PATTERNS IN LAND USE, GEOGRAPHY, AND TOTAL COLIFORM BACTERIA CONCENTRATIONS IN DRINKING WATER SOURCES FOR THE SANTEE SIOUX NATION

Haskell Environmental Research Studies

Amanda Rouillard

July 2019

Table of Contents

Introduction

The overall aim of my project is to study patterns between land use, elevation, and floodwaters on drinking water quality in Santee, Nebraska. Livestock pastures and septic lagoons are two primary point-source pollutants of total coliform bacteria, specifically fecal coliform, in groundwater wells used for the reservation. Floodwaters, channelized runoff, and high concentrations of bacteria will further degrade water sources used for drinking water within Santee.

Background

A significant portion of Indian Country experience a disparity concerning safe drinking water. Reservations are historically underserved when it comes to access of potable water sources, typically a result of poor tribal and government structure, and lack of economic resources. The Omaha tribe in Macy, Nebraska had multiple outbreaks of fecal coliform bacteria in their groundwater, in 2013 and 2016, due to poor well construction. The water supply made a significant number of tribal members ill, and resulted in a declared state of emergency (Reece 2016). Total Coliform bacteria (CB) are microorganisms present in the digestive tract of mammals, including humans. Santee is a tribal reservation located in northeastern Nebraska without access to clean drinking water due to CB contamination (McGinnis and Davis 2001). (See figure 2) Santee was established by President Andrew Johnson's Executive Order of 1866, as a home for the Santee Sioux Nation (Reclamation 2004). Water is essential for life and connects all living things. Indigenous people consider water a sacred element important to cultural beliefs and practices.

Santee is supplied with unsafe drinking water due to fecal coliform bacteria contamination in water supplies. Ground water from wells within the reservation cannot be consumed by residents. Safe drinking water must be purchased. The Safe Drinking Water Act (SDWA) was authorized by Congress in 1974 to regulate water quality standards for drinking purposes and to enforce primary standards or maximum contaminant levels associated with health risks (Bureau of Reclamation 2004). A high percentage of wells sampled within reservation boundaries exceed the U.S. Environmental Protection Agency (EPA) primary drinking water standards for CB (Bureau of Reclamation 2004). A population without access to safe drinking water is a concern for public health, food safety, natural resource management, and environmental protection.

Research Question

How does land use increase fecal coliform bacteria concentrations in ground water sources for the Santee Sioux Nation? My project examines land-use patterns, geographical features, and climatic events in relation to drinking water quality for the tribe. Research is necessary to discern why poor water quality continues to be an issue for the Santee Sioux Nation with the potential to worsen.

Literature Review

Total Coliform Bacteria

A common technique among scholars is the use of total coliform bacteria as an indication of contaminated water. CB are microscopic organisms who reside in the lower intestines of warm-blooded mammals. CB do not cause disease, their presence indicates more dangerous bacteria, such as salmonella, may be present (Gosselin et al. 1997). Sometimes CB are excreted in both human and animal fecal matter, serving as an indicator of recent contamination by

sewage or livestock operations (Chirila, Minea, and Iancu 2010). Fecal coliform are a subgroup of total coliform bacteria, *Escherichia coli* (E. coli) is included in this group along with *Citrobacter, Klebsiella*, and *Enterbacter* (Eccles et al. 2017). Groundwater wells containing CB are a health concern for populations relying on contaminated wells as their primary source of water (McGinnis and Davis 2001). When pathogenic microorganisms enter drinking water, they pose a risk to human health (Jamieson et al. 2003). Testing for CB is the most reliable way to monitor water quality in a specific source. Members of the Santee Sioux Nation receive unfit water due to the mobilization of CB into ground water sources.

Source of Pollution

A prevalent source of fecal coliform bacteria are septic lagoons and livestock pastures. There are several mechanisms for bacteria to enter water systems including surface runoff, groundwater flow, and direct discharge. In regards to sewage pollution potential, the most important factor of a sewage system malfunction is age (Bishop et al. 1998). A number of ground conditions also increase the likelihood of sewage leaking such as groundwater movement and fluctuating levels of the water table. Livestock are considered one of the major sources of microorganisms in ground water systems (Jamieson et al. 2003). CB is excreted by cattle and carried in to water supplies, lower concentrations are carried into ground water due to the relationship between water and soil, while higher concentrations are found in surface waters because of direct contact. Septic lagoons and livestock pastures are examples of how CB gains access into drinking water supplies.

Flooding

Researchers have noted a strong environmental link between flooding and ground water contamination. Heavy rainfall events and flooding are characterized by high volumes of water and increased streamflow. Water quality is impacted through runoff transporting suspended solids, chemical, and biological substances into bodies of water (Roig et al. 2011). Unfit ground water supplies are a leading cause of waterborne disease outbreaks, notably within developed countries due to the common misconception that ground water is a universally safe resource (Eccles et al. 2017). At least 36 waterborne disease outbreaks preceding heavy rain or flooding events were reported to the Center for Disease Control and Prevention (CDC) between 1971 and 2008 (Andrade et al. 2018). High concentrations of fecal coliform bacteria occur when stormflows peak during spring months. Heavy rainfall generates bacteria transport-mechanisms, which may degrade water quality for an extended period of time. (Jamieson et al. 2003). Heightened mobility of pathogenic microorganisms further increase human susceptibility to disease when in contact with contaminated water (Andrade et al. 2018). Flooding and heavy rain events are associated with contamination of ground water by increasing the pathogen load into water resources. This type of pollution involves many intricate ecological relationships requiring further analysis.

My project fits within existing research by combining information on the drinking water deficit in Santee with geographical and land use patterns, and to examine potential of future pollution due to seasonal flooding events. CB contamination of groundwater supplies is found in rural areas of the Midwest however, the frequency of CB contamination in Indigenous communities is less discussed. Water quality on reservations throughout the United States is

relatively poor and underreported, my research will help bring awareness about water issues pertaining to the Santee Sioux Nation.

Data and Methods

For this project I compiled environmental data concerning well water quality, land characteristics, geographical features, and data from past flooding events. Reports by the United States Department of the Interior, Bureau of Reclamation from 2004, 2006, 2008, and 2011 were used and are available online. These reports include background information on the Santee Sioux Nation, data on water quality, septic system information, livestock, and agricultural practices within the reservation. Esri's ArcGIS, a geographic information system, was used to access geospatial datasets to explore the geography of Santee. Light detection and ranging (LIDAR) datasets were used to survey land-use and cover of the study area. The United States Geological Survey (USGS) Water Information System was used to access data from specific water monitoring sites and dates of hydrological events. Data was analyzed to form an overall view of the state of water provided to members of the Santee Sioux Nation and to show how relationships between geography, land-use, and flooding impacts water quality.

Analysis

Water System Infrastructure

A water supply network consisting of wells, treatment, and distribution provide public water to the reservation. There are five principal aquifers underlying the study area, of which three are commonly used, the Quaternary alluvial aquifer, the Ogallala aquifer, and the Dakota aquifer. The Coddel aquifer and Lower Paleozoic aquifer systems have limited use due to occurrence and depth (McGinnis and Davis 2001). Water is first drawn from two forty-foot wells

located along Bazile Creek in the western portion of the reservation. Combined both wells pump an average of 200 gallons per minute (Reclamation 2004). Water is then treated in a "chlorine building" before being transported to storage. The distribution system consists two buried water storage tanks, which can hold up to 195,000 gallons of water. From here a six inch water main then distributes water throughout the reservation (Reclamation 2004). Effectiveness of Santee's water supply network is dependent on contact time of chlorination treatment to provide adequate disinfection.

Water Quality

Water delivered to members of the Santee Sioux Nation is of poor quality due to high concentrations of fecal coliform bacteria. According to a report composed by the Bureau of Reclamation in 2006, 44% of ground water samples taken within reservation boundaries exceed EPA primary drinking water standards for CB. Streams and surface waters were sampled and 100% contained CB, > 200 colony forming units per 100 milliliters (Reclamation 2006). A lack of pesticides in samples indicate the contaminate source is likely point-source pollution from livestock pastures or septic systems, as opposed to non-point source agricultural pollution (Reclamation 2006). Findings indicate the poor quality of water supplied to residents is likely due to contamination of CB from livestock pastures and septic lagoons operated on tribal land. Contaminant sources are positioned at higher elevations in comparison to groundwater wells allowing contaminants to travel easily downhill, a main factor in high contamination levels in groundwater sources.

Current Techniques

A primary counterpoint in the detection of coliform bacteria in water sources are methods used to observe CB in drinking water. Current methods are time-consuming and sensitive, as result are not adequate for in field response to a heavy runoff event such as flooding (Roig et al. 2011). Laboratory techniques used to detect the presence of coliform bacteria in water is based on microbial cultures. Methods used include the multiple-tube fermentation technique and the membrane filter technique, both of which require specific media and incubation conditions. Detecting CB and Escherichia coli (E.coli) is based on specific enzyme activity of beta-galactosidase and beta-glucuronidase (Rompré et al. 2002). The membrane filter technique is most commonly used because of simplicity and affordability. Current techniques are not only time-consuming but have limitations, such as the duration of incubation. Due to such factors common methods used to detect coliform bacteria in drinking water are not efficient in times of crisis such as a flooding event.

Septic Lagoons

A potential source of microbial pollution in Santee's groundwater is septic system effluent from sewage lagoons utilized by the tribe. Sewage system effluent is liquid waste or sewage discharged from a septic system into a water source (Bishop et al. 1998). The tribe's septic system involves waste disposal in four septic lagoons located outside of the residential area. The lagoons were constructed in 1978 and last reconditioned in 1993 due to excess leakage (Reclamation 2004). The septic system also consists of a gravity collection network with a submersible lift station, which pump wastewater from homes at low elevations to the septic lagoons located over 100 feet higher (Reclamation 2004). CB are present in human fecal matter

making these lagoons a likely source of bacteria. The lagoons are constructed above ground and at a much higher elevation, and as a result are exposed to run off carrying fecal coliform bacteria downhill into ground water sources used for the tribe. Ground water contamination caused by septic system effluent needs to be assessed to determine the scale of problems so action can be taken to secure potable water for the tribe.

Land Use

Another potential source of microbial pollution are livestock pastures located on reservation land, which coincide with portions of the study area with the highest elevation. Forests dominate the northern portion of the area and on bottom lands along Bazile, Lost, and Howe Creeks. Pasture and rangeland are primarily on dissected plains with moderate to steep slopes. Cropland exists in the remainder of the study area, mainly in areas of rolling hills with slight to moderate slopes (Reclamation 2006). Cattle not only pollute water sources, but also represent a large portion of water demand. The tribe operates the Saint Bar Ranch producing beef and alfalfa, an important income for the Santee Sioux Nation. The ranch spans approximately 3,400 acres of tribal land and owns 800-head of cattle and 100-head of buffalo. A growth for the Saint Bar Ranch is anticipated, the number of cattle is expected to grow to 1,000 and buffalo to 200 (Reclamation 2006). Buffalo are significant to the tribe, they promote cultural ties as well as tourism for the area.

Elevation

Elevation plays an important role in how water moves through the environment and on water quality. During heavy rain events some water cannot be absorbed into the soil, excess water flows downhill in the form of runoff. As water moves, it picks up sediments and

contaminants such as CB and transports the pollutants from high elevations to low elevations. This results in increased concentrations of pollutants in low elevation catchment areas such as Santee. As a result, the tribe's drinking water is negatively impacted by land-use at higher elevations. Catchments dominated by a particular land-use, such as livestock pastures, show patterns in water quality, like the presence of CB (Larned et al. 2004). Elevation is key to high levels of runoff, which can be channelized into specific water sources such as Bazile Creek, increasing amounts of contamination in drinking water supplies for the Santee Sioux Nation. The lowest point of the study area is the bottomlands to the north along the Missouri River at 1200 feet. Between 30 and 70 feet higher are groundwater wells along Bazile Creek used to supply water for the tribe. Over 100 feet higher are the four exposed septic lagoons. Around 1400 to 1800 feet up are the highest portions of the reservation, as well as the location of livestock pastures. All sources of CB are at much higher elevations than groundwater wells making it easier for these bacteria to gain access into the water supply. (See figure 1)

Location	**Elevation (feet) Lowest point**	**Elevation (feet) Highest Point**
Within tribal land	1200	1900
Wells*	1230	1270
Septic Lagoons	1320	1340
Pastures	1400	1800

*Of the two wells used the lowest was the well located to the north and the highest was the well located to the west

Flooding and Heavy Rain Events

Due to geographic location, Santee is susceptible to seasonal flooding and heavy rain events. Runoff from hydrologic events acts as a transport-mechanism for coliform bacteria. Runoff carries CB from livestock pastures and septic lagoons, uphill, into ground water, downhill. Water sources are located along Bazile Creek at low elevations, as a result the water has high concentrations of contaminants, including (CB). Bazile Creek enters the reservation from the south and continues north into the Missouri River, in all it drains a total of 365 square miles, 56.2 of which are tribal lands (Reclamation 2004). The health of Bazile Creek is represented in the quality of water obtained from ground water wells below. Due to an increase of sediments within Bazile Creek, flooding has become more common in areas of low elevation.

In 1999, a record flood submerged the well field resulting in contamination of the public water supply by fecal coliform bacteria efficient enough to declare a state of emergency (Reclamation 2004). Several months of cleanup were required to return the water supply to tribal members, in response emergency water was trucked in for an extended period. Following the flooding event, wells were elevated above the floodplain to a height declared sufficient to avoid predicted flooding problems. Heavy rain events resulting in flooding, like this occasion, can overflow septic systems resulting in increased microbial contamination of drinking water (Boholm and Prutzer 2017). Flooding events may also cause infrastructural damage to water supply systems.

In March of 2019, the Midwest experienced catastrophic flooding, three-fourths of Nebraska counties declared a state of emergency, including the Santee Sioux Nation. (See figure 3) Heavy rainfall and rapid snowmelt caused swelling of creeks and rivers resulting in the

collapse of dams, bridges and roads throughout the state. A major cause of devastation was the amount and size of ice carried in flood waters. Economic damage for the state of Nebraska was estimated to surpass $1.3 billion. Costs include $449 million in damage to roads, levees and other infrastructure; $440 million in crop losses and $400 million in cattle losses (Schwartz, 2019). Santee suffered a power outage after five power lines were toppled by floodwaters and ice. Infrastructural damage to the water distribution system cut off the water supply to tribal members. Damage to the main road into Santee made it difficult for repairs and to receive supplies. Combined these factors caused the tribe to evacuate some families and elderly to the casino south of Santee (Abourezk, 2019). A website to request funds collected donations to help pay for repairs. Surrounding communities volunteered and donated bottled water, food, hygiene products and other supplies. Several tribes gifted money for repairs and donated supplies including the Winnebago, Ponca, Sisseton Wahpeton Oyate, Shakopee and Yankton Sioux (Abourezk 2019). Majority of communities who assisted, both tribal and non-tribal, were also impacted by the flood, yet still came together to help one another.

Climate Change

Groundwater resources have the potential to be strongly impacted by climate change, the main source of water used for the Santee Sioux Nation. A predicted increase in frequency and intensity of flooding events has the potential to escalade bacterial contamination in groundwater supplies (Andrade et al. 2018). (See figure 4) Increasing temperatures boost microbial growth, and with insufficient treatment or distribution systems water is more prone to contamination (Boholm and Prutzer 2017). It is probable that groundwater supplies for Santee will degrade more quickly due to climate change.

Policy

Deficient assistance or acknowledgment of water quality issues on reservations is a result of inadequate tribal and government structures. Tribes are recognized as domestic-dependent nations by the United States government. The Bureau of Indian Affairs (BIA) handles relations between tribal nations and the United States government, history between these entities formed a distrust experienced today. The Federal Indian Trust Responsibility is an important principal when discussing tribal and government relationships. According to the BIA, "The federal Indian trust responsibility is a legal obligation under which the United States has charged itself with moral obligations of the highest responsibility and trust toward Indian tribes (BIA 2019)." This trust doctrine is a legal obligation on the U.S. to protect tribal treaty rights, lands, assets and resources in respect to indigenous communities (BIA 2019). Subsequently, complications occur when discussing whether or not potable water sources are a tribal, state or federal issue (Reece 2016). Such complexity makes it difficult to contest the right for safe drinking water in many Indigenous communities.

Discussion

One solution to supply residents of Santee with clean drinking water is to construct a surface water treatment plant at the Missouri River. To accommodate for low elevation and fluctuation of water and sediment near the residential area of Santee, the treatment plant should be constructed up river, from there treated water can be distributed to the reservation (Reclamation 2008). Another option would be to construct a new treatment plant near the existing well field along Bazile Creek. The current well field could be expanded or new wells could be installed in the south-east corner of the reservation (Reclamation 2008). Water from the

southern portion of the study area is less susceptible to contamination in comparison to current wells used to supply water. Both options would provide tribal members with access to clean drinking water, substantially improving the quality of life in Santee.

Personal Impact Statement

Growing up in Santee I experienced a drinking water deficiency first-hand and was unaware because this issue is such an accepted norm on the reservation. Unsafe drinking water forces residents, including myself and my family, to buy water for drinking purposes from the store. The location of Santee was a decision made by the federal government, which forcibly removed my ancestors from their indigenous homelands and placed the population in a location prone to poor water quality. My research was conducted to educate the public about this matter, and to express how our drinking water predicament is indeed not normal.

Conclusion

Patterns between land use, elevation, and location make Santee's ground water sources more susceptible to bacterial contamination by fecal coliform bacteria. Annual flooding and heavy rain events result in channelized runoff further increasing the likelihood of bacteria being transported into groundwater sources. Supplying members of the Santee Sioux Nation with clean drinking water would require an initial investment for a new treatment plant, distribution system, and storage system. The economic price is worth the cost of something everyone deserves the right to, something essential to all life, water.

Figure 1:

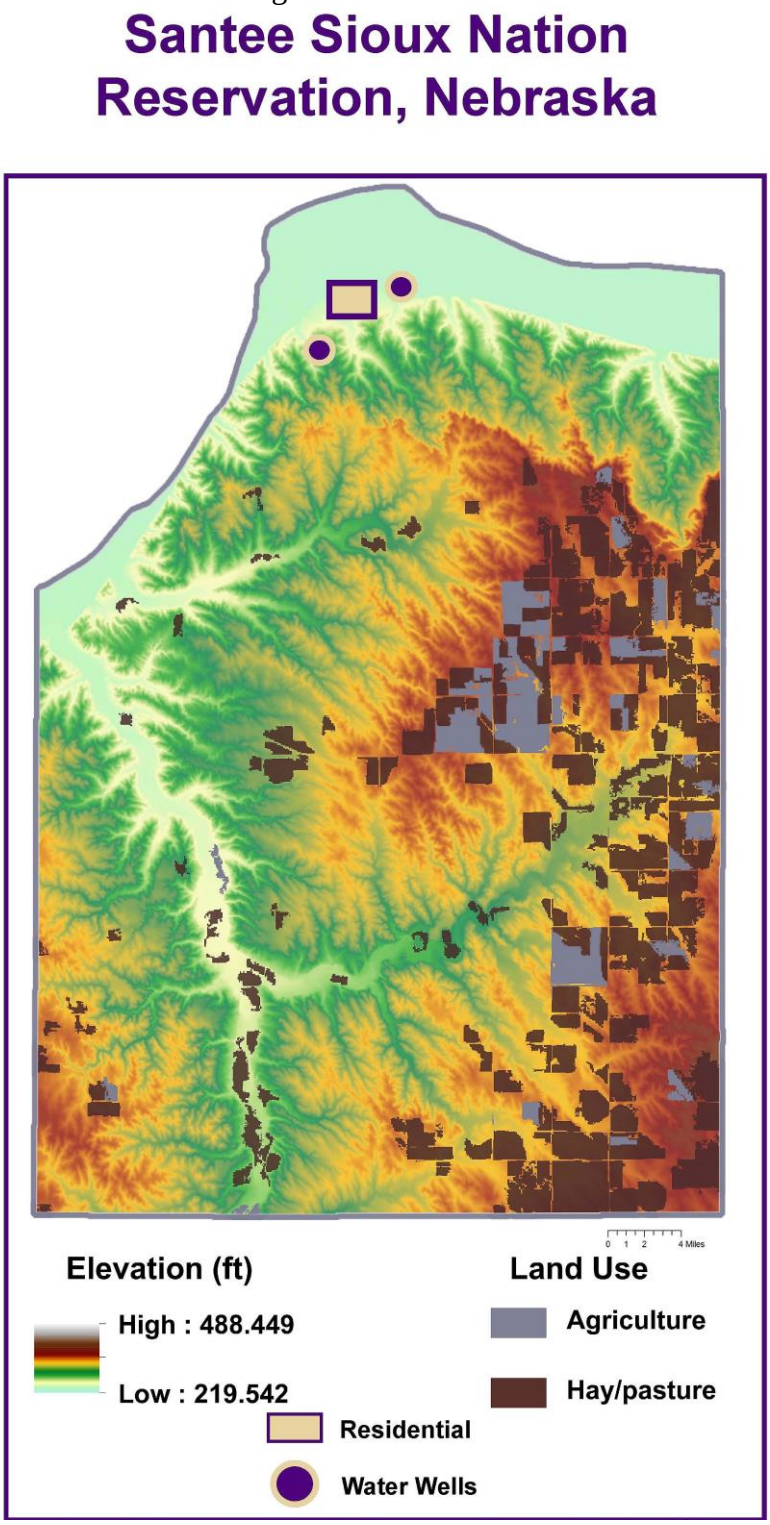
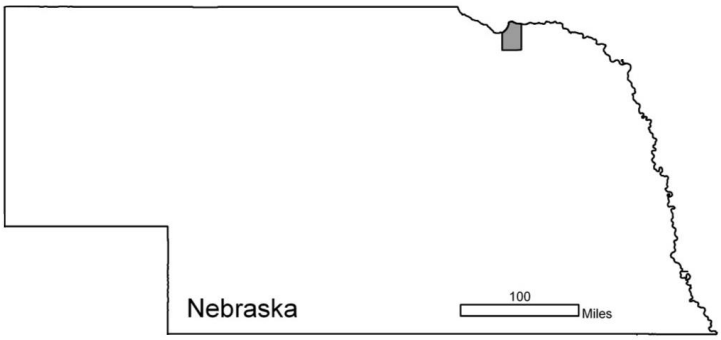


Figure 2:

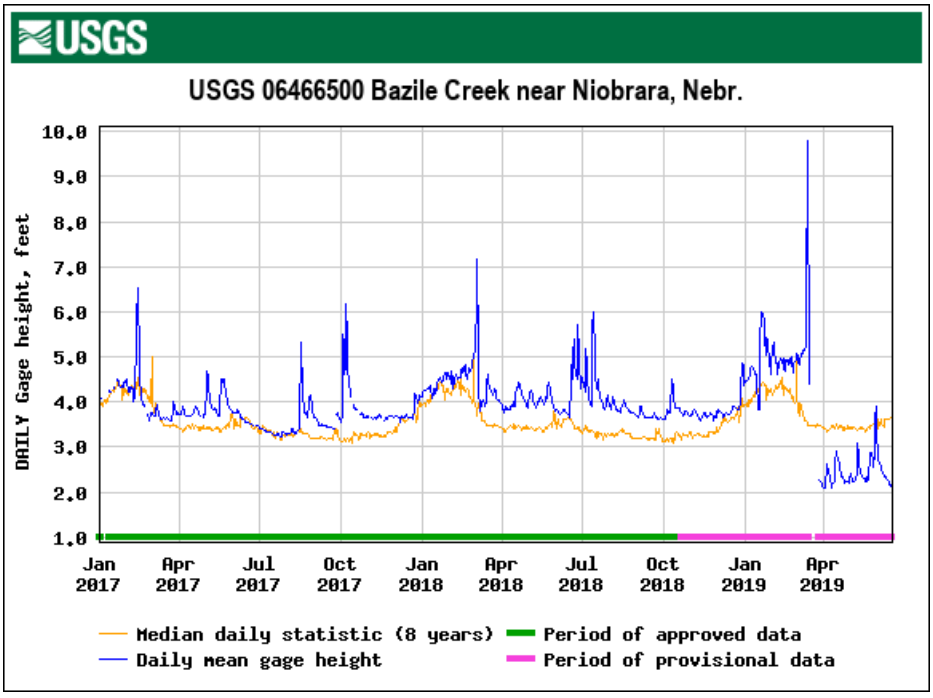


Maps by Amanda Rouillard and Josh Meisel. Data Sources: National Elevation Dataset (NED), National Land Cover Database (NLCD), Nebraska Department of Natural Resources, Ground Water Well Data (NDNR).

Figure 3

A. Spur 54D, entry into Santee Nebraska
B. Highway 12 flood damage
C. Ice left behind from 2019 flood

Figure 4



Bibliography

Abourezk, Kevin. March 19, 2019. ""Santee Sioux Tribe Slowly Getting Back to Normal After Unprecedented Flooding." Indianz. https://www.indianz.com/News/2019/03/19/santee-sioux-tribe-getting-back-to-norma.asp.

Andrade, L., J. O'Dwyer, E. O'Neill, and P. Hynds. 2018. "Surface Water Flooding, Groundwater Contamination, and Enteric Disease in Developed Countries: A Scoping Review of Connections and Consequences." Environmental Pollution 236 (May): 540–49. https://doi.org/10.1016/j.envpol.2018.01.104.

Bishop, P. K., B. D. Misstear, M. White, and N. J. Harding. 1998. "Impacts of Sewers on Groundwater Quality." Water and Environment Journal 12 (3): 216–23. https://doi.org/10.1111/j.1747-6593.1998.tb00176.x.

Boholm, Åsa, and Madeleine Prutzer. 2017. "Experts' Understandings of Drinking Water Risk Management in a Climate Change Scenario." Climate Risk Management 16 (January): 133–44. https://doi.org/10.1016/j.crm.2017.01.003.

Chirila, Ioan, Luminița Minea, and Luminita Smaranda Iancu. 2010. "Microbiological Aspects of Underground Water Quality for Human Consumption in Rural Area." Analele Ştiinţifice Ale Universităţii Alexandru Ioan Cuza Din Iași,Sectiunea II A : Genetica Si Biologie Moleculara. 2010.

Eccles, Kristin M., Sylvia Checkley, Darren Sjogren, Herman W. Barkema, and Stefania Bertazzon. 2017. “Lessons Learned from the 2013 Calgary Flood: Assessing Risk of Drinking Water Well Contamination.” Applied Geography 80 (March): 78–85. https://doi.org/10.1016/j.apgeog.2017.02.005.

Gosselin, David C., Jacqueline Headrick, Rod Tremblay, Xun-Hong Chen, and Scott Summerside. 1997. “Domestic Well Water Quality in Rural Nebraska: Focus on Nitrate-Nitrogen, Pesticides, and Coliform Bacteria.” Groundwater Monitoring & Remediation 17 (2): 77–87. https://doi.org/10.1111/j.1745-6592.1997.tb01280.x.

Jamieson, Rob C., Robert J. Gordon, Steven C. Tattrie, and Glenn W. Stratton. 2003. “Sources and Persistence of Fecal Coliform Bacteria in a Rural Watershed.” Water Quality Research Journal 38 (1): 33–47. https://doi.org/10.2166/wqrj.2003.004.

Larned, Scott T., Mike R. Scarsbrook, Ton H. Snelder, Ned J. Norton, and Barry J. F. Biggs. 2004. “Water Quality in Low-elevation Streams and Rivers of New Zealand: Recent State and Trends in Contrasting Land-cover Classes.” New Zealand Journal of Marine and Freshwater Research 38 (2): 347–66. https://doi.org/10.1080/00288330.2004.9517243.

McGinnis, Shelley, and R. Davis. 2001. “Domestic Well Water Quality within Tribal Lands of Eastern Nebraska.” Environmental Geology 41 (3–4): 321–329.

Reece, Nathan A. “Water Quality on Reservations in Nebraska.” Environmental Studies Undergraduate Student Theses. University of Nebraska, Lincoln. 2016

Roig, B., I. Delpla, E. Baurès, A. V. Jung, and O. Thomas. 2011. “Analytical Issues in Monitoring Drinking-Water Contamination Related to Short-Term, Heavy Rainfall Events.” TrAC Trends in Analytical Chemistry, Climate-Change Impacts on Water Chemistry, 30 (8): 1243–51. https://doi.org/10.1016/j.trac.2011.04.008.

Rompré, Annie, Pierre Servais, Julia Baudart, Marie-Renée De-Roubin, and Patrick Laurent. "Detection and enumeration of coliforms in drinking water: current methods and emerging approaches." Journal of microbiological methods 49, no. 1 (2002): 31-54.

Schwartz, Matthew S. March 21, 2019. “Nebraska Faces over $1.3 Billion In Flood Losses.” NPR. https://www.npr.org/2019/03/21/705408364/nebraska-faces-over-1-3-billion-in-flood-losses.

U.S Department of the Interior, Bureau of Indian Affairs. What is the federal Indian trust responsibility? N.a. 2019. https://www.bia.gov/frequently-asked-questions

U.S Department of the Interior. Draft Feasibility Study for Water Supply System Economics and Water Demand Analyses Component FY. Santee Sioux Nation and the Village of Niobrara, Nebraska. Status Report Summery. Bureau of Reclamation, Nebraska-Kansas Area Office, Great Plains Region, (2006).

U.S Department of the Interior. Municipal, Rural, and Industrial Water Supply System Feasibility Study Status Report. Santee Sioux Nation and the Village of Niobrara, Nebraska. Status Report Summery. Bureau of Reclamation, Nebraska-Kansas Area Office, Great Plains Region, (2008).

U.S Department of the Interior. Needs Assessment – MR&I Water System, Santee Indian Reservation, Nebraska. Frenchman Unit Draft Appraisal Report. Bureau of Reclamation, Nebraska-Kansas Area Office, Great Plains Region, (2004).

U.S Department of the Interior. Northeastern Nebraska Water Supply System Appraisal Report. Bureau of Reclamation, Nebraska-Kansas Area Office, Great Plains Region, Rural Water Supply Program, (2011).

Ye, Lin, Qing-hua Cai, Rui-qiu Liu, and Ming Cao. "The influence of topography and land use on water quality of Xiangxi River in Three Gorges Reservoir region." Environmental Geology 58, no. 5 (2009): 937-942.