NEBRASKA NATURAL RESOURCES COMMISSION

Water Sustainability Fund

Application for Funding

Section A.

ADMINISTRATIVE

PROJECT NAME: Hydrogeologic Mapping for Water Sustainability Projects in the Middle Republican Natural Resources District

PRIMARY CONTACT INFORMATION

Entity Name: Middle Republican Natural Resources District

Contact Name: Sylvia Johnson

Address: 220 Center Ave, P.O. Box 81, Curtis, NE 69025

Phone: 308-367-4281

Email: sjohnson@mrnrd.org

Partners / Co-sponsors, if any: Conservation and Survey Division, School of Natural Resources, University of Nebraska-Lincoln

1. Dollar amounts requested: (Grant, Loan, or Combination)

   Grant amount requested. $ 697,289

   Loan amount requested. $

   If Loan, how many years repayment period?

   If Loan, supply a complete year-by-year repayment schedule.

   Are you requesting less than 60% cost share from the fund? NO

   If so what % ?

2. Permits Needed - Attach copy for each obtained (N/A = not applicable)

Nebraska Game & Parks Commission (G&P) consultation on Threatened and Endangered Species and their Habitat	N/A☒	Obtained: YES☐	NO☐
Surface Water Right	N/A☒	Obtained: YES☐	NO☐
USACE (e.g., 404 Permit)	N/A☒	Obtained: YES☐	NO☐
Cultural Resources Evaluation	N/A☒	Obtained: YES☐	NO☐
Other (provide explanation below) Click here to enter text.	N/A☒	Obtained: YES☐	NO☐

3. Are you applying for funding for a combined sewer over-flow project?

   YES☐ NO☒

   If yes, do you have a Long Term Control Plan that is currently approved by the Nebraska Department of Environmental Quality?

   YES☐ NO☐

   If yes attach a copy to your application. Click here to enter text.

   If yes what is the population served by your project? Click here to enter text.

   If yes provide a demonstration of need. Click here to enter text.

   If yes and you were approved for funding in the most recent funding cycle, then resubmit the above information updated annually but you need not complete the remainder of the application.

4. If you are or are representing an NRD, do you have an Integrated Management Plan in place, or have you initiated one?

   N/A☐ YES☒ NO☐

5. Has this application previously been submitted for funding assistance from the Water Sustainability Fund and not been funded?

   YES☐ NO☒

   If yes, have any changes been made to the application in comparison to the previously submitted application? Click here to enter text.

If yes, describe the changes that have been made since the last application.
Click here to enter text.

No, I certify the application is a true and exact copy of the previously submitted and scored application. (Signature required) Click here to enter text.

Section B.

DNR DIRECTOR'S FINDINGS

Does your project include physical construction (defined as moving dirt, directing water, physically constructing something, or installing equipment)?

YES☐ NO☒

1(a). If yes (structural), submit a feasibility report (to comply with Title 261, CH 2) including engineering and technical data and the following information:

A discussion of the plan of development (004.01 A);
Click here to enter text.

A description of all field investigations made to substantiate the feasibility report (004.01 B); Click here to enter text.

Maps, drawings, charts, tables, etc., used as a basis for the feasibility report (004.01 C); Click here to enter text.

A description of any necessary water and land rights and pertinent water supply and water quality information, if appropriate (004.01 D);
Click here to enter text.

A discussion of each component of the final plan including, when applicable (004.01 E);

Required geologic investigation (004.01 E 1); Click here to enter text.

Required hydrologic data (004.01 E 2); Click here to enter text.

Design criteria for final design including, but not limited to, soil mechanics, hydraulic, hydrologic, structural, embankments and foundation criteria (004.01 E 3). Click here to enter text.

1(b). If no (non-structural), submit data necessary to establish technical feasibility including, but not limited to the following (004.02):

A discussion of the plan of development (004.02 A);

The MRNRD wishes to develop innovative modeling tools to evaluate management alternatives for two interrelated water sustainability projects:

1. An assessment of management alternatives for areas of aquifer depletion in northwestern Hayes County (Figure 1). Reducing or stabilizing water table declines in Hayes County is critical to achieving the goals of the MRNRD's Integrated Management Plan (IMP).

2. Hydrogeologic evaluation of Culbertson Canal to understand the canal recharge system. Use of the canal for managed aquifer recharge (MAR) will provide flow augmentation for the Republican River (Figure 1).

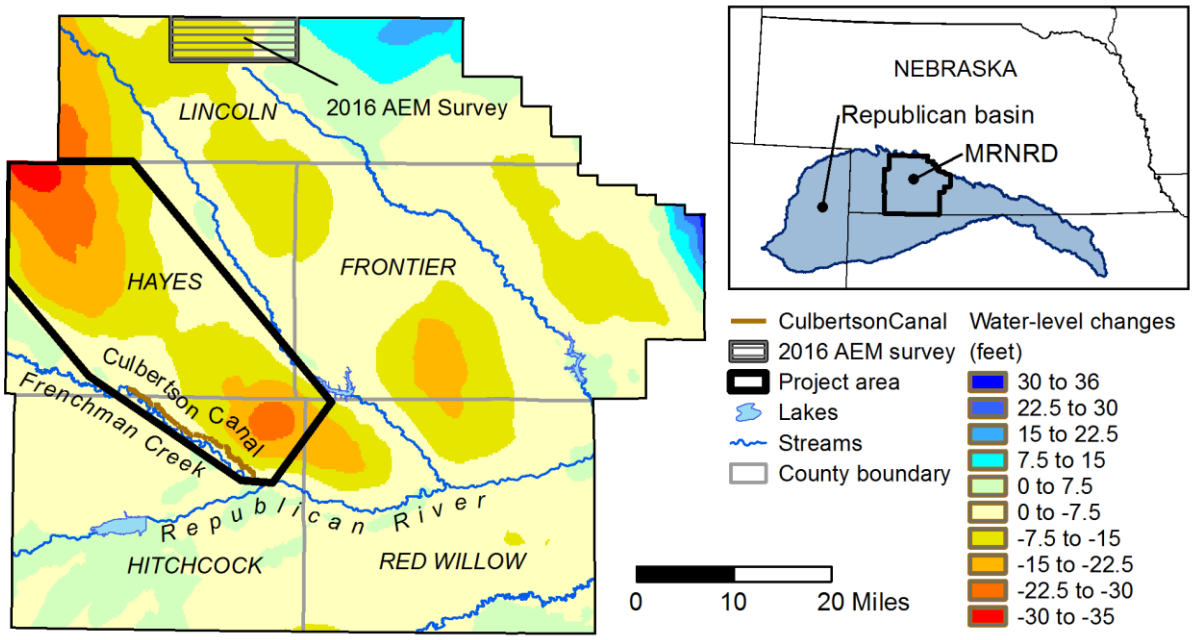

Figure. 1. Map of the Middle Republican Natural Resources District (MRNRD). Water-level changes recently mapped by the Conservation and Survey Division show as much as 30 – 35 feet of decline between predevelopment (prior to the 1960's) and 2016. The project area is shown in the black polygon. Culbertson Canal is located on the southern end of the project area.

The two projects are interrelated because both lie within the Frenchman Creek watershed where groundwater and surface water are interconnected. Management of groundwater in Hayes County affects the viability of the potential MAR project on Culbertson Canal. However, the hydrogeologic system is not well-understood. To develop the necessary models and tools, MRNRD aims to complete the following work items:

- Conduct detailed hydrogeological mapping of northwestern Hayes County
- Characterize the hydrogeology beneath Culbertson canal
- Analyze the impacts of management options on groundwater levels and stream flows
- Locate sites of potential managed aquifer recharge projects

A description of field or research investigations utilized to substantiate the project conception (004.02 B);

This study will use leading tools and methods from geophysics, geology, and hydrogeology, including airborne electromagnetics (AEM), towed transient electromagnetics (tTEM), subsurface sampling, and sophisticated computer models (see Attachment 1 for details and references). The MRNRD has established a close working relationship with the Conservation and Survey Division (CSD) over the past few years. CSD has developed partnerships with leading experts and is poised to conduct a thorough, scientifically sound investigation. An AEM survey in 2016 in nearby Lincoln County showed that this technique can successfully produce images highlighting differences in aquifer and aquitard materials in the Ogallala Group (Figure 2). The proposed

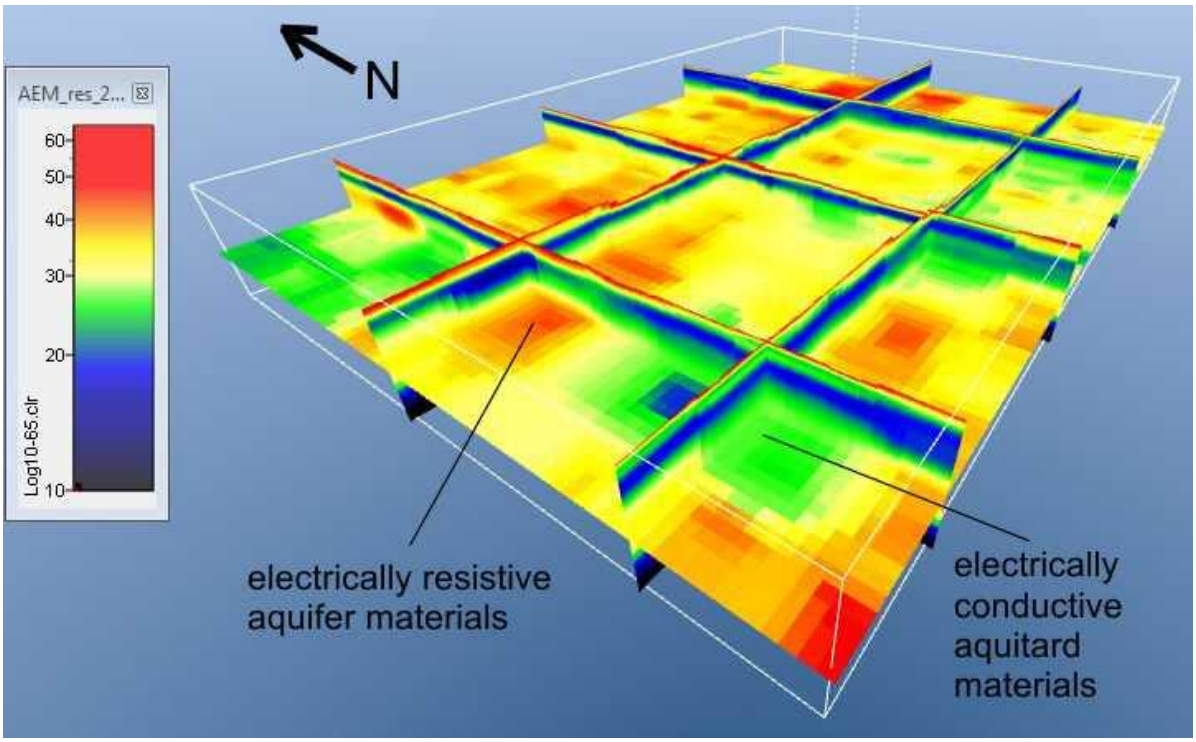

Figure 2. 3D view of gridded conductivity values from 2016 AEM survey in Lincoln County. View is toward northeast. Distance from west to east along grid box is ~12 miles.

project will build robust geological and hydrostratigraphic models which will provide estimates of hydrogeologic properties and their associated uncertainties. These parameters and uncertainties will be incorporated into a MODFLOW groundwater model for simulating the impacts of various management alternatives on aquifer depletion, streamflow, and canal recharge.

To characterize the hydrogeology in the area of Culbertson Canal, a new technique will be used to provide high-resolution images of the subsurface. The towed transient electromagnetic (tTEM) system was recently developed at Aarhus University out of the need for high-resolution, cost-effective surveying at higher resolution than AEM (Figure 3). The tTEM system is towed by an ATV. It uses a transmitter loop mounted on a frame with sledges. The receiver coil is towed 30 ft behind the transmitter. A full dataset is obtained every 10 – 12 ft at a production speed of 10 – 12 mph. Data are processed using methods directly adopted from AEM. With this setup, around 250 acres per day can be mapped in 3D. The tTEM system is compact and easy to mobilize, and is more economical than AEM for certain mid-size applications. Moreover, it has proven useful for assessment of managed aquifer recharge sites in places such as California.

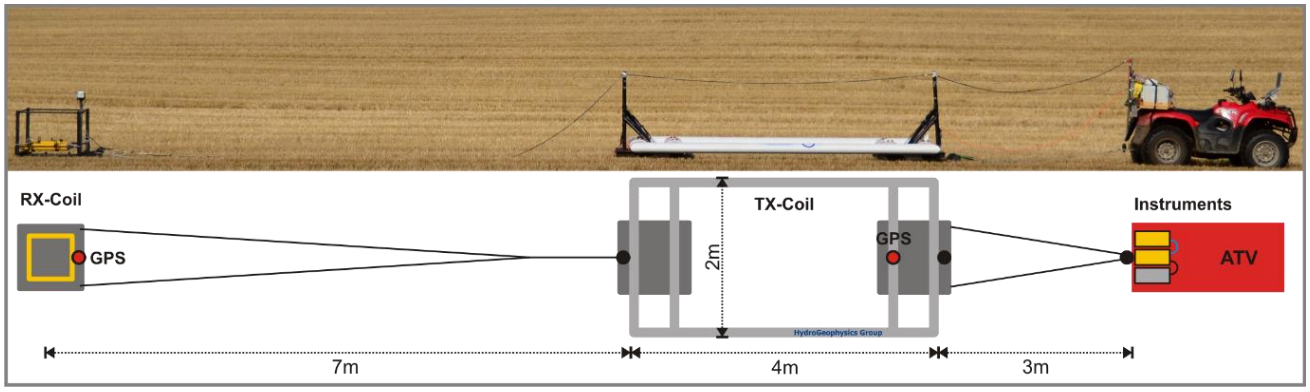

Figure 3. The tTEM system. Rx-Coil indicates the receiver coil and Tx-coil indicates the transmitter coil both sitting on sledges. The yellow boxes on the ATV indicate the receiver and transmitter electronics and grey box is the battery-box for power supply. GPSs are marked with red dots.

Collaboration between Nebraska and Denmark

Given the integration of multiple disciplines, close collaboration between experts in various fields is necessary. Geologists at the Conservation and Survey Division (CSD) will work closely with geophysicists and geologists at

the Geological Survey of Denmark and Greenland (GEUS) and Aarhus University in Denmark. CSD and the Denmark team will collaborate with a consulting firm experienced in Republican River basin models (Brown and Caldwell of Lakewood, CO has been hired by MRNRD for previous modeling projects). CSD geologists have local, first-hand knowledge of the study area, and they have experience in geological and hydrogeological interpretation of AEM data (e.g. Divine and Korus, 2014; Korus, 2013, 2016, 2018). Denmark has significant experience in SkyTEM, an AEM system developed at Aarhus University. GEUS has broad experience in geological and hydrogeological interpretations of AEM data (e.g. Høyer et al., 2015; Jørgensen et al., 2015; Sandersen and Jørgensen, 2003).

Geophysical and Geological Modeling

A key component linking all aspects of this project is the understanding of the subsurface geological structure. The geological framework is essential for thorough handling, assessment, and inversion of the AEM and tTEM data. Therefore, significant effort is put into producing results that are geologically reasonable. This involves a tight collaboration between the geophysicists and the geologists whereby each group iteratively checks the mutual consistency between the geophysics and the geological expectations. The 3D geological model will focus on interpretations of geological formations, since each formation has unique hydrogeologic properties. The geological model will function as a framework for the development of the hydrostratigraphic models described below.

Hydrostratigraphic and Groundwater Modeling

Hydrostratigraphic units contribute to large uncertainties in many groundwater models (e.g. Seifert et al. 2012, Zhou et al. 2014, Scheidt et al. 2017, Marker et al. 2017). Therefore, improving the realism of the hydrostratigraphic models and estimating uncertainty in the hydrologic properties will be an essential part of the modelling process. With these estimates, the uncertainties can be understood, evaluated, and integrated into the decision-making process.

Multiple Point Statistics (MPS) will be used to reproduce spatial patterns of subsurface geology from a Training Image (TI). The TI is a conceptualization of the geometry and patterns of physical property variation, which will come from the geological model. This will ensure that the hydrostratigraphic models are geologically reasonable in terms of structural appearance. Using MPS, the

various contributions of uncertainty, including spatial coverage, borehole lithology, geophysics, and the geophysical-geological correlation, are merged to produce a suite of hydrostratigraphic model realizations. The entire model ensemble reflects the uncertainty of the hydrostratigraphic interpretation and can be used to calculate uncertainties in the MODFLOW simulations.

A basin-wide MODFLOW model will be developed for the Frenchman Creek basin by consultants familiar with Republican Basin models. The various model components will come from recent modeling efforts and other available data. A local grid refinement will be placed into this model to input the AEM-derived hydrostratigraphic model ensemble. Multiple simulations will be run to test the sensitivity of the model to various hydrostratigraphic inputs. The impacts to the groundwater system, fluxes between aquifers, streams, and canals, and the uncertainties associated with these simulations will be computed. These model runs will provide the MRNRD with quantifiable options for groundwater management and MAR.

Coring and Characterization of the Vadose Zone

After potential locations for MAR are identified in the previous task, each location will be drilled to characterize geology and geochemistry of the vadose zone. Samples will be analyzed for nitrate, uranium, and arsenic. Previous monitoring in Hitchcock and Red Willow counties identified potential deposits of naturally occurring geologic nitrate in the vadose zone (Boyce et al., 1976; Spalding, 1996). It is important that these deposits are not located in the pathway of induced recharge. Elevated concentrations of uranium and arsenic have been identified in groundwater in several areas of the state (Gosselin, Klawer, et al., 2004). It is important that these contaminants are not introduced during recharge.

A description of the necessary water and/or land rights, if applicable (004.02 C);

The Frenchman Valley Irrigation District (FVID) has water rights dating to 1890 and 1960 on Frenchman Creek (appropriations D-24 R and A-9802 R) for 132.75 cubic feet per second (cfs) at the Culbertson Canal diversion. A long term lease agreement between FVID and MRNRD was signed in 2016 that allows the MRNRD to use the water to evaluate the canal recharge system (Attachment 2). The agreement gives MRNRD access to diverted water and allows it to utilize the water delivery system to create groundwater recharge

and flow augmentation to the Republican River for Compact compliance and credits. This water is available when the FVID is not delivering water to its patrons.

A discussion of the anticipated effects, if any, of the project upon the development and/or operation of existing or envisioned structural measures including a brief description of any such measure (004.02 D).

Existing operations will not be affected directly by the proposed project. The outcomes of the project may determine that the FVID is used as part of a MAR project. The use of Culbertson Canal for this purpose is already agreed upon in the long term lease agreement between FVID and MRNRD (Attachment 2).

2. Provide evidence that there are no known means of accomplishing the same purpose or purposes more economically, by describing the next best alternative.

Hydrogeologic mapping at the spatial scale and level of detail proposed herein is not possible in any other way. AEM and tTEM are the forefront of technology for this purpose. The next best alternative to achieve the same amount of detail would be to drill boreholes every 200 ft for 1,634 miles, totaling 43,138 boreholes. This would cost nearly $130,000,000 and take hundreds of years to accomplish. Clearly this option is not feasible. Another alternative is to forego new data collection altogether, and instead, make decisions about groundwater management and MAR with very limited knowledge of the hydrogeology. Making uninformed decisions could result in unnecessary consequences such as undue restrictions on pumping and loss of farm income, accidental mobilization of contaminants in the vadose zone, and inadequate measures to ensure proper augmentation of flow to the Republican River.

3. Document all sources and report all costs and benefit data using current data, (commodity prices, recreation benefit prices, and wildlife prices as prescribed by the Director) using both dollar values and other units of measurement when appropriate (environmental, social, cultural, data improvement, etc.). The period of analysis for economic feasibility studies shall be fifty (50) years or with prior approval of the Director, up to one hundred (100) years [T261 CH 2 (005)].

- Describe any relevant cost information including, but not limited to the engineering and inspection costs, capital construction costs, annual operation and maintenance costs, and replacement costs. Cost

information shall also include the estimated construction period as well as the estimated project life (005.01).

All costs are related to data collection, model construction, and research activities, as shown below. Additional details of the budget are provided in Section D, Part 4.

- AEM and tTEM surveys totaling 1,634 line-miles, including university research and development of geological and hydrostratigraphic models using state-of-the-art techniques ($778,343)
- Drilling and sampling for lithologic and geochemical characterization ($33,805)
- Development of MODFLOW groundwater model and incorporation of AEM/tTEM-derived products ($350,000)
- Total ($1,162,148)

Source of Cash	July 1, 2019 to June 30, 2020	July 1, 2020 to June 30, 2021	Total Cost
WSF REQUEST	$295,280	$402,008	$697,289
MRNRD COST SHARE	$196,854	$268,006	$464,859
TOTAL PROJECT COST	**$492,134**	**$670,014**	**$1,162,148**

- Only primary tangible benefits may be counted in providing the monetary benefit information and shall be displayed by year for the project life. In a multi-purpose project, estimate benefits for each purpose, by year, for the life of the project. Describe any intangible or secondary benefits separately. In a case where there is no generally accepted method for calculation of primary tangible benefits describe how the project will increase water sustainability, such that the economic feasibility of the project can be approved by the Director and the Commission (005.02).

There is no generally accepted method for calculation of primary tangible benefits; however, the project will increase water sustainability. The results of the hydrogeologic mapping will result in actionable information for the implementation of canal recharge projects along the 19 miles (30 km) between Palisade and Culbertson in the Frenchman Creek valley. These projects will

provide flow augmentation to the Republican River. The management actions taken for western Hayes County as a result of the mapping and modeling effort will help reduce or stabilize groundwater-level declines and reduce long-term depletions to streamflow.

- All benefit and cost data shall be presented in a table form to indicate the annual cash flow for the life of the proposal, not to exceed 100 years (005.03).

Source of Cash	July 1, 2019 to June 30, 2020	July 1, 2020 to June 30, 2021	Total Cost	Benefit
WSF REQUEST	$295,280	$402,008	$697,289	*Cost savings of not having to drill test holes over 600 sq. mile area*
MRNRD COST SHARE	$196,854	$268,006	$464,859	
TOTAL PROJECT COST	**$492,134**	**$670,014**	**$1,162,148**	**$130,000,000**

- In the case of projects for which there is no generally accepted method for calculation of primary tangible benefits and if the project will increase water sustainability, the economic feasibility of such proposal shall be demonstrated by such method as the Director and the Commission deem appropriate (005.04).

The estimated cost of the AEM and tTEM surveys, along with the associated research outputs, is $778,343. This is 10 – 30% below similar past projects. This study includes research activities by three different institutions, providing access to some of the world's foremost authorities on geophysical methods. Based on past experiences with conducting geophysical surveys in Nebraska, a reasonable cost expectation for AEM data acquisition and basic interpretation ranges from $530 to $681 per line mile (K. Cameron, personal communication). For the 1,634 line miles in this proposal, a cost of $866,020 to $1,112,754 would be expected. An important difference between this survey and most previous surveys is that CSD geologists and a team of outside experts will deliver novel, peer-reviewed results using newly developed methods, including geostatistical realizations of hydrogeologic parameters as inputs to MODFLOW. These deliverables have not been part of past AEM surveys. Despite these increased research outputs, the cost is below expectations.

4. Provide evidence that sufficient funds are available to complete the proposal.

The MRNRD has budgeted $350,000 in their 2018 – 2019 budget for modeling projects.

5. Provide evidence that sufficient annual revenue is available to repay the reimbursable costs and to cover OM&R (operate, maintain, and replace).

6. If a loan is involved, provide sufficient documentation to prove that the loan can be repaid during the repayment life of the proposal.

   N/A

7. Describe how the plan of development minimizes impacts on the natural environment.

   No physical construction will occur that could seriously impact the environment. The plan of development includes airborne operations. No contact with the land will occur during the survey flights, reducing environmental impact. The modeling work is carried out on computers. The outcomes of this work will benefit the environment by reducing aquifer depletion and providing steady streamflow to the Republican River.

8. Explain how you are qualified, responsible and legally capable of carrying out the project for which you are seeking funds.

   The MRNRD is the legal entity responsible for regulating and controlling groundwater use within its boundaries. The MRNRD has established a close working relationship with the Conservation and Survey Division (CSD) over the past few years. CSD has developed partnerships with experts at the Geological Survey of Denmark and Greenland (GEUS) and Aarhus University of Denmark, both leading institutions in the development and application of AEM and tTEM technologies, as well as geological and hydrostratigraphic modelling. These collaborations, partnerships, and trusted relationships allow the MRNRD to conduct a thorough, scientifically sound investigation.

9. Explain how your project considers plans and programs of the state and resources development plans of the political subdivisions of the state.

   The Annual Report and Plan of Work for the Nebraska State Water Planning and Review Process provides information on several key areas of Department

water planning activities, including current and future activities regarding information, data, and analysis capabilities, as well as water resources planning and management. The Water Resources Cash Fund is used to support water management efforts in fully appropriated or overappropriated basins. These funds can be utilized to aid management actions taken to reduce consumptive uses of water, or to enhance streamflow or groundwater recharge. This project meets several of the goals within the Water Sustainability Fund, such as reducing aquifer depletion, mitigating threats to drinking water, the approval of an integrated management plan and groundwater management plan, the contribution of water supply management goals such as agricultural uses, municipal and industrial uses, recreational benefits, wildlife benefits, conservation, and preservation of water resources. The project also meets the goals of enhancing water quality and complying with interstate compacts.

10. Are land rights necessary to complete your project?

YES☐ NO☒

If yes, provide a complete listing of all lands involved in the project.
Click here to enter text.

If yes, attach proof of ownership for each easements, rights-of-way and fee title currently held.
Click here to enter text.

If yes, provide assurance that you can hold or can acquire title to all lands not currently held.
Click here to enter text.

11. Identify how you possess all necessary authority to undertake or participate in the project.

MRNRD has the necessary authority to participate in this project. Nebraska Statute, Chapter 2, Article 32 establishes Nebraska's NRDs and gives them authority to develop and execute plans, facilities, works, and programs relating to water supply and the development, management, utilization, and conservation of groundwater and surface water. The MRNRD and the Nebraska Department of Natural Resources (DNR) jointly developed an Integrated Management Plan (IMP) in accordance with the Nebraska Ground Water Management and Protection Act, Neb. Rev. Stat. 46-701 to 46-753 (Reissue 2004). The current IMP is effective January 15, 2016. The IMP contains goals and objectives consistent with the proposed project. These goals

and objectives and how the project will help the MRNRD meet them are explained in Section C, Part 2.

12. Identify the probable environmental and ecological consequences that may result as the result of the project.

There are no known, negative environmental and ecological consequences that may result as the result of the proposed project.

Section C.

NRC SCORING

In the NRC's scoring process, points will be given to each project in ranking the projects, with the total number of points determining the final project ranking list.

The following 15 criteria constitute the items for which points will be assigned. Point assignments will be 0, 2, 4, or 6 for items 1 through 8; and 0, 1, 2, or 3 for items 9 through 15. Two additional points will be awarded to projects which address issues determined by the NRC to be the result of a federal mandate.

Notes:

- The responses to one criterion *will not* be considered in the scoring of other criteria. Repeat references as needed to support documentation in each criterion as appropriate. The 15 categories are specified by statute and will be used to create scoring matrixes which will ultimately determine which projects receive funding.

- There is a total of 69 possible points, plus two bonus points. The potential number of points awarded for each criteria are noted in parenthesis. Once points are assigned, they will be added to determine a final score. The scores will determine ranking.

- The Commission recommends providing the requested information and the requests are not intended to limit the information an applicant may provide. An applicant should include additional information that is believed will assist the Commission in understanding a proposal so that it can be awarded the points to which it is entitled.

Complete any of the following (15) criteria which apply to your project. Your response will be reviewed and scored by the NRC. Place an N/A (not applicable) in any that do not apply, an N/A will automatically be placed in any response fields left blank.

1. Remediates or mitigates threats to drinking water;

- Describe the specific threats to drinking water the project will address.
- Identify whose drinking water, how many people are affected, how will project remediate or mitigate.
- Provide a history of issues and tried solutions.
- Provide detail regarding long range impacts if issues are not resolved.

Threats to Drinking Water

Elevated levels of nitrate-nitrogen have been detected in groundwater in northeastern Hitchcock County near Culbertson Canal (NDEQ, 2017), where MAR sites will be eventually be located. Moreover, high concentrations of naturally occurring vadose zone nitrate have been previously identified in south central Nebraska (Boyce et al 1974; Spalding, 1996). Uranium and arsenic are also known groundwater contaminants for this area.

People Affected/How Project will Mitigate

The water supply for the City of McCook, population 7,540 (www.census.gov), is affected by nitrate and uranium and has to undergo treatment before use.

Infiltration of good quality water through a vadose zone with low levels of naturally occurring contaminants will help to dilute existing contaminants in the alluvial aquifer. Assessment of uranium and arsenic will also help determine the suitability of the unsaturated zone for managed aquifer recharge. Measurement of nitrate and other potential groundwater contaminants in the vadose zone will prevent accidental mobilization during recharge and help better evaluate locations for recharge. The proposed project will ultimately evaluate use of managed aquifer recharge in an area known for nitrate contamination from agricultural sources and uranium and arsenic contamination from natural sources.

History of Tried Solutions

In 1992, the MRNRD enacted a Special Protection Area for groundwater quality in the southern part of the District. The purpose of the area is the reduce nitrate contamination in groundwater. The City of McCook operates a treatment plant to remove nitrate, arsenic, and uranium from its water supply prior to distribution. http://www.cityofmccook.com/index.aspx?NID=106 https://sdwis-dhhs.ne.gov:8443/DWW/

Long Range Impacts

The long range impacts of groundwater contamination include degradation of human health, disruptions to the supply of public and private drinking water, and increased treatment costs for the declining population base.

2. Meets the goals and objectives of an approved integrated management plan or ground water management plan;

- Identify the specific plan that is being referenced including date, who issued it and whether it is an IMP or GW management plan.
- Provide the history of work completed to achieve the goals of this plan.
- List which goals and objectives of the management plan the project provides benefits for and how the project provides those benefits.

Integrated Management Plan

The proposed project meets the goals and objectives of the Integrated Management Plan (IMP) jointly developed by the Middle Republican NRD and the Nebraska Department of Natural Resources, effective January 15, 2016. This IMP was revised from the original IMP effective January 18, 2005. The main goals addressed are:

Goal 1. In cooperation with the State of Nebraska and the other NRDs, maintain compliance with the Compact as adopted in 1943 and as implemented in accordance with the Settlement Agreement approved by the United States Supreme Court on May 19, 2003.

Goal 2. Ensure that ground water and surface water users within the MRNRD assume their share, but only their share, of the responsibility to keep Nebraska in compliance with the Compact.

Goal 3. Provide that MRNRD's share of compliance responsibility and impacts to streamflow be apportioned within the MRNRD in an equitable manner and by minimizing, to the extent possible, adverse economic, social, and environmental consequences.

Goal 4. Reserve and protect any increases to streamflow available from regulation or supplemental programs, enacted or implemented to maintain Compact compliance, from any use that would negate the benefit of such regulation or programs, to the extent allowed by statute and the surface water controls of this IMP.

History of Management Actions

The MRNRD has taken several steps to achieve integrated management goals. These steps include reductions in irrigation acres, moratoriums on new irrigation wells, certification of irrigated acres, limits on expansion of irrigated acres, and required metering of irrigation wells.

Observation Network

The MRNRD has been working to improve its network of groundwater-level observation wells. In 2016, the MRNRD began working with the Conservation and Survey Division to conduct a district-wide hydrogeologic assessment and select sites for observation wells. Seven test holes were drilled in 2016 and 2017 and three observation wells were installed in Hayes County. This work is funded in part by a Nebraska Environmental Trust Grant. By the end of 2018, nine new wells will have been installed in the area of the proposed new mapping. These wells will provide monitoring data useful for tracking groundwater depletions in accordance with section VIII of the IMP.

High-Tech Irrigation

The MRNRD has installed 60 high-tech, wireless irrigation monitoring systems, funded in part by a 2016 Water Sustainability Grant. The use of this technology will reduce consumptive uses of water in the Republican basin. It provides growers with real-time information about their irrigation systems, allowing them to be more efficient with their water use through irrigation scheduling, knowing when and how much to irrigate, and making timely decisions about the application of fertilizer and chemicals. Section VIII A of the IMP identifies irrigation scheduling as a potential project to achieve the goals and objectives of the plan.

NRCS Ogallala Aquifer Initiative Project

Hayes and Hitchcock Counties were included in a FY2016 project to enable voluntary participation in conservation practices. Focus was on converting irrigated to dryland farming, changing from sprinkler to subsurface irrigation systems, and installing soil moisture monitoring equipment. These practices help conserve irrigation water and improve groundwater quality.
https://www.mrnrd.org/sites/default/files/page_attachments/middle_republican_nrd_gets_additional_funding_for_water_quantity.pdf

Benefits to Goals and Objectives of IMP

This project benefits multiple goals and objectives of the IMP:

Goal 1. In cooperation with the State of Nebraska and the other NRDs, maintain compliance with the Compact as adopted in 1943 and as implemented in accordance with the Settlement Agreement approved by the United States Supreme Court on May 19, 2003.

This project will provide the best available scientific information for making management decisions that help the MRNRD do its part to maintain compliance with the Compact. These management actions will be aimed at stabilizing the groundwater levels in Hayes County and providing recharge to the alluvial aquifer in Frenchman Creek valley. Stabilizing declines will help reduce long-term depletions to streamflow. Recharge to the alluvial aquifer will offset the effects of pumping during times when water is needed throughout the basin. It will also provide near-term and long-term stability of streamflow to Frenchman Creek, which will provide augmentation of flow to the Republican River. These outcomes will directly help Nebraska maintain compliance with the Compact by reducing near- and long-term depletions to streamflow.

Goal 2. Ensure that ground water and surface water users within the MRNRD assume their share, but only their share, of the responsibility to keep Nebraska in compliance with the Compact.

Goal 3. Provide that MRNRD's share of compliance responsibility and impacts to streamflow be apportioned within the MRNRD in an equitable manner and by minimizing, to the extent possible, adverse economic, social, and environmental consequences.

The groundwater model developed from this project will allow hydrologists to compute the impacts of proposed management actions on groundwater levels and streamflows. The model will aid in determining the share of compliance responsibility shared between reductions in consumptive uses and managed aquifer recharge. This information will help to determine appropriate boundaries of any new management areas and to quantify the allowable groundwater depletions within these boundaries. This will help to ensure that reductions in consumptive uses are equitable and that these reductions minimize economic, social, and environmental consequences. It will also help the MRNRD to take on its share of the responsibility to keep Nebraska in compliance with the Compact.

Goal 4. Reserve and protect any increases to streamflow available from regulation or supplemental programs, enacted or implemented to maintain Compact compliance, from any use that would negate the benefit of such regulation or

programs, to the extent allowed by statute and the surface water controls of this IMP.

Objective 5. Achieve the required reductions in water use through a combination of regulatory and supplemental programs designed to reduce beneficial consumptive use. To the extent funds are available, incentive programs will be made available to as many MRNRD water users as possible.

The hydrogeological mapping and groundwater modeling proposed herein will provide the best available analysis of hydrologic connections between aquifers, streams, and canals in the project area. An understanding of these connections will help achieve the stated goal in two ways: 1) Stabilizing groundwater levels in Hayes County, through appropriate management actions informed by detailed knowledge of the hydrogeologic system, will help protect streamflow to Frenchman Creek and the Republican River. 2) Preservation of flows to Frenchman Creek will help protect the water right for Culbertson Canal, which in turn will help protect surface water users and water sources for future MAR sites.

3. Contributes to water sustainability goals by increasing aquifer recharge, reducing aquifer depletion, or increasing streamflow;

List the following information that is applicable:

- The location, area and amount of recharge;
- The location, area and amount that aquifer depletion will be reduced;
- The reach, amount and timing of increased streamflow. Describe how the project will meet these objectives and what the source of the water is;
- Provide a detailed listing of cross basin benefits, if any.

Location, Area, and Amount of Recharge

The results of the hydrogeologic mapping will result in actionable information for the implementation of canal recharge projects along the 19 miles (30 km) between Palisade and Culbertson in the Frenchman Creek valley. The maximum amount of recharge that could be achieved by MAR relates to the FVID surface water appropriations on Frenchman Creek (D-24 R and A-9802 R), which specify a total of 132.75 cubic feet per second (cfs) from Frenchman Creek at the Culbertson Canal diversion. Appropriation number D-24 R has a priority date of 5/16/1890, and A9802 R dates to 3/17/1960. The MRNRD has an agreement with FVID that outlines a plan to use the irrigation delivery system to study the effects and benefits of MAR (Attachment 2). The agreement allows the FVID to deliver water to those irrigators

requesting it, while allowing the MRNRD and FVID to gather data to quantify the recharge benefit.

The amount of water potentially available for canal recharge can be estimated from annual water distribution records kept by the U.S. Bureau of Reclamation. Between 1999 and 2012, maximum annual losses from mains and laterals of the Culbertson Canal system was 8,246 acre-feet (in 2009). These losses represent total losses to seepage and evaporation. A recent study by Brown & Caldwell identified 7,893 acre-feet of canal seepage and 178 acre-feet of evaporation losses.

Location, Area, and Amount of Reduced Aquifer Depletion

The project area extends from northwestern Hayes County to northeastern Hitchcock County (Figure 1). This area has experienced the largest aquifer depletions in the MRNRD, both in terms of absolute magnitude and percentage of the saturated thickness. The average groundwater-level decline from predevelopment to 2016 in the project area was 12.7 ft. The maximum decline was 33.5 ft.

Reach, Amount, and Timing of Increased Streamflow

A recent study by Brown & Caldwell simulated seepage losses in the canal using the Republican River Compact Accounting (RRCA) model. A single value for bed conductivity and thickness was used for the entire canal reach. The total return to the stream from canal seepage and in-field losses in 2015 data was estimated to be 7,474 acre-feet.

The hydrogeologic mapping proposed here would be used to optimize site placement and maximize recharge potential to the aquifer with the available water. Rather than use a single number representing bed conductivity, as in the Brown & Caldwell study, the hydrogeologic properties and thicknesses of various subsurface units will be estimated along the entire canal reach using advanced techniques derived from geophysical surveys. This will allow a more detailed look at seepage through the canal, its storage in the aquifer, and the timing and location of its potential return to the stream.

The FVID has surface water appropriations on Frenchman Creek (D-24 R and A-9802 R) for 132.75 cubic feet per second (cfs) at the Culbertson Canal diversion. The use of this water is spelled out in Section 2 of the long term lease agreement between MRNRD and FVID. The FVID agrees to divert water and utilize the water delivery system to create groundwater recharge and flow augmentation to the Republican River for Compact compliance and credits. This water is available when the FVID is

not delivering water to its patrons. The results of the hydrogeologic mapping in this proposal will be used to make immediate decisions about the implementation of this agreement.

4. Contributes to multiple water supply goals, including, but not limited to, flood control, agricultural use, municipal and industrial uses, recreational benefits, wildlife habitat, conservation of water resources, and preservation of water resources;

- List the goals the project provides benefits.
- Describe how the project will provide these benefits
- Provide a long range forecast of the expected benefits this project could have versus continuing on current path.

Water Supply Goals

This project benefits the water supply goals of the USBR's The Frenchman Cambridge Division. The Division was designed for 66,000 acres of land along the Republican River and its tributaries (Bell, 1997). The goals are to:

- provide reliable irrigation water for increased crop production
- provide flood control
- create recreational opportunities
- preserve wildlife.

In brief, the MRNRD's Integrated Management Plan (IMP) goals are to:

- maintain compliance with the Compact
- ensure that groundwater and surface water users assume their share of maintaining compliance with the Compact
- provide compliance responsibility be apportioned in an equitable and environmentally responsible manner
- protect any increases to streamflow from use that would negate its benefit.

How Project will Provide Benefits

The project lies within the area determined by the Department of Natural Resources to be Hydrologically connected surface water and groundwater for fully appropriated designations (DNR, 2018). The proposed hydrogeologic mapping and groundwater model simulations will give the MRNRD information to designate new management areas and determine volumes of water necessary to achieve its IMP goals. This may include pumping restrictions, water use allocations, and targeted voluntary conservation programs to reduce aquifer depletion. By slowing, halting, or reversing the depletions, natural stream flow to the Republican River and its tributaries will be

protected, thereby preserving water rights associated with the Frenchman-Cambridge Division water supply systems.

Long Range Forecast

Under current conditions, natural flows in Frenchman Creek and Republican River have been impacted by water table declines from groundwater irrigation. These two streams have experienced substantial declines in streamflows since the mid-1960s (HDR, 2006). Records at several of the stations showed little or no flow at times in the recent past. Annual diversion volumes to Culbertson Canal have steadily decreased since the 1970's (HDR, 2006). Clearly, continuing on the current path means that water supplies to the FVID and FCID canal systems are in jeopardy. Successful implementation of science-based management systems will reduce aquifer depletion and contribute to a more stable and secure surface water supply. A secure water supply means that the goals of the surface water system will be realized well into the future.

5. Maximizes the beneficial use of Nebraska's water resources for the benefit of the state's residents;

- Describe how the project will maximize the increased beneficial use of Nebraska's water resources.
- Describe the beneficial uses that will be reduced, if any.
- Describe how the project provides a beneficial impact to the state's residents.

Maximize Beneficial Use

Beneficial use of the water will be maximized by quantifying the amount, location, and timing of groundwater pumping that can be sustained under Compact stipulations. Over the long-term, the benefit to future generations of humans and other species will be preserved. Water may be put to use only if it is readily available. Given the downward trends in streamflow and groundwater levels in the Republican River basin, the long-term security and availability of this water supply is in question. In order to sustain these water supplies for future generations, water managers need choose between various water management options. Making these choices requires the best available scientific information. The geologic, hydrostratigraphic, and groundwater models derived from the proposed project will provide robust, scientifically defensible information for understanding the interconnected groundwater and surface water supplies in the basin.

Reductions of beneficial use

Beneficial uses will not be reduced directly as a result of the data collection and modeling, but depending on the outcomes of this work, the MRNRD may consider management options or set new irrigation allocations in certain areas. However, through the implementation of the *High-Tech Irrigation* project, as well as an increasing awareness and willingness of producers to be more water-efficient, decreases in consumptive use are already happening in the District through smart irrigation management. The reductions of beneficial use will have a positive impact on the availability of water for future generations.

Beneficial Impact

Beneficial impacts includes assisting with Compact compliance, mitigating and offsetting groundwater depletions, and protecting Nebraska's water infrastructure. Future water sustainability projects in the MRNRD will be informed by scientifically sound maps, models, and research products from the proposed project. This science-based management will help, for example, to properly implement canal recharge projects to ensure timely flow augmentation to the Republican River and to create appropriate offsets for groundwater pumping.

6. Is cost-effective;

- List the estimated construction costs, O/M costs, land and water acquisition costs, alternative options, value of benefits gained.
- Compare these costs to other methods of achieving the same benefits.
- List the costs of the project.
- Describe how it is a cost effective project or alternative.

Costs, Comparisons, and Alternatives

The total cost of $1,175,939 includes geophysical surveys covering 600 mi^2, production of 3D geological and hydrostratigraphic models, targeted drilling to verify subsurface geology, sampling of potential groundwater contaminants, and development of a groundwater model to evaluate water management, recharge, and flow augmentation options. These tools will be used to help the MRNRD achieve its IMP goals and maintain Compact compliance.

Value of Benefits Gained

The benefits gained include increased ability to comply with the Republican River Compact. The cost of non-compliance would be many millions of dollars in legal fees

and payments by the State of Nebraska. As an example, Kansas' most recent lawsuit sought $70 million from Nebraska for noncompliance in 2005-2006. Nebraska paid more than $5 million in the final settlement, but the magnitude of the original litigation request shows what is potentially at stake if Nebraska does not comply with the Compact.

Other methods

Other methods are not viable. One alternative method to the geophysical surveys would be to drill boreholes every 200 ft for 1,634 miles, totaling 43,138 boreholes. It would cost nearly $130,000,000 to drill that many test holes. The Conservation and Survey Division has drilled approximately 6,000 boreholes in Nebraska since 1931. At the historical rate of 67 test holes per year, it would take more than 600 years to drill enough holes to match the spatial sampling frequency of AEM soundings. Clearly this option is not feasible.

Another alternative is to forego data collection and make new groundwater management regulations and build canal recharge projects without the benefits of science. The potential consequences are undesirable and may be costly. This alternative could possibly result in reduced aquifer depletion and provide aquifer recharge, but making uninformed decisions could also result in unnecessary consequences. These include undue restrictions on pumping and loss of farm income, accidental mobilization of contaminants in the vadose zone, and inadequate measures to ensure proper augmentation of flow to the Republican River during times of need.

Cost effectiveness

The estimated cost of the AEM and tTEM surveys, along with the associated research outputs, is $778,343. This is 10 – 30% below similar past projects. This study includes research activities by three different institutions, providing access to some of the world's foremost authorities on geophysical methods. Based on past experience with conducting geophysical surveys in Nebraska, a reasonable cost expectation for AEM data acquisition and basic interpretation ranges from $530 to $681 per line mile (K. Cameron, personal communication). For the 1,634 line miles in this proposal, a cost of $866,020 to $1,112,754 would be expected. An important difference between this survey and most previous surveys is that CSD geologists and a team of outside experts will deliver novel results using newly developed research methods, including geostatistical realizations of hydrogeologic parameters as inputs to MODFLOW. Deliverables will be peer-reviewed. Despite these improvements to the outputs, the cost is below expectations.

7. Helps the state meet its obligations under interstate compacts, decrees, or other state contracts or agreements or federal law;

- Identify the interstate compact, decree, state contract or agreement or federal law.
- Describe how the project will help the state meet its obligations under compacts, decrees, state contracts or agreements or federal law.
- Describe current deficiencies and document how the project will reduce deficiencies.

Interstate Compact

The proposed project will help Nebraska meet its obligations under the Republican River Compact.

How Project Helps Meet Obligations

The proposed project will provide additional groundwater model information for the forecasting of available water supplies and the development of management alternatives. Each year, the DNR forecasts the available short- and long-term streamflow available to comply with the Compact. It utilizes up-to-date information for its groundwater models. The hydrogeologic mapping proposed herein will improve the accuracy of these forecasts. In the event of expected shortfalls, the MRNRD provides DNR with details regarding management alternatives. The proposed study will help the MRNRD develop well-informed management alternatives based on best available science.

The cost of non-compliance would be many millions of dollars in legal fees and payments by the State of Nebraska. As an example, Kansas' most recent lawsuit sought $70 million from Nebraska for noncompliance in 2005-2006. Nebraska paid more than $5 million in the final settlement, but the magnitude of the original litigation request shows what is potentially at stake if Nebraska does not comply with the Compact.

Current Deficiencies

The most recent forecast of allowable depletions in the Republican River Basin (DNR, 2018) shows a 2017-2018 total potential Compact obligation deficit of 20,400. In the MRNRD, the forecast of additional Compact compliance volume that may be required in 2018 is 5,100 acre-feet. The proposed project will help the MRNRD address short- and long-term deficits by providing the necessary information to use MAR as an effective flow augmentation alternative in water-short years.

8. Reduces threats to property damage or protects critical infrastructure that consists of the physical assets, systems, and networks vital to the state or the Untied States such that their incapacitation would have a debilitating effect on public security or public health and safety;

- Identify the property that the project is intended to reduce threats to.
- Describe and quantify reductions in threats to critical infrastructure provided by the project and how the infrastructure is vital to Nebraska or the United States.
- Identify the potential value of cost savings resulting from completion of the project.
- Describe the benefits for public security, public health and safety.

Property

Privately owned water wells in the area are used for drinking water, irrigation, and livestock. The Frenchman Valley Irrigation District (FVID) and Frenchman-Cambridge Irrigation District (FCID) provide irrigation water supply via a system of canals, laterals, and ditches. These water delivery systems are critical to the local agricultural economy.

Reductions in threats

Groundwater contamination threatens drinking and livestock water supplies for rural residents. Storage of higher quality water in the aquifer will reduce the threat to well contamination by nitrate-N and other contaminants in the area.

Reducing aquifer depletion in western Hayes County will minimize additional streamflow reductions in Frenchman Creek and the Republican River. This will help preserve natural flows in the streams. These natural flows are critical to the delivery of surface water to the canals and the long-term viability of surface water irrigation in the FVID and FCID.

Potential Value of Cost Savings

The benefits gained include increased ability to comply with the Republican River Compact. The cost of non-compliance would be many millions of dollars in legal fees and payments by the State of Nebraska. As an example, Kansas' most recent lawsuit sought $70 million from Nebraska for noncompliance in 2005-2006. Nebraska paid more than $5 million in the final settlement, but the magnitude of the original

litigation request shows what is potentially at stake if Nebraska does not comply with the Compact.

Benefits to Public Security, Health and Safety

This project greatly enhances the accuracy and predictive power of hydrologic models. Accurate models of Nebraska's natural and man-made water systems are necessary to provide a secure supply for all beneficial uses. A secure supply of good quality water is fundamental to public health and safety.

9. Improves water quality;

- Describe what quality issue(s) is/are to be improved.
- Describe and quantify how the project improves water quality, what is the target area, what is the population or acreage receiving benefits, what is the usage of the water: residential, industrial, agriculture or recreational.
- Describe other possible solutions to remedy this issue.
- Describe the history of the water quality issue including previous attempts to remedy the problem and the results obtained.

Quality Issues

Elevated levels of nitrate-nitrogen have been detected in groundwater in northeastern Hitchcock County near Culbertson Canal (NDEQ, 2017), where MAR sites will be eventually be located. Moreover, high concentrations of naturally occuring vadose zone nitrate have been previously identified in south central Nebraska (Boyce et al 1974; Spalding, 1996). Uranium and arsenic are also known groundwater contaminants for this area.

Description

Assessment of uranium, arsenic, and nitrate levels in the vadose zone will help determine the suitability of the managed aquifer recharge sites. MAR will improve groundwater quality through the deliberate recharge of the groundwater using good quality surface water. The rural populations of southern Hayes and northern Hitchcock counties, including the Village of Culbertson, population 578, will receive benefits of improved water quality. The water supply for the City of McCook, population 7,540 (www.census.gov), is affected by nitrate and uranium and has to undergo treatment before use. Although it is located 10 miles downstream of the proposed project, groundwater flows from the end of the canal toward McCook, so recharge could help to improve groundwater quality downstream of the canal terminus.

History of Tried Solutions

In 1992, the MRNRD enacted a Special Protection Area for groundwater quality in the southern part of the District. The purpose of the area is the reduce nitrate contamination in groundwater. The City of McCook operates a treatment plant to remove nitrate, arsenic, and uranium from its water supply prior to distribution. http://www.cityofmccook.com/index.aspx?NID=106 https://sdwis-dhhs.ne.gov:8443/DWW/

10. Has utilized all available funding resources of the local jurisdiction to support the program, project, or activity;

- Identify the local jurisdiction that supports the project.
- List current property tax levy, valuations, or other sources of revenue for the sponsoring entity.
- List other funding sources for the project.

Local Jurisdiction

The Middle Republican Natural Resources District (MRNRD) is the local jurisdiction that supports the project.

Sources of Revenue

The MRNRD has a 3.1846 mil levy. The Republican River Basin has been found to be fully appropriated and therefore it is subject to irrigated occupation tax. Occupation Tax in the District is as follows:

- 2007 = $7.04 per acre
- 2010 = $4.90 per acre
- 2011 = $8.50 per acre
- 2012 = $9.43 per acre
- since 2013 = $10.00 per acre (maximum limit).

Other funding

No other sources of funding are available at this time

11. Has a local jurisdiction with plans in place that support sustainable water use;

- List the local jurisdiction and identify specific plans being referenced that are in place to support sustainable water use.
- Provide the history of work completed to achieve the goals of these plans.
- List which goals and objectives this project will provide benefits for and how this project supports or contributes to those plans.
- Describe and quantify how the project supports sustainable water use, what is the target area, what is the population or acreage receiving benefits, what is the usage of the water: residential, industrial, agriculture or recreational.
- List all stakeholders involved in project.
- Identify who benefits from this project.

Local Jurisdiction

The Middle Republican Natural Resources District (MRNRD) and the Department of Natural Resources jointly developed an Integrated Management Plan (IMP), effective January 15, 2016. This plan is in place to support sustainable water use.

History of work completed

The MRNRD has had allocations since 2005. The allocation periods have been set as 2005 – 2007, 2008 – 2012, and 2013 – 2017. Average usage per year (in inches) was as follows:

- 2005 – 8.81
- 2006 – 10.01
- 2007 – 8.23
- 2008 – 8.90
- 2009 – 8.14
- 2010 – 7.85
- 2011 – 8.44
- 2012 – 16.78
- 2013 – 10.13
- 2014 – 9.07
- 2015 – 9.75
- 2016 – 10.25
- 2017 – 10.84

Goals and Objectives

In brief, the MRNRD's Integrated Management Plan (IMP) goals are to:

- maintain compliance with the Compact
- ensure that groundwater and surface water users assume their share of maintaining compliance with the Compact

- provide compliance responsibility be apportioned in an equitable and environmentally responsible manner
- protect any increases to streamflow from use that would negate its benefit.

How Project Supports Sustainable Water Use

This project will provide the best available scientific information for evaluating management alternatives to reduce or stabilize aquifer depletion in Hayes County and provide MAR to Frenchman Creek valley. These outcomes will directly help Nebraska maintain compliance with the Compact by reducing near- and long-term depletions to streamflow.

The groundwater model developed from this project will allow hydrologists to compute the impacts of proposed management actions on groundwater levels and streamflows. The model will aid in determining the share of compliance responsibility shared between reductions in consumptive uses and managed aquifer recharge. The hydrogeological mapping and groundwater modeling proposed herein will provide the best available analysis of hydrologic connections between aquifers, streams, and canals in the project area.

Benefits to Stakeholders

Stakeholders that will benefit include groundwater irrigators, surface water irrigators, rural residents that rely on groundwater for domestic purposes, residents in villages and cities who rely on groundwater for municipal supply, as well as those who value recreation and wildlife provided by surface water and groundwater-dependent ecosystems.

12. Addresses a statewide problem or issue;

- List the issues or problems addressed by the project and why they should be considered statewide.
- Describe how the project will address each issue and/or problem.
- Describe the total number of people and/or total number of acres that would receive benefits.
- Identify the benefit, to the state, this project would provide.

Issues Addressed

Aquifer depletion and declining stream are issues of statewide significance because they:

- threaten our ability to comply with Interstate Compacts, Decrees, and Agreements,
- reduce water available for irrigation, which is key to Nebraska's agricultural economy,
- have a negative impact on recreation and wildlife in streams and reservoirs.

How Project will Address Issues

The proposed project will help the MRNRD achieve its stated goal of assisting in long-term Compact compliance, and reducing its existing groundwater use within the District by 20% from the 1998 to 2002 baseline pumping volumes. When combined with streamflow augmentation and incentive programs, the MRNRD's groundwater deletions will be maintained within its portion of Nebraska's Allowable Groundwater Depletions as computed through use of the Republican River Compact Administration Groundwater Model.

People and Acres Receiving Benefits

The MRNRD covers 3,843 square miles (2,459,520 acres) of land in southeast Nebraska. Land use comprises 54% rangeland, 33.5% dry land farming, and 12.5% irrigated farming. The project area covers 600 square miles (384,000) of the most heavily irrigated acreage in the District. However, the benefits of the project will go beyond the boundaries of the project area because groundwater and surface water are interconnected throughout the greater Republican River basin.

Benefit to the State

The proposed project will deliver a new suite of innovative models for water resources management and infrastructure changes. The methods can be adapted to other areas of the state that have experienced problems similar to those in the MRNRD. Hydrologists using these methods and tools will be able to assess water management alternatives using a much-improved understanding of the hydrogeologic framework, drawing upon the latest scientific research and technology.

13. Contributes to the state's ability to leverage state dollars with local or federal government partners or other partners to maximize the use of its resources;

- List other funding sources or other partners, and the amount each will contribute, in a funding matrix.
- Describe how each source of funding is made available if the project is funded.

- Provide a copy or evidence of each commitment, for each separate source, of match dollars and funding partners.
- Describe how you will proceed if other funding sources do not come through.

Funding Matrix

Funding Source **indicates partner with no direct cash contribution*	July 1, 2019 to June 30, 2020	July 1, 2020 to June 30, 2021	Total Cost
WSF REQUEST	$295,280	$402,008	$697,289
MRNRD COST SHARE	$196,854	$268,006	$464,859
UNL Conservation and Survey Division	--	--	--
TOTAL PROJECT COST	**$492,134**	**$670,014**	**$1,162,148**

Funding Availability

The MRNRD has a 3.1846 mil levy. The Republican River Basin has been found to be fully appropriated and therefore it is subject to irrigated occupation tax, which is currently maxed out at $10/acre. Funding as been made available in the MRNRD annual budget.

How Project will Proceed

If WSF funding is not approved, MRNRD will continue to collect data and develop models for improved water management. However, the completion of these tasks will be seriously delayed, and water sustainability goals may not be met within the planning timeframe. Furthermore, if WSF funds are not available, many of the innovative methods proposed herein may need to be delayed or cut altogether.

14. Contributes to watershed health and function;

- Describe how the project will contribute to watershed health and function in detail and list all of the watersheds affected.

How Project Contributes to Watershed Health and Function

This project will contribute to the improvement of groundwater quality and quantity, thus increasing the health and function of the Frenchman Creek watershed within the Republican basin. Managed aquifer recharge (MAR) will provide flows to Frenchman Creek and the Republican River. Measurement of nitrate, uranium, and arsenic in the vadose zone will inform the design of canal recharge projects so as to prevent accidental mobilization of these contaminants by infiltrating water and help better evaluate locations for recharge. MAR can be used to limit the pollution of surface water through geo-purification and natural attenuation. Use of good quality water for aquifer recharge will dilute existing nitrate contamination in the alluvial aquifer and in any return flow to the stream.

15. Uses objectives described in the annual report and plan of work for the state water planning and review process issued by the department.

- Identify the date of the Annual Report utilized.
- List any and all objectives of the Annual Report intended to be met by the project
- Explain how the project meets each objective.

Annual Report

The Annual Report is dated September, 2017
https://dnr.nebraska.gov/sites/dnr.nebraska.gov/files/doc/water-planning/statewide/annual-report-to-legislature/2017/20170914_2017AnnualReportToLegislature.pdf

Objectives

The four-year work projection for the Republican basin identifies the following objectives:

- Technical analyses to develop and test specific conjunctive management action scenarios via modeling tool outputs
- Review of Integrated Management Plans
- Development of a Basin-Wide Plan
- Ensure compliance with the Compact
- Prioritize and evaluate data collection needs

How Project Meets Objectives

The project provides technical analyses specifically related to conjunctive management. The hydrogeologic evaluation of the Culbertson Canal system will

allow the MRNRD to determine best strategies and actions to utilize or store excess surface water when it is available and use groundwater during periods of limited surface water availability. The geologic and hydrostratigraphic model results will be input to a groundwater model to analyze the effects of changing the timing and location of water, so it can be used more efficiently.

The proposed project will deliver a new suite of innovative models for water resources management and infrastructure changes. These models are pertinent to the IMP jointly developed by the DNR and MRNRD, as well as the development of a new Basin-Wide Plan for the Republican basin. The underlying goal of these plans is to ensure compliance with the Compact. The tools developed from this project will directly contribute to the state's ability to achieve this goal.

16. Federal Mandate Bonus. If you believe that your project is designed to meet the requirements of a federal mandate which furthers the goals of the WSF, then:

- Describe the federal mandate.
- Provide documentary evidence of the federal mandate.
- Describe how the project meets the requirements of the federal mandate.
- Describe the relationship between the federal mandate and how the project furthers the goals of water sustainability.

Federal Mandate

The Republican River Compact is a federal mandate. The Supreme Court rulings, including the Final Settlement Stipulation of 2002 and the Court decisions of 2015, are federal mandates (2 USCS § 1555).

Documentary Evidence

The Republican River Compact is documented in Nebraska Revised Statute 1-106 https://nebraskalegislature.gov/laws/appendix.php?section=1-106

The 2002 Final Settlement Stipulation is available from the Department of Natural Resources https://dnr.nebraska.gov/sites/dnr.nebraska.gov/files/doc/water-planning/upper-platte/republican-river-compact/final-settlement.pdf

The Court decisions of 2015 are available from the Department of Natural Resources https://dnr.nebraska.gov/sites/dnr.nebraska.gov/files/doc/water-planning/upper-platte/republican-river-compact/20150224-kansas-v-ne.pdf

How Project Meets Requirements

This project will provide the best available scientific information for making management decisions that help the MRNRD do its part to maintain compliance with the Compact. These management actions will be aimed at stabilizing the groundwater levels in Hayes County and providing recharge to the alluvial aquifer in Frenchman Creek valley. Stabilizing declines will help reduce long-term depletions to streamflow. Recharge to the alluvial aquifer will offset the effects of pumping during times when water is needed throughout the basin. It will also provide near-term and long-term stability of streamflow to Frenchman Creek, which will provide augmentation of flow to the Republican River. These outcomes will directly help Nebraska maintain compliance with the Compact by reducing near- and long-term depletions to streamflow.

Relationship Between Federal Mandate and Water Sustainability Goals

The primary goal of the IMP is to maintain compliance with the Compact.

Goal 1. In cooperation with the State of Nebraska and the other NRDs, maintain compliance with the Compact as adopted in 1943 and as implemented in accordance with the Settlement Agreement approved by the United States Supreme Court on May 19, 2003.

Section D.

PROJECT DESCRIPTION

1. Overview

In 1,000 characters *or less*, provide a brief description of your project including the nature and purpose of the project and objectives of the project.

Groundwater levels have dropped as much as 30 ft in the MRNRD since the 1960's. Flows to the Republican River and its tributaries have declined substantially. These issues threaten Nebraska's ability to comply with the Republican River Compact. The proposed project will build a foundation of hydrogeological knowledge from which to implement water sustainability actions aimed at reducing aquifer depletion in western Hayes County and developing a managed aquifer recharge (MAR) system along Culbertson Canal to augment flow to the Republican River.

The proposed project will deliver a new suite of innovative models for water resources management and infrastructure changes. It will use leading tools and methods including airborne electromagnetics (AEM), towed transient electromagnetics (tTEM), subsurface sampling, and sophisticated computer models. Aquifer parameter estimates and associated uncertainties will be incorporated into a MODFLOW groundwater model for simulating the impacts of various management alternatives on aquifer depletion, streamflow, and canal recharge.

2. Project Tasks and Timeline

Identify what activities will be conducted by the project. For multiyear projects please list what activities are to be completed each year.

This project is proposed as a two-year project.

Year 1
Conduct AEM survey of western Hayes County
Drill test holes in support of AEM survey
Conduct geophysical processing and inversion of AEM data
Build 3D geological models using AEM inversions
Construct hydrostratigraphic models using geological models and AEM inversions
Year 2
Conduct towed electromagnetic (tTEM) survey of Culbertson Canal
Drill vadose zone cores and analyze geochemistry of samples in support of tTEM survey
Conduct geophysical processing and inversion of tTEM data
Build MODFLOW model of Frenchman Creek basin and input hydrostratigraphic model ensemble into local grid refinement
Run groundwater model simulations and provide outputs and reports to MRNRD
Prepare reports and publications of results

3. Partnerships

Identify the roles and responsibilities of agencies and groups involved in the proposed project regardless of whether each is an additional funding source. List any other sources of funding that have been approached for project support and that have officially turned you down. Attach the rejection letter.

Middle Republican NRD (MRNRD): The MRNRD will administer the grant, if awarded, and secure a subaward contract with CSD to carry out the geophysical surveys, geologic/hydrostratigraphic modeling, and drilling/sampling. The MRNRD will provide assistance with project logistics and land access when necessary.

MRNRD will also secure a contract with a groundwater modeling consultant of their choice, under the advise of teams from CSD, GEUS, and Aarhus University, to ensure

tight project collaboration and transfer of knowledge. The consultant will be experienced in model development for the Republican River basin, and will have the necessary competencies to carry out the work plans set out in this proposal.

Conservation and Survey Division (CSD): CSD geologists will work closely with the GEUS and Aarhus, securing subawards to implement the proposed work plan. This will include developing software projects, handling data, and conducting modeling work. CSD will coordinate the preparation of reports and publications.
CSD geologists and hydrogeologists will perform all necessary planning and logistics related to the AEM survey, including defining system specifications, securing technical details in agreements with contractors, and coordinating the work items with the subawardees. In addition, CSD will gather background information and collect new data. The CSD test hole drilling program will conduct all necessary drilling operations for the project and geologists will log the test holes. CSD will manage all data associated with the project and provide long-term security of the data via Nebraska GeoCloud.

Geological Survey of Denmark and Greenland (GEUS): The GEUS team will process the geophysical data and run geophysical inversions. The GEUS team will use geological knowledge in the inversions by applying a-priori information and/or specifying targeted regularization constraints. Successful application of this workflow involves tight collaboration between the GEUS geophysicists and the Nebraska geologists whereby each group iteratively checks the mutual consistency between the geophysics and the geological expectations. Thus, the workflow requires many geophysical inversion runs to develop a consistent geophysical-geological interpretation.

Aarhus University: The Aarhus group will assist with project planning and daily quality control of the acquired tTEM data during the survey. Aarhus will test equipment, prepare it, and handle shipment; will travel to the US to start up the survey and train local personnel in operation of the tTEM system; report project findings; and provide daily quality control of the acquired data. The Aarhus team will lead the development of geostatistically-derived hydrostratigraphic models. Aarhus will use Multiple Point Statistics (MPS) or other techniques to reproduce spatial patterns of subsurface geology from a Training Image (TI). Aarhus will work closely with the CSD and GEUS teams to deliver products, transfer knowledge, and communicate results.

4. Other Sources of Funding

Identify the costs of the entire project, what costs each other source of funding will be applied to, and whether each of these other sources of funding is confirmed. If not, please identify those entities and list the date when confirmation is expected. Explain how you will implement the project if these sources are not obtained.

See Attachment 3 for documentation of CSD-UNL budgeted items, shown here with asterisk*.

Task	*Budget justification*	*Year 1*	*Year 2*	*Total cost*
**Airborne electromagnetic survey (AEM) of western Hayes County*	Contracted to geophysical survey company. Survey area is 2000 km^2. Line spacing is 1 km, totaling 2000 line kilometers. Estimated cost is $130 per line km.	$260,000		$260,000
**Towed electromagnetic survey (tTEM) of Culbertson canal*	Cooperative agreement with Aarhus University. Approximately 21 days of equipment use and technical support.		$76,766	$76,766
**Drilling and sampling to support geophysical survey interpretation.*	Test hole drilling, coring, and geochemical sampling. 4500 ft of drilling. Lab costs for 325 samples at 10 sites.	$11,000	$22,805	$33,805
**Senior personnel and graduate student hours.*	Planning, logistics, and implementation of field studies. Laboratory analyses and modeling work. Approximately 12 person-months.	$55,470	$71,251	$126,721
**Outside expertise for processing, inversion, and modeling of geophysical and geological data*	Consultation with geophysicists and geologists at Geological Survey of Denmark and Greenland (GEUS)	$117,144	$83,827	$200,971
	Consultation with geophysicists at Aarhus University	$24,000	$26,025	$50,025
**Direct expenses for travel, software licensing, and database development*	Travel includes two trips to Denmark and four trips to field site. Software licensing and database development for Nebraska team only. Publication costs for reports and maps.	$24,520	$39,340	$63,860
Groundwater model development	Contract with consuting firm to build groundwater model incorporating inputs from AEM and tTEM surveys		$350,000	$350,000
WSF REQUEST		$295,280	$402,008	$697,289
MRNRD COST SHARE		$196,854	$268,006	$464,859
TOTAL PROJECT COST		**$492,134**	**$670,014**	**$1,162,148**

5. Support/Opposition

Discuss both support and opposition to the project, including the group or interest each represents.

Support for the project has been expressed from the Frenchman Valley Irrigation District (FVID) and Frenchman Cambridge Irrigation District (FCID). See attached letters of support.

No known opposition to the project has been expressed.