Appendix F. Watershed Management Presentation Materials

Section Overview

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

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"Why Watershed Management" handout from August 2017 stakeholder meeting 2
"Why Watershed Management" handout from November 2017 stakeholder meeting 11

Aug 15, 2017

Why Watershed Management
By Ted Tietjen

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

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

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

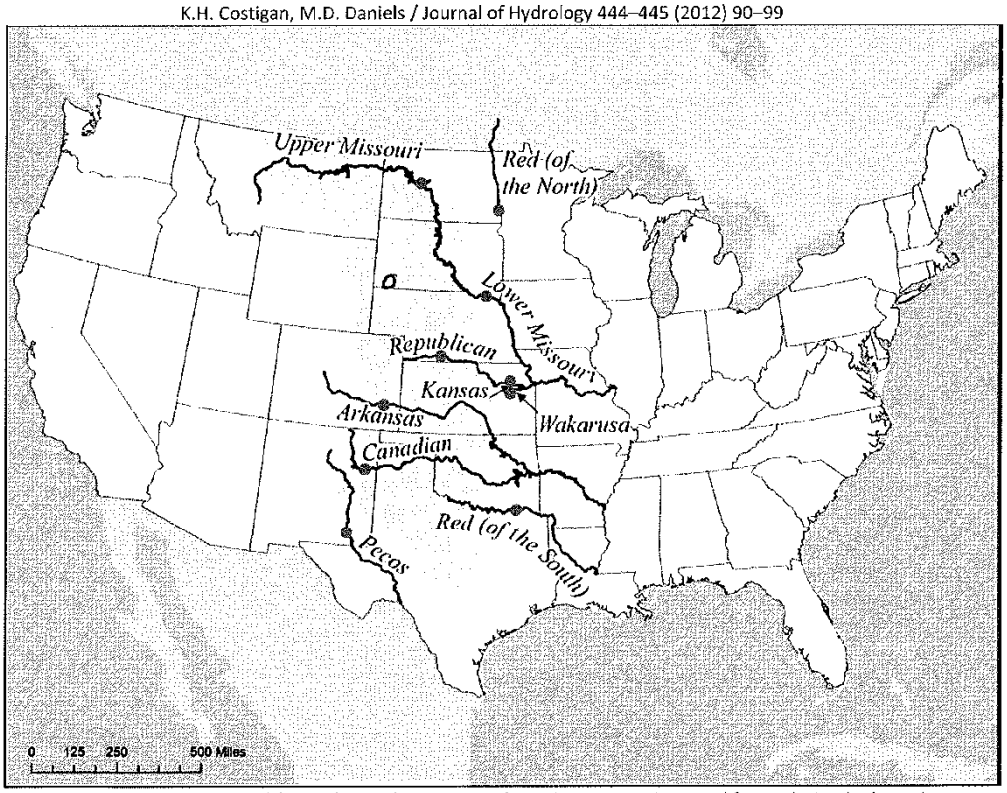


Fig. 1. Location of systems used for analysis, where gray circles indicate gage sites used for analysis. The boundary of the Great Plains USA is delineated in light gray.

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

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

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

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

That leads to the next question?

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

The manual is available through NRCS or online vendors.

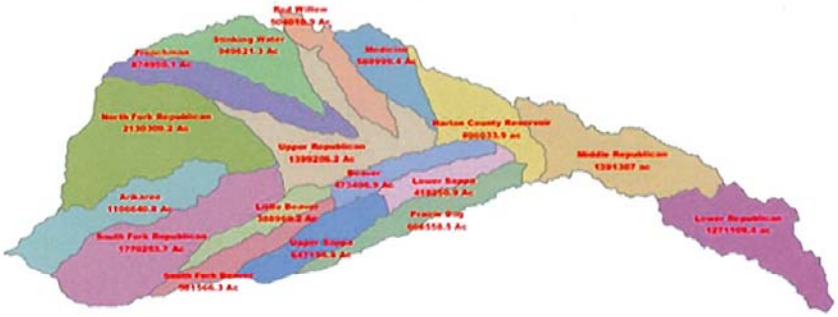
For every action there is a reaction and sometime there are unintended consequences. "**The Stream Corridor Restoration**" training should be required for those that serve on NRD and Irrigation District boards to better understand how streams function.

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

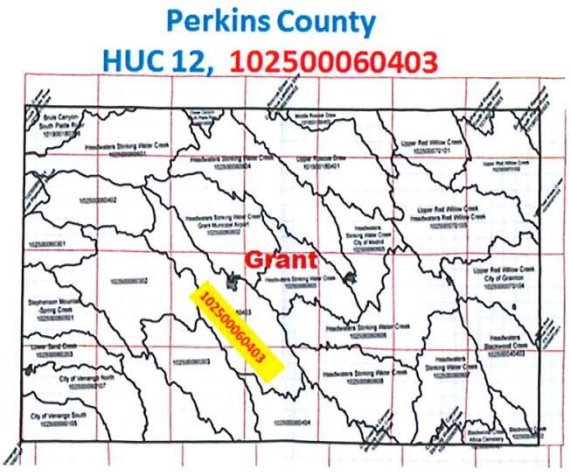
USGS has identified all watersheds in the US using Hydrologic Units that range in size from 1 through 12.
Example:
Missouri River is a HUC 10

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

Republican HUC 102500(01-17)
= 17 Units



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



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

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

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

Examples:

Perkins County consumptive water use estimates for 2007

12-Aug-17 — **Perkins County , NE**

Average Rainfall 35.48 **Inches** 2007

Adams Lumber data

CROP	ACRES	Inches CONSUMPTION	Inches DEPLETION	Acre/Inches	Growing Season	Growing Season Precipitation
Irrigated Corn (150 bu/ac)	115500	23.0	5.9	1,059,442	April - Sept.	20.1
Irrigated Corn (200 bu/ac)	0	25.0	6.9	0	April - Sept.	20.1
Irrigated Corn (220 bu/ac)	0	27.0	4.9	0	April - Sept.	20.1
Irrigated Corn (240 bu/ac)	0	28.0	3.9	0	April - Sept.	20.1
Ir. Sugar Beets ("x" ton/ac)	1100	22.7	-0.5	-545	April - Sept.	20.1
Ir. Soybeans (30 bu/ac)	5100	23.0	5.9	45,553	May - Sept.	24.9
Ir. Soybeans (60 bu/ac)	0	24.0	7.9	0	May - Sept.	24.9
Ir. Soybeans (70 bu/ac)	0	25.5	6.1	0	May - Sept.	24.9
Ir. Sorghum ("x" bu/ac)	0	23.0	5.9	0	May - Sept.	24.9
Ir. Dry Edible Beans ("x" lbs/ac)	3200	22.0	9.9	32,776		
Ir. Potatoes ("x" tons/ac)	0	29.0	2.9	0		
Irrigated Alfalfa ("x" tons/ac)	1200	40.6	-5.7	-11,265		
Sunflowers ("x" lbs/ac)	2900	22.5	5.4	21,093		
Irrigated Wheat ("x" bu/ac)	16200	26.6	5.2	86,378	August - June	25.1
Ir. Small Grains (other)	0	26.6	5.2	0		
Dryland Corn (100 bu/ac)	62600	17.5	14.1	885,725	April - Sept.	21.6
Dryland Soybeans (45 bu/ac)	600	16.7	15.2	9,123	May - Sept.	20.5
Dryland Sorghum	200	17.6	14.2	2,866	April - Sept.	20.5
Wheat/Corn/Soybean/Wheat	0	17.5	14.4	0		
Dryland Edible Beans	0	16.7	15.3	0	May - Sept.	20.5
Dryland Alfalfa	300	19.2	12.7	6,396	March - Nov.	0.5
Dryland Wheat	111200	15.1	16.9	1,877,854	August - June	25.1
Summer Fallow Wheat	56155	9.4	22.5	1,241,988	August - June	25.1
Summer Fallow Wheat/Corn	0	11.0	21.0	0		25.5
Dryland Small Grains (Oats/Wild	0	15.0	12.9	0		
Conservation Reserve(CRP)	42219	21.1	10.5	450,042		
Other AG. Lands	993	16.6	15.3	15,225		
Range, Pasture, Grasses	92775	13.1	12.5	1,193,462	March - Oct.	22.0
Riparian Forest & Woodlands	1669	13.1	12.5	21,417	March - Oct.	22.0
Wetlands	126	37.0	-25.1	-2,409	Feb. - Oct.	22.0
Open Water	0	46.0	-16.1	0	N/A	
Waste Land	1042	13.0	12.9	13,475		
Buildings & Building Sites	2470	16.6	15.3	37,570	N/A	
Urban Land & towns	0	13.7	12.2	0	N/A	
Rural Roads (Unsurfaced)	9150	13.0	12.9	118,328	N/A	
Totals	**561,002**			**7,821,568**		

Representative Equivalent

7,821,568 A/Inches

651,797 A/feet

Perkins County consumptive water use estimates for 2008

12-Aug-17		Perkins County NE					
Average Rainfall	18.77	Inches	2008				
Adams Lumber data							
CROP	ACRES	Inches CONSUMPTION	Inches DEPLETION	Acre/Inches	Growing Season	Growing Season Precipitation	
Irrigated Corn (180 bu/ac)	0	23.0	-6.1	0	April - Sept.	13.6	
Irrigated Corn (200 bu/ac)	104500	25.0	-8.1	-847,192	April - Sept.	13.6	
Irrigated Corn (220 bu/ac)(Silage)	500	27.0	-10.1	-5,054	April - Sept.	13.6	
Irrigated Corn (240 bu/ac)	0	28.0	-11.1	0	April - Sept.	13.6	
Ir. Sugar Beets ('x' ton/ac)	1900	22.7	-15.5	-30,033	April - Sept.	13.6	
Ir. Soybeans (50 bu/ac)	0	23.0	-6.1	0	May - Sept.	11.5	
Ir. Soybeans (60 bu/ac)	15600	24.0	-7.1	-110,969	May - Sept.	11.5	
Ir. Soybeans (70 bu/ac)	0	25.5	-8.9	0	May - Sept.	11.5	
Ir. Sorghum ('x' bu/ac)	200	23.0	-6.1	-1,221	May - Sept.	11.5	
Ir. Dry Edible Beans ('x' lbs/ac)	6200	22.0	-5.1	-31,738			
Ir. Potatoes ('x' tons/ac)	0	29.0	-12.1	0			
Irrigated Alfalfa ('x' tons/ac)	2500	40.6	-23.7	-59,268			
Sunflowers ('x' lbs/ac)	2900	23.5	-6.6	-19,160			
Irrigated Wheat ('x' bu/ac)	10500	26.6	-9.7	-104,835	August - June	14.4	
Ir. Small Grains (other)	0	26.6	-9.7	0			
Dryland Corn (100 bu/ac)	49700	17.5	-0.9	-45,078	April - Sept.	13.6	
Dryland Soybeans (45 bu/ac)	800	16.7	0.2	154	May - Sept.	24.9	Representative Equivalent fee
Dryland Sorghum	0	17.6	-0.7	0	April - Sept.	24.9	-1,129,851 Ac/inche
Wheat/Corn/Soybean/Wheat	0	17.5	-0.6	0			-94,154 Ac/feet
Dryland Edible Beans	0	9.4	7.5	0	May - Sept.	11.5	
Dryland Alfalfa	500	19.2	-2.3	-1,154	March - Nov.	25.5	
Dryland Wheat	94400	19.2	-2.3	-217,751	August - June	14.4	
Summer Fallow	107562	9.5	7.1	762,937	August - June	14.4	
Summer Fallow Wheat/Corn	0	12.3	4.6	0			
Dryland Small Grains (Oats/Millet	0	16.0	-1.1	0			
Conservation Reserve(CRP)	41574	21.1	-4.2	-174,502			
Other AG. Lands (hay)	11200	16.6	0.3	3,252			
Range, Pasture, Grasses	87564	19.1	-2.2	-193,254	March - Oct.	22.0	
Riparian Forest & Woodlands	0	19.1	-2.2	0	March - Oct.	22.0	
Wetlands	166	51.0	-40.1	-7,460	Feb. - Oct.	23.6	
Open Water	0	45.0	-35.1	0	N/A		
Waste Land	4741	19.0	-2.1	-9,993			
Buildings & Building Sites	2453	16.6	0.3	726	N/A		
Urban Land & towns	5402	19.7	-2.8	-15,163	N/A		
Rural Roads (Unsurfaced)	9165	19.0	-2.1	-19,311	N/A		
Totals	**561,077**			**(1,129,851)**			

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

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

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

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

Summary

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

Water Balance as a Watershed Management Tool

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

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

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

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

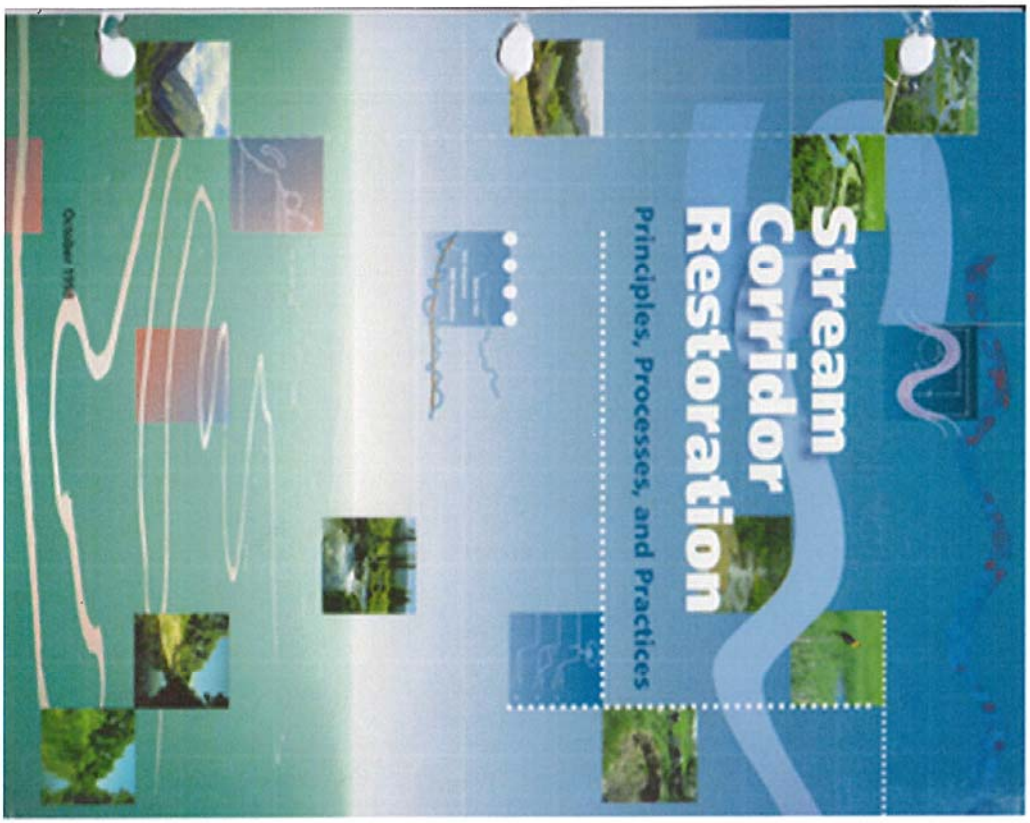
Although we have already developed some surface water storage, because of various reasons it is not likely to be expanded much more. Therefore, identification and development of the best and most effective ground water utilization will be critical with ground water storage management the most possible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

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

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

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

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



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

Why Watershed Management?
By Ted Tietjen
Nov 18, 2017

To: The Republican River Stakeholders
From Ted Tietjen

Why Watershed Management?

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

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

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

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

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

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

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

HUC 12 # 102500060403 in Perkins County, NE

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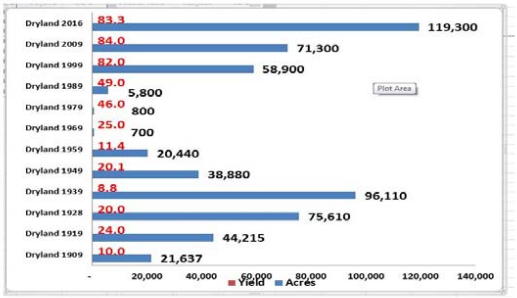
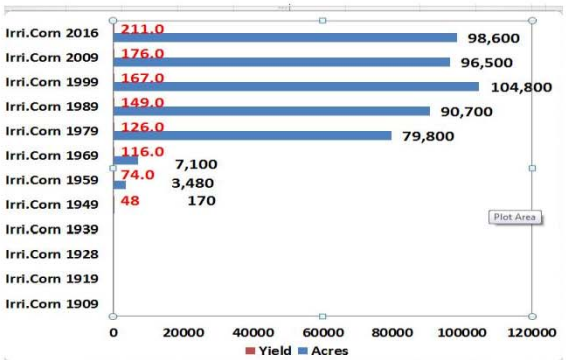
As the data was being gathered for the presentation it became clear there was another strong factor influencing cropping systems that was driving water management was economics. It became very clear that economics was the factor and had a greater impact on what was happening and took precedence over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

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

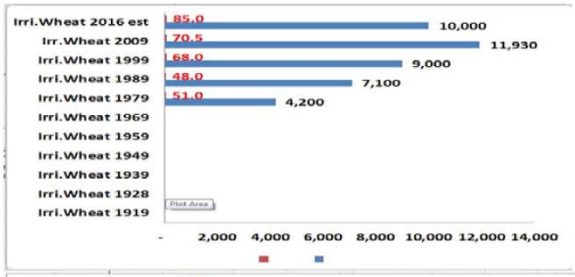


The bar graphs show how the corn cropping system changed. From 1909 to 1939 much of the corn was grown for the livestock. Then starting in the late forties summer fallowing before planting wheat became the norm and lasted until the early 90's when eco-fallow became more common. These eco-fallow acres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

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

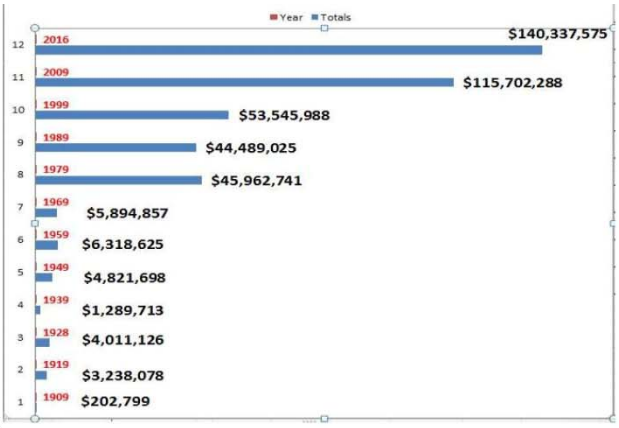


Irrigated corn acres came to the county in the 1950's with yields in the 75 to 80 Bu/A range. Center pivots became popular in the 1970's. At the same time hybrid corn varieties were increasing yields to 125 Bu/A. By **2016 the irrigate corn yields reached an average of 211 Bu/A. Irrigated corn acres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



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

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



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

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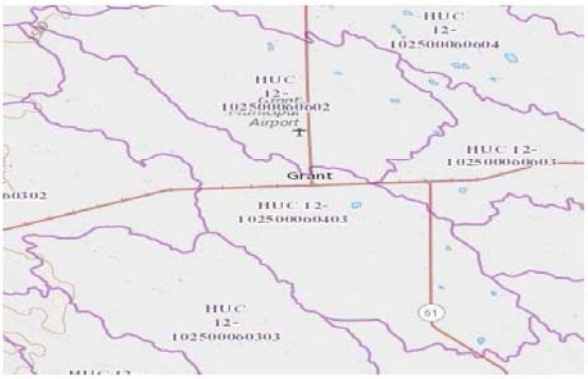
Increased revenue did not really take off until center pivot irrigation development took place. By 1979 the revenue from corn and wheat increased to $45,962,741. In 2016 corn, wheat and soybeans had a cash value of $140,337,575. We did not include other crops and livestock as the data was not available.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



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

How was the data collected?

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

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

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

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

Irrigated crop acres

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

Rain fed acres

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

Pasture, buildings, roads and wasteland acres

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

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

What did the crops look like?

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

Irrigated Soybeans in 2017 on NE 19-10-38

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

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

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Chemical Fallow in 2017 on 14-11-40

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

Dryland Corn in 2017 on SE 35-11-40

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

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

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

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

Bailed Sudan in 2017 on SEC 36-11-40

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

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

CRP Field in 2017 on SE 30-11-39

Center Pivot Corners in 2017 including CRP and Shelter Belts

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Some observations

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

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

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

What was learned?

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

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

What are some of the benefits of watershed management?

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

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

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

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

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

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

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

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

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

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

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

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

Thank you for consideration.