Reclamation website and from the Ainsworth Unit Bulletin archives available online at (http://www.usbr.gov/gp/nkao/ainsworth/).[28] Information was also confirmed via personal conversations with the Ainsworth Irrigation District Manager, Rod Imm, and Bureau of Reclamation Manager, William Peck.

Data for seasonal reservoir operations pertaining to Box Butte Reservoir and the Mirage Flats Irrigation District was retrieved from the Bureau of Reclamation FINAL Resource Management Plan Box Butte Reservoir Chapter 5: Reservoir Operations. Seasonal reservoir contents pertaining to Merritt Reservoir and the Ainsworth Irrigation District were retrieved from the Bureau of Reclamation reservoir content statistical service online.[29] Water loss for each district is the difference between water diverted for irrigation into the canals and surface water actually received by irrigators in each district. Efficiency would then be defined as the percentage of water diverted that is actually received.

Acre-feet of irrigation water received (on a per acre basis) was calculated by dividing the total amount of water received in a given season by the total amount of irrigated acres in the district. The percentage of water lost while transporting surface water supplies in the Mirage Flats Irrigation District assumed to become recharge is estimated to range from 25% to 75% depending on soil type and distances from transfer canals to groundwater aquifers. No substantial recharge is assumed to occur in the Ainsworth Irrigation District.

Water cost per acre-feet in the Mirage Flats district is dependent on three variables and two constants. The constants are the price which irrigators pay and the amount of irrigated acreage in the district. The varying factors are amount received, loss percentage and recharge. The source for surface irrigated acreage is The Bureau of Reclamation and the nominal dollar amount which irrigators pay for service was provided by the Mirage Flats District Manager, Todd Orton.

The two variables which vary depending upon the year are amount of water received and loss percentage but they are expected to be relatively stable over longer periods of time. Recharge rate ranges as used here do not change annually however, since they are represented as a range of values. For purposes of brevity calculations of monetary benefits are therefore conducted at recharge rate assumptions of 0%, 25%, 50%, and 75% intervals. The formula for these calculations is summarized at the bottom of Table 5.4.

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[27] http://www.usbr.gov/projects/Project.jsp?proj_Name=Mirage%20Flats%20Project.
[28] http://www.usbr.gov/projects/Project.jsp?proj_Name=Ainsworth%20Unit%20Project.
[29] http://www.usbr.gov/gp-bin/arcplt_form.pl?MRNE.

Cost of water per acre-foot in the Ainsworth Irrigation District is dependent upon three factors. The factors include quantity received by irrigators; price per acre irrigated for operation and maintenance to the Ainsworth Irrigation District, and price per acre irrigated depending upon land classification paid to the Bureau of Reclamation for repayment of the project. Land classification payments and operation and maintenance fees were given via personal interview with Ainsworth Irrigation District Manager, Rodd Imm, and from contract No. 079D6B005 between the Ainsworth Irrigation District and the Bureau of Reclamation. Quantity received is considered constant since it does not vary from year to year. Fees paid for operation and maintenance are also fixed since it does not vary with land classification or amount received.

Land classifications in the Ainsworth Irrigation District fall into one of three categories based upon production potential of each acre. Class 1 land has the highest fee to the Bureau of Reclamation for repayment of the projects construction while Class 3 ground pays the least and Class 2 falls in-between. Land classification fees are paid in addition to the operation and maintenance fee per acre irrigated.

Price per acre-feet is then calculated based upon all the aforementioned factors. The operation and maintenance fee is added to the land classification payment. The fixed quantity received is converted from inches to acre-feet The sum of the two payments is then divided by the amount of acre feet received per acre to derive a price per acre-feet within the Ainsworth Irrigation District. Since there are three classifications, three prices per acre-feet per acre are estimated for each year.

Mirage Flats Irrigation District

The Mirage Flats Irrigation District (MFID) was completed in 1946 in order to divert, store, and deliver irrigation water to nearby agricultural producers. In 1950 settlement of the area was complete. The final payment to the Bureau of Reclamation from the MFID occurred in 1989.[30]

In 1990, the MFID and the Game and Parks Commission entered into an agreement where the Game and Parks holds title to a portion of the water content in the reservoir for a period of 30 years in order to maintain minimum pool levels to maintain fishery resources. The agreement stipulated that water levels in the reservoir will not fall below 3978 m.s.l. (2,289 acre-ft). A lump sum payment for the water was made in the amount of $294,530 to the district.[31] The contract was amended in 2000 to increase the minimum pool level to 3,979 m.s.l. for the next 20 years for an additional payment of $37,674.[32]

Box Butte Reservoir contains the available storage for the MFID and is fed by the Niobrara River. Total potential storage capacity for Box Butte Reservoir is 45,901 acre-feet The MFID is located in the Upper Niobrara-White NRD and irrigates approximately 11,570 acres located entirely in Sheridan County. The Dunlap Diversion Dam resides in Sheridan County and the Box

[30] http://www.mfid.org/history.php.

[31] Agreement between the United States, the Nebraska Game and Parks Commission, and the Mirage Flats Irrigation District. 23 March 1990.

[32] Amendment to Agreement between the United States, the Nebraska Game and Parks Commission, and the Mirage Flats Irrigation District. 17 March 2000.

Butte Dam and Reservoir is located in Dawes County. Mirage Flats Canal is approximately 14 miles from its diversion source on the Niobrara River to the laterals which supply the district. [33]

MFID irrigators are under no financial obligation to the Bureau of Reclamation for water used and all conservation storage resources are at the MFID's disposal down to a pool elevation of 3,979 feet Irrigators are charged a flat fee per acre they irrigate paid to the MFID for operation and maintenance. Amount allotted per acre depends upon Box Butte Reservoir levels and current demand conditions.[34]

Table 5.1 Box Butte Reservoir Potential Storage Capacity and Pool Levels

Space	Net Capacity (acre-ft)	Water Elevation (feet msl)
Surcharge Pool ****	16,740	4,016
No Flood Pool	----	----
Conservation Storage ***	27,769	4,007
Inactive Storage **	2,204	3,979
Dead Storage *	188	3,969

***Dead Storage**: Capacity from which stored water cannot be evacuated by gravity
****Inactive Storage:** Capacity that can be released from the dam but is below design capacity for irrigation
*****Conservation Storage:** The pool allocated to storage of water for irrigation purposes only
******Surcharge Pool**: Capacity between the top of conservation pool and the maximum water surface elevation
[**From: From Bureau of Reclamation FINAL Resource Management Plan Box Butte Reservoir Chapter 5: Reservoir Operations pp. 50**]

Using the capacity water levels summarized in Table 5.1 of the Mirage Flats History section and assuming very little loss between storage and destination, irrigation potential is approximately 2.3 acre-feet per acre (acres irrigated=11,570). [35] Table 5.2 shows the amount of water diverted at Dunlap Diversion Dam and the actual amount of water irrigators have received over the last ten years based upon figures from the Bureau of Reclamation.

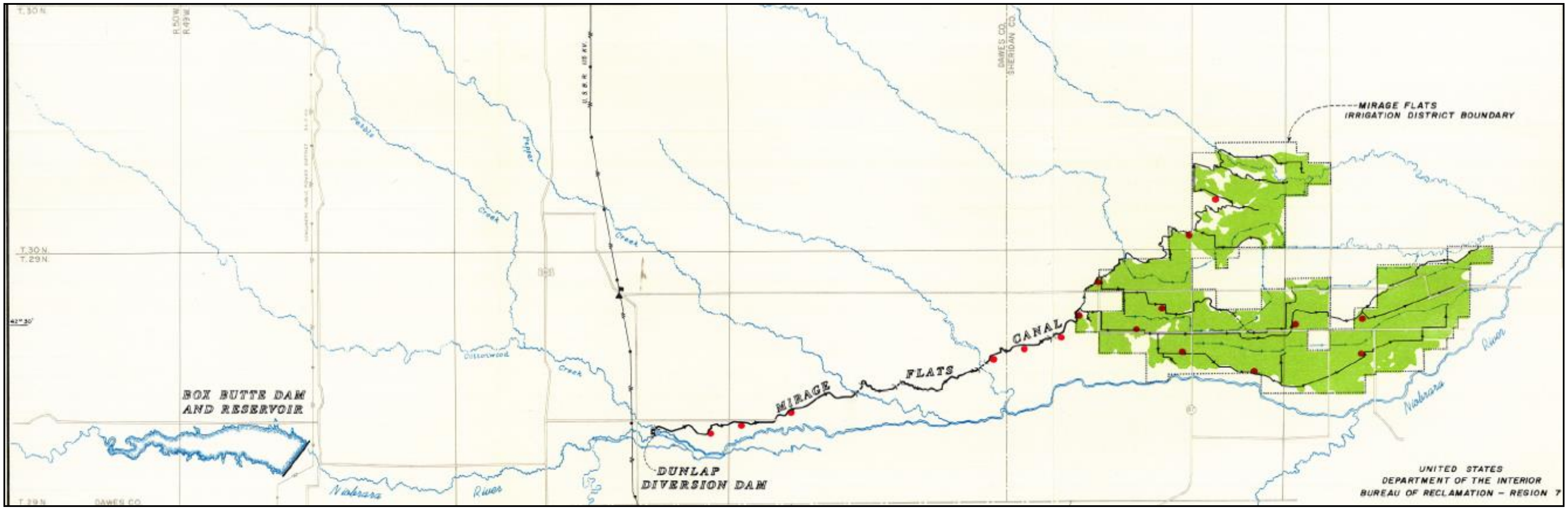
The most current estimate for surface water delivery by the MFID for the 2010 irrigation season is .2 acre-feet (2.4 inches) per acre.[36] The approximate range of surface water delivery quantity over the last ten years has been 1.2 inches and 8.5 inches per year (.1 to .7 acre-feet).[37]

Historic trends in Box Butte Reservoir inflow and outflow appear to partially explain the discrepancy between potential allocation and actual allocation. Inflow and outflow has been consistently falling since 1956 due to upstream farm conservation practices as well as ground-water reserve depletion. Average annual inflow prior to 1956 was 22,100 acre-feet. The average

[33] Referenced from Bureau of Reclamation online at: http://www.usbr.gov/projects/Project.jsp?proj_Name=Mirage%20Flats%20Project.
[34] Information via phone interview with Todd Orton, manager of the Mirage Flats Irrigation District on 12/18/2009.
[35] (Conservation Storage Maximum 27,769) / (acres irrigated 11,670).
[36] http://www.mfid.org/index.php.
[37] Personal interview with Upper Niobrara White NRD Water Resources Manager Sheri Daniels on 1/21/2010.

Figure 5.1

Mirage Flats Irrigation District Map



FEATURE	EXISTING	POTENTIAL
DIVERSION DAM		
RESERVOIR		
CANAL		
LATERAL		
DRAIN		
SIPHON		
TRANSMISSION LINE		
DEEP WELL		
IRRIGATED PROJECT LAND		

[Verbatim From Bureau of Reclamation Final Resource Management Plan Box Butte Reservoir Chapter 5: Reservoir Operations p. 5] has since decreased further with a decade average of 16,200 acre-feet between 1997 and 2006.[38] In fact, Box Butte Reservoir has failed to reach maximum capacity in every single year except one in the last 25 years. As a result there has simply been less water available to divert at Dunlap Diversion Dam.

Table 5.2 Water Diverted, Received, and Total Loss of Water per Acre Irrigated in the Mirage Flats Irrigation District[39]

Year	Total Quantity Diverted*	Total Quantity Received*	Total Loss**	Loss as Percentage of Total	Quantity Received Per Acre***
1999	12699	7697	5002	39%	0.66
2000	14150	8266	5884	42%	0.71
2001	12571	7755	4816	38%	0.66
2002	12467	6973	5494	44%	0.60
2003	9929	4678	5251	53%	0.40
2004	8553	3490	5063	59%	0.30
2005	10617	4113	6504	61%	0.35
2006	10423	4244	6179	59%	0.36
2007	6963	2504	4459	64%	0.21
2008	5786	1203	4583	79%	0.10
2009	8262	1446	6816	82%	0.12
11 Year Average	10220	4760	5459	57%	0.41

*All Water Values are in Acre-Feet
**Canal loss and total loss represents the difference between water diverted and water received
***See methods section for price conversion equation

Water loss in the Mirage Flats Canal is another cause of decreased water reception. In a typical year the Mirage Flats Canal will lose 5,459 acre-feet of water due to seepage and evaporation. However, in a particularly dry year, the nominal total loss in acre-feet may increase due to high temperatures and moisture depleted lateral beds and canal beds. With reduced flow and thus reduced diversion, the percentage of water lost in the Mirage Flats Canal will tend to increase though the average nominal loss may remain constant. Figure 5.2 illustrates the data contained in Table 5.2. Water loss in the Mirage Flats Canal began to exceed the amount of water delivered to irrigators in 2003. In 2009, the loss of water between the diversion dam and actual delivery exceeded the amount delivered by 471%.

[38] Bureau of Reclamation FINAL Resource Management Plan Box Butte Reservoir Chapter 5 p 52.
[39] Data for Table 5.2 delivered via spreadsheet Mirage Flats Diversion Data and Usage from William Peck at the Bureau of Reclamation.

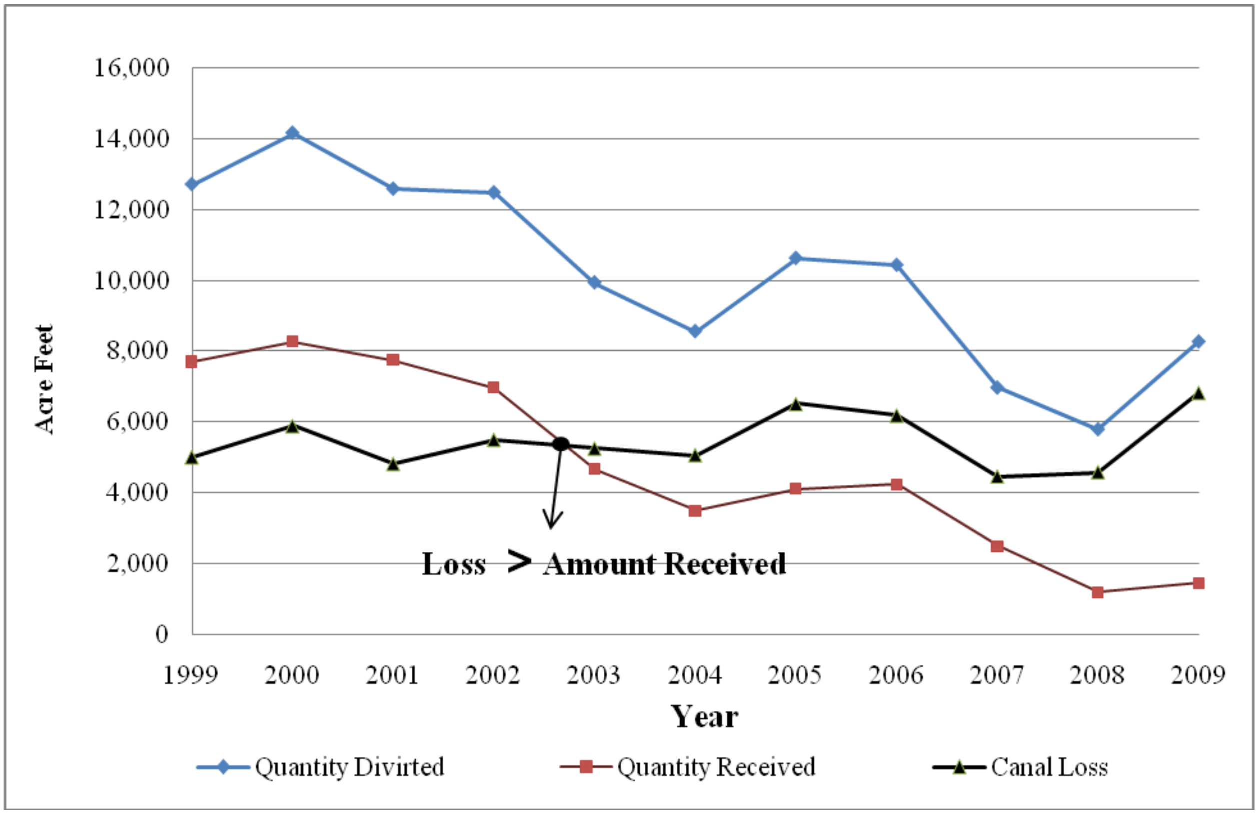


Figure 5.2
Water Diverted, Received, and Lost in the MFID System[40]

Table 5.3 shows corn crop water usage per month and average monthly precipitation. Table 5.3 includes the counties which comprise the Upper Niobrara-White NRD region and the MFID.[41] Precipitation data was taken from the National Weather Services and corn crop water usage from the University of Nebraska Extension Research Program. [42] The table is a useful guide for evaluation of irrigation needs however caution must be taken not to assume that the figures will be precise from month to month. Also important is the fact that water surpluses do not entirely carryover from one month to the next (Yonts 2002).

[40] Data for Figure 5.7 delivered via spreadsheet Mirage Flats Diversion Data and Usage from William Peck at the Bureau of Reclamation on 1/25/2010.
[41] Counties in the Upper Niobrara White NRD include Sioux, Dawes, Sheridan, and Box Butte Counties.
[42] Weather data Online at: http://www.nws.noaa.gov/climate/index.php?wfo=gid.

Table 5.3 Corn Water Usage and Irrigation Need Aggregation for the Upper Niobrara White NRD Including Mirage Flats Irrigation District

Month	Corn Usage*	Precipitation**	Balance***
April	0.25	1.89	1.64
May	1.9	3.02	1.12
June	4.7	2.62	-2.08
July	9.9	2.11	-7.79
August	7.55	1.67	-5.88
September	4.45	1.44	-3.01
Growing Season Avg. Total	28.75	12.75	-16.00
Additional need in acre feet			1.25

***Corn Usage** = Average amount of water in inches used per month by crop per acre
****Precipitation** = Aggregate precipitation in inches per month of the Middle Niobrara NRD region
*****Balance** = Net amount of water available after crop usage
Additional Need = Average additional amount of water required for maximum yield during the growing season in acre-feet

Assuming the allotment for the 2010 irrigation season remains at .2 acre-feet per acre[43], irrigators will require an additional acre feet of water per acre in the coming growing season for maximum potential yield. Using the information contained in Tables 5.2 and 5.3 for Mirage Flats, a reception of .2 acre-feet per acre of surface water implies a diversion of approximately 7,000 acre-feet With average loss being 5,459 acre-feet and assuming a recharge of 50%, irrigators will receive .434 acre-feet per acre from the canal in 2010. Consequently, 76% of the water irrigators will use for their corn crop must come from ground water already present within the MFID.

Large fluctuations in water received by irrigators and a flat fee per acre irrigated yields a substantial variation in the price per acre-feet of water delivered. The per unit price for water delivered has ranged from $24.71 per acre-feet when ample water was available in 2000 to $169.76 per acre-feet when resources were scarce in 2008. Thus, at low diversion quantities, the marginal cost of water delivered increases dramatically in the MFID (personal communication with Todd Orton). [44]

An important consideration of the water that has been described as a “loss” is that water which seeps into the ground from the canal and laterals is not totally lost. A large percentage of seepage water becomes a supplement to precipitation for ground water recharge. Depending upon the percentage of loss that becomes recharge, the marginal cost of water per acre-feet may be substantially reduced if it becomes available through ground water irrigation. (Personal Communication with William Peck) Thus, a better proxy for cost per acre-feet may be based on the amount of water diverted at Dunlap Diversion Dam and a potential recharge credit rather than the amount of surface water delivered alone. However, a caveat to loss becoming recharge is that distance from the canal to well can have a

[43] From: www.mfid.org.
[44] See Methods Section for Marginal Price equation.

large effect on the percentage of seepage or loss that becomes usable to irrigators who actually pay for the diverted water.[45]

Recent surveys suggest the percentage of loss that becomes recharge may vary between 25% and 75%. Table 5.4 juxtaposes three water pricing approximations using water delivered with 75%, 50%, 25%, and 0% of the loss becoming recharge. Figure 5.3 displays the results graphically illustrating the differences in the unit cost of water in acre-feet

Table 5.4 Irrigation Water Prices in Dollars per Acre-Feet under Alternative Recharge Scenarios in the MFID from 1999-2009

Year	Price Per Acre Feet Received No Recharge	Price Per Acre Feet Received 25% Recharge	Price Per Acre Feet Received 50% Recharge	Price Per Acre Feet Received 75% Recharge
1999	26.53	22.82	20.03	17.84
2000	24.71	20.97	18.22	16.11
2001	26.33	22.80	20.09	17.97
2002	29.29	24.47	21.01	18.41
2003	43.66	34.09	27.96	23.70
2004	58.52	42.94	33.92	28.02
2005	49.65	35.59	27.73	22.71
2006	48.12	35.28	27.85	23.00
2007	81.56	56.44	43.14	34.92
2008	169.76	86.95	58.44	44.01
2009	141.23	64.83	42.07	31.14
11 Year Average	**63.58**	**40.65**	**30.95**	**25.26**

Data for Table 5.4 from the Bureau of Reclamation William Peck and from the Mirage Flats Irrigation District Manager, Todd Orton.

**Water Price Per Acre-Ft Received. $= (17.5)/\left[\left(\frac{Y}{11670}\right) - \left(\lambda(1-\omega)\right)\right]$

Y= Quantity Diverted at Dunlap Diversion Dam. λ = Y-Ψ.
Ψ= Surface Quantity Received Through Laterals. ω = Assumed percentage of (Y-Ψ) that becomes recharge.

The most generous assumption of loss becoming recharge yields a marginal price of water average of $25.26 per acre-feet received. A 75% recharge seems unlikely given the distance from the diversion dam to the wells (at least 14 miles) in the MFID. Thus, 25-50% of seepage becoming recharge plus the actual water delivered seems a more reasonable proxy for estimating the price of water in the district.

[45] Harvey, Edwin and Steven S. Sibray 2005.

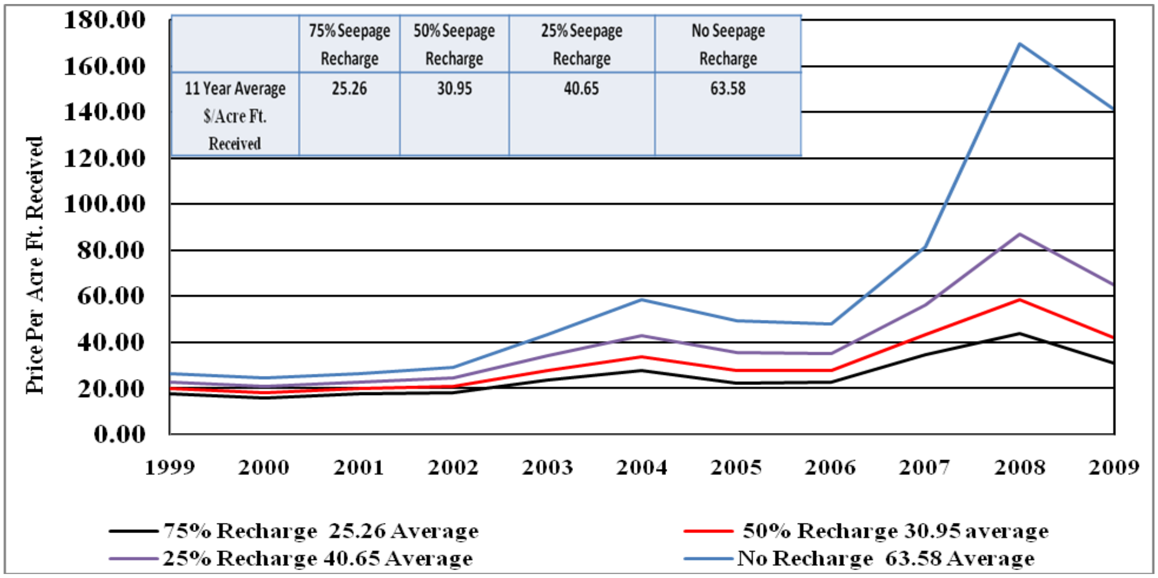


Figure 5.3 Mirage Flats Irrigation District Price per Acre-Feet of Water Received With Varying Loss to Recharge

Ainsworth Irrigation District

The Ainsworth Irrigation District (AID) is located in the Middle Niobrara NRD. Components of the AID include Merritt Dam and Reservoir, laterals, drains, and the Ainsworth Canal. Merritt Dam and Reservoir are located in Cherry County Nebraska just south of Valentine while the irrigated project lands are located in eastern Brown and western Rock County. The AID is fed from the Snake River and diverted by Merritt Dam which is situated 14 miles upstream of the Snake River's confluence with the Niobrara River. Merritt Reservoir's maximum capacity is approximately 74,480 acre-feet. The active conservation capacity for irrigation is 67,686 acre-feet The Ainsworth Canal is 53 miles in length and constructed of concrete.[46]

Construction of Merritt Dam was completed in May 1964 and completion of the Ainsworth Canal occurred in January 1965. The first deliveries of irrigation water began in June 1965 and the project was turned over to the Ainsworth Irrigation District in April of 1967. At project completion, 21,000 acres received water from the AID. Since then, that number has grown and remained steady at approximately 34,000 acres (Simonds, 2009).

The primary purpose for water diversion and storage as per the agreement between the United States Department of the Interior (Bureau of Reclamation) and the Ainsworth Irrigation District is irrigation for crop land. The storage and storage use rights for the water contained in Merritt Dam are held by the Bureau of Reclamation.

The project title for Merritt Dam and Reservoir is held by the Bureau of Reclamation as well as a portion of the land surrounding the reservoir. An agreement between the Bureau of Reclamation

[46] http://www.usbr.gov/projects/Project.jsp?proj_Name=Ainsworth%20Unit%20Project.

and the Nebraska Game and Parks Commission is in effect which grants them access to the areas immediately surrounding the reservoir and a percentage of water contained therein.[47]

Currently the amount of acres irrigated by the project is 33,960. Base allotment received by irrigators from the reservoir is 16 inches annually or 1.33 acre-feet per acre.[48] Maximum potential diversion from the Snake River to the Merritt Reservoir is 105,000 acre-feet However, the annual diversion is generally much less with the largest quantity diverted occurring in 2002 at 90,233 acre-feet Figure 5.4 displays the amount of water released into Ainsworth Canal as well as the amount of water the irrigators actually receive.

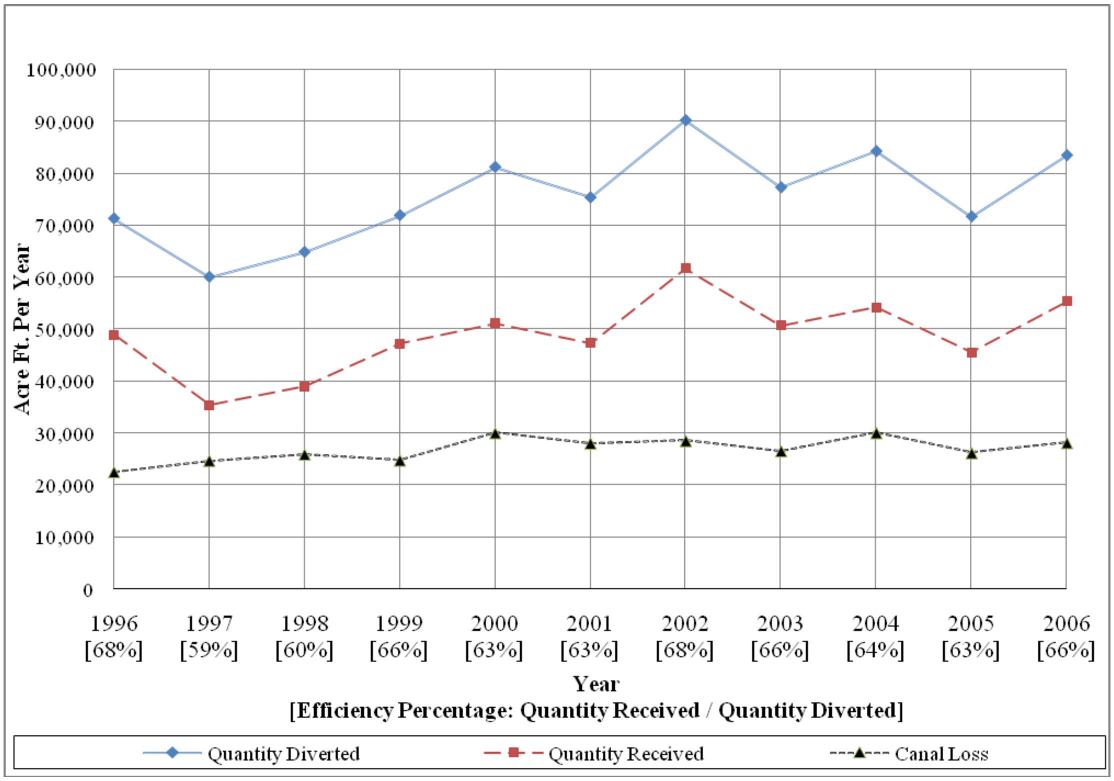


Figure 5.4
Water Diverted/ Received/ Lost/ and Efficiency of the Ainsworth Irrigation System[49]

The nominal figures for canal loss per year during the period captured in Table 5.5 and Figure 5.4 fluctuate between 30,000 acre feet and 22,500 acre feet of water that was released into the Ainsworth Canal but not received as surface irrigation water.

[47] Ainsworth Unit Bulletin Bureau of Reclamation April 2003.
[48] Personal interview with Rod Imm, manager of the Ainsworth Irrigation District.
[49] Data for Figure 5.4 delivered via spreadsheet Ainsworth Diversion Data and Usage from William Peck at the Bureau of Reclamation.

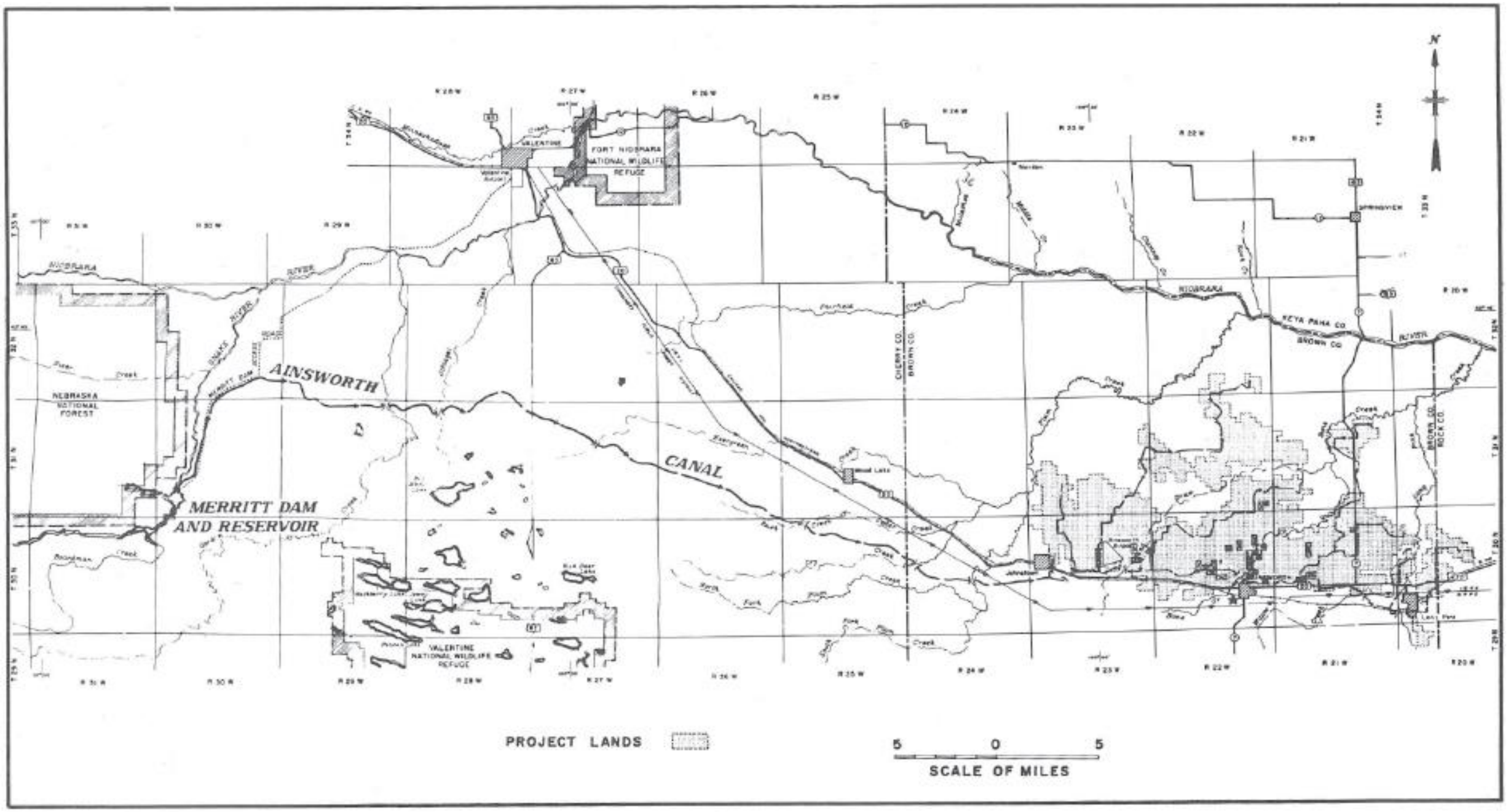


Figure 5.5
Map of the Ainsworth Irrigation District

[Map Verbatim from Bureau of Reclamation Online at: www.usbr.gov/gp/nkao/ainsworth/ainsworthn2.pdf]

On average, the loss between release and reception for the period depicted has been 36%. It may be reasonable to assume that the AID's surface water delivery system is approximately 64% efficient. That is, on average, 64% of the water put into the system reaches its intended destination.

Table 5.5
Water Diverted, Received, and loss of Water per Acre Irrigated of the Ainsworth Irrigation District

Year	Annual Release Into Ainsworth Canal*	Total Quantity Received By Farmers*	Total Loss**	Canal Loss***	Quantity Received Per acre****
1996	71339	48850	22489	32%	1.44
1997	60076	35382	24694	41%	1.04
1998	64881	38958	25923	40%	1.15
1999	71954	47170	24784	34%	1.39
2000	81247	51172	30075	37%	1.51
2001	75390	47302	28088	37%	1.39
2002	90233	61668	28565	32%	1.82
2003	77313	50749	26564	34%	1.49
2004	84275	54164	30111	36%	1.59
2005	71713	45517	26196	37%	1.34
2006	83497	55339	28158	34%	1.63
Average	75629	48752	26877	36%	1.44

*All Water Values are in Acre-Feet
**Canal loss and total loss represents the difference between water diverted and water received
***Quantity Received per acre assumes 33,960 Acres Irrigated In the District
****Quantity Received per acre is an average for all land classes and soil types

[Data for Table 5.5 was obtained from William Peck at the Bureau of Reclamation on 2/08/2010]

Figure 5.4 and Table 5.5 demonstrate a discrepancy between the 1.33 acre-feet base allotment and the amount irrigators have been receiving. Most of the difference may be explained by the ability of irrigators to purchase additional surface irrigation water. An additional acre-foot of water, above the base allotment, may be purchased during the growing season.

Table 5.6 was created in the same manner as Table 5.3 however it uses the data from the counties included in the Middle Niobrara NRD. Based on the information contained in Tables 5.5 and 5.6 it is reasonable to conclude that all of the Ainsworth Irrigation District's irrigation needs for 33,640 acres are met through surface water irrigation**.**

Table 5.6 Corn Water Usage and Irrigation Need Aggregation for the Middle Niobrara NRD Including the Ainsworth Irrigation District

Month	Corn Usage*	Precipitation**	Balance***
April	0.25	1.97	1.72
May	1.9	3.2	1.3
June	4.7	3.01	-1.69
July	9.6	3.37	-6.23
August	6.95	2.2	-4.75
September	3.85	1.6	-2.25
Total	27.25	15.35	-11.9
Additional Need Acre Feet			0.99

***Corn Usage = Average amount of water in inches used per month by crop per acre**
****Precipitation = Aggregate precipitation in inches per month, of the Middle Niobrara NRD region**
*****Balance = Net amount of water available after crop usage**

Additional Need= Average additional water required for maximum yield during the growing season in acre feet

A typical year's growing season precipitation leaves an average corn crop deficient approximately 1 acre-feet of water from maximum potential yield if the precipitation is received at optimal intervals. Since optimal interval precipitation does not usually occur, the additional 0.33 acre-feet may be deemed necessary to supplement dryer months.

Ainsworth Irrigation District irrigators make debt payments associated with irrigation infrastructure costs. In 2006, this was $1,675,000 at annual installments of $167,500. [50] These payments are not dependent on water usage but are influenced by land production measures (class 1 ground requires a repayment of $9.86 per acre to the district while class 2 and 3 ground ratings require $6.4 and $5.03 per acre, respectively).[51]

The annual cost of irrigation, aside from the Bureau of Reclamation repayment, is a flat fee of $26 per acre irrigated annually. The fee is received by the AID for operation and maintenance and comes with the aforementioned allotment of 16 inches or 1.33 acre-feet per year. Since the supply of water has been reasonably stable, the only fluctuation on water cost may come from a nominal change in the cost per acre-foot based on an operation and maintenance increase rather than from variations in quantity supplied.

Additional water may be purchased by irrigators if necessary at a flat rate of $24 per acre-feet meaning that the primary water allotment cost is $19.6 per acre-feet per acre.[52] Based on payments to the Bureau of Reclamation and assuming no additional water is purchased, total water cost per acre irrigated in the AID will vary between $35.86 and $31.03 depending on land classification.

[50] Bureau of Reclamation and Ainsworth Contract No. 079D6B005.
[51] Ground class depends primarily on soil type and grade. Class 1 is considered superior where class 3 would be the least desirable of the 3. Ground classifications may vary within the same field. (PER: Rod Imm).
[52] If 16 inches of water per acre is allotted and 1 acre-feet = 12 inches then 16 inches = 4/3 of an acre-feet and so $26/ (4/3) = $19.55 per acre-feet

6. IRRIGATION VALUES BASED ON AGRICULTURAL LAND SALES

Background

The need to quantify the economic value of irrigation associated with production agriculture has become essential in evaluating the economic feasibility of various water management options in many areas of the Central and Western U.S. This study makes estimates of the marginal value of irrigation (defined as how irrigation contributes to land prices) using several different data sources and approaches.

The net income approach calculates changes in net farm income with and without irrigation. This usually involves the estimation of farm budget models and requires extensive data collection and the use of numerous assumptions involving input costs, productivity associated with alternative farming practices, output prices and time horizons by analysts. Compounding these limitations is the fact that producer incomes derived from irrigation often vary considerably across agricultural producers, locations, and time which may result in inaccurate estimates of the contributory value of irrigation over large areas (such as entire watersheds). For these reasons, most agricultural economists and appraisers are strong advocates of the 'Land Value Method' for measuring the contributory value of irrigation to agriculture due to its basis on empirical market data (agricultural land sale transactions). As well, the approach inherently accounts for the knowledge and expertise of local buyers and sellers of land (Young, 1979).

In many western states that rely on surface irrigation and which have active markets for trading surface water supplies, economists and appraisers simply report observed selling prices (usually auctions and exchanges) while adjusting for transaction costs (Landry 1999; Pritchett, Thorvaldson, and Frasier 2009; Basta and Colby 2010). However, in other central and western states (such as Nebraska and Kansas) that rely either on groundwater or a mix of groundwater and surface water supplies for irrigation, and where there is often not a formal market for trading surface water rights, agricultural economists have generally relied on the 'Land Value Approach' to value irrigation.

The principal assumption underlying the 'Land Value' approach for determining the contributory value of irrigation is that buyers and sellers of agricultural land are able to differentiate the factors of production as they relate to future profits when agreeing to sale prices for agricultural land. Therefore, real estate prices reflect revealed preferences for particular land characteristics including irrigation holding all other land condition factors constant.

There are several alternative approaches in applying the 'Land Value Approach' for valuing irrigation: All rely on real estate market transaction data but differ in relation to data specificity, sample sizes of market transactions, geographical scale, and level of analytical complexity. These alternatives are: pairwise/comparable sales valuations (the approach preferred and most utilized by fee appraisers); observed price differentials between aggregated and survey-based land value data; and the hedonic valuation method (HVM) which is a multiple regression-based technique. HVM relies on parcel specific data which is often collected through the use of GIS technologies.

The pairwise/comparable sale-based approach to valuing irrigation most often relies on comparing paired sales. In the case of valuing irrigation, price differentials would be calculated between irrigated and non-irrigated agricultural sale parcels which are otherwise very similar if not identical (Derbes and Mai 2005). A limitation of this approach is that it is often difficult to identify purely identical agricultural sale parcels that differ only with respect to irrigation activity. Land which is developed for irrigation usually has superior bio-physical characteristics than nearby comparable non-irrigated land parcels (many or most of which are not even possible for irrigation due to some combination of soil characteristics, field slope or the lack of a water source). These issues can sometimes be remedied by the appraiser making price adjustments for differences across parcels which inevitably generates possible valuation errors. Other limitations with pairwise analyses are that it is relatively time consuming and expensive to undertake and that it relies on relatively few market sales and such analyses are non-parametric, meaning that results cannot be verified as being statistically significant. For these reasons pairwise analyses are only undertaken in this present study in cases when there is not enough irrigated sale transactions in particular market segments to estimate hedonic price estimates.

A variation of the comparable sales/appraisal approach is to compare the average market values of large numbers of both irrigated versus non-irrigated land sales derived from annual surveys of farm producers and/or local real estate experts. Producer surveys that collect land value information include the June Agricultural survey by the National Agricultural Statistics Service (NASS), or the agricultural census (both by the U.S. Department of Agriculture). Both of these collect uniform data nationally, and it has been demonstrated in at least two studies that this data is relatively accurate (Gertel 1995; Shultz 2006). However, a major drawback associated with the Federal Land Value data is the level of analysis at which it is released (states or occasionally counties). Also, this data is often not collected annually. For example, the agricultural census which does release data at the county-level of analysis is not conducted every year. As an alternative, numerous state-level land value surveys have been developed over the years which survey bankers, appraisers, and other real estate experts. Often, they are conducted by faculty working in State Land Grant Universities. Such state-level expert option surveys exist in Iowa, Minnesota, and Nebraska and are undertaken by the Federal Reserve Banks as well.

State land value surveys intended to gauge expert opinions are often aggregated within regions of a state intended to represent fairly generalized agricultural land market segments. For example the Nebraska annual land survey by the University of Nebraska-Lincoln (UNL) is conducted within eight unique regions (Johnson and Lukassen 2009). However, these regions are often very large and in many cases do not accurately correspond to watershed boundaries (a unit of analysis of particular interest to irrigation policy decisions).

Expert opinion surveys often have relatively low sample sizes which limits an evaluation of statistical significance of reported land values. Also, when used to estimate irrigation values by comparing irrigated and non-irrigated land values, the approach suffers from the same problem as pairwise analyses in that the bio-physical characteristics (aside from irrigation status) are not always similar. This is particularly a problem in dry areas where, due to insufficient rainfall, irrigation is required for corn and other cropland production. In these areas most land that has suitable characteristics for irrigation (i.e. relatively good soil productivity, level slopes, and water availability) has already been irrigated while non-irrigated land is usually unsuitable for irrigation anyway. Some of the state surveys, including the UNL survey, attempt to conduct such mismatched comparisons by comparing irrigated land values with ‘dry land sales *that have the potential for irrigation’*. However, it is not clear whether there exist enough sales described as ‘dry land with irrigation potential’ in many surveyed markets. Thus, it is difficult for experts to provide accurate survey data on this type of land valuation.

For these reasons, the most reliable and widely accepted approach among economists to value irrigation is the multiple regression-based ‘Hedonic Valuation Method’ (HVM). The HVM is also known as a hedonic price model (the terminology used for the remainder of this present study), or a ‘price attribute model’ or a ‘mass appraisal technique’. The hedonic approach was formerly established by Rosen (1974) and has been used to value a full range of factors influencing real estate prices. The approach was refined and applied specifically to agricultural land sale prices by Palmquist (1989) and is based on the assumption that producers are able to differentiate factors of production as they relate to profits when purchasing agricultural land under the following conditions:

$$P(q,s,z,i) = \int_0^{\infty} R(q,s,z,i)e^{-rs}ds$$

where the price of agricultural land (P) is specified as a function of agricultural rent *R* based on soil quality characteristics q, location *z*, time *s*, the ability to irrigate *i*, and the interest rate *r*. To determine the effect of irrigation on real property sales or the net present value of a string of returns from irrigation this study utilizes a hedonic model:

$$(Price / Acre)_i = \beta_0 + \sum_{i=1}^{n} \beta_q Q_{ij} + \beta_s S_{ij} + \beta_z Z_{ij} + \beta_c I_i + u$$

where the price per acre is a function of a vector of physical characteristics Q, a time trend matrix of dummy variables S, location dummies Z, a vector representing the presence of irrigation rights and physical ability to irrigate I, and a random error term u.

The marginal price of irrigation (both rights and potential bundled together) on sale prices is indicated by the coefficient of a variable measuring the percentage of a sold parcel that is irrigated. This can be considered the price differential between an irrigated versus a non-irrigated parcel while taking into account (controlling for) other factors (productivity measures). This irrigation value represents buyers and sellers opinions regarding the discounted net value of irrigation over time. Therefore, to convert such irrigation values to an annual basis, it is necessary to multiply hedonic based irrigation values by a capitalization rate (the ratio of annual rental rates to sale prices).

Recent estimates of irrigation value tied to real estate almost always rely on hedonic price modeling. Crouter (1987) in a well-cited article estimates a linear regression equation for 53 real property sales near Greeley, CO with water variables represented by acre-feet of surface water delivered to the parcel and a dummy indicating the presence of a well. An index of soil quality available from the NRCS was used to proxy for the physical characteristics of the parcel. Overall, the value of an acre-foot of delivered water was shown to be just under $100 depending on the model used. Crouter (1987) also notes that this relatively low irrigation value may be due to the absence of an explicit water market in the area which leads to higher transaction costs. Torell, Libbin, and Miller (1990) extend this research to the agricultural production in areas served by the Ogallala Aquifer and determined that irrigation was on average worth $545 per acre-foot. Faux and Perry (1999) using hedonic pricing found that irrigation values in Oregon ranged from $514 to $2,551 per acre with the highest values being associated with the highest quality land. Finally, Petrie and Taylor (2007) used hedonic pricing to determine that irrigation well moratoriums and pumping restrictions had significant impacts on irrigation values in Georgia.

Finally, this current research builds on the land modeling experiences of an ongoing USDA NRI-Water and Watersheds Project titled '*Payment Incentives Required for Irrigation Retirement Programs' (NEBR-2007-02859).* This prior research focused on mapping agricultural land sales across the Republican watershed in southwestern Nebraska over the 2000-2006 period in order to estimate hedonic price models to quantify the value of irrigation in each of the different regions (NRDs) in the watershed and to evaluate fair market prices to pay landowners to retire irrigation rights.

A Summary of Irrigation Valuation Approaches of the Present Study

In this present study, the value of irrigation across the Niobrara Basin based on real estate transaction data will involve two alternative approaches and data sources. First, readily available, existing real estate transaction data and survey-based values associated with both irrigated and non-irrigated land are evaluated. These include reported data from:

1) The annual University of Nebraska-Lincoln Agricultural Land Value Survey conducted by Bruce Johnson of the Department of Agricultural Economics and hereafter referred to as the UNL/Johnson Survey data).

2) Recorded agricultural land sales transaction data contained in the 'Form 521' database maintained by the NE Department of Revenue (Property Taxation Division). The '521 Sales' data is actually compiled by county assessors and provided to the Nebraska Department of Revenue for the purposes of evaluating the equity of tax assessments.

Second, land and irrigation values are evaluated by mapping and analyzing the geo-spatial characteristics of all sold agricultural parcels (contained in the '521' sale database). Knowledge of the parcel specific characteristics of sold parcels with regard to land use types, soil productivity, field slope, more precise estimates of the irrigation acreage, and information on water supply factors allows much more complex and site specific (i.e. sub-basin) analyses of the value of irrigation. In particular, such data allows simple estimates of the net value of irrigation (irrigated land sale prices minus non-irrigated prices) and more importantly, for hedonic price modeling which involves the use of multiple regression to estimate the marginal price of irrigation (defined as the contribution that irrigation makes to sale price on a per acre basis).

The time frame of these analyses varies by the particular approach: The Johnson/UNL land value survey covers the 2000 to 2010 period. For all of the analyses based on '521' sales data (direct price comparisons, comparable sale analyses and hedonic price modeling) the analysis will focus on the 2000 to 2009 period since the 2010 data is not yet available from the Nebraska Department of Revenue. For sales-based data evaluated after GIS analyses (for net irrigation valuation estimates hedonic price modeling) the 2000 to 2008 time period is evaluated since GIS-based sales data existed only up to 2008.

All of these real estate-based irrigation values are one time (i.e. perpetual) purchase values. For comparisons with annual water values estimated in other sections of this report, these annual irrigation values are converted to annual values by applying a capitalization rate to either hedonic or comparable sales-based irrigation values. Capitalization rates which represent the ratio of annual rental values to sale prices will be based on average capitalization value of 7.75% based on reported rental and sale prices for irrigated land in the North and Northwest regions from annual Nebraska Farm Real Estate Market Development Reports (Bruce Johnson 2000-2009 UNL).

Land and Irrigation Values Based on Existing Data

Observed differentials between irrigated land values and dry land with irrigation potential values over time come from two alternative data sources:

> 1) The north and northwest regions of the State from the annual Johnson/UNL Land Value Survey;
>
> 2) raw (non GIS-based) sales based data specific to the Niobrara Basin known as the ‘521’ land sale database.

Land value estimates based on the UNL/Johnson agricultural land value survey (administered to real estate experts segregated by eight regions statewide) are summarized in Figure 6.1 for the North and Central regions combined (which provide the best available overlap with the Niobrara Basin). The following categories of reported land values are represented and analyzed: irrigated cropland, dry cropland, pasture land, and dry cropland with irrigation potential.

Estimation of the contributory value of irrigation based on these reported land values will be made by calculating ‘net irrigation values’ or simply the value of irrigation land minus the value of dry land.

The non-irrigated cropland with irrigation development potential values are of particular interest because subtracting this value from reported irrigated land values would generate a much more realistic estimate of the contributory value of irrigation than comparing irrigated land with land with no potential for irrigation. However, a potential limitation of relying on this category of land value for estimating net irrigation values is that very few such sales (dry cropland with irrigation potential) may actually occur making it difficult for survey respondents to accurately report such values particularly on an annual basis.

From Figure 6.2, it can be seen that irrigated cropland values are consistently higher on average than non-irrigated cropland values and pasture land values over time (62%). This differential increased sharply between 2005 and 2010 when the value of pivot irrigation land increased at 11% per year while dry land increased at only 9% per year. Dry cropland and pasture land are very similar while as expected, dry cropland values are higher than dry cropland without irrigation potential.

Net irrigation values shown in the graph are calculated by subtracting irrigated land values from the average of pasture and dry cropland and are therefore in between (the average) these classes of land values.

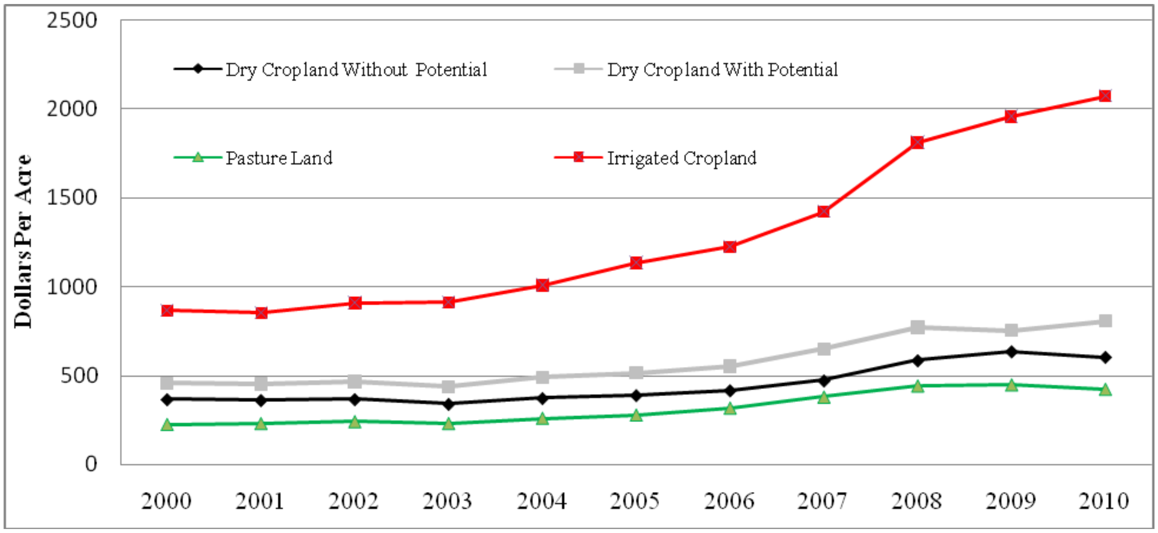


Figure 6.1 Land Values in the 'North' and 'Central' Regions: 2000-2010 (Based on UNL/Johnson Land Value Surveys)

These survey generated land values are shown along corresponding values based on actual sales in Figure 6.2. It should be noted that the survey reported non-irrigated land (without potential) in these comparisons are the average of dry cropland and pasture values. This was deemed necessary since the sales-based values do not distinguish between non-irrigated crop and pasture land.

The sales values are based on a well established and rich arms-length agricultural land sale database collected first by county tax assessors and then the State Property Tax Department for the purposes of assessing and equalizing property taxes. Only arms-length sales (non family to family sales) or sales deemed usable and representative of other sales (deemed by county tax assessors to be with extraordinary conditions) are utilized for the present study. This database is often referred to as the '521' sales database. Year 2009 and 2010 data were not available at the time of this present study.

The '521' sales data contain values for realty and non-realty items, buyers and sellers names, acreage estimates, and legal description of the sold parcels. The database also denotes not only whether a sold parcel was irrigated (yes or no) but the percentage of the irrigation within the parcel is not indicated. Another limitation with this database is that it does not distinguish between crop and pasture land sales and it does not include any soil productivity, parcel slope or well capacity indicators all of which are considered key factors influencing land values.

Knowing these details would require GIS analyses of sold parcels (digitizing land sales and overlaying them with other spatial databases –which is the focus of the next section (comparable sales and hedonic-based valuation approaches).

Survey-based (UNL/Johnson) irrigated land values are slightly higher, but very similar to '521' sales-based irrigation values from 2000 to 2004. But from 2005 to 2009, which is a period when both sets of values began a sharp and steady increase of approximately 12% per year, differences between the two sets of irrigated land values became larger, with sales-based values becoming on average 54% higher than the survey values. This is in stark contrast to the non irrigated land values which are considerably lower than irrigated values (66% lower on average) and for which there are much less extreme differentials between survey and sales-based values (only 12.5% on average).

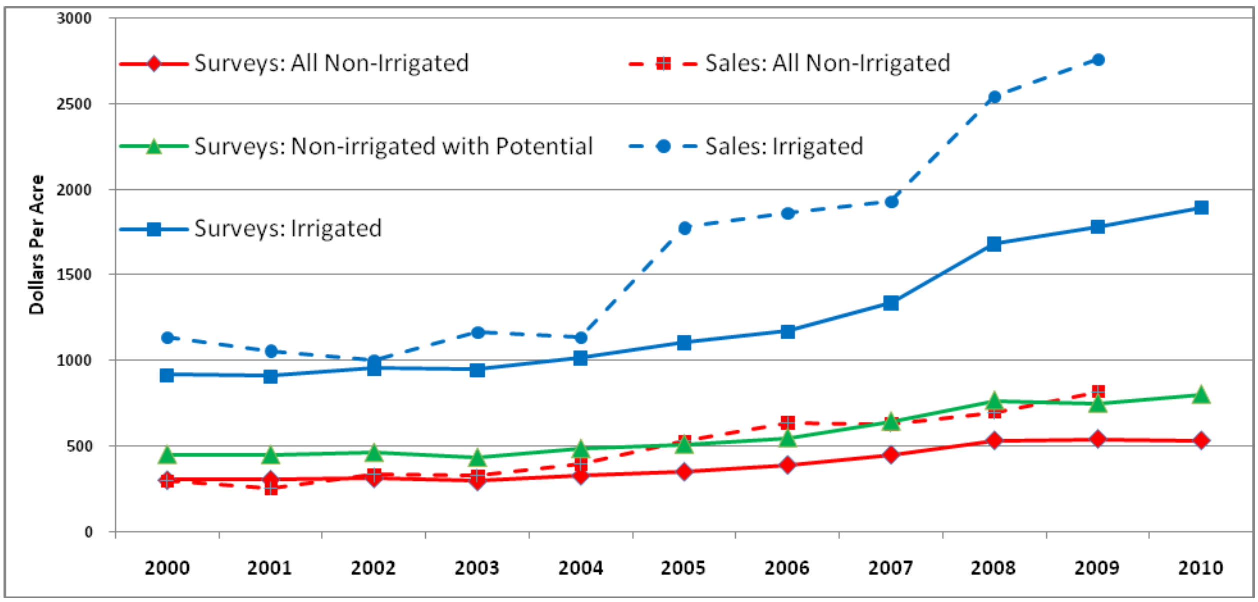


Figure 6.2 Land Values Based on UNL Surveys Versus '521' Sales Database

Net Irrigation Values from Existing Data

Three alternative estimates of the contributory values of irrigation to land values defined as net irrigation values (irrigated values minus dry land values) are portrayed in Figure 6.3.

The first two net irrigation estimates are based on reported UNL/Johnson survey values. They include the difference between irrigated land values and dry land values and then separately the difference between irrigated land values and non-irrigated land with the potential for irrigation development).

The sales-based net irrigation value estimates have the advantage of being based on a relatively large number of actual market transactions but the disadvantage of not being able to distinguish between dry land sales and sales defined as dry land with irrigation potential.

Over the 2000 to 2004 time period all three of the net irrigation value estimates are relatively constant over time with the survey/dry potential values being on average 29% lower than values based on all dry land sales and 42% lower than values based on sales. This is expected as the dry/potential values involve the comparisons of similar land types (i.e. irrigated land with land having irrigation potential). After 2004 all three net irrigation values increased markedly (on average by 13% per year) and the sales-based values remain higher than either of the survey-based values (37% higher than the surveys based on all dry land sales and 43% higher than the survey/potential values).

The differences between survey and sales-based net irrigation value estimates are substantial, particularly from 2005 to 2009. Normally sales-based analyses would be considered more accurate and reliable than survey-based values but in cases of a lack of key information regarding the nature of the ‘521’ sales (i.e. the exact level of irrigated acreage and bio-physical conditions associated with sold parcels), the survey generated values that compare irrigation values to dry land values with irrigation potential are considered to be the most accurate available estimates of irrigation values in the Niobrara Basin. Again, this is because they compare value of similar land types.

These superior survey values (that account for irrigation potential) range from $411 in 2000 to $1,268 in 2010 with an average value over this 10-year period of $655/acre in contrast to an average value of $800/acre using surveys and all dry land values, and $1,146/acre based on the ‘521’ sales.

Finally, the comparable sales and hedonic price approaches to quantify the contributory values of irrigation (in the next section of this report) are expected to be superior to any of these just reported net irrigation values. This is because they will take advantage of parcel-level GIS data that will help isolate the contribution of irrigation to land values while accounting for other bio-physical characteristics. Another advantage of these GIS-based irrigation value estimates is that they can be made in specific areas of the basin which is important because of the hypothesis that conditions and irrigation values vary substantially across the basin.

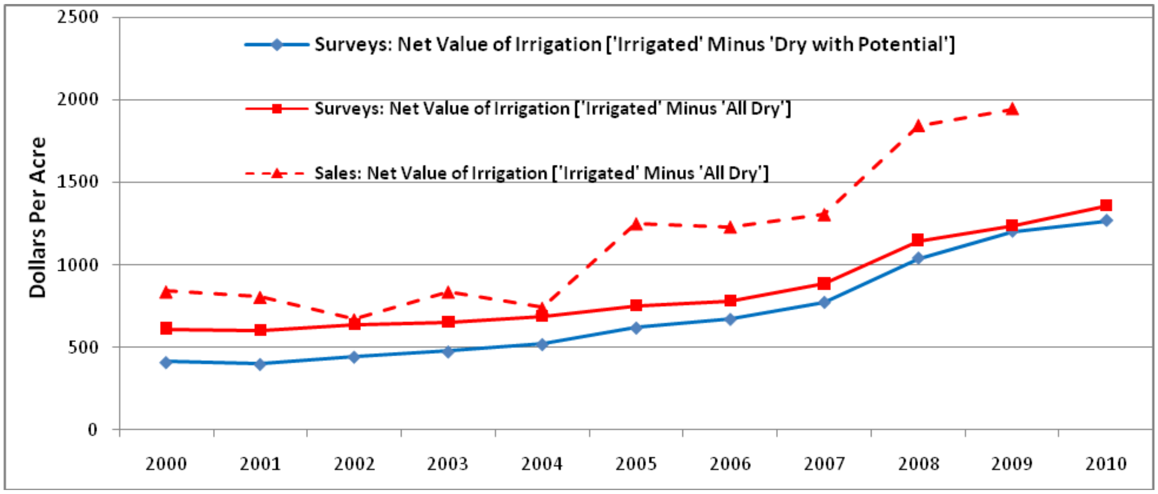


Figure 6.3 Net Irrigation Values Based on Survey versus Sales Data

GIS Analyses of Agricultural Land Sales

The previously described arms-length sales from the '521' database were geo-spatially referenced (digitized into a GIS) using available legal descriptions of sold parcels along with NAIP field imagery and CLU boundaries. This was required to estimate irrigation values in specific sub-regions of the Niobrara Basin (i.e. NRDs) and to make both comparable sales-based analyses and hedonic price estimates of the contributory value of irrigation.

Most of these sales were digitized into a GIS database. Approximately 5% of sales that were excluded was a result of the inability to digitize some sale parcel boundaries due to confusing, missing and/or incorrect legal descriptions, or because key sales transaction data was missing or incorrect. Approximately 1% of the digitized sales were classified as being uncharacteristic outliers and excluded based on comments made by local appraisers and/or assessors related to their a-typical nature. In most cases these were lands purchased for recreational activities by non-agricultural producers.

The parcel boundaries of the remaining sample of approximately 94% of all arms-length sales (904 sales over the 2000 to 2008 time period) were spatially overlaid with the CALMIT 2005 land use database to confirm their crop type and irrigation status. These parcels were also spatially overlaid with variety of other GIS databases including stream and well data (from the USGS and the NDNR), soil productivity data (SRPG measure from SSURGO), and field slopes (from USGS digital elevation maps).

Sales across the Basin from 2000 to 2008 are shown in Figure 6.4 and summarized by land cover type in Tables 6.1 and 6.2. Dry cropland sales are 5% of all sales, and additional inquiries indicated that only about 10% (i.e. five) of these sales had the potential to be irrigated (defined as having similar characteristics as nearby irrigated sales). The paucity of dry cropland sales with irrigation potential may limit the accuracy of the earlier discussed UNL/Survey based estimates of net irrigation values (those based on comparing irrigated sale prices with cropland with irrigation potential prices).

Table 6.1 Agricultural Sales by Land Type (2000-2008)

	Number	Proportion of All Sales
Dry Cropland	44	5%
Irrigated Cropland	205	23%
Pasture	410	47%
Mixed	238	26%
Canyon/Forested Land	7	<1%
Total	904	100%

Table 6.2 Number of Digitized Agricultural Sales with Complete Parcel Level Data by Land Use Type* and Market Segment (2000-2008)

	All	Irrigated	Dry Crop	Pasture	Mixed
Upper Niobrara (All)	245	30	32	104	79
Upper Niobrara-White/North	104	2	11	52	39
Upper Niobrara-White/South	141	28	21	52	40
Middle Niobrara (All)	114	13	0	37	8
Middle Niobrara/North	37	2	0	30	5
Middle Niobrara/South (including the Upper Loup)	77	11	0	61	5
Lower Niobrara (All)	413	106	5	186	116
Lower Niobrara/North	70	0	1	49	20
Lower Niobrara/South	343	106	4	137	96
Upper Elkhorn	125	56	7	29	33

* Seven canyon/forested land sales were dropped from this table

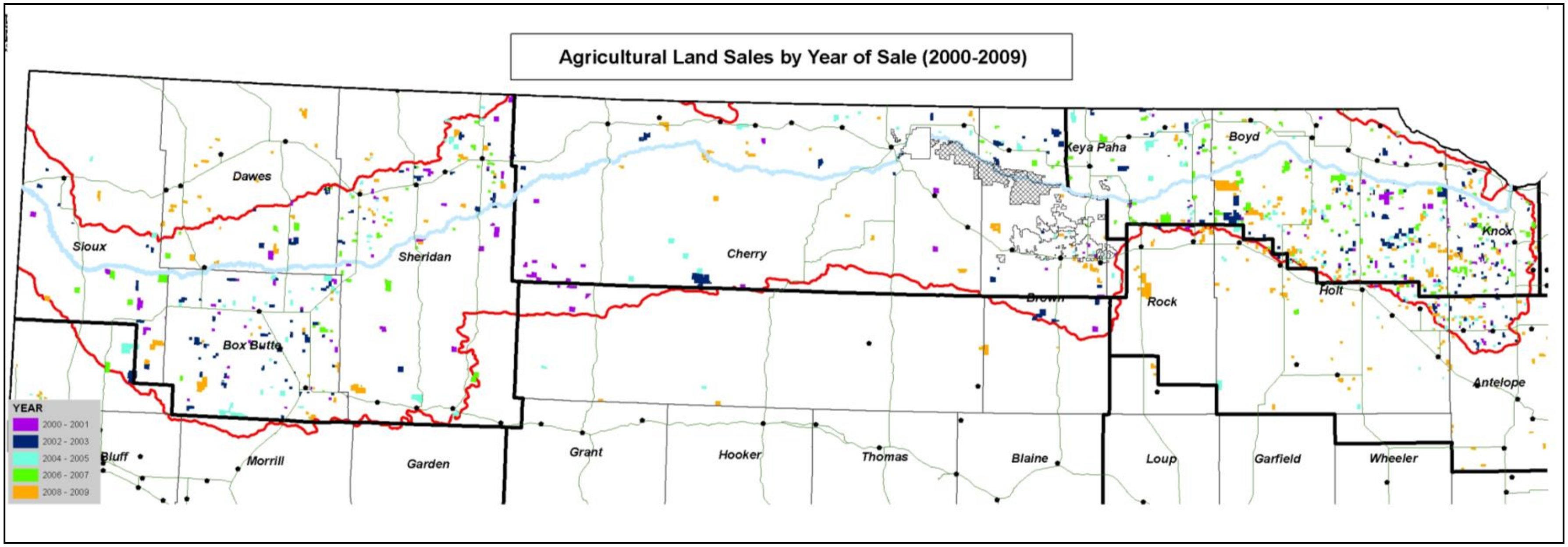


Figure 6.4 The Location of Agricultural Land Sales Across the Niobrara Basin (by Year)

Besides the lack of enough comparable sales of dry cropland with irrigation potential, another limitation with relying on the UNL/Johnson surveys to estimate land and irrigation values is that reported values are not specific to different areas (NRDs and irrigation districts) across the Basin. In fact, there was no basin-wide specific value reported (instead this study had to use average values across two distinct survey regions).

The importance of having region-specific land and irrigation value estimates is summarized in Table 6.3 where it can be seen that land sale prices (both for irrigated and dry land) and corresponding net irrigation values (defined as irrigated land sale prices on a per acre basis minus non-irrigated values without accounting for irrigation potential), vary substantially across the Basin. In fact, net irrigation values range from $325 to $1,027 with a basin-wide average of $928.

These values are reported only to demonstrate the spatial variation in net irrigation estimates across NRDs. Since these net irrigation values do not account for irrigation potential they are likely to be inaccurate and unrealistically high. In fact, they are 42% higher than the net irrigation values of $655/acre estimated from the UNL/Johnson surveys that accounted for irrigation potential.

Table 6.3 Median Land Values ($/Acre) and Simplistic Net Irrigation Value Estimates in Different Market Segments across the Niobrara Basin (2000-08)*

	Irrigated Land	Non-Irrigated Land	Net Irrigation Values (not accounting for irrigation potential)
Upper Niobrara	$753	$335	$418
Upper Niobrara-White/North	$827	$270	$557
Upper Niobrara-White/South	$753	$350	$403
Middle Niobrara (All)	$1,060	$340	$720
Middle Niobrara/North	$625	$300	$325
Middle Niobrara/South	$1,103	$268	$835
Lower Niobrara (All)	$1,477	$630	$847
Lower Niobrara/North	$795	$462	$333
Lower Niobrara/South	1,476	$450	$1,027
Upper Elkhorn	$1,333	$617	$716
Entire Basin	$1,303	$375	$928
Entire Basin (Fully Appropriated Areas)	$1,072	$333	$739
Entire Basin (Non-Fully Appropriated Areas)	$1,492	$613	$839

** Irrigated sales do not include mixed sales (they are only irrigated cropland) while non-irrigated land sales are cropland (when they exist) or crop/pasture/mix sales when an insufficient number of dry cropland sales exist.*

Hedonic Price Models to Measure the Marginal Value of Irrigation

The previously described 904 agricultural land sales for which detailed (parcel-level) bio-physical characteristics have been obtained are used to estimate a hedonic price model for the purposes of estimating the marginal (contributory) price of irrigation.

The general form of the hedonic price model is:

$$(Price / Acre)_i = \beta_0 + \sum_{i=1}^{n} \beta_q Q_{ij} + \beta_s S_{ij} + \beta_z Z_{ij} + \beta_c I_i + u$$

where the of price per acre is a function of a vector of physical characteristics Q, a time trend matrix of dummy variables S, location dummies Z, a vector representing the presence of irrigation rights and ability I, and a random error term u.

The specific form of the hedonic price model involved regressing sale prices on a per acre basis against the size of sold parcels, the proportion of a parcel that is wetlands or wet meadows, the proportion of a parcel that is irrigated, the average soil productivity of a parcel (SRPG), the reciprocal of the average slope of a parcel,[53] the distance from sold parcels to towns containing a population of 2000 persons or greater, time trend variables representing the year in which sales occurred, and finally, dummy variables (yes/no) indicating the NRD in which a sale was located and whether or not it was in a fully appropriated area. These variables along with their summary statistics (means and standard deviations) are summarized in Table 6.4.

The hedonic model was first estimated basin-wide and then separately for unique market segments (NRDs and NRDs north and south of the Niobrara River). The explanatory variable in the hedonic model of greatest interest is the proportion of a sold parcel that is irrigated because this represents the marginal price of irrigation (both rights and potential bundled together). Again, this is considered the effect of changing irrigation status on an acre of land. Conceptually this can be considered to be equivalent to the price differential between an irrigated versus a non-irrigated parcel while taking into account (controlling) for other factors (productivity measures) and hence the marginal implicit price of irrigation on a per acre basis.

[53] Reciprocal function forms for explanatory and variable B_1 are represented by $Y = B_o + B_1 \ 1/X_1$. Such a functional form is commonly used for modeling variables with a satiation or a minimum acceptable level (such as the slope of a field where the use of pivot irrigation is infeasible. The marginal effect of a reciprocal variable (X) is interpreted as $-B_1 \ 1/X_1$ (that is, the sign of estimated coefficient needs to be reversed for interpreting its effect on Y).

Table 6.4 Explanatory Variables in the Basin-wide Hedonic Price Model

Variable	Description	Mean	Std. Dev.
totalac	Sold Acres	339	549
p_wet_meadows	% of the Sold Parcel Comprised of Wet Meadows and/or Wetlands (considered non-irrigatable)	2%	7%
p_ir05calm	% of the Sold Parcel Irrigated	26%	36%
srpg	Soil Rating For Plant Growth	35.1	11.6
slope	Parcel Slope	3.5	3.1
d_u_nrd	If in the Upper Niobrara-White NRD	27%	0.44
d_m_nrd	If in the Middle Niobrara NRD	13%	0.33
d_l_nrd	If in the Lower Niobrara NRD	47%	0.50
d_2001	If sold in 2001	8%	
d_2002	If sold in 2002	11%	
d_2003	If sold in 2003	14%	
d_2004	If sold in 2004	13%	
d_2005	If sold in 2005	6%	
d_2006	If sold in 2006	12%	
d_2007	If sold in 2007	5%	
d_2008	If sold in 2008 or early 2009	22%	
dist_t2000	Distance from Sold Parcel to Nearest Town of 2,000 persons or more (miles)	29	15
d_f_approp	If in a Fully appropriated Area	56%	

The baseline hedonic model that specified sale prices ($/acre) to be a function of bio-physical characteristics of sold parcels, the year of the sale and the NRD in which the sale is located had an R^2 value of 0.69 meaning that 69% of the variation in sale prices are explained by the variables in the model. This is reflected in a statistically significant f-value and most of the explanatory variables having t-values that are statistically significant and with expected signs (positive or negative impacts on sale prices). The estimated coefficients for this model are summarized in Table 6.5.

The variable measuring the percentage of a sold parcel that was irrigated had a statistically significant and positive impact on sale prices at the 99% confidence level. Each additional acre of irrigation adds $827 to total sale prices which is $101 (10%) lower than the net value of irrigation estimated simplistically using raw '521' sales data over the 2000-2008 period, but 26% higher than irrigation values derived from the UNL/Johnson expert opinion surveys.

As expected, wet meadows and parcel slope have a statistically significant and negative impact on sale prices whereas soil productivity (SRPG) and distances to towns of 2,000 people or more have a statistically significant positive impact on price. Somewhat unexpectedly, sale size (total acres sold) did not have a statistically significant impact on price per acre meaning that prices on a per acre basis are not lower for large sales. This may be a result of most sales being relatively large (i.e. a mean sale size of 339 acres). The fact that whether or not a sale was located in a fully appropriated area had a negative impact on sale prices ($91 per acre) is likely a result of a premium being given to land without having any restrictions on and future irrigation development. Finally, time trend variables only from 2005 onwards have a statistically significant impact on sales prices.

If the basin-wide hedonic price model is estimated only for the 2008 year (206 sales) the coefficient of determination (R^2) value of the model falls to 0.61 (meaning that 61% of the variation in sale prices are explained by the variables in the model), and the value of irrigation increases slightly to $888 which indicates that irrigation values increased by 7% from 2007 to 2008.

Hedonic-based estimates of the marginal value irrigation estimated separately for different NRDs are summarized in the top section of Table 6.6. Marginal irrigation prices were successfully estimated for each of the NRDs in the Basin with irrigation values ranging from $596/acre in the Upper Niobrara-White NRD to $911/acre in the Lower Niobrara NRD.

Within more specific market segments (NRD segments identified by whether they are north or south of the Niobrara River), marginal irrigation prices were successful for all markets and ranged from $412/acre in the Middle Niobrara/North to $985/acre in the Middle Niobrara South (which contained 17 sales in the Ainsworth Irrigation District). Other substantial differences were noted between the irrigation values of the north/south of river market segments of the other NRDs which support the use of such a north/south of river market segmentation.

Table 6.5 Estimated Coefficients for the Basin-wide Hedonic Price Model

	Coef.	Std. Err.	t	P>t
totalac	0.00	0.02	-0.21	0.83
p_wet_mead~s	-235.12	143.01	-1.64	0.10
p_ir05calm	827.36	35.16	23.53	0.00
srpg	3.20	1.05	3.03	0.00
recip_slope	62.69	14.77	4.24	0.00
d_u_nrd	-354.37	47.26	-7.5	0.00
d_m_nrd	-211.92	49.93	-4.24	0.00
d_l_nrd	-93.95	32.88	-2.86	0.00
d_2001	-2.92	51.15	-0.06	0.96
d_2002	9.31	47.95	0.19	0.85
d_2003	25.41	46.14	0.55	0.58
d_2004	74.49	46.86	1.59	0.11
d_2005	345.19	54.47	6.34	0.00
d_2006	360.54	47.68	7.56	0.00
d_2007	478.16	57.17	8.36	0.00
d_2008	232.43	43.94	5.29	0.00
dist_t2000	-2.91	0.92	-3.16	0.00
d_f_approp	-91.08	33.68	-2.7	0.01
_cons	473.05	66.83	7.08	0.00

Table 6.6 Hedonic Marginal Irrigation Values by Market Segments (2000-2008)

	Sales	R^2 Value (Hedonic Model)	Marginal Value of Irrigation
Entire Basin	896	.68	$827
By NRD Market Segments			
Upper Niobrara	247	.62	$596
Middle Niobrara & Upper Loup	114	.54	$909
Lower Niobrara	409	.74	$911
Upper Elkhorn	125	.49	$807
By Detailed NRD Market Segments			
Upper Niobrara-White North	104	.57	$701
Upper Niobrara-White South	141	.70	$578
Middle Niobrara North	37	.66	$412
Middle Niobrara South	77	.61	$985
Lower Niobrara North	70	.61	$496
Lower Niobrara South	342	.73	$916

The contribution that irrigation makes to total irrigated land sale values in different market segments in the Niobrara Basin is summarized in Table 6.7. This is calculated by dividing the marginal implicit prices of irrigation (calculated earlier through hedonic price modeling) by mean irrigated land sale prices (only sold parcels that were completely irrigated). The purpose of such a metric is to demonstrate relative value of irrigated land compared to the marginal prices of irrigation. Such metrics could also potentially be used to update marginal irrigation value estimates by applying contribution percentages for specific NRDs with more recently observed sale prices of irrigated land.

Across the entire Niobrara Basin the marginal irrigation values are 63% of average (median) irrigated sale prices with a range of 61% to 89%. These contribution values generally increase as one heads from east to west (from the Lower Niobrara and Upper Elkhorn NRDs in the east to the Upper Niobrara-White NRD in the far western extreme of the Basin). To some extent, this is likely a result of the fact that precipitation levels decrease from east to west meaning that the need for irrigation for crop production increases from east to west. However, an exception to this is the Middle Niobrara/South market segment NRD where the contribution of marginal irrigation prices to total sale prices is the highest of the market segments in the Basin at 89% which may be a result of the fact that this segment includes the Ainsworth Irrigation District which receives a very reliable delivery of irrigation water from Merritt Reservoir on the Snake River.

Table 6.7 The Contribution of Marginal Irrigation Prices to Irrigated Land Values

By NRD Market Segment	Marginal Price of Irrigation ($/acre)	Mean Irrigation Values ($/Acre)	Contribution of Marginal Price to Sale Price
Entire Basin	$827	$1,303	63%
Upper Niobrara (All)	$596	$753	79%
Upper Niobrara-White North	$701	$827	85%
Upper Niobrara-White South	$578	$753	77%
Middle Niobrara (All)*	$909	$1,060	89%
Middle Niobrara North	$412	$625	66%
Middle Niobrara South	$985	$1,103	89%
Lower Niobrara (All)	$911	$1,477	62%
Lower Niobrara North	$496	$795	62%
Lower Niobrara South	$838	$1,459	62%
Upper Elkhorn	$807	$1,332	61%

** Middle Niobrara segments also include the Upper Loup portion of the Niobrara Basin*

Capitalized (Annual) Irrigation Values

The marginal prices of irrigation derived from hedonic price models as summarized in Table 6.7 represents buyers' and sellers' opinions regarding the discounted net value of irrigation over time which means that they are perpetual (one time) values. To convert these perpetual marginal irrigation values to current (annual) values, these marginal values are multiplied by a capitalization rate of 7.5% which represents the ratio of annual rental rates to irrigated land sale prices to in the North and Northwest regions of the state from 2005 to 2010 as reported by the annual UNL/Johnson land value surveys. The resulting capitalized (annual) irrigation values in each market segment over the 2000 to 2008 period are summarized in the first column of Table 6.8. The second column contains the annual value of water per acre-foot of water usage that is based on water need estimates to grow corn in each NRD. Such acre-foot values are useful for comparisons with the cost of water actually paid by surface irrigators and/or the value of water for hydro-electricity generation at Spencer Dam.

Table 6.8 Capitalized (Annualized) and Total Irrigation Values (2000-2008)

Market Segment	Capitalized Values	Capitalized Values Per Acre-Foot of Water Used*
Entire Basin	$62	$67
Upper Niobrara- White (All)	$45	$56
Upper Niobrara-White North	$53	$66
Upper Niobrara-White South	$43	$54
Middle Niobrara (All)	$68	$68
Middle Niobrara North	$31	$31
Middle Niobrara South	$74	$74
Lower Niobrara (All)	$68	$64
Lower Niobrara North	$37	$35
Lower Niobrara South	$69	$65
Upper Elkhorn	$51	$48

** Capitalized values multiplied by water need estimates to grow corn in each NRD. These water use values do not include losses associated with surface water delivery.*

Total irrigation values (capitalized values multiplied by estimated irrigation acres both basin-wide and in fully appropriated areas are summarized in Table 6.9. Basin-wide, current irrigation has an economic value of $44 million per year basin-wide or $29.4 million per year in the fully appropriated areas of the basin. The use of a single basin-wide marginal irrigation value of $62/acre (termed simplistic in the Table) instead of market segment specific values would result in an over-estimation of irrigation values by 12% basin-wide and by 17% in the fully appropriated areas. This justifies the analyses of irrigation acreage and values by specific NRDs and sub-NRD market segments.

Table 6.9 The Annual Value of Current Irrigation Across the Niobrara Basin

Market Segment	Irrigation Values (All Irrigation)	Irrigation Values (Fully Appropriated Irrigation)
Upper Niobrara-White (All)	$12,787,375	$12,628,627
Upper Niobrara-White North	$4,445,795	$4,385,018
Upper Niobrara-White South	$8,341,580	$8,243,609
Middle Niobrara & Loup (All)	$8,450.453	$8,341,580
Middle Niobrara North	$1,141,261	$1,141,261
Middle Niobrara/South & Loup	$7,309,193	$7,309,193
Lower Niobrara (All)	$15,907,628	$6,426,162
Lower Niobrara North	$1,177,454	$1,027,166
Lower Niobrara South	$14,730,173	$5,398,996
Upper Elkhorn	$6,864,649	$2,049,503
Basin Wide (summation)	$44,010,104	$29,440,145
Basin Wide Simplistic*	$49,260,364	$34,347,628

**Total irrigation acres multiplied by a single basin-wide average value for irrigation.*

7. COMPARING ALTERNATIVE WATER USE VALUES IN THE NIOBRARA BASIN

Irrigation Values Versus Surface Water Costs and Hydro-electricity Values

Basin-wide the value of irrigation as measured by buyers' willingness to pay for it, is at $67 per acre-foot, about twice as high as what surface irrigators are actually paying for delivered surface water (between $25 and $40 per acre-foot). In the Ainsworth Irrigation District irrigators pay between $31 to $36 per acre-foot for delivered water while the marginal price of irrigation water in that market segment (Middle Niobrara/South) is $74 per acre-foot. In the Mirage Flats Irrigation District irrigators pay between $25 and $40 per acre-foot of delivered water while the marginal price of irrigation in that market segment (Upper Niobrara-White/South) is $54 per acre-foot.

The annual value of irrigation basin-wide (again $67 per acre-foot used) is substantially higher than the value of water associated with hydro-electricity generation at Spencer Dam (from $0.32 to $1.09 per acre-foot). However, the hydro-electricity generation is a senior water right to irrigation in the Basin and state water law does not dictate that the highest value dictates water rights. As well, hydro-electricity generation at Spencer Dam can be considered non-consumptive in-stream water use in that it is complimentary with upstream recreational floating activities and downstream water uses.

Irrigation Values Versus Recreational Floating and Hydro-electricity Values

Comparing the value of irrigation with in-stream uses (recreation and hydro-electricity generation) must be done carefully and with caveats. First, at the present time, irrigated agriculture and in-stream flow activities at least at their present levels appear to successfully co-exist. Therefore, such comparisons are really only relevant for future scenarios when water scarcity issues as a result of increased irrigated agriculture developments and/or due to changing climatic conditions (i.e. a prolonged drought).

Second, such comparisons are limited because not all types of water-based recreational activities in the Niobrara Basin have been quantified. In fact, to date only the values of recreational floating on a 30-mile stretch of the Niobrara River from Valentine to the Norden Bridge within the Middle Niobrara NRD have been quantified (Shultz, 2009). Two sets of potentially relevant recreation-based economic values that are still unknown are the option/existence/non-use economic values associated with water flows in the Niobrara River, and the value of fishery and wildlife resources particularly in lower reaches of the Niobrara Basin including potential threatened and endangered species.

Finally, it is important to compare known in-stream values (in this case recreational floating and Spencer hydro-electricity generation values) only to irrigation that uses water which could potentially be used for (i.e. compete with) in-stream uses if it that groundwater was not used for irrigation. This means that comparisons should only be made to irrigation that takes place upstream of recreational floating activities and the Spencer Dam hydro-electricity generation site which corresponds to irrigation in the

Middle and Upper Niobrara-White NRDs. The comparisons should also be limited to irrigation within fully appropriated areas (where irrigation has been determined by the NDNR to have a hydrological connection with in-stream flows), and should be adjusted (reduced) in cases where potentially un-used irrigation water would not return in its entirety (100%) to the Niobrara River.

It can be reasonably assumed that all surface water based irrigation would return to the Niobrara River if not used for irrigation, but the same cannot be said for groundwater based irrigation. At the present time, there do not exist sufficiently detailed hydrologic studies in the Niobrara Basin that quantify the site-specific rates of return of non-used groundwater to the Niobrara River. In lieu of such information, irrigation versus in-stream flow comparisons are made here under alternative scenarios of 25%, 50% or 75% groundwater return rates. This range of water-return rates are based on very general (but not universally accepted) findings that groundwater makes up to 50% to 90% of the flow of the Platte, Loups, Elkhorn, and Niobrara Rivers (Goeke, 2010), and the widely understood phenomena that some of the groundwater used for irrigated agriculture returns naturally to aquifers.

Before these comparisons between irrigation and recreation values are made, it is prudent to review the recreational value results from a previously conducted NGPC funded Niobrara River study by Shultz (2009) which estimated annual economic values associated with recreational floating on the Niobrara River from Valentine to Norden Bridge to be $10.9 million per year. Excluding $2.1 million of multiplier effects from this recreational value estimate (since such multiplier effects are not inherently included in the irrigation values of this present study) results in an annual recreational floating value of $8.8 million per year. Combining recreational floating economic values with hydro-electricity generation economic values estimated in this present report (approximately $700,000 per year) results in a combined recreation/hydro-electricity economic value of $9.5 million per year.

Comparisons of in-stream flow values with irrigated agriculture that could potentially influence such in-stream flow activities (under alternative assumptions regarding groundwater return rates) are summarized in Table 7.1.

Table 7.1.1 Hydrologically Connected Irrigated Agriculture Values Versus In-Stream Flow Values*

	All Surface Irrigation and Groundwater Irrigation with Rates of Return of:		
	25%	**50%**	**75%**
All Areas Upstream of Spencer Dam (UN-W, Middle, Loup NRD’s)	$7.7 M (-19%)	$11.9 M (25%)	$17.5 M (84%)
Middle Niobrara NRD Only (Adjacent to Recreational Floating)	$4.9 M (-48%)	$6.2 M (-35%)	$7.5 M (-21%)

**In-Stream flow values of $9.5 million per year are comprised of recreational floating values from Valentine to Norden Bridge along with hydro-electricity generation values at Spencer Dam*

Assuming that 25% of groundwater irrigation (and all surface irrigation) upstream of Spencer Dam would return to the River if not used for irrigation, its value is $7.7 million per year which is 19% lower than the in-stream flow values. Assuming a 50% return rate for groundwater irrigation, it is $11.9 million which is 25% higher than in-stream flow values. Assuming a 75% return rate, irrigation is $17.5 million which is 84% higher than in-stream flow values). However, if the geographical focus of irrigated agriculture versus in-stream flow values are compared only to the middle Niobrara NRD (the area immediately surrounding and upstream of the evaluated in-stream flow activities which includes Cherry, Brown, Keya Paha and parts of Upper Loup Counties), then irrigated agriculture is between 21% to 48% less valuable than in-stream flows depending on assumed groundwater return rates).

Finally it must be emphasized that recreational activities other than floating the NSR portion of the River, as well as option and existence values which residents statewide may place on River Flows, and various fishery/wildlife/ecological values associated with in-stream Niobrara River flows have not yet been estimated and included in these comparisons.

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9. Appendices

A: NPPD Valuation Approaches for Spencer Dam Electricity Generation
B: Approaches Used to Certify Irrigated Acres by the Middle Niobrara NRD
C: Approaches Used to Certify Irrigated Acres by the Upper Niobrara-White NRD
D: Approaches Used to Certify Irrigated Acres by the Lower Niobrara NRD

Appendix A: NPPD Valuation Approaches for Spencer Dam Electricity Generation

As set forth in both the Petition and as proposed in NPPD's Return of Appraisers, the exercise of preference is limited to a twenty (20) year period. NPPD has calculated the cost to replace power generated for the next twenty (20) years on the spreadsheet attached as Exhibit "D".

Exhibit "D" identifies the factors that must be considered when establishing the value of compensation for the power that must be replaced when the Appropriators/Condemners use their junior irrigation water appropriations under the statutes as follows:

- The Petition has indicated the time period for 20 years.
- The preference exercised is for irrigation which generally occurs in the June-August period.
- The Appropriations are for a total of 292 acres for Keim and 1573.55 acres for Breiner.
- Calculation factors for the amount of power to be replaced:
  - NPPD used the power production curves for the hydroelectric generators to determine the amount of power produced at Spencer Hydro based on the average flow values for June, July, and August. This results in the production of 3264 kilowatts of power per cfs per day.
- The cost to replace the power was determined by using the market replacement costs during the next 20 years as established by power marketing planners. NPPD has calculated the average daily cost of power for June (20%) , July (40%), and August (40%) for the next 20-year period to be $66.24.
- The megawatt hours of power produced by each acre-foot (AF) (.01645) of water,

times the average cost of power ($66.24), results in a cost of $1.09/AF of water . This is multiplied by the appropriative right of 3AF to be $3.27 per appropriated acre.

- This value is then discounted at 5.25% for the 20 year period. 5.25% is the appropriate discount rate because the rate represents NPPD's long-term tax-free interest rate. This results in a discounted value of $39.8923 per appropriated acre for the 20-year period.

Questions to Consider

NPPD believes that the following questions are critical to determine the correct cost to replace power from the number expected to be proposed by the Condemners:

1. How can Condemners Keim and Breiner limit their preference exercise to 15 inches per acre per year when they are statutorily granted the right to appropriate three (3) acre feet per year? *See, Sorensen v. Lower Niobrara Natural Resource District;* **Neb.Rev.Stat.** § 46-231.
2. What is the proper number to place on the exercise of the preference per Mwh/acre-foot of water? The Condemners have proposed .0085 Mwh/acre-foot while NPPD believes the correct figure is .01645 Mwh/acre-foot.
3. What will be the price of replacement power for the next twenty years during the months that the preference will most likely be exercised – June, July and August? The Condemners suggest that the price be set at $38.00 based upon a financial report from 2006 involving a year-wide average. NPPD has set forth in Exhibit "D" its projected replacement power rates during the irrigation season which ~~is~~

NPPD's Compensation for Irrigation Preference for use of the Spencer Hydro Water

Line		20-Year
4	**MWH/AF:**	
5	Kw/cfs (Power Production Curves @50% flow exceedance for June (20%) July (40%) and Aug. (40%))	1.36
6	kwh/cfs/day (kw/cfs X 24)	32.64
7	Convert kwh/cfs to MWH/AF (kwh/cfs/day / 1.984 /1000)	0.01645
8		
9		
10		
11	**Period of years:**	20
12		
13	**Cost to replace energy:**	
14	Market Replacement energy	20-yr projected 7x24
15	Timeperiod	Jun (20%), Jul(40%), Aug (40%)
16	Average $/MWH for the timeperiod	$66.24
17		
18		
19	**Total Cost to replace lost energy:**	
20		
21	**Calculated $/AF (MWH/AF X cost to replace power)**	$1.09
22	**AF diverted per acre for irrigator**	3
23	**Calculated $/acre ($/AF * AF per acre for irrigator)**	$3.27
24	**Discounted $/acre (PV of $/acre @ discount rate @ years)**	$39.8923
25	**Discount rate**	5.25%
26	Perfected Irrigated Acres -- Assume 100 acres	*100*
27	$/100 Perfected Irrigated Acres	*$3,989.23*

Abbreviations:

MWH/AF = megawatt hours per acre-foot. One thousand kilowatt hours per acre-foot. This is the amount of energy produced by one acre-foot of water at the Spencer Hydro, based on the Power Production Curve for the units.

AF = acre-feet. This is the volume of water that is required to cover 1 acre to a depth of 1 foot. To convert a rate of flow, in cfs to a volume in AF, one multiplies the flow rate times a constant conversion factor, depending on the duration of the flow. In this case, the flow in cfs is converted to a daily volume in AF by multiplying the cfs times a constant conversion factor of 1.984.

Kw = kilowatt of electrical energy. One thousand watts. A watt is a unit of power.

cfs = cubic feet per second, of water in this case, is the rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second. The volume of water represented by a flow of 1 cfs for 24 hours is equivalent to approximately 1.984 acre-feet (AF).

kw/cfs = kilowatts per cubic feet per second is the amount of electrical power produced by a particular hydroelectrical generator based on the rate of flow of water through the unit. This figure is obtained from Power Production Curves that are specific to a particular generator and set of operating conditions. In other words, for a given flow in cfs, each generator will produce power at a different rate.

kwh/cfs/day = kilowatt hours per cubic feet per second per day. The amount of energy in kilowatt-hours, that are produced by a hydroelectrical generator, assuming a given flow rate in cubic feet per second of water over a day's time.

$/MWH = dollars per megawatt-hour. The cost per megawatt-hour of energy. This can be either the cost to produce the energy or the cost to purchase it, but in this context it is the cost to purchase energy from market resources.

$/AF = dollars per acre-foot. The cost per acre-foot of water.

$/acre = dollars per acre. The cost per acre of irrigated land.

Appendix B:
Summaries of Procedures Used by the Lower/Middle/Upper Niobrara-White NRDs to Certify/Estimate Irrigation Acreage

VERBATIM MATERIAL FROM THE LOWER NIOBRARA NRD

The Lower Niobrara followed these steps in certifying the irrigated acres in the Niobrara fully appropriated potion of the district.

We first received a list of irrigated acres from the County Assessor office in the counties that were fully appropriated in our District. The District then sent letters and certification forms to landowners as well as posted ads in the local newspapers for irrigators and landowner to certify irrigated acres in the fully appropriated areas.

Certification of ground water irrigated acres is required, and certification of surface water irrigated acres is recommended by September 30, 2008, by each landowner or his or her representative that owns irrigated land within the Lower Niobrara NRD Niobrara portion that is fully appropriated.

Proof of Irrigation must be shown prior to October 17, 2007 for the Niobrara fully appropriated portion in order to certify the acres.

The certification forms must be taken to the County Assessor's office for the Assessor to seal. Records provided by the landowner may include signed original record of irrigated acres from the County Assessor, FSA aerial photo delineating irrigated acres, crop insurance records, or any other legal means of proof. The District will certify the greatest amount of acres that can be proven to have historical irrigated acres.

VERBATIM MATERIAL FROM THE MIDDLE NIOBRARA NRD

The rules and regulations outlining the process for certification of irrigated acres in the Middle Niobrara NRD are listed below. Irrigated acre numbers submitted for this report were derived using two shapefiles (certified acres, additional acres not certified) and an Excel spreadsheet of certified irrigated acres from the Middle Niobrara NRD. Irrigated acres north of the Niobrara were selected using the ArcMap selection and statistics tool. These selected acres were then subtracted from the total certified and non-certified acre numbers to derive total numbers of irrigated acres for north, south, and the entire NRD. All numbers are based on the best available information.

Rule 10 - Irrigated Acres Certification

Certification of ground water irrigated acres is required, and certification of surface water irrigated acres is requested by January 1, 2009, by each landowner or his or her representative that owns irrigated land within the Middle Niobrara NRD. The certification records provided by the landowner will include a completed District certification form, signed original record of irrigated acres from the County Assessor, and FSA aerial photo delineating irrigated acres. The County Assessor's records will be used as the final base for irrigated acre certification. In cases where the acres being certified are not accepted by the General Manager or his or her designated representative, the landowner or his or her representative may request to present his or her information to the Variance Committee for their recommendation to the Board.

The Board may take action to approve, modify and approve, or reject the certification provided by the landowner and his or her representative.

Acres to be certified must actually be capable of being supplied with groundwater or surface water through irrigation works, mechanisms, or facilities existing at the time of certification before being approved.

No acres shall be certified for an illegal water well as that term is defined in Section A, Rule 3 of the Middle Niobrara NRD Rules and Regulations.

The information on the forms needs to be corrected and kept current by the landowner or his or her representative.

CRP or other land previously irrigated but currently enrolled in a federal, state, or local government conservation program may receive a variance from the signed original record of irrigated acres from the County Assessor as long as:

1. Acres were irrigated just before being enrolled in a program.
2. Acres are not assessed as irrigated within that county.
3. Acres are certified through the Irrigated Acres Certification process following the conservation program contract termination.

Rule 11 - Other Ground Water Uses

Certification of livestock, municipal, and industrial ground water uses are required by January 1, 2009.

1. Livestock users reporting requirements (in accordance with Neb. Rev Stat. 46-735):

    a. The number and type of livestock.
    b. The number of wells used in livestock operation.
    c. Location and map of use.
    d. Well registration information.
    e. Estimated annual use.
    f. Any other information deemed necessary by the District.

2. Municipality reporting requirements:

    a. The water wells operated by the municipal user.
    b. Total acres within municipal jurisdictional limits, including location and map.
    c. The total irrigated agriculture acres within municipal jurisdictional limits.
    d. The total dry land agricultural acres within municipal jurisdictional limits.
    e. Any acres outside the municipal jurisdictional limits served by the municipal water supply system.
    f. The municipality's population according to the most recent federal population census.
    g. Industrial uses within the municipal system may be identified separately and not counted as part of the municipal allocation.
    h. The number of people served by the municipal water supply system.
    i. Any other information deemed appropriate by the District.

3. Industrial reporting requirements:

    a. The water wells operated by the industrial user.
    b. Total water use by industrial user.
    c. The purpose for which the ground water is used.
    d. The location and map of use.
    e. Any other information deemed appropriate by the District.

VERBATIM MATERIAL FROM THE NIOBRARA-WHITE NRD

Irrigated acres within the Upper Niobrara White Natural Resources District were identified by two methods; acres that were assessed by the county as irrigated ground and/or land that was currently irrigated or reported to United States Farms Service Agency as irrigated. District staff corresponded with the owners of every parcel that was identified as irrigated to determine if the parcel was certified irrigated or not. There was not an accurate GIS coverage of the irrigated acres for the District so staff drew polygons to digitize the certified irrigated fields within the District utilizing aerial photography and legal descriptions obtained from the certification process. The District utilized Microsoft Access to develop a database and is using Access for database management along with ESRI ArcGIS to maintain the digitized layer of the certified acres.

Acres submitted for this report were obtained by selecting the digitized acres that are not in the fully appropriated area of the District and subtracting them from the acres that are certified in the District based on whether they are located north or south of the Niobrara River.

Below is the section of the District's Ground Water Management Area rules and regulations pertaining to certifying uses.

15.13 Certification of Ground Water Use

15.13.1 After the effective date of these controls, and except as otherwise provided herein, any uses, with the exception of municipal and industrial/commercial uses, serviced by regulated water wells within the GWMA are required to be certified by the District. Users will report acres and uses, on forms provided by the District, as required herein. The Board may consider adjustments to certified uses based on evidence presented by the ground water user. The Board will consider new requests for certification of uses monthly. No ground water user, other than municipal and industrial/commercial users, shall apply ground water from regulated wells to acres that have not been certified by the District or otherwise use ground water from regulated wells for a use that has not been certified by the District.

15.13.2 Agricultural reporting requirements –Following the effective date of these rules and regulations, any agricultural water user who is using a regulated well must report the following:

15.13.2.1 Livestock users are to report:

15.13.2.1.1 The number and type of livestock being watered.
15.13.2.1.2 The number of regulated wells used in livestock operation.
15.13.2.1.3 Location of use.
15.13.2.1.4 Well registration information for the regulated well(s) in use.
15.13.2.1.5 Any other information deemed necessary by the District.

15.13.2.2 Irrigation users are to report:

15.13.2.2.1 The number and location of irrigated acres.

15.13.2.2.2 The number of regulated wells serving the acres being certified.

15.13.2.2.3 A copy of the most recent documentation from the county assessor showing irrigated acres.

15.13.2.2.4 For tax-exempt irrigated acres, the user shall provide available documentation as deemed necessary by the District.

15.13.2.2.5 Well registration information for the regulated well(s) serving the acres being certified.

15.13.2.2.6 Surface water appropriation information for amount of surface water delivered to certified acres also served by ground water wells.

15.13.2.2.7 Any other information deemed necessary by the District.

15.13.3 <u>Other use reporting requirements</u> –Following the effective date of these rules and regulations, any other ground water user, with the exception of municipal and industrial/commercial users, who is using a regulated well, must report the following:

15.13.3.1 The nature and extent of the use being certified.

15.13.3.2 The location of the use being certified.

15.13.3.3 The number of regulated wells serving the use.

15.13.3.4 Well registration information for the regulated well(s) serving the use being certified.

15.13.3.5 Any other information deemed necessary by the District.