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# Nebraska's Natural Resource District System: Collaborative Approaches to Adaptive Groundwater Quality Governance

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ABSTRACT: Nonpoint source pollution of groundwater by nitrates from agricultural activity is a persistent problem for which developing effective policy approaches has proven difficult. There is little empirical information on forms of governance or regime attributes that effectively and sustainably address agricultural nonpoint source pollution of groundwater. Nebraska's Natural Resource District (NRD) system is a rare example of a groundwater governance regime that is putting programmes in place that are likely to generate sustainable groundwater quality outcomes. We focus on three groundwater nitrate management programmes in the state that collectively represent the broader NRD system. The research shows that four elements of Nebraska's groundwater governance regime are fundamental to its success in addressing groundwater nitrates: 1) the local nature of governance, which builds trust among stakeholders; 2) the significant authority granted to the local districts by the state, allowing for the development of locally tailored solutions; 3) the collaborative governance approach, which allows potential scale imbalances to be overcome; and 4) the taxing authority granted to NRDs, which enables them to fund locally tailored management solutions. We find that these aspects of the NRD system have created conditions that enable adaptive, collaborative governance that positions the state well to address emerging groundwater quality challenges. We present aspects of the governance regime that are generalisable to other American states as efforts to address nitrate pollution in groundwater increase.

KEYWORDS: Groundwater quality, local governance, nested regimes, nonpoint source pollution, polycentric governance, Nebraska, USA

## INTRODUCTION

Nonpoint source (NPS) pollution of groundwater by nitrates represents a slow-onset disaster (Twigg, 2004). Nitrate is the most common chemical contaminant in groundwater worldwide, and its principal source in the United States (US) is from the long-term, widespread application of nitrogen fertiliser for agriculture (Spalding and Exner, 1993; Rupert, 2008; Exner et al., 2014). The most extensive contamination in the US occurs in groundwater under intensively irrigated areas (Spalding and Exner, 1993; Burow et al., 2010). It can take decades for the cumulative impacts of prolonged nitrate application to materialise. Most often, regulation of NPS pollution does not occur until water quality problems become overt, and regulation generally faces the fiercest resistance in areas with strong agricultural interests (Craig and Roberts, 2015).

Groundwater is a common-pool resource (CPR), which is to say it is a shared natural resource that is both large enough that it is difficult to exclude users, and one where each user's benefit comes at the expense of that of other users (Ostrom, 2000). CPRs are governed within the context of socio-ecological systems (SESs), which are systems where interdependent human relationships are deeply intertwined with biophysical and non-human biological units (Anderies et al., 2004).

Developing effective policy approaches to governing groundwater NPS nitrate pollution has proved challenging for two main reasons. First, nitrates are diffuse and infiltrate into groundwater at the landscape scale. Therefore efforts to address nitrate pollution require changes in farm management among multiple, diverse actors across large areas and multiple SESs. Second, due to the long timescales of groundwater processes and impacts, groundwater policy timeframes are often inconsistent with the hydrogeologic context in which they must function (Gleeson et al., 2012). This means that groundwater NPS nitrate pollution needs to be addressed through a CPR governance regime, defined as, "the wide range of rules, norms, traditions and other institutional arrangements (laws, policies) by which decision making is exercised, enforced and modified, over time, by different actors" (Narayanan and Venot, 2009: 321). Enduring and effective CPR governance regimes tend to share the institutional design principle whereby "appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises" (Ostrom, 1990: 90).

Building on insights from SES thinking and the ideas in this literature on CPR governance, Huitema et al. (2009) identified four conditions for enabling effective water management (including groundwater):

1. Polycentric governance, made up of multiple independent decision-making entities with overlapping and redundant authority, who coordinate on governance decisions (Huitema et al., 2009; Ostrom, 2010);
2. Public participation, meaning collaboration between governmental and non-governmental stakeholders (Huitema et al., 2009);
3. Experimentation with different policy interventions and policy instruments involving multiple stakeholders at various comparable locations; these interventions should be applied (and then evaluated for effectiveness) in order to foster learning, build trust and increase the capacity of governance regimes to deal with uncertainty (Moberg and Galaz, 2005; Huitema et al., 2009; Lejano and Ingram, 2009);
4. Congruence between the boundaries of the resource being governed and the management institutions governing it; this can be accomplished through collaboration between existing jurisdictions or by introducing management at the aquifer or basin scale (Young, 2002; Blomquist and Schlager, 2005; Huitema et al., 2009).

In view of these CPR governance conditions, effective NPS management thus implies a combination of centralised/decentralised and top-down/bottom-up governance regimes, as well as combining steering and self-organisation and having a good policy instrument mix (Marshall, 2008). A review of environmental interventions by Parker et al. (2009) concluded that policy instrument mixes consisting of a combination of voluntary and compulsory regulation, financial support and penalties, education, audits, and business advice instruments are the most effective means by which to achieve sustainability goals. A mixed-intervention approach addresses the variability in views, understanding and goals of different producers (Parker et al., 2009; Borrás and Edquist, 2013). A review by Dowd et al. (2008) mirrors the conclusion of Parker et al. (2009) that mixed-intervention approaches seem to be the most successful policy framework for addressing agricultural NPS pollution.

This is further proven by the experiences of the European Union (EU) in its implementation of the polycentric Nitrates Directive (1991), and of the Water Framework Directive (2000) of which it became an integral part (see, for example, Oenema et al., 2011; Dupnik, 2012; van Grinsven et al., 2012; Dalgaard et al., 2014; Velthof et al., 2014; Boeuf and Fritsch, 2016). These directives are credited with helping to achieve decreases in nitrate concentrations in soil and shallow aquifers in many Northwestern European countries, particularly Belgium, Denmark, Ireland, the Netherlands, and the United Kingdom (Oenema et al., 2011; van Grinsven et al., 2012). Despite the extensive literature on processes and implementation of the EU's Nitrates Directive and Water Framework Directive, there is limited analysis of the role of the governance regime and of the extent to which it is effective in achieving groundwater quality goals (van Grinsven et al., 2012; Boeuf and Fritsch, 2016).

The literature on US polycentric water governance has focused on multiple aspects of water management, such as river basin management and groundwater quantity (see, for example, Garrick et al., 2011; Cosens and Williams, 2012; Bleed and Babbitt, 2015; Closas and Molle, 2016); however, there is still limited empirical research on polycentric governance for groundwater quality management and on what makes it effective (Megdal et al., 2015). Dowd et al. (2008) note that the North American literature on agricultural NPS pollution governance is relatively small, is comprised mostly of theoretical models, and is largely lacking in empirical studies of policy implementation (exceptions include Shortle et al., 2012; Liu et al., 2018). This is particularly true with regard to agricultural NPS pollution of groundwater.

In the US, types of groundwater governance regime vary by state. Roughly two-thirds of states have nested regimes that grant some level of oversight and enforcement authority to local agencies (Megdal et al., 2015). In 36 states, groundwater quantity and quality are managed by different agencies (Megdal et al., 2015), with each state applying a different regulatory approach to groundwater based on institutional structure and policy mixes. In most states, agricultural NPS policy mixes heavily favour voluntary, incentive-based approaches because they are the most politically feasible policy option and are relatively low cost (Claassen, 2003; Dowd et al., 2008; Reimer and Prokopy, 2014). However, these measures are not always effective and do not seem to follow all elements of polycentric governance.

We focus here on the state of Nebraska's Natural Resource District (NRD) system, which is a unique groundwater governance regime that offers a promising approach through which to address NPS groundwater nitrate pollution. The groundwater governance regime in Nebraska is a nested hierarchy built on 23 empowered local institutions called Natural Resource Districts (Ostrom, 2010; Bleed and Babbitt, 2015). Sixt et al. (in press) and Bleed and Babbitt (2015) demonstrate that the NRD system represents a robust governance regime for the sustainable management of groundwater *quantity*. This paper expands upon that analysis to examine the NRD system as it has evolved to include groundwater *quality* governance over the last 30 years. We present the state of Nebraska as a case study for the development of governance regimes that have the potential to address agricultural NPS groundwater nitrate pollution.

This paper is highly relevant to the US, where states will increasingly need to improve or develop their groundwater governance regimes to address the emerging, slow-onset disaster of NPS nitrate pollution of groundwater. More broadly, this paper contributes to the still-limited literature base on the role of governance regime type in achieving groundwater quality goals with regard to agricultural NPS pollution. Finally, this paper is relevant to discussions in countries (e.g. Canada) where reduction of groundwater nitrate concentrations has not been successful (Wassenaar et al., 2006), and countries (e.g. Denmark) where desirable trends in nitrate leaching have been observed (Hansen et al., 2011).

In the next section we discuss the methodological approach of this study, followed by a description of the Nebraska NRD groundwater governance regime and a brief description of the three study areas that are the focus of this research. We then discuss key research findings on the NRD groundwater quality governance regime, highlighting important aspects of successful nitrate management programmes or cases of self-organised collaborations to address NPS nitrate pollution. We close with a summary of the research findings and a discussion of generalisable lessons on effective polycentric groundwater quality governance.

## METHODS

### Methodological approach

This qualitative study assesses factors impacting the formation of nitrogen best management practices (BMP) and remediation programmes in the state of Nebraska. We focus on three programmes that address different aspects of the groundwater NPS nitrate pollution problem in the state and which, collectively, represent the larger groundwater governance regime in Nebraska. These programmes present examples of how a polycentric governance regime that is built on empowered local governance can create the enabling conditions for collaborative approaches to addressing the widespread emergent problem of groundwater nitrate pollution from agricultural activity.

In line with ideas on polycentric governance by Huitema et al. (2009), which are informed by socio-ecological systems studies on CPR governance, we utilised the SES framework developed by Ostrom (2007, 2009) and refined by McGinnis and Ostrom (2014). We used this framework to develop interview questions aimed at identifying the enabling conditions for the self-organising that formed these three programmes – organising that in some cases has achieved reductions in groundwater nitrate concentrations. This approach provided the researchers with a way to analyse how social and ecological domains interact, through observing the activities of human actors in the governance of a CPR (de Loë and Patterson, 2018).

To assess the factors that created the enabling conditions, we conducted a series of semi-structured key informant interviews (primary data), complemented with a literature review (secondary data). Semi-structured interviews provide flexibility for the interviewer to focus on interesting comments and on aspects of the topic on which interviewees have greater levels of expertise (Bruges and Smith, 2009; Turner et al., 2016). The question format consisted of 23 general questions, with probing follow-up questions that were designed to elicit in-depth responses.

We conducted a pilot study in Nebraska in April of 2017 to refine the scope of the research and interview questions, and to develop a list of interviewees. For this pilot, we informally interviewed ten experts on the NRD system and nitrate mitigation efforts in the state. Using snowball sampling, we identified a list of potential interviewees and scheduled interviews for June of 2017.

Thirty-four interviews were conducted with a diverse set of experts including: NRD managers, staff, and board members (13 interviewees); staff from the Nebraska Association of Resources Districts (NARD) (two interviewees); employees of the Nebraska Department of Environmental Quality (DEQ) (five interviewees) and the Department of Natural Resources (DNR) (one interviewee); University of Nebraska-Lincoln water experts and researchers (five interviewees), agricultural producers (four interviewees),[1] one staff person from City of Hastings Utilities, one groundwater management area staff, three agricultural extension experts,[2] and one staff person from the Groundwater Foundation (a groundwater-focused non-profit organisation).[3]

[1] One agricultural producer is also a University of Nebraska-Lincoln employee, and one agricultural producer is also an NRD board member.

[2] Because extension in the United States is facilitated through the land-grant university system, all extension experts interviewed are technically University of Nebraska-Lincoln employees as well, however they are not counted as university employees here.

[3] The identity of each respondent is protected by randomly rearranging the order of their interviews and assigning an anonymous interview number (e.g. Interview 1).

Each interview was conducted either in person or over internet telephony and took 45 to 90 minutes. The interviews were recorded and transcribed for analysis using the NVivo for Mac software package (Version 11.4; QSR International). Interviews were analysed using an analytical framework adapted from the SES framework by which interviewee responses were coded based on all seven first-tier variables, and 35 second-tier variables that function as explanatory factors for the first-tier ones (see Table 1) (McGinnis and Ostrom, 2014). We also coded for three additional variables that were not adequately covered by the SES framework but that interviews revealed were important to the governance of these nitrate management programmes: 'adaptive governance', 'economics of best management practices', and 'local control'.

## Study area: Groundwater governance in Nebraska and the Natural Resource District system

Nebraska has more land under irrigation than any other state in the country, and 85 percent of its 3.4 million hectares (Mha) of irrigated land relies on groundwater as its source (Bleed et al., 2015). Corn production is central to the economy of the state. Nebraska is ranked third in production nationally, and irrigated corn accounts for 66 percent of its irrigated area (USDA-NASS, 2016).

The economic importance of agriculture, and more specifically corn, is central to groundwater quality concerns in Nebraska. Nitrogen fertiliser used in agriculture is the primary source of nitrate contamination in Nebraska's groundwater; more nitrogen fertiliser is applied to corn than to any other crop, and irrigated corn production – more than non-irrigated – is nitrogen intensive (Exner et al., 2014). Considering that approximately 88 percent of Nebraskans, and almost 99 percent of rural residents, rely on groundwater as their drinking water source, the impact on drinking water quality from agricultural activity is of great concern to state policy makers (NDEQ, 2017). The situation is of even more concern in the central and eastern parts of the state, where 83 percent of the irrigated corn is grown and where most of the population lives (USDA-NASS, 2016). Between 1981 and 2010 – the most recent period for accurate statewide data – there has been almost a tripling (from 0.35 to 1.3 Mha) of the area in this part of the state that has groundwater nitrate concentrations higher than the EPA's Maximum Contaminant Level (MCL) for drinking water of 10 mg/L (Exner et al., 2014; Interviews 22, 25).

In Nebraska, NPS nitrate pollution of groundwater is managed locally through the state's 23 NRDs. The NRDs are governed by locally elected boards of directors and have broad and flexible legislative authority that includes the power to issue and enforce groundwater regulations and the power to collect property taxes to fund operations (Hoffman and Zellmer, 2013).

Secondary data sources were consulted to supplement interviews and, where possible, to verify certain claims by interviewees. Secondary data included state government and NRD reports and documents, Groundwater Management Area plans, Wellhead Protection Area plans, and peer-reviewed literature.

The NRD system has its roots in the 1937 federal legislation that created the USDA Soil Conservation Service and enabled the creation of local soil and water conservation districts (Bleed and Babbitt, 2015). The next 30 years saw a proliferation of small government units and single-purpose districts tasked with managing land and water resources, which by the late 1960s numbered over 150 (Bleed and Babbitt, 2015; Closas and Molle, 2016). Attempts to regulate groundwater in Nebraska made very little progress until the 1950s, when a drought called the 'Little Dustbowl', together with rapid expansion of groundwater-fed irrigation and declining groundwater levels, led to an increase in concern over the sustainability of the resource (Kepfield, 1993; Closas and Molle, 2016). In 1959, the state legislature responded by passing the Groundwater Conservation Act, authorising the creation of local regulatory Groundwater Conservation Districts (Aiken, 1980). By the late 1960s it was clear that the disorganised network of soil and water conservation single-purpose districts had become a challenge to effective groundwater governance. There were multiple administrative gaps and no districts with the authority to effectively regulate groundwater (Bleed and Babbitt, 2015). In 1972, legislation was finally passed to reorganise 154 single-purpose districts into 24[4] comprehensive NRDs organised around watershed boundaries (Figure 1) (Aiken and Supalla, 1979).[5]

Table 1. Interview analytical framework, adapted from McGinnis and Ostrom, 2014.

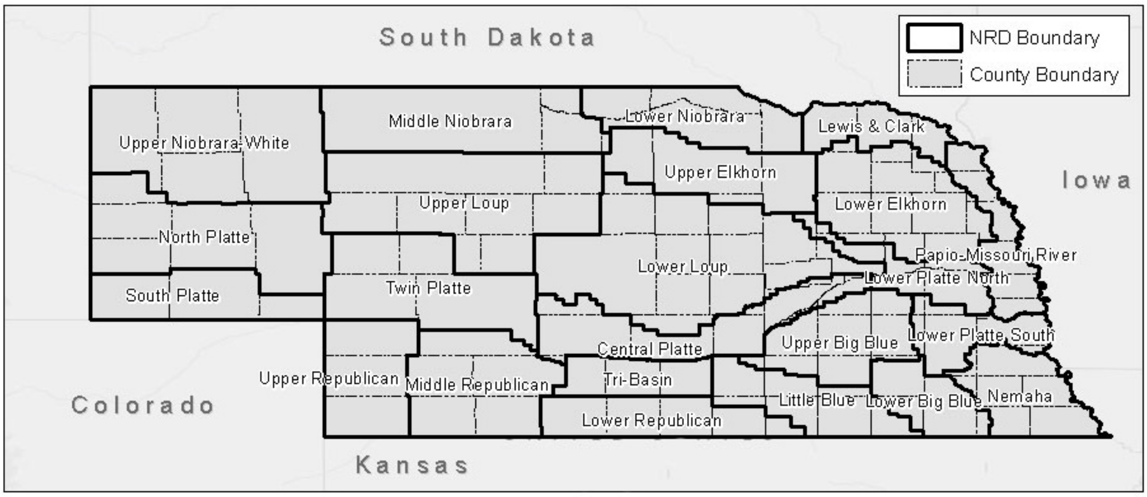
| First-tier variable | Second-tier variable |
|---|---|
| Social, economic and political settings (S) | S2 Demographic trends<br>S4 Other governance systems<br>S5 Markets |
| Resource systems (RS) | RS2 Clarity of system boundaries<br>RS3 Size of resource system<br>RS7 Predictability of system dynamics<br>RS9- Location |
| Governance system (GS) | GS2 Geographic scale of governance system<br>GS3 Population<br>GS5 Rule-making organisations<br>GS6 Rules in use<br>GS8 Repertoire of norms and strategies<br>GS9 Network structure<br>GS10 Historical continuity |
| Resource units (RU) | RU3 Interaction among resource units<br>RU7 Spatial and temporal distribution |
| Actors (A) | A1 Number of relevant actors<br>A3 History or past experiences<br>A5 Leadership/entrepreneurship<br>A6 Norms (trust-reciprocity)/social capital<br>A7 Knowledge of SES/mental models<br>A8 Importance of resource |
| Action situations: Interactions (I) → Outcomes (O) | I2 Information sharing<br>I3 Deliberation processes<br>I4 Conflicts<br>I5 Investment activities<br>I6 Lobbying activities<br>I7 Self-organising activities<br>I8 Networking activities<br>I9 Monitoring activities<br>I10 Evaluative activities<br>O1 Social performance measures<br>O2 Ecological performance measures |
| Related ecosystems (ECO) | ECO2 Pollution patterns<br>ECO3 Flows into and out of focal SES |

*Additional variables*: Adaptive governance; Economics of BMPs; Local control

[4] There were originally 24 NRDs, but two districts were merged in 1989 to create the Papio-Missouri River NRD, reducing the number of NRDs to 23 (Papio NRD, 2019).

[5] See Bleed and Babbitt (2015) and Closas and Molle (2016) for a deeper history of the evolution of Nebraska groundwater governance.

Figure 1. Nebraska Natural Resource District and county boundaries (map by B. Zapatka).




Initially, the NRDs' authority was limited to protecting groundwater quantity. By the early 1980s, nitrate contamination in groundwater had become a significant problem (Schneider, 1990). In 1986, the NRDs were given the authority to establish Groundwater Management Areas (GMAs) to protect water quality and to require the use of BMPs and attendance at education programmes to protect water quality (Exner and Spalding, 1987). Further legislation was passed in 1991 requiring NRDs to revise their groundwater management plans in order to more adequately address groundwater quality issues (Exner et al., 2014).

Each NRD has up to four groundwater quality management tiers (based on nitrate concentrations), with increasingly strict reporting and regulatory requirements at each tier (Exner et al., 2014). Tier regulations may differ slightly among NRDs and are revised occasionally by each NRD, but they are generally set relative to the federal MCL and encourage producers to adopt BMPs (Ferguson, 2015; NARD, 2018). Some general examples of phase requirements include mandatory classes for agricultural producers on fertiliser application BMPs, limitations on seasonal nitrogen fertiliser application, mandatory soil and water sampling, and mandatory crop reporting (NARD, 2018).

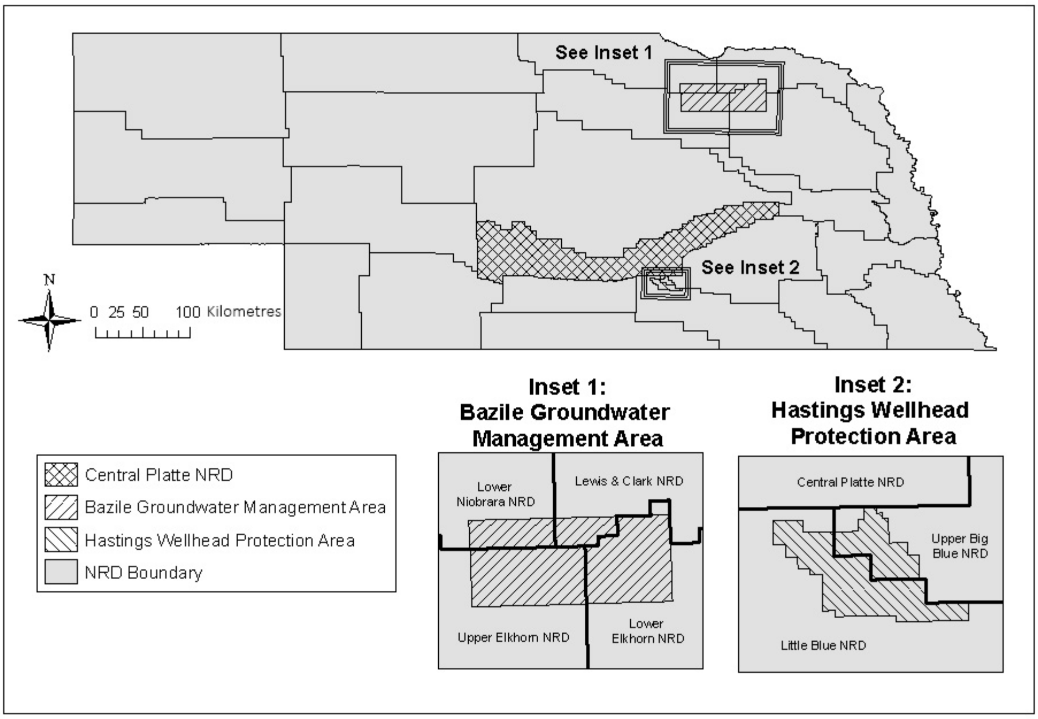
To conduct our analysis, we looked at three specific programmes in the state (Figure 2). Together, they demonstrate a diversity of problems and approaches within the same statewide governance regime. These three programmes are: 1) the Central Platte NRD Groundwater Management Area (CPNRD GMA), which is the oldest NPS nitrate programme in the state and which has demonstrated a successful trend in reducing groundwater nitrate concentrations; 2) the Bazile Groundwater Management Area (BGMA), which brings together four NRDs to address nitrate pollution through a project funded by the Clean Water Act Section 319, the first in the nation; and 3) the Hastings Wellhead Protection Area (Hastings WHPA), which is a collaboration between two NRDs and the city of Hastings, and represents a rare example of a regulatory programme that successfully bridges the rural-urban divide to address the NPS nitrate pollution that is threatening the city's drinking water source.

These three nitrate management programmes collectively offer useful insight into both how a nested groundwater governance regime can be structured to sufficiently respond to emerging groundwater challenges, and how that structure can lead to collaborative regulatory approaches to managing groundwater quality. While every NRD except one (Papio-Missouri River NRD) has at least part of their district under water quality management regulations (NARD, 2018),[6] for several key reasons we focus on the Central Platte, Bazile, and Hastings programmes. First, they represent different aspects of the NRD

[6] See NARD (2018) for a full description of water quality activities in each NRD.

groundwater governance regime and collectively are representative of the broader dynamics present in the state's groundwater governance regime. Second, they overlie the areas of the state with the most severe groundwater nitrate pollution problems and/or where municipal water supplies are affected by nitrate concentrations in excess of the MCL for nitrate (NDEQ, 2017; Interview 25). Finally, as indicated by nine interviewees, these areas stand out in the state for three reasons: they are the first areas where the nitrate problem reached a critical level; the nitrate problem in these three areas crosses jurisdictional boundaries; and the nitrate management efforts in these areas represent creative ways of addressing the cost of supplying safe drinking water to an urban area. Interviewees also believed that the factors that enabled the programmes in these three areas are present throughout the NRD system.

Figure 2. Map of the three nitrate management programmes (map by B. Zapatka).




The CPNRD GMA covers the entire district (Figure 2), and different areas of the district are designated into different phases based on the severity of nitrate contamination (Ferguson, 2015). We provide the four phase levels as a demonstration on how they may exist in any given NRD: Phase 1: 0-7.5 mg/L ; Phase 2: 7.6-15 mg/L ; Phase 3: >15.1 mg/L ; Phase 4: areas where nitrate levels are not declining at an acceptable rate (CPNRD, 2017). There are currently no areas of the NRD below Phase 4. The programme began in 1987 and was the first GMA in Nebraska and the first nitrate regulatory programme in the country (Exner and Spalding, 1987; Schneider, 1990; Aiken, 1993). Since the project started, average nitrate levels throughout the district have declined from 19.2 mg/L to 13.3 mg/L (CPNRD, 2017). While average nitrate levels remain above the MCL, the decline in nitrate concentrations represents a steady trend achieved largely through changes in agricultural management practices by producers. The CPNRD GMA programme has utilised a combination of regulatory and voluntary BMPs supported by cost-share incentives as well as information and education (I&E) activities (Interviews 13, 14, 15, 34). It has become the model for nitrate management programmes in other NRDs across the state (Exner et al., 2014).

The BGMA encompasses 1958 sq. km. and covers parts of four NRDs: Lewis and Clark, Lower Elkhorn, Lower Niobrara, and Upper Elkhorn (Figure 2) (NDEQ, 2016). It is a collaborative effort by the four NRDs and the state DEQ, and is focused on reducing nitrate levels below 10 mg/L through the widespread implementation of BMPs (Radford and Johnson, 2017). The BGMA programme utilises a combination of regulatory and voluntary BMPs supported by cost-share incentives and I&E activities (NDEQ, 2016). The BGMA plan was approved in 2016, and implementation of the programme has recently begun (Radford and Johnson, 2017). This current programme is the culmination of efforts that date back to the 1980s, involving three of the NRDs and called the Bazile Triangle (NDEQ, 2016). The four NRDs self-organised to form the BGMA as a result of monitoring data which showed the nitrate problem to be transboundary in nature. It was an outgrowth of the shared belief that the problem could be more effectively addressed through collaborative action, and that more resources would thereby be available (Interviews 3, 4, 6, 7, 9, 10, 17, 20, 30). The four NRDs are currently in the process of aligning some of their regulatory and management rules and regulations in an effort to streamline management across district boundaries (Interviews 3, 10, 17, 30).

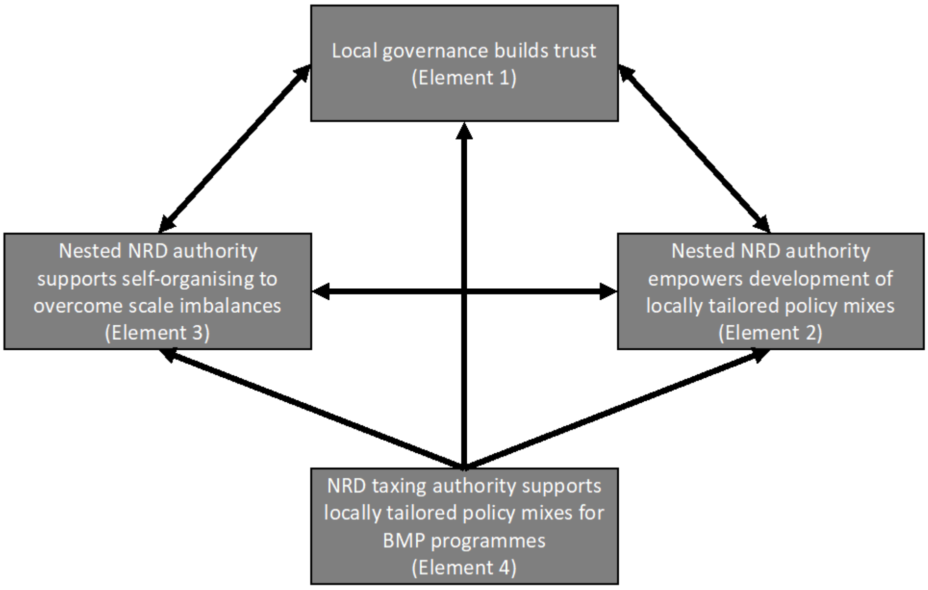
The Hastings Wellhead Protection Area was initiated in 2013 as a collaborative effort by the City of Hastings Utilities, the Little Blue NRD, and the Upper Big Blue NRD. The programme encompasses the city of Hastings and parts of the two NRDs between which the city is divided (Figure 2). The quality of the city's municipal water has traditionally been very high, requiring no treatment before distribution into the system (Hastings Utilities, 2013). Hastings Utilities, however, is currently operating only 17 out of 33 supply wells due to nitrate contamination and because of the recent discovery that nitrates have mobilised naturally occurring uranium in the soil, contaminating some of the wells (Stange, 2017). Hastings Utilities is implementing an innovative set of technological solutions to remediate existing groundwater contamination affecting its municipal water sources, and the NRDs are focused on preventing additional NPS nitrate pollution of groundwater in the outlying agricultural areas through a combination of regulatory and voluntary BMPs supported by incentives and I&E (Little Blue NRD et al., 2012; Stange, 2017). These efforts are aimed at addressing the contamination of the aquifer that is a legacy of decades of fertiliser application, as well as preventing additional contamination in the areas outside the city that impact its municipal water sources.

## RESULTS AND DISCUSSION

Our research findings on these three programmes demonstrate that the Nebraska NRD system meets Huitema et al.'s (2009) four enabling conditions for successful groundwater governance with respect to quality: it is polycentric; it promotes public participation; it promotes experimentation and fosters learning and trust-building among multiple stakeholders; and through collaboration between and across different levels of government, there is congruence between the boundaries of the groundwater resources and the institutions governing them.

We find that the empowered NRD groundwater governance regime creates local enabling conditions for resolving the complex problem of nonpoint source nitrate pollution. Interview responses were clustered around the governance system, actors, and action situations first-tier variables, and around the additional variable of the analytical framework that concerns local control (Table 1). From these responses, we found that there are four elements of the regime type that increase the likelihood of successfully achieving nitrate mitigation goals or of self-organising to address emerging NPS nitrate pollution problems: 1) the nature of local governance in the NRD system and the degree to which it builds trust; 2) the amount of authority that the state has granted to NRDs, thus empowering them to develop locally tailored solutions; 3) the collaborative nature of the NRD system, which allows for potential scale imbalances to be overcome; and 4) the taxing authority granted to NRDs, which enables them to fund locally tailored management solutions. The first three elements positively reinforce each other, and the fourth supports the other three (Figure 3).

Figure 3. Interaction between polycentric governance regime elements.




## Element 1: Local governance builds trust

"Without trust, there is no government" (Interview 2). All 34 interviewees spoke about the role of local governance in nitrate management in Nebraska. The local nature of the NRD governance regime was specifically identified by 33 interviewees as being the most important element of the state's efforts to address NPS nitrate pollution and of its relative success in managing groundwater generally. The one interviewee who did not speak explicitly on this (an extension specialist who instead focused on the technical aspects of BMPs in the CPNRD GMA), still referred to the local, community-oriented approach that has led to a successful trend in this project. The other 33 interviewees noted that the core of the NRD system's unique success was the locally elected boards, the authority to tax, and the freedom of districts to independently tailor activities to local conditions and engage with locally appropriate stakeholders.

Eleven interviewees spoke of trust in the NRDs as being central to the success of the CPNRD GMA and to the effective self-organising by the BGMA and Hastings WHPA. Three producers felt their NRD to be acting in their best interest as farmers and believed it gave them a voice in the regulatory decisions that impacted them. One said, "It's locally governed, so we're a part of it. Working together builds trust" (Interview 33).

Our results indicate that this trust stems from the polycentric regime type in which the locally elected NRD boards (rather than a central state regulatory agency) are the principal regulatory actors that producers interact with most frequently (Figure 3). Four interviewees said that because board members are elected from the communities they govern, people feel they have a participatory role in the NRD that is governing them. One extension expert said, "the more local control the better", and that people "feel like they're part of the decision. It's their problem, and they take ownership of the problem, and they take [more] ownership of the solution" (Interview 12). An early organiser of the programme that became the BGMA summarised his views on the importance of the locally elected NRD boards as follows:

> Local solutions for local problems. And, probably the biggest thing is it's not big government coming in and telling someone what to do, it's the guy you voted for, your neighbour, who is voting, making a policy decision that impacts you. And so, if you don't like it you can certainly pick up the phone and talk to him, or better yet you'll see him down at the coffee shop or diner and you can speak your piece to it. The key that a lot of

> people don't realize is that when an NRD board member votes for something, whether they be a producer or businessman or whatever, they're voting for something that impacts them as well (Interview 20).

It is important to note that not all interviewees felt that the NRDs were fully trusted by producers. One NRD general manager indicated that people generally trust their NRD but that the level of trust varied by the specific regulatory issue (Interview 29). A minority of respondents indicated that the NRDs are not trusted at certain levels because they represent a form of government, and the more an organisation is viewed as a regulatory governmental agency the less trust it has (Interviews 1, 23, 25). However, these views were qualified by some respondents. Two interviewees indicated that the boards of NRDs are trusted because they are made up of locally elected stakeholders but that NRD staff (non-elected officials ranging from the general manager to field technicians) receive less trust (Interviews 23, 25).

These comments on trust in NRDs were also framed in the context of comparative trust and bottom-up versus top-down governance. NRDs, according to some interviewees, are trusted more than state and federal agencies but less than agricultural industry actors (i.e. agronomists, co-ops, seed and fertiliser dealers, and crop consultants) who provide services to agricultural producers. In summary, due to the make-up of their locally elected boards, NRDs are the most trusted governance institutions in the state but, because they serve a regulatory purpose, they are still viewed with some level of mistrust by a minority of stakeholders.

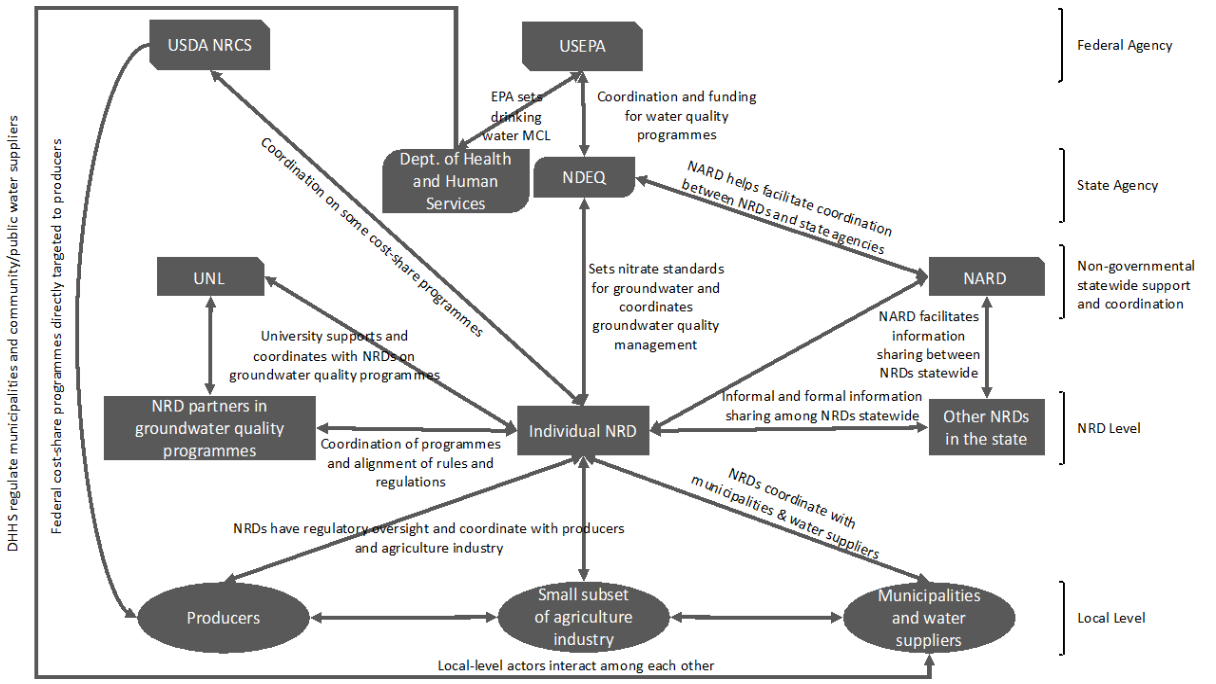
### Element 2: Nested NRD authority with state-level oversight empowers development of locally tailored policy mixes

The state has ceded significant regulatory authority to NRDs while maintaining higher-level oversight. This empowers NRDs to develop locally tailored policy mixes while state oversight requires them to address water quality problems. In Nebraska's polycentric groundwater quality governance regime, the state DEQ sets the standards for groundwater nitrate concentrations based on federal drinking water standards, and state law requires every NRD to have nitrate management plans in place (Figure 4) (Interview 22). NRDs are empowered to develop their own local approaches to achieving these standards. Five interviewees indicated that this nested state oversight provides an effective check against the tendency of NRD boards to set insufficiently strict standards for addressing nitrate problems for fear of being voted out of office. In describing the uniqueness of the NRD system, an interviewee from the University of Nebraska-Lincoln (UNL) said, "In other states, most [state governments] don't want to give up their power. So, Nebraska is unique in how much power the state willingly gave away, and to another elected body at that" (Interview 11).

An interesting caveat noted by two DEQ staff members is that while the state has ultimate authority to regulate nitrates and has parallel authority to put management areas under phase controls, the DEQ does not have the resources to do so on a wide scale. One DEQ staff member noted that while some states have hundreds of staff who work on NPS groundwater pollution, Nebraska's DEQ has fewer than ten. Three interviewees did indicate that the state DEQ does have the resources to enforce NRD compliance on a limited basis, but that it has never needed to because NRDs have been predominantly compliant (Bleed and Babbitt, 2015).

The DEQ focuses on coordinating with NRDs and other stakeholders in its regulatory role and encourages multiple districts to work together on nitrate issues that cross NRD boundaries (Interviews 1, 21, 25). The non-governmental statewide NARD is an additional actor that helps facilitate information sharing between NRDs and, through a liaison, helps coordinate between NRDs and state agencies (Interview 7). The UNL also supports NRD activities through its research ties with agricultural extension programmes and its coordination with NRDs on different groundwater quality programmes (Figure 4).

Figure 4. Simplified polycentric governance regime model showing key actors and how they interact.




This small DEQ regulatory footprint is by design. As described in Element 1, local governance is highly valued in Nebraska. The localised governance that state law has granted to NRDs allows them to set up programmes that are reflective of local conditions, promote different BMPs, set different benchmarks for phase levels, and gives them the flexibility to adapt to new problems as they emerge (Interviews 7, 9, 10, 15). They have, in fact, so much flexibility that, if necessary, they can manage nitrate problems at the individual field level, a scale made possible because NRD staff know their districts and producers (Interview 15).

In their efforts to reduce nitrates in groundwater, most US states rely on voluntary programmes that focus on education and awareness. Nebraska's polycentric governance regime empowers NRDs to develop their own policy mixes. The seven NRDs in this research have focused on mixed-intervention approaches, preferring voluntary and incentive-based measures but instituting regulatory measures at certain nitrate concentration phase levels (Table 2). They often exercise the different policy instruments in approaches built around collaboration and coordination with other actors in the regime (Figure 4 and Table 2). The empowered NRDs are the principal drivers behind the cooperative approach. The Hastings WHPA is an exception to this, however, as the initial effort was driven by the City of Hastings Utilities, and the WHPA action plan was a collaboration between the city, the Little Blue NRD, the Upper Big Blue NRD, and local stakeholders. But, even here, partnership with the two NRDs is necessary to achieve nitrate goals, and they play the central role in the adoption of best management practices.

Based on responses from 25 interviewees, the most common types of BMPs being promoted in local policy mixes include: nitrogen inhibitors, soil sampling, water sampling, limits on autumn fertiliser application, variable-rate applicators, centre pivot irrigation, fertigation (applying fertiliser via centre pivots), flow metres, cover crops, moisture sensors, split feeding, spoon-feeding, and factoring in the nitrogen present in the irrigation water when deciding how much fertiliser to apply.

Table 2. Summary of primary policy mixes utilised in nitrate NPS groundwater pollution programmes.

| Policy instrument | Type of instrument | Primary actors behind policy instrument | Description |
|---|---|---|---|
| I&E to agricultural producers on nitrogen fertiliser impacts and BMPs | Voluntary and mandatory | NRDs, agriculture industry actors, DEQ, UNL/Extension, Department of Agriculture Natural Resources Conservation Service (USDA NRCS), other agricultural producers | ▪ Education on nitrogen impacts and BMPs reaches producers via multiple actors and is often coordinated by NRDs.<br>▪ Participation is usually voluntary, except when there is a regulatory requirement for the producer to attend classes and/or be certified.<br>▪ Information on BMPs is shared between agricultural producers informally in social settings and formally via demonstration plots, usually coordinated by the NRDs. |
| I&E to broader community on nitrogen fertiliser impacts and groundwater nitrate contamination | Voluntary | NRDs, DEQ, UNL/Extension | ▪ Information on the nitrate pollution problem, and activities to address it, is shared via multiple formats, including: NRD newsletters, NRD meetings, workshops, local TV and print media, and social media. |
| Cost-share programmes to encourage BMP adoption by agricultural producers | Incentive-based and voluntary | NRDs, USDA NRCS | ▪ NRDs choose which BMPs they want to incentivise through cost-sharing; cost-share programmes may differ by NRD and within NRDs (based on groundwater nitrate concentrations).<br>▪ USDA NRCS has multiple cost-share programmes which are a source of federal funds for producers.<br>▪ Some NRDs supplement USDA NRCS cost-share funding to increase the level of support to producers and add additional incentive for BMP adoption.<br>▪ Participation by producers in cost-share programmes is voluntary. |
| Regulatory requirements for the use of specified BMPs | Mandatory | NRDs | ▪ NRDs may require the use of some BMPs (e.g. soil sampling, crop reporting, and seasonal limits on fertiliser application) at different groundwater nitrate concentration phase levels. |

With the exception of limits on autumn fertiliser application – which is usually a regulatory phase requirement and also carries some potential risks around weather impacts to planting in the spring – all of the nitrate management BMPs in these programmes have a proven potential to increase producer profitability and maintain or improve yields (Interviews 16, 20, 22, 24). The increase in profitability stems from the lower marginal input costs for fertiliser and for pumping water (where BMPs reduce water use).

Cost-share programmes are important policy instruments because they lower BMP adoption costs to farmers, which can help make some BMPs financially beneficial when they might not otherwise have been if the farmer were responsible for the full cost (Interviews 13, 23). Some of the BMPs that require specialised equipment have a high cost of entry, and the flexibility granted to NRDs to develop their own programmes has allowed them to implement cost-share programmes that reflect local priorities (Interview 3, 5, 17).

Regulatory policy instruments include phase-level-specific mandatory BMPs and required I&E. Most of the NRDs in this project have a requirement that producers who apply nitrogen fertiliser be certified and go through yearly educational programming on nitrogen management (some require it at specific phase levels). At those trainings, information on different BMP options and on the impacts of excess nitrogen fertiliser application is shared (Interviews 9, 16, 23, 28).

I&E is an important component of the nitrate management programmes in this study. Interviewees described coordinated approaches to educating stakeholders on nitrate management programmes, on groundwater monitoring data, and on the NPS nitrate pollution problem in general. These approaches include newsletters, pamphlets, public meetings, individual interaction with producers, print and social media, local radio and television, demonstration plots, and field day tours. Three interviewees noted that being persistent with the messaging and getting NRD staff out to meet regularly with producers has been an important component of BMP adoption. Six interviewees also noted that as individual producers see the benefits from adopting BMPs they communicate with other producers, which has increased adoption of the practices.

I&E activities that present well-regarded, long-term monitoring data that shows the extent and historical sources of the nitrate problem have played an important role in alleviating tensions over the sources of pollution (i.e. crop production vs animal feeding operations), the efficacy of BMPs, and new regulatory requirements (Interviews 7, 28, 30). Particularly in the CPNRD GMA, there were tensions early on with regard to the source of the nitrate problem and increasing regulations, but extensive I&E with producers led to widespread acceptance of nitrogen fertiliser as the source and buy-in in the programme (Interviews 13, 14, 34). One producer said that showing the benefits of the BMPs – that they are effective and that producers can save money while still getting desired levels of production – has been crucial to the success of the programme. As he said, "It’s been education the whole time" (Interview 34).

Finally, the involvement of agriculture industry actors is an important component of multiple aspects of the policy mixes. A survey of farmers in 11 Corn Belt states (including Nebraska) by Loy et al. (2013) showed that agriculture industry actors have the greatest level of influence on land management decisions by producers and are among the most trusted sources of information on conservation practices. Fourteen interviewees indicated that the NRDs in this study have engaged with these agriculture industry actors to build trust among producers, which has helped to overcome conflicts over the science, data, and efficacy of the BMPs being promoted. These interviewees noted that the NRDs have engaged agriculture industry actors by paying crop consultants a per-acre fee to help producers implement nutrient and irrigation BMPs, by involving them in BMP demonstrations, by having them help producers calculate nitrogen fertiliser needs from soil and water samples, and by having them assist producers in filling out required reporting forms.

### Element 3: The empowered local governance regime supports formal and informal networking and encourages collaboration, allowing NRDs to overcome potential scale imbalances

Long-term collaboration and coordination promotes development of the strong social networks and trust that can make polycentric governance both efficient and effective (Imperial, 2005; Huitema et al., 2009). The legislative action granting all NRDs the same authority and responsibilities and requiring that they achieve safe nitrate levels encourages collaboration to occur where it is mutually beneficial, such as in the BGMA and Hastings WHPA programmes (Interview 21). As one NRD public relations manager said of the ability to form partnerships:

> The authority to get into these local agreements has paid so many dividends. It's made it so much easier for us to legally get into contracts and work together. I can't stress enough the leveraging of partnerships. It just helps because now you've got all these different resources: financial, technical, volunteer, boots on the ground resources to help in all these kinds of projects that [NRDs] can't do on [their] own (Interview 27).

From their inception, the regulatory independence of the NRDs has encouraged extensive informal communication among boards and managers from different NRDs (Interview 21). The NARD also plays a coordinating role, arranging multiple formal meetings per year where NRD boards and staff and the public meet and share ideas and experiences (Interviews 3, 13, 21, 22). One NRD manager also indicated that there are five formal meetings per year that bring together all NRD managers, and that in the BGMA the four NRD managers get together monthly to discuss the project.

This networking and collaborative polycentric governance has allowed Nebraska to address potential scale imbalances between groundwater quantity management (for which NRD regulatory authority was originally granted) and the emergent problem of NPS nitrate pollution in groundwater.

Groundwater pollution in two of these projects, the BGMA and Hastings WHPA, initially appears to present a potential scale mismatch between the governance boundaries of the NRD – which were drawn along surface watershed boundaries for managing quantity – and the nitrate pollution patterns that flow between four NRDs in the BGMA and two in Hastings (Cumming et al., 2006). These two groundwater quality programmes demonstrate an adaptive capacity in the NRD system for addressing potential scale mismatches that have developed with the emergence of the nitrate problem.

The BGMA and Hastings WHPA projects demonstrate that the governance system is sufficiently flexible to allow NRDs to self-organise in order to adapt to problems that do not align with the original governance boundaries. Those boundaries are still relevant for the overall management of groundwater and it would be impractical to create management boundaries that are different for quantity and for quality. Instead, the governance regime is set up so that state-level regulatory oversight requires individual NRDs to meet groundwater quality standards, with NRDs empowered to address challenges in the way that is most appropriate for the scale of the problem. In some situations, acting collectively may be the best approach to addressing a problem at the appropriate scale.

In describing the formation of the BMGA, nine interviewees reported the realization by the NRDs and the state DEQ that nitrate pollution went beyond individual NRD borders. By self-organising, the four NRDs were able to leverage EPA Clean Water Act funding in order to collectively address the problem present in the larger aquifer. Their demonstration of a collaborative approach also allowed them to make a stronger case for receiving federal funding. At the local level, getting more partners involved in the project and having a larger critical mass of participants made it easier to sell the programme to individual NRD boards (Interview 5). Additionally, as part of the collaboration, the four NRDs in the BGMA are aligning their nitrate concentration phase levels in order to streamline reporting requirements, something that will benefit producers who farm across districts (Interview 3). The authority granted to the local NRDs allows for the flexibility to adapt their regulatory approaches in ways that benefit their constituents, a significant step in building more trust (Interview 3).

In the Hastings WHPA, it was the city that drove the self-organising process, but because the municipal boundaries are split between two NRDs and because nitrate pollution is primarily from agricultural activity in the surrounding farmland of both NRDs, it needed to coordinate with the districts in organising to achieve its goals (Interviews 7, 9, 26, 29). The city and the NRDs recognised that they could leverage their resources collaboratively to better address the problem (Interview 27). Because the NRDs had been granted significant regulatory authority, they had the necessary flexibility to develop the collaborative programme that is now in place.

In summary, in relevant situations informal and formal coordination encourages information sharing and supports self-organising between NRDs. This connects with Elements 1 and 2, where trust and the ability to design local solutions combine to build collaborative approaches that help to overcome potential scale imbalances and promote BMP adoption.

### Element 4: NRD taxing authority supports locally tailored policy mixes for BMP programmes

The final component of the governance regime that has been beneficial to these programmes is the ability of NRDs to collect property taxes to fund operations. The regulatory and taxing authority granted to the NRDs provides them with the resources to enforce regulations and enables them to develop locally based incentive and I&E programmes for promoting nitrogen management BMPs (Interviews, 12, 15, 16, 25, 30). Generally, collection of taxes by the NRD boards has not been difficult (Interviews 22, 25). NRD taxes represent a small portion of taxes paid, averaging only 3.6 percent of total property taxes levied between 2008 and 2018 (Nebraska Department of Revenue, 2018), and the farmer-dominated NRD boards typically take a frugal approach to NRD expenditures, raising taxes only when additional expenditures are justified (Interview 7). Additionally, because the boards are locally elected, taxpayers can decide through their vote whether the benefits they receive are worth the tax paid to the NRD (Bleed and Babbitt, 2015).

The NRD tax base also insulates the districts from the variable nature of outside funding sources (e.g. grants), enabling them to continue with nitrate management programmes once grant cycles are complete (Interviews 9, 25, 30). As an NRD water resources manager said, these taxes provide a reliable base for district activities, something that is generally not available to local governance institutions in other states. Finally, these taxes give NRDs the ability to top up (sometimes by as much as 90 percent) cost-share BMP programmes undertaken with the state government and with the US Department of Agriculture Natural Resources Conservation Service (USDA NRCS). They are thus able to provide additional incentives to encourage producer adoption of locally prioritised BMPs (Interviews, 3, 5, 7, 9, 13, 17, 23).

Taxing authority granted to NRDs is a key element of the system, creating a funding base for collaborative, coordinated approaches and monitoring activities. Monitoring data, in turn, inform policy-mix decisions (regulatory, voluntary, cost-sharing), and is also used in I&E trust-building activities, as well as supporting programme monitoring and evaluation at both the DEQ and NRD levels. Experimentation by individual NRDs with different policy mixes is also partially funded through local taxes. Experiences with different approaches are shared between NRDs, which supports collaborative approaches to programmes and creates a larger community that can draw on the pool of experimentation in the development of local solutions.

## SUMMARY AND CONCLUSION

Nebraska's NRD system presents a rare example of a groundwater governance regime conducive to positive sustainable groundwater quality outcomes. The long-term success of these programmes remains to be determined, but a significant and desirable downward trend in nitrate concentrations has already been achieved in the CPNRD GMA, and every interviewee who discussed the programme expressed confidence that this trend would continue and that it would achieve groundwater quality goals.

The other two programmes, the BGMA and Hastings WHPA, have not existed long enough to show significant changes in groundwater nitrate levels. Because of the long timescales of groundwater processes, and due to geologic differences between the BGMA and Hastings WHPA, it could be many years before groundwater nitrate concentration trends can be attributed to these two programmes. In the Hastings area, for example, the travel time of nitrate from the surface to the aquifer is between 30 and 50 years (Interview 26). In the near term, nitrate concentrations could actually increase as excess nitrogen applied decades ago percolates through the soil profile into the underlying aquifer (Interview 26). What these programmes have demonstrated, however, is that the authority granted to the NRDs has been successfully utilised to self-organise and to develop collaborative programmes that are built on principles proven to be successful in the CPNRD GMA and adaptable to the local conditions in each geography.

This study focused on three programmes in Nebraska. It included seven NRDs, representing almost one-third of the NRD system. These three programmes cover different aspects of nitrate management efforts which collectively represent the broader NRD regime: single-district responses, multi-district self-organising, and multi-district-urban self-organising. The enabling conditions for self-organising and collaborative approaches are present statewide, and we expect to see an increase in their application as more NRDs are required to scale up nitrate mitigation efforts due to the continuing emergence of the nitrate problem.

Perhaps the greatest challenge to these and future nitrate mitigation programmes comes from the long timescales associated with reducing nitrate concentrations in groundwater. While the CPNRD GMA has seen desirable results from its efforts, it will take many years to see if the BGMA and Hastings WHPA can reduce groundwater nitrate concentrations to safe levels. One interviewee (Interview 25) expressed concern that because nitrates in groundwater do not present an immediate threat that people see in their daily lives, nitrate issues may be pushed to the back burner as other, more immediate challenges occur, such as the record floods in Nebraska in the spring of 2019. Many interviewees also expressed uncertainty about whether the community-oriented and collaborative NRD system could have been be created in the current era due to changes in politics and the increasing polarisation of American culture. Continuing the notable successes of the NRD system will require recognising and planning for these changing conditions (see, for example, Bleed and Babbitt, 2015; Sixt et al., in press).

The goal of this paper was to identify characteristics within Nebraska's groundwater governance regime that are conducive to limiting NPS pollution of groundwater by nitrates and, in the longer run, reducing nitrate concentrations to within safe levels. Our broader goal for this research was to derive generalisable aspects of the governance regime that are applicable elsewhere as efforts increase to address nitrate pollution of groundwater. In Section 3, we discussed the four elements of regime type specific to the Nebraska NRD system and demonstrated how empowered local governance can create the conditions for resolving complex common-pool resource problems. The elements of the polycentric regime are complementary (Figure 3) and the NRD system works because all the parts connect. Elements 1, 2, and 3 are reciprocal: local governance builds the trust needed to implement policy mixes, and this trust is necessary for self-organising; conversely, I&E policy instruments and the culture of networking and collaboration that support self-organising help to build trust in the NRDs. Element 4, NRD taxing authority, provides a funding mechanism for local governance and locally tailored policy mixes, as well as helping fund some activities in collaborative programmes that are formed through self-organising (e.g. the BGMA and Hastings WHPA). Collectively, these conditions create the legitimacy, transparency, accountability, inclusiveness, fairness, integration, and capability that build stakeholder support for a governance system (Lockwood, 2010; Kiparsky et al., 2017).

From these four Nebraska-specific elements, we present four generalised principles of this governance system that are applicable beyond Nebraska. These are:

1. Local-level governance bodies whose leaders are elected by the stakeholders they serve, encouraging transparency and accountability, and building trust;
2. A nested, polycentric regime that grants significant regulatory authority and flexibility to local-level governance bodies while maintaining regulatory oversight on overall sustainability goals at the state level;
3. The importance of coordination and collaboration among key actors in the nested regimes, including the ability to self-organise to overcome potential scale imbalances, share information between local-level and higher-level governance bodies, and involve multiple actors in mixed-intervention approaches;
4. Granting of taxing authority to local-level governance bodies so they can fund general operations, mixed-intervention approaches, and collaborative efforts.

Using the NRD system as an example, we provide empirical evidence showing that Huitema et al.'s (2009) recommendations for designing water governance regimes are applicable in the design of effective groundwater quality governance regimes addressing agricultural NPS pollution. All of Huitema et al.'s (2009) enabling conditions are embedded in the principles listed above, with the addition of giving taxing authority to local-level governance bodies – an important component in the broader success of groundwater governance (see, for example, Bleed and Babbitt, 2015; Sixt et al., in press).

We highlight the importance of cooperative approaches to NPS pollution programme development and management, and emphasise the need for local-level governance bodies to have access to a reliable source of funding (in this case taxing authority). Finally, we present an empirical counterpoint to scepticism of higher-level authorities' willingness to yield decision-making power to lower levels in nested, polycentric regimes governing complex resource systems. While it is not a principal critique of polycentric governance, it has been noted that in complex resource management situations, higher-level government authorities may be reluctant to yield their decision-making power to lower-level authorities (e.g. Marshall, 2008; Ross and Dovers, 2008; Huitema et al., 2009; Ross and Martinez-Santos, 2010). It is true that the state DEQ represents a higher-level authority with oversight over nitrate regulation. However, as discussed earlier, the DEQ's regulatory footprint is small and the state has willingly ceded significant authority to the local-level NRDs in a way that is unique among American states.

Policy implications from this work are perhaps very relevant to the American context, as the NRD system exists under conditions shared by other states: it is nested under the same federal oversight as the other 49 states; it is part of a uniquely American type of federalist system; it is culturally similar to other states in the same region; and its agricultural production system is similar to other states in the region.

The analysis is currently most applicable to California's Sustainable Groundwater Management Act (SGMA), which was passed in 2014 and has not yet been fully implemented. Kiparsky et al. (2017) noted that the institutional design of California's SGMA provides a model for other states as they develop their own groundwater governance regimes. It is true that the SGMA is noteworthy as a polycentric groundwater governance regime, and because it is still in the initial implementation stages the experiences of the state will be invaluable to the development of governance regimes elsewhere in the US. However, Nebraska's NRD regime has been in place since 1972, and its NRDs have been developing groundwater quality plans, both individually and collaboratively, since the 1980s. Many of the polycentric approaches intrinsic to the SGMA are reflective of the NRD system, and consultation with experts from Nebraska could be beneficial to California as it implements the SGMA.[7] We recommend that future research includes comparative analyses of the experiences of these two polycentric regimes, as findings from such research could enhance the effectiveness of groundwater quality governance elsewhere.

[7] In fact, representatives from the NARD have been consulted by the state of California.

While the scope and applicability of this paper is most relevant to the US context, we do recommend further research comparing EU experiences to those in Nebraska. EU policy mixes tend to favour regulatory instruments and to limit member countries' freedom to pursue flexible economic instruments (Oenema et al., 2011), while policy mixes in the US tend to favour voluntary, incentive-based instruments. The Nebraska example provides a case where voluntary and incentive-based measures are preferred, but where regulatory measures are instituted in situations where these approaches are insufficient. Additionally, as with much of the European experience, most of the NPS nitrate management programmes in Nebraska have not been around long enough to see significant changes in nitrate concentrations in groundwater – particularly in deep aquifers. Both the EU and Nebraska provide early examples from which to learn about effective governance of complex groundwater systems in conditions of uncertainty regarding the longer-term impacts of governance decisions. Comparing these two groundwater governance systems could help identify common conditions for achieving adaptive groundwater governance across a more diverse range of governance system types.

Further research is warranted in order to determine whether the NRD system is replicable elsewhere in the US or internationally. Governance regimes are complex networks influenced by diverse interests and power relations (Pahl-Wostl, 2015). Policy instruments that work in one place may fail in another. Thus, governance is not just the organisations that manage a resource; it is the people, culture, and collective experience involved in the path to sustainable decisions. Effective governance is as much about the context of the governance system as it is about the policy instruments developed to govern them. As Ostrom (2007) points out, there are no institutional panaceas that guarantee effective governance.

Nebraska may possess characteristics that limit the applicability of its groundwater governance regime beyond its borders. For example, it is the only state in the US to have a unicameral legislative body, and it is possible that the NRD system is a result of optimal conditions that were present in the early 1970s. We recommend additional research on the possible influence of the geographic and temporal conditions in place at the time of the creation of the NRDs, and whether this may limit or support applicability of the NRD model elsewhere. However, our findings add to a growing body of empirical evidence showing that governance regimes conducive to sustainable CPR outcomes can be developed across a wide range of geographical, political and resource system contexts and that, where these regimes exist, they express a common set of enabling conditions that led to their formation.

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