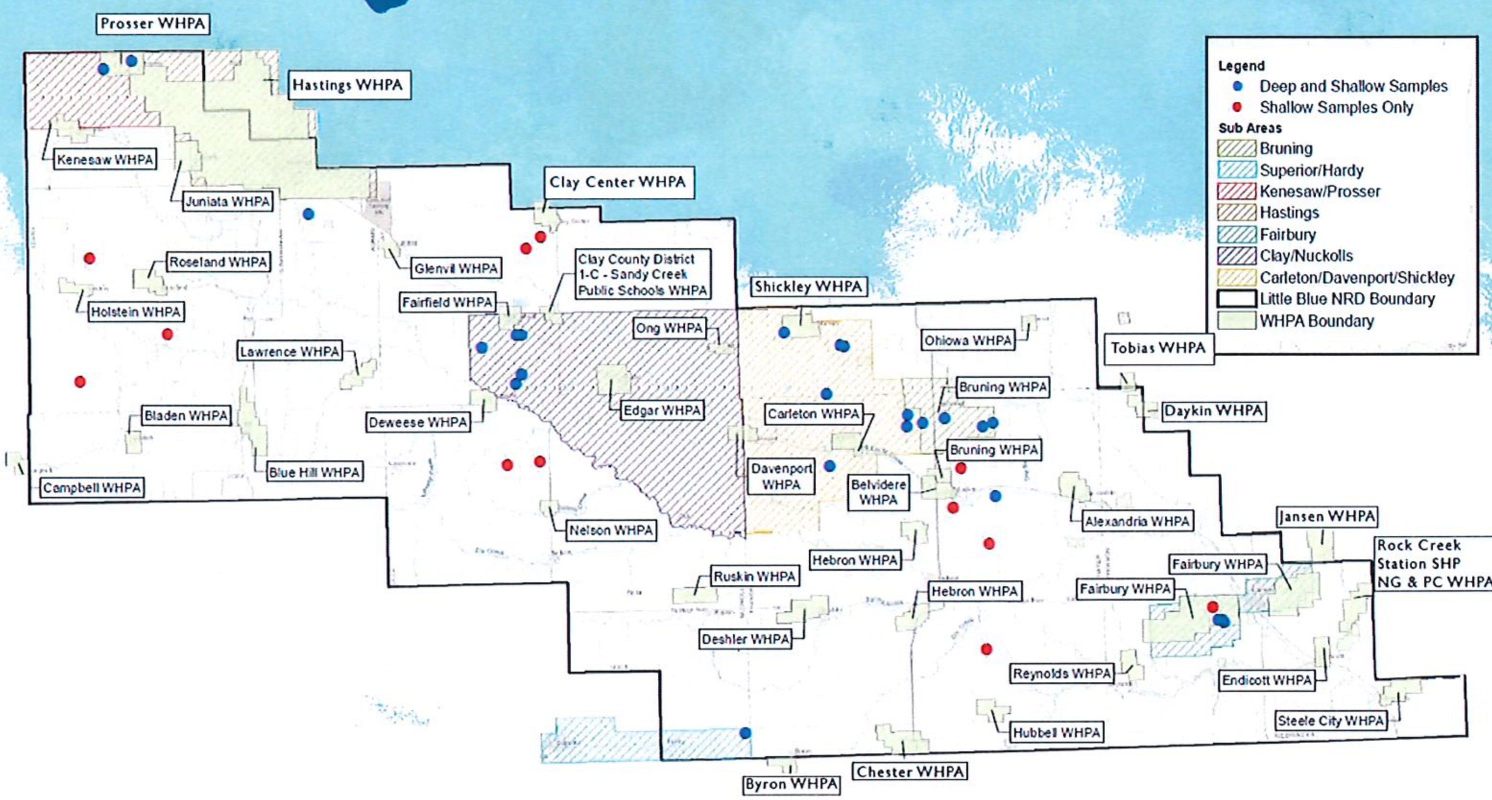
Out of the Blue

Special Edition 2022

Newsletter for Little Blue Natural Resources District



Vadose Zone Assessment Report

INTRODUCTION

In 2015, a Vadose Zone Assessment was completed in support of the development of the Little Blue River Basin Water Management Plan (Plan) and to identify the effectiveness of nitrate management efforts relative to nitrate concentrations in the vadose zone and groundwater. Based on the Vadose Zone Monitoring Program outlined in the Plan, a second Vadose Zone Assessment study was completed in late 2020, (see sampling site map above,) aimed to replicate the sampling and analysis efforts of the Vadose Zone Assessment completed in April of 2015 to provide quantifiable data on the effectiveness of ongoing nutrient management efforts, provide additional groundwater and vadose zone data, and provide Little Blue Natural Resources District (LBNRD) with a direct comparison of nitrate concentrations from 2015 to 2020 in specific areas of land use such as irrigated row crop, pasture, etc. In addition to replicating the information gathered during the 2015 Assessment, this Vadose Zone Assessment also includes the analysis of ammonium on all samples, soil moisture, pH, and texture on the deep samples.

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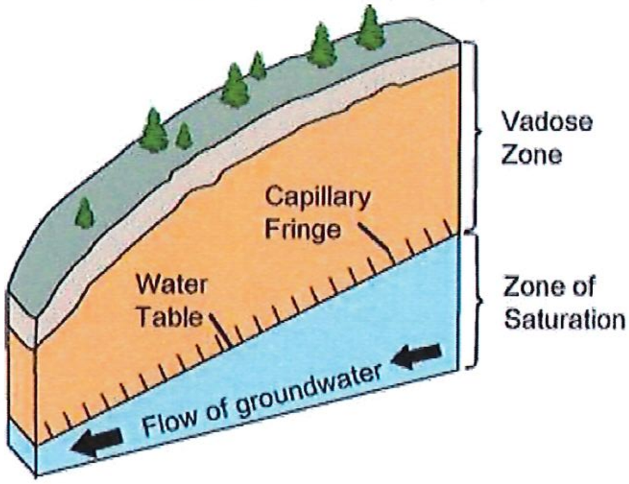
WHAT IS THE VADOSE ZONE?

The vadose zone is the area between the land surface and the top of the water table (see figure below).

When nitrogen fertilizer is applied to the surface and makes its way into the vadose zone, the nitrogen is either utilized biologically by the crop being grown or it works its way downward to the aquifer. This is why the amount and timing of fertilizer application is so vital to helping keep nitrates out of the groundwater.

Vadose Zone Illustration



LITTLE BLUE NRD GROUNDWATER QUALITY MANAGEMENT

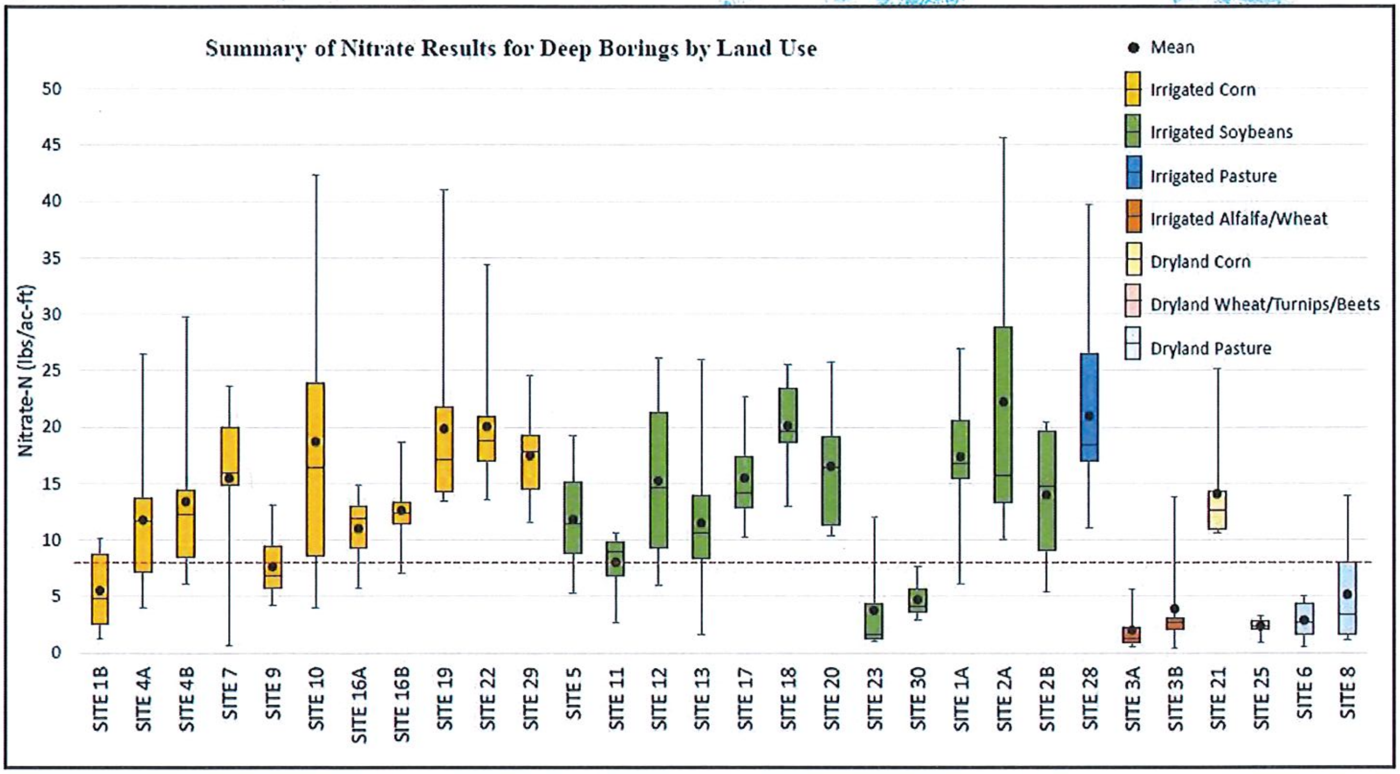
Little Blue NRD's philosophy regarding groundwater problems is that prevention is less costly than correction. Therefore, the district has adopted programs that emphasize proactive protection of groundwater, rather than a reactive, corrective approach. LBNRD established its first Groundwater Management Plan in July of 1986. Rules and Regulations for enforcement of the LBNRD Groundwater Management Area were revised and effective as of April 2022. The Rules and Regulations outline the entire LBNRD as a Level I Management Area. Groundwater users within the Level I Water Quality Management Area are to comply with requirements related to well construction, well spacing, water transfers, flowmeters, certification of well and acres, water use reporting, nitrogen fertilizer restrictions, and determination of groundwater level changes. The objectives of this Groundwater Management Plan are to describe the water resources of the LBNRD, document the uses and demands on the resource, explain what measures are already in place to manage the resources, and describe measures that the LBNRD will use in the future, should conditions dictate, to achieve the Reservoir Life Goal established by the LBNRD Board of Directors. The LBNRD also updated the Groundwater Management Plan to incorporate new hydrogeologic information and monitoring data which have been valuable in assessing the groundwater conditions and evaluating the direction of actions necessary to protect the resources for future generations.

LBNRD Board of Directors approved and adopted an Integrated Management Plan developed cooperatively with the Nebraska Department of Natural Resources (NDNR) in August 2019. This plan will serve as a road map for jointly managing hydrologically connected groundwater and surface water in the District for the short term and the long term. It further serves as a framework which enables the District and the Department to coordinate management actions and monitor groundwater and surface water, in order to better protect water resources for future generations.

EVALUATION OF 2020 RESULTS

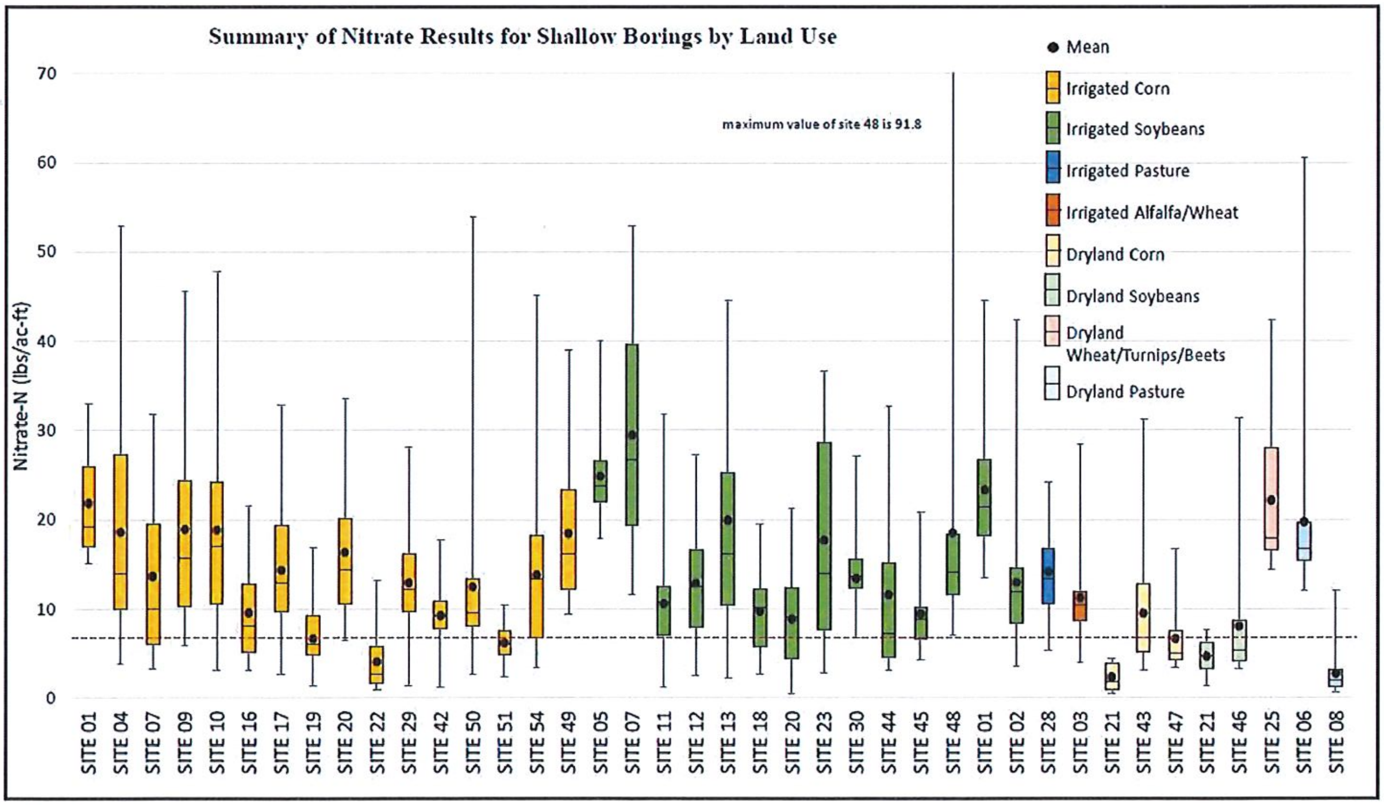
Background Nitrate Levels in Vadose Zone

Nitrogen is present in every natural system, at different levels. These naturally occurring nitrogen levels are commonly referred to as background levels. Previous investigations used 8 lbs/ac-ft to represent background nitrate concentrations, therefore, individual sample results above 8 lbs/ac-ft were considered to be elevated in this investigation.



Deep Borings

The results from the deep soil borings are summarized in the graph above, differentiated by land use.



Shallow Borings

The results from the shallow soil borings are summarized in the graph above. Each site typically included five shallow borings. The graph represents a combination of all five borings for each site grouped by land use.

Root Zone Analysis

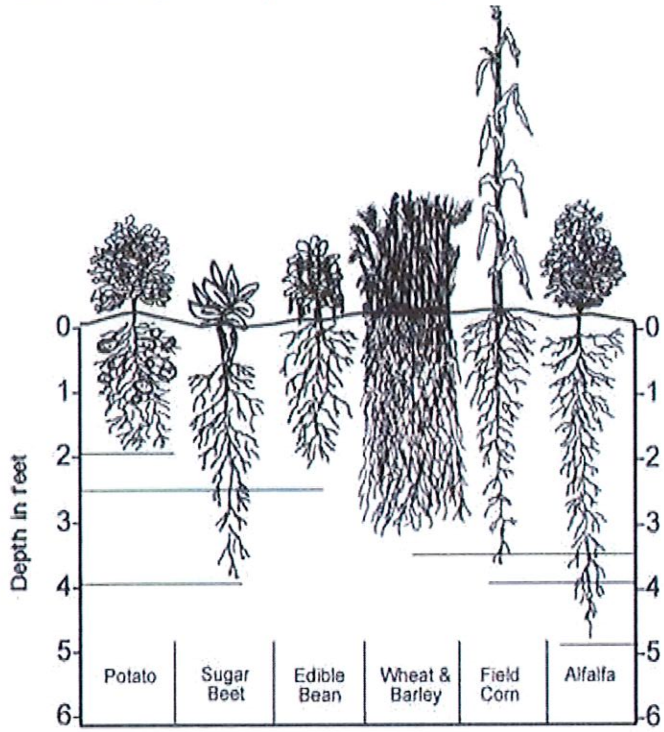
For all sites combined, the average nitrate in the root zone (0-6 ft) was 10.9 lbs/ac-ft and the average nitrate below the root zone (6-15 ft) was 14.6 lbs/ac-ft. In comparison, from the 2015 Assessment, considering only the sites that were included in both studies (2020 and 2015), the combined average nitrate in the root zone (0-6 ft) was 12.3 lbs/ac-ft and the average nitrate below the root zone (6-15 ft) was 10.7 lbs/ac-ft. For all sites sampled in the 2015 Assessment, the average nitrate in the root zone (0-6 ft) was 11.3 lbs/ac-ft and the average nitrate below the root zone (6- 15 ft) was 10.2 lbs/ac-ft. The table below shows a breakdown by land use for 2020 shallow sampling results.

Summary of Nitrate Results for Shallow Borings by Root Zone

Land Use	Nitrate-N (lbs/ac-ft)	
	Above Root Zone (0-6 ft)	Below Root Zone (6-15 ft)
Irrigated Corn	10.8	13.8
Irrigated Corn/Rye* (1)	18.1	18.6
Irrigated Soybeans	12.3	16.9
Irrigated Soybeans/Rye/Wheat* (3)	16.7	17.9
Irrigated Pasture	12.2	15.4
Irrigated Alfalfa/Wheat	11.9	10.7
Dryland Corn	6.4	8.2
Dryland Soybeans	3.8	5.2
Dryland Soybeans/Wheat* (1)	5.7	9.5
Dryland Pasture	10.3	11.8
Dryland Wheat/Turnips/Beets*	19.7	23.6

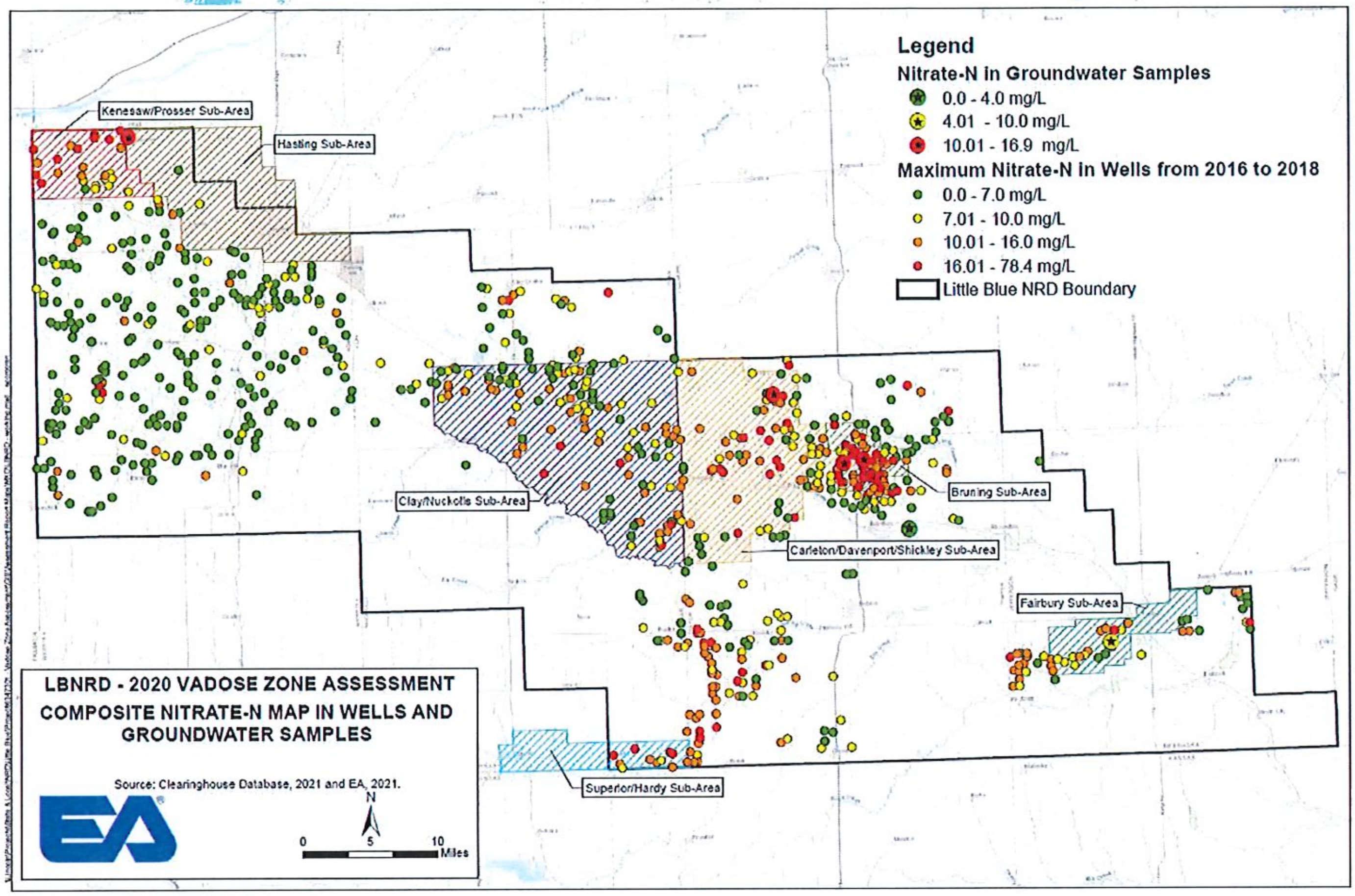
* Cover crop rotation

It was observed that for almost all land uses, higher nitrate was present below the root zone. Another observation was that land use with cover crop rotation has higher average nitrate than their non-cover crop land use counterpart. Cover crops are generally expected to reduce the potential for nitrate leaching from farm fields by mimicking natural ecosystems, such as prairies, where some plant species grow whenever the ground is thawed. They function by accumulating the inorganic soil nitrogen between main crop seasons and holding it in an organic form, thus preventing it from leaching. However, the observations contradict the expected results that sites with cover crop would represent lesser nitrate concentration and reduce nitrate leaching. One of the key reasons may be nitrate management at these sites; for example, if additional fertilizer is applied for the cover crop, there may be more opportunities for the nitrate to leach during irrigation and precipitation events. Since this is an unexpected result, monitoring the sites with cover crop and their management practices may be beneficial.



Nitrate in Groundwater

Nitrate in groundwater is reported in mg/L or ppm. The maximum concentration limit (MCL) is 10 ppm as set by the EPA. Six groundwater samples were collected as a part of the resampling efforts. Four samples recorded above 10 ppm nitrate concentrations, with the maximum being 16.9 ppm at Site 20 which was a soybeans pivot field. In addition, nitrate concentrations in groundwater were obtained from the Clearinghouse Database. LBNRD has a groundwater sampling program that includes sampling of some sites on an annual basis with other sites sampled on a rotational basis. A composite map of groundwater nitrate that includes groundwater nitrate data from 2016 to 2018 provides a recent snapshot of nitrogen across the district. (See Nitrate Map on Page 5.) For wells with multiple sampling results, the highest nitrate value was used.



CONCLUSIONS AND RECOMMENDATIONS

The purpose of the vadose zone assessment was to provide a better understanding of the changes in nitrate within the vadose zone and to assist in identifying the effectiveness of nitrate management efforts relative to nitrate concentrations in the vadose zone and groundwater. The information presented in this Report will support the LBNRD's groundwater quality management efforts.

Conclusions

Based on the results of the vadose zone field data collection and evaluation, the following conclusions are presented, grouped by subject.

General

• Elevated nitrate levels are present in vadose zone and groundwater throughout the district, suggesting that the nitrate levels will likely continue to increase as water leaches through the vadose zone and into the groundwater. Generally, the highest average nitrate levels were found under irrigated cropland, as seen in the summary of nitrate results by land use.

• Average nitrate below the root zone was found to be higher than in the root zone, indicating that nitrate is leaching below the root zone and has potential to affect the groundwater nitrate concentrations in the upcoming years.

• Nitrate results from shallow borings were often found to be different from deep boring results. This could happen for various reasons and can be influenced by multiple factors. When the nitrate is higher in shallow samples but not in deep samples, it might be indicative of recent manure or fertilizer applications. When the nitrate is higher in deep samples, but not in shallow samples, it might indicate improvements to recent management practices. Detailed nutrient management data is often helpful for evaluation of this variability. Having both deep and shallow sampling results provides a more comprehensive understanding of the site than would be obtained if only deep or only shallow sampling were conducted.

• Field surface and soil profile concentrations are highly variable, even within a single field. Results from an individual boring can be non-representative and misleading. To provide a better understanding of actual conditions, multiple samples need to be collected, and evaluated as a group to identify outliers and provide more representative averages.

• Several management areas showed noticeable reduction in some nitrate concentrations, while not in others. Clay/Nuckolls Sub-Area had an increase in nitrate concentration in both deep and shallow borings; however, several sites had land use changes. Carleton/Davenport/Shickley Sub-Area had some reduction in nitrates, but the 2020 results are still above background levels.

Nitrate Loading by Land Use

• Some land use changes were observed and indicated that conversion from a pasture to cropland contributed to increased nitrogen in the vadose zone. In 2020, there were fewer sites with the land use as grass/pasture, or alfalfa; therefore, there was not enough data to establish representative average conditions for these land uses.

• The results suggest that use of a corn-soybean rotation might result in lower nitrate loading in the soil profile compared to continuous corn farming. However, nutrient management appears to be the key factor influencing nitrate loading for both practices.

• The study included only a few dryland row crop sites, but the results indicate that dryland row crop fields would be expected to have noticeably lower nitrate concentrations in the vadose zone than irrigated row crop fields.

Nitrate Management

• LBNRD has rules and regulations in place that relate to water quality, using a stepwise approach (Levels or Phases), with different requirement depending on the Level/Phase. Nitrate management practices required by the NRDs are generally focused on education and training of the producer, fertilizer application requirements, and reporting.

• For the overall LBNRD area, the average nitrate concentration from 2014 to 2020 increased by 1.3 lbs/ac-ft and 1.1 lbs/ac-ft in deep and shallow soil samples, respectively. Out of 36 sampled sites, 20 sites showed increase in nitrate concentration while 16 sites showed decrease in nitrate concentration for shallow sampling averages. Out of 30 deep borings, 12 borings showed an increase in average nitrate concentration, while 18 borings showed a decrease in average nitrate concentration.

• Sites within existing LBNRD Water Quality Sub-Areas with additional management requirements were generally found to have an average of 1.2 N lbs/ac-ft (for shallow sampling) more in comparison to areas outside of the Water Quality Sub-Areas for shallow sampling. Water Quality Sub-Areas were formed to address nitrogen issues in areas with elevated concentrations. Due to the time it takes for nitrogen to migrate through the soil, it often takes years for management practices to substantially affect nitrogen concentrations. Effective nitrogen strategies and monitoring consider the delayed responses between

management actions and measurable differences. Future monitoring should consider these delays, with a time series of measurements to determine the effects of chosen management on soil and groundwater levels.

• There are a few cropland sites in this 2020 Assessment with noticeable reduction in nitrate since 2014. For example, two exceptions to this conclusion include sites 11 and 12, which were found to have average nitrate only slightly above background levels and have reductions of about 7.1 lbs/ac-ft and 15.5 lbs/ac-ft, respectively. Management practices at these two sites included: crop rotation (corn/soybeans), spring application of nitrogen fertilizer, regular use of an agriculture consultant, and regularly following laboratory recommendations from soil sampling results.

• Through the isotope analysis, it was generally found that the source of nitrate at isotope-sampled sites is from commercial ammonia fertilizer.

• Additional management practices exist that could help reduce nitrate levels; however, some of the emerging practices have had minimal research and studies to document effectiveness.

Recommendations

The following recommendations are presented:

• Changes in land use and cropping practices appear to be one of the most effective means to reduce additional nitrate loading to the groundwater system. Wider encouragement of certain crops, irrigation practices, and cropping techniques would be beneficial.

• The nitrate management practices seem to work for some sites, while not for others. Management and monitoring programs need to consider that changes to on-farm practices will take years to manifest in vadose zone sampling results. For example, if the depth to groundwater is 50 ft, and vertical migration of nitrate is about 2.5 ft/yr, it will take about 20 years before the reduced loading due to improve management practices would reach the groundwater. Ongoing monitoring continues to be recommended as the best way to track performance of management practices.

• Sampling of more farms in Clay/Nuckolls Sub-Area is recommended, as the current data suggests noticeable increase of nitrate in the area, largely due to conversion of dryland cropland to irrigated cropland.

• Shallow rather than deep borings may provide a better understanding of the more immediate effects of on-farm management practices. Programs that support use of annual soil sampling and use of crop consultants by producers to optimize nitrogen application are recommended.

• Overall nitrates below the root zone were higher than in the root zone. Continued groundwater monitoring and occasional deep borings are recommended to get a better idea of how the groundwater quality will be affected in the long-term.

• Sites with cover crop showed higher nitrate than their non-cover crop counterparts. This was an unexpected result, and further investigation of cover crop management by the LBNRD is recommended.

• Continued routine monitoring of the vadose zone through deep and shallow sampling every 5 years is recommended. This consistent, long-term approach will help the LBNRD in prioritizing management practices based on their effectiveness of reducing nitrate concentrations.

Recommended Management Practices:

• Diversified Crop Rotation – Diversified crop rotation is the practice of growing and rotating a variety of crops among plots on the same field to encourage crop resistance to pests and pathogens, improve soil conditions by not depleting soil nutrients, and improve soil nutrient content by growing cover.

• Dryland Crops – Dryland crops have been shown to have lower potential for nitrate leaching from farm fields because of the amount of water available to transport the nitrate vertically through the vadose zone is less than irrigated lands. Programs that limit the conversion of dryland to irrigated or encourage conversion from irrigated to dryland would help reduce nitrate loading.

• Alfalfa – Sites where the current land use was alfalfa production were found to have greatly reduced nitrate loading within the vadose zone. Programs that would encourage alfalfa production on lands that are currently used for row crop would help reduce nitrate loading.

• Conservation Reserve Program (CRP) – The CRP is a land conservation program administered by the Farm Service Agency. Well Head Protection Areas are eligible for enrollment into the CRP. Land in the CRP would not require fertilizing, eliminating a primary source of nitrate contamination.

• Continuous No-till Management – No-till systems essentially eliminate tillage, and can decrease soil erosion, minimize fuel and labor requirements, and potentially reduce leaching of nutrients past the root zone.

• Chemigation – Chemigation is the injection of agricultural chemicals into water flowing through an irrigation distribution system for application to land, crops, or both. With chemigation, the rate of application can be regulated, and chemicals may be applied at the exact time needed by plants to produce maximum results.

• Nitrification Inhibitors – Nitrification is the process by which nitrate is formed through the oxidization of ammonium into nitrite and then into nitrate by nitrifying bacteria. Nitrification inhibitors slow this process down, thus maximizing plant uptake of nitrate before leaching occurs.

• Perennial Prairie Strips – Prairie strips consist of native vegetation planted amongst row crop fields. The intent is to enhance the soil health and diversify plant species, thus increasing plant uptake of nitrogen in fields.

• Additional research and studies are needed to evaluate the effectives of emerging technologies such as Variable Rate Irrigation (VRI) and nitrogen inhibitors. Opportunities for the research in these areas should be encouraged through coordination with entities such as UNL, and active pursuit of grant funding opportunities for specific studies.

If you have any questions about this Report, Contact Tyler Goeschel at the Little Blue NRD office in Daventport, NE at 402-364-2145 or email at tgoeschel@littlebluenrd.org.

THANK YOU TO OUR PARTNERS AND COLLABORATORS FOR MAKING THIS VADOSE ZONE ASSESSMENT POSSIBLE.

EA Engineering, Science, and Technology, Inc.

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The Nebraska Environmental Trust
preserving NATURAL NEBRASKA™ for future generations

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