What's in Your Well?

The Hidden Dangers of Nitrates in Rural Drinking Water

A report by Prairie Rivers Network

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EXECUTIVE SUMMARY

Nitrate is one of the most common water contaminants worldwide and poses significant risk for ecological and human health. These risks are especially prevalent in rural areas where land cover is predominantly conventional row-crop agriculture (e.g., corn and soybeans) and fertilizer application rates are high. Nitrate pollution poses a serious problem for water quality in Illinois, yet not enough is known about the prevalence and extent of rural well contamination. This paper examines the problem of nitrate pollution in these wells and presents solutions for better understanding and addressing the issue.

In Illinois, thousands of drinking water wells are contaminated by nitrate. High levels of nitrate impair water quality and harm aquatic life. Much attention has been paid to the pollution of surface waters (e.g., rivers, streams, and lakes) and Illinois' contribution to the Gulf of Mexico dead zone. However, the presence of this pollutant can have significant consequences locally.

Consumption of nitrate is associated with serious human health hazards. It is well documented that feeding infants nitrate rich water, generally as part of baby formula, can contribute to methemoglobinemia—widely known as blue baby syndrome—a potentially fatal condition that starves infants of oxygen. Research continues to point to health risks for adults as well, linking consumption of nitrate to increased risk of various illnesses and cancers. Moreover, the increased risk for these illnesses has been connected to exposure at levels well below those which have previously been regarded as safe.

Despite considerable health risks, not enough is known about the extent and degree of nitrate contamination in rural wells throughout Illinois. The limited data that does exist suggests widespread nitrate contamination, especially for shallow rural wells in agricultural settings. This paper employs available water quality data from non-residential wells (e.g., restaurants, places of worship, campgrounds) as a proxy to investigate the extent of contamination across the state. Analysis reveals high levels of nitrate in wells throughout the state, especially along some major rivers. Some well logs show nitrate levels well above the U.S. EPA's drinking water standard. This preliminary analysis raises serious concerns that many Illinois residents may be unknowingly exposed to high levels of nitrates and subject to higher risk of certain illnesses and diseases.

Illinois policy makers have recognized that the state must reduce the amount of nitrate that leaves the state and makes its way to the Gulf of Mexico. Illinois is responsible for 20% of the nitrate that results in the Gulf dead zone.[1] The Illinois Nutrient Loss Reduction Strategy has brought diverse stakeholders together in an effort to reduce Illinois' outsized contribution to the dead zone. This goal is laudable, but we must also address nitrate contamination of local groundwater, especially in drinking water sources.

Robust, statewide well testing would provide much-needed data on the extent of nitrates in Illinois drinking water. Outreach to rural well owners and wide-scale adoption of farming practices that reduce pollution and restore soil health are needed. This can be achieved by adequately funding state conservation and water quality programs and incentivizing better farming practices. The cost of inaction is too high—steps need to be taken now to protect people and the environment.

PART ONE:
NITRATE AND SHALLOW RURAL WELL CONTAMINATION

Nitrate is one of the most prevalent water pollutants in U.S. groundwater.[2] Much attention has been directed toward nitrate's contribution to the Gulf of Mexico dead zone, an area thousands of square miles with oxygen levels so low that it cannot support aquatic life. But nitrate contamination of local drinking water supplies is also a growing concern, particularly for states with large agricultural sectors like Illinois. Many Illinois residents and communities are unaware of the presence and dangers of nitrate in their drinking water, but well testing shows that this problem is occurring throughout the state.

Nitrate is a known human health hazard that is regulated in public drinking water. Ingesting too much can cause blue baby syndrome, a potentially fatal condition that starves infants of oxygen. In 1962, as part of the Safe Drinking Water Act, the federal legal limit for nitrate in drinking water was set to 10 mg/L. However, new research indicates that long-term consumption of water rich in nitrate may be hazardous at much lower levels. Methemoglobinemia, the underlying condition causing blue baby syndrome, has been found at subclinical levels in infants given water contaminated with nitrate at levels below the current drinking water standard.[3] Furthermore, a growing body of literature is finding potential links between nitrate exposure at or below 5 mg/L with increased risks of certain cancers, thyroid disease, and birth defects.[4] This suggests that the current federal legal limit is far too high.

Exposure to nitrates at levels once thought safe may lead to serious health problems, with implications for a much larger share of the population. To protect Illinois residents from nitrate-related illnesses, we need to know the full extent of nitrate contamination of our water. As research continues, communities must have access to the latest science so they can make informed decisions based on their own risk profile.

Nitrate enters water from two main sources, agricultural lands and wastewater treatment facilities. While wastewater treatment plants are subject to regulation requiring the removal of nitrate, farms are largely unregulated. Nitrogen, an essential nutrient for plant growth, is often applied to farmland as chemical fertilizer. The applied nitrogen is then converted to nitrate in the soil. Nitrate is water soluble, so when too much fertilizer is added to the soil it can be washed into our rivers or leached into groundwater. In Illinois, agricultural lands account for 80% of the nitrates reaching our rivers.[5]

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Typical corn and soybean farming practices not only make nitrate fertilizer vulnerable to being washed off fields but also encourage nitrate stored in the soil to leach into water. These conventional row crop farming systems, which are the dominant form of agriculture in Illinois, do not provide enough carbon for soil organisms throughout the year, resulting in the loss of nitrate that would otherwise remain stored in the soil. To prevent this loss, alternative farming systems make use of carbon sources that keep nitrate in the soil, including leaving carbon-rich crop residue such as corn stalks in the field after harvest or planting cover crops after the main crop which release carbon substances from their roots to feed soil microbes.

Significant strides have been made in filtering nitrate out of wastewater. But to approach nitrate reduction efforts through wastewater improvement alone will result in diminishing returns for increasing costs. With so much nitrate pollution coming from agricultural lands, the biggest water quality return on investment for the public dollar would be to prevent nitrate from leaving farms in the first place. And in addition to preventing nitrate pollution, conservation cropping systems can improve farms' resiliency and bottom line.

Nationally, 20% of shallow wells in agricultural areas are believed to have nitrate levels above the drinking water standard.

VULNERABILITY OF SHALLOW WELLS

Elevated concentrations of nitrate are most common in shallow (less than 100 feet deep) domestic wells located in agricultural areas with large nitrogen sources, including fertilizer use and livestock.[6] Shallow rural wells are some of the most vulnerable to nitrate contamination because they are more likely to receive surface water and are adjacent to the main source of nitrate in our water—agricultural pollution. Nationally, 20% of shallow wells in agricultural areas are believed to have nitrate levels above the drinking water standard.[7]

Unlike public water systems, private wells are not protected by regulations to ensure minimum water quality standards and are not required to monitor nitrate concentrations.[8] Approximately 40 million Americans rely on private drinking water supplies which are not subject to U.S. EPA monitoring and standards.[9] In Illinois, an estimated 400,000 private wells provide drinking water to roughly 1.3 million people.[10] Furthermore, surveys have found limited awareness among private well owners about the dangers of nitrate and the need to test their wells annually.[11]

As a result, there is the potential for thousands of families across Illinois to have nitrate contaminated well water, yet be unaware of the risks to their families, neighbors, and communities.

PART TWO:

ILLINOIS FALLS SHORT

The state of Illinois lags behind other Midwest states in its collection of data on rural well water quality. The lack of data on nitrate levels in private domestic wells makes it difficult to assess the extent to which people and communities are being exposed. Communities at a higher risk of nitrate exposure and its attendant health impacts may be completely unaware of the threat.

By comparison, the Minnesota Department of Agriculture has developed the Township Testing Program to determine the current nitrate concentration of private domestic wells in their state.[12] Managed by local Soil and Water Conservation Districts, this testing program offers free nitrate testing on a rotating multi-year schedule for residents in townships that are vulnerable to nitrate contamination.

Similarly, Wisconsin recently completed a survey that, while limited in scope, provided a valuable overview of nitrate contamination throughout the state. The survey looked at agricultural chemicals in private well water, including nitrate,[13] and was conducted by the Wisconsin Department of Agriculture, Trade and Consumer Protection in coordination with the Wisconsin Field Office of the National Agricultural Statistical Service. This is the fifth survey Wisconsin has completed on agricultural chemicals in private domestic wells since the 1990s.

Illinois has far less information available on nitrate levels in private wells. In 1992, the Illinois Department of Agriculture, the Illinois State Geological Survey, and the Illinois State Water Survey conducted a pilot study of nitrates in private rural wells.[14] However, the study was limited to only five counties. This pilot program was intended to test the procedures and protocols for a statewide survey, but unfortunately a full statewide survey was never funded.

Compounding the problem of limited data availability, there is also little awareness on the need to test nitrate levels among private well owners. A Minnesota survey on this issue found that only about 1/3 of respondents had tested their well water for nitrate within the past three years.[15] Nitrate has no taste, so well owners are not able to detect nitrate contamination without testing. And with no outward signs of contamination, well owners remain unaware of the need to test. Further, many were unaware that carbon filters do not remove nitrate.

People in this survey who were concerned about nitrate contamination were much more likely to say they test their water, drink bottled water, or think property values have declined in the county due to poor water quality. Raising awareness around the dangers of nitrate may increase the number of people testing their wells for nitrate contamination.

In Illinois, there has been insufficient governmental support for raising the visibility of this issue. In 2005, the Governor's office announced a new campaign to encourage private well owners in Illinois to test their water for nitrate; testing was offered at public health departments. This program ended in 2016. In a sampling of 100 Illinois rural well owners undertaken by Prairie Rivers Network in 2020, 69% felt that they did not have enough opportunities to learn about their well water. Illinois has cut funding to educate well owners on how to protect themselves at a time when we are seeing rising levels of nitrate in our groundwater. Rural well owners need more resources to protect themselves.

This lack of data and awareness around nitrate contamination of Illinois drinking water leaves thousands exposed to nitrate at levels above the drinking water standard and the state woefully unprepared to address this crisis. Without more and better data, we risk an inadequate and unfocused response in addressing this health threat.

Only 1/3 of people surveyed had tested their well water for nitrate within the past three years, and well owners remain unaware of the need to test.

PART THREE:

WIDESPREAD NITRATE CONTAMINATION

It is possible to gain some understanding of current nitrate levels in Illinois' shallow rural wells, even if incomplete, by looking at shallow public wells and private well studies conducted in select parts of the state. Nitrate levels in groundwater appear to be elevated in some parts of Illinois as evidenced by the limited testing that has been done by the Illinois Environmental Protection Agency (IEPA), Illinois Department of Agriculture (IDOA), and National Water-Quality Assessment (NAWQA) program. The Illinois State Water Survey pilot study, mentioned in the previous chapter, found some counties to have 15 - 40% of their rural wells over 10 mg/L nitrate-n.[16]

A theme that emerges from what little data we do have on Illinois shallow groundwater is that some wells are experiencing extraordinarily high nitrate contamination. IDOA's Nitrate Monitoring Well Network found the Havana Lowlands area of Mason County to have nitrate levels ranging from 18 - 48mg/L nitrate-n. In this location, the sand and gravel aquifers and a high occurrence of agricultural irrigation wells are the suspected sources of well contamination.

In 2006, IEPA began testing a subset of public wells for nitrates as part of their Nitrate Monitoring Network. In 2014, IEPA found elevated nitrate levels in community water systems. This led IEPA to conduct a Nitrate Trend Study which found a range of 0.16 - 19 mg/L nitrate-n.[17]

IDOA has tested a separate network of monitoring wells, the Dedicated Pesticide Monitoring Well Network, every two years for nitrate. This network consists of monitoring wells meant to assess the condition of shallow groundwater and are predominantly in areas where the aquifer is within 20 feet of the surface. IDOA found nitrate levels in many of its wells to be over 10 mg/L for multiple years. While surface waters typically see seasonal fluctuations, groundwater nitrate levels are more likely to be consistently high once they are contaminated.[18] This rings alarm bells because chronic exposure is a concern for cancer and birth defects.

The National Water-Quality Assessment (NAWQA) Program has found Illinois to have some of the highest nitrate levels found in private wells in the country, with samples reaching almost eight times (77 mg/L) the drinking water standard.[19] Modeling based on NAWQA well samples predicts that the average nitrate level for private wells in the Lower Illinois River Basin is exceptionally high. The relatively high nitrate fertilizer applications, specific geology, and prevalence of wide diameter wells are believed to contribute to the high nitrate levels seen in West Central Illinois.

It is also possible to glean information about nitrate levels in untested private domestic wells by looking at nearby public shallow rural wells for which there is data.[20] [21] These wells can be used as a proxy to learn about the likely extent of nitrate contamination in private rural wells. In our research, we chose to focus on well data from public sources outside of municipalities (e.g., restaurants, places of worship, campgrounds) which tend to be shallower than community water systems (see Map 1). Our findings show widespread nitrate contamination of wells throughout Illinois, with particularly high concentrations along major rivers like the Rock, Mississippi, and Illinois. The highest well sample reached over 40 mg/L nitrate-n.

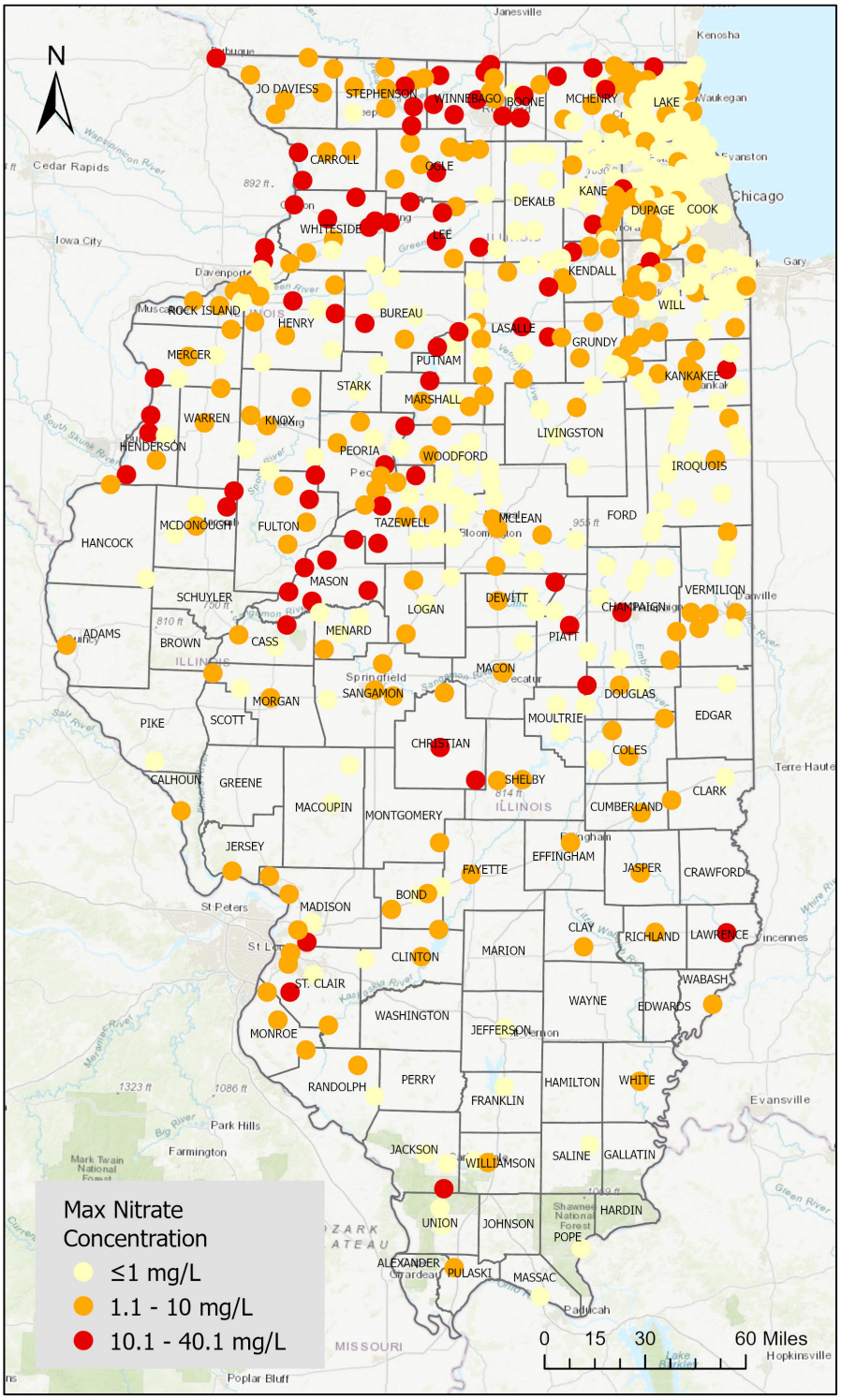
The significant concentration of elevated nitrate in wells along the Rock River in northwest Illinois is consistent with recent trends of increasing nitrate loads in the river itself. Seeing high nitrate levels in both surface and groundwater in these areas may indicate an interplay between them in agricultural settings. This phenomenon has also been seen in the Mississippi River, where some of the highest nitrate loads have been found during periods of low precipitation. According to USGS, the likely source of river contamination in such cases is groundwater with high levels of nitrate discharging into the river.[22]

Prairie Rivers Network analyzed data from the Illinois State Water Survey's well testing programs showing wells with elevated nitrate levels near the Rock and Illinois Rivers as well as spread across central Illinois and reaching into the southern parts of the state.[23] The highest nitrate sample was over 90 mg/L nitrate-n.

Each of these data sources provides an intriguing but incomplete glimpse into Illinois' shallow groundwater. It is clear that high nitrate levels can be seen across the state, and in some areas at levels many times the drinking water standard. However, systematic statewide analysis of nitrate contamination of rural wells is needed to understand the full breadth of the problem.

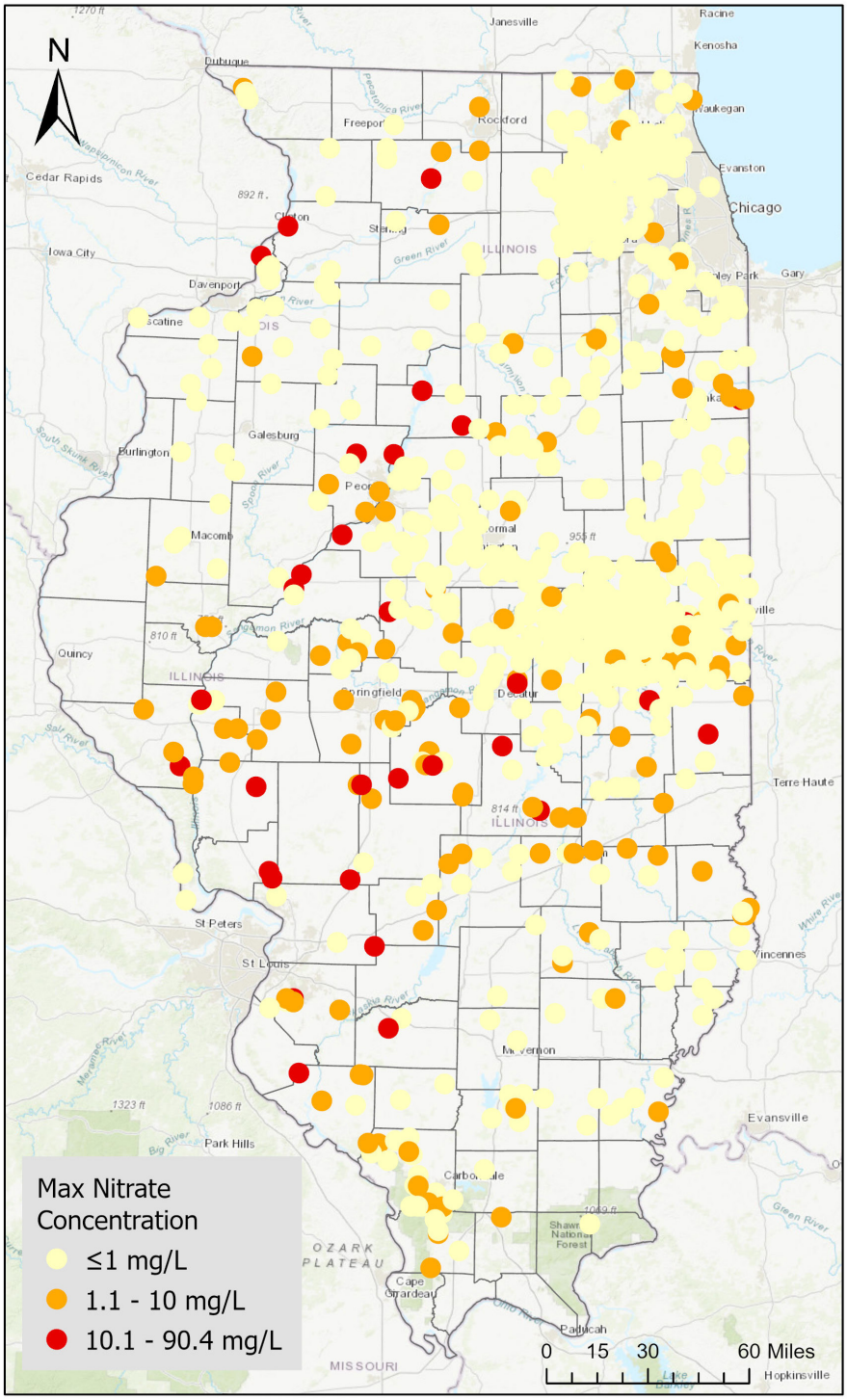
National studies have found some of the highest nitrate concentrations in the country in Illinois.

Map 1: Maximum nitrate concentration in non-community public wells (2002-2020).[24] [25]



Maximum nitrate levels of shallow public wells from Illinois Department of Public Health records. Red dots represent wells that have exceeded the nitrate drinking water standard of 10 mg/ L. Orange wells are elevated above background levels. High nitrate levels are seen in particular along the Illinois and Rock Rivers.

Map 2: Well samples from Illinois State Water Survey well testing programs.[26]



Maximum nitrate levels of wells from several well testing programs of the Illinois State Water Survey. Red dots show wells that have exceeded the nitrate drinking water standard of 10 mg/L. Orange wells are elevated above background levels. High nitrate levels are seen scattered across the state.

PART FOUR:

LANDSCAPE BASED SOLUTIONS

Reducing nitrate levels in rural wells cannot be addressed on a well-by-well basis; it requires a statewide solution. The most effective way to prevent nitrate from contaminating these wells is to prevent it from getting into water in the first place. Since the majority of nitrate comes from agricultural activities, protecting water will require a broadscale change to agricultural practices across Illinois.

Reducing excess fertilizer beyond the Maximum Return to Nitrogen (MRTN), which is the most profitable nitrogen application rate, and moving the majority of fertilizer to spring application is a start, but achieving a large reduction in runoff will require a new approach to cropping systems. Conservation practices do not work in isolation, but are made more or less effective based on the overall management of the farm. We must move towards farming systems that work with natural systems to hold nitrate in the soil.

The most effective conservation practices tend to involve growing additional plants in or adjacent to a crop field which feed the soil biology and take up leftover nitrogen before it is washed off the field. This is then cycled back into the soil ecosystem to be released for a future crop. In recent years, more farmers have begun to realize the benefit of planting cover crops which take up excess nitrogen from the field. Field buffers, prairie strips, and wetlands can also be installed, filtering much of the nitrogen load from the water leaving the field. Other practices such as bioreactors create an environment on the edge of the field to grow bacteria which remove nitrate, again cleaning nitrogen from the water before it exits the field.

To reduce nitrate runoff, the majority of farmers need to be involved in the following:

- Having living roots in the soil for most of the year (e.g., cover crops)
- Applying nitrogen fertilizer mostly in the spring at the MRTN
- Leaving crop residue undisturbed

Reducing nutrient pollution is a monumental challenge that will require funding for conservation programs and widespread buy-in for these practices. While we often hear that changing our agricultural system will be expensive, we remain unaware of the extraordinary price we pay by doing nothing. It is increasingly clear that there are serious and significant public health and economic costs to our inaction. We can build more widespread public support by focusing on conservation practices that provide additional benefits beyond improving water quality. Many of these same practices also improve farm resiliency and help us mitigate and adapt to climate change.

A key characteristic of many water quality practices is that they increase the amount of carbon in the soil. Increased soil carbon improves soil structure, increasing its water infiltration and drainage. This is not only important for farmers who are facing both more high intensity storms and droughts due to climate change, but to anyone living by a river that floods. Furthermore, removing carbon from the air and storing it in the soil helps draw down greenhouse gasses which are causing the climate to change in the first place. After the oceans, our soils are the largest carbon sink. If we want to draw down the amount of carbon in the atmosphere, the soil is the logical destination for excess carbon. Unlike treatment options at wastewater plants which only address symptoms of the problem, landscape-based solutions take a more holistic approach and thus are able to take on several of the greatest challenges of our time.

The most effective conservation practices tend to involve growing additional plants in or adjacent to a crop field which feed the soil biology and take up leftover nitrogen before it is washed off the field.

Soil with a crumbly texture full of worm and root channels is the result of using farming practices like cover crops that feed the soil ecosystem, and hold soil and nutrients in place. (Photo credit: NRCS/SWCS photo by Lynn Betts)

PART FIVE:
HOW ILLINOIS CAN PROTECT OUR DRINKING WATER

Prairie Rivers Network has identified several actions that should be taken to improve our understanding of and address the problem of nitrate in drinking water in Illinois. Our recommendations center on data collection, education and outreach, and long term planning. We need to know the full extent of nitrate pollution in Illinois water if we are to make informed decisions to address the problem.

1. The state should conduct a comprehensive survey of nitrate in rural wells.

2. Archived state well drilling records should be digitized and entered into a public database.

3. The state should develop an outreach program for private rural well owners, educating them about nitrate and offering free nitrate testing.

4. Nitrate pollution should be addressed in the latest revision of the Illinois State Water Plan.

It is imperative that Illinois officials and policy makers understand that nitrate is a local water concern. Among water advocates, government agencies, and in the media, nitrate pollution has largely been defined as a problem impacting the Gulf of Mexico. Prairie Rivers Network encourages the public and policy makers to focus on impacts closer to home.

There are efforts and entities currently tasked with reducing the nitrate and phosphorus loads that cause Gulf hypoxia, but these efforts have struggled to find consistent funding and are falling woefully short. The issues of Gulf hypoxia and local drinking water contamination are absolutely related; proper resourcing of Gulf hypoxia efforts would also pay dividends in protecting Illinois' drinking water sources. To address the broader problem of nutrient pollution, the state needs to provide long-term funding for the Nutrient Loss Reduction Strategy effort. It is especially important to have stable funding for the super gages, which test nitrate levels in our major rivers, and our Soil and Water Conservation Districts, who are our "boots on the ground" for protecting soil and water quality.

Nitrate levels are on the rise in Illinois public water systems, and we do not currently know the full extent of the problem in private wells, especially shallow rural wells. The Nutrient Loss Reduction Strategy has brought together environmental, state agency, and agricultural industry partners to reduce nitrate and phosphorus pollution flowing out of our state and contributing to the Gulf of Mexico Hypoxia Zone, yet a renewed effort needs to focus on the issue closer to home. The governor, the General Assembly, state agencies, and the public must recognize how nitrate pollution impacts public health and prioritize actions that will protect vulnerable drinking water sources. There are state programs and on-farm practices that can turn the tide. We need to adopt and implement them as quickly as possible.

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At Prairie Rivers Network, we protect and restore our rivers. We return healthy soils and diverse wildlife to our lands. We transform how we care for the earth—and each other.

Our strategy must reflect the scale of our crisis. So we're ambitious, passionate, and vocal about all we do. We educate, empower, and encourage people to act. We give voice to those who have compelling stories of resistance and renewal.
And we partner with people and organizations who know—and implement—what it takes for all life to flourish.

As we move into the future,
we can make an impact together.

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