

**PRELIMINARY DRAFT  
PLAN FOR REVIEW**



# Wahoo, Nebraska Wellhead Protection Plan

February 2022

*Supported by:*



*Funding provided by:*



THIS PAGE LEFT INTENTIONALLY BLANK

DRAFT

THIS PAGE TO BE REPLACED AND NDEE APPROVAL LETTER INSERTED AS PDF

THIS PAGE LEFT INTENTIONALLY BLANK

# City of Wahoo, Nebraska



## Wellhead Protection Plan

**NDEE PRELIMINARY REVIEW DRAFT 2-1-2022**

*Prepared: January 2022*

*Adopted by Wahoo: **DATE TO BE INSERTED***

*Approved by NDEE: **DATE TO BE INSERTED***

### Acknowledgements

Preparation of this plan was made possible by funding assistance provided by the Nebraska Department of Environment and Energy Source Water Protection Grants Program.



***Prepared for: Wahoo Department of Utilities, Nebraska***

***Prepared by: JEO Consulting Group, Inc.***

***JEO Project Number: 201011.00***

**PRIMARY WELLHEAD PROTECTION PLAN CONTACTS**

Entity	Name	Title	Phone/Email
Wahoo Department of Utilities	Ryan Hurst	Utilities Manager	402-443-3222 hurst@wahoo.ne.us
City of Wahoo	Melissa Harrell	City Administrator	402-443-3222 harrell@wahoo.ne.us
Nebraska Department of Environment and Energy	Tatiana Davila	Wellhead Protection Coordinator	402.471.3376 Tatiana.davila@nebraska.gov
Lower Platte North NRD	Daryl Andersen	Water Dept. Manager	402.443.4675 dandersen@lpnrd.org

*This wellhead protection plan has been prepared to assist the Wahoo Department of Utilities (DOU) to proactively protect and manage the aquifer that is the source of community drinking water. It has been written with guidance published by the Nebraska Department of Environment and Energy (NDEE).*

***JEO Contact Information:***



**Jonathan Mohr** | Environmental Planner/Scientist

**JEO CONSULTING GROUP INC**

2000 Q Street, Suite 500 | Lincoln, Nebraska 68503

phone: 402.474.8787

[jmohr@jeo.com](mailto:jmohr@jeo.com)

## TABLE OF CONTENTS

List of Tables.....	iv
Table of Figures .....	iv
List of Appendices.....	v
List of Abbreviations and Acronyms.....	v
Nebraska’s Wellhead Protection Program Summary .....	vi
<b>Chapter 1. Introduction .....</b>	<b>1</b>
<b>1.01 About This Plan .....</b>	<b>1</b>
<b>1.02 Future Updates to The Plan .....</b>	<b>1</b>
<b>1.03 Community Background.....</b>	<b>1</b>
<b>1.04 Natural Resources Districts .....</b>	<b>3</b>
<b>1.05 Nebraska Groundwater.....</b>	<b>3</b>
<b>1.06 Groundwater Pollution in Nebraska .....</b>	<b>5</b>
<b>1.07 Groundwater Aquifer .....</b>	<b>10</b>
<b>Chapter 2. Community Water System.....</b>	<b>17</b>
<b>2.01 Nebraska’s Public Water System Program.....</b>	<b>17</b>
<b>2.02 Water System Information.....</b>	<b>17</b>
<b>2.03 Community Well Nitrate Sampling.....</b>	<b>20</b>
<b>Chapter 3. Wellhead Protection Area .....</b>	<b>21</b>
<b>3.01 Delineation .....</b>	<b>21</b>
<b>3.02 Land Use.....</b>	<b>24</b>
<b>Chapter 4. Potential Contaminant Source Inventory .....</b>	<b>27</b>
<b>4.01 Existing Groundwater Contamination.....</b>	<b>34</b>
<b>Chapter 5. Regulatory Authority .....</b>	<b>38</b>
<b>5.01 City of Wahoo.....</b>	<b>38</b>
<b>5.02 Natural Resources Districts .....</b>	<b>41</b>
<b>5.03 State of Nebraska .....</b>	<b>41</b>
<b>Chapter 6. Emergency, Contingency, and Long Term Planning.....</b>	<b>42</b>
<b>6.01 Emergency and Contingency Planning.....</b>	<b>42</b>
<b>6.02 Long Term Planning.....</b>	<b>43</b>
<b>6.03 Drought Planning .....</b>	<b>43</b>
<b>Chapter 7. Management Strategies .....</b>	<b>45</b>
<b>7.01 Activities Completed to Date .....</b>	<b>45</b>
<b>7.02 Planned Activites for the Near Future.....</b>	<b>45</b>
<b>7.03 Potential Activities for Consideration .....</b>	<b>46</b>
<b>7.04 Best Management Practices for Consideration .....</b>	<b>46</b>
<b>Chapter 8. Public Education and Notification .....</b>	<b>48</b>
<b>8.01 Opportunity for Public Input .....</b>	<b>48</b>
<b>8.02 Planning Stakeholder Committee .....</b>	<b>48</b>
<b>8.03 Meeting Summary.....</b>	<b>48</b>
References.....	50
List of Appendices.....	52

**USB Drive** (located in binder cover pocket) - Digital copy of the plan, appendices, and GIS data.

## LIST OF TABLES

Table 1: Municipal Water System Information.....	18
Table 2: Active Municipal Water Supply Well Information .....	18
Table 3: Wahoo Water Use Summary (2016-2020).....	19
Table 4: 2020 Land Use in the WHP Area .....	25
Table 5: Summary of Wahoo Contaminant Source Inventory.....	30
Table 6: Summary of Existing Groundwater Contamination in the Wahoo WHP Area.....	35
Table 7: Required Well Setback Distances, by Nebraska State Titles.....	39
Table 8: NRCS Source Water Protection Priority Practices.....	47
Table 9: Wahoo Wellhead Protection Stakeholder Committee Members.....	48

## TABLE OF FIGURES

Figure 1: Location of Wahoo.....	2
Figure 2: Historical Population of Wahoo.....	3
Figure 3: Density of Active Registered Irrigation Wells - December 2015.....	4
Figure 4: Groundwater Level Changes – Predevelopment to Spring 2019.....	5
Figure 5: Illustration of the Root Zone, Unsaturated Zone, and Groundwater .....	7
Figure 6: Most Recent Nitrate Concentrations from Wells Sampled 2000 - 2019 .....	8
Figure 7: Typical Routes of Groundwater Contamination .....	11
Figure 8: Aquifer Vulnerability, Geologic Cross Section Locations, Nitrate Concentrations .....	13
Figure 9: Hydrogeologic Cross Section J-J' .....	14
Figure 10: Hydrogeologic Cross Section Y-Y'.....	15
Figure 11: Hydrogeologic Cross Section K-K' .....	16
Figure 12: Active Municipal Well Locations.....	18
Figure 13: Average Water Use Between Wahoo and Other Populations.....	20
Figure 14: Nitrate Concentrations in Wahoo City Wells.....	21
Figure 15: Official 2018 Wahoo WHP Area Map with Aerial Background .....	23
Figure 17: Varying Types of Land Use. (A) Irrigated Row crops; (B) Urban setting; (C) Natural vegetation. .....	24
Figure 17: 2020 Land Use and Certified Irrigated Acres in the Wahoo WHP Area.....	26
Figure 18: Common Types of Potential Contaminant Sources. (A) Leaking Fuel Drums; (B) Livestock Waste; (C) Abandoned Wells; (D) Parking Lot Runoff.....	28
Figure 19: Contaminant Source Inventory in the Wahoo WHP Area.....	31
Figure 20: NDEE Regulated Facilities in the Wahoo WHP Area .....	32
Figure 21: Registered Wells in the Wahoo WHP Area .....	33
Figure 22: City of Wahoo ETJ and WHP Area.....	40



## LIST OF APPENDICES

**APPENDIX A: GROUNDWATER MODELING DOCUMENTATION AND MAPS**

**APPENDIX B: PUBLIC WATER SYSTEM DOCUMENTS**

**APPENDIX C: SELECT ORDINANCES AND MUNICIPAL CODES**

**APPENDIX D: CONTAMINANT SOURCE INVENTORY**

**APPENDIX E: EMERGENCY RESPONSE INFORMATION**

**APPENDIX F: PLAN ADOPTION MATERIALS**

**APPENDIX G: DOCUMENTATION OF STAKEHOLDER INVOLVEMENT**

## LIST OF ABBREVIATIONS AND ACRONYMS

BMP	Best Management Practice		
CRP	Conservation Reserve Program	NeDNR	Nebraska Department of Natural Resources
CSD	Conservation & Survey Division		
CSI	Contaminant Source Inventory	NEWARN	Nebraska Water/Wastewater Agency Response Network
Database	Quality Assessed Agrichemical Contaminant Database	NI	Nitrogen Inhibitor
EPA	Environmental Protection Agency	NPDES	National Pollutant Discharge Elimination System
ET	Evapotranspiration	NRD	Natural Resources District
ETJ	Extraterritorial Jurisdiction	NPS	Nonpoint Source Pollution
Gpcpd	Gallons per customer per day	Ppb	Parts per billion
GWMA	Groundwater Management Area	PWSS	Public Water Supply System
GWMP	Groundwater Management Plan	SDWA	Safe Drinking Water Act
GWMPA	Groundwater Management and Protection Act	The city	City of Wahoo
LPNNRD	Lower Platte North Natural Resources District	TOT	Time of Travel
LPSNRD	Lower Platte South Natural Resources District	UNL	University of Nebraska-Lincoln
MCL	Maximum Contaminant Level	USDA	United States Department of Agriculture
Mg/L	milligrams per liter	USGS	United States Geological Survey
NDA	Nebraska Department of Agriculture	VRI	Variable Rate Irrigation
NDEE	Nebraska Department of Environment and Energy	WARN	Water/Wastewater Agency Response Network
NDHHS	Department of Health and Human Services	WhAEM	Wellhead Analytic Element Model
		WHP	Wellhead Protection

---

## NEBRASKA'S WELLHEAD PROTECTION PROGRAM SUMMARY

*A WELLHEAD PROTECTION AREA IS THE SURFACE AND SUBSURFACE AREA SURROUNDING A COMMUNITY DRINKING WATER WELL OR WELL FIELD, THROUGH WHICH CONTAMINANTS ARE REASONABLY LIKELY TO MOVE TOWARD AND REACH SUCH WATER WELL OR WELL FIELD (§46-1502).*

### NEBRASKA'S WELLHEAD PROTECTION PROGRAM

The Nebraska Department of Environment and Energy (NDEE) administers the Wellhead Protection (WHP) Program, which began after the Nebraska Legislature passed LB 1161 in 1998 (Neb. Rev. Stat. §46-1501 – 46-1509), authorizing the Wellhead Protection Area Act. The Act sets up a voluntary process for public water supply systems to implement a local WHP plan. The intent of this WHP planning process is to establish guidelines for communities and other public water suppliers to develop local WHP plans. A WHP plan does not provide any new powers to a community; it serves as a guide to local decision makers tasked with protecting the community drinking water supply. All community public water supplies in Nebraska have a Wellhead Protection Area map as of October 1, 2004.

### WELLHEAD PROTECTION PLAN REQUIREMENTS

1. **Delineate the WHP Area** – A WHP area map that shows the area that is critical for protecting a community's drinking water supply source.
2. **Perform a Contaminant Source Inventory (CSI)** - Conducting a CSI involves locating and documenting activities, structures, and locations which could affect the quality of the drinking water source.
3. **Manage potential contaminants** - After identifying potential contaminant sources within the WHP area, the community can develop projects or other management tools to ensure a safe drinking water supply. This can include: zoning, local ordinances, working with landowners to implement best management practices (BMPs), and public outreach education.
4. **Develop emergency and contingency plans** - These plans assist a community in responding to events such as natural disasters, contamination, and drought.
5. **Educate and involve the public** - Community awareness helps provide citizens with the information they need to protect drinking water, reduce pollution, and increase their participation in wellhead protection efforts.

---

## CHAPTER 1. INTRODUCTION

### 1.01 ABOUT THIS PLAN

This planning document is prepared for the City of Wahoo (the city), led by the Department of Utilities (DOU), as a general guide to manage the source of their drinking water, particularly as it relates to water quality. Adoption of the document is indicative to water system users, the community, and outside agencies that the city values its water system and desires systematic and proactive protection for its drinking water sources. This plan confers no new legal requirements or regulatory authority to the city, or any other entity. Projects and programs implemented through the plan are voluntary.

The planning process is an opportunity to continue to build and develop relationships between all stakeholders while also developing projects and programs. It is a valuable component through which communities engage with the public and project partners to develop source water planning documents. Source water refers to water used as drinking water for public or private water supplies. This can include surface water from streams, rivers, and lakes, as well as groundwater from aquifers. Wahoo's source of drinking water is from local groundwater. Protecting source water reduces risks to public health from contaminated water exposures (EPA, 2018). This planning process brings together community leaders, agency representatives, landowners, and technical specialists – many of which may have competing interests, differences in viewpoints, conflicting terminologies, or a general lack of knowledge about water management. This process challenges stakeholders to re-evaluate their own ideas and continue learning more about source water issues.

### 1.02 FUTURE UPDATES TO THE PLAN

It is recommended that the plan, goals, and action items be reviewed annually by the WHP Stakeholder Committee. Groundwater and WHP related actions should be documented, reported, evaluated, and revised during this time. Five-year updates should include any changes to potential sources of contamination or land use within the WHP area or the addition of a municipal well. Long-term water quality and use trends should be evaluated and extrapolated into future projections to ensure sustainability of the source water is maintained.

NDEE, the Nebraska Department of Health and Human Services (NDHHS), and the Lower Platte North Natural Resources District (LPNNRD) should be consulted during each update to determine if additional information has been developed or if any related regulations or other requirements require a review of the plan.

### 1.03 COMMUNITY BACKGROUND

The City of Wahoo is located in eastern Nebraska, in Saunders County, about 25 miles from both Lincoln and Omaha (Figure 1). The population of Wahoo, now approximately 4,548, has seen steady growth

throughout the 20<sup>th</sup> century (Figure 2). The city is a popular bedroom community for professionals commuting into Omaha and Lincoln.

In addition to the City of Wahoo, private drinking water systems within the WHP area will also benefit from this plan. Approximately 205 rural homes and 144 privately owned registered domestic wells currently exist throughout the WHP area. If groundwater nitrate pollution continues unchecked, safe drinking water may not be available in the future both for the city and private citizens without expensive treatment alternatives. Proper management of water resources within the WHP area is vital to the city's future.

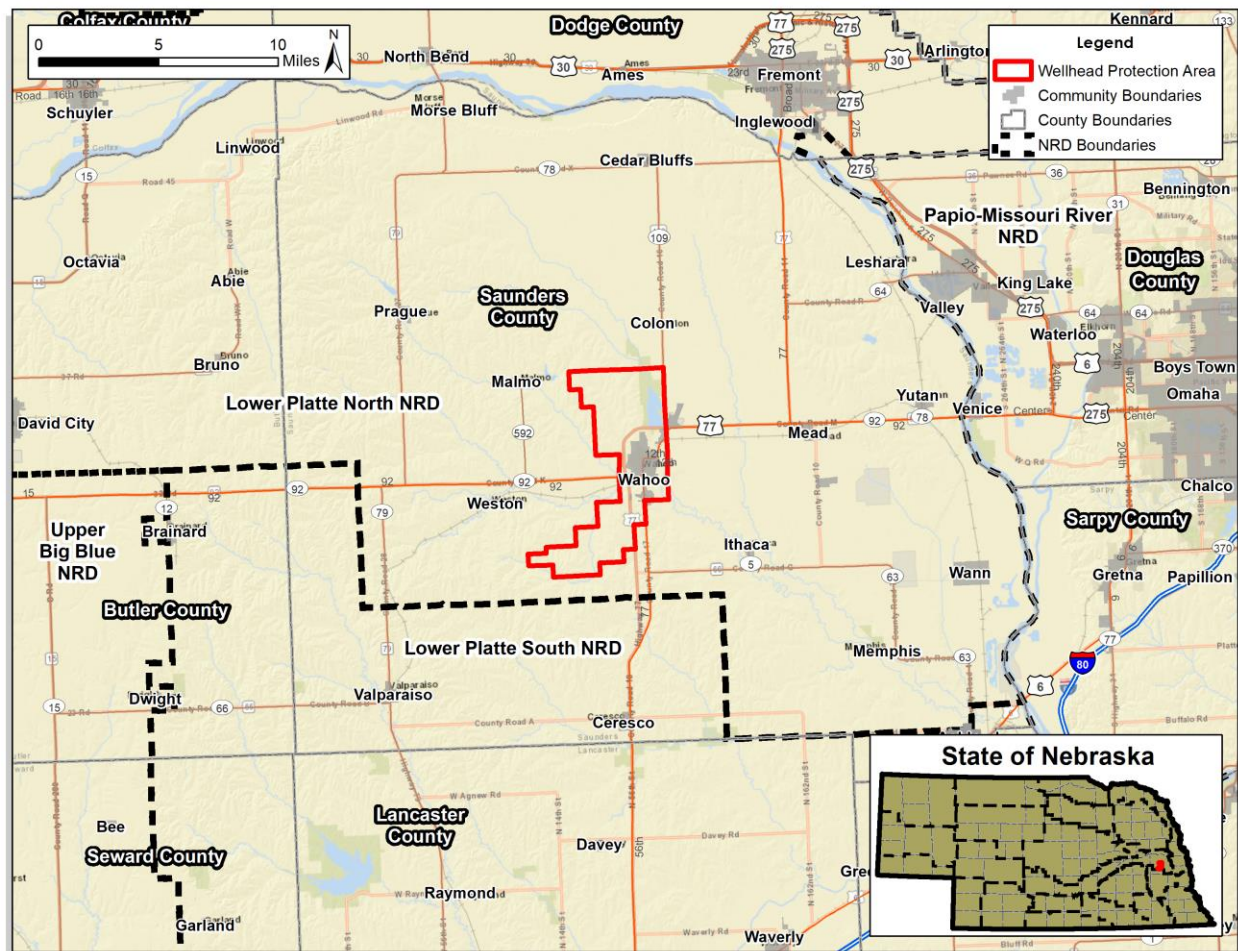
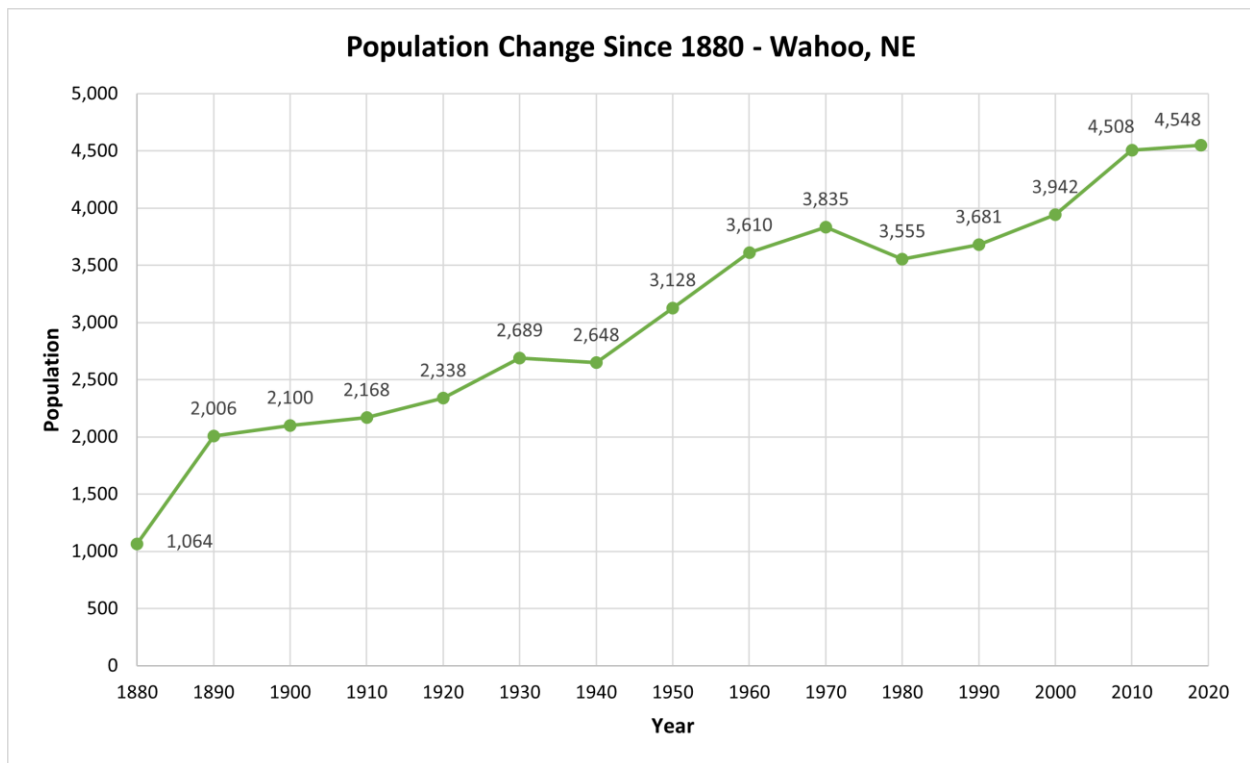


Figure 1: Location of Wahoo



Source: US Census Bureau, 2018

**Figure 2: Historical Population of Wahoo**

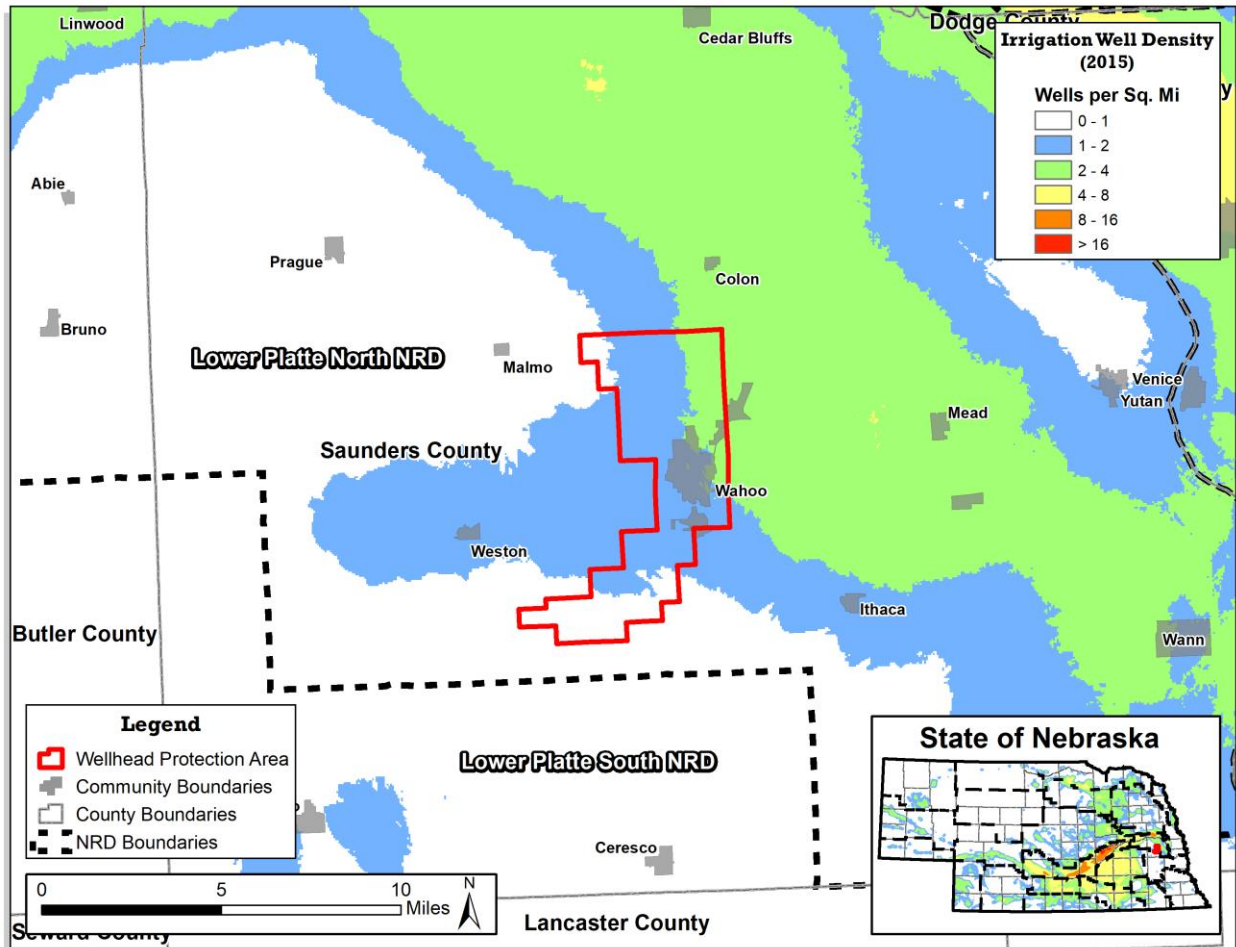
### 1.04 NATURAL RESOURCES DISTRICTS

Natural Resources Districts (NRDs) are government entities, led by a locally elected board of directors, with broad responsibilities to protect natural resources. Major Nebraska river basins form NRD boundaries, enabling districts to respond best to local needs. Nebraska's NRDs are involved in a variety of projects and programs to conserve and protect the state's natural resources, especially groundwater. The board of directors governs each district and much of their funding is provided by local property taxes. The city's WHP area falls within the LPNNRD boundaries.

### 1.05 NEBRASKA GROUNDWATER

Nebraska has significant groundwater sources throughout the state. Groundwater uses include irrigation, water supply for humans and animals, and uses for commercial and industrial activities. Nebraska receives nearly 88% percent of its public drinking water and nearly 100% of its private water supply from groundwater sources (NDEE, 2019). Agriculture, the state's largest industry, is dependent on this resource as well. As of November 2018, the Nebraska Department of Natural Resources (NeDNR) listed over 96,000 active irrigation wells and over 31,000 domestic wells registered in the state (NDEE, 2019). **Figure 3Error!**

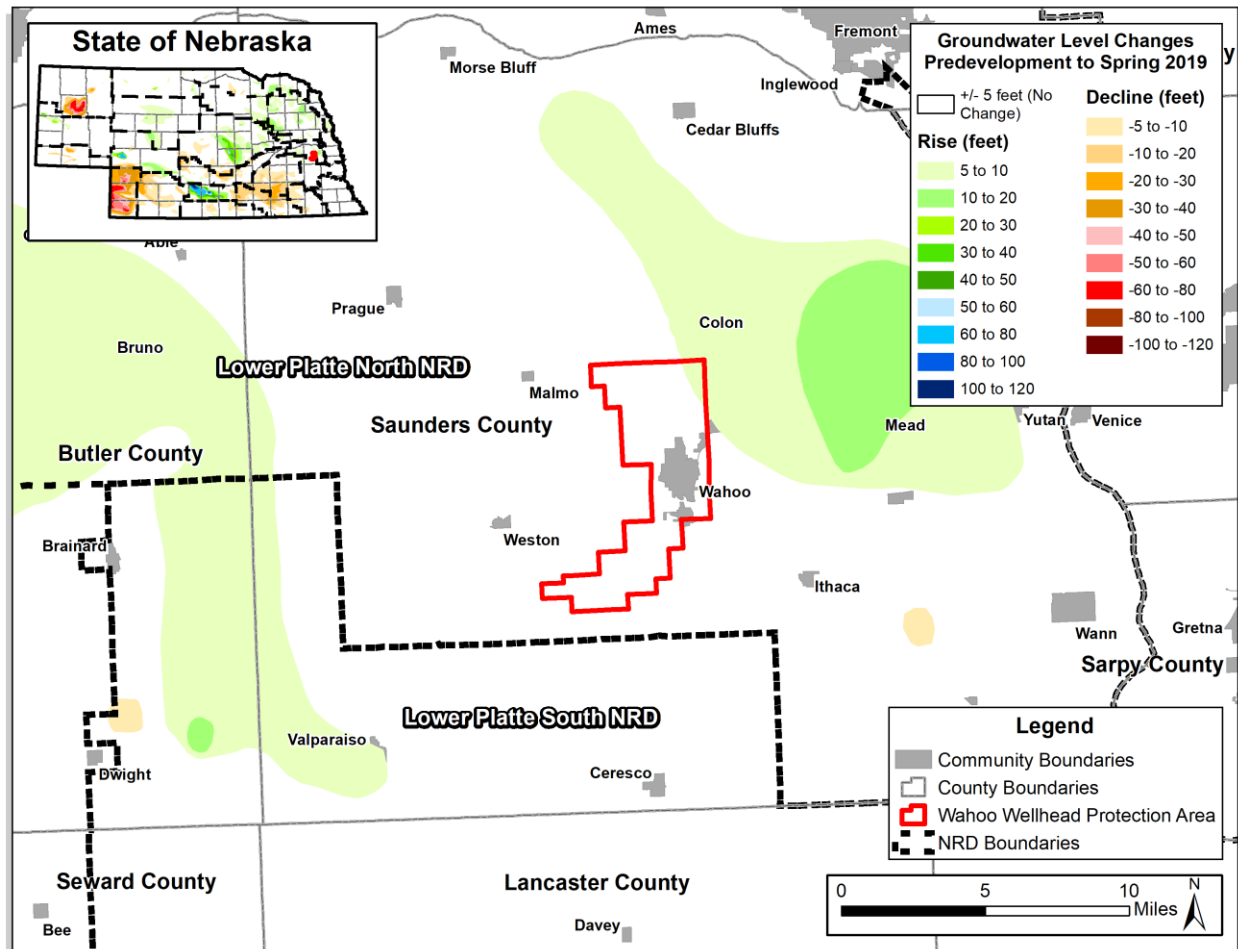
**Reference source not found.** displays the density of registered irrigation wells near Wahoo. Domestic and low-capacity wells were not required to be registered with the state prior to 1993, therefore thousands of unregistered domestic wells also exist in unknown locations.



Source: UNL Conservation & Survey Division

**Figure 3: Density of Active Registered Irrigation Wells - December 2015**

In respect to groundwater withdrawal, aquifer elevation is measured to establish trends in groundwater level and availability. Figure 4 characterizes the change in groundwater levels from pre-development to the spring of 2019. Most of Nebraska, which is underlain by the High Plains Aquifer, has groundwater available in adequate amounts. However, other areas, primarily those in the east and northwest regions of the state, have difficulty providing adequate yields. Groundwater in the east can be more limited because glaciation and erosion have deposited many geologic formations with variable properties. While some areas of Nebraska have seen rises and declines in excess of 100 feet, the region around Wahoo has seen minimal change, although the area directly east has seen moderate increases.



Source: UNL Conservation & Survey Division

Figure 4: Groundwater Level Changes – Predevelopment to Spring 2019

**1.06 GROUNDWATER POLLUTION IN NEBRASKA**

Groundwater pollution throughout Nebraska varies by the type of pollutant and scale of the contamination. Generally, three types of pollutants are of concern to water quality in Nebraska: nitrates, pesticides, and bacteria (coliforms, *E. coli*, etc.). The presence of pesticides in water supplies is an increasing concern. Atrazine is one of the commonly detected pesticides found in drinking water wells of Nebraska which is consistent with usage, as well as its relatively high mobility and persistence. Coliform group bacteria are microscopic, generally harmless organisms living in the digestive system of warm-blooded animals. Although coliform bacteria do not directly cause diseases, they are often indicators of other, more dangerous bacteria. Sources of fecal coliform are septic systems, barnyards, and animal waste lagoons (Gosselin, 1997).

## NITRATE POLLUTION

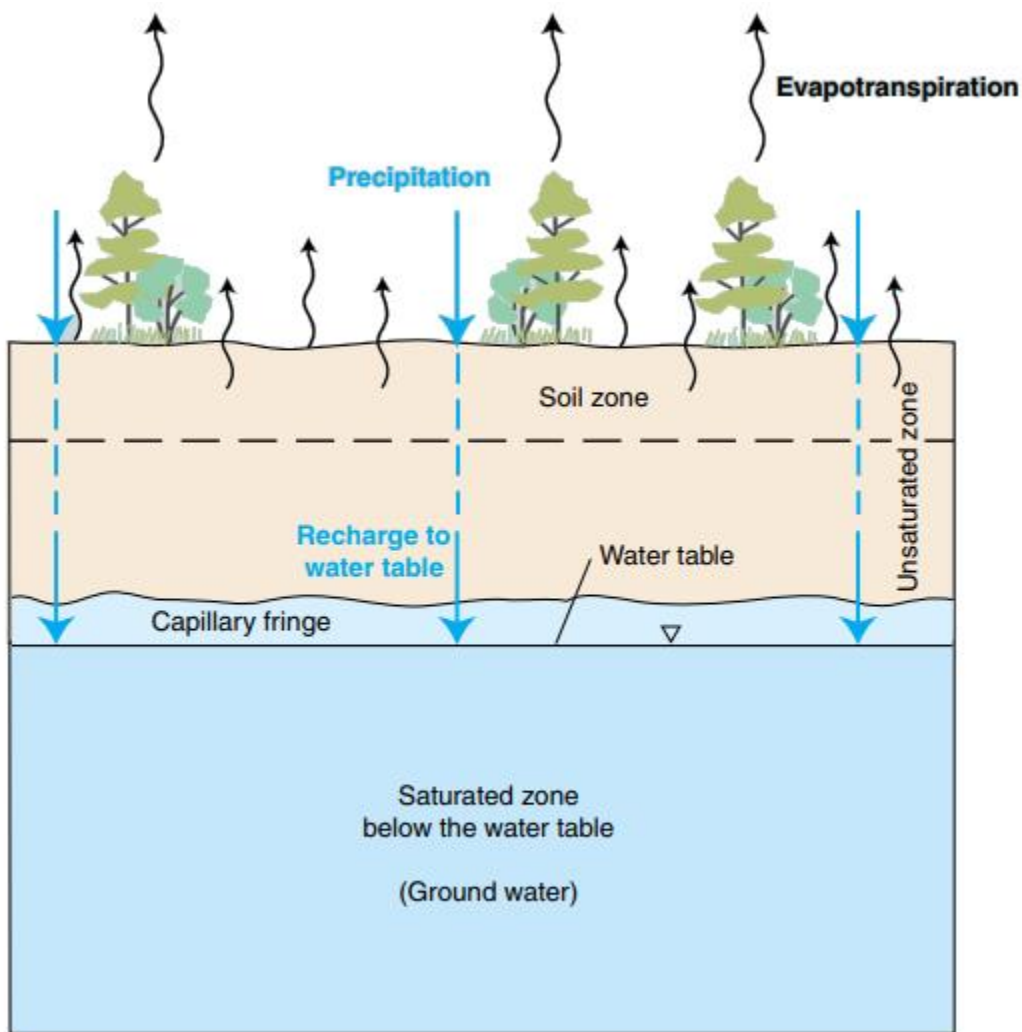
Of the three most common municipal water source pollutants, the most pervasive is nitrate-nitrogen (nitrate). Groundwater pollution, especially due to nitrate, is a growing concern for many communities in Nebraska. Nitrates in public water systems are also a concern for state agencies such as the NDEE and NDHHS, which are responsible for working with public drinking water systems.

In an undisturbed natural system, perennial vegetation utilizes nitrogen, thus limiting available nitrate that can leach into groundwater. However, agricultural development throughout the area has removed much of the perennial vegetation, replacing it with annual crops, and increased the application of both organic and inorganic forms of nitrogen as a fertilizer for crop fields. When crops do not fully utilize the nitrogen, it leaches through the vadose zone and into groundwater (Figure 5). In general, nitrates that are present below the root zone (approximately six feet below the soil surface) cannot be utilized by plants or crops. These nitrates eventually migrate to the aquifer unless they encounter a geologic formation that prevents this, such as a thick clay layer between the ground surface and the aquifer.

High levels of nitrates in drinking water are known to cause methemoglobinemia, or “blue baby syndrome” in infants and immune-compromised adults. Methemoglobinemia reduces the oxygen-carrying capacity of blood, often resulting in blue skin coloring around the mouth, hands, and feet. In severe cases methemoglobinemia can cause seizures and death from reduced oxygen levels in the body. Additionally, when nitrates in the body are broken down and converted into the chemical compound nitrite, they can react with other compounds (amines) in the body and form nitrosamines - a cancer-causing compound (NHDES, 2006). Other carcinogenic compounds have been known to become more prevalent when high levels of nitrates are present in drinking water. Due to these risks, the US Environmental Protection Agency (EPA) has set a Maximum Contaminant Level (MCL) of 10 milligrams per liter (mg/L) for nitrate-nitrogen in drinking water.

The city monitors nitrate levels in all municipal wells annually and routine water quality testing has shown that nitrate levels have not exceeded the MCL. As of 2021, the highest nitrate concentration measured at a city well was 5.05 mg/L (NDHHS, 2020).





Source: USGS, 1999

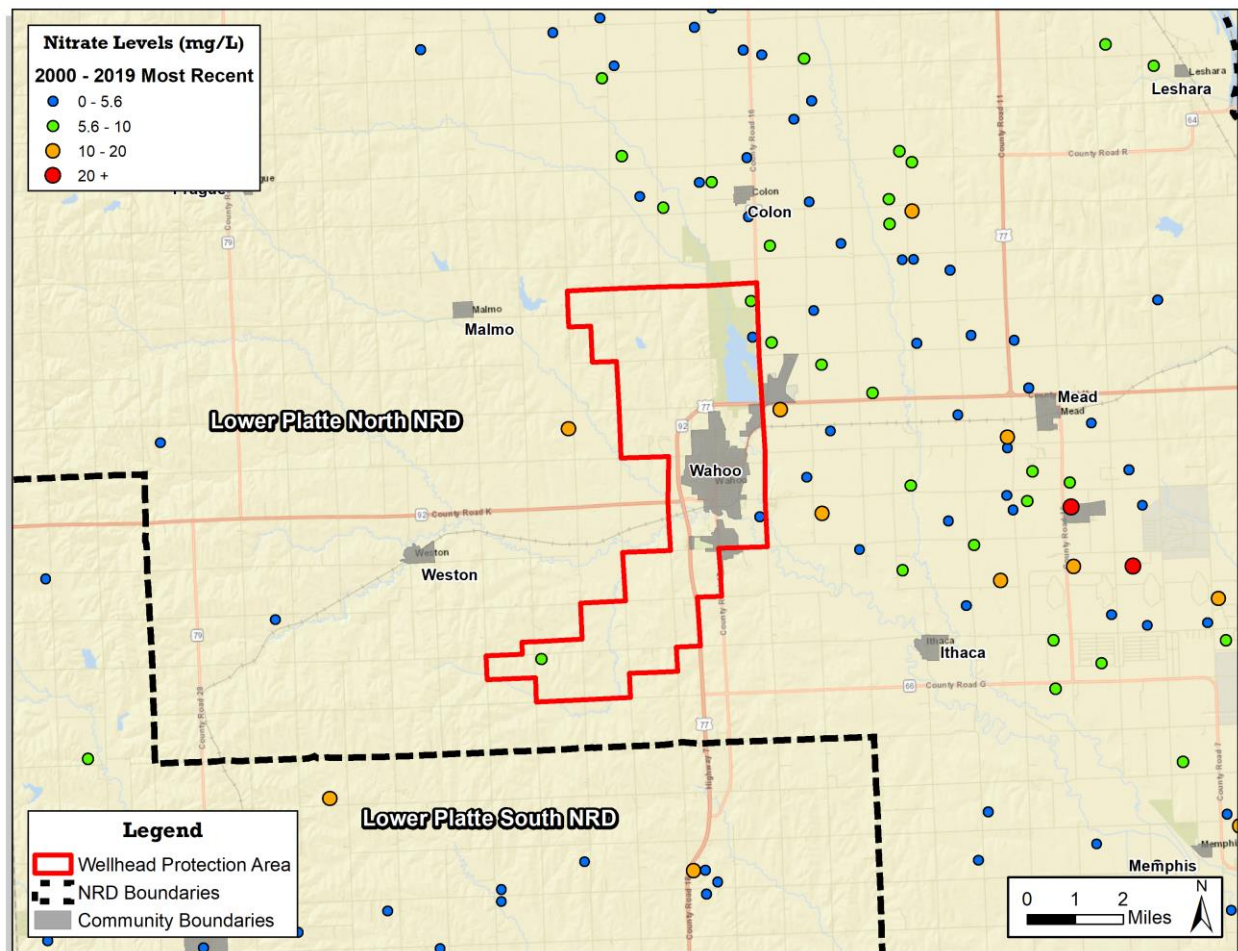
**Figure 5: Illustration of the Root Zone, Unsaturated Zone, and Groundwater**

An extensive network of groundwater monitoring and quantity/quality evaluation exists throughout the State. This effort involves multiple entities, including:

- Natural Resources Districts (23 in total)
- Nebraska Department of Agriculture (NDA)
- NeDNR
- NDEE
- NDHHS
- Public Water Suppliers
- University of Nebraska-Lincoln (UNL)
- United States Geological Survey (USGS)

Monitoring results are compiled in the Quality Assessed Agrichemical Contaminant Database for Nebraska Groundwater (Database). The Database compiles groundwater monitoring data from different sources and provides public access to the results. Available water quality data ranges from 1974 to the present. Monitoring data is collected from irrigation and domestic supply wells in addition to dedicated groundwater monitoring sites. The number of designated groundwater monitoring wells has increased through the past several years across the State. The Database is available online at: <https://clearinghouse.nebraska.gov/>

A review of the Database provided the most recent nitrate concentrations for each well sampled in and around the WHP area since 1997 (Figure 6 **Error! Reference source not found.**). Of the four wells sampled within the WHP area, two have nitrate concentrations of 5.6 mg/L or less and two have concentrations between 5.6 – 10 mg/L. None has a concentration that exceeds the MCL of 10 mg/L.



Source: Quality-Assessed Agrichemical Contaminant Database for Nebraska Groundwater (NDEE, 2020)

Figure 6: Most Recent Nitrate Concentrations from Wells Sampled 2000 - 2019

## EMERGING CONTAMINANTS

In recent years, groundwater managers in Nebraska have become concerned that the overall groundwater chemistry is changing and naturally occurring elements in the aquifer material are being released into the groundwater. A recent study (Weber, 2015) considered the relationship of elevated groundwater nitrate levels and uranium concentrations in groundwater. Elevated uranium concentrations are found in many regions, including those without anthropogenic uranium activity (mining, nuclear testing, etc.), indicating a source of natural uranium contamination. Research indicates that natural uranium in the subsurface may be oxidized and mobilized as the nitrate (in many forms) moves through the root zone and eventually to groundwater. Shallow groundwater was determined to be the most susceptible to co-contamination. Weber (2015) indicated that nitrate concentrations near the MCL are correlated to elevated groundwater uranium concentrations; thus, nitrate, a primary groundwater contaminant, can be a factor leading to secondary uranium concentration.

This correlation is significant because consumption of uranium contaminated drinking water has been linked to nephrotoxicity (toxicity in the kidneys) and ototoxicity (damage to the inner ear) and, thus, poses a health risk (Weber, 2015). Some public water supply systems treat not only nitrates, but also uranium (NDEQ, 2018). In addition to drinking water concerns, food crops irrigated with contaminated water have been demonstrated to accumulate uranium, thus leading to an additional uranium exposure through food crops (Weber, 2015).

While Wahoo's drinking water has not yet violated the MCL for any emerging contaminants, a wide range of regulated contaminants such as arsenic and selenium has been found in the city's drinking water. The reported value of arsenic in 2019 was 3.01 parts per billion (ppb), while the MCL is 10 ppb (City of Wahoo, 2019). This is not yet a widespread issue but may become so in the future and will require close monitoring.

---

## 1.07 GROUNDWATER AQUIFER

### SETTING AND CHARACTERISTICS

The availability of groundwater in an area depends heavily upon the local subsurface geology. Areas with low bedrock elevation and high saturated ground thickness are desirable for well construction, as these areas are more likely to provide high quantities of groundwater with lower effort from well pumps. The quality of groundwater will vary based on geology. The geology of the WHP area contains unconsolidated Quaternary deposits of glacial outwash and alluvium underlain by Dakota Sandstone bedrock. Low-permeable clay and silt deposits overlay the Principal Aquifer in varying thickness. Where these deposits are thick, the groundwater receives more protection from contaminants due to lower infiltration rates. The Platte River valley aquifers are present north and east of the WHP area, and the Todd Valley aquifer is present to the west. In this area, the Platte River and its supporting channels used to exist, cutting away the bedrock to a deeper depth. As the river migrated, alluvial sands and gravels were deposited in the valley left by the river, and this alluvial fill was capped with fine materials like silt, loess, and clay. These conditions form a paleovalley aquifer. These deep paleovalley aquifers combined with unconsolidated sand and gravel aquifers from modern river valleys closer to the surface are known as the Principal Aquifer (LRE, 2021).

### VULNERABILITY TO CONTAMINATION

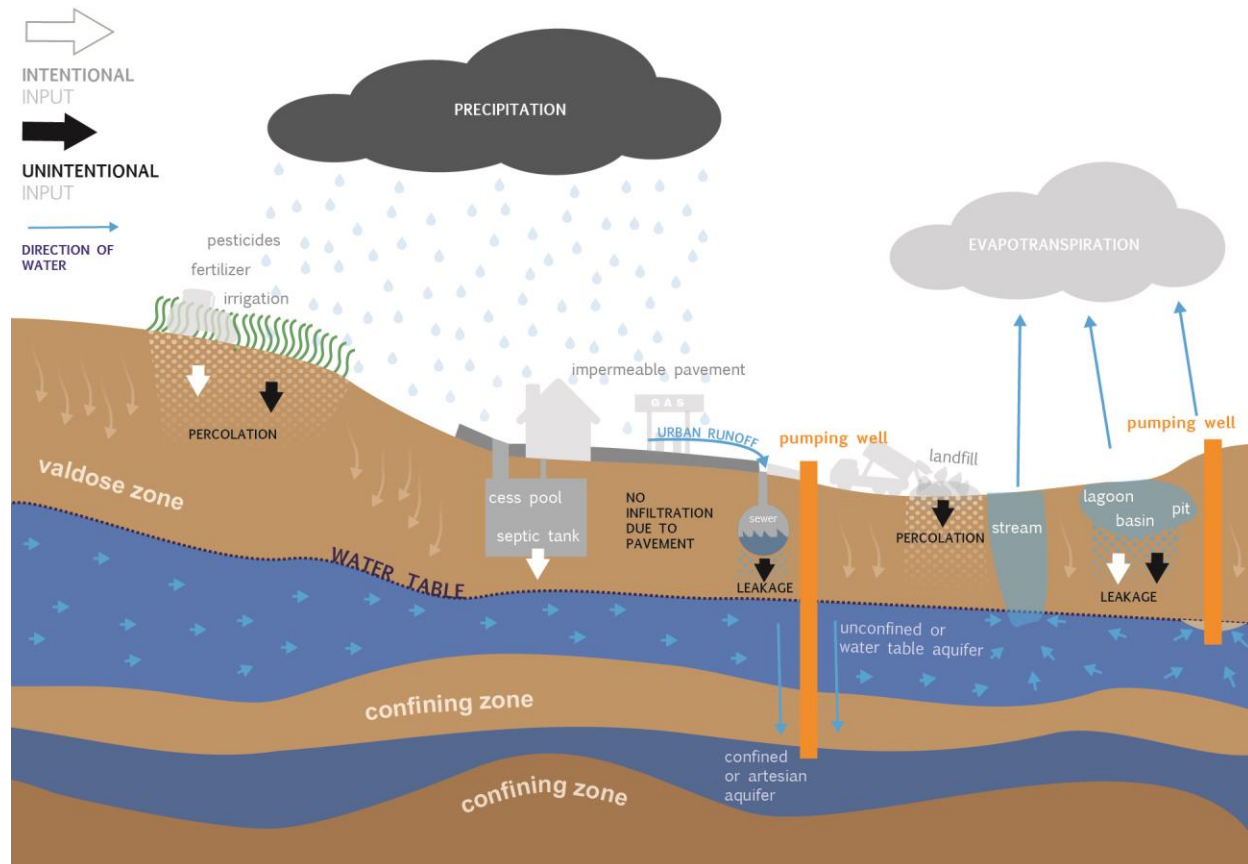
Regions that are within an aquifer zone or rely on the groundwater produced by a well are vulnerable to contamination from human activities. There are various computer models available that serve as a practical visualization tool for decision making which quantify or illustrate that vulnerability. Alone, they do not fill a direct role, but cumulatively contribute to understanding the issues. In general terms, it is relatively easy to delineate areas of high vulnerability, difficult to determine that an area has very low vulnerability, and nearly impossible to reliably define fine gradations between the two.

Solely utilizing any model to address management decisions should be done conservatively and with additional information. Groundwater management requires cooperative efforts between regulatory agencies, policy makers, natural resources managers, educators, the public, and technical experts. Actions based solely on a vulnerability assessment should be tempered by the uncertainty of the assessment and the confidence of the technical experts in the assessment they have produced (National Research Council, 1993).

Groundwater vulnerability is a function of the properties in the natural system where groundwater is found; however, the risk of contamination may be relatively low or high regardless of the vulnerability. Contamination risk is assessed by the proximity or siting of a source where potential introduction of a pollutant into a vulnerable area may exist. Additional groundwater monitoring of vulnerable areas may aid in reducing the risk of contamination. It is important that decisions and management of resources distinguish between vulnerability and risk (Rahman, 2008). Figure 7 illustrates the many ways in which

contamination may be introduced to a groundwater system (risk factors). Contamination risk increases when there are more contaminate sources that are present, regardless of the vulnerability.

**BECAUSE THE WELLHEAD PROTECTION AREA IS THE MOST CRITICAL AREA FOR RECHARGE OF THE COMMUNITY'S SOURCE OF DRINKING WATER, IT SHOULD BE CONSIDERED HIGHLY VULNERABLE AND EVERY RISK FACTOR SHOULD BE EVALUATED CAREFULLY.**



Source: Adapted from University of Texas at Austin – Center for Research in Water Resources

**Figure 7: Typical Routes of Groundwater Contamination**

A detailed hydrogeologic vulnerability assessment was conducted for the Wahoo WHP area in support of this plan. The assessment was completed to better understand the vulnerability of the aquifer to contaminant infiltration. This information can be used to help the city identify low vulnerability locations for potential future well sites, and areas to target in order to mitigate future contamination and evaluation of land management strategies. The assessment was completed utilizing NeDNR well logs, UNL-CSD test hole data, and the most recently available nitrate concentration data for select wells in the WHP area.

The assessment resulted in three geologic cross sections showing the Principal Aquifer underlain by the Dakota Bedrock (Figure 9, Figure 10, and Figure 11), and an aquifer vulnerability map (Figure 8). The majority of the WHP area is classified as moderately vulnerable to contamination based on the results of this assessment (LRE, 2021). Areas classified as highly vulnerable, including the location of Well 4, should be the top priority for the city to investigate potential sources of contamination and implement the recommendations in this plan to protect water resources. The complete assessment report is available in Appendix A.

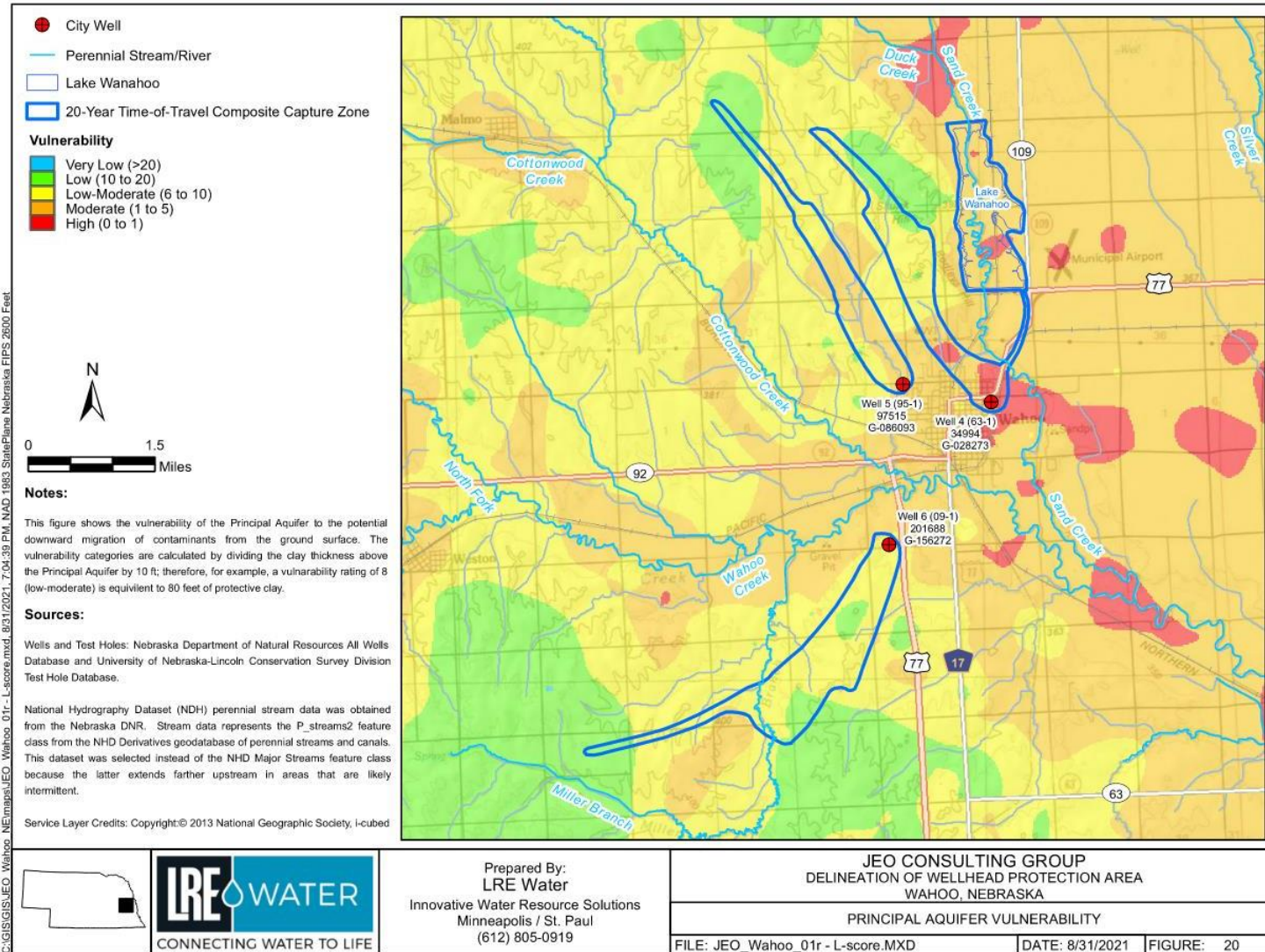


Figure 8: Aquifer Vulnerability, Geologic Cross Section Locations, Nitrate Concentrations

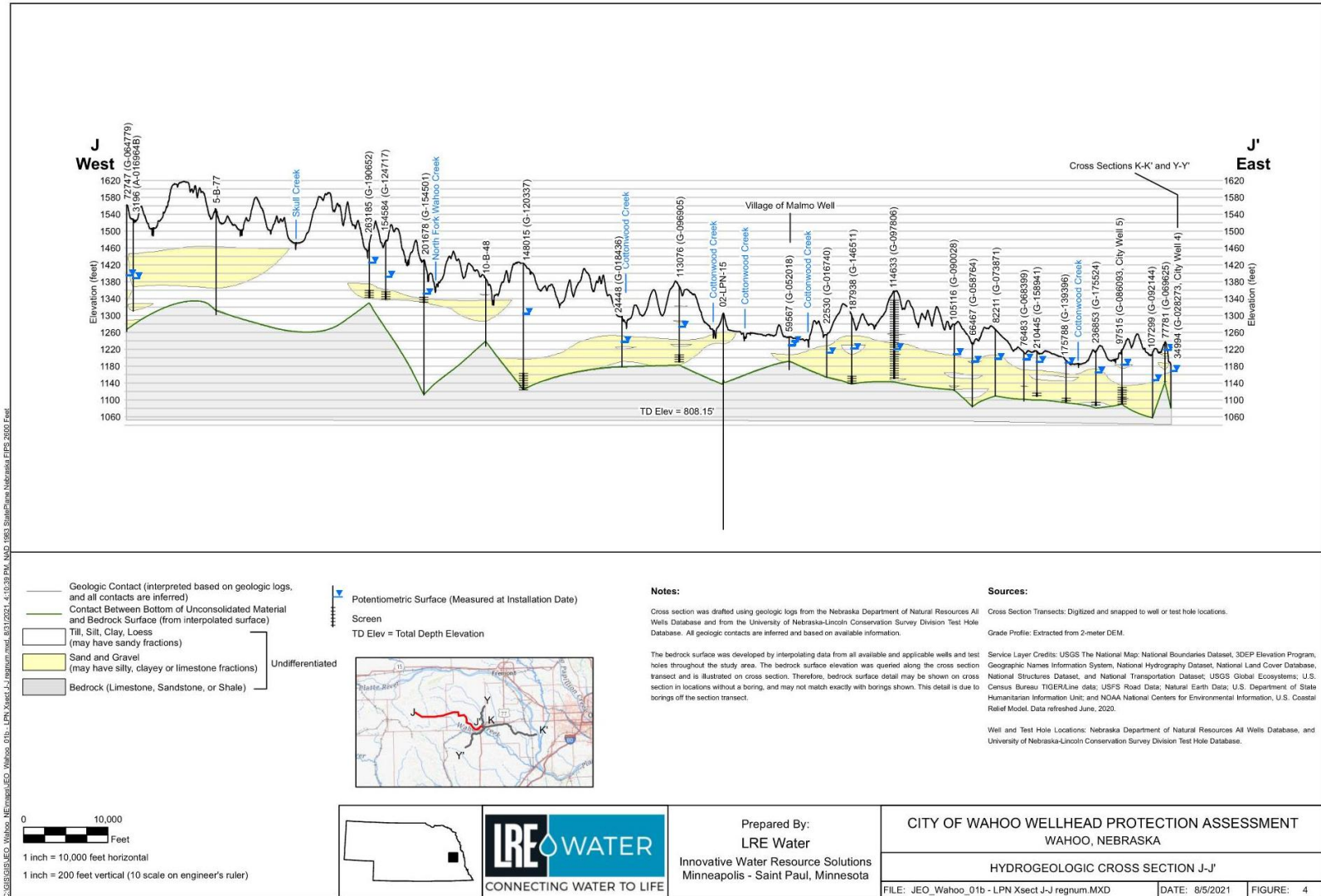


Figure 9: Hydrogeologic Cross Section J-J'



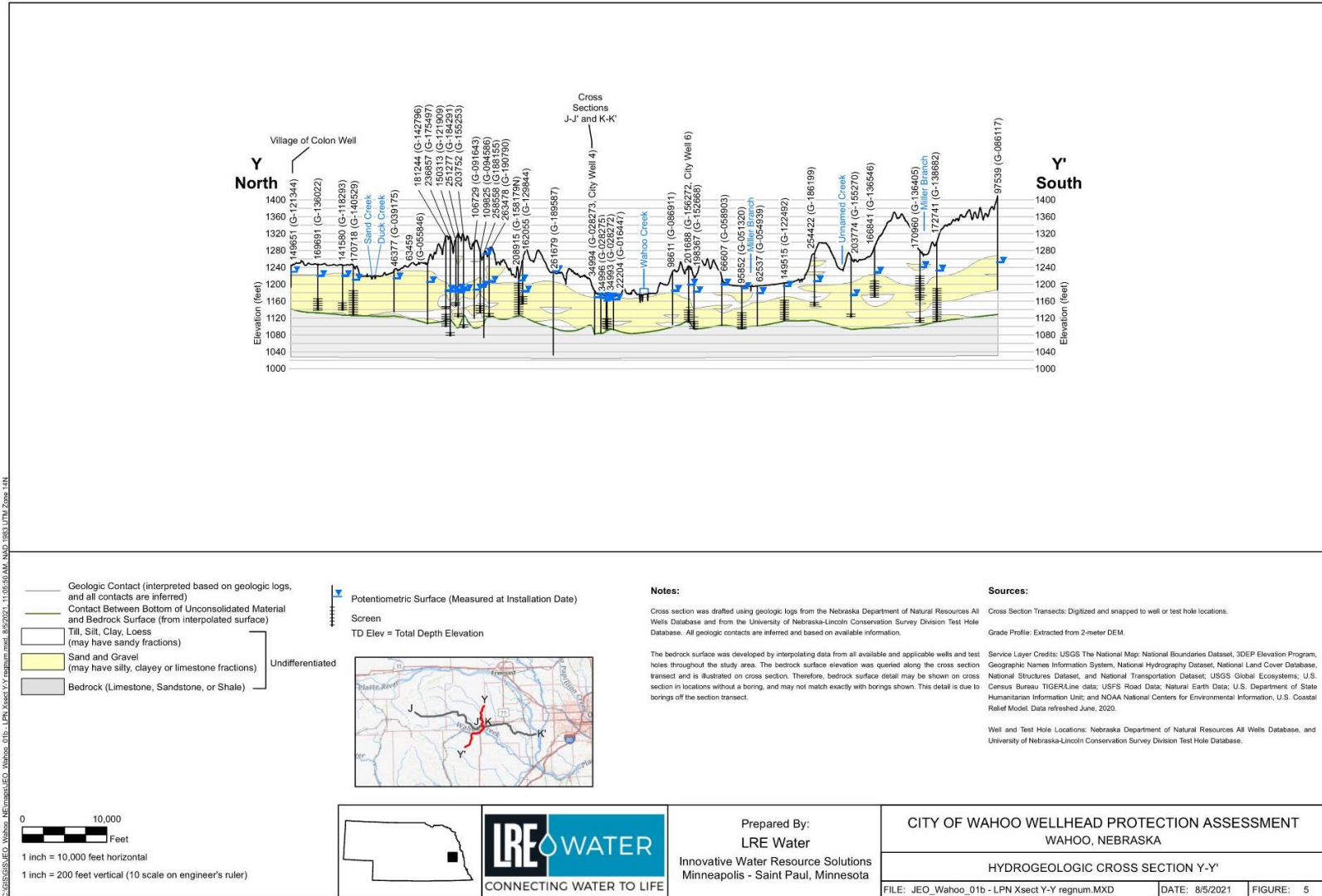


Figure 10: Hydrogeologic Cross Section Y-Y'

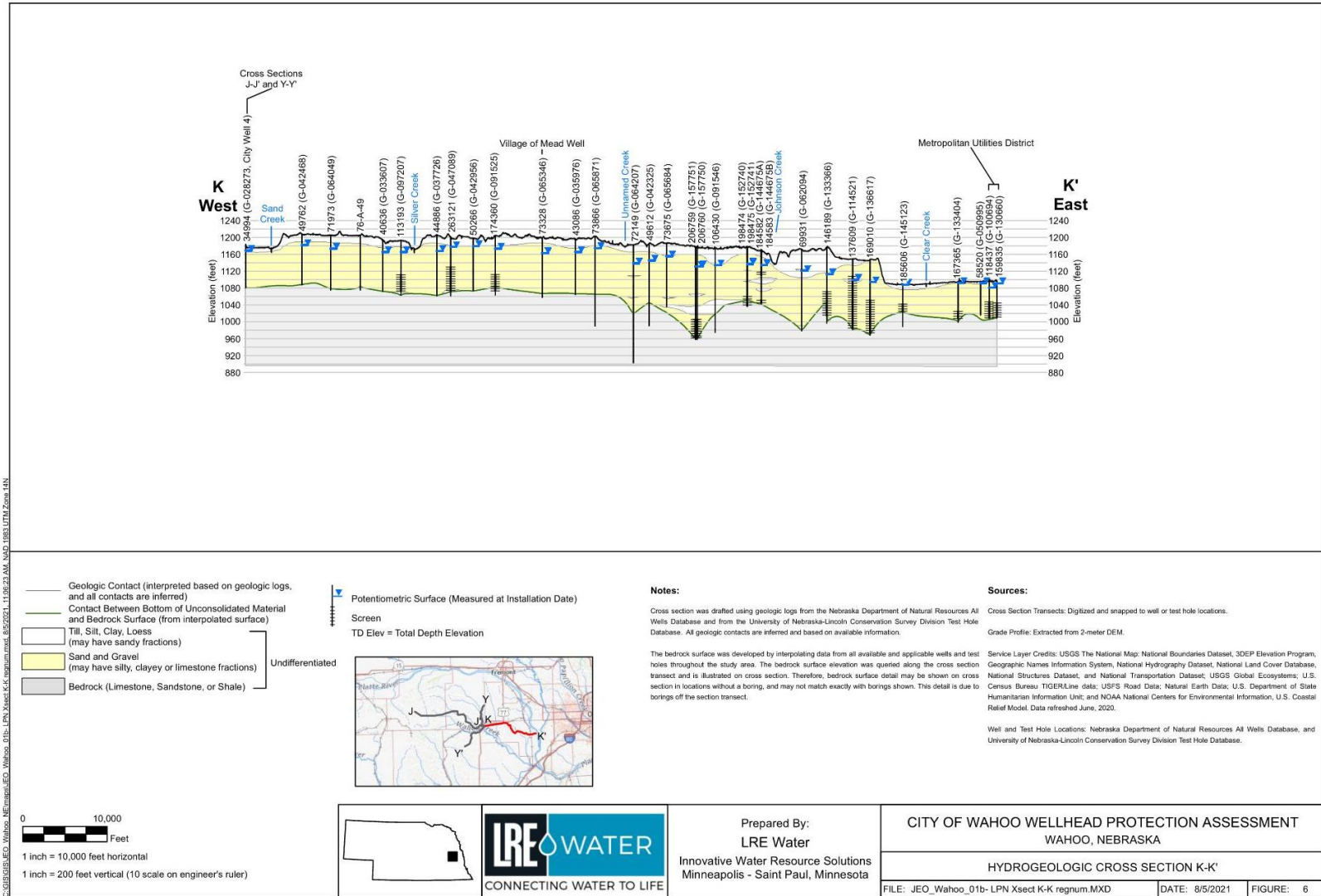


Figure 11: Hydrogeologic Cross Section K-K'

---

## CHAPTER 2. COMMUNITY WATER SYSTEM

### 2.01 NEBRASKA'S PUBLIC WATER SYSTEM PROGRAM

The EPA established the Public Water System Supervision Program under the authority of the 1974 Safe Drinking Water Act (SDWA). With the SDWA and subsequent 1986 Amendments, EPA regulates the limits of contaminant levels in drinking water nationwide to ensure that public water supplies are safe for human consumption. Within the State of Nebraska, the Division of Public Health of the NDHHS administers the Public Water System Supervision Program, under EPA guidance. The mission of the Public Water System Program of NDHHS is to protect the health and welfare of Nebraskans by assuring safe, adequate, and reliable drinking water.

*PEOPLE EXPECT THEIR DRINKING WATER WILL BE SAFE WHEN THEY TURN ON THE FAUCET.*

NDHHS's Department of Regulation and Licensure visits all Public Water Supply Systems (PWSSs) to conduct sanitary surveys once every three years for community water systems. A sanitary survey is an on-site review of the water source, facilities, equipment, operations, and maintenance of a public water system for the purpose of evaluating the system's adequacy and ability to reliably produce and distribute safe drinking water within the confines of regulatory requirements. The city's most recent sanitary survey was completed in January 2022, and a copy can be found in Appendix B. The State of Nebraska requires communities to provide a Water Quality Report annually to residents. The report consists of a single page summary of water quality test results for the year. The most recent water quality report is included in Appendix B and is also available at the city office.

### 2.02 WATER SYSTEM INFORMATION

The DOU's drinking water supply system includes three active wells located throughout the community (**Error! Reference source not found.**), one water tower, and a distribution system serving over 4,880 people (JEO, 2020). The supply wells provide water of high quality that does not generally require any treatment for contaminants although it is chlorinated once per year, and as needed if coliform bacteria is detected. A summary of the water system's information is included in Table 1. Specific information about each municipal well is presented in Table 2.

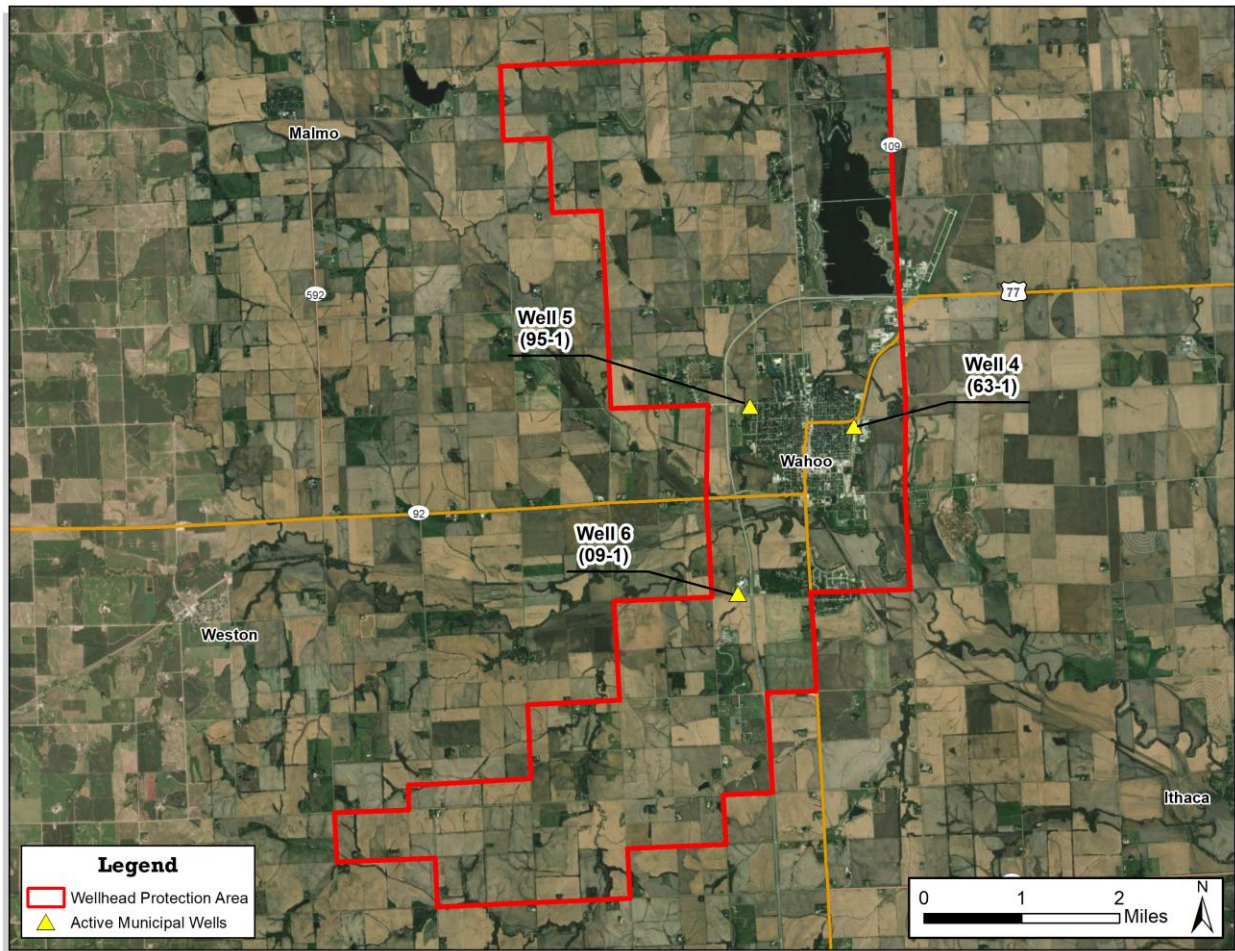


Figure 12: Active Municipal Well Locations

Table 1: Municipal Water System Information

General System Information	
System ID	NE31-15512
Maximum Daily (24-hour) Production Capability	4.1 million gallons
Total Production for 2021	242.710 million gallons
Active service connections	1,745
Population served	4,508

Source: Public Water Supply Routine Sanitary Survey (2018)

Table 2: Active Municipal Water Supply Well Information

Registration #	Local Name	Year Drilled	Total Well Depth (ft)	Top of Screen Depth (ft)	Screen (ft)	Current Capacity (gpm)
G-028273	Well 4 (63-1)	1963	103	73	30	1,200
G-086093	Well 5 (95-1)	1995	132	89	40	1,000
G-156272	Well 6 (09-1)	2009	133.9	102.5	31.4	760

Source: JEO, 2020

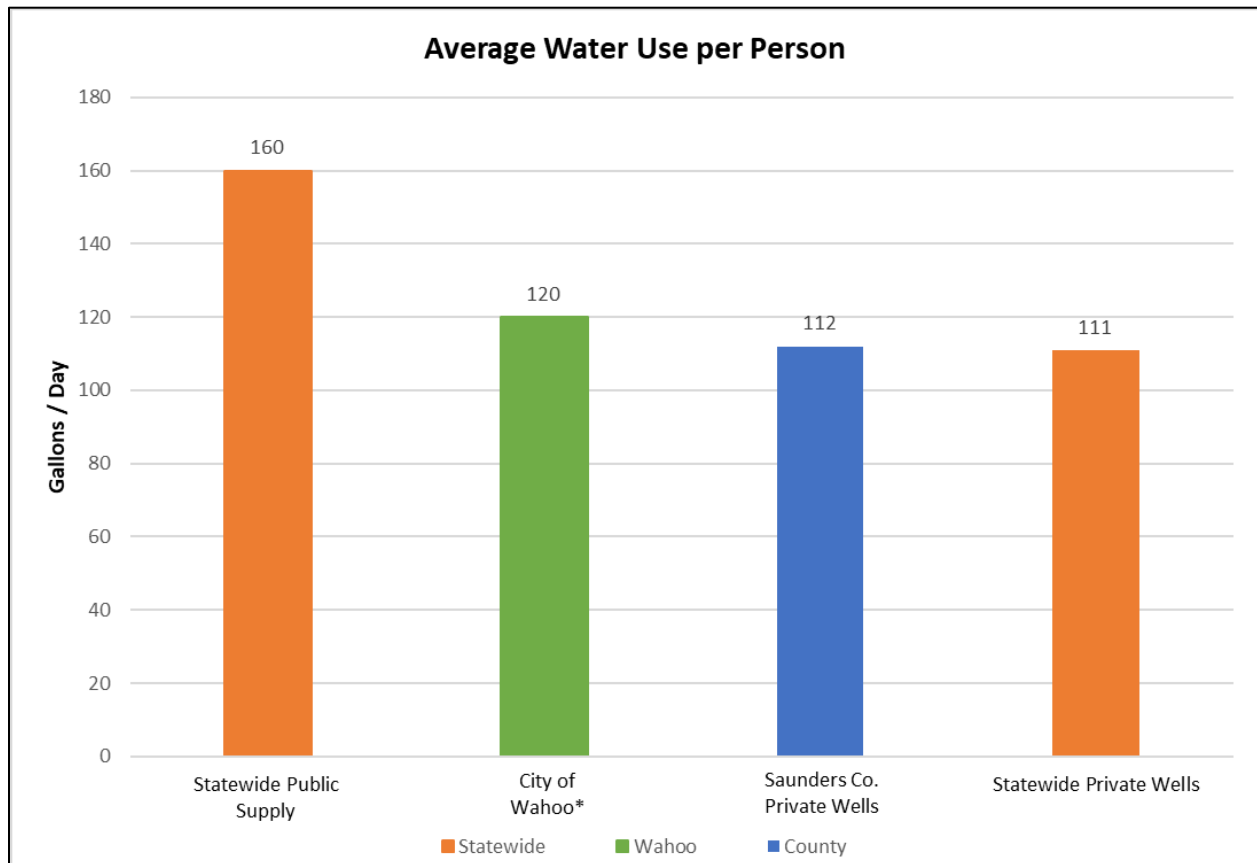
## MUNICIPAL WATER USE

Pumping information for each of the municipal wells is summarized below in Table 3. Pumping volumes fluctuated between 2016-2020 but increased overall. Based on an average daily flow from 2017-2020 of 590,000 gpd, the daily water use of the city is 120 gallons per customer per day (gpcpd). This volume is at the top end of the typical industry-standard range of 80-120 gpcpd and less than the Nebraska statewide public supply average of 160 gpcpd (**Error! Reference source not found.**). Pumping volumes vary greatly on a local, county, and statewide basis between both public and private water supplies. There are likely measures that Wahoo water system customers can take to become more efficient in their uses. Additionally, the DOU should look at improving their accounting of unmetered activities to identify places that savings could be made. These actions will not only reduce utility bills but will also ease the burden on the water system and groundwater aquifer during drought years. Current estimates are projecting Wahoo's population to continually increase; therefore, it is expected that water consumption volumes will continue to increase over time. Implementing water conservation measures now, such as programs to provide low-flow showerheads and low-flush toilets, high-efficiency washing machines, and landscape conservation techniques, could help minimize the pumping volumes necessary in the future.

**Table 3: Wahoo Water Use Summary (2016-2020)**

Year	Well 4	Well 5	Well 6	Total
2016 (gal)	85,687,924	52,441,727	67,476,398	205,606,049
2017 (gal)	83,764,938	66,466,736	71,131,572	221,363,246
2018 (gal)	76,613,698	62,357,041	66,069,809	205,040,548
2019 (gal)	81,878,116	70,226,809	47,063,445	199,168,370
2020 (gal)	62,804,761	95,716,628	84,189,380	242,710,769
5-Yr Avg (gal)	78,149,887	69,441,788	67,186,121	214,777,796

Source: JEO, 2020

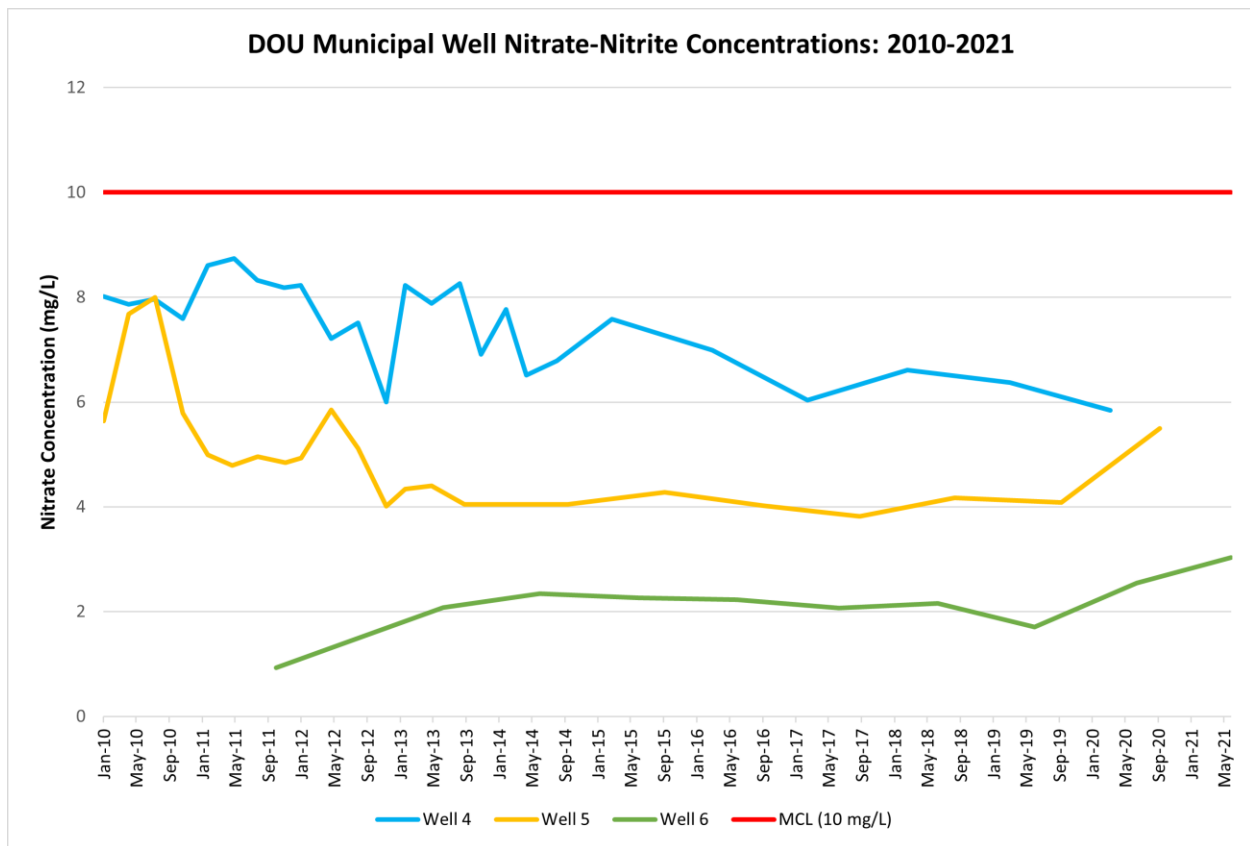


Sources: *Maupin and others, 2014*; *\*JEO, 2020*

**Figure 13: Average Water Use Between Wahoo and Other Populations**

### 2.03 COMMUNITY WELL NITRATE SAMPLING

NDHHS maintains a database of public drinking water system data on their website through the Drinking Water Watch. Nitrate sampling data from the last decade has been compiled for the city and can be seen in Figure 14. The chart also displays the EPA MCL for nitrates at 10 mg/L as a red line. Nitrate concentrations in individual municipal wells varied between approximately 2-8 mg/L. Nitrates are known to occur naturally in groundwater, with a typical background concentration of 3 mg/L. Concentrations above 3 mg/L indicate a level of indirect human impact, while concentrations above 5 mg/L are indicative of direct human activity (Gosselin, 1997).



Source: NDHHS Drinking Water Watch

Figure 14: Nitrate Concentrations in Wahoo City Wells

## CHAPTER 3. WELLHEAD PROTECTION AREA

### 3.01 DELINEATION

The city’s previous WHP area map was provided by NDEE in February 2016. The WHP area map was updated in October 2021 (Figure 15). The updated WHP area was created by LRE Water Inc. using the USGS MODFLOW code, a three-dimensional, cell-centered, finite difference, saturated flow modeling code.

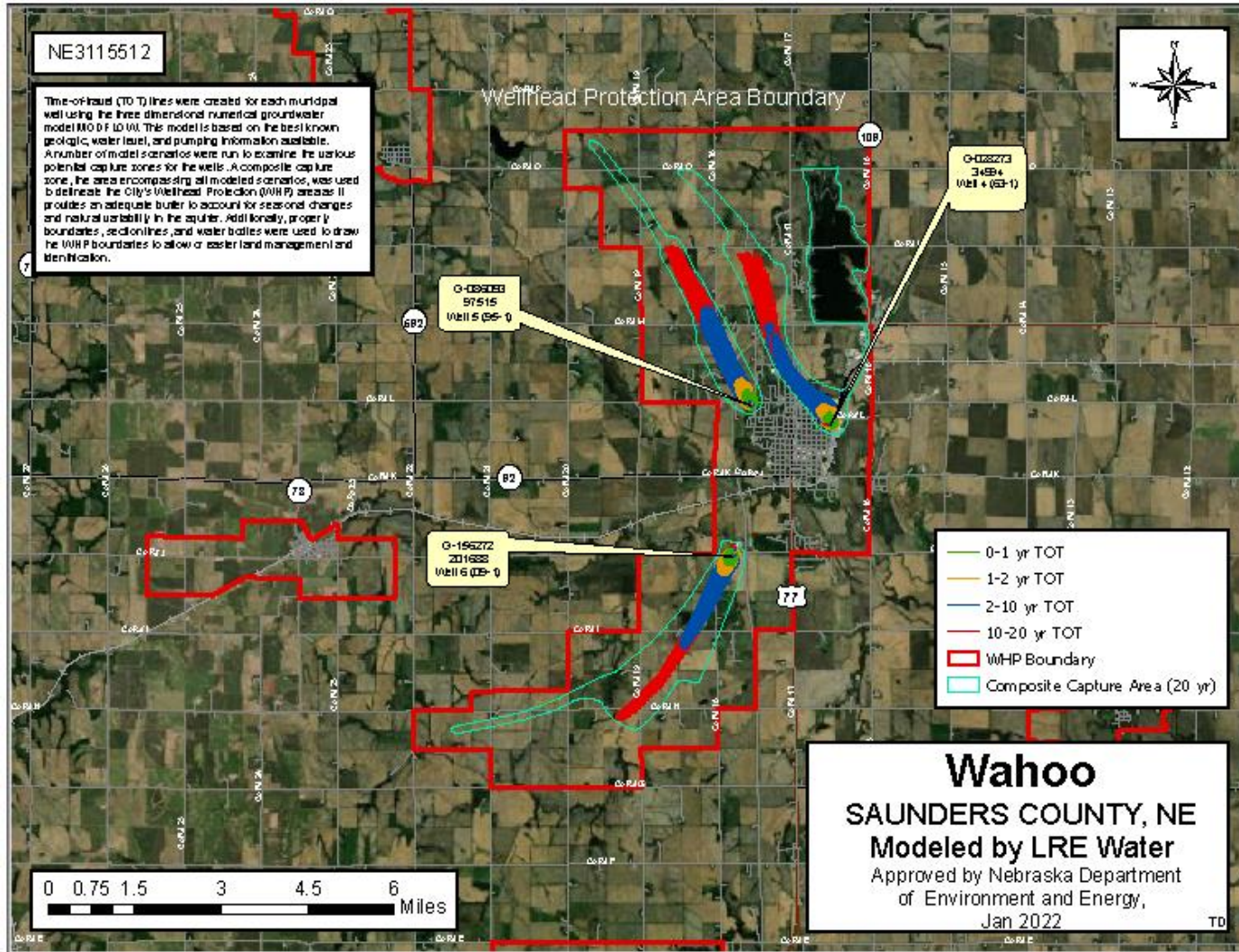
The modeling generates flow lines, which depict the approximate path groundwater, or a contaminant in groundwater, will take to reach a well. These flow lines are associated with an estimated time-of-travel (TOT). One set of TOT path lines are delineated for each active well: one, two, 10, and 20-year. The WHP area was based on the composite capture zone, which represent the areas that could contribute water of the wells within a 20-year TOT.

The WHP boundary is drawn slightly larger than the composite capture zone shown on the map to accommodate seasonal changes and natural variability of the aquifer. The WHP area is statutorily recognized as a boundary in which a community manages potential contaminant sources through the WHP program. The WHP area is drawn around the 20-year time-of-travel along visible or easily identifiable boundaries such as roads, rivers, creeks, section, quarter-section, and quarter-quarter sections lines. The WHP area does not cross ownership parcels. This allows for easier land management and identification. Maps are periodically updated as modeling advances, the science behind aquifers advances, as wells are added/removed from use, or as well pumping volumes change.

Wahoo's WHP area is made up of a continuous area covering approximately 15,000 acres. The city officially recognized the updated WHP area with an adoption ordinance on January 25, 2022. The ordinance can be found in Appendix C.

***THE WELLHEAD PROTECTION AREA MAP BY ITSELF DOES NOT GIVE A COMMUNITY ANY ADDITIONAL AUTHORITY OR PROTECTION OF THE PUBLIC WATER SUPPLY. IT IS PURPOSELESS UNLESS A COMMUNITY ENACTS ORDINANCES, ZONING, OR INITIATES VOLUNTARY ACTIVITIES WITHIN THE WHP AREA.***





Source: NDEE, 2018

Figure 15: Official 2018 Wahoo WHP Area Map with Aerial Background

### 3.02 LAND USE

Land use and land cover are two separate terms, yet they are often used interchangeably. Land use describes how people utilize the land (i.e. urban or agriculture), while land cover describes the physical material of the earth's surface (i.e. types of vegetation). For the purposes of this plan, the term land use will be used with the understanding that intentional management of the land is implied.

Certain types of land uses are commonly associated with varying potential for different types of contaminants, as shown in Figure 17.

**Agricultural areas**, particularly row-crops, may contribute to non-point source (NPS) pollution. They can potentially contribute to nitrates, herbicides, and other contaminants flowing into surface water and infiltrating through the soil into groundwater. Irrigated cropland is particularly vulnerable to increased nitrogen leaching.

**Urban land areas**, particularly areas of impervious surfaces, may contribute to NPS by increased runoff, overapplication of lawn fertilizers, oils, solvents, or grease spills, or other industrial byproducts. Urban areas can contribute to water pollution at a high rate due to the high concentration of facilities or land uses which can contribute to water pollution.

**Natural vegetation**, such as trees, grasses, and shrubbery are generally considered to have the capability of improving or protecting water quality. Natural vegetation may serve as a buffer and filter between pollutant sources and water bodies. The vegetation often partially removes contaminants and nutrients before they enter waterbodies.

**A****B****C**

**Figure 16: Varying Types of Land Use. (A) Irrigated Row crops; (B) Urban setting; (C) Natural vegetation.**

Land use data from 2020 was collected from the United States Department of Agriculture (USDA) National Agricultural Statistics Service CropScape – Cropland Data Layer online platform (Table 4). Most of the land in the WHP area is used as cropland (70.5%), especially to grow corn and soybeans (Figure 17). The second largest land use category is developed (12.2%) which includes all urban areas (single/multi-family homes, city parks, streets/roads, etc.). This category is primarily made up of the community itself. This category is followed by grass/pasture (8.7%), including barren land and sod. The remainder of the WHP area is taken up by open water, primarily Lake Wanhoo, and relatively small amounts of forest and wetlands.

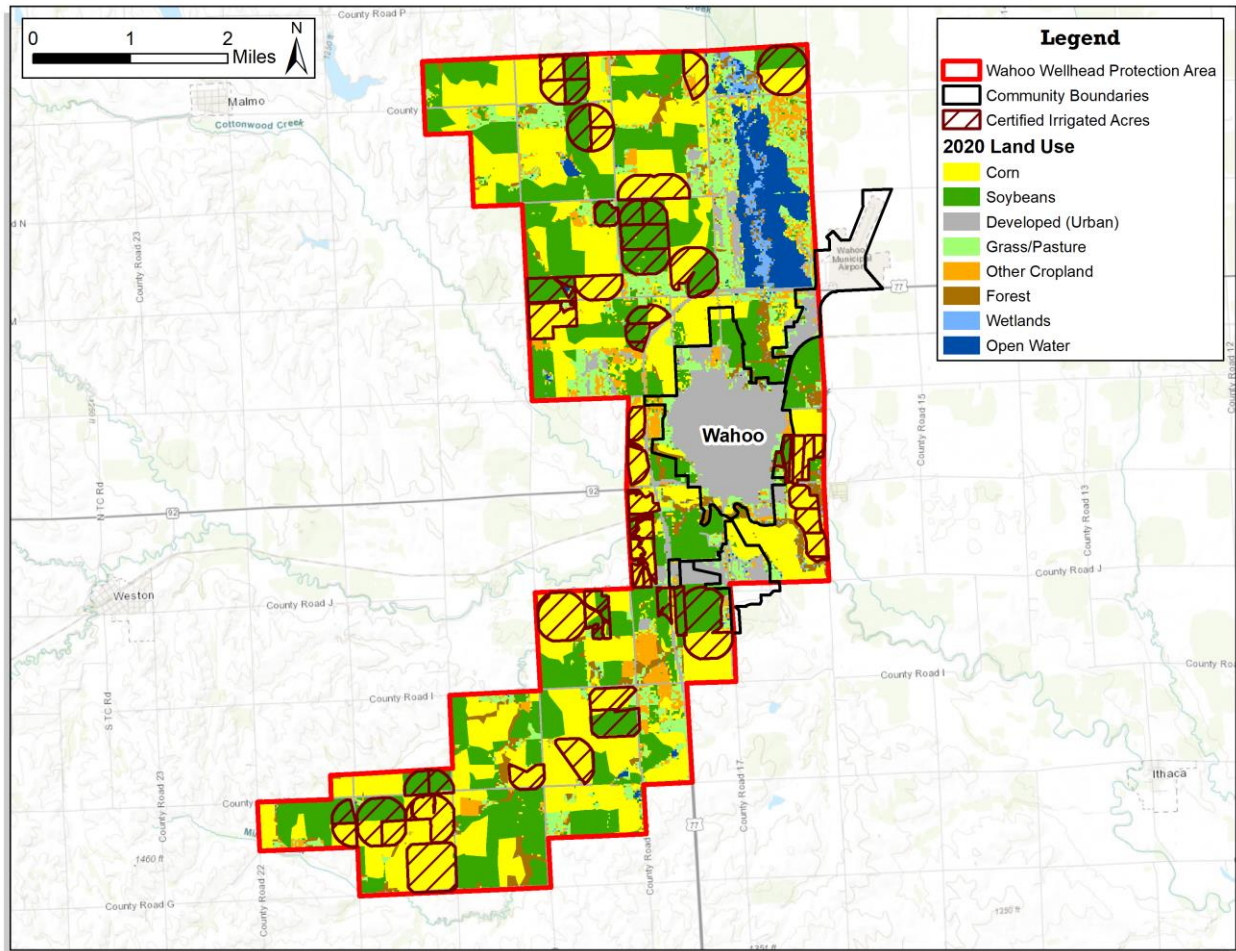
**Table 4: 2020 Land Use in the WHP Area**

Land Use Category	2020 Acres	% of WHP Area
Corn	5,506	36.7%
Soybeans	4,373	29.2%
Developed (Urban)	1,822	12.2%
Grass/Pasture	1,297	8.7%
Other Cropland	678	4.5%
Open Water	570	3.8%
Forest	550	3.7%
Wetlands	188	1.2%
<b>Total</b>	<b>14,984</b>	<b>100.0%</b>

Source: USDA, 2020

## IRRIGATED ACRES

Nitrate leaching losses from applied fertilizer and the spreading of manure can be exacerbated by irrigation water application. Identifying and utilizing BMPs that improve irrigation management and/or reduce the levels of applied nitrate fertilizer will result in decreased nitrate loading to both surface and groundwater resources. Within the LPNNRD, all irrigated acres are certified by the NRDs to manage groundwater quantity and quality concerns. Figure 17 displays the certified irrigated acres in the Wahoo WHP area. In total there are approximately 2,808 certified irrigated acres making up 19% of the WHP area. 135 acres in the WHP Area are irrigated with surface water, comprising about 5% of the total irrigated acres. In 2020, approximately 60% of irrigated acres were used to grow corn and 37% were used to grow soybeans. Irrigation wells make up 9% of all registered wells in the WHP area.



Source: USDA, 2020

Figure 17: 2020 Land Use and Certified Irrigated Acres in the Wahoo WHP Area

---

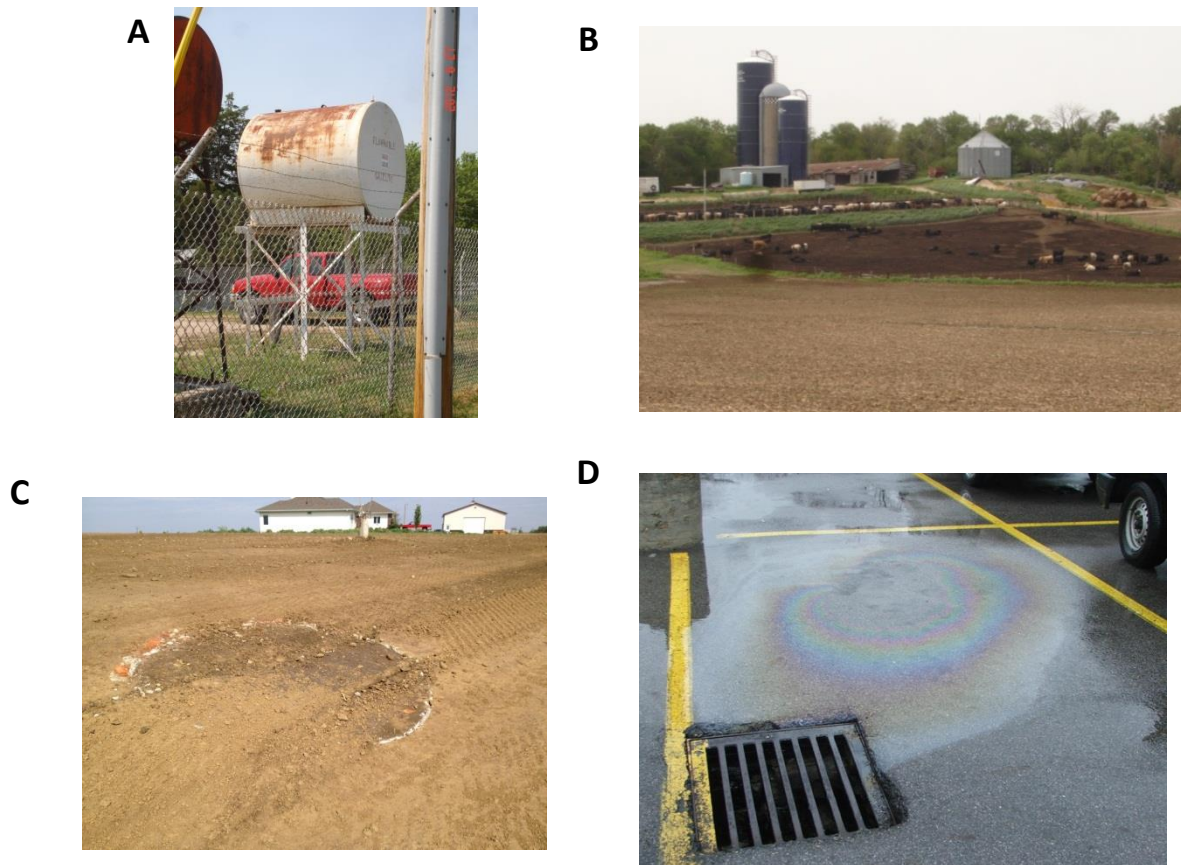
**CHAPTER 4. POTENTIAL CONTAMINANT SOURCE INVENTORY****BACKGROUND**

The purpose of a contaminant source inventory (CSI) is to identify potential drinking water contaminants or sources that the contaminants may originate from. The CSI is a major step in establishing a WHP plan and includes recording locations and information on potential contaminant sources such as fuel storage tanks, livestock operations, equipment storage yards, and many others (Figure 18).

A CSI allows a community to plan for and manage potential contaminant sources and decide where to focus educational and management efforts to minimize the likelihood of source water contamination. Strategies to limit pollution may vary greatly within the WHP area because of the varying types of potential contaminant sources. Several management strategies are discussed to limit NPS in Chapter 7: Management Strategies. The inventory is compiled from existing databases and on-the-ground observations. Even if identified in the CSI, a feature may not be contributing to contamination presently but may still present a risk.

***UNDERSTANDING WHAT POTENTIAL CONTAMINANT SOURCES EXIST WITHIN THE WHP AREA ALLOWS A COMMUNITY TO MAKE INFORMED DECISIONS AND SAFELY MANAGE THREATS TO THEIR DRINKING WATER SUPPLY.***

It is important to note that this inventory only represents a snapshot of the area's history. There may be features which have already contributed to groundwater contamination and left no record of their existence on the surface. Features recorded in the past may not be actively operating today. It is important to record historical land uses and activities due to the long period of time required for groundwater to respond to changes at the land surface. It is important to note that, even if identified in the CSI, a feature may not be contributing to contamination presently but may still present a risk.



**Figure 18: Common Types of Potential Contaminant Sources. (A) Leaking Fuel Drums; (B) Livestock Waste; (C) Abandoned Wells; (D) Parking Lot Runoff**

Based on guidance provided by NDEE, the inventory typically consists of the following types of points:

#### **Agricultural**

- Fuel Storage
- Grain Storage
- Water Wells
- Chemigation
- Livestock
- Abandoned Wells

#### **Commercial and Light Industrial**

- Auto Repair
- Dry Cleaners
- Fuel Stations
- Machine Shops
- Rail Yards
- Large Parking Lots

#### **Industry**

- Manufacturing Plants
- Gas/Oil Wells
- Junk Yards
- Landfills
- Sewage Treatment Facilities

#### **Other**

- Cemeteries
- Golf Courses
- Highway/Road Maintenance Yards
- Other Wells

---

## METHODOLOGY

Wahoo's CSI is a compilation of multiple sources:

- NDEE Regulated Facilities Database
- Nebraska Department of Agriculture Registered Pesticide Dealers Database
- State Fire Marshal Underground Storage Tank Database
- Nebraska Oil and Gas Conservation Commission Gas and Oil Wells Database
- NeDNR Registered Wells Database
- JEO Consulting Group, Inc. in-field survey completed September 2021

Note that the data made available through outside agencies was furnished for interpretive reasons. To the extent possible, the data is current, accurate, and reliable. However, there may be discrepancies in the information and not all map location coordinates have been verified. In addition, JEO assumes no legal responsibility, either implied or expressed, about the accuracy, completeness, reliability, or appropriateness of this data made available through or retrieved from these agencies.

## SUMMARY

A summary of all sites identified through the CSI is displayed in Table 5. CSI points are displayed in Figure 19, NDEE regulated facilities in Figure 20, and registered wells in Figure 21. Note that locations of underground storage tanks and registered pesticide dealers could not be mapped reliably.

The CSI identified 322 possible contaminant sources within the Wahoo WHP area. Of these sites, 192 were residences, including 146 acreages and 46 farmsteads. Equipment storage (33) and grain storage (18) sites that were identified include those that are found on acreages or farmsteads and were counted separately as they pose different threats to drinking water quality. 12 livestock operations were identified. Various other sites included automotive service (18), center pivots (17), gas stations (6), machine shops (4), two cemeteries, two medical clinics, a golf course, and a general 'other' category. Further information on the CSI, including the master table of all identified potential contaminant sources, is available in Appendix D.

There are 51 applicable NDEE regulated facilities in the WHP area (not including pesticide dealers or underground storage tank sites). Only sites that were active or of unknown status were included. Some of these facilities fall under multiple regulated categories, and some are listed in the same category multiple times, for example, if a single site contains multiple onsite wastewater treatment systems. Therefore, the number of sites in each category will add up to more than 51. The majority of these sites are made up of National Pollutant Discharge Elimination System (NPDES) compliance sites (26), onsite wastewater treatment systems (17), resource conservation recovery (12), and SARA Title III (10). The remainder of the sites include underground injection control (8), livestock waste control (6), integrated waste management (3), brownfields (3), leaking storage tanks (2), and superfund sites (2).

There are 339 active registered wells in the WHP area. Of these, 144 are used for domestic water supply, 71 for monitoring ground water quality, 53 for 'other' uses, 29 for irrigation, 23 for groundwater level observation, 13 for closed loop underground heat exchange, two for open loop heat pumping, two for injection, and two for industrial or commercial supply. Note that 'other' is a use category provided by NeDNR. There are no oil or gas wells in the WHP area. There are likely additional wells in the WHP area that are inactive, abandoned, or decommissioned. Additional studies could identify the locations of unused or abandoned wells for proper decommissioning.

**Table 5: Summary of Wahoo Contaminant Source Inventory**

NeDNR Registered Wells	
Well Use	Count
Domestic	144
Monitoring (Ground Water Quality)	71
Other	53
Irrigation	29
Observation (Ground Water Levels)	23
Ground Heat Exchanger well - Closed Loop Heat Pump well	13
Heat Pump well - Open Loop Heat Pump Well	2
Injection	2
Commercial/Industrial	2
Oil & Gas Wells*	0
<b>Total</b>	<b>339</b>

\*Regulated by Oil & Gas Conservation Commission

Note: Includes only active wells.

Potential Contaminant Source Type	Count
Acreage	146
Farmstead	46
Equipment Storage	33
Grain Storage	18
Automotive Service	18
Center Pivot	17
Other	17
Livestock Operation	12
Gas Station	6
Machine Shop	4
Cemetary	2
Medical Clinic	2
Golf Course	1
<b>Total</b>	<b>322</b>

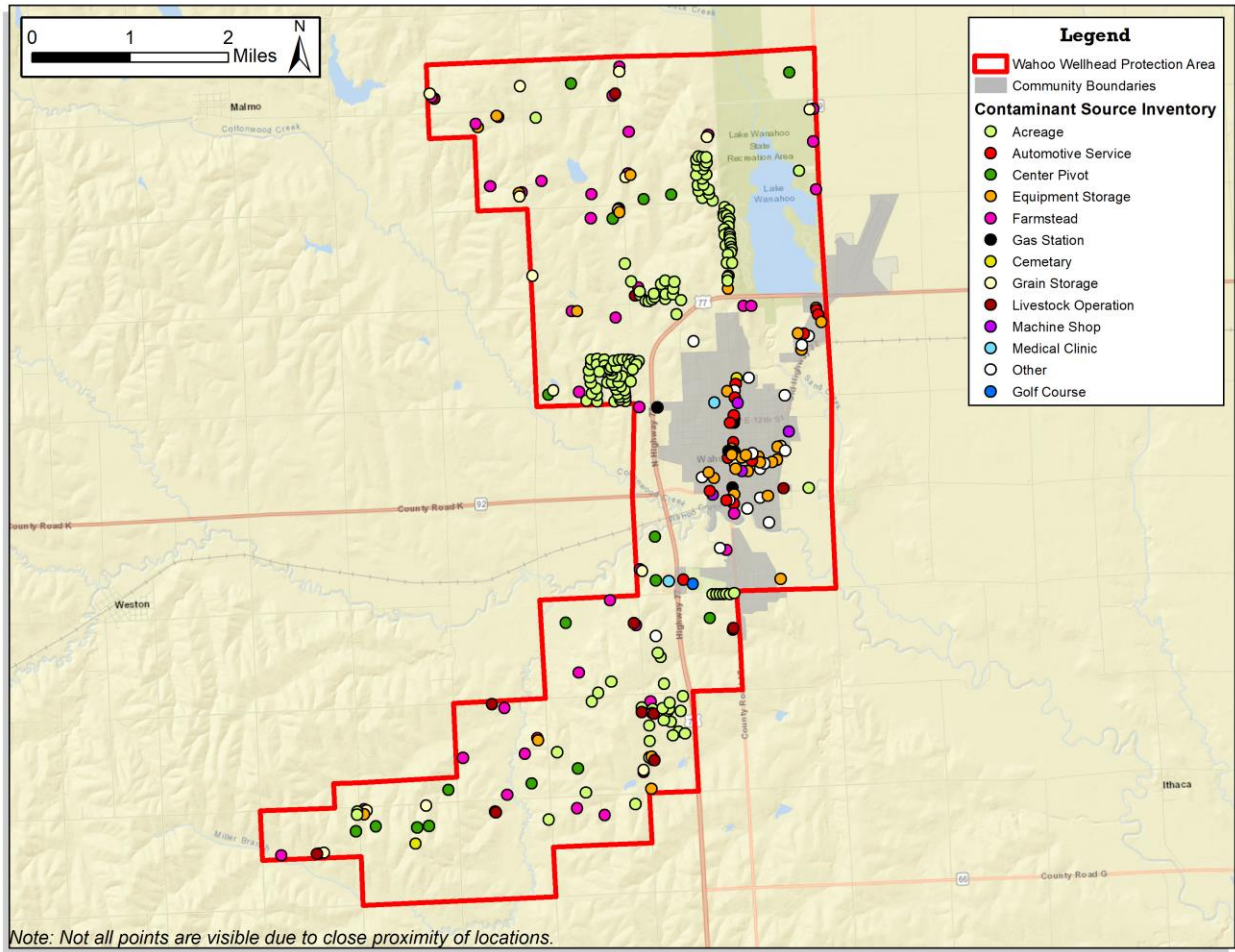
Applicable NDEE Registered Facilities	
Program	Count
NPDES Permits and Compliance	26
Onsite Wastewater Treatment	17
Resource Conservation Recovery	12
SARA Title III	10
Underground Injection Control	8
Underground Storage Tank Sites*	6
Livestock Waste Control	6
Integrated Waste Management	3
Pesticide Dealers**	3
Brownfield	3
Leaking Storage Tanks	2
Superfund	2
<b>Total</b>	<b>98</b>

\*Regulated by State Fire Marshall. Each site may have multiple tanks.

\*\*Regulated by NE Department of Agriculture

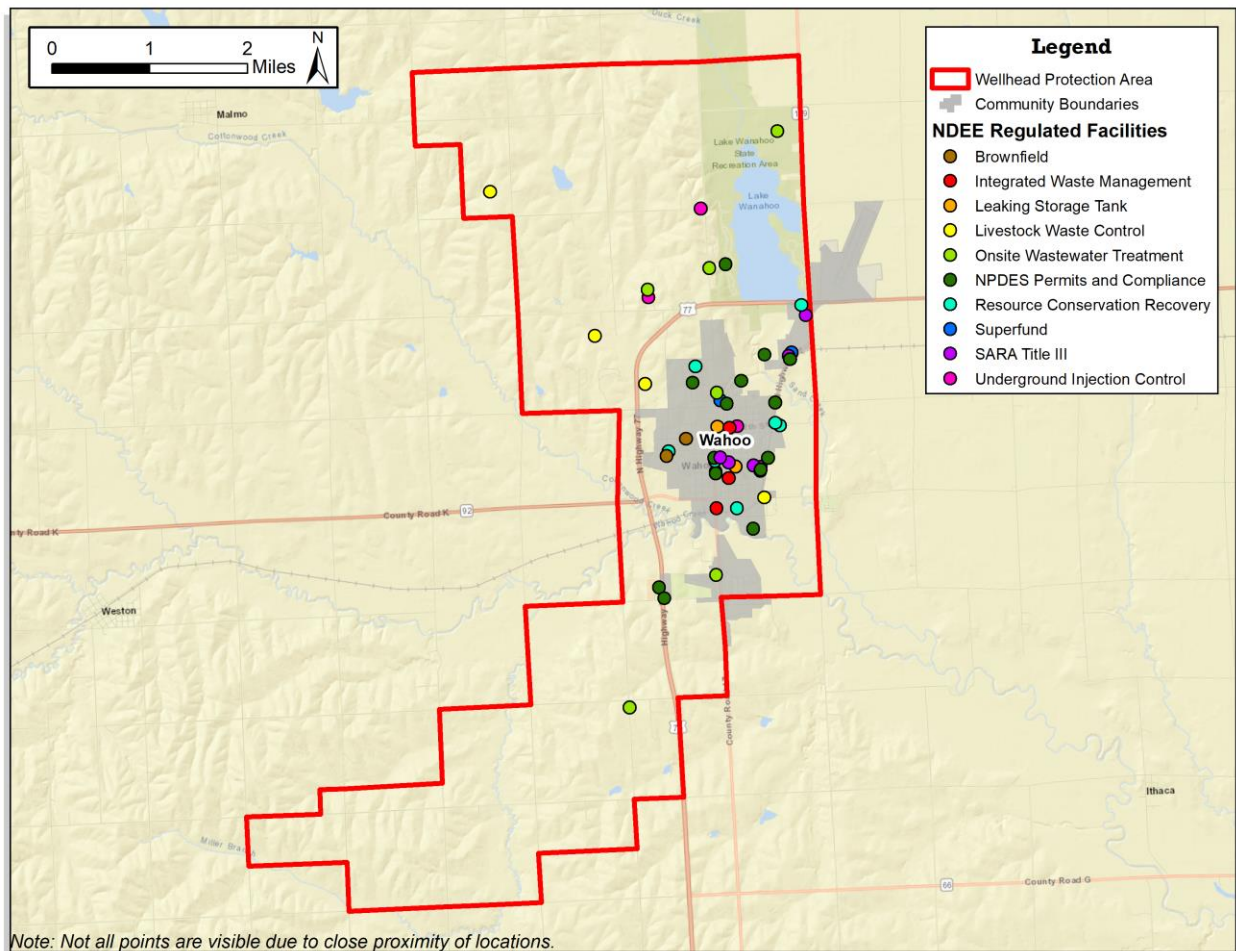
Note: Includes only active sites. Each site may be regulated by more than one program.





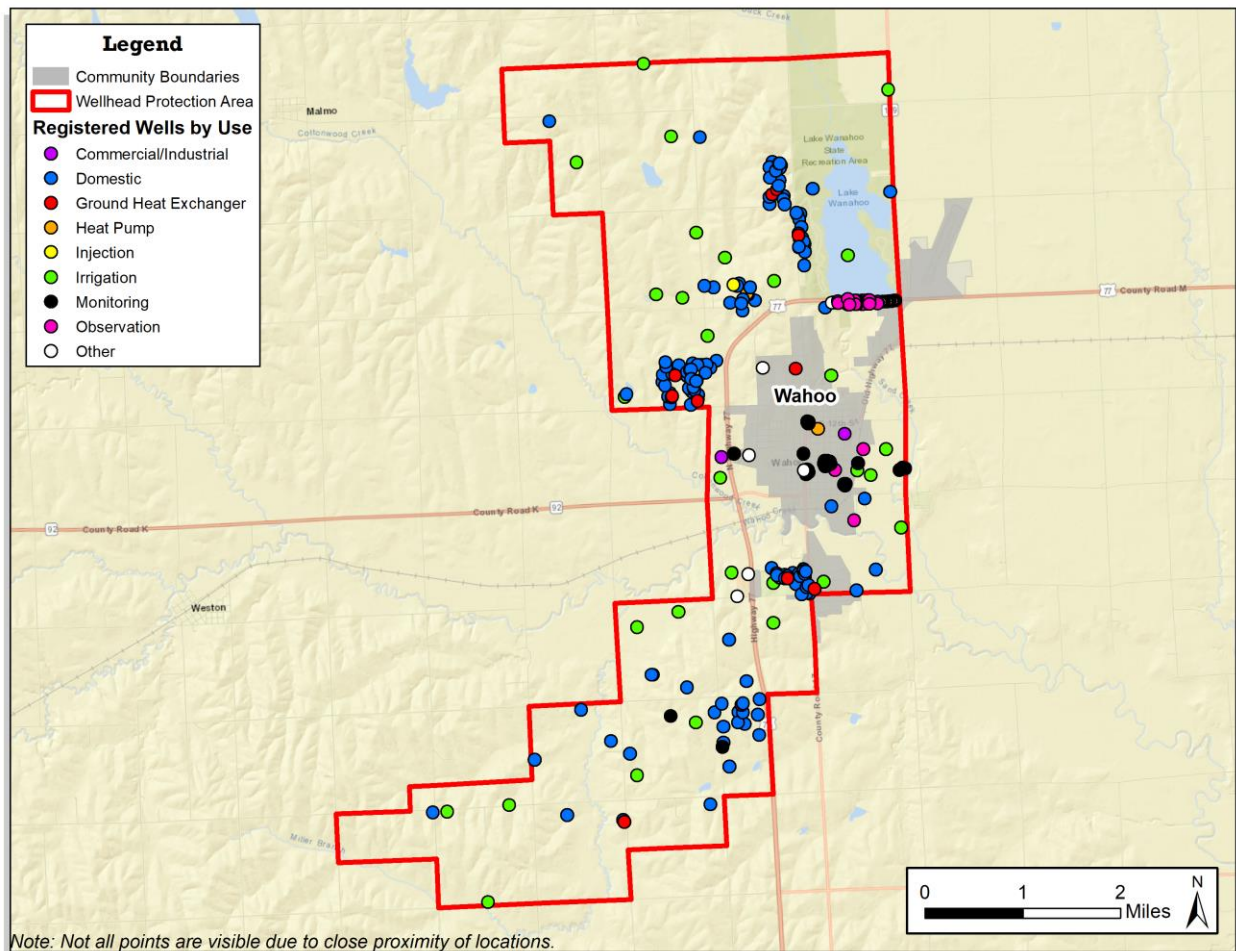
Source: JEO Consulting Group CSI – September 21, 2021

Figure 19: Contaminant Source Inventory in the Wahoo WHP Area



Source: NDEE Regulated Facilities Database

Figure 20: NDEE Regulated Facilities in the Wahoo WHP Area



Source: NeDNR Registered Wells Database

Figure 21: Registered Wells in the Wahoo WHP Area

**4.01 EXISTING GROUNDWATER CONTAMINATION**

There are existing sites, listed as NDEE regulated facilities, within the WHP area that are known to have, or have had, contamination of the potential for contamination of soil and water. These sites are under the regulatory authority of NDEE. While specifically addressing those sites or activities is not the focus of this plan, they are discussed here as their presence may play a role in the public's perception of the risks to their drinking water. Table 6 describes these facilities as provided by NDEE. Additional information can be found in Appendix D or may be obtained by contacting NDEE.

**Table 6: Summary of Existing Groundwater Contamination in the Wahoo WHP Area**

Name	Status	Summary
Saunders Co Health Services	Active	Nov 2008 Phase I Environmental Site Assessment (ESA) report for Saunders County Hospital. <b>Primarily lead-based paint and asbestos-containing materials are the recognized environmental conditions.</b>
Cerny Auto Body-Towing	Active	In early 2007, the property was up for sale and a Phase I ESA was initiated by NDEQ upon request, then the property was purchased by an owner who did not need a Phase I ESA and it was cancelled.
Slemin Property	Active	2009 Phase I ESA identified some stained soil at northwest part of site. A few lead acid batteries were observed on a wooden pallet in an open field. Several empty ASTs and metals drums observed on site. Report noted potential for lead-based paint and asbestos-containing materials.
Burkley Envelope Co	Active	Former lagoon / surface impoundment on site. PA Apr 1984, SI Dec 1989, collected soil, soil-gas, and groundwater samples and were all non-detect for VOCs and metals. <b>Assigned No Further Action under CERCLA and archived in CIRCLIS in Dec 1989.</b>
Denver Plastics Nebraska Ltd	Active	Manufactured custom plastic products for various industrial and commercial applications. 2018 Pre-CERCLIS Site Screening investigation was done by EPA START Contractor. Sampled six private wells and soil and groundwater sampling on site. <b>No evidence of a release was identified and no further action warranted.</b>
Wahoo Landfill (closed unlicensed dump)	Inactive	Unlicensed landfill/dump site operated from 1968 to 1994. Near eastern perimeter of the WPA. NDEE issued a <b>No further Action decision in 2010.</b>
Wahoo Solid Waste Disposal Site	Inactive	PA completed Dec 1990, SI completed Oct 1992; low levels of VOCs and heavy metals in groundwater. <b>No Further Remedial Action Planned under CERCLA, archived in CERCLIS Oct 1992.</b>
Oct 2008 private wells testing, within 1.5 miles east and south of Wahoo, NE	Inactive	Over 60 registered private wells. <b>Six wells were sampled and were all non-detect for VOCs.</b>
Saunders Co Health Services	Inactive	On May 28, 1991 one tank removed. Performed site investigation, public noticed and closed site 4/12/92
Bishop Neumann High School	Inactive	Clean Closure 9/29/89
Cerny Auto Body-Towing	Inactive	Tanks removed 6/76/06. Performed site investigation. Public noticed and closed 1/18/18.
J & K Auto Parts	Inactive	Clean Closure 2/22/93

Parkview Motors	Inactive	Clean Closure 12/9/88
Muthas Auto Body	Inactive	Clean Closure 3/3/98
Midtown Amoco	Inactive	Tanks removed 2/10/92. Performed free product cleanup. Public noticed and closed 8/20/12.
Midtown Amoco	Inactive	Same as above.
Wahoo Civic Center	Inactive	Tanks removed 8/17/89. Clean Closure 9/29/89
Wahoo Oil Co Service Station	Active	Tanks removed 2/4/99. Failed SSTL's, cleanup system installed and site continues cleanup.
NDOT Wahoo Yard	Inactive	Tanks removed 7/17/92. Site closed with contamination 2/9/93.
Casey's General Store 2700	Active	Tanks 7/23/97. Free product recover system installed and site continues cleanup.
Gottschalks Athletic Goods	Inactive	Tanks removed 4/27/89. Tier 1 investigation performed. Monitoring, then site closure 10/3/12
Wahoo City Offices	Inactive	Tanks removed 8/25/89. Site assessment 12/21/89, public noticed and closed 5/10/90.
Woitka Auto Body	Inactive	Tanks removed 10/6/89. Clean closure 3/5/90.
US Postal Service	Inactive	Tanks removed 1/22/92. Clean closure 3/31/93.
Wahoo One Stop	Inactive	Product lines removed 10/29/91. Tier 1 performed 11/27/2002. Site closed.
Windstream Communications	Inactive	Tanks removed 6/15/92. Clean closure.
Windstream Communications	Inactive	Same as above.
Dean's Automotive	Inactive	USTs removed and Tier 1 performed. Closed with contamination 2/10/2012
Saunders County Highway Dept	Inactive	Dispenser leak. Surface spill. Site over-excavated and closed 12/23/16
Union Pacific Railroad	Inactive	USTs removed 9/25/89. Site investigation performed. Site public noticed and closed 3/15/91
Roland Beach Farm	Inactive	General vapors in house complaint. Closed 9/19/94
Lindy Glass Inc	Inactive	UST release 10/13/88. Cleanup system installed 5/2/220. Public noticed and closed 11/19/2012
Wahoo Street Shop	Inactive	USTs removed 11/6/90. Site investigation performed. Public noticed and closed 3/31/2005.
Wayne Placek Trust Farm 8776	Inactive	600 Gallon UST removed. No CAR required. "Deferred Tank"
Chief Motel	Inactive	USTs removed 6/7/99. No investigation required. Clean Closure.
Barrister's Garden	Inactive	USTs removed 7/19/90. No investigation required. Clean closure.
Wahoo Oil Co Service Station	Inactive	USTs removed 12/17/98. Additional USTs removed 10/23/08. Free Product found. Site still under remediation.
Wahoo Oil Co Service Station	Inactive	Same as above.
Wahoo Oil Co Service Station	Inactive	Same as above.

---

Denver Plastics Nebraska Ltd	Inactive	Surface Spill of Hydraulic Oil -25 gallons. Over-excavated release and the site was closed 8/5/14
Contech Construction Products	Inactive	Property Sale Phase 1 found petroleum contamination 1/2/02. Performed a Tier 1 at the site 11/3/16. Site was public noticed and closed 9/7/17.
Saunders County Highway Dept	Inactive	Leakage from pump dispensers 8/8/90. Step 7 performed 12/13/90. Site closed 12/11/90
Wahoo Oil Co Bulk Plant	Inactive	UST release 9/11/89. Site began cleanup 12/13/94. Site public noticed and closed 12/1/2005.

Source: (NDEE, personal communication December 7, 2021)

---

## CHAPTER 5. REGULATORY AUTHORITY

### 5.01 CITY OF WAHOO

Due to the different threats and limits of jurisdiction across the WHP area, it is important that any current or future ordinances and/or zoning districts are flexible, enforceable, and developed with citizen/landowner input.

#### WAHOO MUNICIPAL CODE

Communities, including Wahoo, have the legislative authority to implement and enforce ordinances in order to protect the public health, safety, and general welfare of its residents. This power gives the city the ability to regulate actions within the corporate limits and potentially within its extraterritorial jurisdiction (ETJ), which is discussed in detail below. Currently, Chapter 53 of the Wahoo Board of Public Works Policy and Procedure Manual provides information on the Water Department's authorization, operations, and protection of the community's drinking water, within the city and its jurisdiction. Existing ordinances that may protect groundwater include:

- Section 53.05: Restricted Use
- Section 53.26: Pollution

In order to enforce regulatory control over the WHP area outside of the corporate limits, zoning controls would need to be considered in cooperation with Saunders County. The relevant pages of the Wahoo Board of Public Works Policy and Procedure Manual can be found in Appendix C, or at the city office.

#### WELL SETBACK DISTANCES AND ENCROACHMENTS

Well setbacks are regulated by nine different state regulations as summarized in Table 7. The most recognized setbacks are maintained by NDHHS and established in the latest version of Nebraska Title 179 – *Public Water Systems*, Chapter 7 (NDHHS, 2010). While these setbacks are identified by NDHHS, it is the responsibility of the local public water system and community to actively enforce or ensure compliance with the setback distances. Any setback distance or encroachment violations found by NDHHS must be eliminated or justified by an engineer to NDHHS. If necessary, NDHHS will take enforcement measures against the water system, but not on the violator or owner of the encroachment. This could include, but is not limited to, identifying a system as “vulnerable” or requiring additional monitoring. Essentially, if a community does not adopt and enforce these setbacks there is no active protection.

It is recommended by NDEE that communities formally recognize and enforce well setback distances through ordinance or zoning. This should be done in a way that the distances are automatically updated in accordance with any changes to the law. The City of Wahoo will recognize the setbacks as part of this plan and will recognize the WHP area through their code of ordinances and will enforce well setback distances.



**Table 7: Required Well Setback Distances, by Nebraska State Titles**

Category	Distance (ft)	Nebraska State Title								
		179	178	119	122	123	124	126	130	198
Water Well*	1,000	X	X							
Sewage Lagoon	1,000	X			X	X	X			
Land application of municipal/industrial waste material	1,000	X					X			
Feedlot or feedlot runoff/Livestock waste control facility	1,000	X								
Underground disposal system (septic, cesspool, etc.)	500	X			X		X			
Corral	500	X								
Pit/Vault toilet	500	X					X			
Wastewater holding tanks	500	X					X			
Sanitary landfill/Dump	500	X								
Chemical or petroleum product storage	500	X								
Sewage treatment plant	500	X								
Sewage wet well	500	X								
Sanitary sewer connection	100	X								
Sanitary sewer manhole	100	X								
Sanitary sewer line	50	X				X				
Class V domestic wastewater disposal wells	1,000				X					
Class V wells constructed above water table	1,000				X					
Class V well injecting into or constructed through uppermost aquifer	1,000				X					
Livestock waste control facility	1,000								X	
Fertilizer (paunch manure)	500							X		
Static pile or wind row paunch storage	500							X		
Paunch storage lagoon	500							X		
Paunch manure static pile or wind row storage	500							X		
Wastewater land application and effluent	500			X						
Absorption, infiltration, and evaporative systems	500						X			
CAFO manure, litter, or process wastewater applied	100								X	
New Secondary Containment/Loadout Facility	100									X

\*Only enforceable on Public Water System Wells.

Source: Nebraska Department of Environmental Quality, personal communication, May 15, 2017

## ZONING CONTROLS

The city has an adopted Comprehensive Plan (2017), zoning regulations (2020), zoning map (2018), transportation corridor design standards (2019), and subdivision regulations (2012). All these documents are available at the city office. The city and Saunders County could work collectively to create resolutions and ordinances in accordance with Nebraska Revised Statute 13-327 that apply to the WHP area outside of the city ETJ. Figure 22 illustrates the city's ETJ in comparison with the WHP area. The northwestern and southwestern portions of the WHP area is not included in the city's ETJ. City zoning ordinances only apply to areas within the ETJ.

Currently, Wahoo's Comprehensive Plan gives information about the wellhead protection program for future reference and displays the wellhead protection area but does not outline any additional regulations for the area. The city's Subdivision Regulations do mention wellhead protection regulations as one of the criteria for determining if an individual septic system may be installed. The city intends to amend their zoning regulations and adopt a wellhead protection overlay district. Such amendment would involve a

public hearing and recommendation by the Planning Commission and a public hearing and ordinance adoption by the city board. The wellhead protection overlay district will be illustrated on the Official Zoning Map and any adopted wellhead regulations would take priority over the underlying zoning district. An “overlay” district does not replace other zoning districts that may be located in the same area, it simply adds additional requirements (related to the districts purpose) that uses in the district must meet.

Saunders County has adopted a Comprehensive Plan, per the Nebraska Association of County Officials, which gives them the authority to enact zoning. Saunders County Planning and Zoning Department has jurisdiction over the unincorporated areas of the County, and currently has zoning regulations, last revised in April 2020. Saunders County’s zoning regulations do not currently have a wellhead protection overlay district within their regulations.

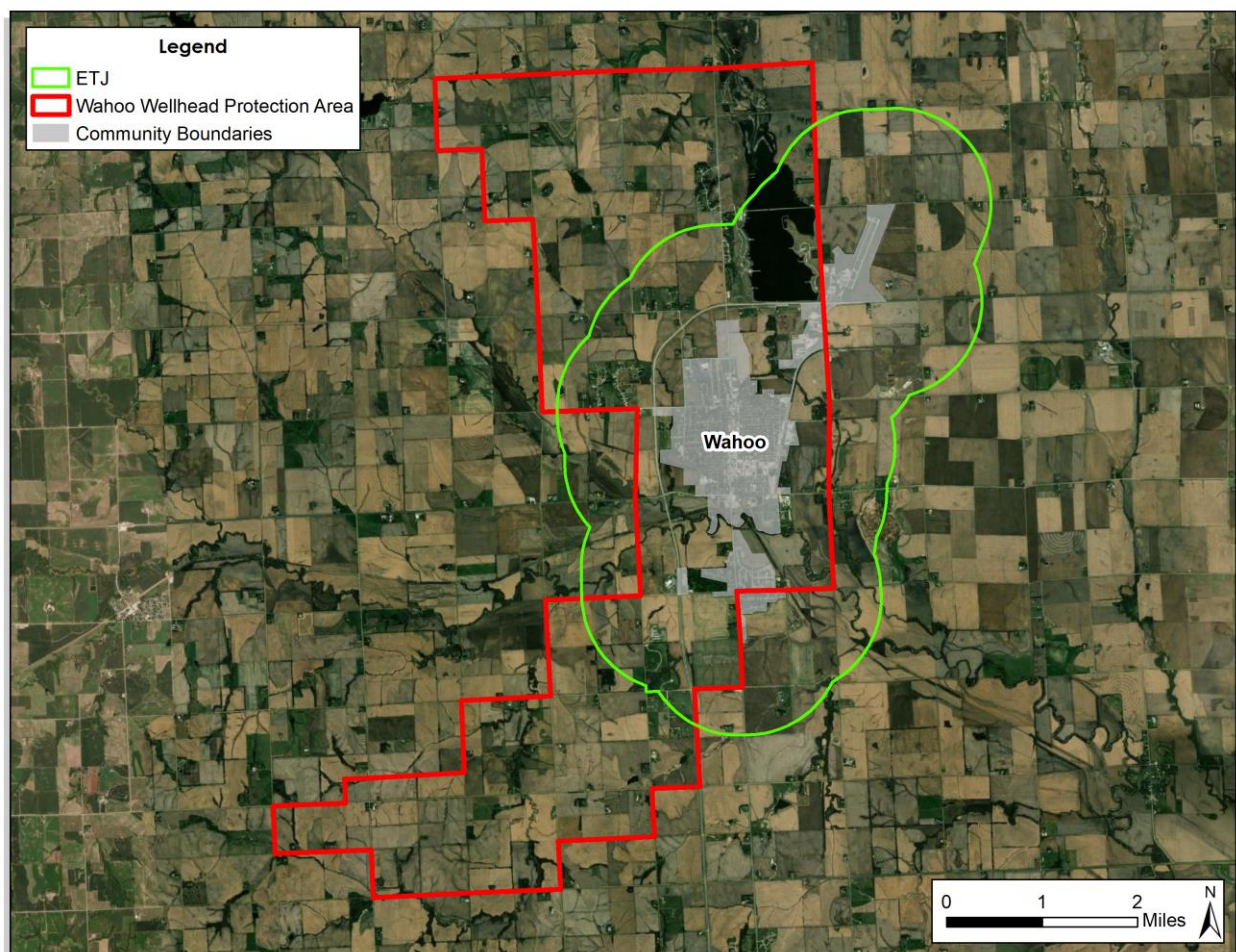


Figure 22: City of Wahoo ETJ and WHP Area

---

## 5.02 NATURAL RESOURCES DISTRICTS

All NRDs have the ability to require BMPs or to regulate practices in groundwater management areas (GWMAs) to protect groundwater quality and quantity. This authority originated in the Groundwater Management and Protection Act (GWMPA), which was passed by the Nebraska Legislature in 1984. In 1985, the state passed LB 1106 which required the NRDs to prepare groundwater management plans specific to their area and submit these plans to the NeDNR. In 1991, LB 51 was enacted, requiring NRDs to expand their management plans to include ground water quality protection. The LPNNRD's policies and rules are outlined in their Groundwater Management Area Rules and Regulations available online at: <https://lpnnrd.org/downloads/>. Pertinent information is summarized below.

### GROUNDWATER MANAGEMENT PLAN SUMMARIES

#### Lower Platte North NRD

The LPNNRD Groundwater Management Plan was first implemented in 1997 and last amended in 2018. Currently the LPNNRD has designated the area around Wahoo as a Phase I GWMA, and a Limited Development Groundwater Control Area. Development within this area is restricted to no more than 200 new acre-feet of irrigation per year. Phase I requirements include:

- Operators using fertilizer must be certified every four years
- Water well permits are required for new and replacement wells
- Well permit required for high-capacity wells greater than 50 gallons per minute
- Restrictions on application timing of commercial fertilizer in certain soil groups

## 5.03 STATE OF NEBRASKA

State statutes and laws are summarized in Appendix C as well as a listing of Nebraska's legislature statutes that allow local jurisdictions to protect public health and safety. Generally, the regulatory authority to manage WHP areas falls to local government entities. At the state level, NDEE approves WHP areas and can assist communities with WHP planning, including funding to support certain activities such as well closures, public meetings, incentives for BMPs, etc.

---

**CHAPTER 6. EMERGENCY, CONTINGENCY, AND LONG TERM PLANNING****6.01 EMERGENCY AND CONTINGENCY PLANNING**

Wahoo's Public Water System Emergency Response Plan is required by NDHHS and is available in Appendix E. The plan provides information and actions to be utilized in the event of a short-term emergency. The plan contains contingency procedures and emergency contact information to deal with the following emergencies/contingencies:

- Cyber attack – business system
- Drought/loss of source water
- Earthquake
- Finished water contamination
- Fire
- Flood
- Loss of SCADA from a cyber attack or malfunction
- Loss of water storage
- Power loss
- Prolonged water outage
- Severe weather
- Source pump failure
- Source water contamination
- Terrorism or vandalism
- Transmission and/or distribution system failure

**NEBRASKA WATER/WASTEWATER AGENCY RESPONSE NETWORK**

The city is currently a member of the Nebraska Water/Wastewater Agency Response Network (NEWARN). NEWARN is a statewide Water/Wastewater Agency Response Network (WARN) of “utilities helping utilities” to:

- Prepare for the next natural or human-caused emergency.
- Organize response according to established requirements.
- Share personnel and other resources statewide, by agreement.

NEWARN provides water and wastewater utilities with:

- A Mutual Aid Agreement and process for sharing emergency resources among water and wastewater agencies statewide.
- A mutual assistance program consistent with other statewide mutual aid and assistance programs and the National Incident Management System.
- The resources to respond and recover more quickly from a natural or human caused disaster.
- A forum for developing and maintaining emergency contacts and relationships.

Additional information can be found at <http://www.newarn.org/>

---

## 6.02 LONG TERM PLANNING

Wahoo's 2017 Comprehensive Plan has a number of goals relevant to the protection and maintenance of the drinking water supply. The most relevant are objectives under the infrastructure and environmental goals:

- **INF-2** Continue to expand and upgrade the water, electric, stormwater, and sanitary sewer system in a manner that will guide growth in a systematic and responsible manner.
- **ENV-1** Zoning and subdivision regulations should reflect the priority to protect the environmental and natural resources of Wahoo through the encouragement of preservation and conservation practices.

## 6.03 DROUGHT PLANNING

Agriculture is the primary sector affected by drought; however, impacts on rural and municipal water supplies can be severe. A drought plan can be an effective means to improving information flow on drought conditions, severity, and impacts. Thus, the timelines of mitigation and emergency response actions can be adequately updated. Mitigation actions for water supply systems commonly fall under the following categories:

- Assessment programs
- Water supply augmentation/development of new supplies
- Public awareness/education programs
- Water use conflict resolution
- Drought contingency plans
- Mutual aid agreements between communities/organizations

## WATER CONSERVATION PLAN

A water conservation plan is a strategy or combination of strategies developed by a public drinking water system. The intent of a water conservation plan is to identify actions to reduce water losses, waste, or consumption and increase the efficiency with which water is used, treated, stored, and transmitted. Additionally, water conservation leads to increased energy conservation and cost savings for utilities and their customers. Recommended actions/elements of a plan include:

- Conduct water use audits for consumers
- Offer fixture retrofits and replacements
- Offer rebates and incentives
- Promote water reuse and recycling
- Encourage landscape efficiency
- Reduce excessive distribution system pressure
- Identify Voluntary or Mandatory Water-Use Restrictions

The city does not currently have a water conservation plan. It is recommended that the city develop one, as discussed in Chapter 7.

### **DROUGHT READY COMMUNITIES**

The National Drought Mitigation Center, located at UNL, has developed a program known as “Drought-Ready Communities”. The intent of the program and associated “Guide to Community Drought Preparedness” is to help communities understand and reduce their drought risk. A certified drought ready community has taken steps to:

- Involve a representative cross section of the community
- Learn how drought has affected them in the past and how it would likely affect them in the future
- Set up a system to monitor and communicate about drought conditions in the community
- Prepare and document a set of actions to take before and in response to drought
- Educate the public about water, drought, and the community’s drought plan

Currently, Wahoo is not a certified Drought Ready Community. It is recommended that the city become one, as discussed in Chapter 7. Additional information is available online at:

<https://drought.unl.edu/droughtplanning/AboutPlanning/PlanningProcesses/Drought-ReadyCommunities.aspx>.

## CHAPTER 7. MANAGEMENT STRATEGIES

The intent of this plan is to provide a guideline for protecting the city’s drinking water source. This chapter outlines what has been done in the past and practical management alternatives that could be utilized by the city, landowners, producers, and resource managers to further protect the drinking water supply from nonpoint source pollution. Actions include a variety of approaches such as education, on-the-ground BMPs, data collection, regulatory options, and other projects.

### 7.01 ACTIVITIES COMPLETED TO DATE

The city has maintained a proactive stance in managing water quality in the WHP area. As summarized below, efforts completed before or during development of this plan include the following:

- The city completed a Water System Preliminary Engineering Report in December 2020 to evaluate improvements that could be made to their public water system.
- A hydrogeologic assessment was completed to determine aquifer vulnerability in the WHP area in August 2021.
- An effort to locate and decommission abandoned wells occurred in 2021 and 2022.
- Add others as appropriate.

### 7.02 PLANNED ACTIVITIES FOR THE NEAR FUTURE

The merits of many potential management activities were discussed during the planning process. During the development of the plan the city was actively seeking abandon wells for decommissioning. The city will explore the activities below and anticipates executing more actions in the near future:

- **Decommission Abandoned Wells** – Abandoned wells can directly channel contaminated surface water into groundwater, and so pose a considerable risk to water supplies. Abandoned wells must be decommissioned (filled, sealed, and plugged) according to state law or they are deemed “illegal”.
  - The LPNNRD will pay up to 75% of well decommissioning costs. Work must be done by a licensed well driller to qualify for cost-share, and a cost estimate must be obtained beforehand and submitted to the NRD for approval and inspection. If approved by LPNNRD, reimbursement will be provided to the well owner after work has been completed and paid for.
- **Well Setback Ordinance** – The city currently recognizes well setback standards, and the state setbacks are also incorporated into the overlay zone written in 2022.
- **Ongoing Public Education** – Education is often the first step in a successful WHP program. There are many entities which could assist in education efforts such as local schools, LPNNRD, UNL Extension, and the Nebraska Rural Water Association.
  - **Public education efforts may include, but are not limited to:**

- Focus groups
- Community workshops
- Press releases
- “Test-Your-Well” nights
- Distributing brochures
- School poster contests
- News/information articles
- Utility bill stuffers
- **Education could be on a variety of topics, such as:**
  - Nonpoint source pollution
  - Proper animal waste handling
  - Aquifer and groundwater basics
  - Private well and wastewater system management
  - Fertilizer and Pesticide application
  - Urban and Rural BMPs

### 7.03 POTENTIAL ACTIVITIES FOR CONSIDERATION

- **Drought / Water Conservation Planning & Readiness** – As previously discussed in Chapter 6.03, Wahoo could work with the National Drought Mitigation Center to become a certified Drought Ready Community. This would further enhance water conservation, help the city prepare for times of drought or water shortages, and provide another avenue for community involvement. Part of this process would be creating a water conservation plan for the city. This could also include completing a drought mitigation plan, completing drought planning exercises, and updating the city’s existing ordinances to improve how drought is handled.
- **Test-Your-Well Nights** – Hosting additional “Test-Your-Well Nights” with LPNNRD will provide outreach opportunities for public education about the WHP plan.

### 7.04 BEST MANAGEMENT PRACTICES FOR CONSIDERATION

Many BMPs have proven effective in reducing nonpoint source pollution and are commonly employed in Nebraska. In 2019 the NRCS expanded their National Water Quality Initiative to include source water protection. In 2020, the NRCS identified a list of BMPs with the greatest impact to source water protection (Table 8). These, along with BMPs identified through stakeholder feedback, are detailed in the following sections. NRCS offers up to 90% cost share on priority BMPs implemented in source water protection areas (WHP areas) through the National Water Quality Initiative. Implementation efforts are likely to be focused on these priority BMPs; however, this does not preclude other innovative practices that may be appropriate to specific projects or site conditions from being pursued. Information and education should always accompany BMP implementation efforts. Selection of BMPs or other actions should always consider field level characteristics, a producer’s management goals, and technical or financial resources



available. Additionally, because this is a voluntary plan, all BMPs will need willing landowners to implement them. The city could work in cooperation with the NRDs on a program to place nutrient reducing BMPs within the WHP area.

**Table 8: NRCS Source Water Protection Priority Practices**

Practice Code	Practice Name	High Priority Practice*
327	Conservation Cover	No
328	Conservation Crop Rotation	Yes
332	Contour Buffer Strips	No
340	Cover Crop	Yes
342	Critical Area Planting	No
351	Water Well Decommissioning	No
355	Well Water Testing	No
386	Field Border	No
390	Riparian Herbaceous Cover	No
391	Riparian Forest Buffer	No
393	Filter Strip	No
412	Grassed Waterway	No
430	Irrigation Pipeline	No
441	Irrigation System, Micro Irrigation	Yes
442	Sprinkler System	Yes
449	Irrigation Water Management	Yes
512	Forage and Biomass Planting	No
550	Range Planting	No
590	Nutrient Management	Yes
595	Integrated Pest Management	Yes
635	Vegetated Treatment Area	No
656	Constructed Wetland	No
657	Wetland Restoration	No
659	Wetland Enhancement	No

\*High Priority Practices have the potential to receive up to 90% cost-share.  
Source: (NRCS, 2020)

## CHAPTER 8. PUBLIC EDUCATION AND NOTIFICATION

### 8.01 OPPORTUNITY FOR PUBLIC INPUT

There must be proper documentation of public involvement to achieve NDEE approval. Development of this plan has followed the guidance of NDEE to ensure proper opportunity for public input. The following steps below are the basic minimum requirements that must be documented:

1. Prepare a WHP Plan
2. The plan is made available for public review at least 30 days prior to the meeting where public comment will be taken on the plan
3. Public comment is taken at a regularly scheduled meeting of the “controlling entity”

Materials documenting the fulfillment of each of these items (copies of newspaper notices, affidavit of publication, minutes, etc.) are located in Appendix F.

### 8.02 PLANNING STAKEHOLDER COMMITTEE

An eleven-member stakeholder committee was established at the initiation of the WHP planning process (Table 9). The stakeholder committee was responsible for plan review and served as local contacts to residents to provide information during the planning period.

**Table 9: Wahoo Wellhead Protection Stakeholder Committee Members**

Name	Representing	Title
Travis Beavers	City Government	Building Inspector and Zoning Administrator
Cody Brem	City Government	City Clerk
Ryan Hurst	City Utilities	Utilities General Manager
Dr. Paul Sutton	Community	Doctor
Shannon Hauswald	Community	Wahoo Public School Employee
Tom Koenecky	Community	Landowner
Tom Hrdlicka	County	County Supervisor
Daryl Andersen	LPNNRD	Water Resources Manager
Tatiana Davila	NDEE	Groundwater Geologist
Jonathan Mohr	JEO	Environmental Planner
Dave Henke	JEO	Senior Project Manager

### 8.03 MEETING SUMMARY

During the development of this WHP plan, the city established a stakeholder committee, which met multiple times, and a held public open house to offer residents and property owners an opportunity to voice their opinion or ask any questions about wellhead protection and the planning process. Below is a summary of the types and dates of meetings. Notifications for stakeholder meetings were by email, phone

calls, and word of mouth. Sign-in sheets and other public notification materials are located in Appendix G. Note that some meetings were held virtually due to the COVID-19 pandemic.

#### **Project Kickoff Meeting – February 25, 2021**

Department of Utilities representatives met with JEO, LRE, city representatives, LPNNRD, and NDEE to discuss the planning process, roles and responsibilities, the wellhead protection area model, stakeholder and public involvement, data sources for the wellhead protection plan, plans to create a wellhead protection overlay zone, well decommissioning, and the overall project schedule.

**Notification:** Attendees were invited to the meeting by email and phone calls.

#### **Stakeholder Meeting #1 – September 7, 2021**

JEO facilitated a meeting at the Wahoo City Offices that introduced stakeholders to the wellhead protection plan, including its purpose, a model of the area, efforts towards well decommissioning, and potential zoning changes. Attendees had the opportunity to ask questions and share any comments.

**Notification:** JEO emailed the full group and the City recruited individuals to join the stakeholder group.

#### **Technical Group Meeting – December 2, 2021**

#### **Stakeholder Meeting #2 –**

**Notification:**

#### **Public Open House –**

**Notification:**

---

**REFERENCES**

- City of Wahoo, 2019. Annual Water Quality Report for January 1 to December 31, 2019.
- City of Wahoo Utilities, 2021. Public Water System Emergency Plan. Published March 22, 2021.
- Gosselin, D.C., Headrick, J., Tremblay, R., Chen, X., and Summerside, S., 1997. Domestic well water quality in rural Nebraska: Focus on nitrate-nitrogen, pesticides, and coliform bacteria: Groundwater Monitoring & Remediation, v. 17, no. 2, p. 77-87. <https://doi.org/10.1111/j.1745-6592.1997.tb01280.x>
- JEO Consulting Group, Inc, 2020. 2020 Water System Preliminary Engineering Report. Prepared for the City of Wahoo, Nebraska. Published December 2020.
- LRE Water. 2021. Wellhead Protection Area Delineation: Department of Utilities, Wahoo, NE. Prepared for JEO Consulting Group, Inc. Published August 31, 2021.
- Maupin, M.A., Kenny, J.F., Jutson, S.S., Lovelace, J.K., Barber, N.L., and Linsey, K.S., 2014. Estimated use of water in the United States in 2010. U.S. Geological Survey Circular 1405, 56 p, <https://dx.doi.org/10.3133/cir1405>.
- National Research Council, 1993. Ground Water Vulnerability Assessment: Contamination Potential Under Conditions of Uncertainty: Washington, DC. National Academies Press, 210p.
- Natural Resources Conservation Service. 2020. Source Water Protection Practices. Presented at the January 2020 Nebraska Association of Resources Districts Legislative Conference.
- Nebraska Department of Environment and Energy. 2019. 2019 Nebraska Groundwater Quality Monitoring Report. NDEE Groundwater Section. Prepared November 2019. Retrieved from: <http://deq.ne.gov/Publica.nsf/PubsForm.xsp?documentId=7AA33E82AAC4119C862584C400682884&action=openDocument>.
- Nebraska Department of Environmental Quality (NDEQ). 2018. 2018 Nebraska Groundwater Quality Monitoring Report: Lincoln, NE, Water Quality Division. Retrieved from: <http://deq.ne.gov/publica.nsf/pages/WAT258>.
- Nebraska Department of Health and Human Services, 2010. Title 179 Public Water Systems: Chapter 7 Siting, Design, and Construction of Public Water Systems. Available at: [https://sos.nebraska.gov/rules-and-regs/regsearch/Rules/Health\\_and\\_Human\\_Services\\_System/Title-179/Chapter-07.pdf](https://sos.nebraska.gov/rules-and-regs/regsearch/Rules/Health_and_Human_Services_System/Title-179/Chapter-07.pdf)
- Nebraska Department of Health and Human Services, Drinking Water Branch Water Watch, <https://sdwis-dhhs.ne.gov/>, accessed September 20, 2021.

- New Hampshire Department of Environmental Service (NHDES). 2006. Environmental Fact Sheet: Nitrate and Nitrite: Health Information Summary: Concord, NH, NHDES Water Division. Retrieved from: <https://www.des.nh.gov/organization/commissioner/pip/factsheets/ard/documents/ard-ehp-16.pdf>.
- Rahman, A., 2008. A GIS based DRASTIC model for assessing groundwater vulnerability in shallow aquifers in Aligarh, India: Applied Geography, v. 28, no. 1, p. 32-53. <https://doi.org/10.1016/j.apgeog.2007.07.008>.
- United States Bureau of the Census, 2018. American Community Survey 5-year Estimates: U.S. Census Bureau
- United States Department of Agriculture, 2020. Cropland Data Layer, Washing, DC: National Agricultural Statistics Service. Available at: <https://nassgeodata.gmu.edu/CropScape/>.
- Weber, K., Nola, J., 2015. Natural Uranium Contamination in Major U.S. Aquifers Linked to Nitrate: Environmental Science and Technology Letters, vol. 2, no. 8, p. 215-220. <https://doi.org/10.1021/acs.estlett.5b00174>.

**LIST OF APPENDICES**

**APPENDIX A: GROUNDWATER MODELING DOCUMENTATION AND MAPS**

**APPENDIX B: PUBLIC WATER SYSTEM DOCUMENTS**

**APPENDIX C: SELECT ORDINANCES AND MUNICIPAL CODES**

**APPENDIX D: CONTAMINANT SOURCE INVENTORY**

**APPENDIX E: EMERGENCY RESPONSE INFORMATION**

**APPENDIX F: PLAN ADOPTION MATERIALS**

**APPENDIX G: DOCUMENTATION OF STAKEHOLDER INVOLVEMENT**