Good morning Chairman Grindberg and Water Topics Committee members. Thank you for this opportunity to speak today about prolonged flooding impacts on soil. I am Chris Augustin, an Area Soil Health Specialist for the NDSU Extension Service. I am stationed at the North Central Research Extension Center in Minot.

The Mouse River Valley is an area formed from lake bed and river sediments from Glacial Lake Souris and its tributaries (USDA-SCS, 1990). This is an area that developed under lowland flooding occurring from a common annual spring snowmelt. Arid areas can benefit from spring floods for crop production. The Mouse River Valley in the Towner North Dakota area depends on the annual spring floods to provide adequate water for good hay and crop production.

However, problems occur during years where flood waters occupy areas for most of the growing season. These problems include changes in soil properties and invasive plant species that infest native hay lands and crop lands that can have a lasting effect. These prolonged saturated conditions from flooded soils may change aggregate stability, pH, cation exchange capacity (CEC), minerology, increase salinity, and modify other soil traits.

Aggregate stability is the ability of a soil to resist breaking apart. Aggregate stability has been found to decrease under flooding conditions (De-Campos et al., 2009). Some aggregate stability decrease is believed to be related to the expansion of 2:1 clay minerals (common clays found here) and some resulting from increased soil particle repelling from increased CEC. As aggregate stability decreases, erosion can increase which over time, degrades soil health. Nutrients such as phosphorus are lost with soil particles and may cause algae blooms that reduce water oxygen levels in downstream water bodies that can kill aquatic organisms. (Pierzynski et al., 2005).

Soils can act like a magnet. Cation exchange capacity is that magnet that allows a soil to hold onto positively charged ions. This force is caused by soil organic matter and clay. Phillips and Greenway (2008) found that a soil's CEC increases while saturated. Cation exchange capacity is believed to increase from waterlogging that swells a soil and exposes more exchange sites. This isn't necessarily a bad thing. As CEC increases more positively charged nutrients like ammonium can be held to the soil and their loss prevented. Plants may then uptake these bound nutrients later in the growing season or a following growing season (Sparks, 2003).

Prolonged saturation voids the soil of oxygen as it is used up by soil organisms or vented to the atmosphere. The lack of oxygen prevents oxidation to occur and creates a reducing environment. The reduced environments can alter forms of manganese, iron, and others changing their solubility and adversely affect how they react in the soil. This can also increase soil pH (Brady and Weil, 2002). Under saturated conditions, nitrogen can be lost through denitrification and leaching, while phosphorus may be lost through increased runoff.

Resulting high water tables from prolonged flooding can increase soil salinity. In most cases, soil salinity is the white areas seen on the land. The increased salinity can adversely affect crop quality and yield. Saline conditions can shift plant species to more salt tolerant specie that may not be as desirable as the original native hay land. Soil salinity increases when water soluble salts are dissolved and relocated from deeper soil horizons to the root zone. Over time, these salts can be concentrated, and precipitate in the A horizon as the soil dries. (Sparks, 2003).

As of now, I can't say if these adverse soil traits have increased from prolonged flooding along the Mouse River. However, I have witnessed undesirable traits while assisting producers impacted by the Mouse River floods.

I've witnessed all sorts of debris spread about once these flooded areas have receded. Debris includes down fallen trees, fence poles, a water heater, carpet-like moss, and much more. The fallen and scattered debris has created more work for an already overworked and stressed people. This has also taxed the wildlife and cattle. Weeds like Canada Thistle that provide little or no forage value have increased in many areas. I've ridden a.t.v.'s in these areas and have seen wormwood taller than me while standing on the a.t.v.

While inspecting some soils and digging in areas, I have experienced a rotten egg odor that has a tendency to be associated with hydrogen sulfide. It is believed that this odor is being created from a soil lacking oxygen (Vepraskas and Faulkner, 2001) which is needed by countless beneficial soil microbes that help with important soil functions like nutrient cycling or the secretion of glomalin; a glue like substance that aids with soil aggregation and can reduce the incidence of erosion (Brady and Weil, 2002).

Other areas where I have dug have expressed olive like colors. These colors indicate prolonged saturated conditions (Schaetzel and Anderson, 2005). I can't say that's a result from the 2011 or 2013 floods, but according to the Soil Survey of McHenry County (1990) soils like the Ludden soil series should be a very dark grey or the Fargo soil series should be black.

Dr. Frank Casey, NDSU Department of Natural Resource Sciences asked me to read a statement he has put together regarding a Mouse River Flood research project. The following is his statement:

In spring of 2013, land owners contacted faculty from the School of Natural Resource Sciences with concerns about the impacts of Souris R. flooding on their lands. The land-owners were interested in assessing how flooding durations impacted the long-term soil and rangeland quality of their lands, and the associated declines to ranching productivity. At earlier dates, other NDSU REC and Extension personnel were contacted regarding this issue to assess what could be done and whether treatments could be established to bring back forage quality.

An emergency appropriations of $80,000 was provided to the NDSU Agricultural Experiment Station in June 2013 to have NDSU personnel conduct research and assess the problem. The following is what has been conducted so far on this project:

1) Faculty from the School of Natural Resource Sciences visited the location in May to gather an initial assessment of the problem and develop strategies. The result of this initial visit is attached (Souris_Flooding_May23.pdf).

2) Between June and August NDSU personnel visited about strategies, hypotheses, goals, budget, timelines, and teams. NDSU personnel met in-person at three occasions. Additionally personnel worked

independently to create a draft proposal that resulted from these initial meetings. The draft proposal from July 25, 2013 is attached (Souris_River_Proposal_V3.pdf).

3) Drs. Aaron Daigh (Soil Science) and Ryan Limb (Range Science) were delegated the task of achieving the research goals. Dr. Limb toured the region in early October.

4) A search for a post-doc scientist was initiated in the fall of 2013 to conduct the research. A post-doc was decided because of the short limited time to provid science-based assessment of the flooding. Dr. Xuelian Bai (post-doc soil science), was recruited and officially hired to lead the research in early 2014

5) During this spring and summer, our approach will be to cast a fairly wide net and sample approximately 5 locations north and south of the highway (there seemed to be differences when we toured there last fall). At each of those 10 locations, we want to run transects perpendicular to the river and sample multiple points along the transect. Our assumption is that the flood impacts will be greatest closer to the river channel with longer standing water. Along each transect, we will sample multiple soil properties and with multivariate techniques, find out what standing water is doing to the soil. We will also sample the soil seed bank to see what viable native/non-native seeds remain (adding additional seed may not be necessary if it is already in the soil). Once we have a better idea of what the underlying problems are, we can tailor restoration/recovery solutions around the problems.
Dr. Francis X.M. Casey

Thank you for your time, Chairman Grindberg and Water Topics Committee members.

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Souris River Flooding Near Towner, ND
Initial Meeting with Landowners
May 24, 2013 10:30 a.m. – 3:00 p.m.

I. **Overview of Issue:** McHenry Co Extension Office, Towner, ND
Landowners: Mr. Tom Miller, Mr. Leland Goodman
Policy Personnel: Daryl Lies (District Rep. for US Congressman Kevin Cramer)
NDSU Personnel: Chris Augustin (Extension Area Specialist, Minot), Abbey Wick (Assistant Professor Soil Health, Extension State Specialist; School of Natural Resource Sciences), Kevin Sedivec (Professor Range Science, Extension State Specialist; School of Natural Resource Sciences), Frank Casey (Director of School of Natural Resource Sciences). Raquel Duben-Dibble (McHenry County Extension Agent) was not able to attend but helped with preparations for the meeting.

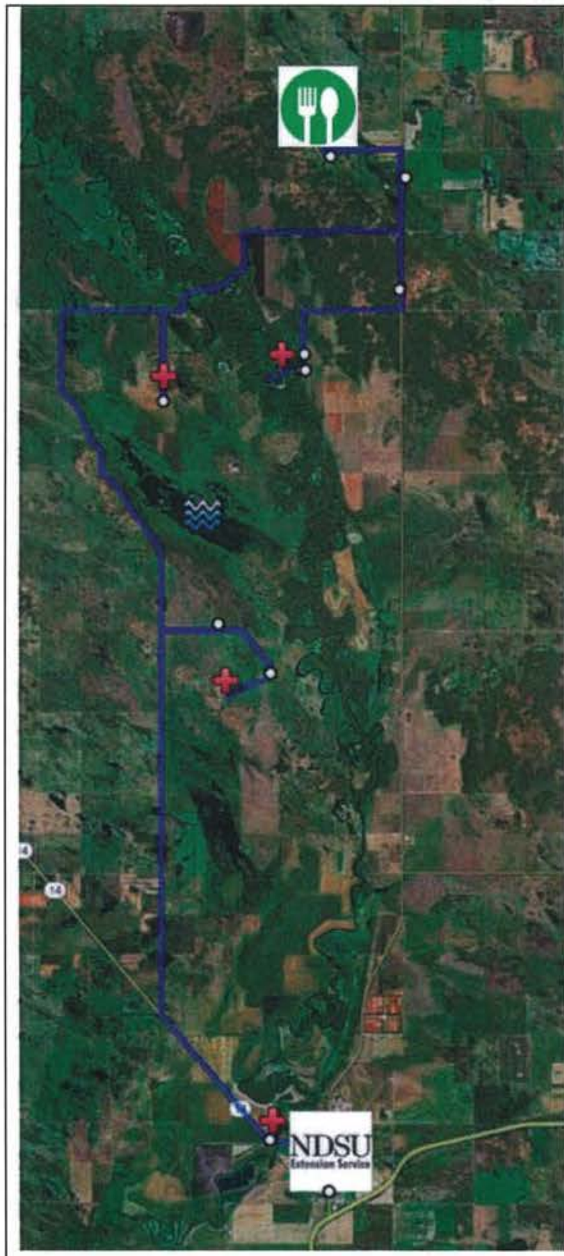
Timing, Duration, and Amount of Flood Releases
– In general, annual releases upstream from dams do not cause problems, except if the flooding happens for certain durations and amounts, and after June 1.
– 2011 flooding was a major impact, where floodwater remained on impacted areas in excess of five months (throughout the summer and into September)

Impacted Areas
The effects of flooding around the Souris R. near Towner are different and generally broken up into 5 different geographic sections. Starting downstream and moving south:

1) J Clark Salyer Refuge to Eaton Project
2) Eaton Project
3) South of Eaton to Velva?
4) South of Velva to Sawyer
5) Area surrounding the 4 listed locations above

When investigating the impacts and determining management strategies, these locations should be considered.

II. **Tour of Impacted Area:** Toured the impacted area and met some landowners impacted by the late season floods.



1) **Jim Haman/Tom Miller** – Portions of these fields were still flooded. There was extensive establishment of quack grass. Alfalfa was traditionally cultivated in these fields, but it hasn't been for several years. The ditches, which were part of the Eaton project, were flowing away from the river towards the west. Several portions of the field were wet, which appears to be in response to lateral groundwater flow. Since the soils are sandy and apparently able to easily conduct water, the water table responds directly to the stage of the river. It was noted here and elsewhere on this trip that the high river levels cause "subirrigation," which I am interpreting as lateral ground water flow.
2) **Dave Wagner** – Portions of this field were still under water. Mr. Wagner mentioned that he likes the flooding, but if water stays on the land long (i.e., beyond June 1) it become problematic. It appeared that there was extensive establishment of quack grass at this location too. Mr. Wagner asked if there is a grass that can be planted to outcompete and replace the quack grass in these fields.
3) **USFWS Easement** – Mr. Goodman drove us north and pointed out a US Fish and Wildlife easement. Mr. Goodman indicated that this easement is continuously wet as a result of sedimentation and plugging of a once free-flowing channel.
4) **Divide** – Mr. Goodman brought us to an area of higher elevation separating the easement drainage area (north and west) and drainage to the Souris (east). This area was isolated by floodwater. Mr. Goodman indicated that that since 1999 he has incurred $1.35 M in losses directly resulting from the late season flooding.
5) **Goodman Homestead** – Barbara and Leland Goodman graciously treated their guest (Tom Miller, Daryl Lies, Chris Augustin, Abbey Wick, Kevin Sedivec, and Frank Casey) to dinner. Afterwards, the Lelands showed photographs of flood impacts (e.g., filamentous algae, dead trees, poor or no germination). Additionally, LIDAR ground elevation maps and aerial images from the ND State Water Commission were provided to show an overview of the flooding issue. Maps were provided by James Fay (NDSWC).
6) **Goodman Property** – Our final visit was to a location east of the Souris R. We took four-wheelers west to view flood impacted lands; however, we could not cross flooded roads.

III. Plan of Action:

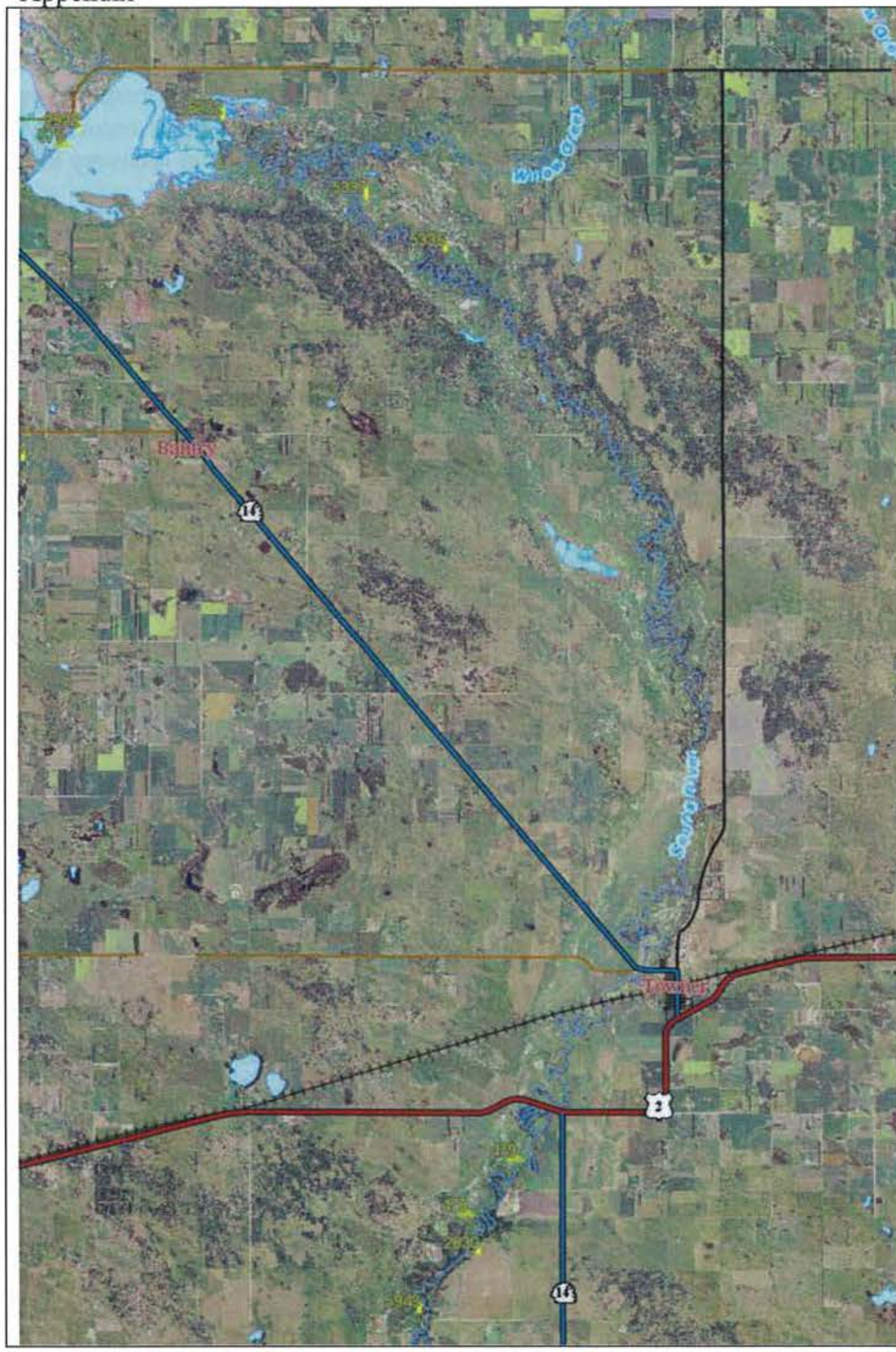
The following suggested goals should be considered for each of the five impacted areas:
Goal 1 – Identify the underlining processes that cause the post flood soil and range problems
Goal 2 – Define the extent of problem from ecological, ranching, and economic perspectives.
Goal 3 – Find a means to remediate flood impacted areas so that ranchers are able recover sooner from releases that cause late season, long-duration flooding. The typical recovery time is 5 years after major flooding events (?).

Other Notes:

Does the cattle industry in the area relies upon having both the hay lands in the fine textured soils that are flooded and the grazing lands on the coarse textured soils (sand hills)?
Is it typical to have cattle on the grazing lands for 6 months and then use the hay production as feed for the remaining 6 months? Without the alfalfa production on the hay lands, the industry suffers.

What goes into the equation that determines when, how long, and amounts of water retention upstream?

Appendix



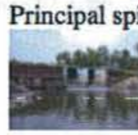
Location: 15507606CA

Name		EATON DAM	
Other Name		EATON IRRIGATION DAM	
Longitude		-100.4883	
Latitude		48.2739	
Designer		KADRMAS, LEE & JACKSON P.C.	
County		McHenry	
Purpose		Irrigation	
Federal River Class		SOURIS RIVER	
National ID		ND00229	
Emergency Plan		No	
Total Drainage Area (sq. mi.)		0.0	
Federal Hazard Class		Low	
Year Built		1934	
Inspection Date		09/28/2010	
Owner Name		EATON IRRIGATE BOARD	
Vertical Datum			
Top Dam Width		0.0	
Max Dam Height		21.0	
	Elev (ft)	**Area (acres)**	**Vol (ac-ft)**
Max Pool	1,466.0	386.0	2,448.0
Emergency	1,461.0	248.9	1,161.5
Normal	1,451.0	61.0	81.3
Drawdown Pipe	0.0	0.0	0.0
Stream Bed	1,445.0	0.0	0.0

1 Associated Permit(s)

Construction Permit	233
Applicant	EATON IRRIGATE BOARD
Water Permit	
Water Resource District	Mchenry County
Status	Approved
Date Approved	10/4/88

Principal spillway (upstream)-2002



Principal spillway (downstream)-2002

click photo to enlarge

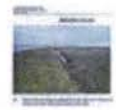
Location: 15907719AB

Name	DAM 320 (J.C. SALYER NWR)
Other Name	J CLARK SALYER NWR
Longitude	-100.6547
Latitude	48.5871
Designer	USFWS (BS)
County	McHenry
Purpose	Fish & Wildlife
Federal River Class	SOURIS RIVER
National ID	ND00329
Emergency Plan	No
Total Drainage Area (sq. mi.)	14,000.0
Federal Hazard Class	Low
Year Built	1935
Inspection Date	06/12/2001
Owner Name	US FISH & WILDLIFE
Vertical Datum	
Top Dam Width	16.0
Max Dam Height	13.0

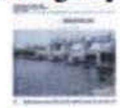
	Elev (ft)	Area (acres)	Vol (ac-ft)
Max Pool	1,428.0	6,006.0	24,492.0
Emergency	1,425.0	4,044.0	9,390.0
Normal	1,423.0	2,131.0	3,053.0
Drawdown Pipe	0.0	0.0	0.0
Stream Bed	1,415.0	0.0	0.0

1 Associated Permit(s)

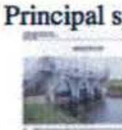
Construction Permit	369
Applicant	US FISH AND WILDLIFE
Water Permit	00169(29)
Water Resource District	Mchenry County
Status	Approved
Date Approved	1/18/91



Emergency spillway-2001



Principal spillway downstream-2001



Principal spillway upstream-2001

click photo to enlarge

I. STATEMENT OF PROBLEM

Lowland flooding is a common annual event from spring snowmelt. Arid areas can benefit from spring floods for crop production. The Souris River Valley in the Towner North Dakota area depends on the annual spring floods to provide adequate water for good hay and crop production. Flooding of the Souris River of higher frequency and longer duration has adversely affected production of over 40 thousand acres in northern McHenry County, ND. *[Nate Derby is working on a LIDAR-based map of this region we can include here.]* An early estimated loss to farmers and livestock producers from this flooding is approximately $5,000,000. Forage quality and quantity has dramatically decreased in rangelands sandwiched between water-managed practices that slowly release water flows at J. Clark Sayler National Wildlife Refuge and that increase flow rates to mitigate upstream flooding in Minot, ND and Canada. During 2011 in the affected rangeland, floodwater stood from the early spring, throughout the summer, and did not leave until late fall. As a result of the duration and timing of the 2011 flooding, native grasses and vegetation did not recover in 2012. Lowlands along the river are relied upon for forage production, but these lowlands have been invaded by quackgrass, foxtail barley, and annual/perennial weed species (predominately red goosefoot – *Chenopodium rubrum L.*). For example, land located 10 miles north of Towner, ND that traditionally produced 2,800 hay bails has only produced a maximum of 1,600 bails since 1999, and in 2012 only produced 782 bails. North Dakota State University's Agricultural Experiment Station and Extension personnel propose to address the impacts that flood duration has on rangeland and soil quality, and the subsequent economic effects. Additionally, NDSU AES and Extension personnel will attempt to develop management practices that can be applied to recover flooded rangelands.

II. BACKGROUND INFORMATION

The area affected by flooding was formed from lacustrine and alluvial sediments from Glacial Lake Souris (USDA-SCS, 1990). Aboveground rangeland and below ground soil problems occur during years where floodwaters occupy areas for most of the growing season. These problems include changes in soil properties and invasive plant species that infest native hay lands and crop lands that can have a lasting effect. These prolonged reducing conditions (i.e. low oxygen levels) from flooded soils may change aggregate stability, pH, cation exchange capacity (CEC), minerology, increase salinity, and modify other soil traits.

Impacts to Soil: Various soil physical, chemical and biological properties are altered under periodic flooding conditions. The physical property of aggregate stability has been found to decrease under flooding conditions, with aggregate stability being greater on cultivated soils when compared to uncultivated soil (De-Campos et al., 2009). Some aggregate stability decrease could be related to the expansion of 2:1 clay minerals leading to the bursting of stable aggregates, and an increase in soil particles repelling each other as result of an increase in CEC. During a 14-day experiment, decreases in aggregate stability were greatest initially and generally decreased through time (Philips and Greenway, 2008). It was also observed during this 14-day experiment, that CEC increases when soils are saturated, via exposure of additional exchange sites; and that results dependent upon the amount and type of soil colloids, pH, and ionic strength.

Biological activity is also greatly impacted by water-logged conditions and prolonged saturation. The lack of oxygen, which occurs during water logging, prevents oxidation, decreases the reduction potential (Eh), and limits functional soil processes by soil microbes. The reduced soil environment can alter forms of Mn, Fe, and others metals, changing their solubility and how they react in the soil. As Eh decreases, pH increases. (Brady and Weil, 2002). Macro nutrients like nitrogen can be removed from surface soils through denitrification and leaching, while phosphorus may be lost through increased runoff (transport of sediment).

Chemically, salinity becomes more of a concern in flooded soils through increase solubilization of water soluble salts and relocation from deeper soil horizons to the surface horizons as soils dry and salts precipitate. The increased salinity can adversely affect crop quality and yield and shift plant species that are more salt tolerant and may not be as desirable as the pre-existing native hay land.

Impacts to Rangeland: [Sedevic and Limb]

III. PROPOSED GOALS, OBJECTIVES, TESTABLE HYPOTHESIS, AND RESEARCH QUESTIONS

The first goal of this proposal is to investigate flooding duration impacts on rangeland, soils, and economics in affected cattle production area. A second goal that might be achieved is the development of a better management strategy that helps recover this flooded region.

Objectives, Testable Hypothesis, and Research Questions to Achieve the First Goal

Objective 1-1: Determine the affect of standing floodwater duration on soil

Testable Hypothesis for Objective 1-1: If floodwater duration negatively impacts the soil, then the longer the floodwater stands on the surface the greater the negative impacts on soil quality parameters

Research Question for Objective 1-1: How does standing floodwater beginning in the early spring and lasting for different durations impact the soil quality parameters?

Objective 1-2: Determine the affect of standing floodwater duration on rangeland

Testable Hypothesis for Objective 1-2: If floodwater duration negatively impacts the rangeland, then the longer the floodwater stands on the surface the greater the greater the negative impacts on rangeland quality parameters.

Research Question for Objective 1-2: How does standing floodwater beginning in the early spring and lasting for different durations impact the aboveground rangeland quality parameters?

Objective 1-3: Project the spatial extent and estimate economic impacts from the affects of floodwater duration on soil and rangeland quality parameters found in Objectives 1-1 and 1-2

Testable Hypothesis for Objective 1-3: If floodwater duration effects on soil and rangeland quality parameters are known, then accessible spatial data (e.g., LIDAR, NRCS Soil Survey) and economic tools can be used to project the spatial and economic impacts to this region.
Research Question for Objective 1-3: How do the affects of floodwaters on the measured soil and rangeland quality parameters project spatially, and what are the economic impacts of this spatial distribution?

Goals, Testable Hypothesis, and Research Questions to Achieve the Second Goal
[Limb and Sedevic – provide testable hypothesis and research questions for this second Goal]

IV. APPROACHES TO ACHIEVE OBJECTIVES

Specific Experiments and Methods to Achieve Objectives [Augustin, Daigh] that may be used are the following: (i) from snow melt to June 1 (based on ranchers experience in the region they say that there is a beneficial effect up until June 1 and after that it is detrimental), (ii) snow melt to July 15, and (iii) snow melt to September 1. Soil and Rangeland quality parameters will be measured before the plots are flooded and observed through time as the plot recover from the inundations.]

General Measurement Methods

Soil Measures: [Augustin, DeSutter, Daigh, and Wick – List here the soil measures that will be made and cite the methods. Some measures can be made on the experimental plots during flooding, such as redox potential, temperature, or perhaps OM. Additionally on the experimental plots, soil quality properties should be measured before and just after flooding and followed through time after the various flood durations.]

Soil pH and salinity levels will be measured pre- and post-flooding using the saturated paste method and a Hach HQ40D dual input handheld meter with IntelliCAL pH and conductivity probes.

Soil aggregate size distributions and stability pre- and post-flooding will be evaluated according to Six et al. (1998) for the following size classes: large macroaggregates (2000-8000 μm), small macroaggregates (250-2000 μm) and microaggregates (53-250 μm).

Quick-tests for soil biological activity (i.e. respiration) of soil collected both pre- and post-flooding will conducting using the Solvita test with digital color reader (DCR; http://www.solvita.com). Once differences are determined using this quick test and other soil quality data point to specific issues with biological function, for example nitrogen cycling, we may include enzyme assays to isolate specific reductions in activity of primary soil microorganisms.

Areas of the study will be mapped using an EM-38 or VERIS Technologies EC Mapping System. Mapping data will be used to find similar areas for the experiment.

Soil texture will be determined in the topsoil (0 – 15 cm) and subsoil (15 – 30 cm) through sieving and the hydrometer method described by Gee and Bauder (1986). Soil bulk density will be determined in the top soil and sub soil using the core method described by Blake (1965). Soil penetration resistance will be recorded to a depth of 45 cm using a FIELDSCOUT SC 900 Soil Compaction Meter.

Carbon fractions of soil samples will be determined by a high-temperature dry combustion method using a Skalar Primac^{SC} TOC Analyzer. Inorganic carbon will use the high temperature method, but with the addition of a 20% H_3PO_4 solution as described by Nelson and Sommers (1996).

CEC of the soil will be measured using an unbuffered salt extraction method described by Sumner and Miller (1996). Redox measurements of the soil will be done using a platinum electrode and recorded with a data logger (Patrick et al., 1996).

Field capacity, permanent wilting point, and available water capacity will be determined.

Rangeland Measures: [Limb and Sedivec – List here the range measures that will be made and cite the methods. On the experimental plots, rangeland quality measures should be made before and immediately after flooding. They should also be followed through time on the plots after the floodwaters are removed.]
Spatial and Statistical Methods: [Daigh, Augustin, and Ripplinger – list here the general spatial and statistical approaches and cite]
Economic Applications: [Ripplinger – list here the economic tools that will be used to assess the impacts of flooding in this region based on the soil and rangeland measures]

V. TIMELINE

Goal I – Flooding effects on rangeland, soils, and economics									
	2013	*2013*	*2014*	*2014*	*2014*	*2014*	*2015*	*2015*	*2015*
Activities	*S*	*F*	*W*	*Sp*	*S*	*F*	*W*	*Sp*	*S*
***Plots:** Establish experimental plots, and obtain baseline data*		X	X	X					
Objective 1-1: Floodwater effects on soil				X	X	X		X	X
Objective 1-2: Floodwater effects on rangeland				X	X	X		X	X
Objective 1-3: Spatial and economic							X	X	X

Goal I – Flooding effects on rangeland, soils, and economics									
	2013	*2013*	*2014*	*2014*	*2014*	*2014*	*2015*	*2015*	*2015*
	S	*F*	*W*	*Sp*	*S*	*F*	*W*	*Sp*	*S*
Objective 2-1		X	X	X	X	X	X	X	X

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