Upper Niobrara River Compact Meeting

Meeting Minutes

Nebraska Department of Natural Resources (NeDNR)

Wyoming State Engineer's Office (WSEO)

3:00 PM Mountain Time

October 5th, 2016

Conference Call – GoTo Meeting

1. **Introductions and agenda review** (see Attachments A & B)

Tom Hayden	NeDNR	Pat O'Brien	UNWNRD
Tim Freed	NeDNR	Jeff Cowley	WSEO
Gordon "Jeff" Fassett	NeDNR	Brian Pugsley	WSEO
Melissa Mosier	NeDNR	Pat Tyrrell	WSEO
Lynn Webster	UNWNRD	Bill Wilson	Public

2. **Review of previous meetings**

   a. **Review of minutes from October 22, 2015, meeting:** Bill Wilson, of Sioux County, NE, requested a change to the October 2015 minutes to reflect that two flood events, not one, occurred in June of 2015. The first event occurred in the Manville/Lusk area on June 3rd and 4th, and the second occurred in the Van Tassell area near the state line and Highway 20 on June 5, 2015. After discussion, the Niobrara Compact representatives agreed to the correction (Attachment C).

   b. **Review of Technical Group discussions from April 5, 2016:** No corrections or additions were made to the notes from the April 2016 Technical Group discussions.

3. **State Reports**

   a. **Wyoming:** Jeff Cowley provided copies of a spreadsheet (Attachment D) listing permits approved in the Niobrara Basin since fall 2015. Pat Tyrrell pointed out that the list includes a few applications that have not been approved due to potential upcoming changes to Wyoming's spacing requirements. On behalf of Wray Lovitt, Brian Pugsley reported that measurements were made near the state line, but that in general, little activity had taken place since fall 2015.

   b. **Nebraska:** Tom Hayden reported on measurements and activities in the Nebraska portion of the Basin. Good flow was reported at the Stateline, Agate, and Niobrara River above Box Butte Reservoir streamgage sites. Box Butte Reservoir began the season with good elevation and carryover from the past year. As of right now, the Bureau of Reclamation is still planning to lower the elevation of Box Butte Reservoir to repair toe drains. Administration did not occur in the Compact area in the past year, but did occur in the Basin downstream.

4. **Update on studies related to the Niobrara Basin**
   a. **Niobrara River Basin WaterSMART Study:** Tim Freed reported that the study is complete but has not yet been posted to the Bureau's website.
   b. **UNWNRD Conjunctive Management Model Project:** Parties are still considering which modeling scenarios to pursue and discussions between UNWNRD and NeDNR are occurring.
   c. **WYDOT Lusk Wyoming Flood Study:** The WYDOT Lusk Wyoming Flood report (Attachment E) was forwarded to NeDNR staff in June 2015. Depending on the equations and distributions used in the analyses, the Lusk area flood in June 2015 fell between the 100-year and 1000-year event range. The report was completed by USGS for WYDOT. Tyrrell added that another significant event this year was a 25,000 acre fire that began in the Prairie Center Control Area of northern Goshen County.
   d. **Clarification on the USGS and UNL monitoring wells near the state line:** The state line monitoring well discussed at the April 2016 Technical Group meeting has been confirmed to be one well from which data is reported by both UNL and USGS. The reason that the data points are off 0.7 ft is likely because the USGS uses a different measure point system. Lynn Webster informed the group that UNL's Conservation and Survey Division (CSD) used to monitor this well until UNWNRD took over in 1998. Aaron Young with CSD will report to the group if more clarification on the reading discrepancies on the well is found.
5. **Compact discussion:** Tyrrell commented that he is glad to hear reports of upward trends in regard to both ground and surface water in the Basin. He also noted that it is good to see the mutual benefits that arise through similar modeling efforts directed independently by Nebraska and Wyoming. Lastly, Tyrrell noted that managing conflict between ground and surface water users in the area from Lusk to Le Grange has been eased due to a wet cycle taking place in the southeast portion of Wyoming over the past few years.

   Webster reported that UNWNRD still has a moratorium on high capacity wells and has also noticed an upward trend in the groundwater wells that it monitors.
6. **Public comment:** No other public comment was made**.**
7. **Next meeting date:** The Niobrara Compact Technical Group meeting (via conference call) will be held on **Thursday, April 20, 2017, at 2:00 CT / 1:00 MT.**

AGENDA
UPPER NIOBRARA RIVER COMPACT ANNUAL MEETING

Nebraska Department of Natural Resources (NDNR)
Wyoming State Engineer's Office (WSEO)

Thursday, October 5, 2016, 3:00 p.m. (Mountain Time)
Branding Room
Goshen Co. Fairgrounds, Torrington, Wyoming

Agenda Items:

1. Introductions and agenda review
2. Review of previous meetings
    a. Review the minutes from October 22, 2015, meeting
    b. Recap Technical Group discussions from April 5, 2016
3. State reports
    a. Wyoming
    a. Nebraska
4. Update on studies related to the basin
    a. Niobrara River Basin WaterSMART Grant
    b. UNWNRD Conjunctive Management Model Project
    c. WYDOT Lusk Wyoming Flood Study
    d. Clarification on the USGS and UNL monitoring wells near the state line
5. Compact discussion
6. Other items
7. Public comment period
8. Set date for next Upper Niobrara River Compact meeting and Technical group
9. Adjourn

UPPER NIOBRARA RIVER COMPACT MEETING

Meeting Date: October 5, 2016

Place/Room: Torrington, WY

Name:	Representing:	E-Mail:
Tim Freed	Ne DNR	tim.freed@nebraska.gov.
Jeff Fassett	" "	Jeff.Fassett@nebraska.gov
Brian Pugsley	SEO Wyoming	Brian.Pugsley@wyo.gov
Jeff Cowley	SEO WYO	jeff.cowley@wyo.gov
Pat Tyrrell	" "	patrick.tyrrell@wyo.gov
Melissa Mosier		
Tom Hayden	DNR Bridgeport office	
Lynn Webster	UNWNRD	webster@unwnrd.org
Pat O'Brien	unwnrd	obrien@unwnrd.org
Bill Wilson	Sioux Co., NE	wilsonranch1989@bbcwb.net

Summary of Meeting between
Nebraska Department of Natural Resources (NDNR) and
Wyoming State Engineer's Office (WSEO)

3:00pm (Mountain Time)
October 22, 2015
Branding Room
Goshen Co. Fairgrounds, Torrington, Wyoming

I. Introductions and agenda review

The meeting was attended by the following:

Name	Representing
Jeff Fassett	Nebraska Department of Natural Resources (DNR)
Tim Freed	Nebraska DNR
Tom Hayden	Nebraska DNR
Pat O'Brien	Upper Niobrara White Natural Resource District (NRD)
Lynn Webster	Upper Niobrara White NRD
John Harju	Wyoming State Engineer's Office (SEO)
Wray Lovitt	Wyoming SEO
Sue Lowry	Wyoming SEO
Brian Pugsley	Wyoming SEO
Beth Ross	Wyoming SEO
Pat Tyrrell	Wyoming SEO
Bill Wilson	Citizen At-Large

There were no additions to agenda. In staffing updates, Beth Ross recently took over Jodee Pring's position with the SEO after Jodee departed in 2014. Beth will represent Wyoming for Technical Group calls and assignments moving forward. Tim Freed also joined the Niobrara Compact Technical Group on behalf of the Nebraska DNR.

II. Review the minutes from prior meetings

There were no corrections or additions to the meeting summaries from the October 21, 2014 meeting or the April 10, 2015 Technical Group conference call.

III. State Reports

a. Wyoming

Wray Lovitt reported on water supply conditions for the past water year, in which the outlook started off rough but due to the significant level of precipitation starting in June, the supply forecast improved. The SEO performed a number of high capacity safety of dams inspections as a result of the heavy June rains. The high flow level from the Lusk flood that occurred in early June is unknown. Although Manville is the headwaters, he confirmed that Lusk only received about an inch and a half of rain therefore the high flows likely came from a wider drainage area. One reservoir overtopped but there was no damage related to it. Many stock reservoirs experienced damage from the heavy rains. State line gages were destroyed from a separate storm and local area rain gages later reached maximum capacity. Suffice to say, there was no regulation in Wyoming in the basin during the summer thanks to the heavy rains.

John Harju reported that not much oil and gas exploration has occurred in the Wyoming portion of the Niobrara drainage since the last meeting. There have not been any new surface water related permits in the area in years and about five domestic and/or stock watering wells have been approved since the April Technical Group meeting. Some permits have been denied because of inadequate well spacing.

b. Nebraska

Tom Hayden reported that administration on the Niobrara started around March 30th but was eased for much of the summer due to heavy rains. It was reinstated at Mirage Flats on July 13th and at Spencer on July 29th.

Nebraska streamgages saw the effects of two early June heavy rain events: the first event occurred on June 3rd and 4th in the Manville and Lusk areas, and the second event occurred on June 5th in the Van Tassell area near the state line and Highway 20. Following this event, the Nebraska DNR tracked peak flows throughout the drainage: the state line inflow peaked on June 5th at 10.13 feet and 1,650 cfs. Six miles downstream at 33 Ranch (which was the only gage that was lost as a result of the Manville flood), the peak was 8.78 feet and 1,380 cfs. Twelve miles further downstream at Agate the peak occurred on June 7th at 8.5 feet and 1,000 cfs, then further on June 8th at 11 feet and 1,240 cfs. Above Box Butte reservoir, flows reached 250 cfs and remained at that level for eight days; by June 11th the storage level reached 23,473 AF.

IV. Update on various studies related to the basin

a. UNWNRD Conjunctive Management Model Project
b. Niobrara River Basin WaterSMART Study

Tim Freed provided an overview of Integrated Water Management Division efforts currently underway at the Nebraska DNR. He then reviewed the background of the WaterSMART grant in collaboration with the Bureau of Reclamation. Two models developed under this grant evaluate the impacts of climate variability on water resources availability in the basin. The Upper Niobrara-White groundwater model – also referred to as an integrated or conjunctive water management model – examines the hydrologic impacts of climate conditions and multiple management scenarios for the Upper Niobrara Basin. The Central Nebraska groundwater model examines the impacts for the Middle and Lower Niobrara basins. Both models utilize historically calibrated baseline data to explore baseline flow and groundwater level changes subject to three different climate variability scenarios (more precipitation, lower precipitation and higher temperatures, and central tendency conditions). They also allow for the exploration of flows under various demand scenarios. The results from these efforts look at the effects of stress and future water availability to assess how the model performs.

Now that the research goals under the grant have been completed, the DNR modeling team planned to meet about the Integrated Water Management Plan and decide next steps on how to proceed with this and other groundwater modeling efforts.

V. Compact discussion

Pat Tyrrell reviewed past discussions on surface water permit monitoring provisions. Tom Hayden pointed out that the state line monitoring well depth 54-year historic high is 37.5 feet. The last reading was 35.66 feet. There are other monitoring wells in this districted that are not monitored by the Nebraska DNR; several NRDs work with the USGS closely on managing these monitoring wells. There has been some indication that the summer floods helped augment groundwater levels. Groundwater withdrawals from NRD wells were minimal this year because of available surface water flows. Wray Lovitt added that the situation was the same in Wyoming this year. Pat Tyrrell highlighted the Horse Creek metering order on 60 wells in the basin, and Jeff Fassett acknowledged that Nebraska also has a fairly aggressive effort to require meters on wells across the state in collaboration with several NRDs.

VI. Public comment

Bill Wilson, a citizen of Sioux County, Nebraska, joined the meeting and briefed the committee about the widespread damages throughout the North Platte and Niobrara River basins as a result of the early June floods. He requested to see analysis of the possible peak flows and recharge in the basin as a result of the floods. Tom Hayden reminded everyone that Nebraska has a relatively good idea of these peak flows as reported earlier during the meeting. Everyone agreed that more information from the impacts on the Wyoming side of the basin is needed. John Harju offered to bring monitoring well data to the next Compact meeting to illustrate if any changes were seen before and after the floods in Wyoming.

Mr. Wilson also asked about the possible influences of snowpack from the Van Tassel and Duck Creek areas on streamflow; Wray Lovitt offered to calculate the acreage of these drainages and Tom Hayden added that monitoring well data from the state line would be useful for this exercise as well.

VII. Future meeting arrangements

It was agreed that the technical group should meet in the spring again via teleconference. A tentative date was set for April 5th, 2016.

The next Compact meeting was set to be in person during the same timing as the fall North Platte Decree Committee (NPDC) meeting. The meeting for the fall, 2016 will be scheduled when the NPDC April meeting is held.

VIII. Other items

There were no other items to discuss.

The Meeting adjourned at 4:20pm.

Notes compiled by:
Beth Ross
December 28, 2015

Permits Approved in Niobrara River Basin in Wyoming since Last Fall Meeting on October 22, 2015

WR Number	PriorityDate	Company	FirstName	LastName	FacilityName	Uses	Twn	Rng	Sec	Qtr-Qtr	Appropriation(GPM)	Longitude	Latitude
P204922.0W	11/27/2015	W JOAN LENZ 2007 REVOCABLE TRUST			2ND ENL. STURMAN #7	MIS	032N	063W	24	SE1/4NW1/4	20	-104.371333	42.736288
P204993.0W	12/31/2015		MARLIN AND DAWN	GODFREY	NODE 1	DOM_GW	032N	062W	33	NE1/4NE1/4	0	-105.058617	42.079917
P205093.0W	02/04/2016	HYTREK FAMILY TRUST - DALE HYTREK TRUST			HYTREK WELL #1	STK	032N	064W	07	NW1/4NW1/4	25	-104.594582	42.768148
P205145.0W	02/24/2016		MARLIN	GODFREY	G-3	STK	032N	064W	30	NE1/4NW1/4	25	-104.588503	42.724088
P205527.0W	05/10/2016		FRANK	LADWIG	DEER HORN	DOM_GW	033N	065W	13	SW1/4SW1/4	25	-104.615603	42.829716

Notes:

The State Engineer's Office is still holding, unapproved, three irrigation use applications that violate the spacing policy currently in place for the area.

The "MIS" use for Permit No. U.W. 204922 allows water from the well to be used to supply a stock watering pipeline system serving 10 stock watering tanks within a 2 square mile area.

Wyoming
Department of Transportation
"Providing a safe, high quality, and efficient transportation system"
5300 Bishop Boulevard
Cheyenne, Wyoming 82009-3340

Matthew H. Mead
Governor

William T. Panos
Director

June 3, 2016

Lusk Wyoming Flood Study
Flood Date: June 3 and 4, 2015
WYDOT

Prepared by:

William R Bailey

William R. Bailey, P.E., Hydraulic Engineer, WYDOT

Jeri D. Yearout

Jeri D. Yearout, P.E., Hydraulic Project Design Engineer, WYDOT

Background

A large storm occurred over the Niobrara River watershed in the evening hours of June 3, 2015, and lasting into the early morning hours of June 4. The storm tracked from southwest to northeast over the entire 73 square mile watershed. Doppler radar images indicate the storm lasted approximately 4 hours. Figure 1 shows the Niobrara River watershed at Lusk. The storm lead to serious flooding in Lusk, including the failure of the bridge over the railroad on US85. According to the National Weather Service, precipitation varied from 4.69 inches in the northern parts of Niobrara County to 7.11 inches south-southeast of Lusk.

The objective of this study is to estimate the flood frequency (return period) of the June 4, 2015 flood and to show the possible error in return period estimates depending on methodology used. This also illustrates the complexity in estimating the peak discharge.

Hydrology

The Flood Insurance Rate Map (FIRM) shows an area of Zone A. Zone A floodplain delineation are rough estimates. The map is dated March 18, 1986. A Flood Insurance Study (FIS) with estimates of hydrology was not located on the FEMA website. The FIRM is shown in Figure 2.

Hydrology calculation estimates from 1982 for the bridge over the Niobrara River were found. Using equations from Water-Resources Investigations 76-112, values using a weighted average of Region 2 and 3 were estimated. These estimates are shown in Table 1. At that time, a value of 2180 cfs for the 100-year flood was obtained from FEMA. This value was used in the design of the bridge.

The USGS Regression equations from Floodflow Characteristics of Wyoming Streams (10) and Peak Flow Characteristics of Wyoming Streams (39) were used. For the 1988 study, the drainage area is located in the Plains region with a geographic factor of 1.0, a precipitation index of 14, and a basin slope of 287 feet per mile. The 2003 equations were computed using a composite soil index of 2.61. These flood frequency estimates are shown in Table 1.

A log Pearson type III and Gumbel flood frequency analysis was performed using the stream gage near the Wyoming border approximately 30 miles east of Lusk. The drainage area for the stream gage is 445 square miles. The results are listed in Table 1. The flood frequency from the stream gage analysis is substantially less than those estimated using the USGS Regression equations. This is unexpected due to the much larger drainage area at the stream gage. This might be due to a number of factors such as land use or the analysis of base flow conditions. The Gumbel distribution produces higher estimates than the log Pearson III analysis.

Table 1 - Hydrology Estimates from Regression Equations

Frequency	1976 eqns weighted avg	1988 equations	2003 equations	IPIII gage	Gumbel
2	440	329	206	20	17
5	1180	845	700	77	65
10	2070	1310	1320	162	156
25	3600	2130	2570	373	469
50	5180	3170	3940	652	1063
100	7150	3980	5790	1093	2389
200		5700	8228	1775	5344
500		8121	12730	3235	15401
1000		10613	15358	4463	

Note:
The log Pearson III (IPIII) and Gumbel analysis are not area adjusted to the site. The gage drainage area is 455 square miles making gage area adjustments unreliable. The drainage area at Lusk is 73 square miles.

The Community Collaborative Rain, Hail & Snow Network (CoCoRaHS) indicates there is a site southwest of Lusk that received 2.62 inches of precipitation on June 3. Figure 3 shows the location of the gage in relation to the Niobrara River drainage area. The gage is not located in the watershed area.

The drainage area was broken into 9 subareas using the Watershed Modeling System (WMS) software. The areas were roughly broken into subareas where changes in soil types occurred. A HEC-1 model was created as shown in Figure 4. Several different strategies were used to estimate discharges.

An NRCS type II rainfall distribution with a 100-year 24 hour rainfall of 3.8 inches from NOAA Atlas II was used. SCS curve number show a range for each soil type. For this reason a range of curve numbers were used for comparison in a sensitivity analysis. Curve numbers of 61 for NRCS type B soil and 80 for type D soil produced a discharge estimate of 4050 cfs. Another analysis utilized the same model, only changing the curve number to 65 for type B soils and 75 for type D soils produced a discharge estimate of 4740 cfs.

The total rainfall of 2.62 inches from the CoCoRaHS data using the NRCS type II rainfall distribution, curve numbers of 65 for type B soils and 75 for type D soils produced a discharge estimate of 1850 cfs.

A HEC-1 model of the drainage area without being divided into subbasins was also created. Using the NRCS type II rainfall distribution with a total storm precipitation of 3.8 inches yielded a discharge of 3330 cfs. A curve number of 65 for type B soils and 75 for type D soils were used.

Radar imagery from Weather Underground (www.wunderground.com) was obtained approximately every 30 minutes for the duration of the storm. The images were geo-referenced in WMS, showing a background radar image under the drainage subareas. Figure 5 shows a radar image from June 3 at 11:12PM under the subareas used in the HEC-1 model. The colors of the radar are only categorized as light to heavy rainfall. An arbitrary amount of inches of rainfall was used for each color. A composite amount of rainfall was determined for each radar image over each subarea. This was then converted to the amount of inches over each watershed for each time step. The radar data was scaled to a total rainfall of 3.8 inches. The discharge at Lusk was estimated to be 7390 cfs. The radar data was also scaled to the CoCoRaHS rainfall of 2.62 inches, which resulted in a discharge of 2960 cfs.

The rainfall intensities from Doppler radar do not necessarily measure the rainfall the hits the ground thus introducing input data error.

All the different methods and the subsequent discharges are shown in Table 2. The table indicates there can be a large range of values when using rainfall runoff methods.

Table 2 - Hydrology Estimates using Rainfall Runoff Methods

Method	Discharge cfs
100-yr 24 hour type II, NOAA=3.8 in CN=61 B soil, CN=80 D soil, w/ subbasins	4050
100-yr 24 hour type II, NOAA=3.8 in CN=65 B soil, CN=75 D soil, w/ subbasins	4740
24 hour type II, CoCoRaHS=2.62 in CN=65 B soil, CN=75 D soil, w/ subbasins	1850
radar data, 3.8 in. total storm precip. CN=65 B soil, CN=75 D soil, w/ subbasins	7390
radar data, 2.62 in. total storm precip. CN=65 B soil, CN=75 D soil, w/ subbasins	2960
100-yr 24 hour type II, NOAA=3.8 in CN=65 B soil, CN=75 D soil, no subbasins	3330

USGS Flood Peak Estimate

The USGS was requested to estimate the peak discharge of the flood. An indirect determination was completed about 1.5 miles downstream of the bridge, along Wasserburger Road. The total peak discharge was computed as the sum of separate road overtopping and culvert computations. The discharge was estimated to be 9300 cfs.

Aerial Reduction Factor

Aerial reduction factors are used to adjust point rainfall to spatially distributed rainfall depths over the entire watershed. The 1972 NOAA atlas provides a generalized ARF for large regions of the United States. The radar images were also used to develop the aerial reduction factor (ARF) for this storm. This is useful in comparing the local ARF to the ARFs presented in the NOAA Atlas. Figure 6 compares the ARF calculated for this storm and the ARF presented in the NOAA Atlas. The June 4, 2015 storm has more reduction than the generalized NOAA atlas indicating a smaller discharge peak than what is produced for a rainfall runoff analysis. If the storm was distributed like the NOAA ARF then the flood peak would have been larger. The ARF must be used in estimating the return period of the storm over the watershed. The ARF suggests that the return period of the point rainfall is larger than the return period averaged over the watershed.

Storm Return Period

The return period at rain gages provide point rainfall return periods. The ARF is used to adjust the total rain fall and duration to estimate the averaged return period of the storm over the watershed.

The rain gage at Harrison, Nebraska has the best available record and intensity duration frequency. The 100-year 6 hour event is 3.37 inches, 500-year is 4.28 inches and the 1000-year is 4.69 inches.

The rainfall hyetograph from Doppler radar average over the watershed is 2.7 inches for the storm duration of 4 hours. This indicates the averaged storm rainfall return period is 50 years.

The entire 4 hour storm was broken into several smaller durations, such as 30 minutes, 1 hour, 2 hours, and 3 hours. Table 3 shows the average rainfall for several smaller durations within the entire storm and their corresponding frequency using the Harrison, Nebraska rain gage.

Table 3 - Storm Frequency for Small Storm Durations

storm length	avg rainfall (in)	frequency (yr)
30 minutes	3.86	1000+
	2.69	500
	1.84	100
	2.76	1000
1 hour	3.52	1000+
	3.81	1000+
	2.28	100
	3.90	1000+
2 hours	3.09	200
	3.45	500
	3.60	500
	3.34	500
3 hours	3.25	200
	2.93	100

Conclusion

The flood of June 3 and 4, 2015, was estimated to be 9300 cfs by the USGS. According to the 1976 regression equations, this flood was greater than the 100-year frequency. The 1988 regression equations show this flood to be approximately a 700-yr flood. The 2003 equations indicate the Niobrara River flood to be approximately a 220-year flood. Figure 7 compares the regression equation values to the USGS estimated flood flow.

The June 4, 2015 flood peak of 9300 cfs would exceed the 200-year flood event for Gumbel distribution and greater than the 1000-year event using the log Pearson III distribution. These estimates were made assuming there are no watershed conditions that cause significant attenuation of peak flows.

This study illustrates the complexities of estimating the return period of an event. The return period of the event can not be estimated using the return period of the rainfall depth. The return period of the storm and the return period of peak are different due to antecedent soil condtions, spatial and temporal distributation of the storm cell.

The range of return period estimates produced in this study suggests that the June 3 and 4, 2015 floood event exceeds the 100-year return period and is possibly much greater.

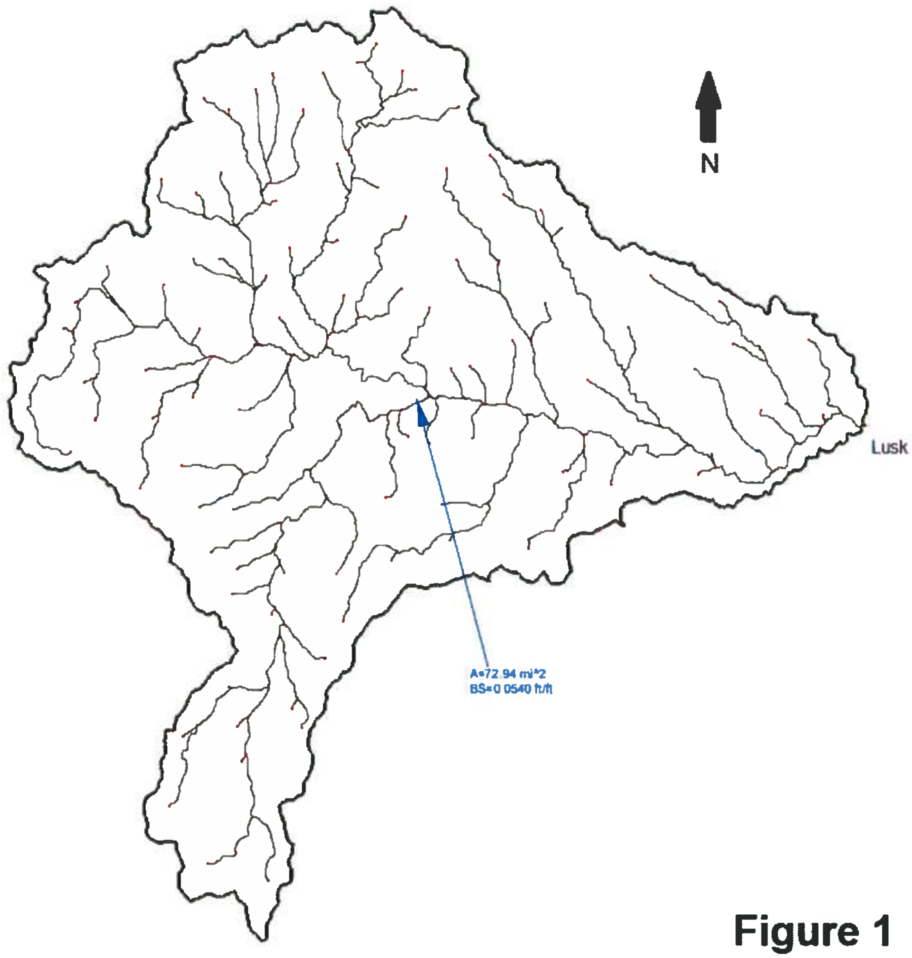

Figure 1

2015 Lusk Flood
Storm Study
June 3, 2016
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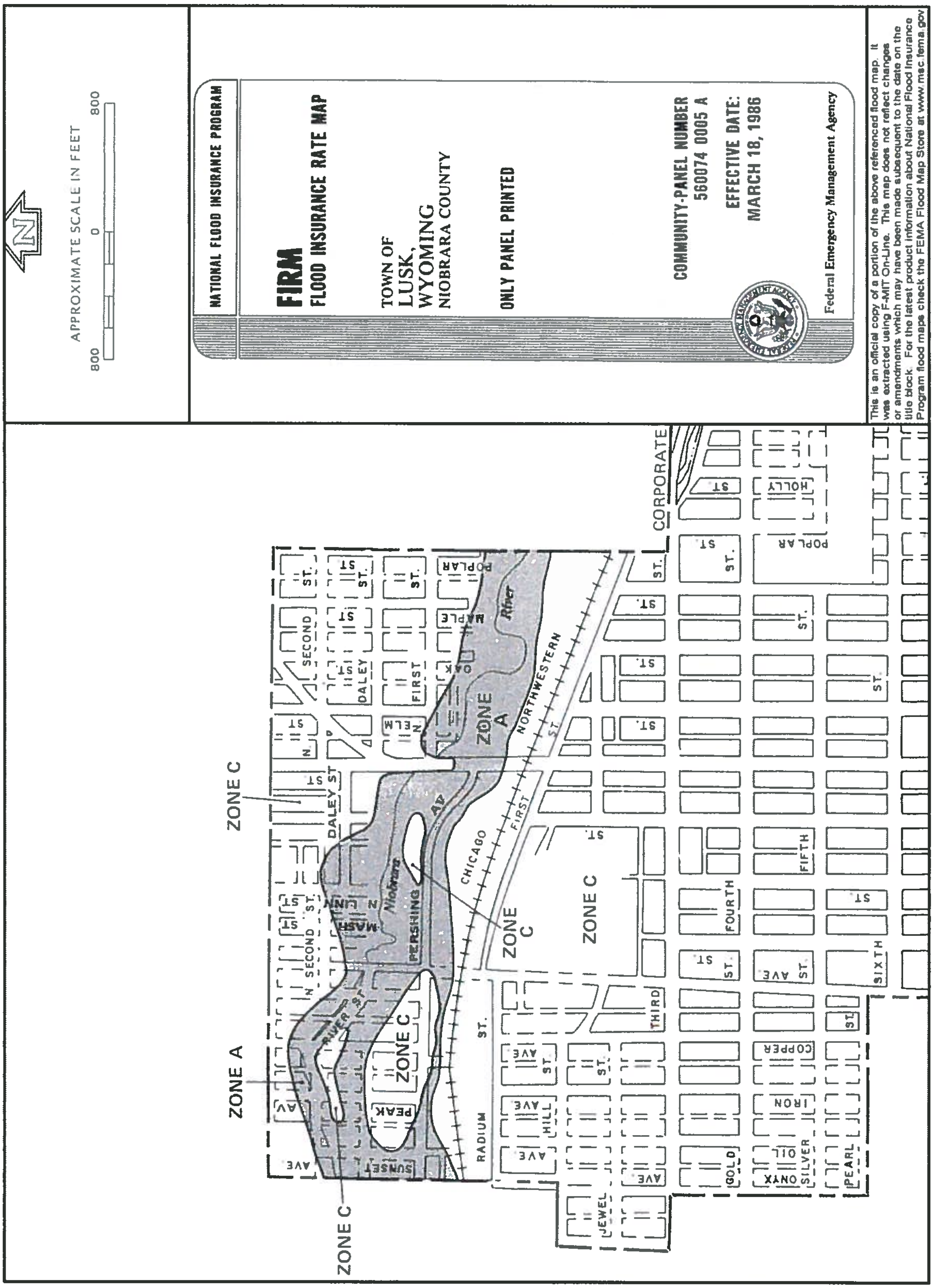

Figure 2

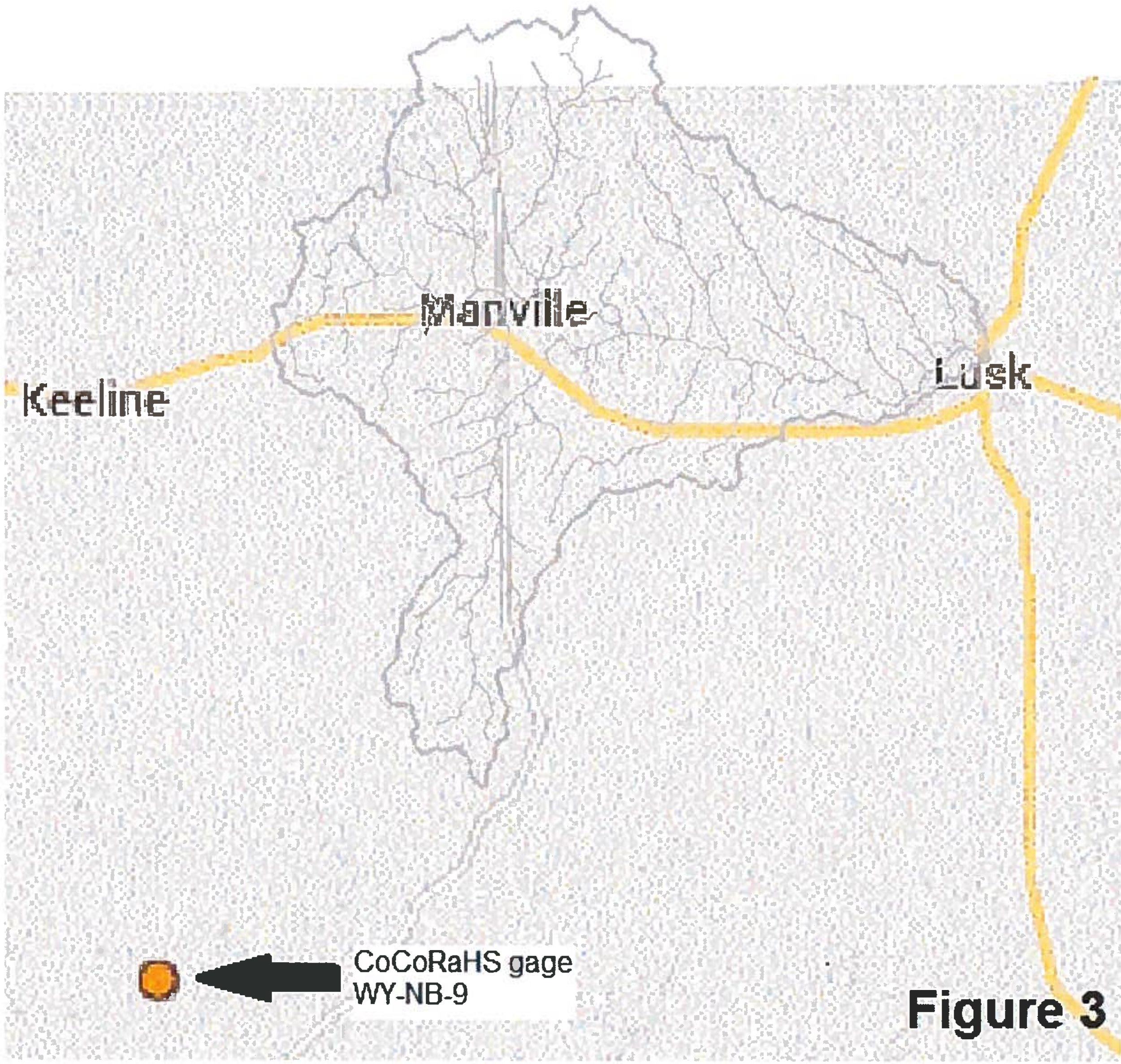

Figure 3

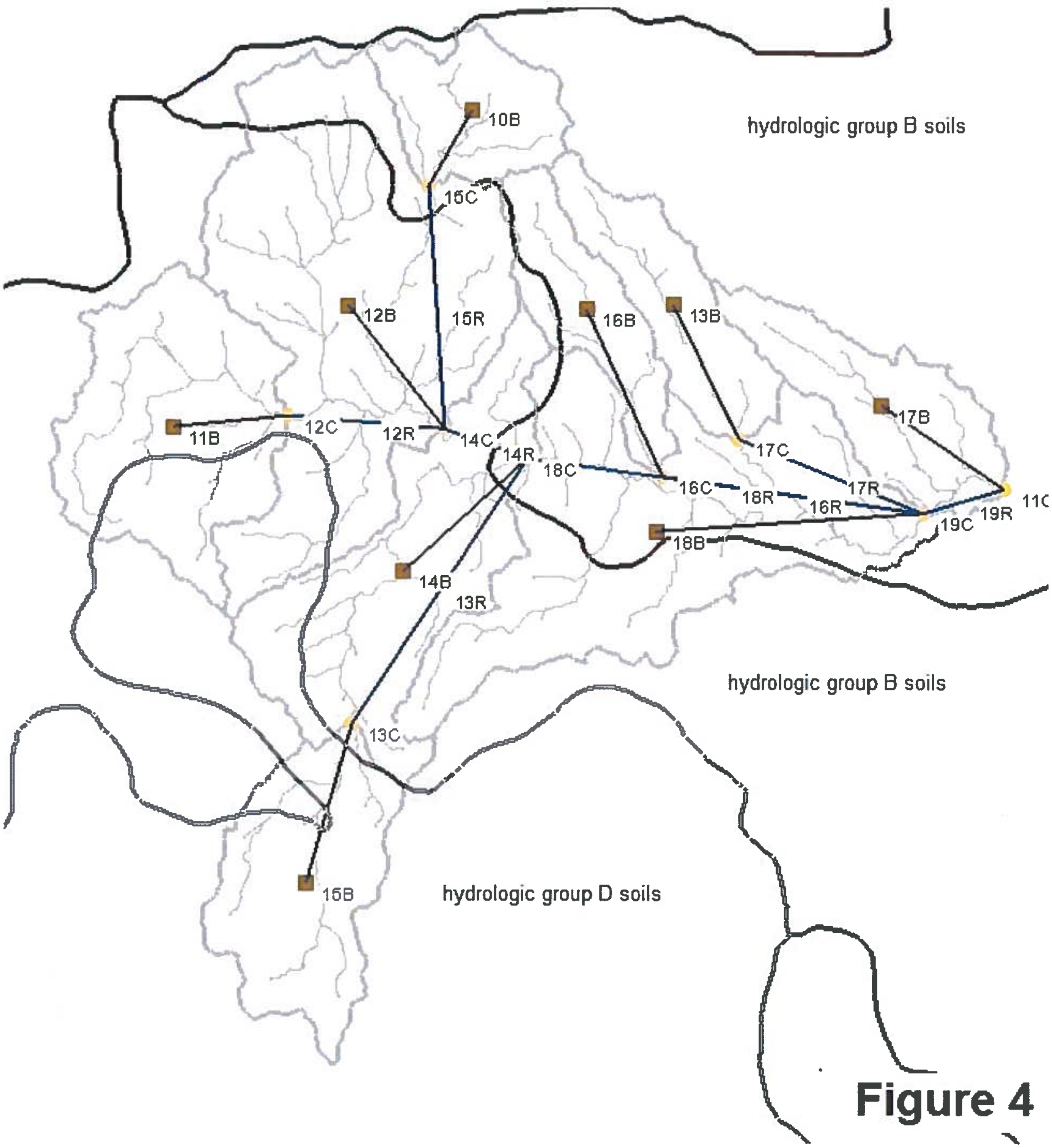
10B
15C
hydrologic group B soils
12B
15R
16B
13B
17B
11B
12C
12R
14C
14R
18C
17C
16C
18R
16R
17R
11C
19R
19C
18B
14B
13R
hydrologic group B soils
13C
15B
hydrologic group D soils

Figure 4

2015 Lusk Flood
Storm Study
June 3, 2016

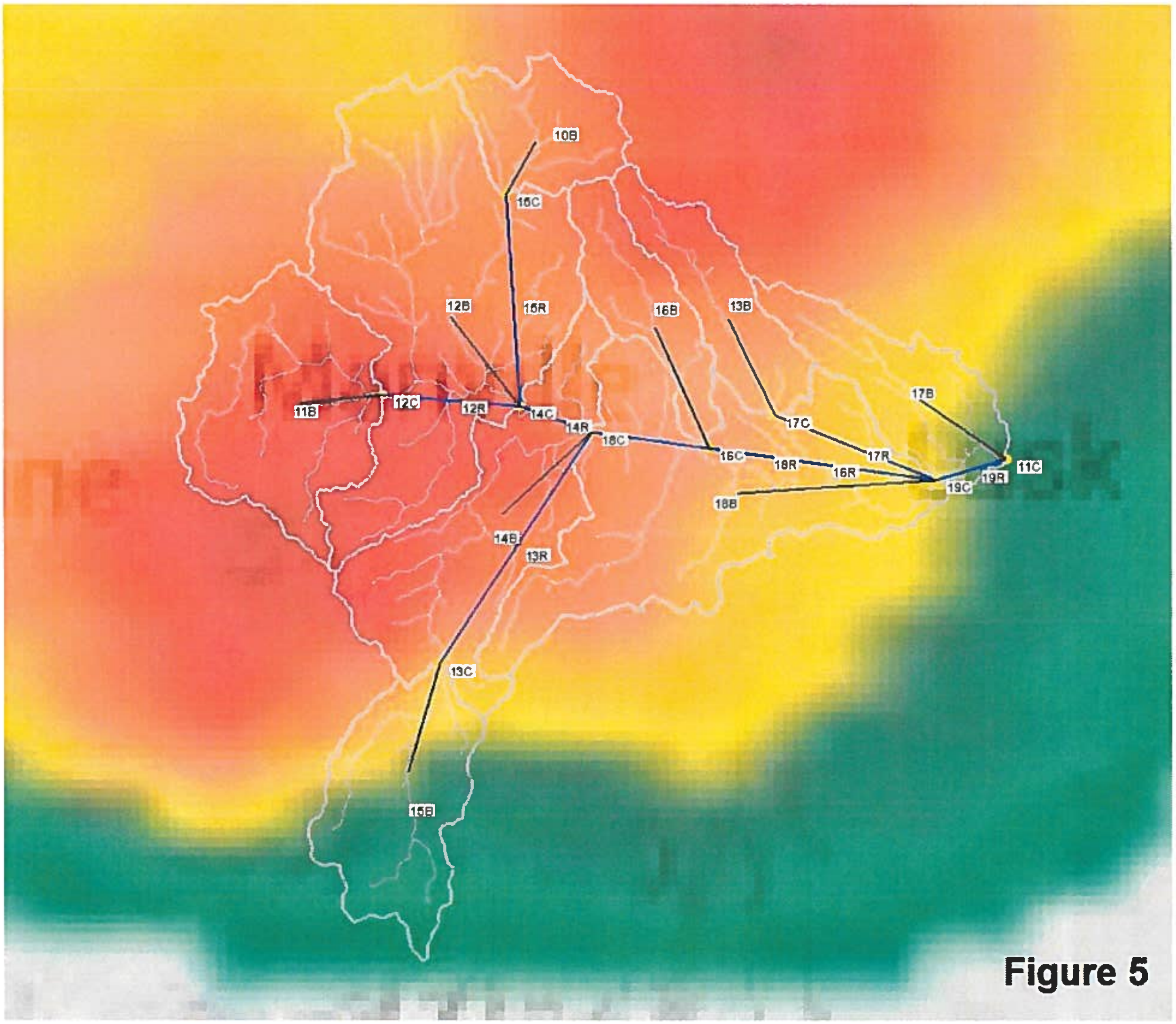

Figure 5

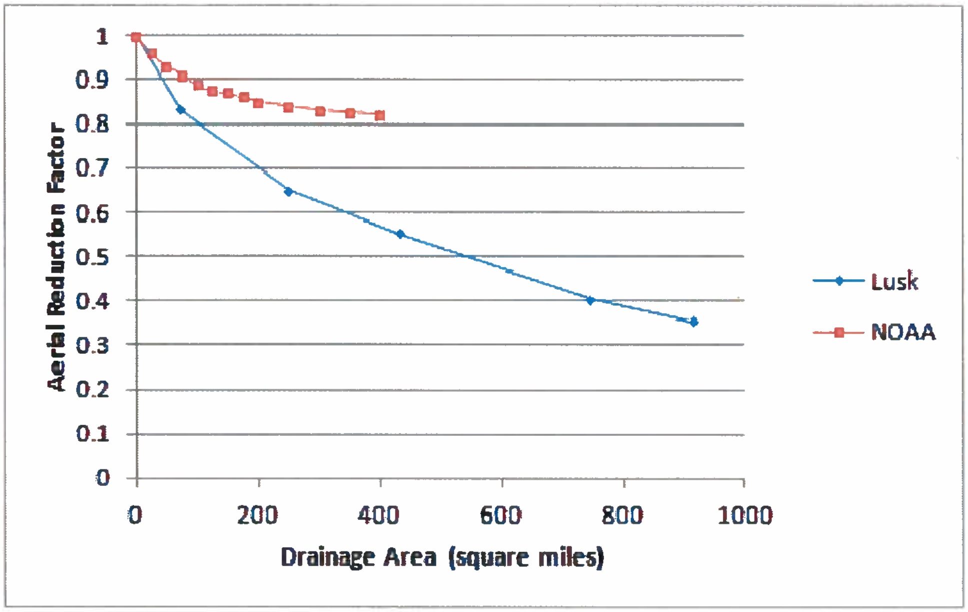

Figure 6

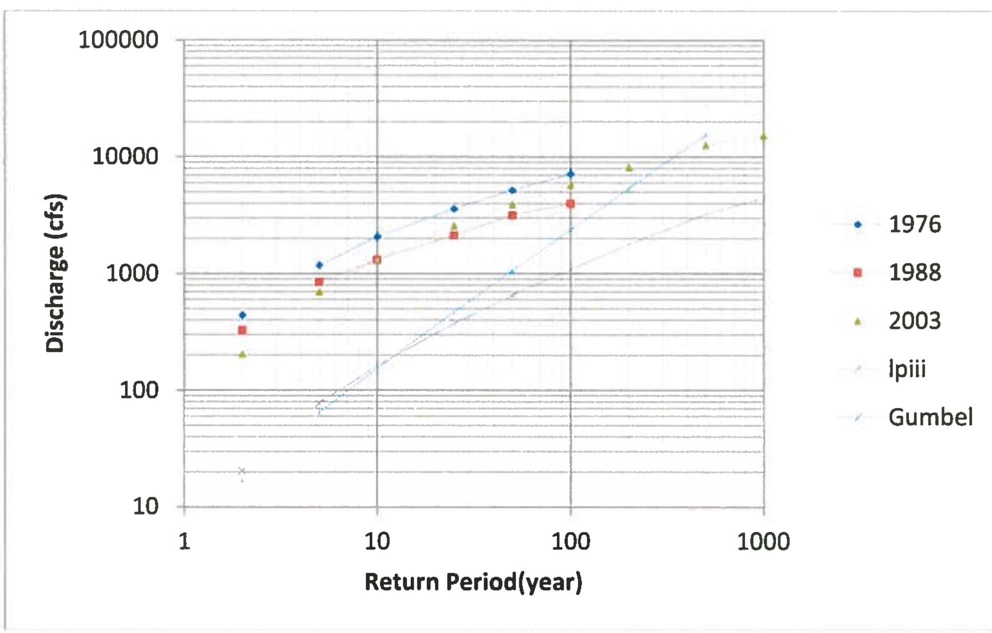

Figure 7

The USGS estimate of 2450 cfs flood peak through the railroad bridge opening is considered accurate if the bridge super structure was not collapsed prior to or during the peak discharge, or that the railroad bridge opening was not blocked by other debris.

The design of the Niobrara Highway US 85 Bridge was approximately 2180 cfs. It was blocked with lots of drift making it difficult to estimate the discharge through the bridge. The addition of the railroad bridge discharge of 2450 cfs and the Niobrara River Bridge design discharge of 2180 cfs produces a total discharge of 4630 cfs. That discharge does not include the portion of the discharge that diverted through the town south of the railroad bridge.

LUSK Flood Sensitivity Analysis

The rainfall runoff model parameters are subject to a range of values that are selected by the user.

A high and low curve number for each sub basin was input into the model to compute a range of flood estimates such that the most probable flood discharge lies within the range of estimates.

Hydrologic soils for pasture or range land

B soils CN 61 to 79

D soils CN 80 to 89

The June 3-4, 2015 hyetograph from the Doppler radar aerial distribution study

Low discharge estimate 2136 cfs

High discharge estimate 7072 cfs

Average estimate 4604 cfs.

Sensitivity Analysis Frequencies for Different Methods

	frequency				
method	1976	1988	2003	lplll	Gumbel
low estimate 2136 cfs	11	25	20	270	90
high estimate 7072 cfs	n/a	390	150	1000+	250
avg estimate 4604 cfs	40	130	68	1000	180

Extreme Events and Climate Change

A trend analysis was made to give insight as to the potential effects of climate change. The term climate change is widely used by not well defined such that communication regarding extreme events and climate change is difficult. This study is not intended to endorse or refute anthropogenic effects of the climate or that the climate may be significantly changing. The trend analysis suggests that flood peaks are not increasing but appear to be decreasing.

One may ask if the Lusk flood event was a result of climate change. The fact that extreme events occur in all climates and events larger than the June 4, 2015 event have likely occurred in historic period, the June 2015 is not necessarily attributed to a change in climate. However if the climate has changed then all weather events large or small are a result of climate change. This paradox is not possible to resolve with current technology. This trend analysis suggests that large events are not increasing in occurrence. A rigorous stationarity analysis may prove otherwise. A rigorous stationarity analysis is beyond the scope of this study.

A true significant climate change would have a significant change in the flood frequency estimates. As shown in this study, a wide range of flood frequency estimates can be made using various methods. The rainfall runoff methods may have variables that would respond to changes in climate. For instance the rainfall hyetograph could be climate adjusted if the rainfall frequency due to climate change can be estimated. The USGS regression equations and the stream gage analysis methods are not readily adaptable to estimate changes in peak discharges due to change in global average temperature.

It is difficult to accurately estimate a flood frequency curve for any climate, even with extensive data. The most impact to man will be in the lower frequency ranging from 10 to 100-year since they occur more frequently.

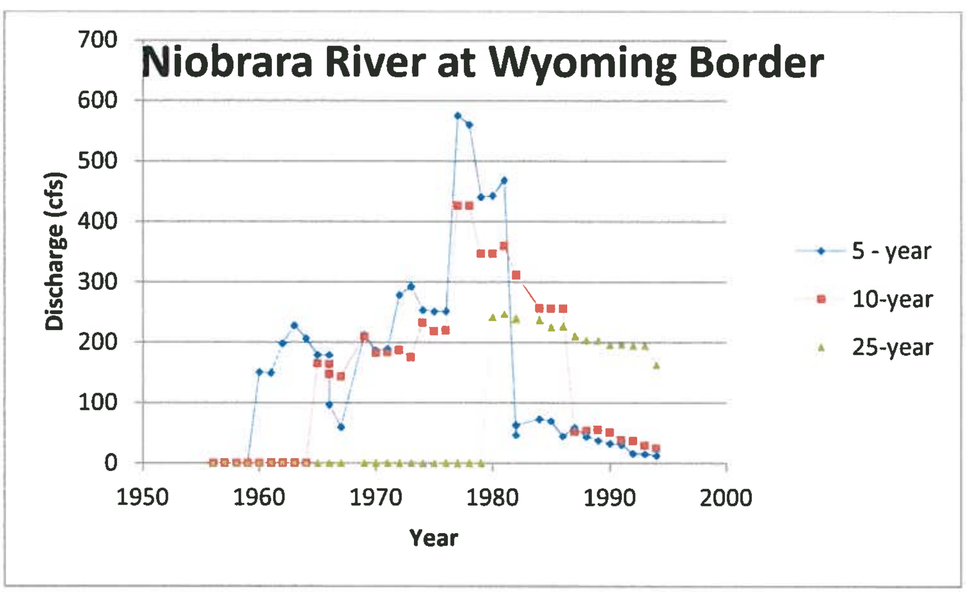

Figure 8 – Niobrara River Near Wyoming Border

A trend analysis of the Niobrara River gage was made using the 5, 10 and 25 year moving averages as shown in Figure 8. The rise in global average temperatures began in about 1970. There has been no global increase in temperature in the last 15 years (2000- 2016).

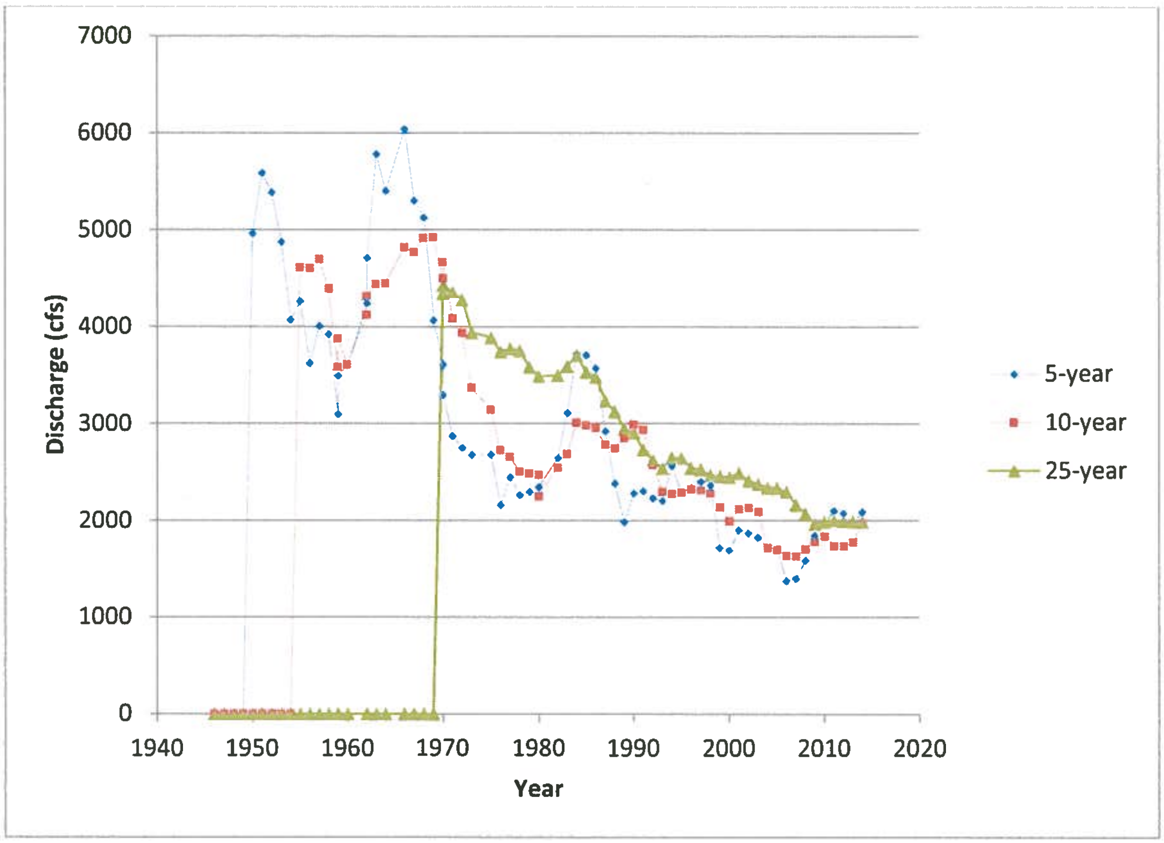

Figure 9 – Niobrara River near Sparks Nebraska

The trend analysis of the 5, 10 and 25 year moving averages shows no increased trend in peak runoff or extreme events. The decrease could be attributed to climate change, watershed conditions or random variation in flood events over a long period of time.

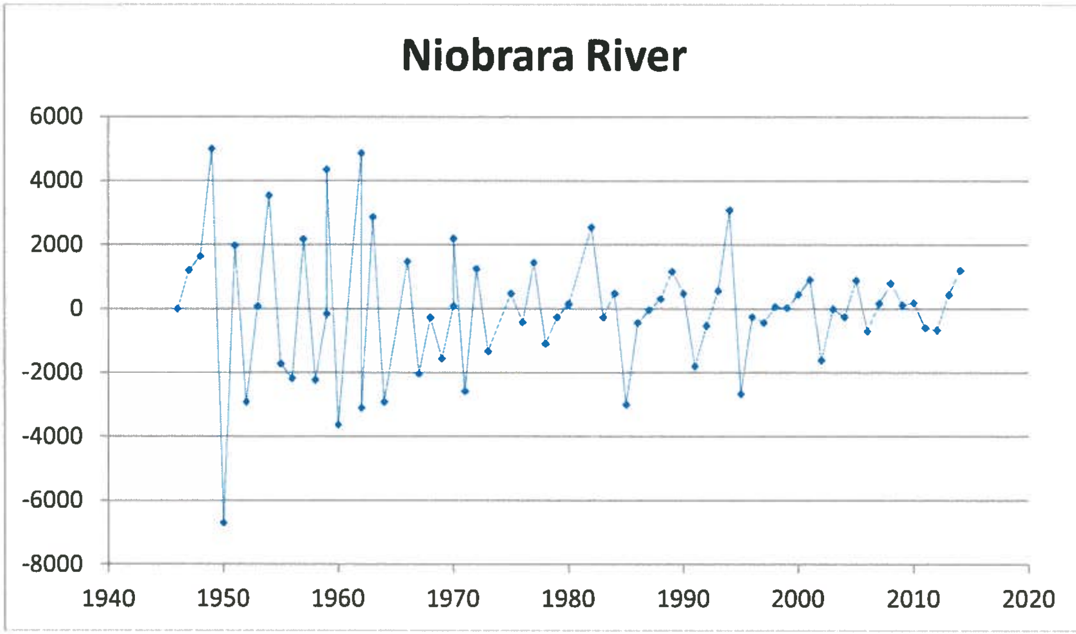

Figure 10 Random Walk Difference Data

A random walk through the data showing the difference in yearly change in discharge Dy = $(y_t - y_{t-1})$. Visually the yearly differences in peak fluctuations appear to be decreasing with time. The 2015 flood however is not included in the data. There appears to be a larger fluctuation in yearly peak differentials from 1945 to 1965.

A regression of the difference data does not show an upward or downward trend. There appears to be a downward trend in the fluctuation of peak discharges. The trends may be attributed to land use changes and possibly "climate change".

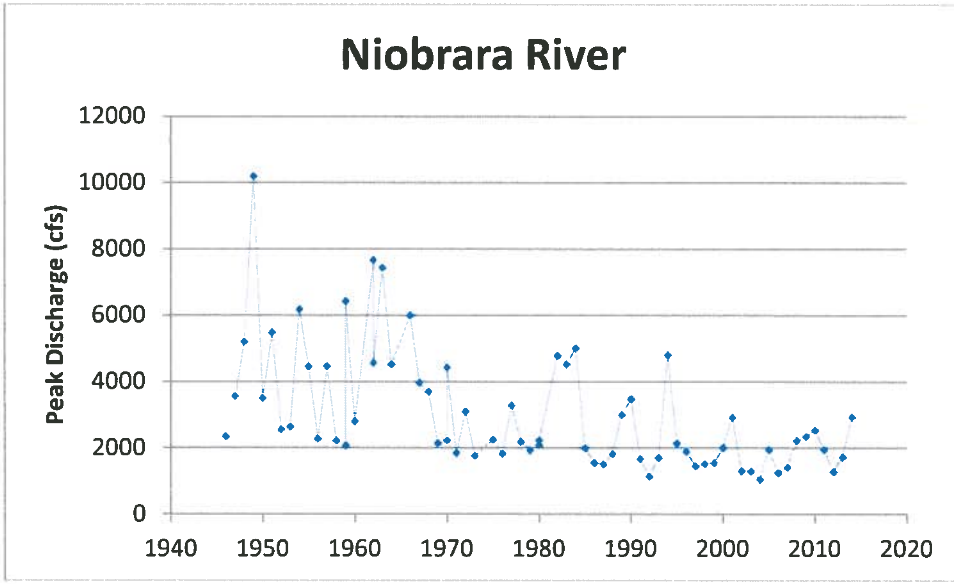

Figure 11 – Niobrara River Yearly Peak Discharges, Sparks gage

The 2015 flood peak is not shown on the graph. The Niobrara River stream gage at Sparks Nebraska has a drainage area of 7150 square miles.

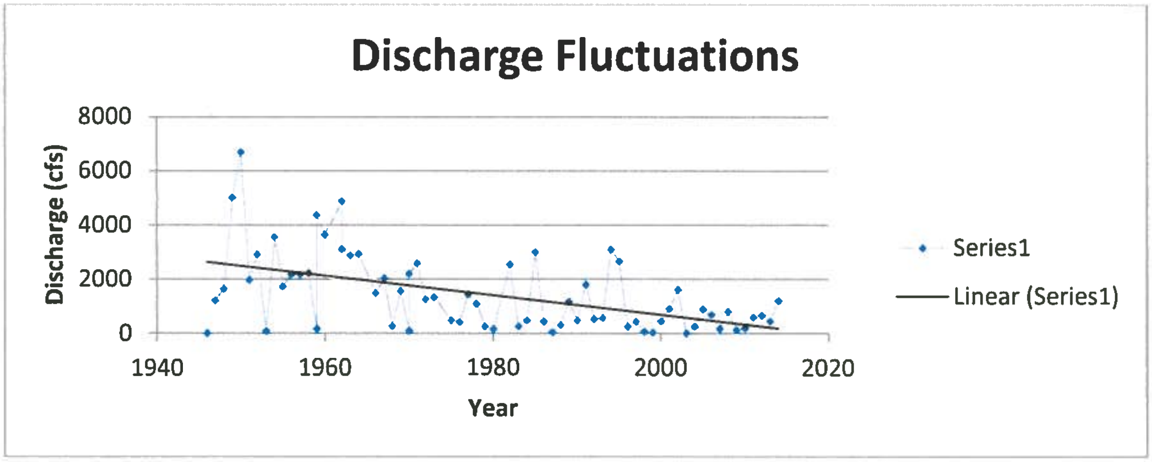

Figure 12 - Trend in Yearly Discharge Fluctuations

The 2015 flood peak was not included in the data since it is not yet available.