January 2013

Nebraska Department of Natural Resources

Integrated Water Management Division

Upper Platte River Recharge and Flood Mitigation Demonstration Project:

Part of the Conjunctive Management Toolbox

Technical Memorandum- January 2013

Integrated Water Management Division
Nebraska Department of Natural Resources

Technical Memorandum

This technical memorandum (TM) is intended to provide a brief or preliminary summary of a project or experiment without extensive technical analysis. It is not intended to be so in depth that one be able to recreate the experiment based upon the information given, but rather to present a broad overview of the methods and analysis while highlighting the results and conclusions. Although the content is of a technical manner, the TM should be understood by an audience with a general scientific background.

Acknowledgements

The Department would like to thank the natural resources districts and the Irrigation Districts for their hard work, collaborative efforts, and perseverance in carrying out this project. Cooperators include: Central Platte, North Platte, South Platte, Tri-Basin, and Twin Platte Natural Resources Districts; Bridgeport Irrigation District; Castle Rock Irrigation District; Central Irrigation District; Central Nebraska Public Power and Irrigation District; Chimney Rock Irrigation District; Cozad Canal Company; Enterprise Irrigation District; Farmers Irrigation District; Keith Lincoln County Irrigation District; Lisco Irrigation District; Minatare Canal Company; Nebraska Public Power District; Nine Mile Irrigation District; Pathfinder Irrigation District; Paxton-Hershey Water Company; Platte Valley Irrigation District; South Side Irrigation Company; Suburban Irrigation District; Thirty Mile Canal Company; Western Irrigation District; and Winters Creek Canal Company. Without the efforts of all of these parties, this project would not have been as successful.

Funding for the project includes the Central Platte, North Platte, South Platte, Tri-Basin, and Twin Platte Natural Resources Districts; and the Nebraska Environmental Trust.

1.0 Summary

Twenty-one irrigation districts participated in the Spring 2011 Recharge and Flood Mitigation project during the months of April and May. Twenty irrigation districts participated in the Fall 2011 Recharge and Flood Mitigation project during the months of September through December. In order to quantify the volume of water that was recharged by the canals, canal losses were developed for each canal. Canal losses were calculated using diversion and spill discharge measurements or were estimated from existing data sources. Based on the diversion records and calculated losses, recharge volumes were calculated by canal and summarized by natural resource district (NRD). Recharge volumes for each canal were used in conjunction with response functions developed by the technical committee under the Platte Basin Habitat Enhancement Program (PBHEP) to calculate estimated accretions/depletions to the Platte River.

2.0 Method

A total of 23 canals that divert water from the North Platte River, the South Platte River, and Platte River participated in the 2011 Recharge Project in the spring, fall, or both. Each individual canal began diverting at different times depending upon permit requirements and readiness of the canal and its operators. Average daily diversions were used to determine the amount of water that entered each canal for a total of 30 days during the spring. Average daily diversions were used to determine the amount of water that entered each canal subsequent to irrigation operations during the fall. Average daily diversions were used until diversions stopped in the fall, regardless of the number of days. Several of the canals were forced to shut down their canals during the recharge time period due to extreme weather conditions or to make repairs on the canal. The period of time for those canals was extended to include 30 days of actual diversions, with the exception of Pathfinder Irrigation District. Pathfinder Irrigation district did not participate for the full 30 days during the spring due to additional operational requirements of the district.

The Department of Natural Resources' (Department) Bridgeport Field Office was tasked with conducting and coordinating discharge measurements at the spill locations for each canal in order to do water balance calculations. Due to demands on the field office associated with the high water levels during the 2011 water year, a number of canal spills went unmeasured. If canal spill measurements were available, water balance calculations were conducted to determine the percentage of the total diversion that was lost. If measurements were not available, estimates of canal loss were taken from the STELLA model developed under the COHYST 2010 project. Estimated and calculated canal losses were compared against historical seepage measurements and operational efficiencies used and developed by the irrigation districts. Table 1 summarizes the participating projects, the method used to determine canal loss, and the total number of days considered during the spring and fall.

Irrigation Project	Method	Spring Diversion Days	Fall Diversion Days
Pathfinder Canal	Measurement	15	0
Farmers Canal	Measurement	30	0
Enterprise Canal	Measurement	30	0
Winters Creek Canal	Measurement	0	46
Central Canal	Measurement	30	36
Castle Rock Canal	Measurement	30	39
Minatare Canal	Measurement	30	33
Nine Mile Canal	Measurement	30	41
Chimney Rock Canal	Measurement	30	47
Belmont Canal	Seepage Runs	30	47
Lisco Canal	Measurement	30	31
Keith Lincoln Canal	Measurement	30	37
Suburban Canal	Measurement	30	33
North Platte Canal	Model	30	31
Paxton Hershey Canal	Model	30	45
Phelps County Canal	Measurement	0	100
Thirty Mile Canal	Model	30	32
Orchard Alfalfa Canal	Model	30	38
Gothenburg Canal	Model	30	34
Cozad Canal	Model	30	31
Dawson Co. Canal	Model	30	34
Kearney Canal	Model	30	9
Western Canal	Measurement	30	75
Western Ponds	Measurement	41	49

Table 1: Projects diverting excess Platte River basin flows for flood mitigation and seepage demonstration during the spring and fall of 2011.

2.1 Measured Canal Loss & Recharge Volume

Water balance calculations were performed on the canals when and where discharge measurements of the spills were available. Some canals had only one spill measurement while other canals had several. For each spill measurement taken the rate of water measured at the canal spill was subtracted from the average daily diversion rate to determine the rate of canal loss. The loss was then divided by the average daily rate of diversion to calculate a daily loss as a proportion of the total volume of water diverted. The equations used are shown below. For canals with multiple measurements the average loss was calculated and used in the next step of the analysis. An example is given below from the Minatare Canal. Four spill measurements were taken with loss rates calculated as 21 percent, 25 percent, 23 percent, and 36 percent. The average value for these calculations is 26 percent. To estimate a total volume of diverted water that seeped into the ground or recharged, the average loss value was multiplied by the volume

diverted. The volume diverted was calculated based upon multiplying the average daily diversion rate (in cubic feet per second) for each day by 1.9835, converting it to a daily volume (acre-feet per day). The daily volumes were summed to calculate the total volume diverted. For Minatare, the total spring diversion was 2,709 acre-feet (AF) and the average loss value was 26 percent. The resultant recharge volume is 704 AF.

$$Canal\ Loss\ \% = \left(\frac{daily\ diversion\ rate - rate\ measured\ at\ spill}{daily\ diversion\ rate}\right) * 100\%$$

This equation simplifies as follows:

$$Canal\ Loss\ \% = \left(\frac{daily\ diversion\ rate}{daily\ diversion\ rate} - \frac{rate\ measured\ at\ spill}{daily\ diversion\ rate}\right) * 100\%$$

$$= \left(1 - \frac{rate\ masured\ at\ spill}{daily\ diversion\ rate}\right) * 100\%$$

The final simplified equation is the version used in the spreadsheet calculations (see appendix A).

Minatare				
Date	**Diversion Rate (cfs)**	**Measured at Spill (cfs)**	**Spill Location**	**Loss**
4/5/2011	48	37.7	Minatare Spill	21%
4/13/2011	44	33.1	Minatare Spill	25%
4/20/2011	40	30.9	Minatare Spill	23%
4/26/2011	49	31.3	Minatare Spill	36%
			Measured:	**26%**
			***Estimated:**	
			Used:	**26%**

$$Canal\ Recharge = Canal\ Diversion * \frac{Canal\ Loss\ \%}{100\%}$$

$$Minatare\ Canal\ Recharge = 2709\ AF * \frac{26\%}{100\%} = 704\ AF$$

2.2 Modeled Canal Loss & Recharge Volume

Estimates of average canal loss based upon total water diverted were obtained from the STELLA model. The loss estimates in the STELLA model were developed by HDR Engineering, Inc. for

the COHYST study. Loss estimates from the STELLA model were calculated at 32 percent[1] of the canal's total diversion. For example, Paxton Hershey Canal did not have measured spill data, the total volume diverted was 1724 AF and the loss rate, from STELLA, was 32 percent so the calculated volume of water recharged was 552 AF.

2.3 Western Canal and Pond Loss & Recharge Volume

Western Canal losses were calculated using the water balance method based on discharge measurement at the canal's spill. In addition to the canal recharge, nine ponds were used as recharge pits to increase the overall amount of recharge to the system. Twin Platte Natural Resource District (TPNRD) placed staff gages at each of the pond sites and established volume quantities at each respective gage height. The staff gages were then read by TPNRD weekly to determine the rate of seepage per day for each pond. Recharge activities varied for each pond, but most of the ponds operated for 41 days. The recorded number of days for each pond was used to calculate the recharge at each site. Diversions into the pond were not used to adjust the water balance calculation when determining the loss along Western Canal. Most of the recharge ponds were not diverting water on the days where discharge measurements were conducted at the canal spill. In addition, the quantity of water diverted from the canal into the ponds was within the discharge measurement error band at the spill.

2.4 Accretions to the Platte River

Estimates of canal and pond recharge volume were combined with depletion functions developed by the technical committee under the PBHEP program to estimate the recharge effects on flows in the Platte River, or accretions. The depletion functions are defined for six zones within each NRD. Legal sections corresponding to the extent of the canal where water was routed were used to calculate an average zone number to determine the appropriate response curve. The depletion functions represent a fixed change that persists through time; therefore, an accretion function was developed to represent the recharge water occurring as a discrete pulse during a single year. This was accomplished by shifting the depletion function curve by one year (one time increment on the curve) and subtracting the shifted value from the original depletion function, thus creating a response function. The response function was then multiplied by the canal loss value to estimate Platte River accretions for the next 50 years. Figure 1 provides an example. Different canals and different distribution patterns regarding diverted flows create different temporal patterns of accretions (figure 2).

[1] Engel, J., unpublished data, COHYST 2010, Canal Seepage Estimates.

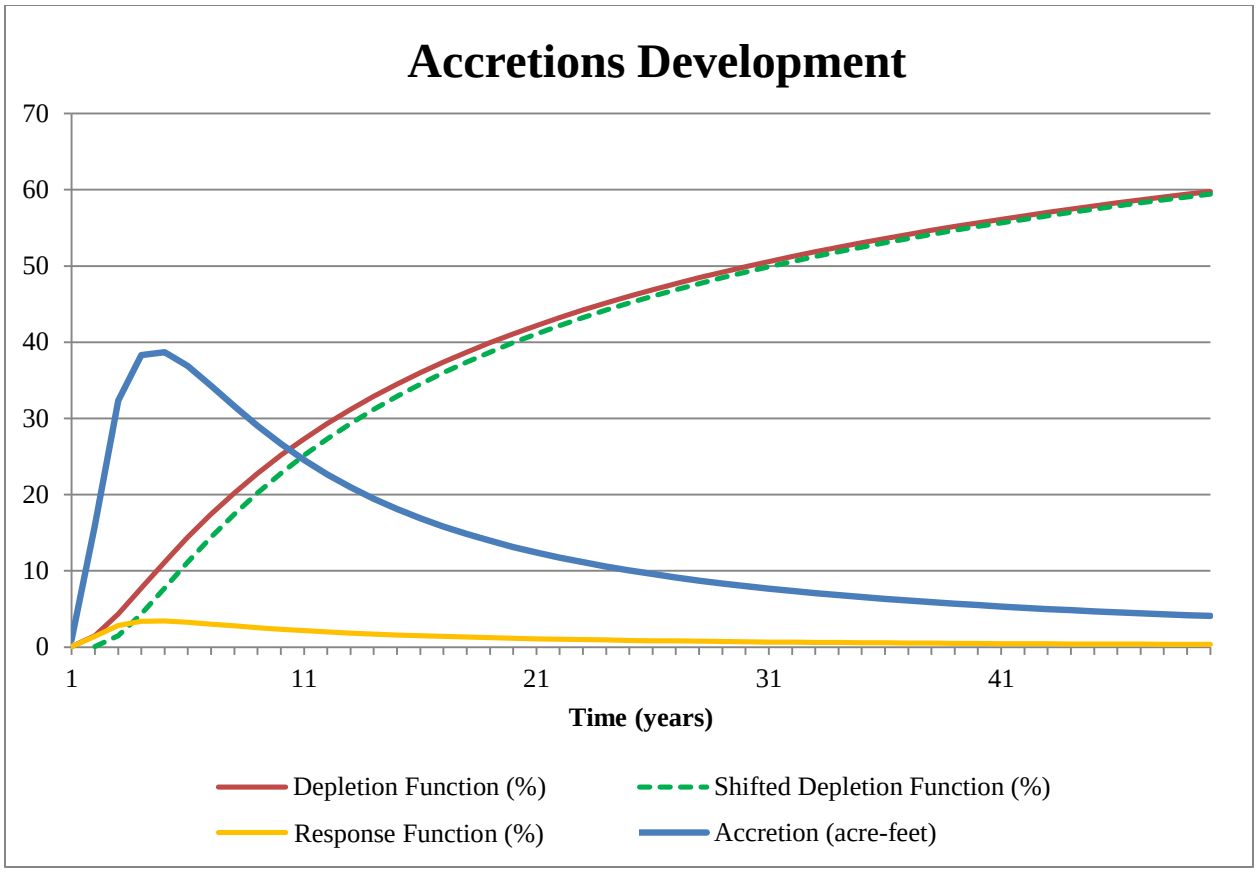

Figure 1: Cartoon illustrating temporal accretions estimation process using PBHEP zone functions (Depletion Functions) to create response function and estimated accretions. Below is a table showing the numbers used to generate the response function and an example of the calculations done to get the estimated accretions.

Year	1	2	3	4	5	6	7	8	9	10
Depletion Function (%)	0.083	1.496	4.353	7.737	11.155	14.412	17.442	20.234	22.800	26.684
Shifted Depletion Function (%)	0.000	0.083	1.496	4.353	7.737	11.155	14.412	17.442	20.234	22.800
Response Function (%)	0.083	1.413	2.857	3.384	3.419	3.257	3.030	2.792	2.565	2.357

Canal Loss = 1132 AF in year 1

$$Accretion_{Year\ 1} = 1132\ AF * \frac{0.083\%}{100\%} = 0.94\ AF$$

$$Accretion_{Year\ 10} = 1132\ AF * \frac{2.357\%}{100\%} = 26.68\ AF$$

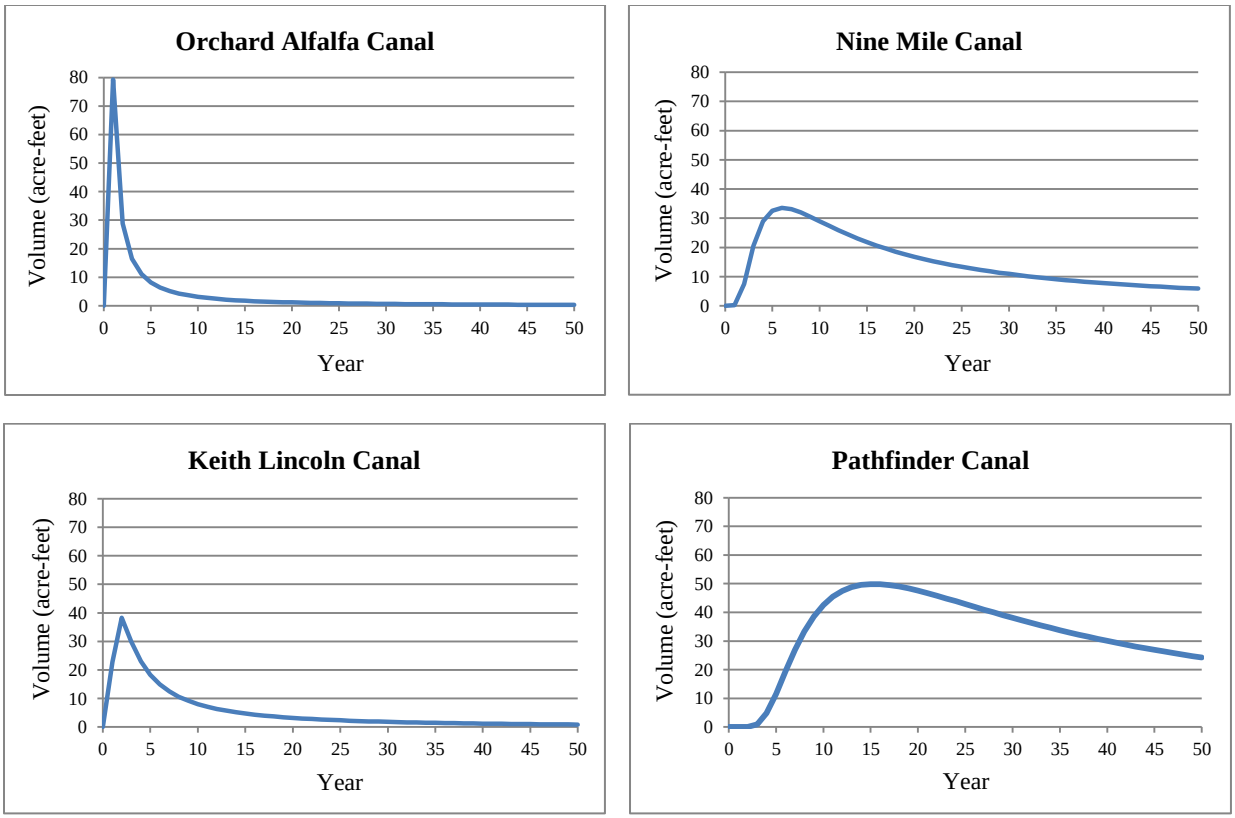

Figure 2: Accretions estimated from four different canals illustrating a variety of temporal patterns in estimated accretions to the Platte River.

3.0 Summary of Results

Results are summarized for each canal and the Western Canal Pond seepage project. These results are then aggregated by natural resources district. The estimated accretions to Platte River streamflow in each natural resources district is shown in table 2. These results estimate that the annual accretion during the first decade is approximately 1,000 to 1,500 AF per year and residual accretions greater than 500 AF per year will persist for 25 years. NRD specific estimates show a 50-year benefit to streamflow of between 2,000 and 12,000 AF, with total 50-year benefits around 36,000 AF. Table 3 presents the canal specific source data indicating that approximately 140,000 AF of water was diverted, of which about 65,000 AF is estimated to have seeped into groundwater storage. This indicates that much of the benefit from this single seepage demonstration may persist well beyond the 50-year planning horizon presented here. Water use and management practices in the interim will fundamentally effect the realization of these benefits, though this project has provided options that would not have been available if the Department and its collaborating partners had not taken the opportunity to divert and store abundant excess flows in the Platte River throughout 2011.

Year	NPNRD	SPNRD	TPNRD	TBNRD	CPNRD	Annual Total
2011	3	3	422	0	634	1062
2012	83	44	853	21	671	1672
2013	229	89	868	69	590	1844
2014	328	105	805	104	511	1853
2015	381	107	724	121	445	1777
2016	405	102	644	126	392	1669
2017	414	95	574	125	348	1555
2018	413	88	513	121	311	1446
2019	406	81	461	115	281	1344
2020	396	75	416	109	255	1251
2021	384	69	378	103	233	1167
2022	371	64	345	97	214	1091
2023	357	59	316	91	198	1022
2024	343	55	291	86	183	959
2025	330	51	269	81	171	903
2026	317	48	250	77	159	851
2027	305	45	233	72	149	804
2028	293	42	218	68	140	761
2029	281	40	204	65	132	722
2030	271	38	191	62	124	685
2031	260	36	180	59	118	652
2032	251	34	170	56	111	621
2033	241	32	161	53	106	593
2034	233	30	152	51	100	567
2035	224	29	145	48	96	542
2036	216	28	138	46	91	519
2037	209	26	131	44	87	498
2038	202	25	125	43	83	478
2039	195	24	119	41	80	460
2040	189	23	114	39	77	442
2041	183	22	109	38	74	426
2042	177	21	105	36	71	410
2043	171	21	101	35	68	396
2044	166	20	97	34	66	382
2045	161	19	93	33	63	369
2046	157	18	90	32	61	357
2047	152	18	86	30	59	346
2048	148	17	83	30	57	335
2049	144	17	80	29	55	324
2050	140	16	78	28	53	315
2051	136	16	75	27	52	305
2052	132	15	73	26	50	296
2053	129	15	70	25	48	288
2054	126	14	68	25	47	280
2055	122	14	66	24	46	272
2056	119	13	64	23	44	265
2057	117	13	62	23	43	258
2058	114	13	61	22	42	251
2059	111	12	59	21	41	244
2060	108	12	57	21	40	238
10yr Benefit	**3056**	**787**	**6281**	**911**	**4439**	**15474**
50yr Benefit	**11341**	**1913**	**11991**	**2753**	**8171**	**36168**

Table 2: Estimated annual accretions to the Platte River summarized by Natural Resources District. Units are acre-feet.

Project	Spring Diversion	Fall Diversion	Total Diversion	Total Recharge	10 year Benefit	50 year benefit
Pathfinder Canal	12718	0	12718	5087	178	1690
Farmers Canal	18425	0	18425	8660	1470	4471
Enterprise Canal	2559	0	2559	1689	287	872
Winters Creek Canal	0	882	882	42	7	22
Central Canal	524	1022	1545	331	56	171
Castle Rock Canal	1595	1069	2664	1198	42	398
Minatare Canal	2709	2338	5048	1207	205	623
Nine Mile Canal	1521	1114	2635	1850	314	955
Chimney Rock Canal	948	2965	3913	1049	178	542
Belmont Canal	2241	2965	5206	2789	98	926
Lisco Canal	2229	1516	3746	1301	221	672
Keith Lincoln Canal	1349	1914	3263	1676	833	1259
Suburban Canal	1230	1781	3010	1527	759	1147
North Platte Canal	2842	4245	7088	3616	1798	2716
Paxton Hershey Canal	1724	2483	4207	1691	425	1011
Western Ponds (TP)	0	0	0	3013	758	1801
Thirty Mile Canal	4134	5141	9275	2968	1640	2317
Orchard Alfalfa Canal	732	1871	2603	833	592	716
Gothenburg Canal	4641	5729	10370	3318	741	1915
Cozad Canal	1335	1714	3049	976	364	663
Dawson Co. Canal	2652	3450	6101	1952	104	741
Kearney Canal	4528	3832	8360	2675	997	1818
Phelps Canal	0	5558	5558	5163	911	2753
Western Canal (30% SP, 70% TP)	4528	15158	19687	9695	2439	5796
Western Ponds (SP)	0	0	0	392	55	174
Totals:	**75,165**	**66,746**	**141,911**	**64,699**	**15,474**	**36,168**

Table 3: Estimation of 10 and 50 year accretions to the Platte River by canal or contracting entity. Units are acre-feet.

Appendix A – Spreadsheet Calculations

A spreadsheet named *Recharge_2011_Final.xlsx* was developed to conduct the recharge calculations and is summarized according to the individual tabs of the spreadsheet below.

Tab 1: "2011_Seepage Extent"

This table is a tabulation of legal sections where water was routed in each canal. It is based upon data contained in maps provided by Irrigation Districts in coordination with the Department's Bridgeport Field Office showing locations where water was routed during the project. These maps are available with the permit filings and can be obtained by contacting the Department.

Tab 2: "Response zone f'n"

Response functions corresponding to six zones for each natural resources district are included in this tab. Functions assume a permanent introduced stress and were developed by the PBHEP technical committee[2] using COHYST databases and the Hunt[3] (1999) equation. Zone averages calculated by relating the section data from Tab 1 to the response function zone maps (Appendix B) are reported in this tab as well. The spatial relation was performed in ArcGIS. This tab also notates the natural resources district assigned to each canal, as well as the Response Function Zone.

Tab 3: "Total Diversions Spring"

Average daily diversion rates in cubic feet per second from April 1, 2011, through May 31, 2011, for each canal were imported into the spreadsheet from the Platte Water Accounting Program (PWAP) database[4]. Those rates were used to generate a daily volume of water, in acre-feet, diverted using the conversion factor of 1.9835. The gray cells represent the 30 days of diversions that were used to calculate the total acre-feet of water diverted during the recharge period.

Tab 4: "Recharge Rates Spring"

Data from the discharge measurement conducted by Department field office staff and provided by Tom Hayden were entered into the spreadsheet to determine the daily and average percentage of canal loss. Each measurement rate was compared to the average daily diversion rate to calculate a loss value for that day. Multiple daily loss values for one canal were averaged to arrive at a final loss values for a single canal. For canals where measurements were not available,

[2] Approved by the PBHEP administrators as part of the "Trial Protocol for PBHEP Funds" at the April 7, 2010, meeting in North Platte, NE (Platte Basin Habitat Enhancement Project. *Meeting of the PBHEP Administrators*. 7 April 2010) and, after editorial changes (Czaplewski, Mark. "FW: Revised PBHEP Protocol with Depletion Zone Figures." Email to PBHEP Administrators. June 17, 2010), finalized on June 30, 2010 (Czaplewski, Mark. "PBHEP." E-mail to PBHEP Sponsors and Partners. June 30, 2010).

[3] Hunt, B. (1999), Unsteady Stream Depletion from Ground Water Pumping. Ground Water, 37: 98–102.

[4] PWAP is an accounting program used by the Department of Natural Resources Bridgeport Field Office to apportion natural flow and track storage.

estimates from the COHYST 2010 STELLA model were entered. The canals are organized by natural resource districts.

Tab 5: "Div + Recharge by NRD Spring"

Based upon the data in the "Total Diversions Spring" tab and "Recharge Rates Spring" tab, the total volume of water recharged is calculated and listed in acre-feet for each canal. The canal diversions and recharge rates are then summarized and listed by natural resources district. Individual canal values relating to each of the NRDs were assigned according to the table in Tab 2 and are reported in the sheet. Because Western Canal is within the bounds of two NRDs, the canal recharge was distributed as 70 percent Twin Platte NRD and 30 percent South Platte NRD. Of the nine ponds utilized under Western Canal, seven of the ponds were located inside Twin Platte NRD and two ponds were located in South Platte NRD. The ponds were measured individually and diversions and canal recharge were assigned according to the NRD where they exist.

Tab 6: "Total Diversions Fall"

Average daily diversions rates in cubic feet per second from September 1, 2011, through November 14, 2011, for each canal were imported into the spreadsheet from the PWAP database. Those rates were used to generate a daily volume of water, in acre-feet, diverted using the conversion factor of 1.9835. Average daily diversions from September 1, 2011, through January 5, 2012, for the Phelps Canal were imported into the spreadsheet from the PWAP database. January diversions for the Phelps Canal are included in this report for 2011. The gray cells represent the days of diversions that were used to calculate the total acre-feet of water diverted during the recharge period.

Tab 7: "Recharge Rates Fall"

Data from the discharge measurement conducted by Department field office staff and provided by Tom Hayden were entered into the spreadsheet to determine the daily and average percent of canal loss. Each measurement rate was compared to the average daily diversion rate to calculate a loss value for that day. Multiple daily loss values for one canal were averaged to arrive at a final loss values for a single canal. For canals where measurements were not available, estimates from the STELLA model were entered. For the Phelps canal, daily monitoring and spill estimation information was provided by Cory Steinke from Central Nebraska Public Power and Irrigation District (CNPPID).

Tab 8: "Div + Recharge by NRD Fall"

Based upon the data in the "Total Diversions Fall" tab and "Recharge Rates Fall" tab, the total volume of water diverted and recharge is calculated and listed in acre-feet for each canal. The

canal diversions and recharge rates are then summarized and listed by natural resource districts. Individual canal values relating to each of the NRDs were assigned according to the table in Tab 2 and are reported in the sheet. Because Western Canal is within the bounds of two NRDs, the canal recharge was distributed as 70 percent Twin Platte NRD and 30 percent South Platte NRD. Of the nine ponds utilized under Western Canal, seven of the ponds were located inside Twin Platte NRD and two ponds were located in South Platte NRD. The ponds were measured individually and diversions and canal recharge were assigned according to the NRD where they exist.

Tab 9: "Total Recharge by NRD 2011"

Data from the "Div + Recharge by NRD Spring" and "Div + Recharge by NRD Fall" tabs are listed in this tab by canal and summed to show the total recharge during 2011.

Tab 10: "Spring Response"

Data from the "Div + Recharge by NRD Spring" and "Response zone f'n" tabs are incorporated in this tab by canal to create annual accretion functions and accretions by canal.

Tab 11: "Fall Response"

Data from the "Div + Recharge by NRD Fall" and "Response zone f'n" tabs are incorporated in this tab by canal to create annual accretion functions and accretions by canal.

Tab 12: "2011summary"

Data from the "Spring Response" and "Fall Response" tabs are incorporated in this tab to aggregate annual accretions by NRD. Data from the "Spring Response" and "Fall Response" tabs, as well the "Div + Recharge by NRD Spring," "Div + Recharge by NRD Fall," and the "Total Recharge by NRD 2011" tabs were used to create a diversions and benefits summary by canal.

Appendix B – Response Function Zone Maps by NRD

The following maps were drafted by the PBHEP administrators for the purpose of evaluating the expected relative effects of proposed projects. The maps were developed using simple distance calculations as well as location-specific information believed to influence the relative similarity or difference among projects geographically. The maps are considered draft and while informative are not intended to represent a definitive quantitative assessment of relative response. Modeling tools currently in development are anticipated to provide a more robust measure of the spatial distribution of meaningful response function zones that are expected to supersede these maps upon their completion. The attached maps illustrate the response function zones one (1) through five (5). Response zone 6 is assumed to be any remaining area within the respective natural resources districts.

Appendix B – Response Function Zone Maps by NRD

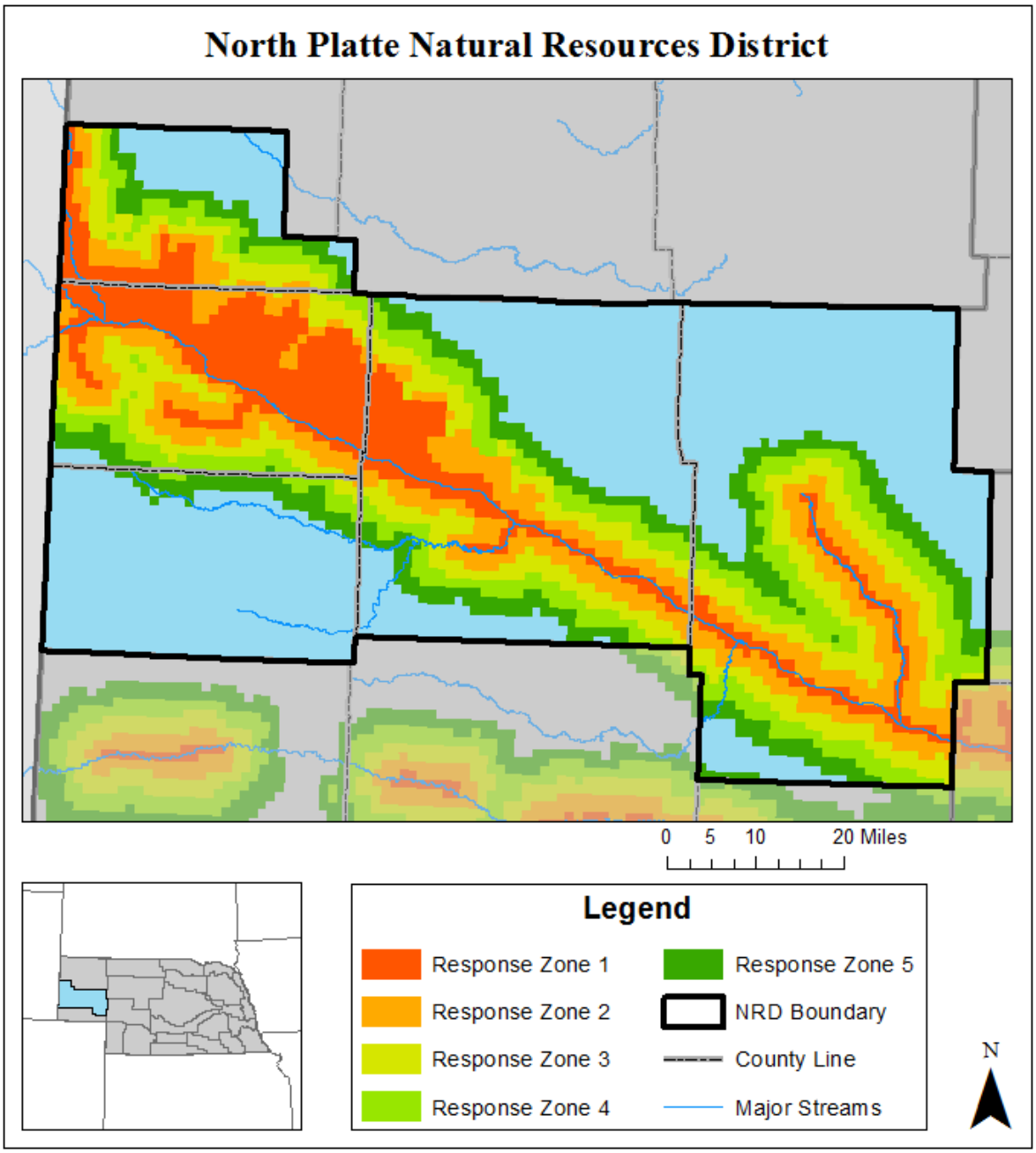

Figure 1: North Platte Natural Resources District response function zones.

Appendix B – Response Function Zone Maps by NRD

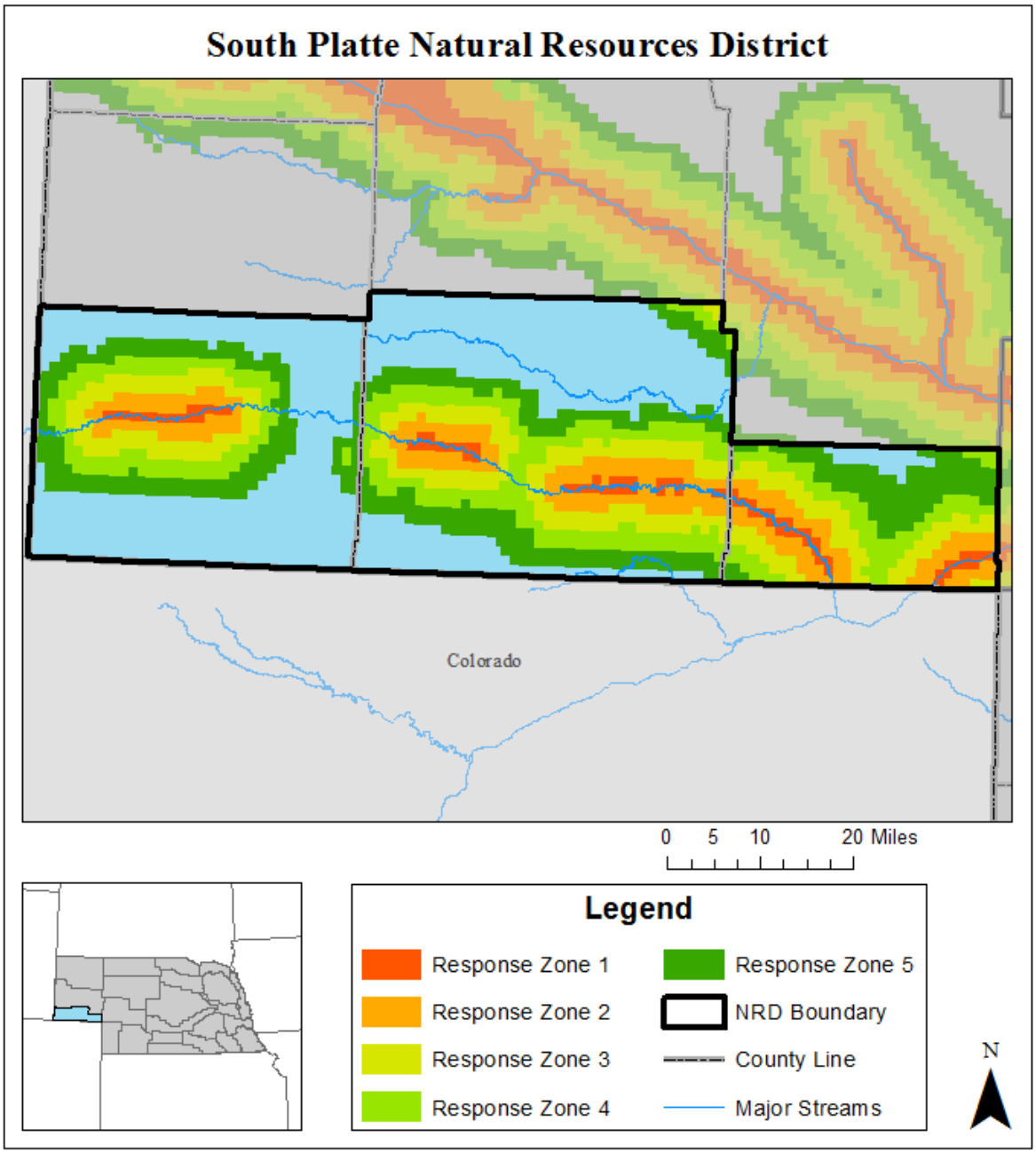

Figure 2: South Platte Natural Resources District response function zones.

Appendix B – Response Function Zone Maps by NRD

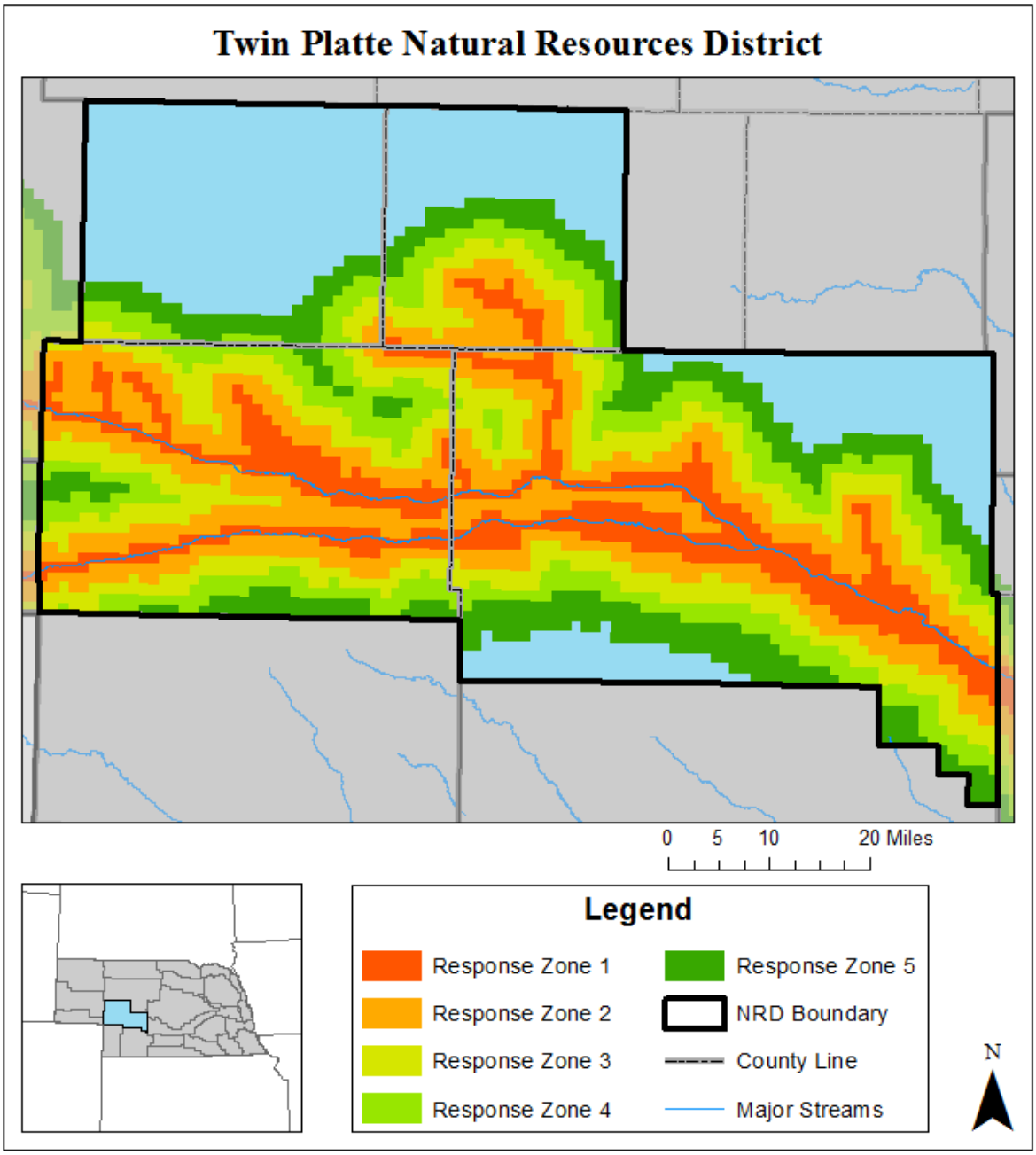

Figure 3: Twin Platte Natural Resources District response function zones.

Appendix B – Response Function Zone Maps by NRD

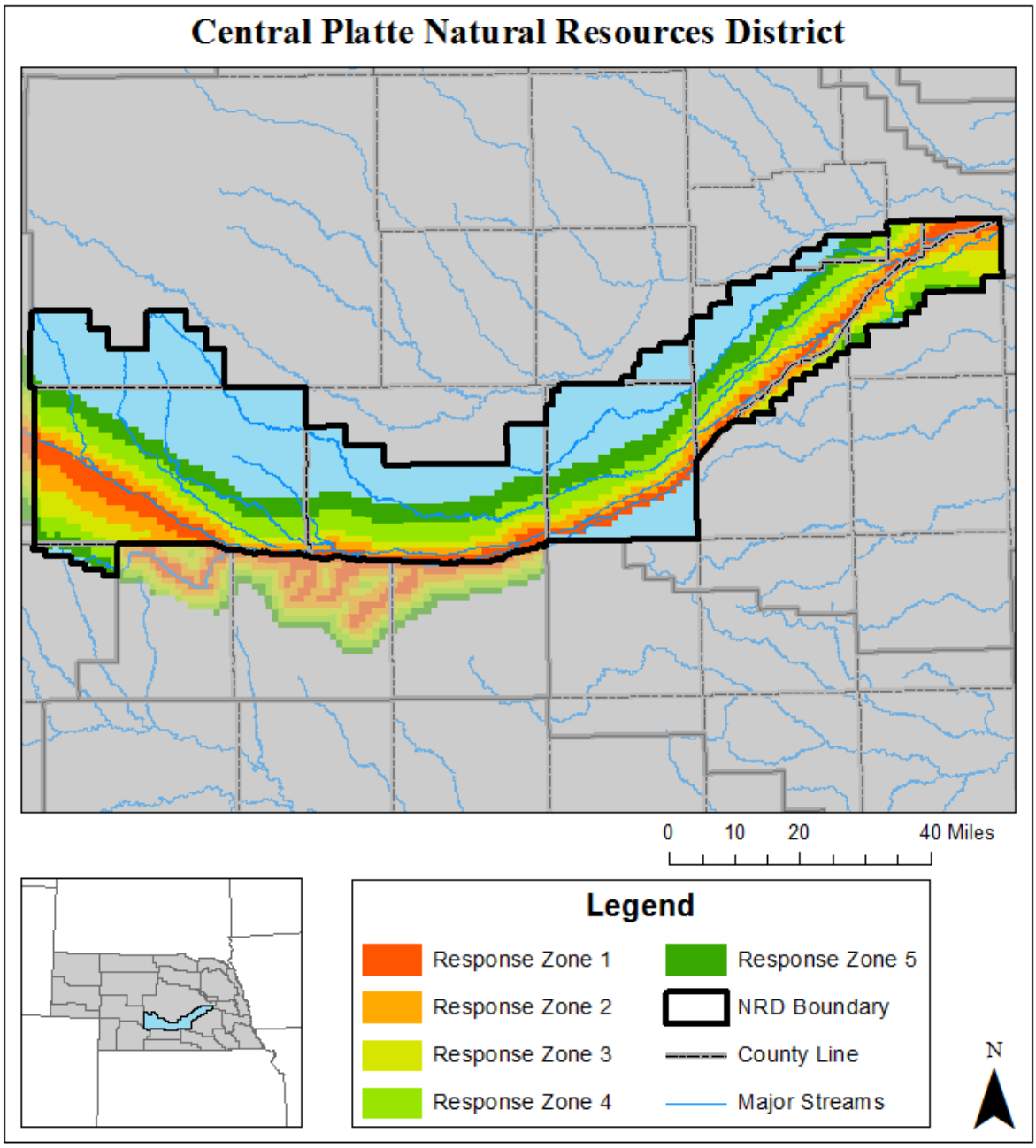

Figure 4: Central Platte Natural Resources District response function zones.

Appendix B – Response Function Zone Maps by NRD

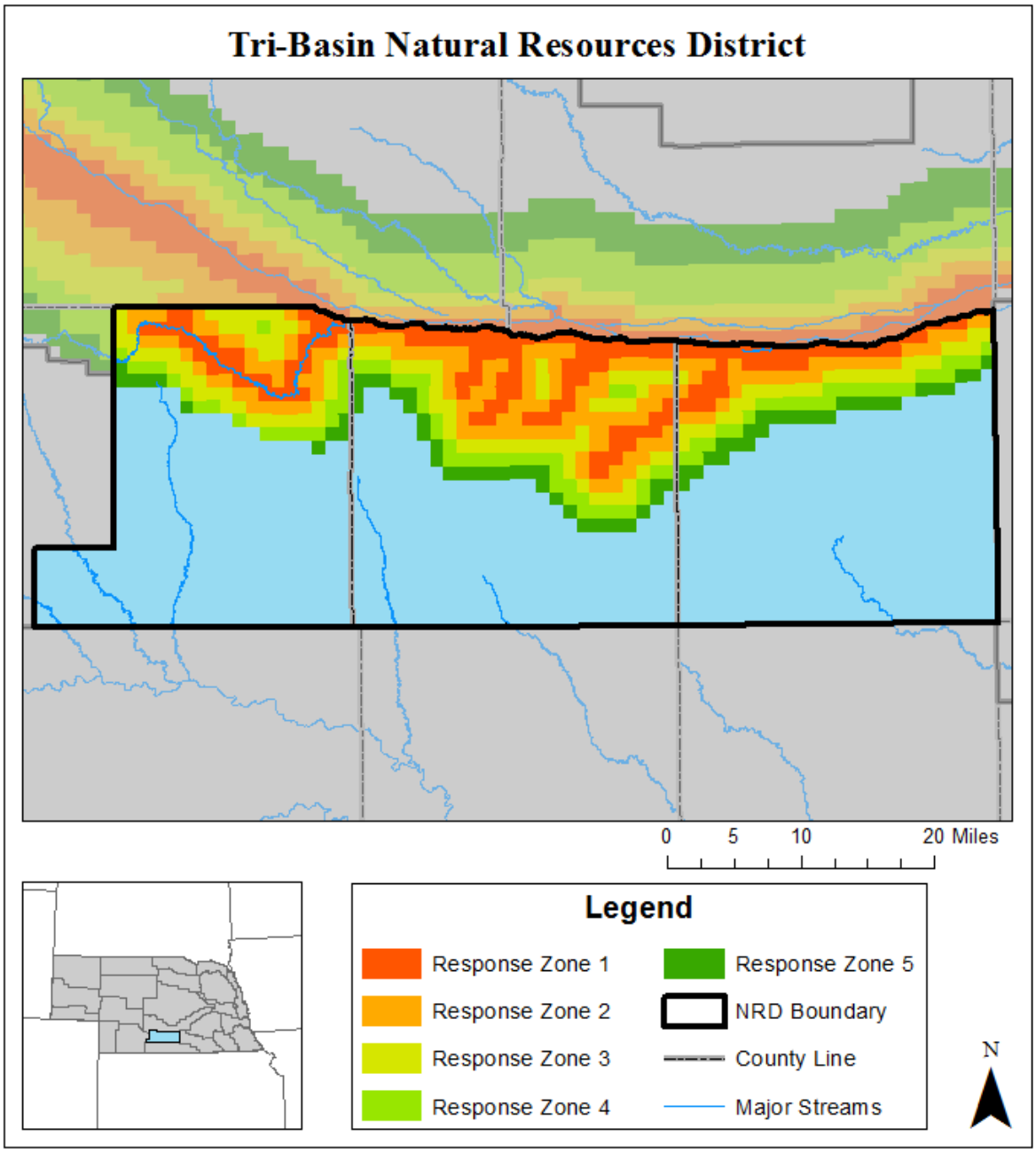

Figure 5: Tri-Basin Natural Resources District response function zones.