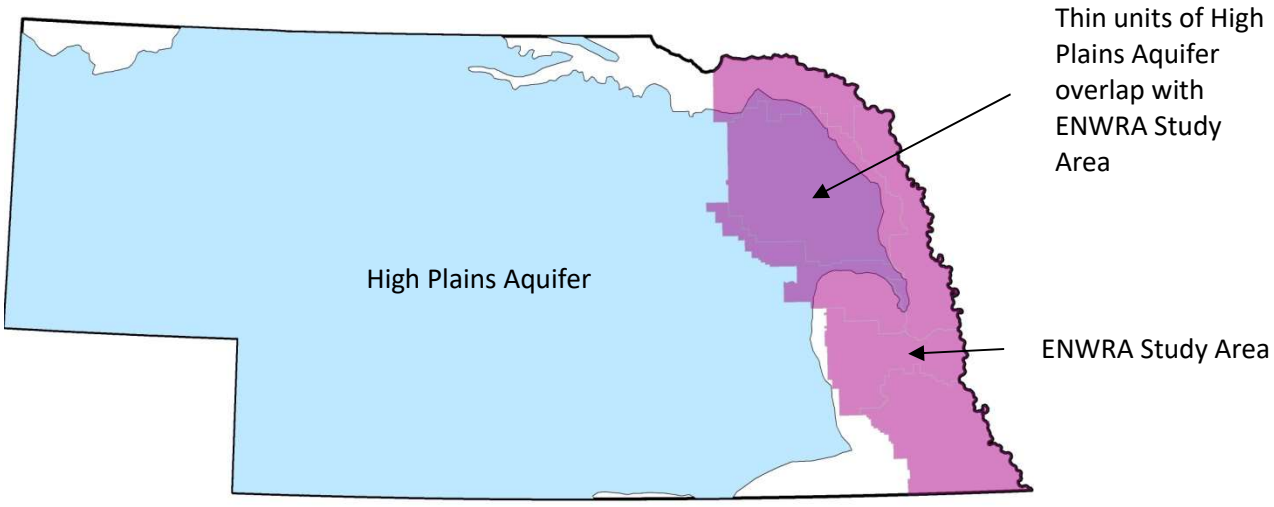
EASTERN NEBRASKA WATER RESOURCES ASSESSMENT (ENWRA) LONG-RANGE PLAN
March 31, 2020

INTRODUCTION

The Eastern Nebraska Water Resources Assessment (ENWRA) Project was initiated in 2006 for the purpose of cooperatively characterizing the geology and hydrogeology of the glaciated portion of eastern Nebraska. This portion of Nebraska is hydrogeologically distinct from central and western Nebraska because the water-rich deposits that constitute the High Plains Aquifer are thin or absent in eastern Nebraska (illustration below and included as Figure 1 within the Figures attachment). As a result, significant water supply demands are made on alluvial valleys. Outside of alluvial valleys, subglacial and interglacial water-bearing units are limited in extent and are very heterogeneous, making them vulnerable to overuse and depletion. ENWRA project sponsors believe that increased study and understanding of the hydrogeologic complexity of eastern Nebraska will advance fair and sustainable management of its water resources.



Map of ENWRA study area in relation to High Plains Aquifer
Source: Conservation and Survey Division, University of Nebraska-Lincoln

DESCRIPTION OF THE ENWRA PROJECT

The ENWRA sponsors consist of six Natural Resources Districts (NRDs): Lewis & Clark, Lower Elkhorn, Papio-Missouri River, Lower Platte North, Lower Platte South, and Nemaha. Technical advisors for the project include the U.S. Geological Survey (USGS), the Conservation and Survey Division of the Institute of Agricultural and Natural Resources at the University of Nebraska—Lincoln (CSD), Nebraska Department of Natural Resources (NeDNR), and the Nebraska

Department of Environment and Energy (DEE). A full-time Project Coordinator manages day-to-day project activities.

The ultimate goal of ENWRA is to develop a three-dimensional geologic framework and water budget for eastern Nebraska. This framework and water budget will include the glacial till uplands, alluvial valleys, and their intersections. At the start of the project, the ENWRA partners decided that the complexities of local hydrogeology made characterizing the entire study area at once practically impossible. Even the technology needed to map buried aquifers remained unproven in eastern Nebraska. Therefore, pilot studies, designed to investigate these complex systems on a limited scale, were deemed necessary in order to both predict the level of success achieved by methods employed and to identify any potential procedural and interpretational challenges at an early stage. It was decided the initial efforts of ENWRA would be spent characterizing three pilot study sites. In the process of those studies, a "toolbox" of investigative methods and procedures was identified, developed, and tested. Figure 2 of the Figures attachment depicts the ENWRA pilot and partner study sites conducted to date. Summaries of the pilot study results are included in Appendix A.

ENWRA has transitioned from the pilot study phase and accomplished large strides toward it ongoing goals and objectives with test hole and monitoring well advancements, water level and groundwater sampling data collection, creation of the ENWRA archive database, over $15,000,000 in projects funded by grant awards, and various hydrogeologic assessment results reporting (available on enwra.org website) in the last 13 years. The sponsors recognize this benchmark as an opportunity to structure long-term cooperation and coordination between their individual Districts, and between the NRDs and other entities taking our current status into consideration.

ENWRA ORGANIZATION

Six NRDs sponsor the ENWRA project. NRDs are governed by Boards of Directors. These Boards are advised by the District General Manager, who is advised by technical staff. The six NRDs that sponsor the ENWRA project are formally partnered via an Interlocal Agreement, which each Board of Directors approves and each General Manager signs (Appendix C). Continued involvement with the ENWRA project must be reapproved by each Board of Directors when the term of the Interlocal Agreement expires. The current term for the Interlocal Agreement is five years (June 30, 2017- June 30, 2022). One NRD, the Lower Platte South, is the primary sponsor of the project. All agreements and contracts with non-NRD entities must be approved by the Lower Platte South Board of Directors and be signed by the Lower Platte South General Manager.

As stipulated in the ENWRA Interlocal Agreement, the General Managers from each of the participating NRDs will meet at least annually to review the status of ENWRA. In this annual meeting, the General Managers will also review and approve updates to the long range plan.

The annual monetary contribution expected from each NRD is specified in the Interlocal Agreement. These contributions are pooled and used to fund a mutually agreed upon scope of work called the primary project. This scope of work may or may not be equally divided between the sponsoring NRD areas.

Each NRD that sponsors the ENWRA project has at least one technical staff member that sits on the ENWRA Technical Committee. This Technical Committee meets approximately four times per year, or as necessary, to discuss ongoing project activities and make decisions regarding potential future activities. Decisions made by the Technical Committee that involve the pooled source of money need to be approved only by the Lower Platte South Board of Directors.

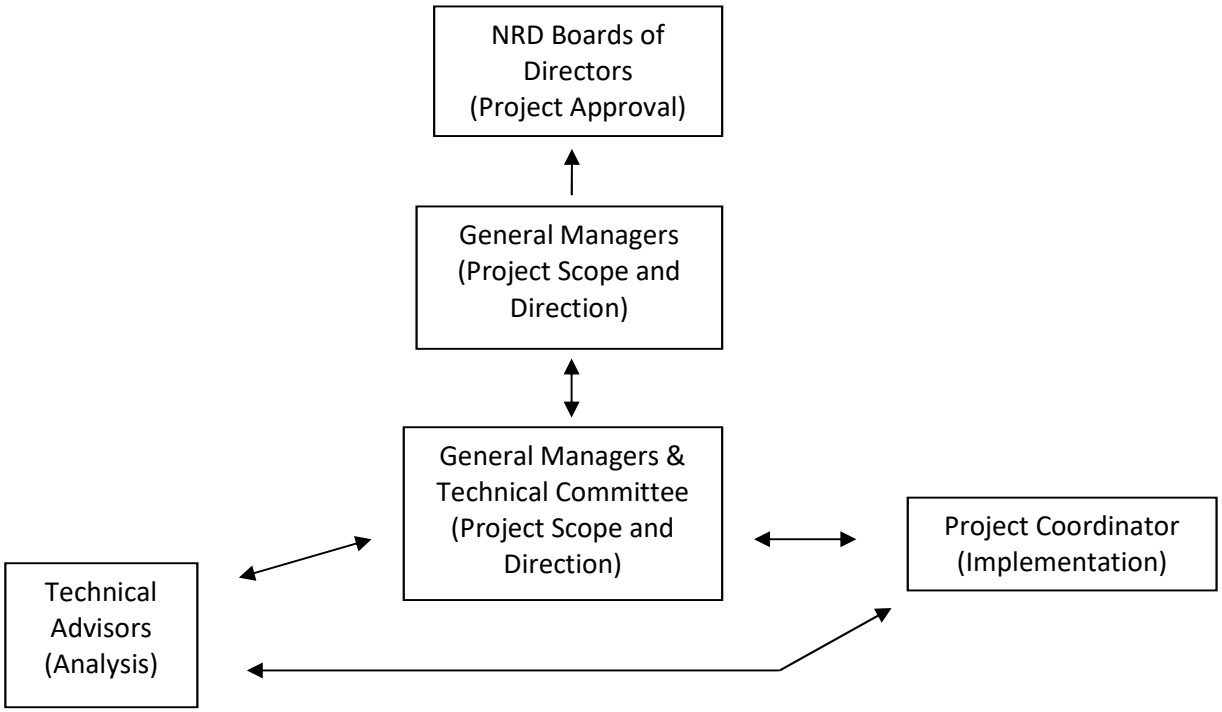
A Project Coordinator, currently housed at the Lower Platte South NRD, implements the decisions made by the Technical Committee. The Project Coordinator is currently a full-time staff Hydrogeologist position with the Conservation and Survey Division (CSD) of the University of Nebraska Lincoln, School of Natural Resources, where the coordinator's duties are shared between both ENWRA and CSD. ENWRA dues pay CSD for 60% of the coordinator's salary semi-annually. Duties of the Project Coordinator for ENWRA include: writing grant applications and reports; scheduling meetings and developing agendas; negotiating contracts and agreements; organizing work performed by Technical Advisors and contractors; presenting results; assisting with field work, data analysis, and publications; and providing technical assistance to the ENWRA partners on non-ENWRA projects, as desired. Duties of the Coordinator for CSD include: assisting with the eastern Nebraska geological survey service areas in test hole drilling and geologic interpretation, and reporting.

The ENWRA Technical Advisors currently consist of representatives from four entities: CSD, the Nebraska Department of Natural Resources (NeDNR), the U.S. Geological Survey (USGS), and the Nebraska Department of Environmental Quality (representation is through the Nebraska Association of Resources Districts [NARD] liaison). More than one person from each entity can serve as a Technical Advisor. Service as a Technical Advisor is voluntary and attendance at ENWRA meetings is not compensated. Advisors from additional entities, including private consultants, may be added.

If one or more of the ENWRA NRDs wish to fund a secondary project with money additional to their annual contribution stipulated by the Interlocal Agreement, they can do so provided the goals of the project are consistent with the ENWRA objectives. The NRD(s) funding the secondary project will have the ultimate responsibility for all decision making, resource allocations, and prioritizing study objectives. One of the NRDs funding the project will also have signatory authority (instead of Lower Platte South, unless Lower Platte South is funding the secondary project). The ENWRA Project Coordinator will coordinate secondary projects and the ENWRA Technical Committee will provide input, as desired.

Some Technical Advisors may fulfill specific technical tasks for one or many ENWRA projects. The scope of work, budget, and schedule for these tasks will be established in an Interlocal Agreement, Joint Funding Agreement, or contract specific to each project.

A schematic of the ENWRA organizational structure is illustrated below. For the primary project, the Sponsoring NRD Boards of Directors and Sponsoring General Managers will include all six of the NRDs. For secondary projects, the Sponsoring NRD Board(s) of Directors and Sponsoring General Manager(s) will consist of a subset of the six. The Technical Committee, Project Coordinator, and Technical Advisors will be the same, regardless of the project.



ENWRA Organization Structure

PURPOSE OF THE LONG RANGE PLAN

In the state of Nebraska, the quality and quantity of groundwater resources are managed at the local level by NRDs and at the state level by NeDNR and NeDEE. NeDEE regulates water quality. NeDNR conducts statewide oversight of groundwater quantity through approval of Groundwater Management Plans (written by NRDs), and implementation of legislative mandates. NeDNR also has primary responsibility for managing the quantity of surface water, though the NRDs have some responsibility for surface water due to the fact that groundwater and surface water are hydrologically connected in places and because that connection is recognized in state law. Water resources in hydrologically connected areas can be (and in some cases must be) managed using Integrated Management Plans adopted by the affected NRDs and NeDNR. The ENWRA sponsors

plan to use ENWRA as a vehicle to study and manage both groundwater and hydrologically connected water. The data gathered will be used to enhance the effectiveness of Groundwater Management Plans and inform Integrated Management Plans, where applicable.

The decision to use ENWRA to study groundwater and hydrologically connected water, coupled with the complex glacial geology of eastern Nebraska creates the likelihood that ENWRA will be working on multiple small- to mid-sized projects at any given time. These projects will likely have variable scales of resolution, use a variety of geologic and geophysical techniques, and have multiple funding sources. The purpose of this Long Range Plan is to enhance the cost-effectiveness and timeliness of these potential projects through coordination. The sponsors recognize that the execution of this plan depends on some factors outside of their control, the most notable of which is funding. Additionally, the changing membership of the elected NRD Boards of Directors, as yet unknown water resources conditions, future regulations, and emerging technology may result in the addition or removal of some projects from this long range plan. The sponsors therefore view this plan as a living document, subject to periodic revision.

ENWRA OBJECTIVES AND POTENTIAL PROJECTS

The ENWRA sponsors have collaboratively identified long-term objectives. Projects that further each objective are listed below and within a Project and Objectives Matrix Table available in Appendix B. Future projects across NRD boundaries will be added and prioritized in the Table.

Identifying the location and volume of aquifers (Objective 2) focuses the refinement of the geologic framework to areas in which there is economic and ecologic returns on the investment in the study. The specific locations listed represent areas in which competition for groundwater is occurring and scientific data to support management decisions is still lacking.

Estimating recharge rates (Objective 3) is necessary to manage pollutant sources (such as feedlots) and provide accurate input to numerical models, the results of which can be sensitive to the recharge parameter.

Assessing the connection between groundwater and surface water (Objective 4) is necessary to understand how pumping groundwater will affect surface water flows and how increased surface flows may recharge groundwater. Knowing the extent of hydrologic connection can optimize both groundwater pumping and in-stream flows.

Estimating water budgets (Objective 5) requires assimilation of all the data regarding the geologic framework, inputs and outputs to a hydrologic system. Water budgets are necessary to assess if water resources are being sustainably managed, and if not, approximate how long the resource will remain viable.

Characterizing natural and anthropogenic groundwater concerns (Objective 6) is necessary to identify potential pollution prior to contamination of an entire drinking water source. Preventing contamination is much cheaper than treating it.

Distributing data, developing new partners and funding sources, assessing applicability of new technology/parallel project/entity developments, and retaining a project coordinator (Objectives 7, 8, 9, and 1) are all activities that are necessary to keep the ENWRA project moving forward and maintain its value to the sponsors.

1) Retain a Project Coordinator to oversee projects, implementation of the Long Range Plan and provide technical assistance. The Coordinator position and salary is shared with CSD as reflected in Amendment 6 of the ENWRA Interlocal Agreement (Appendix C). The coordinator salary will also be included as a line item in primary grant applications as appropriate. If the primary grant is not funded, the ENWRA portion of the Project Coordinator salary will be paid from ENWRA dues.
2) Identify the location and volume of aquifers
    a. Map priority areas that represent data gaps in the existing hydrogeologic framework using airborne geophysical surveys (Figure 3)
        i. Isolated/limited quantity aquifers (block flights, aquifer boundaries, target depths vary)
        ii. Area north of Adams, Nebraska and other limited areas in the Nemaha NRD (localized aquifers, hydrogeologic connections, top 300 feet [ft])
        iii. Missouri River Upland tributaries (local aquifers, top 800 ft)
    b. Map Secondary Bedrock Aquifers - Map in priority areas/blocks over time, evaluate and assess through combination of evaluation methods (geophysical surveys, select deep test holes, sampling and age dating, incorporate parallel project data [evaluation of registered well logs/other consultant and/or partner entity work]). Should be considered a Nebraska GeoCloud (NGC) project as part of work toward the Eastern Nebraska geological model using Denmark as an example. Possibly break up into smaller geography driven evaluation areas where pertinent/discernible/relevant or break up into areas based on use in each district (example: irrigation, domestic, municipal etc.). Initial reconnaissance of quality/sustainability of secondary bedrock aquifers presented in 2015 WSF Application with USGS.
    c. Advance geologic test holes (Approximately one to four NRDs at $9,150 per NRD per year budgeted with ENWRA funds) – Figure 4 depicts existing test hole locations.
    d. Maintain and add monitoring wells (NRD efforts for this count toward the $9,150 in ENWRA reimbursable ENWRA related assessment work)
    e. Continued sponsorship and participation in Nebraska GeoCloud (NGC) to house and access AEM data and produce accessible geo products online. Will need to support the Interlocal agreement and a coordinator /specialist

position representative of eastern Nebraska's portion of NGC. ENWRA will need to continue to evaluate CSD staffing needs/availability/workload (est. costs parallel objective 1) and NGC related positions and/or consultant contracts.

3) Estimate recharge areas and rates
    a. Map recharge areas (Figure 5). Evaluate ENWRA AEM and existing datasets and collaborate with partner entities (example UNL vadose efforts) to identify recharge areas and target specific study areas in a variety of settings for big picture of vadose framework
    b. Maintain/add/reevaluate recharge stations and projects.
4) Assess potential connections between groundwater and surface water
    a. Continue to evaluate Hydrologically Connected Areas (HCAs) - update CSD datasets (water table, transmissivity, etc.); incorporate CSD & NeDNR & ENWRA & NGC frameworks (will need to work with NeDNR on Lower Platte Missouri River Tributaries (LPMT) numerical model needs).
    b. Map saline groundwater, map salt spring & stream reaches, and map salt/fresh boundary in secondary bedrock formations using variety of methods
    c. Review/incorporate ongoing alluvial valley assessment work - identify gaining/losing reaches, streambed characteristics, and potential cross-aquifer connections.
5) Estimate water budgets for management decisions. Calculate groundwater in storage, estimate/calculate sustainability – ongoing activity. Includes ENWRA participation in NGC, working with NeDNR and keeping up to date with partners' water budget work and planning. Prioritize target areas (maybe NGC related projects) for marginal or drought sensitive areas and areas with pressing management concerns
6) Characterize natural and anthropogenic water quality concerns - analyzed constituents vary according to concern in primary or secondary aquifers. Continue pilot sites and consider collaborative vadose and groundwater quality projects
7) Assemble, analyze and distribute data
    a. Continue support and participation in the NGC for airborne electromagnetic (AEM) geophysical survey and other 3-D hydrogeologic assessment related projects. Provide continued evaluation and support on eastern Nebraska's behalf for potential buildouts, interfaces, and routine update and sustaining activities associated with the NGC. ENWRA has previously committed about $25,000 per year for the past four fiscal years toward the NGC development project through a state water sustainability fund (WSF) grant with other sponsoring NRDs across the state who have collected AEM data. ENWRA will evaluate an annual budget item with other NRDs supporting the NGC to best provide for the continued success of the NGC.
    b. Continue ENWRA data input and upload, distribution and notification of results to partners, website updates (includes maintaining ENWRA Dropbox linked to downloadable content on ENWRA's website), and presentations on

data to promote further scientific uses of the data and benefits to water managers

8) Develop a variety of partners and funding sources - on-going effort as opportunities arise, funding opportunities will drive the priorities.
9) Continue to assess the applicability of new technology, similar assessment type projects, legislature driven developments, and water policy precedents with the potential of benefiting ENWRA objectives. Example entity and relevant activities to continue to monitor: NeDNR, CSD, USGS, NeDEE, RWDs, USACE [Mead], Municipalities [well field evaluations], MUD, NPPD, OPPD, NRCS, NRD/Basin Coalitions and other assessment and modeling efforts statewide.

Figures

Figure 1

Map of ENWRA study area in relation to High Plains Aquifer

Source: Conservation and Survey Division, University of Nebraska-Lincoln

Figure 2

This map depicts existing airborne geophysical survey flights conducted in the ENWRA area as of the finalization of this 2019 Long Range Plan (dated March 2020):

- ENWRA pilot study site locations (Ashland, Firth and Oakland in red)
- Sprague and Swedeburg HEM study site blocks (red)
- USACE Mead HEM study block (orange)
- Clarkson-Howells and Dwight-Valparasio-Brainard Time Domain Electromagnetic (TDEM) survey blocks (purple)
- 2014/2015 ENWRA and 2014 LENRD TDEM reconnaissance survey transects (green)
- 2016 ENWRA TDEM flight lines and blocks (black)
- 2018 ENWRA TDEM flight lines and blocks (blue)

Figure 3

This map represents the priority mapping areas listed under item 2A in the OBJECTIVES AND POTENTIAL PROJECTS Section of the Long Range Plan text and described in the Projects and Objectives Matrix Table in Appendix B. Isolated/limited quantity aquifers (block flights, target depths vary) are not individually depicted. Additionally, specific pilot areas (Lower Elkhorn Wayne Co., Lower Platte North SQS2 etc.) planned for AEM incorporation with NeDNR's numerical model work are not depicted.

Figure 4

This map represents the primary existing readily available geological datasets across eastern Nebraska used for the airborne geophysical survey reports and current/planned EWNRA work:

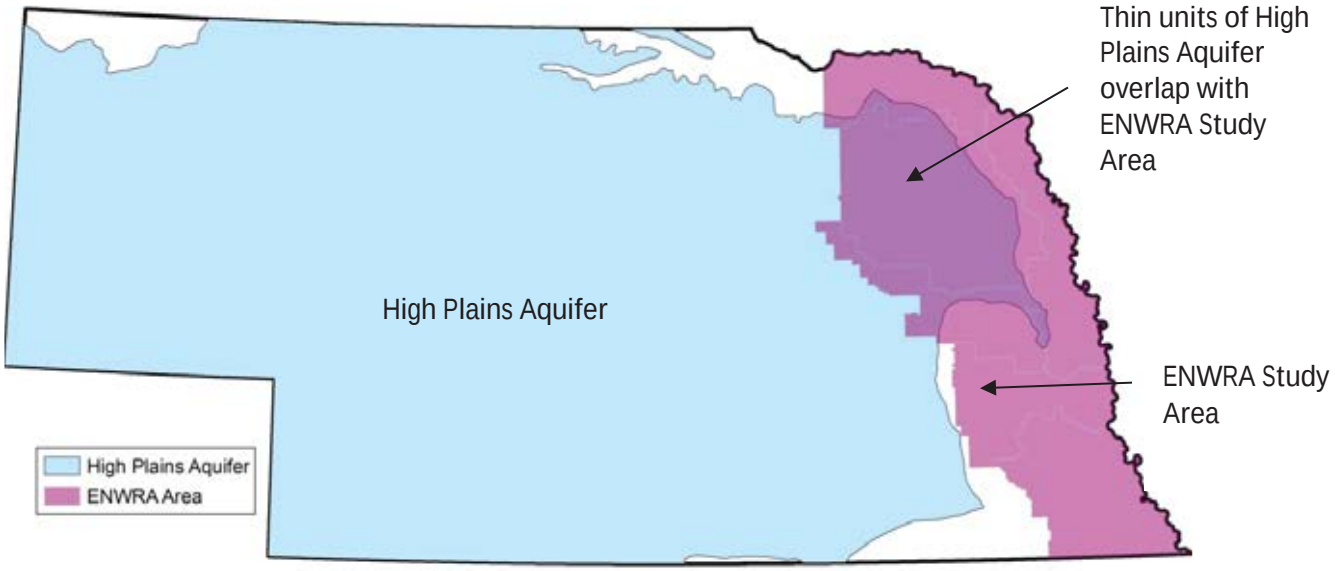
- CSD statewide test hole database (black dots - includes unfinalized 2007-2019 installed test hole locations)
- CSD cross-sections (published [red lines] and unpublished [black lines])
- Nebraska Oil and Gas Conservation Commission Database (NOGCC) borehole locations (blue triangles)
- CSD Geologic Bedrock Map (basemap colors by formation)
- StateMap Program 7.5 Minute Geologic Quadrangle maps (surface geology) - availability is depicted for quad boundaries (red hatching)
- ENWRA archive scan files and ENWRA access database (not depicted on map)
- NeDNR registered well database (not depicted - greater than 250,000 records exist for ENWRA, select registration logs used to supplement where test hole data is lacking)

Figure 5

This map compiles SSURGO soil data as collected by the Natural Resources Conservation Service (NRCS). When the NRCS categorizes soil type, they also assign a hydrologic group. These groups represent soils having the same runoff potential under similar storm and cover conditions. Hydrologic groups are used to estimate runoff from rainfall. There are seven primary groups ranging from high infiltration rates to very slow infiltration rates. The map is intended to be used as a screening tool to inform the location of new recharge stations (four stations exist) and planning further recharge assessment work. Recharge datasets for a variety of soil groups and geographic settings are desired.

APPENDICES

Map of ENWRA Study Area in Relation to High Plains Aquifer



Source: Conservation and Survey Division, University of Nebraska-Lincoln

Figure 1

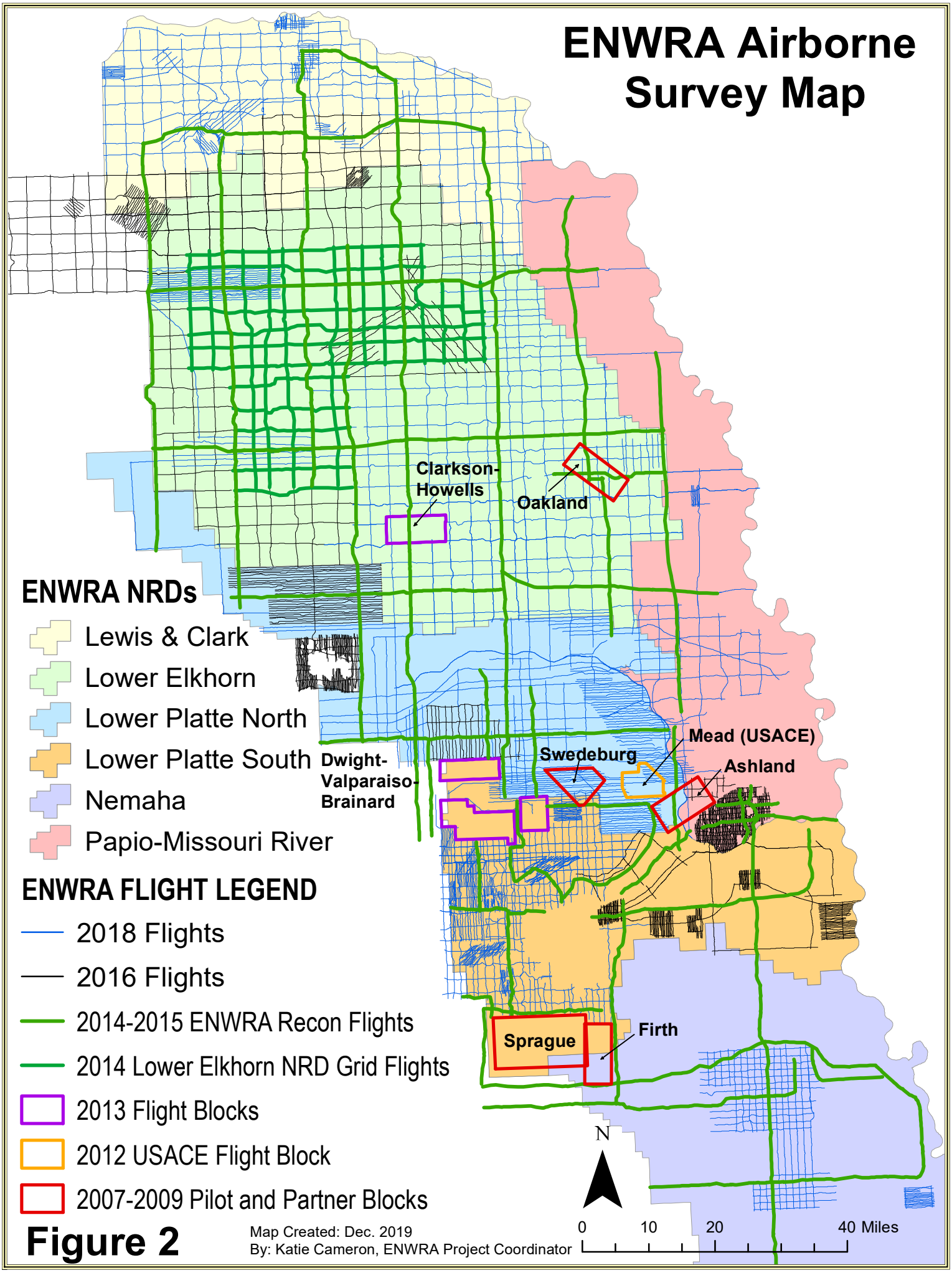
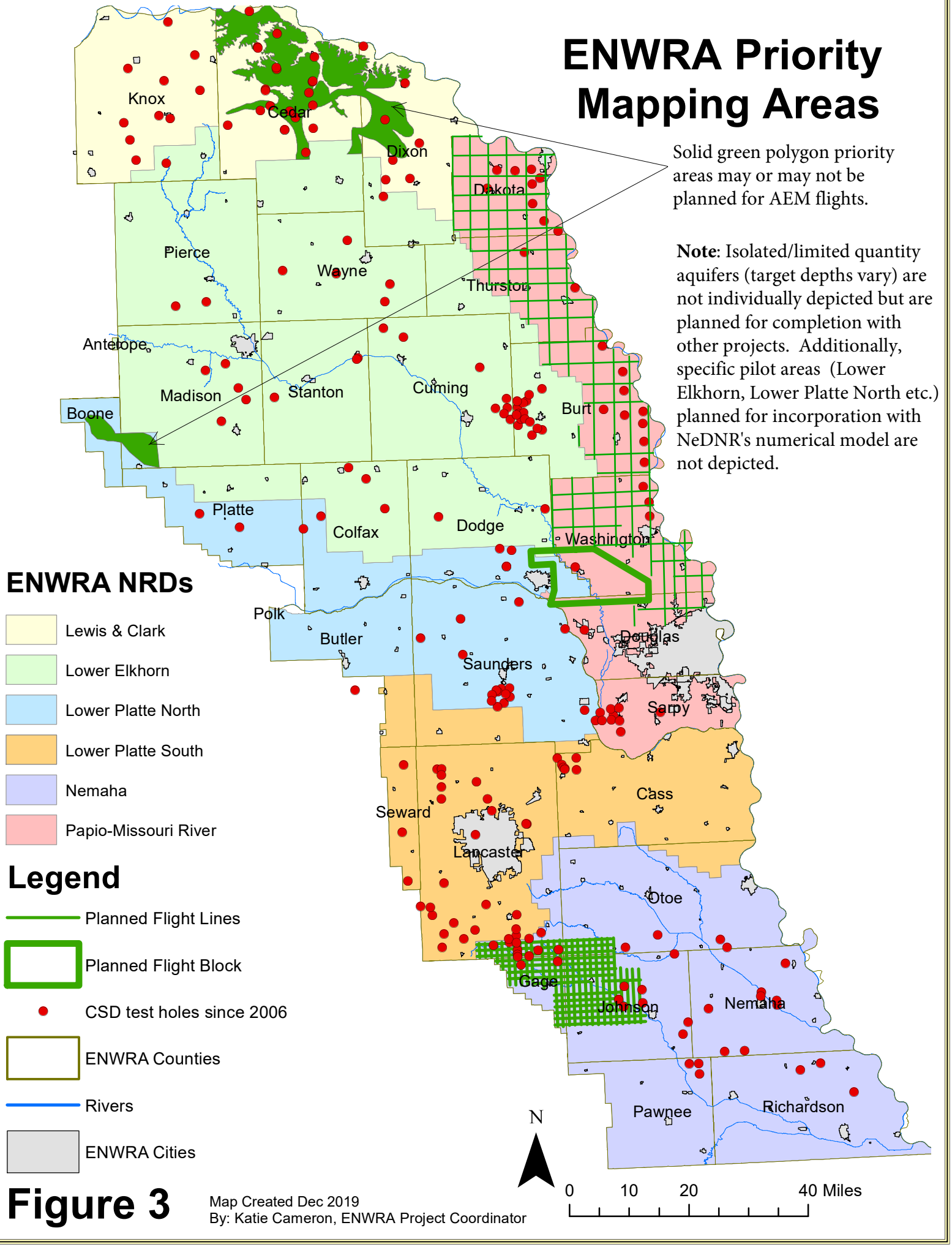
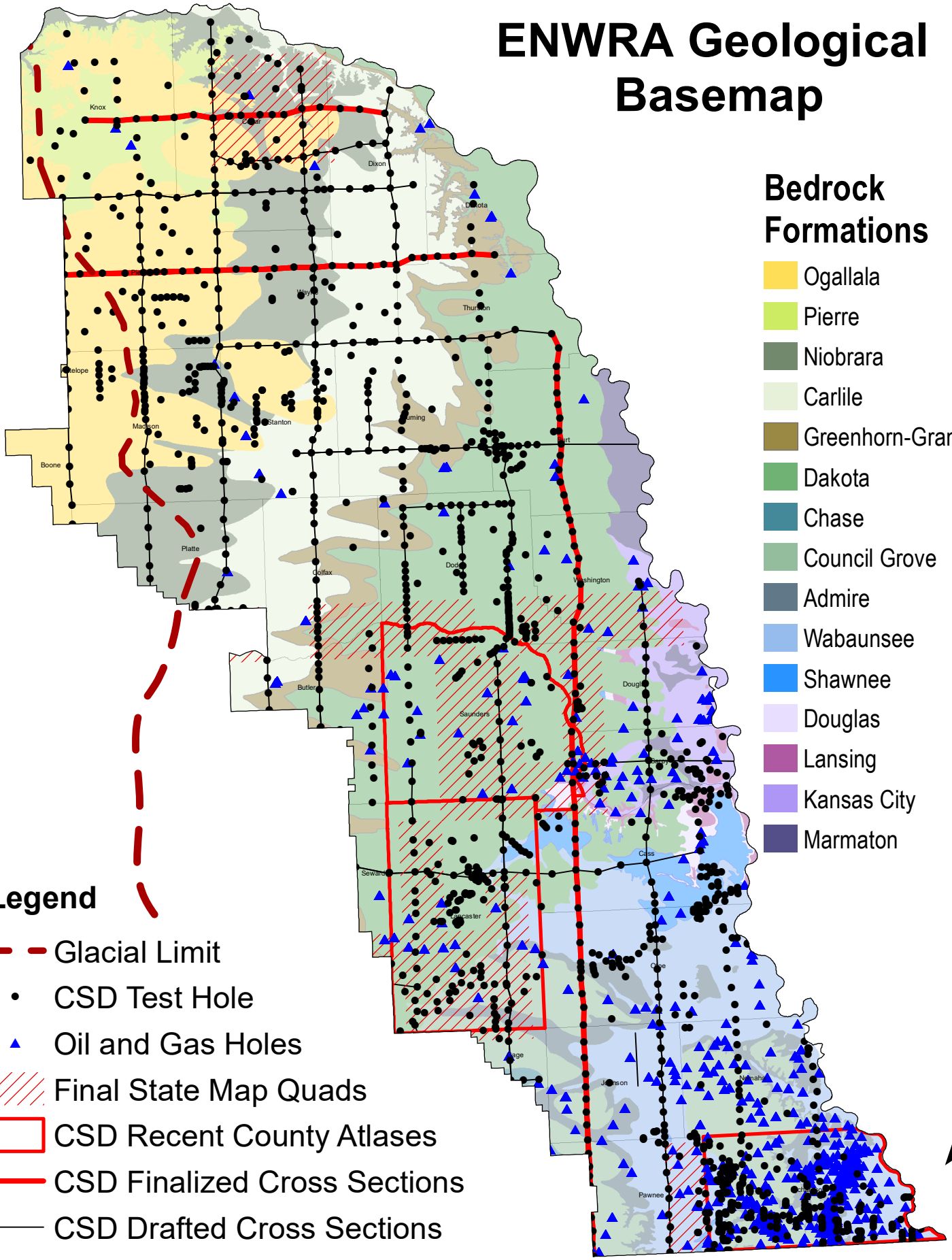

ENWRA Airborne Survey Map
Clarkson-Howells
Oakland
Dwight-Valparaiso-Brainard
Swedeburg
Mead (USACE)
Ashland
Sprague
Firth
ENWRA NRDs
Lewis & Clark
Lower Elkhorn
Lower Platte North
Lower Platte South
Nemaha
Papio-Missouri River
ENWRA FLIGHT LEGEND
2018 Flights
2016 Flights
2014-2015 ENWRA Recon Flights
2014 Lower Elkhorn NRD Grid Flights
2013 Flight Blocks
2012 USACE Flight Block
2007-2009 Pilot and Partner Blocks
N
0
10
20
40 Miles
Map Created: Dec. 2019
By: Katie Cameron, ENWRA Project Coordinator

Figure 2


ENWRA Priority Mapping Areas
Solid green polygon priority areas may or may not be planned for AEM flights.
Note: Isolated/limited quantity aquifers (target depths vary) are not individually depicted but are planned for completion with other projects. Additionally, specific pilot areas (Lower Elkhorn, Lower Platte North etc.) planned for incorporation with NeDNR's numerical model are not depicted.
Knox
Cedar
Dixon
Dakota
Pierce
Wayne
Thurston
Antelope
Madison
Stanton
Cuming
Burt
Boone
Platte
Colfax
Dodge
Washington
Polk
Butler
Saunders
Douglas
Sarpy
Cass
Seward
Lancaster
Otoe
Gage
Johnson
Nemaha
Pawnee
Richardson
ENWRA NRDs
Lewis & Clark
Lower Elkhorn
Lower Platte North
Lower Platte South
Nemaha
Papio-Missouri River
Legend
Planned Flight Lines
Planned Flight Block
CSD test holes since 2006
ENWRA Counties
Rivers
ENWRA Cities
N
0 10 20 40 Miles
Figure 3
Map Created Dec 2019
By: Katie Cameron, ENWRA Project Coordinator

ENWRA Geological Basemap



Bedrock Formations

- Ogallala
- Pierre
- Niobrara
- Carlile
- Greenhorn-Graneros
- Dakota
- Chase
- Council Grove
- Admire
- Wabaunsee
- Shawnee
- Douglas
- Lansing
- Kansas City
- Marmaton

Legend

- Glacial Limit
- CSD Test Hole
- Oil and Gas Holes
- Final State Map Quads
- CSD Recent County Atlases
- CSD Finalized Cross Sections
- CSD Drafted Cross Sections

N

0 12.5 25 50 Miles

Figure 4

Created: November 16, 2017
By: Katie Cameron, ENWRA Project Coordinator
Basemap Source: http://snr.unl.edu/data/geographygis/geology.aspx - digitized version 1970s -1986

ENWRA Soils Data Hydrologic Group Map

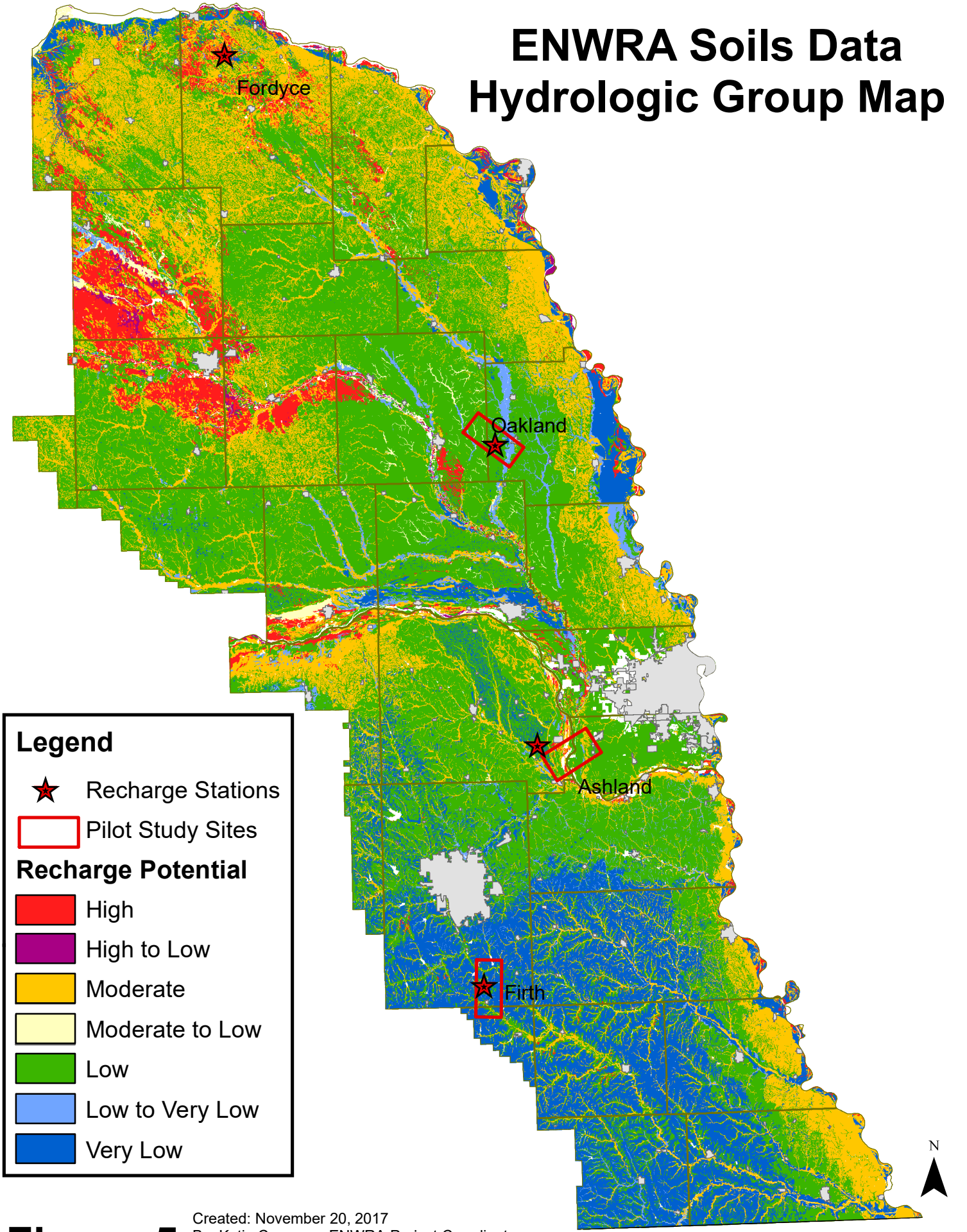


Figure 5

Created: November 20, 2017
By: Katie Cameron, ENWRA Project Coordinator
Basemap Source: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627

APPENDIX A
PILOT STUDY SUMMARIES

The uppermost bedrock unit in eastern Nebraska is generally either Cretaceous-age shale and sandstone or Pennsylvanian-age limestone. Rivers and streams traversing these bedrock units sometimes incised channels which became filled with sand and gravel. Later, during the Quaternary period, the bedrock surface and channels were covered with glaciers and subsequently buried by glacial till and outwash sand and gravel. These buried channels and outwash deposits can serve as aquifer units, but their location, geometry, and areal extent are variable, making them difficult to find and manage. If the Cretaceous Dakota formation is present at a location as sandstone it can also serve as an aquifer, though the quality and quantity of water sourced from the Dakota is widely variable.

This understanding of the geologic framework is based almost exclusively on drilled test holes and outcrops. Test holes and outcrops are reliable sources of data, but in complex areas the geologic units are not consistent between adjacent test holes, resulting in data gaps in the hydrologic framework. From a management perspective, data gaps are of most concern where there is a localized source of water for which multiple users compete.

Management concerns led to the development of the ENWRA project. At the inception of the project, the sponsors decided a pilot study approach to the first three years of the study, in which various technologies were applied to three geologically distinct study sites, would be the most efficient way to characterize eastern Nebraska's varied geology (Korus and Divine, 2007; Divine et al., 2009a).

Several tools and techniques were applied, including non-invasive geophysical techniques such as Helicopter Electromagnetic (HEM), Time Domain Electromagnetic (TDEM), and passive seismic surveys. Additionally, subsurface investigations including heat dissipation probes, soil moisture probes, test holes, monitoring wells, and pressure transducers were conducted. HEM was found to provide useful information in two of the three pilot study sites where there was little to moderate thicknesses of glacial till (Smith et al., 2007). The TDEM results were consistent with the test hole drilling, but did not provide the resolution of the HEM data sets. Passive seismic surveys did not provide a confident pick of the bedrock surface due to the low velocity contrast and the gradational change in the velocity structure. Heat dissipation probes, soil moisture probes, test holes, monitoring wells, and pressure transducers, although not useful for large-scale characterizations, were deemed critical for better understanding local aquifers. As a result of the early pilot study work, Lower Platte South and Lower Platte North sponsored additional HEM surveys in their districts in 2009, funded in part by the Nebraska Environmental Trust (Divine et al, 2009b).

While HEM was being applied as a powerful tool, the sponsors continued to seek a non-invasive tool for large-scale characterization in areas where glacial till is thick and the aquifers are deeply buried. As part of its Year 3 budget, ENWRA provided funds for the U.S. Geological Survey (USGS) to further study three geophysical tools that may be useful in areas where saturated sand and gravel units are buried by thick sequences of glacial till.

The first tool was microgravity. This technique can detect fairly small changes in gravity generated by varying density of geologic material. At the study site in eastern Nebraska, the

bedrock density variations dominated the signal. Sand and gravel deposits were not delineated and this tool was deemed not applicable to water resources studies in eastern Nebraska (Abraham et al., 2010).

The second tool tested was Controlled Source Audio-Magnetotelluric (CSAMT). This technique is electrical and has resolution between 100 and 1000 meters below ground surface. Conductive material (silt and clay) at the surface does not limit the effectiveness of this method (as is the case with Helicopter Electromagnetic surveys). At the study site in eastern Nebraska, the signal was dominated by bedrock electrical variability. Electrical interference from a pipeline, power lines, and pivots degraded the quality of the data. This tool was deemed not applicable to water resources studies in eastern Nebraska (Abraham et al., 2010).

The third tool tested was TDEM. This technique is electromagnetic, but the signals penetrate deeper than the helicopter electromagnetic signals. At the study area in eastern Nebraska, the USGS studied ways to enhance the initial TDEM results and determined that airborne TDEM could be applied as an anomaly detector in eastern Nebraska. As an anomaly detector, the method could identify geologic/depositional patterns in the subsurface if the flight covers an area large enough for the patterns to be discerned. A large-scale survey using a high-powered time-domain airborne system was recommended. However, in thick, dense tills, neither the depth to the sand unit, its resistivity, nor its thickness can be resolved. The purpose of flying TDEM would be to identify the location of a potential aquifer so that test holes can be strategically located. In thinner, sandy tills, TDEM is applicable for identifying the depth to the aquifer, the resistivity of the aquifer, and the thickness of the aquifer (Abraham et al., 2012).

Following the technology evaluations at the pilot study sites, additional information was gathered regarding TDEM flights for ENWRA's 2012 Nebraska Environmental Trust (NET) grant application request in Fall 2012. Up-to-date airborne TDEM technologies and associated inversion algorithms (examples: VTEM or SkyTEM systems) for aquifer mapping purport potential better resolution (similar to the HEM resolution) could be attained with the thick tills. Building on the results presented within the USGS study report (Scientific Investigations Report 2011-5228 available on ENWRA's Media/Downloads page), current studies have shown further successes using TDEM in airborne electromagnetic surveys (AEM). The Lower Elkhorn and Lower Platte South contracted with XRI Geophysics, LLC for approximately 150 square miles (Clarkson-Howells and Dwight-Valparaiso-Brainard areas) of AEM surveys using TDEM in 2013. Those block flights and the following 2014-2015 reconnaissance flight results have shown that well-calibrated TDEM AEM survey methods allow for large-scale, non-invasive characterization in areas where glacial till is thick and the aquifers are deeply buried. The ENWRA project understands, with this recent proven AEM technology and study work to date, that it has identified the minimum number of tools needed to characterize the geologic framework for eastern Nebraska.

In 2016, the HEM data collected in 2007 at the pilot study sites was enhanced using surrounding TDEM recon survey line data from 2015 and newer evaluation and visualization techniques to gain more utility and understanding from the datasets. A paper was publicized: *Three-dimensional architecture and hydrostratigraphy of cross-cutting buried valleys using airborne electromagnetics, glaciated Central Lowlands, Nebraska, USA*. Sedimentology. 64:553-581; Korus, J. T., Joeckel, R. M., Divine, D. P., Abraham, J. D. 2016. In 2016 and 2018, several additional

TDEM flights were flown in eastern and central Nebraska totaling over 19,000 line-miles (over 15,000 of which was by ENWRA NRDs) through successful Nebraska Water Sustainability Fund (WSF) applications (https://nrc.nebraska.gov/water-sustainability-fund-0). Additionally, ENWRA contracted with Aqua-Geo Frameworks, LLC to provide new datasets for each of the pilot sites in downloadable Google Earth format in 2016 and to re-format all ENWRA data into a Nebraska specific coordinate system (EPSG 32104 in meters, EPSG 26852 in feet) in 2019. The Google Earth datasets are readily available to the public from the ENWRA website along with all the other ENWRA-related AEM flight reports to date (files stored on ENWRA's Dropbox and links to Dropbox are embedded on ENWRA's website).

Further, ENWRA has collaborated with CSD, USGS and other NRDs who have flown geophysical flights to house and make accessible all the airborne geophysical data collected in Nebraska through the Nebraska GeoCloud (NGC) project. The development of the NGC (using the expertise of I-GIS of Denmark with the state WSF and funding from 10 NRDs) is scheduled for completion in 2020 and is planned with upload and download capability (geophysical projects and associated geological datasets) for different levels of users (federal state and local agencies, the public, and contractors).

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APPENDIX B
ENWRA OBJECTIVES AND PROJECTS MATRIX

Project and Objectives Matrix Table

Objective/Project		Management Concern	Sponsor	Area (mi^2 / line km)	Potential Funding Sources	Fiscal Years	Estimated Cost*	Notes
1. Retain a Project Coordinator		--	all 6 NRDs	--	ENWRA\Grants	2021-2031	$700,000	$70,000 annually for salary and benefits over 10 years (shared position, 40% CSD, 60% ENWRA renews April 2020)
2. Identify the Location & Vol. of Aquifers								
A.	**Map priority areas using AEM**							
	Isolated/limited quantity aquifers	limited quantity	all 6 NRDs	2,500 / 2,000	ENWRA Dues/NET/ WSF/DNR/NRD	2021-2031	$1,000,000	block flights, aquifer boundaries, target depths will vary
	Area north of Adams and other limited areas	limited quantity	Nemaha	270 / 1,575	ENWRA Dues/NET/ WSF/DNR/NRD	2021-2031	$787,500	delineate boundaries, use AEM or combination of methods, target top 300 feet
	Missouri River Upland tributaries	limited quantity	PMR	1,200 / 800	ENWRA Dues/NET/ WSF/DNR/NRD	2021-2031	$400,000	map Quaternary tributary aquifers present between the uplands and Missouri River, use AEM or combination of methods, target top 800 feet
	Fremont to Arlington area	limited quantity & quality	PMR - LPN	250 / 1,400	ENWRA Dues/NET/ WSF/DNR/NRD	2021-2031	$700,000	map area between Fremont and the Arlington paleovalley with AEM, target top 300 feet
B.	**Secondary bedrock aquifer reconnaissance**	limited quantity & quality	all 6 NRDs	--	ENWRA Dues/USGS/NET/ WSF/DEQ/DNR	2021-2031	>$1,000,000	next phase to be determined - builds on initial reconnaissance of quality/sustainability - 2015 WSF Application with USGS, deep test hole and monitoring well investments, and AEM investments
C.	**Advance geologic test holes**	limited quantity & quality	all 6 NRDs	--	ENWRA Dues/ NET/WSF/ CSD/NRDs	2021-2031	$540,000	assume 60 holes averaging 600 feet deep at $9,000 per hole for lithology match-up with AEM
D.	**Maintain and add monitoring wells**	quantity and quality trends	all 6 NRDs	--	ENWRA Dues/USGS/NET/ WSF/DEQ/DNR	2021-2031	$500,000	assume 50 wells at $10,000 per well (includes select intallations of telemetry or other mon. instrumentation)
E.	**Continued sponsorship and participation in Nebraska GeoCloud (NGC) to house and access AEM data and produce accessible products online**	geologic framework	all 6 NRDs	--	ENWRA Dues/CSD/ USGS/WSF/DNR/ DEQ/NRDs	2021-2031	$700,000	support the Interlocal Agreement and coordinator/specialist position. Continue to evaluate CSD staffing needs/availability/workload, NGC related positions and/or NGC consultant contracts (est. costs parallel objective 1)

Project and Objectives Matrix Table

Objective/Project		Management Concern	Sponsor	Area (mi^2 / line km)	Potential Funding Sources	Fiscal Years	Estimated Cost*	Notes
3. Estimate Recharge Areas and Rates								
A.	**Map recharge areas**	recharge/ sustainability/ quality	all 6 NRDs	--	ENWRA Dues/NRDs/ NET/WSF/USGS	2021-2031	--	evaluate AEM and existing data (potential UNL vadose, NGC, USGS, CSD, DNR collaborations) to identify recharge areas and target study areas
B.	**Maintain and add/re-evaluate vadose zone stations & recharge projects**	recharge/ sustainability	all 6 NRDs	--	ENWRA Dues/USGS/ NET/WSF	2021-2031	$400,000	assume 10 stations at $40,000 per station, requires Technical Advisor to direct and evaluate
4. Assess Potential Connections Between Groundwater & Surface Water								
A.	**Continue to evaluate HCAs and unidentified HCAs**	interrelated water	all 6 NRDs	--	USFWS/ENWRA Dues/WSF/CSD/ NET/county/NRDs	2021-2031	--	update CSD datasets; work with DNR to get Lower Platte Missouri River Tribs model (LPMT) updated with AEM and NGC frameworks
B.	**Map saline groundwater**	interrelated water, quality	LPS/LPN	--	NRDs/ENWRA Dues/NET/ WSF/USFWS	2021-2031	--	map salt spring & stream reaches and salt/fresh (Maha) boundary in Dakota formation using variety of methods
C.	**Review/incorporate ongoing work in alluvial aquifers**	interrelated water	all 6 NRDs	--	ENWRA Dues/NET/ WSF/NRDs	2021-2031	--	identify gaining/losing reaches, streambed characteristics, potential cross aquifer connections
5. Estimate/Calculate Water Budgets		management decisions	all 6 NRDs	--	ENWRA Dues/NET/ WSF/DNR/NRDs	2021-2031	$100,000	part of ultimate goal of a 3-D hydrogeological framework and water budget for all ENWRA, work with DNR on LPMT model updates
6. Characterize Natural And Anthropogenic Water Quality Concerns		quality/ recharge/ sustainability	all 6 NRDs	--	DEQ/EPA/USGS/ ENWRA Dues/ WSF/NET	2021-2031	$300,000	analyzed constituents vary according to concern in primary or secondary aquifers, continue pilot sites and consider collaborative projects
7. Assemble, Analyze, and Distribute Data								
A.	**Continued Sponsorship and Participation in NGC (See Objective 2E above)**	--	all 6 NRDs	--	ENWRA Dues/CSD/ USGS/WSF/DNR/ DEQ/NRDs	2021-2031	--	Interlocal Agreement will outline this annual budget item, NGC will house and make accessible the bulk of our data
B.	**ENWRA progress and assessment updates to partners, the online website, and presentation audiences**	--	all 6 NRDs	--	--	2021-2031	--	joint effort with Technical Advisors, Data Providers, and Project Coordinator
8. Develop a Variety of Partners and Funding Sources		--	all 6 NRDs	--	--	2021-2031	--	on-going effort as opportunities arise
9. Continue to Assess the Applicability of New Technology and Parallel Projects/Developments/ Precedents		--	all 6 NRDs	--	--	2021-2031	--	this task will occur if potential new technology and potential parallel projects/entities/laws develop

LIST OF ACRONYMS

CSD	Conservation & Survey Division
NeDEE	Nebraska Department of Environment and Energy
NeDNR	Nebraska Department of Natural Resources
ENWRA	Eastern Nebraska Water Resources Assessment
EPA	Environmental Protection Agency
HCA	Hydrologically Connected Area
HEM	Helicopter Electromagnetic
IWMPP	Interrelated Water Management Plan Program
LC	Lewis & Clark NRD
LE	Lower Elkhorn NRD
LPN	Lower Platte North NRD
LPS	Lower Platte South NRD
N	Nemaha NRD
NARD	Nebraska Association of Resources Districts
NET	Nebraska Environmental Trust
NRCS	Natural Resources Conservation Service
NRD	Natural Resources District
NSF	National Science Foundation
PMR	Papio-Missouri River NRD
SSURGO	Soil Survey Geographic Database
TDEM	Time Domain Electromagnetic
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish & Wildlife Service
USGS	U.S. Geological Survey
WRRI	Water Resources Research Initiative
WSF	Water Sustainability Fund

DESCRIPTION OF FUNDING SOURCES

Water Sustainability Fund (WSF)

The WSF is a source of financial support to help the State achieve the goals set out in § 2-1506, Rules (Title 261) adopted by the Nebraska Natural Resources Commission (NRC) which oversees Fund operations including selecting successful applications, and NeDNR (Title 264) which oversees administration. NRDs with integrated management plans in place (or in the beginning stages) may submit applications annually (due in July, approximately $11 Million in funds available annually with a 10% set-aside for projects requesting <or = $250,000). The applications are reviewed by the Director of the Nebraska Department of Natural Resources who checks the applications for eligibility and then recommends the eligible projects to the Natural Resources Commission for scoring and approval of grant funds. At 40% local fund match is required.

Nebraska Environmental Trust (NET)

The money is this fund is supplied through state lottery revenue. NET funds environmental projects in various categories, including: water, air quality, habitat, soil management, and waste management. The amount of money in the fund varies depending on the amount and distribution of lottery revenue. Projects can vary in length from one to three years. Project sponsors may submit applications annually, which are reviewed by outside reviewers. NET funds are administered through the NET Board of Directors and the Nebraska Game and Parks Commission. At least 20% local fund match is required.

National Science Foundation (NSF)

The money in this fund is supplied through the federal government. The scope of projects funded is immense and may vary in length. These projects are generally headed by a Principal Investigator with a PhD and publishing history, and are therefore usually given to universities, though non-university entities are allowed to apply. Federally funded agencies and entities are not typically eligible to receive NSF funds directly. No local fund match is required.

U.S. Environmental Protection Agency (EPA)

The EPA provides grants in a variety of categories, including nonpoint source grants (Section 319), and research and development grants. Any potential ENWRA applications would be developed in cooperation with NeDEE.

U.S. Fish and Wildlife Service (USFWS)

The USFWS provides a grant to local governments called the Cooperative Conservation Initiative, the purpose of which is to restore natural resources and establish or expand wildlife habitat. At least 50% local fund match is required.

U.S. Geological Survey Cooperative Funds (USGS)

USGS offices receive an allotment of federal funds which they may put towards supporting work with cooperators. These funds are specific to a certain office, and for a cooperator to receive the funds, the work must be accomplished using personnel from that office. The USGS typically offers 20-25% cost matching.

Water Resources Research Institute (WRRI)

The money in this fund is supplied by the EPA through 104(b) funds, referencing section 104 of the Clean Water Act which applies to reduction and elimination of pollution. Application for funds is made through cooperation between the USGS and state-established water centers (affiliated with universities). The USGS submits proposals, after which state and federal agencies recommend some for funding. Projects can vary in length from one to three years. The total amount available (nationally) annually is $920,000. No single project can exceed $250,000, and most are much smaller. At least 50% local fund match is required.

Please refer to MASTER COPY for fully executed agreements

APPENDIX C
ENWRA INTERLOCAL AGREEMENTS