1987

Groundwater Quality and Policy Options in Nebraska

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Potential contaminants and the occurrence of groundwater contamination in Nebraska are discussed. An overview of Nebraska's policy response to groundwater quality reveals that the policy has been fragmentary and generally reactive. Although a comprehensive groundwater quality protection strategy is needed if the groundwater is to be protected from potential point and nonpoint sources of contamination, it must recognize the site-specific nature of most groundwater contamination. The Nebraska Chemigation Act and the Petroleum Products and Hazardous Substances Storage and Handling Act passed in 1986 were the first comprehensive legislation addressing prevention of point source contamination. Proactive policies for the prevention of nonpoint groundwater contamination are an economic necessity in today's political climate.

Groundwater quality has progressed from a little known concept in the 1960s and 1970s to a household term in the 1980s. The presence of trace levels of certain inorganic and organic chemicals in groundwater and their potentially harmful health effects have ignited the public's interest in the quality of drinking water. This concern has been fueled by the media, as evidenced by the many television, radio, and newspaper presentations with themes about the degradation of groundwater quality.

Coupled with mounting concern about the quality of groundwater are rapid advances in analytical techniques, which have detected compounds previously unknown in groundwater and made their analysis routine. Many substances can be measured in part per trillion and even part per quadrillion (1/1,000,000,000,000,000). Mounting nationwide concern has forced Congress to appropriate
large sums of money to regulate and investigate major sources of groundwater contamination and to clean up contaminated sites.

Groundwater is vital to Nebraska. With the exception of the rural households serviced by the Cedar-Knox Rural Water District, which supplies surface water, groundwater satisfies the water use demands of the entire rural population. Eighty-four percent of the public water supply demand is met with groundwater (Conservation and Survey Division, unpublished data). Only Crawford and Blair and the small communities of Crofton and St. Helena are not served by groundwater. Chadron and the Metropolitan Utilities District, which serves the Omaha area, rely on both surface and groundwater. Thus, 90 percent of the state’s residents use groundwater for drinking water and other domestic needs. Seventy-two percent of the irrigation needs and 85 percent of the self-supplied industrial needs are met with groundwater (Lawton and others, 1983). Because this natural resource is essential to the development of the state, its quality must be maintained.

Quality describes the physical, biological, chemical, and radiological characteristics of groundwater. The assessment of the quality, however, is dependent upon the intended use, because the importance of each property is relative to the intended use and the user.

The hardness of water readily illustrates the relativity of quality. Except for groundwater underlying the Sandhills, groundwater in Nebraska is moderate-to-very hard. Hardness, which is principally calcium and magnesium, reduces the water’s suitability for domestic and industrial uses. Inside hot water heaters, coffee pots, tanks, and boilers, hardness causes scale formation, which impedes the transfer of heat. Scale is
aesthetically undesirable in toilet bowls and on plumbing fixtures. While softened water is ideal for laundering, bathing, and dishwashing, it is unsatisfactory for drinking because sodium has replaced calcium and magnesium. Softened water also makes beverages tasteless and causes corrosion in machines and boilers where a thin layer of scale is desirable. The components of hardness are not harmful when ingested; consequently, hardness in drinking water is not regulated. In fact, evidence suggests that hardness in drinking water helps build strong heart muscles. The public’s assessment of the quality of hard water would be based mostly on aesthetics, while an industry’s would be based on operating costs.

In general, the public probably assesses drinking water quality based on properties which can be evaluated by personal experience, such as taste, odor, and appearance, and on media hype. In a recent *Los Angeles Times* survey, nearly 40 percent of California residents used bottled water or water filtered in the home as their primary source of drinking water (Troise, 1986). The primary reason for using bottled or filtered water was taste, rather than health concerns. Seventy-seven percent of the respondents to the 1986 Nebraska Annual Sociological Indicators Survey (Booth, 1987) thought there were "man-made chemicals in the drinking water which could affect their health." Seventy-six percent ranked the problem as a serious or moderately serious one. In an ironic twist, residents of southeastern Nebraska thought the problem was less serious than other Nebraska residents. Booth attributed this to the large urban population which has less direct exposure to water quality problems than rural and small community residents. The highest regional frequency of point source
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### Table 1 - Primary groundwater quality standards and established maximum contaminant levels (MCLs)

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MCL</th>
<th>Physiological Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inorganic chemicals (mg/l):</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.05</td>
<td>toxic; carcinogen ?</td>
</tr>
<tr>
<td>Barium</td>
<td>1.0</td>
<td>toxic</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.01</td>
<td>toxic; carcinogen ?</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.05</td>
<td>carcinogen ?</td>
</tr>
<tr>
<td>Fluoride</td>
<td>4.0</td>
<td>dental mottling</td>
</tr>
<tr>
<td>Lead</td>
<td>0.05</td>
<td>carcinogen ?; teratogen</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.002</td>
<td>toxic</td>
</tr>
<tr>
<td>Nitrate-nitrogen</td>
<td>10</td>
<td>methemoglobinemia</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.01</td>
<td>suspect carcinogen</td>
</tr>
<tr>
<td>Silver</td>
<td>0.05</td>
<td>skin discoloration</td>
</tr>
<tr>
<td><strong>Organic chemicals (μg/l):</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endrin</td>
<td>0.2</td>
<td>carcinogen</td>
</tr>
<tr>
<td>Lindane</td>
<td>4</td>
<td>carcinogen</td>
</tr>
<tr>
<td>Methoxychlor</td>
<td>100</td>
<td>teratogen</td>
</tr>
<tr>
<td>Toxaphene</td>
<td>5</td>
<td>toxic</td>
</tr>
<tr>
<td>2,4-D</td>
<td>100</td>
<td>carcinogen</td>
</tr>
<tr>
<td>2,4,5-TP Silvex</td>
<td>10</td>
<td>carcinogen; teratogen</td>
</tr>
<tr>
<td>Total trihalomethanes</td>
<td>100</td>
<td>carcinogen</td>
</tr>
<tr>
<td><strong>Radionuclides (pCi/l):</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radium-226 &amp; radium-228</td>
<td>5</td>
<td>carcinogen</td>
</tr>
<tr>
<td>Gross alpha activity (includes Ra-226; excludes radon &amp; uranium)</td>
<td>15</td>
<td>carcinogen</td>
</tr>
<tr>
<td>Gross beta activity</td>
<td>50</td>
<td>carcinogen</td>
</tr>
</tbody>
</table>

Primary Source: Nebraska Department of Environmental Control. Title 118 - Ground Water Quality Standards and Use Classification. November 22, 1986.
Table 2 - Secondary groundwater quality standards and established maximum contaminant levels (MCLs)

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>MCL (mg/l)</th>
<th>Aesthetic effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride</td>
<td>250</td>
<td>taste</td>
</tr>
<tr>
<td>Copper</td>
<td>1</td>
<td>taste</td>
</tr>
<tr>
<td>Iron</td>
<td>.3</td>
<td>stains</td>
</tr>
<tr>
<td>Manganese</td>
<td>.05</td>
<td>stains</td>
</tr>
<tr>
<td>Sulfate</td>
<td>250</td>
<td>taste</td>
</tr>
<tr>
<td>Zinc</td>
<td>5</td>
<td>taste</td>
</tr>
</tbody>
</table>

Primary Source: Nebraska Department of Environmental Control. Title 118 - Ground Water Quality Standards and Use Classification. November 22, 1986.

Overview of Groundwater Quality

Because chemicals are widespread in the environment and most chemicals are at least slightly soluble in water, contaminants can be transported to the aquifer by recharge. Recharge, which is water reaching the surface of the water table (see figure 1), is a primary influence on groundwater quality in Nebraska. Sources of recharge include bodies of surface water, such as rivers, lakes, streams, canals, reuse pits, and lagoons; infiltrating precipitation; and irrigation water.

Chemical contaminants can occur naturally or they can be anthropogenic, that is, introduced by man. Major naturally occurring contaminants are derived from the breakdown of minerals (salts) and organic matter in the soil, and from the dissolution of minerals in the unsaturated and saturated zones (see figure 1). Anthropogenic contaminants include chlorinated organic solvents, metals, nitrates, and pesticides. Whether natural or anthropogenic, the source of the contaminant can be described as line, point, or nonpoint. Chemicals can seep
Saturated zone
Spaces between sediment particles are filled with water i.e. groundwater

Unsaturated zone
Spaces between sediment particles are partially filled with water

into aquifers along the length of a waterway (a line). Hence rivers, streams, and canals are potential line sources of contamination. Point sources originate at discrete locations, such as disposal pits, lagoons, abandoned feedlots, wells, spills, landfills, surface impoundments, and underground storage tanks. Nonpoint contamination is dispersed over an area. Fertilizer and pesticides applied to fields and precipitation are potential nonpoint sources.

**Line Sources of Contamination**

The Platte River is by far the most important line source of recharge in Nebraska. Because the public
supply wells of most towns and cities along its 500-mile path in Nebraska pump groundwater from the Platte River alluvium, the wells, in essence, are pumping considerable amounts of Platte River water. An estimated 40 percent of Nebraska's population served by public water supplies relies on this alluvial aquifer, which is composed of sediments deposited by the Platte River. Although potable, water in the Platte River and in the alluvium generally contains higher concentrations of many naturally occurring chemicals than water pumped from most of the state's shallow aquifers. This chemical load, known as total dissolved solids (TDS), is a measure of the amount of mineral matter dissolved in the water. The elevated TDS in the groundwater surrounding the North Platte, South Platte, and Platte Rivers indicates that there is lateral seepage of canal and river water (figure 2). The pumping of irrigation wells in the Platte Valley exacerbates this transfer, as does recharge from canal-irrigated bottomland.

Anomalously high concentrations of chloride, sulfate, calcium, sodium, and uranium in Platte River water identify the river's contribution to the groundwater. Generally, these chemicals do not invoke water quality concerns. Uranium could be the exception. Uranium concentrations average about 25 parts per billion (ppb) and uranium contributes about 20 picocuries (a unit quantity of any radioactive nuclide in which 0.037 disintegrations occur per second) of alpha radiation per liter (pCi/l) (Spalding and Druliner, 1981). Although this radiation is higher than the maximum contaminant level (MCL) of 15 pCi/l allowed in public drinking water supplies, the MCL does not include alpha radiation from radon and uranium (table 1). Therefore, the water still is in compliance with drinking water regulations if less than 15 pCi/l total alpha activity is contributed by
FIGURE 2
Concentrations of Dissolved Solids in Groundwater in Nebraska

EXPLANATION
Zones of concentration, milligrams per liter

- 0 - 200
- 201 - 500
- 501 - 1000
- Greater than 1000

nuclides other than uranium and radon. The beneficial uses of the river water could be curtailed in the near future when the EPA promulgates a MCL for uranium.

Pesticides in runoff from treated fields appear to be the greatest anthropogenic threat to drinking water derived from the infiltration of water from the Platte River. Recently, low levels of the herbicides atrazine, alachlor (Lasso), cyanazine (Bladex), and trifluralin (Treflan) and the insecticide carbofuran (Furadan) were identified in the Des Moines, Iowa, water supply (U.S. Water News and the Freshwater Foundation, 1987). Because Des Moines derives its drinking water supply from infiltrated Des Moines River water, an analogous situation could be present in Nebraska. The Conservation and Survey Division in the Institute of Agriculture and Natural Resources of the University of Nebraska-Lincoln currently is sampling the Platte River at 27 locations between Scottsbluff and Omaha. Preliminary data obtained during a high runoff event in the spring indicate the presence of several pesticides in part per billion quantities. These concentrations appear related to runoff from unimproved croplands.

**Point Sources of Contamination**

While point sources of groundwater contamination generally result from human activities, many times natural processes occurring within the aquifer cause local groundwater contamination. Within these relatively small areas, low oxygen levels in the groundwater favor reactions that solubilize metals contained in minerals in the aquifer or that produce gases. High concentrations of iron, manganese, uranium, radon, and hydrogen sulfide can be produced. In some cases, changing the depth of the well screen or the areal siting of the well will
improve the situation. While the health effects caused by ingesting water with high levels of radon (decay product of radium) and uranium are questionable, elevated concentrations of hydrogen sulfide, iron, and manganese are primarily a nuisance. High concentrations of radium and uranium in groundwater occur in the basal Chadron unit beneath Crawford (Spalding and others, 1984) and in the basal Pleistocene near Alda in Hall County (Spalding and Loope, 1984a and 1984b). Hydrogen sulfide, iron, and manganese make groundwater less attractive by imparting odor (rotten egg smell from hydrogen sulfide), taste (a bitter taste to coffee and other beverages from iron and manganese), and stains (iron and manganese). While these nuisance chemicals are removed from most public water supplies, they remain the principal water quality concern for many rural Nebraskans. As more domestic wells are drilled deeper to avoid agricultural contaminants at the top of many aquifers, the number of iron, manganese, and hydrogen sulfide complaints will increase.

There is a long and growing list of anthropogenic point sources of groundwater contamination in Nebraska. Some of these sources have been causing problems for the past 70 years; others have been discovered only recently. These contaminants are associated with agriculture; petroleum storage; munitions production; solid and hazardous waste disposal; and a multitude of industries, ranging from dry cleaning plants to heavy equipment manufacturing.

Since the late 1940s, sporadic elevated nitrate levels have been reported in the groundwater of the eastern quarter of Nebraska. A recent study (Exner and others, 1985) of the lower Nemaha basin (in extreme southeastern Nebraska) showed that 71 percent of the sampled wells had nitrate-nitrogen concentrations
above 10 parts per million (ppm), coliform bacteria, or both. The areal distribution of the nitrate concentrations was indicative of point source contamination. Leachates from animal wastes were the major contaminant, while siting and construction of the contaminated wells were inadequate to protect the integrity of the water supply. The incidence of nitrate-nitrogen contamination, that is, wells with more than 10 ppm nitrate-nitrogen, in this 1,100 square mile area was 37 percent (figure 3). This is similar to the frequencies (22 percent and 18 percent) reported in two areas of about 7,200 square miles in eastern Nebraska with point source nitrate-nitrogen contamination (Exner, 1980a and 1980b). These data indicate that nitrate is the most widespread groundwater contaminant in rural eastern Nebraska.

According to the Nebraska Department of Health (NDOH) (1987), incidences of nitrate contamination throughout rural areas of the eastern quarter of Nebraska increased between 1979 and 1984 (figure 4). Eighteen of the 26 towns in Nebraska in violation of the nitrate-nitrogen MCL were in the eastern quarter of the state (NDOH, 1987). In nonirrigated areas these elevated concentrations probably result from point source nitrate contamination.

Although much of the nitrate contamination in the eastern quarter of Nebraska originates as point sources, new evidence suggests that nitrate from nonpoint sources can contaminate the groundwater beneath irrigated fields even in areas where the unsaturated zone sediments are predominantly fine-textured silts and clays (Kitchen, 1987). Previously, researchers thought that even under irrigation significant quantities of nitrate did not pass through thick layers of fine-textured sediments; consequently, most groundwater in the eastern quarter of Nebraska was assumed much less likely to be
FIGURE 3
Areal Distribution of Concentrations of Nitrate-Nitrogen in Lower Nemaha Basin Groundwater, Nebraska

contaminated by nonpoint sources of nitrate. Generally, nitrate levels in the eastern quarter of Nebraska are higher in groundwater contaminated by point sources than in groundwater contaminated by nonpoint sources. This is a response to the higher levels of nitrate in the leachate from point sources, and the lack of groundwater available for dilution because of the thinness of the aquifer.

The potential for nitrate contamination from manure-covered soils is dependent upon the animal density in the barnyard or feedlot. Nitrate-nitrogen is less likely to accumulate in the deep soil profile of feedlots that are always stocked. These soils have an undisturbed and
continuously accumulating manure pack where hoof compaction and excreted urine keep the surface sealed, damp, and reducing. In this environment conversion of ammonia to nitrate is unlikely (McCalla and others, 1972; Elliot and others, 1973). When the feedlot is abandoned, surficial drying and cracking promote conversion of urea to nitrate and the subsequent leaching of nitrate through the unsaturated zone and, ultimately, to the groundwater. Because most barnyards and corrals are not stocked in the summer, the physical and chemical processes occurring in the manure pack would parallel those in an abandoned feedlot.

Few cases of point source pesticide contamination have been reported to the Nebraska Department of Environmental Control (NDEC), although several have occurred. Most of the accidents occurred when chemicals were applied near surface waters that were in hydraulic connection with the groundwater, or when the chemical was back-siphoned from a mixing tank and was injected directly into the groundwater. One of the first documented cases occurred in Kimball in 1969. The herbicide picloram (Tordon), allegedly sprayed on weeds around a waste lagoon, contaminated the municipal water supply and caused the demise of several hundred greenhouse tomato plants. A similar event occurred in Bassett in 1975. Trace levels of arsenic in the municipal water were attributed to the use of an arsenic herbicide around the municipal sewage lagoon. These two examples illustrate the incompatibility of siting wells near lagoons.

Farmers have been known to contaminate their domestic water supplies when mixing pesticides. Back-siphoning occurs when the water hose remains in the pesticide mixing tank and the well pump shuts down. The contents of the mixing tank subsequently are siphoned into the well.
Back-siphoning during chemigation is a potentially severe contamination problem. Chemigation is the application of chemicals, usually pesticides or fertilizer, to crops through an irrigation system. Basically, the concentrated chemical is metered into the irrigation water and applied with the irrigation water. Chemigation systems provide a direct route for contamination of the groundwater by pesticide or fertilizer concentrates if the backflow prevention equipment fails, or if the system is operated illegally without a check valve.

Recently, leaky underground storage tanks have become a source of concern as point sources of contamination. In Nebraska, most of these tanks contain leaded and unleaded gasoline and diesel fuel. Industrial solvents are stored in a few tanks. As early as 1960, however, gasoline contamination was reported in an aquifer in Nebraska. Tens of thousands of gallons of gasoline were floating on the water table near and beneath the Swift Company plant in Gering (Crawford, 1960). Since 1980, the Nebraska State Fire Marshal (NSFM) has responded to 88 life-threatening incidences caused by fuels migrating into sewer systems or home basements (J. Gross, 1987). During this same period, the NDEC investigated 186 fuel leaks that either were not life-threatening or occurred within the seven largest cities (W. Imig, 1987) (figure 5). Both agencies expect an increase in the number of reports of leaky fuel tanks during the next 2 years, as more station owners become aware that procrastination in reporting leaks results in more extensive contamination and more costly cleanup.

Gasoline and diesel fuel are organic compounds that do not dissolve in water and are lighter than water; consequently, the fuel is found at the water table. Although the fuel remains relatively stationary and does
not move with the groundwater flow, there are water-soluble compounds in the fuel. The presence of these compounds (benzene, toluene, and xylene) in the groundwater usually indicates petroleum contamination. Because relatively large quantities of these compounds can be dissolved in the groundwater and move with the flow, serious groundwater quality problems can develop, and they create much more concern than the immobile fuel. Nine municipalities in Nebraska have trace levels of one or all three compounds in a public supply well or monitoring wells in the vicinity of the public supply wells (NDOH, 1987). In these instances, the sources are
most likely leaky underground storage tanks at gas stations or surface spills. In Nebraska, there have been at least two incidences of groundwater contamination from leaky storage tanks containing the pure industrial solvents toluene and xylene.

Another class of groundwater contaminants receiving much press are liquids that do not readily dissolve in water and are heavier than water. These organic compounds are volatile and most contain chloride. Like the fuel-derived compounds, benzene, toluene, and xylene (BTX), these compounds are soluble enough in water that the concentrations can have serious groundwater quality implications but; unlike BTX, these compounds sink through the saturated zone and reside at the bottom of the aquifer. These compounds are used primarily as degreasers, grain fumigants, and paint removers. In Nebraska, trichloroethylene (TCE), carbon tetrachloride, and tetrachloroethylene (PCE) are the most frequently found compounds of this type in the groundwater. TCE, PCE, or both, have been identified in groundwater beneath 13 towns or municipalities, while traces of carbon tetrachloride were found in groundwater beneath 20 other towns (NDOH, 1987).

Waste disposal sites at ordnance facilities that manufactured munitions also have contaminated the state's groundwater. A 3-mile plume of RDX (Research Department Explosive) and a 1-mile plume of TNT have been traced to the decommissioned Cornhusker Army Ordnance facility west of Grand Island (Spalding and Fulton, in press). As part of the remedial action presently being undertaken, contaminated soils at the suspected source areas are excavated and incinerated to remove the munition residues. The costs for cleanup and extending the municipal water supply to homes in the affected area are approaching $10 million.
Munitions were manufactured at three other ordnance facilities in Nebraska. All three have been abandoned. Both groundwater and soil are being monitored at the former Army ammunition plant at Meade and the former Navy ammunition depot east of Hastings. Monitoring of soil and groundwater at the former Sioux Ordnance Facility, north of Sidney, is not planned in the near future.

In Nebraska, 36 landfills are licensed to accept municipal waste (B. Baugh, 1987). Because second class cities and villages have been exempt from landfill licensing requirements since 1972, NDEC estimates there are 350 to 400 open dumps in the state (B. Baugh, 1987). Certainly some of these dumps and landfills are contaminating the groundwater, but the impact on local groundwater quality is unknown.

Nonpoint Sources of Contamination

Nonpoint contamination results from the dissolution of a widespread, relatively uniform source that can be of natural or anthropogenic origin. It results in large areas of contaminated groundwater with relatively uniform concentrations.

In Nebraska, naturally occurring nonpoint contamination occurs where metals and other chemicals in aquifers with poor quality water are solubilized and migrate into the aquifer used as a potable water supply. These chemicals also can be present in saturated sediments that do not produce recoverable quantities of groundwater, and they can migrate into the producing aquifer.

Significant selenium contamination occurs in the groundwater in areas of Boyd, Keya Paha, and northern Holt counties (Engberg and Spalding, 1978). In these
areas, the water-bearing sediments are thin and yield small quantities of groundwater. In order to ensure that an adequate supply of water is available, wells are drilled into the bedrock to provide additional storage space for water. The creation of this reservoir can mobilize selenium in the bedrock. Moderately high selenium concentrations also occur in groundwater in some parts of the Dakota Aquifer, the principal source of potable groundwater in eastern Nebraska. Volcanic ash beds in northwestern Nebraska are a third source of moderately high selenium concentrations in the groundwater.

The distribution of high fluoride concentrations in the groundwater is quite similar to that of selenium, indicating that both chemicals are derived from similar source rocks (Engberg and Spalding, 1978). Except in isolated cases, the concentrations of these naturally occurring, nonpoint contaminants are not severe enough to cause health problems.

All anthropogenic nonpoint contamination in Nebraska is related to agriculture, which is the state's largest industry. In 1986, this industry used 1.6 billion pounds of nitrogen fertilizer in Nebraska (Nebraske Department of Agriculture, in preparation). In 1984, the last year for which statistics are available, 30 million pounds of pesticides were applied to Nebraska farmland (Johnson and Kamble, 1984). Poor management of these agrichemicals and irrigation water have resulted in nonpoint groundwater contamination.

The short distance to the water table (less than 20 feet), large areas of well-drained to excessively well-drained soils, and intensive fence row-to-fence row irrigated corn agriculture make areas of the Central Platte Natural Resources District (NRD), northern Holt County, and an area west of Sidney the most vulnerable
to nonpoint agronomic groundwater contamination in Nebraska. Groundwater underlying large areas of the Central Platte NRD is contaminated with fertilizer-derived nitrate (Spalding and others, 1978; Gormly and Spalding, 1979). Between 1974 and 1984, the area with nitrate-nitrogen concentrations greater than 10 ppm increased, as did the average nitrate-nitrogen concentration of the contaminated groundwater (Exner and Spalding, 1976; and Exner, 1985). In Holt County, nonpoint nitrate-nitrogen contamination from fertilizer occurred north of the Elkhorn River in areas of intensive irrigation development (Exner and Spalding, 1979). Because of the low chemical load of this Sandhills-type groundwater, additions of sulfate and chloride from potash and sulfamag fertilizers were also apparent in the groundwater. Another area of nonpoint nitrate contamination appears to be developing west of Sidney. Presently, this area, smaller in areal extent than the other two areas, is the site of a detailed investigation by the Conservation and Survey Division of the University of Nebraska-Lincoln.

Areal nitrate contamination in the central Platte, northern Holt County, and an area west of Sidney may be only the tip of the nonpoint nitrate contamination iceberg. Additional investigations in areas of southeast and south-central Nebraska with fine-textured, irrigated soils indicate that in 13 years the nitrate has moved at least 65 feet through an unsaturated zone of predominately silt and clay (Spalding and Kitchen, in preparation). One must conclude that all nitrogen-fertilized, irrigated areas in Nebraska could be subject to nitrate pollution if better fertilizer and water management is not practiced. Most of the nitrate-contaminated wells in the Central Platte NRD also contained trace levels of atrazine, which has been
statistically correlated with the nitrate concentrations. Some wells also tested positive for alachlor (Lasso).

Nebraska's Policy Response to Groundwater Contamination

From the preceding discussion it is apparent that the quality of groundwater has deteriorated in many areas of Nebraska, that the quality in these areas continues to worsen, that new areas of contamination will occur, and that there are many potential sources of contamination that can affect groundwater quality. The public policy responses to the deterioration of Nebraska’s groundwater include doing nothing, educating residents, and regulating contaminants.

Historical Perspective of Public Policy

Until the 1980s, programs protecting the quality of groundwater in Nebraska were virtually nonexistent. In the early 1970s, research and educational programs were just beginning to address agronomic nonpoint nitrate contamination of groundwater. Although research showed that changes in agricultural practices had the potential to improve groundwater quality without compromising crop yields, the agricultural community was reluctant to implement these recommendations. Legislation and judicial decisions reflected the impetus in the development of groundwater reserves for irrigation. Rules and regulations that were promulgated were directed at specific point sources of contamination. None of the policy goals, however, were aimed at preserving the integrity of the vastly uncontaminated supply.
Regulation of Potential Line Sources of Contamination. As stated earlier, the most important line source for groundwater recharge in Nebraska is the Platte River. Because different rules and regulations govern the quality of surface water, they are discussed later.

Regulation of Potential Point Sources of Contamination. Although the Nebraska Supreme Court ruled in 1894 (Beatrice Gas Company v. Thomas, 41 Neb. 662, 59 N.W. 925) that "landowners were entitled to protection of their drinking water from contamination, and that, under a private nuisance theory, one who pollutes his neighbor's drinking water supplies would be liable for the damages caused," it was not until 1961 that protection of groundwater quality was addressed in Nebraska's statutes. In that year, legislation was passed requiring abandoned irrigation wells to be sealed to prevent contaminants from reaching groundwater supplies (Aiken, 1987). No other laws or regulations protecting the quality of groundwater were forthcoming in the next decade.

As early as 1972, the state legislature recognized the potential for severe and imminent contamination, should an irrigation pump accidentally shut off on a system used to apply water and fertilizer simultaneously. The statute required that fertigation systems be equipped with a backflow prevention device. This device is designed to prevent siphoning of the contents of the fertilizer tank into the irrigation well and, subsequently, into the aquifer if the irrigation pump fails. This statute later was revised in 1977 to require backflow prevention devices on irrigation systems used to apply pesticides. The legislation, which was the first true chemigation law, did not regulate equipment design or specifications or require
inspection of chemigation systems. Comprehensive chemigation legislation was passed in 1986.

In 1971, the Unicameral enacted the Nebraska Environmental Protection Act. This legislation consolidated environmental responsibilities from a variety of state agencies into one administrative unit, the Nebraska Department of Environmental Control (NDEC). Creating such an agency enabled the state to use federal technical and financial assistance more effectively. The NDEC was given broad authority to protect Nebraska's groundwater quality, which included adopting and enforcing regulations. The NDEC wrote rules and regulations for some potential point source contaminants in its early years (table 3); however, it was not until 1978 that protection standards for groundwater quality were adopted.

The NDEC chose to adopt the federal primary and secondary drinking water standards for Nebraska's groundwater, and applied them to groundwater with a total dissolved solids (TDS) concentration of less than 10,000 mg/l (NDEC, 1978). Primary standards are set for contaminants that are hazardous or produce undesirable physiological effects on humans, animals, and plants. Maximum contaminant levels were adopted for ten inorganic compounds, six organic compounds, radium, and gross alpha and gross beta activity.

Secondary standards are applied to constituents that impart odor, color, or taste to the water and are aesthetically undesirable. The criteria basically were those shown in tables 1 and 2.

At the time these rules were promulgated initially pollution accidents were dealt with idealistically. If "toxic or taste-and-odor producing substance" was spilled and had the potential to contaminate the groundwater, the responsible individual was to notify the NDEC and, withi
Table 3 - Regulated potential point sources

<table>
<thead>
<tr>
<th>Potential point source</th>
<th>Effective date</th>
<th>Regulatory authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual waste treatment lagoons</td>
<td>1977</td>
<td>NDEC</td>
</tr>
<tr>
<td>Septic tank systems</td>
<td>1977</td>
<td>NDEC</td>
</tr>
<tr>
<td>Livestock waste control facilities</td>
<td>1983</td>
<td>NDEC</td>
</tr>
<tr>
<td>Solid waste disposal</td>
<td>1983</td>
<td>NDEC</td>
</tr>
<tr>
<td>Underground injection and mineral production wells</td>
<td>1982</td>
<td>NDEC</td>
</tr>
<tr>
<td>Mineral exploration holes</td>
<td>1983</td>
<td>NDEC</td>
</tr>
<tr>
<td>Chemical systems</td>
<td>1986</td>
<td>NDEC</td>
</tr>
<tr>
<td>Underground storage tanks</td>
<td>1986</td>
<td>NSFM</td>
</tr>
<tr>
<td>Hazardous waste management</td>
<td>1987</td>
<td>NDEC</td>
</tr>
<tr>
<td>Abandoned wells (excludes domestic wells)²</td>
<td>1975</td>
<td>NDWR</td>
</tr>
<tr>
<td>Improperly constructed wells</td>
<td>in preparation</td>
<td>NDOH and NDEC</td>
</tr>
</tbody>
</table>

Effective date of rules and regulations

²All abandoned wells will be subject to the forthcoming NDOH and NDEC Title 178.

5 days, clean up the ground and groundwater to the extent required by the NDEC, using an unspecified NDEC-approved method (NDEC, 1978).

Regulation of Potential Nonpoint Sources of Contamination. Nonpoint source contamination first was addressed in 1975 in the Groundwater Management Act (GMA). It gave NRDs, which were formed in 1972 by consolidating soil and water conservation districts, watershed districts, and similar boards, broad groundwater management authority. The principal intent of the GMA was to slow or reverse groundwater mining by authorizing NRDs to request groundwater control area designation from the director of the Nebraska Department of Water Resources (NDWR). Groundwater quality control areas, however, could be designated "if the development and utilization of the groundwater supply had caused or was likely to cause within the foreseeable future dewatering of an aquifer resulting in a deterioration of the groundwater quality that made it
unsuitable for the purpose for which it was being utilized" (Statutes of Nebraska, Sect. 46-658).

In 1979, the Lower Loup NRD requested a groundwater control area designation partly because of deterioration of groundwater quality. The request was denied by the director of the NDWR. One reason for the denial was that the chemical degradation of the groundwater supply had not, nor was it anticipated to, result exclusively from the dewatering of the groundwater reservoir (NDWR, 1980). The NRD did not petition for groundwater quality control area designation the next year (1981) when the act was amended to include present or foreseeable contamination.

Further revision of the Groundwater Management Act in 1981 produced the Groundwater Management and Protection Act (GWMPA). This act vested NRDs with the sole authority to request groundwater quality control area designations from the director of the NDWR to prevent current or foreseeable pollution. No longer did the pollution need to be related to dewatering an aquifer. If a control area was designated, the statute authorized the NRD, with NDWR approval, to implement corrective measures that would mitigate or eliminate the condition that lead to the contamination. These corrective measures included at least one of the following: Irrigation scheduling which would regulate the application of water so that it would not move below the root zone; allocation of groundwater withdrawals among users; rotation of groundwater use; stricter requirements for well spacing; installation of flow meters to measure withdrawals; and any other reasonable regulations (Statutes of Nebraska, Sect. 46-666).

If, following a public hearing, the NRD deemed that these controls were not protecting users from contaminated groundwater, a moratorium on the drilling
of new irrigation wells could be declared for 1 year. This provision and the renewal of the moratorium for 1-year intervals were subject to the approval of the director of the NDWR. Domestic wells were not affected by the controls within a groundwater quality control area. Although not a provision of the GWMPA, NRDs within groundwater quality control areas were required to establish a groundwater quality monitoring program in cooperation with NDEC, and provide University of Nebraska-Lincoln fertilizer guidesheets to irrigators.

In 1984, the director of the NDWR approved regulations proposed by the Upper Republican NRD to protect groundwater quality in a control area established in 1977. The NRD required aural permits for each chemigating system. The system needed a properly functioning check valve and a device to shut off the injection pump when the irrigation pump shut off to qualify for the permit (Aiken, 1984). It is noteworthy that the only quality control area designation was instituted for a potential point source contaminant.

Subsequent revisions of the Groundwater Management and Protection Act in 1982 authorized NRDs to establish groundwater management areas, and to implement controls without NDWR approval upon completion of a groundwater management plan and its review by the director of the NDWR. While areas of groundwater quality concern were to be identified in the plan, the authorized controls (allocation of total withdrawal, rotation of use, well spacing requirements, and the use of flow meters) were more effective in regulating withdrawals than in protecting quality (Statutes of Nebraska, Sect. 46-673.09). Throughout the history of the Groundwater Management Act and the Groundwater Management and Protection Act, the authorized controls in groundwater quality control and management areas were
better suited to alleviating quantity degradation than quality degradation.

Recent Policy Developments

The first policy issue study addressing groundwater quality was completed as part of the State Water Planning and Review Process initiated in 1978 and 1979 (Nebraska Natural Resources Commission, 1980). Most, but not all, of the alternatives for protecting groundwater quality had been recommended in the Section 208 Water Quality Management Plan for the State of Nebraska (Nebraska Natural Resources Commission, 1979). This policy issue study did not result in any new legislation.

In 1983, Governor Kerrey formed a Water Independence Congress to develop a set of principles and specific recommendations for developing a water policy for the state. The 40-member congress had diverse economic, political, philosophical, and professional backgrounds, and represented every geographic area of Nebraska. Its recommendations, as well as the development of a Groundwater Quality Protection Strategy by the NDEC in 1984, resulted in more conscious policy decisions than had been made in all the preceding years.

Regulation of Potential Line Sources of Contamination. Surface water quality must comply with standards set by NDEC (NDEC, 1987). The use of the surface water dictates the set of criteria that are enforced. The Platte River has been given an agricultural rather than a public drinking water supply use classification because municipalities do not supply treated water from the river, but, instead, obtain infiltrated river water from wells on islands in the river or along
the river. The general criteria for water with an agricultural classification prohibit the presence of waste or toxic substances that have undesirable effects in crops or livestock. The only numerical criteria are for conductivity, a measurement used to approximate total dissolved solids and nitrate-nitrogen.

**Regulation of Potential Point Sources of Contamination.** Two specific recommendations of the Water Independence Congress (1983) and the Nebraska Groundwater Protection Strategy draft (NDEC, 1984) were the clarification and modification of the existing law addressing backflow prevention devices on irrigation systems and the enactment of legislation to regulate chemical and petroleum storage. Included in these recommendations were specific issues that needed legislative attention. Both the Nebraska Chemigation Act and the Petroleum Products and Hazardous Substances Storage and Handling Act were passed in the 1986 session of the Unicameral. This was the first legislation with explicit regulations for the prevention of groundwater contamination by two potential point sources.

The Nebraska Chemigation Act (Statutes of Nebraska, Sects. 46-1101 to 46-1148) is a comprehensive law regulating the application of farm chemicals through irrigation systems. NRDs and the NDEC are authorized to "document, monitor, regulate, and enforce chemigation practices in Nebraska" (Statutes of Nebraska, Sect. 46-1102). The law enumerates the safety equipment required on each chemigation system with equipment specifications to be adopted by the NDEC, and requires chemigator certification and a permit to operate the system. NRDs, under NDEC supervision, are charged with enforcement. Each year NRDs must inspect the chemigation system and verify that the applicator is a certified chemigator.
before issuing a permit. NRDs also must conduct periodic inspections of chemigation systems.

The Petroleum Products and Hazardous Substances Storage and Handling Act (Statutes of Nebraska, Sects. 81-15.117 to 81-15.127) provided for registration and inspection of storage tanks for petroleum products and hazardous substances and a cleanup fund for orphaned tanks. Rules and regulations adopted and promulgated by the State Fire Marshal include: Procedures and specifications for construction, design, installation, replacement, or repair of tanks; a permit system; an inspection system; monitoring systems; notification of abandonment; procedure for ensuring safety of abandoned tanks; financial responsibility; and leak detection, inventory, and tank testing systems. Primary responsibility for administration of the legislation was given to NDEC.

Nebraska's groundwater protection standards were revised in 1986. In the new document, *Ground Water Quality Standards and Use Classification* (NDEC, 1986a), EPA's new numerical quality criteria were adopted; all groundwater in the state was classified based upon its present or potential use as a drinking water supply, and a remedial action strategy was developed for point source contaminated groundwater.

The new primary and secondary standards for which final maximum contaminant levels have been set are presented in tables 1 and 2. By 1989, this list will include standards for 14 volatile organic chemicals, 24 inorganic and 39 organic chemicals, 5 microorganisms, and 5 radionuclides. These criteria are the basis for regulatory programs and remedial action, and mostly apply to all groundwater, except Class GC (NDEC, 1986a).
Title 118 classifies groundwater in Nebraska as either GA, GB, or GC. Class GA groundwater is used (or is proposed to be used) as a public drinking water supply. The areal extent of the groundwater in this classification can be defined by the hydrogeologic conditions around the well or perimeter of the well field as approved by the NDOH, within a 1,000-foot radius of the well or perimeter of the well field, within an area at least as large as a 1,000-foot radius that has been designated through local ordinances, or within an area zoned or purchased by a local government for the purpose of developing a public drinking water supply well (NDEC, 1986a). The intent of these criteria is protection of the groundwater in the area immediately around the well or well field from land-use activities that could contaminate the groundwater.

Currently, groundwater not classified as GA is classified as GB. This groundwater is used as a private drinking water supply, or it has the potential of being used as a private or public drinking water supply. Class GC groundwater, which has not yet been assigned to any groundwater in Nebraska, has little or no potential as a public or private drinking water supply.

Groundwater classification is one of the criteria that NDEC will consider when setting regulatory requirements for potential point sources of contamination. Currently, classification is not addressed in the rules and regulations for potential point sources for which NDEC has regulatory authority (table 3), and the classification does not address nonpoint sources of contamination.

In Title 118, NDEC also has established a Groundwater Remedial Action Protocol to handle present or potential point source contamination of groundwater. The protocol determines the type and the extent of the action necessary to mitigate contamination. The necessary
action is dictated by remedial action classes (RACs). RACs depend on the use or potential use of the groundwater as a drinking water supply, and are based upon the condition of the groundwater prior to contamination.

Minimum requirements for cleanup are imposed upon the responsible party within each RAC. The maximum time allowed for cleanup is 20 years. LB 1199, which would have established the Environmental Response and Liability Act, a state superfund, to cleanup contaminated groundwater, died in committee during the 1986 legislative session.

**Regulation of Potential Nonpoint Sources of Contamination.** LB 1106 (1984), an outgrowth of the Water Independence Congress, required each NRD to prepare a groundwater management plan. Implementation, however, is optional. All the NRDs have written groundwater management plans, except the Upper Republican NRD which the NDWR exempted because almost the entire district is a groundwater control area.

In 1986, the Unicameral made sweeping revisions of the GWMPA. For the first time, nonpoint source contamination was addressed seriously in the statutes. LB 894 had two major provisions. First, a NRD could propose a groundwater management area primarily to protect water quality. This provision eliminated control area designation based solely on deterioration of groundwater quality. Second, the NDEC received the authority to designate special groundwater protection areas.

If a management area is proposed primarily to protect water quality, the plan must also be reviewed by the NDEC. Best management practices (BMP) and attendance at educational programs designed to protect
water quality were added to the three control measures (allocation of total withdrawal, rotation of use, and well spacing requirements and use of flow meters) previously authorized for use in management areas. BMP are the "scheduling of activities, maintenance procedures, and other management practices utilized to prevent or reduce present and future contamination of groundwater which may include irrigation scheduling, proper timing of fertilizer and pesticide application and other fertilizer and pesticide management programs" (Statutes of Nebraska, Sect. 46-657). A management area can be dissolved after the district holds a public hearing and approves dissolution.

The efficient management of irrigation water, fertilizer, and pesticides is critical to protecting the integrity of the quality of groundwater. These practices have been advocated for at least a decade, and the University of Nebraska Cooperative Extension Service, the Institute of Agriculture and Natural Resources, and the NRDs have tried to educate area producers about their environmental and economical advantages. The Hall County Water Quality Special Project, initiated in 1979, was a cooperative study among the Central Platte NRD, the University of Nebraska, and federal agencies to demonstrate on a fraction of the 65-square mile area in western Hall County that groundwater nitrate-nitrogen levels could be maintained or reduced through improved nitrogen and water management. When the voluntary program concluded after 4 years, Bockstadter and colleagues (1984) reported that the groundwater nitrate-nitrogen levels had stabilized. The remedial effects of these practices in a groundwater quality management area will be time dependent, and will vary with the area's soil nitrogen characteristics and the thickness of fine-textured sediments in the unsaturated zone.
The Central Platte NRD has developed a model groundwater management plan with extensive controls within designated groundwater quality management areas (Central Platte NRD, 1985). Controls within the management areas are dependent upon the concentration of nitrate in the groundwater. The regulations include banning the application of commercial nitrogen fertilizer on sandy soils during fall and winter; restricting commercial nitrogen fertilizer application until after November 1 on soils that are not sandy, and then allowing applications only with the use of a NRD board-approved inhibitor applied at their approved rate; analyzing the nitrogen content of soils (one composite of eight probes per field or every 40 acres, whichever is less) and irrigation well water annually; requiring attendance certification at district-developed or approved educational programs on best management practices; and reporting of nitrogen concentrations in irrigation well water and soils, crop to be grown and yield goal, recommended nitrogen fertilizer application rate, amount of commercial nitrogen fertilizer applied to each field, and the actual yield obtained annually. If an individual should fail to comply with these controls, the NRD is authorized to issue a cease and desist order after 10 days' notice (Statutes of Nebraska, Sect. 46-663).

The second provision of LB 894 is a significant departure from the local option philosophy that has dominated the Ground Water Management and Protection Act. While the statute recognizes that NRDs "as local entities are the preferred regulators of activities which may contribute to (nonpoint) contamination in both urban and rural areas, the NDEC should be given authority to regulate sources of contamination when necessary to prevent serious deterioration of groundwater quality" (Statutes of Nebraska, Sect. 46-674.02). Consequently,
NRDs no longer can choose to ignore groundwater quality degradation caused by nonpoint source contaminants.

If data available to the NDEC indicate that contamination is occurring or is likely to occur in an area in the foreseeable future, NDEC identifies the area as a potential problem area (NDEC, 1986b), conducts a study to determine if the contamination is point or nonpoint in origin, identifies the areal extent of contamination, and issues a written report. If nonpoint source contamination is present or likely to occur in the foreseeable future, the local NRD is notified and a public hearing is held to determine if a groundwater quality special protection area (SPA) will be designated. The five criteria to be considered in designating a SPA are whether (nonpoint source) contamination of groundwater has occurred or is likely to occur in the foreseeable future, whether groundwater users are experiencing or will experience substantial economic hardships as a direct result of current or reasonably anticipated activities which cause or contribute to contamination of groundwater, whether methods are available to stabilize or reduce the level of contamination, and whether administrative factors directly affect the ability to implement and carry out regulatory activities (Statutes of Nebraska, Sect. 46-674.07). If the director of the NDEC determines that a SPA will be established, a report, which identifies the specific reasons for establishing the SPA and the possible causes of the contamination, must be issued. Subsequently, an order declaring the area a SPA and indicating its geographic and stratigraphic boundaries must be issued. The local NRD then must prepare, adopt, and submit to the NDEC an action plan designed to stabilize or mitigate both the level of contamination and its areal extent.
If the action plan is approved by the director of the NDEC, the protective measures must be carried out until the director determines that the contamination has stabilized at, or been reduced to, a level that is not detrimental to the beneficial uses of the groundwater. If the action plan is not approved, or the revised plan is not approved, or a plan is not submitted to the NDEC, the director is authorized to specify and enforce the necessary protective measures.

The special protection area action plan prepared by a NRD must include the specifics of a NRD-instituted educational program to inform the public about methods for stabilizing or mitigating the level of contamination and preventing the increase or spread of the contamination, the required controls, and an implementation schedule. The protective measures, which are similar to those permitted in a groundwater quality management area, require water users to participate in educational programs, implementation of best management practices, and other reasonable measures to alleviate the conditions for which the special protection area was established (Statutes of Nebraska, Sect. 46-674.09). Users who do not comply with the protective controls established in a SPA are subject to as much as a $500 fine, or are guilty of a Class III misdemeanor (Statutes of Nebraska, Sect. 46-674.17) which carries a $500 fine, 3 months in jail, or both. The protective measures are to remain in effect until the level of contamination is reduced or stabilized and the area of contamination has not increased. The SPA designation may be removed after the director of the NDEC has determined that the level of contamination has stabilized or been reduced to a level that is not detrimental to the beneficial uses of the groundwater. The NRD, in cooperation with NDEC, also
must establish a groundwater monitoring program within the SPA.

The special protection area statutes do not address straightforwardly the failure of an NRD to implement an approved action plan or to enforce strictly the protective measures of the plan. There are differences of opinion as to whether NDEC would assume control if either situation occurred. If the threat of the NDEC designating special protection areas and, possibly, setting and enforcing protective measures were to prod NRDs into requesting water quality management areas within their districts, then the intentions of the statute may have fallen short. If a NRD fails to implement an approved action plan, the designation of a SPA does no more to protect groundwater quality than does the requirement that a NRD prepare a groundwater management plan and address water quality. While it is unlikely that a NRD would not implement the action plan, leniency in enforcing the protective measures could occur.

Policy Strategies

Nebraska’s groundwater quality policy has been fragmentary and, generally, a reactive policy, that is, the programs are either corrective and respond to known contamination problems or are a response to new EPA policies and regulations. Because the policies have been corrective, they lack the long-range planning characteristic of a groundwater protection program. Legislative changes must occur if the policies, particularly those regarding nonpoint contamination, are to protect the quality of the groundwater resource. NDEC’s Groundwater Quality and Use Classification, which addresses point source contamination, is weaker than their draft Groundwater Protection Strategy. In order to
protect groundwater from point source contamination, the rules and regulations for each potential point source must be rewritten in stronger language.

Nonpoint Nitrate Contamination

Nitrate contamination of the groundwater from nonpoint sources will become worse because nitrate-nitrogen concentrations will continue to increase in the contaminated areas, and new areas of contamination are anticipated. Implementation of protective measures permitted in groundwater management or special protection areas will not have an immediate effect on nitrate-nitrogen levels in the groundwater. Because nitrate is still present in the unsaturated zone, it will take time for this nitrate to reach the aquifer. Also, the nitrate levels in the groundwater will not decrease unless the contaminated groundwater is used for irrigation and the nitrate utilized by plants. Nitrate contamination can be anticipated in irrigated areas with fine-textured soils. Although nitrate is predicted to move at a slower rate through thick layers of unsaturated sediments than through coarser textured sediments, eventually, the nitrate will reach the aquifer.

A variety of options are available for dealing with nonpoint nitrate contamination. Three are related to controlling the source of contamination, and the fourth to land use. The first option is to continue the farming practices responsible for the nonpoint contamination and be resigned that the nitrate levels in the groundwater and the areal extent of the contamination will increase. Atrazine concentrations will most likely increase, and other pesticides may become detectable in the groundwater.
The second option is education and implementation of best management practices. The success of this option in reducing nitrate concentrations in the groundwater is debatable. During the last decade, farmers in areas of the Central Platte NRD had the opportunity to participate in a program (technical information, expertise, and field measurements of crop needs were supplied) that could help decrease the amounts of nitrogen fertilizer moving below the root zone. The efficacy of this option relies on farmers' voluntary compliance with best management practices, the number of acres in the program, and the duration of the farmers' participation.

Stricter regulations are the third nonpoint source control option. While present statutes may require use of best management practices in management or special protection areas underlain by nitrate-contaminated groundwater, regulation of fertilizer application rates could be necessary. Because there is no substitute for nitrogen fertilizer, restricting the amount of fertilizer used in areas underlain by nitrate-contaminated groundwater would put farmers within the area at an economic disadvantage. Such a policy would be highly discriminatory, but an effective program probably will require the implementation of best management practices and regulation of fertilizer application rates.

Land-use restrictions are a viable alternative to nonpoint nitrate source control. Activities that have the potential to pollute the groundwater could be prohibited in designated areas. Groundwater in these areas would serve as the potable water supply for areas where the groundwater is contaminated. In essence, polluting activities would be permitted in certain areas, the groundwater quality would be permitted to deteriorate, and the groundwater would be written off as a potable supply. Preservation of sections of the Sandhills and
other pristine areas with good quality groundwater would assure those in nonpoint contaminated areas of a continuous supply of potable water. Such a solution eliminates balancing the cost-benefit ratios of production and regulation in areas that currently have nonpoint nitrate contamination or projected water quality problems.

Several municipalities have purchased islands in the Platte River for their well fields. This was a conscious decision to avoid nitrate contamination by utilizing natural physical barriers. This strategy has worked well; however, the promulgation of new maximum concentrations for contaminants (for example, uranium) present in Platte River water could cause problems for these municipalities.

**Nonpoint Pesticide Contamination**

As discussed earlier, pesticides have been detected in nonpoint nitrate-contaminated groundwater in the Central Platte NRD and in Holt County. Because Nebraska has not designated a state agency to accept enforcement responsibility for the 35 products listed as restricted use pesticides by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the regulatory authority for pesticide use in Nebraska remains with the EPA. Nebraska is the only state that has not accepted enforcement responsibility for FIFRA. If the proposed national Groundwater Safety Act and FIFRA amendments become law, the enforcement of this new and more stringent groundwater protection legislation also will remain with the EPA.

The EPA could ban all pesticide use in Nebraska and, consequently, could shut down agriculture within the state. Although this is very unlikely, the reluctance of Nebraska to assume responsibility for FIFRA will, most
likely, precipitate increased regulatory action by the EPA in Nebraska. The absence of a state agency to enforce FIFRA has caused communication problems between Nebraska and the EPA, and it has left Nebraska without a pesticide regulatory agency. Presently, the use of pesticides deemed environmentally unsafe by university researchers in other states cannot be restricted or banned in Nebraska. Consequently, insecticides, such as aldicarb, that can be leached from soils easily, will, in all likelihood, be applied to potatoes grown in the Sandhills. Aldicarb, which has already contaminated the groundwater on Long Island and in Florida and Wisconsin, will most likely contaminate the highly vulnerable Sandhills groundwater. As with nonpoint nitrate contamination, the course of action will be remediation. The wiser position, and one that hindsight should have taught us, is prevention. Applications of aldicarb should be banned in the Sandhills and on other highly permeable soils in Nebraska. Many states, including Massachusetts, California, New York, and Florida, have either restricted or banned the use of pesticides that are known to contaminate the groundwater.

In areas of Nebraska where the primary groundwater producing unit is contaminated, a deeper secondary producing unit has become the major source of potable water. Regulation of well construction is needed to protect these secondary producing units from contamination introduced by lax drilling practices. Because most center pivots require a minimum of 800 gallons of water per minute to operate, and more if they are to operate efficiently, irrigation well drillers need to provide maximum water yields. In many areas of Nebraska, drillers are obtaining groundwater from more than one producing unit to obtain a high-yield well.
Layers of fine-textured sediments (aquitards) between aquifers naturally limit the transfer of water between producing units. Screening the well or gravel packing the space between the borehole and the casing in the two producing units provides a pathway for chemical exchange between the water producing units.

In a documented case (Spalding and Cady, 1986), tracer compounds were injected into an irrigation well 3 miles west of Grand Island. The tracers moved out of the bottom of the well, through a gravel-packed borehole in the aquitard (60 percent clay and 40 percent silt), and into the secondary producing unit. This occurrence is a direct result of drilling the hole deeper than necessary and back-filling with gravel. Many irrigation wells in this area, and presumably in other areas of Nebraska, are drilled through aquitards and the annular space packed with gravel or screened in two or more water producing units. Pressure differences, caused by pumping from both producing units, usually result in the downward movement of the groundwater; consequently, the holes in the aquitard act as conduits for recharging the secondary producing unit. If the groundwater in the upper producing unit is contaminated, in this case with agrichemicals, the window in the aquitard provides a vehicle for the vertical spread of the pollutant.

Unfortunately, pressure differences of a few feet between two producing units are not usually noted by well drillers. While the rules and regulations (NDOH and NDEC, in preparation) being written for well construction address drilling through confining layers, these layers would be recognized by drillers only if there were large differences in pressure between the water-producing units. The new rules and regulations will not allow wells to be screened in two producing units if one of the units is known or suspected of having
contaminated groundwater. Overdrilling, as observed in the central Platte area, is not addressed in the forthcoming regulations.

Many irrigation wells that are drilled through the aquitard or screened in two or more producing units are used to chemigate. If the backflow prevention equipment fails, the potentially toxic compounds would be siphoned into the secondary aquifer. Because the lack of site-specific hydrologic data and accurate drilling logs leave doubts about the groundwater flow pattern in many areas of Nebraska, the application of potentially toxic compounds through chemigation systems should be limited to areas that are not near high-yield municipal wells. This precaution should be used in addition to the mechanical safety devices already required by the Nebraska Chemigation Act.

Waste Disposal

Although hazardous and low-level radioactive waste disposal are politically unpopular issues, Nebraska should consider developing secure disposal facilities for both types of waste. The state would then be assuming, rather than shirking, responsibility for correctly disposing of the hazardous and low-level radioactive wastes generated in the state. Not only will properly sited facilities with state-of-the-art design for both types of wastes protect groundwater at the disposal sites from contamination, but having accessible sites will protect groundwater throughout the state from indiscriminate disposal of hazardous and low-level radioactive wastes. Certainly some of the 350 to 400 unlicensed open dumps in Nebraska are receiving hazardous wastes that could be contaminating the groundwater. In addition to being a potentially lucrative
operation, a technologically advanced disposal industry might lure other industries to the state.

Properly sited facilities with state-of-the-art design also are needed if the groundwater is to be protected from contamination at solid waste disposal sites. Alternative waste disposal strategies should be explored fully. Because of potential groundwater contamination, landfills in Iowa will no longer be licensed after 1990. Iowa presently supports incineration as a viable alternative to landfilling.

Research

While it is evident that there is a need for groundwater quality protection legislation, not only in Nebraska but throughout the country, many researchers would say that legislation is now leading technology. Presently, a better understanding of the processes that control contaminant migration in the unsaturated and saturated zones is needed. This knowledge comes from site-specific field studies and not from regional or simulated studies. While local taxing entities, for example NRDs in Nebraska, provide some money for research, the large sums that are necessary for sophisticated equipment must come from the state or federal government. Presently, an inordinate amount of the total funding for groundwater programs is allocated to regulatory agencies and large engineering firms for site investigation and remedial action. Nebraska, with its wealth and dependence on groundwater, certainly should assume a leadership role in groundwater research.
Funding

The appropriation of money for groundwater quality protection and cleanup lies with the legislature. While a successful protection program requires substantial funding, the costs of a preventive policy are much less than those of a corrective policy.

Several states have used their taxing authority to establish state superfund programs. In Iowa, money raised through fees for registration of pesticides, pesticide dealers, and storage tanks; retailers of household hazardous materials; disposal of solid wastes; and taxes on nitrogen fertilizers are directed to a variety of groundwater protection programs. Iowa also has proposed that $17.5 million in oil overcharge money be allocated to their groundwater protection fund. Nebraska, on the other hand, lacks a groundwater protection fund; perhaps it is time to establish a fund to help enable research and protective strategies.

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