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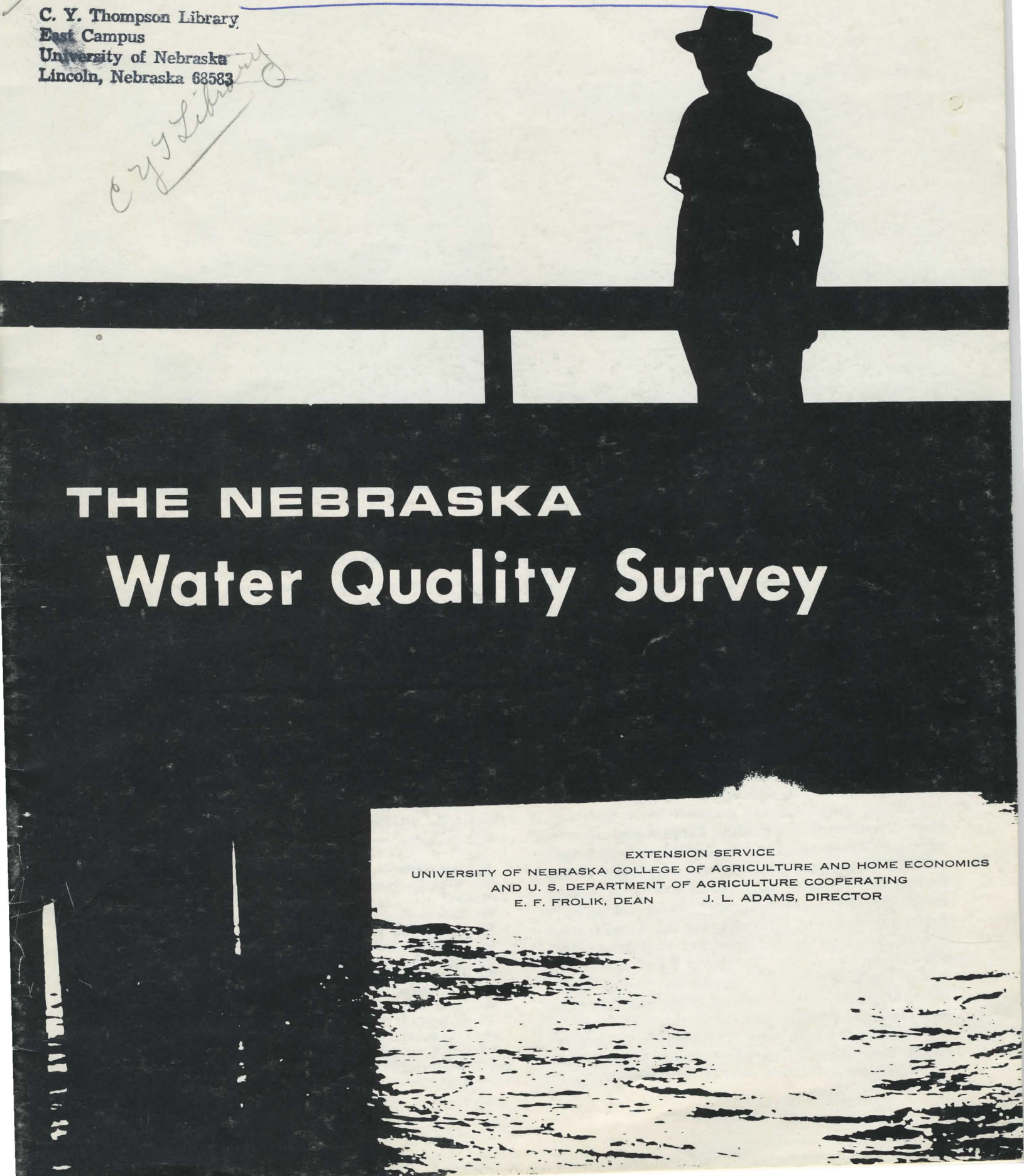

THE NEBRASKA Water Quality Survey

EXTENSION SERVICE
UNIVERSITY OF NEBRASKA COLLEGE OF AGRICULTURE AND HOME ECONOMICS
AND U. S. DEPARTMENT OF AGRICULTURE COOPERATING
E. F. FROLIK, DEAN J. L. ADAMS, DIRECTOR

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The following men were appointed by Dean E. F. Frolik, University of Nebraska College of Agriculture and Home Economics, to serve on a committee to investigate nitrates in ground water and to make recommendations for needed courses of action:

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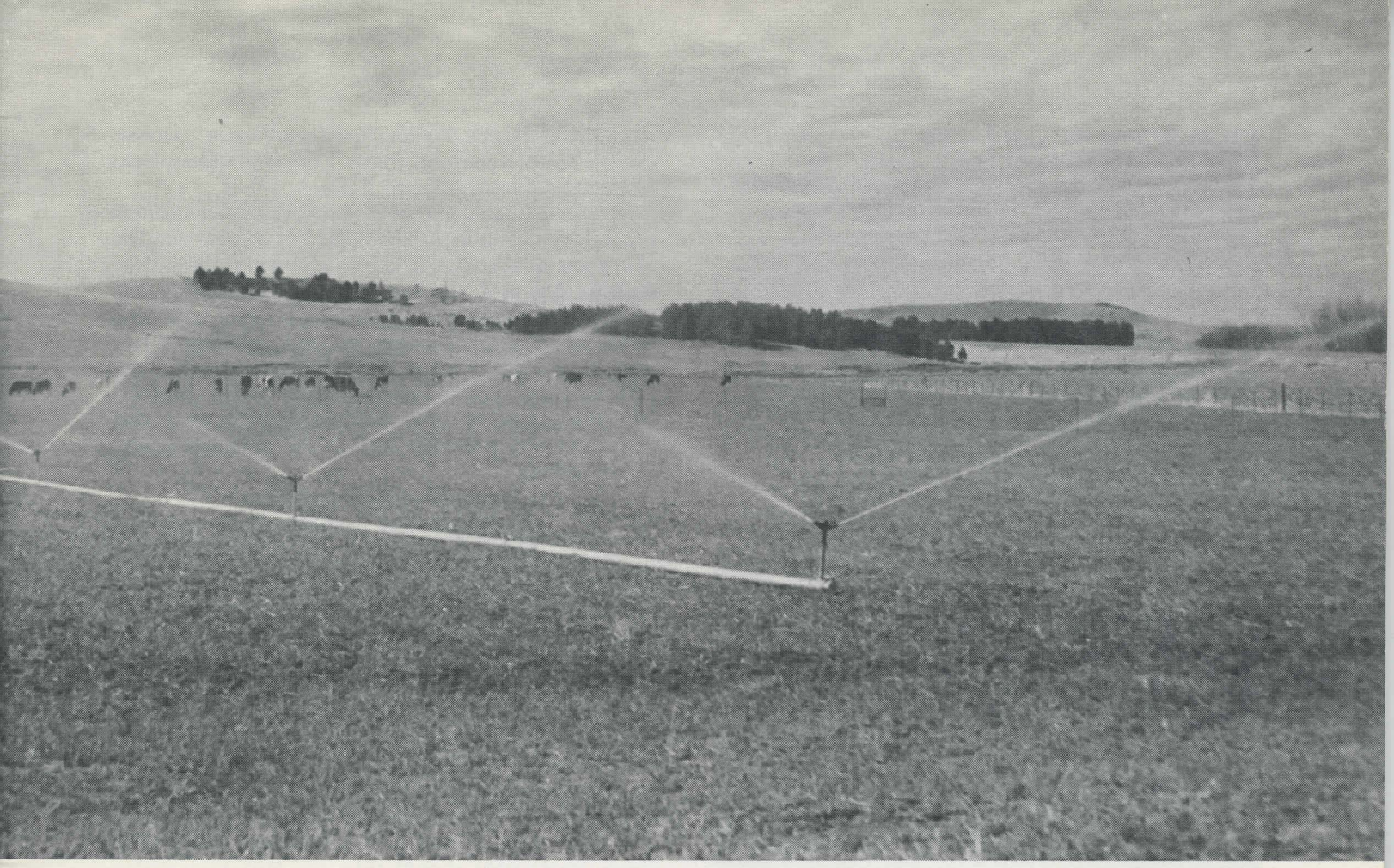
Mr. Paul Fischbach, Agricultural Engineering (Agricultural Extension)
Mr. Ralston Graham, Department of Information
Dr. R. M. Hill, Department of Biochemistry and Nutrition
Dr. Crosby Howe, Department of Veterinary Science
Mr. Dan Jones, Jr., State Water Resources Department
Mr. Delno Knudsen, Agronomy (Agricultural Extension)
Dr. C. L. Marsh, Department of Veterinary Science
Mr. H. E. McConnell, State Health Department
Mr. R. A. Olson, Department of Agronomy
Mr. E. C. Reed, Conservation and Survey Division
Dr. Paul E. Schleusener, Department of Agricultural Engineering, Committee Chairman.



SUMMARY AND CONCLUSIONS

Water Quality for Irrigation

In general, the quality of Nebraska ground water is good. There are, however, areas in the state where management practices should be followed to prevent excessive accumulation of salts.

The survey shows that high salinity ground water is present in parts of Saline, Lancaster, Dundy and Keith Counties. Other areas, known to contain enough sodium to constitute an alkali hazard, but not sampled in this survey, are in Box Butte County.

Management practices can be followed which will permit safe use of poor quality water. By proper application of water, excessive salts can be leached from most irrigated Nebraska soils. In some cases gypsum can be applied with high sodium water to permit the sodium to be leached through the soil without harm.

Farmers need to know the quality of water being used and the management practices necessary for safe use.

Soil Fertility and Nebraska's Ground Water

Nebraska's ground water contains varying amounts of certain chemicals, some of which have fertilizer value when this water is used for irrigating crops.

The survey revealed that potassium, calcium, magnesium and sulfur, all essential nutrient elements, are generally present in substantial quantities in our ground water. When soils deficient in any one or more of these elements are irrigated, ground water often supplies sufficient amounts of these elements to meet crop needs. There are, of course, local areas where this is not true. Any irrigator using ground water is advised to have a water sample tested.

The amount of nitrogen in Nebraska ground water appears to be low except for a few localized areas. The amount of phosphorus is probably too low to supply any worthwhile amount for crop production.

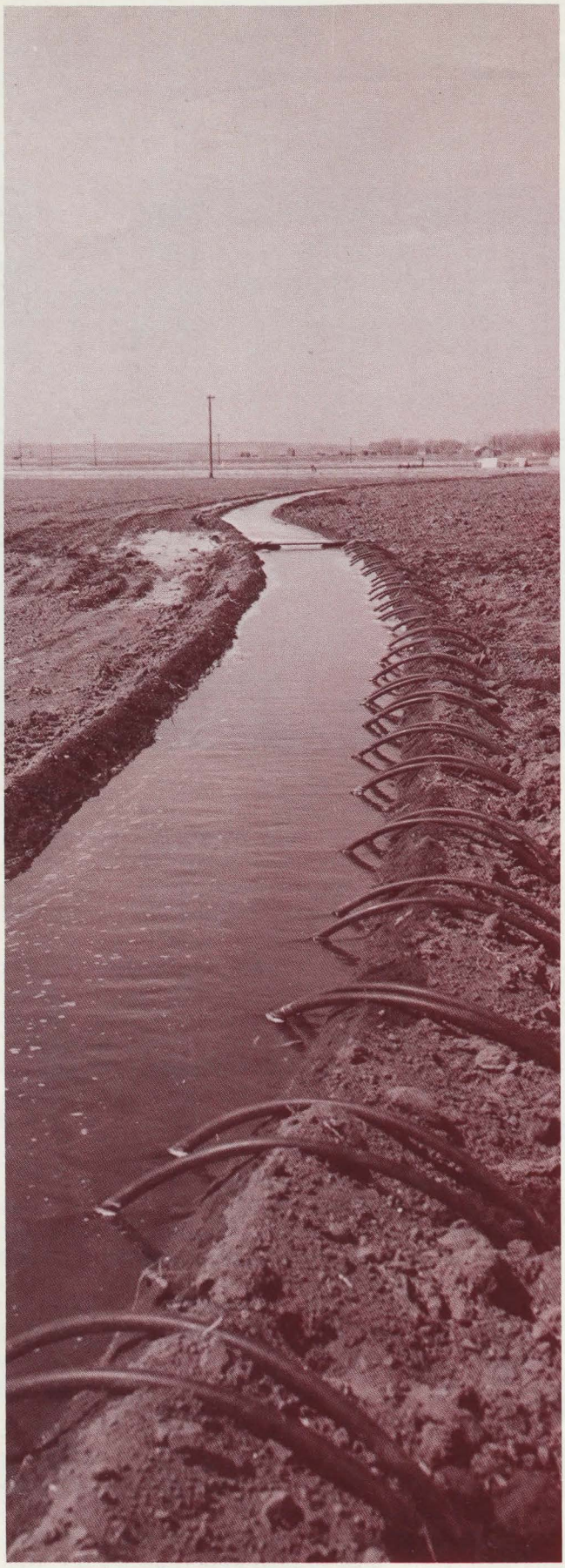
Nearly two-thirds of the water samples tested contained enough boron to prevent boron deficiency in most crops irrigated with this water. In only one sample was the boron high enough to cause concern with respect to toxicity for crop production.

Knowing what elements are present in irrigation water and the relative levels can have an important bearing on the total soil management of an irrigated farm in Nebraska.

The Nitrate Pollution of Ground Water

Thirty of the 1,166 samples tested during the 1961 irrigation season had concentrations of 10 ppm or more nitrate-nitrogen. Concentrations of 10 ppm nitrate-nitrogen or greater are considered hazardous to infants if used for their water supply or in their formulae, according to the State Health Department.

The water samples with concentrations of nitrate-nitrogen greater than 10 ppm were from Seward, Mer-



rick, Sioux, Dawes, Phelps, Fillmore, Nance, Stanton, Dodge, Holt, Knox and Platte Counties. Most of the samples were from Merrick County.

Nitrate is soluble and moves with the water through the soil, resulting in an economic loss of nitrogen fertilizer out of the root zone. Consequently, the nitrate problem has profound implications in irrigation and fertilization management practices. Rain or irrigation water moves down through the soil carrying nitrate with it.

If leaching is required to remove excess harmful salts, this should be done after the crop has used most of the nitrate, probably late in the growing season, fall or spring.

Corrosion and Incrustation

Corrosion and incrustation due to water quality seldom are serious in Nebraska if wells are properly designed and managed for conditions and chemical nature of the water.

In the future incrustation may be a more serious problem than corrosion.

Attention should be given to water quality in locating a well. Well owners should follow reasonable operating practices to prevent incrustation. Drillers should be prepared in the near future to deal with problems of renovation by use of well cleaning treatments, including acids. Educational institutions and professional associations should take the lead in teaching means and methods of renovation.

PURPOSE OF THE STUDY

The Water Quality Survey was conducted to:

1. Determine the content of nitrate and other mineral constituents in Nebraska's ground water.
2. Evaluate the effects of nitrate and other constituents on soil properties, crop production, and incrustation and corrosion of wells and pumping plants.

NATURE OF THE STUDY

The high quality of Nebraska ground water has been a point of pride for Nebraskans. Few states have such large volumes of high quality water stored underground so readily available to lands suitable for irrigation.

State Study

An irrigation water quality survey was started in July of 1961 in Nebraska. About 1,200 samples were obtained during July and August of 1961; all but 31 were ground water samples taken from irrigation wells. The remaining 31 were obtained from the Nebraska Bostwick Irrigation District canals and drainage ditches in the Panhandle section of Nebraska which drained into the North Platte River. The 1,200 water samples represent about 5 percent of the irriga-

tion wells in the area of the state irrigated from ground water.

High Nitrate Follow-up Study

Another 305 water samples were obtained from irrigation and domestic water wells during July and August of 1962. Locations of these wells were selected from the 1961 survey. Water samples were taken from those wells that showed high concentrations of nitrate-nitrogen in 1961 and from the wells surrounding these, in an attempt to determine the extent of the areas with high concentrations of nitrate in the ground water.

Seward County Study

During 1960, 1961, 1962 and 1963 water samples were also obtained from several irrigation wells in Seward County during the spring, irrigation season, and in the fall, to observe changes in nitrate-nitrogen concentration and to determine if there was any correlation with fluctuations in ground water levels.

The survey sampling was done largely by local people under the supervision of County Extension Agents, local irrigation associations, extension board members and extension specialists.

Water Analysis

Laboratory determinations were made by the University of Nebraska Soil Testing Service for:

1. Specific conductance
2. pH
3. Calcium
4. Sodium
5. Magnesium
6. Potassium
7. Nitrate
8. Phosphate
9. Carbonate
10. Bicarbonate
11. Chloride
12. Sulfate
13. Iron
14. Boron

Section 1
Water Quality and Irrigation

By Delno Knudsen
Extension Agronomist (Soil Testing)

Mineral content of water determines whether that water is satisfactory for irrigation. Few people would attempt to irrigate with ocean water since it is salty. Ground water and inland surface water also contain salts, but usually in much lower quantities. The kind and amount of these salts dissolved in water determine whether it can be satisfactorily used for irrigation.

If irrigation water contains enough salts to cause an excessive accumulation in the soil, plant growth is restricted. As the applied water evaporates from the soil and transpires through the plant, salts remain in the soil. Repeating this process may cause more salts to accumulate, depending on the salt content of the water and the amount of leaching that takes place in the soil.

Total salt content is one of the factors affecting water quality for irrigation. This is commonly determined by measuring the amount of electric current the water will conduct. Salinity hazard is another name for this water quality factor.

A second factor influencing the quality of irrigation water is sodium content in relation to the magnesium and calcium content. If the sodium in the soil solution becomes high compared to calcium and magnesium, the sodium will tend to replace calcium on the exchange sites of the clay. If this is allowed to continue until the clay is 15 percent or more saturated with sodium, an alkali problem or slick spot will occur. Alkali or sodium hazard is usually determined by calculating the sodium adsorption ratio (SAR), Figure 1.

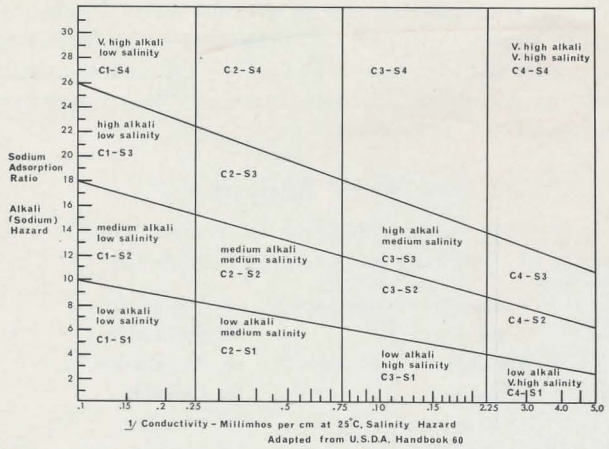
Residual sodium carbonate (RSC) values have also been suggested as a tool to evaluate water quality. The application of RSC values is not fully understood because it is difficult to predict some of the chemical reactions that may affect the minerals after the water is applied to the soil. RSC is a calculated evaluation of the amount of sodium carbonate and bicarbonate that would remain if the calcium and magnesium were precipitated as carbonates (lime). Sodium and potassium remaining in solution would increase the alkali hazard. If the calcium and magnesium are no longer in solution, the possibility of sodium replacing calcium (and hydrogen in acid soils) on the clay surface increases. This could result in an alkali soil if enough sodium is applied.

A third consideration is the boron content of the water. If too much boron is applied to the soil by irrigation, crop growth may be restricted due to boron toxicity. This does not appear to be a problem in Nebraska with the ground water now being used for irrigation.

Survey Results

In general, the quality of Nebraska ground water is good. There are, however, areas in the state where management practices should be followed to prevent excessive accumulation of salts.

Figure 1. Diagram for classification of irrigation water according to sodium (alkali hazard and salinity hazard).[1]



Total Salt Content

More than 80 percent of the wells sampled yielded water which could be used for irrigation without any salinity hazard resulting from normal irrigation practices.

About 17 percent would require applications of 10 to 30 percent additional water (leaching requirement) beyond that needed by crops to prevent excessive salt accumulation. Rainfall, if it penetrates the soil, will have a dilution effect and will reduce the leaching requirement accordingly.

Only three percent of the wells contained enough salts so that the salinity hazard could not be controlled by water management. From the survey and other studies it is known that high salinity ground water is present in parts of Saline and Lancaster Counties as well as in Dundy and Keith Counties (Table 1).

In 46 of the 85 counties sampled, one or more wells yielded water in the high salinity class. In nine counties, 50 percent or more of the samples were classified as having a high salinity hazard. In 24 counties, 30 percent or more of the samples were high. Salinity hazard areas appear to exist in the central Platte Valley, Deuel, Cedar and Dundy Counties. Tests on the water from one well in Keith County indicated a hazard. Appendix Figure 1 illustrates the salt content of ground water throughout the State. This map includes data collected by the Conservation and Survey Division of the University of Nebraska and from this survey.

Sodium Content

On the basis of sodium adsorption ratio (SAR) sodium or alkali hazard appears to be confined to local spots in the State. An average SAR of 0.7 is quite low. Only one sample was classified as having a medium sodium hazard. The remainder were low. Figure 2 shows the average SAR values for each county and Figure 3 illustrates the average sodium content in ppm.

There are known areas in Nebraska where the ground water contains enough sodium to constitute an alkali hazard. Areas, not included in this sampling, are known to exist in Lancaster, Saline and Box Butte Counties.

Table 1. Salinity of Nebraska ground waters (number of water samples from each county by U.S.D.A. classification for salinity hazard).

County	Low	Medium	High	Very high	County	Low	Medium	High	Very high	County	Low	Medium	High	Very high
Adams	1	26	0	0	Furnas	0	6	3	0	Nuckolls	1	13	3	0
Antelope	0	9	0	0	Gage	0	10	0	0	Perkins[a]	0	6	0	0
Arthur	1	0	0	0	Garden	1	7	2	0	Phelps	0	12	8	0
Banner	0	5	0	0	Garfield	2	3	0	0	Pierce	0	9	1	0
Blaine	3	1	0	0	Gosper	0	5	3	0	Platte[a]	2	19	1	0
Boone	0	5	0	0	Grant	0	0	1	0	Polk	0	28	3	0
Box Butte	0	19	1	0	Greeley	0	10	0	0	Red Willow	0	6	3	0
Brown	7	0	0	0	Hall	0	31	17	0	Saline	0	10	2	0
Buffalo[a]	0	22	18	0	Hamilton	3	64	7	0	Sarpy	0	4	0	0
Burt	0	7	1	0	Harlan	0	9	1	0	Saunders	0	8	1	0
Butler	0	11	5	0	Hayes	0	9	0	0	Scotts Bluff	0	2	8	0
Cedar	0	3	2	0	Hitchcock	0	5	5	0	Seward[a]	0	35	1	0
Chase	0	10	0	0	Holt[a]	9	4	0	0	Sheridan	0	6	0	0
Cherry	3	0	0	0	Hooker	2	0	0	0	Sherman	0	7	0	0
Cheyenne	0	9	0	0	Howard	0	11	0	0	Sioux	0	4	1	0
Clay	0	45	0	0	Jefferson	0	8	2	0	Stanton[a]	0	5	4	0
Colfax	0	14	0	0	Johnson	0	4	1	0	Thayer	2	21	0	0
Cuming	0	5	0	0	Kearney	1	25	2	0	Thomas	4	0	0	0
Custer	1	14	1	0	Keith	0	9	11	1	Thurston[a]	0	2	3	0
Dakota	0	5	0	0	Kimball	0	10	0	0	Valley	0	10	0	0
Dawes[a]	0	5	3	0	Knox	0	3	2	0	Washington	0	0	1	0
Dawson	0	21	31	0	Lancaster	0	5	4	0	Wayne	0	3	0	0
Deuel	0	4	7	0	Lincoln	0	14	8	0	Webster	0	7	3	0
Dixon	0	2	0	0	Logan	2	2	0	0	Wheeler	3	2	0	0
Dodge[a]	0	18	7	0	Loup	2	3	0	0	York	0	71	0	0
Douglas	0	7	2	0	McPherson	1	0	0	0					
Dundy	0	4	4	2	Madison	0	6	2	0					
Fillmore[a]	0	43	10	0	Merrick[a]	5	91	12	0	State				
Franklin	0	10	0	0	Morrill	0	6	4	0	(Numbers)	57	994	225	3
Frontier	0	8	0	0	Nance[a]	1	14	0	0	(percent)	4.5	77.7	17.6	0.2

[a] Includes new locations sampled in 1962.

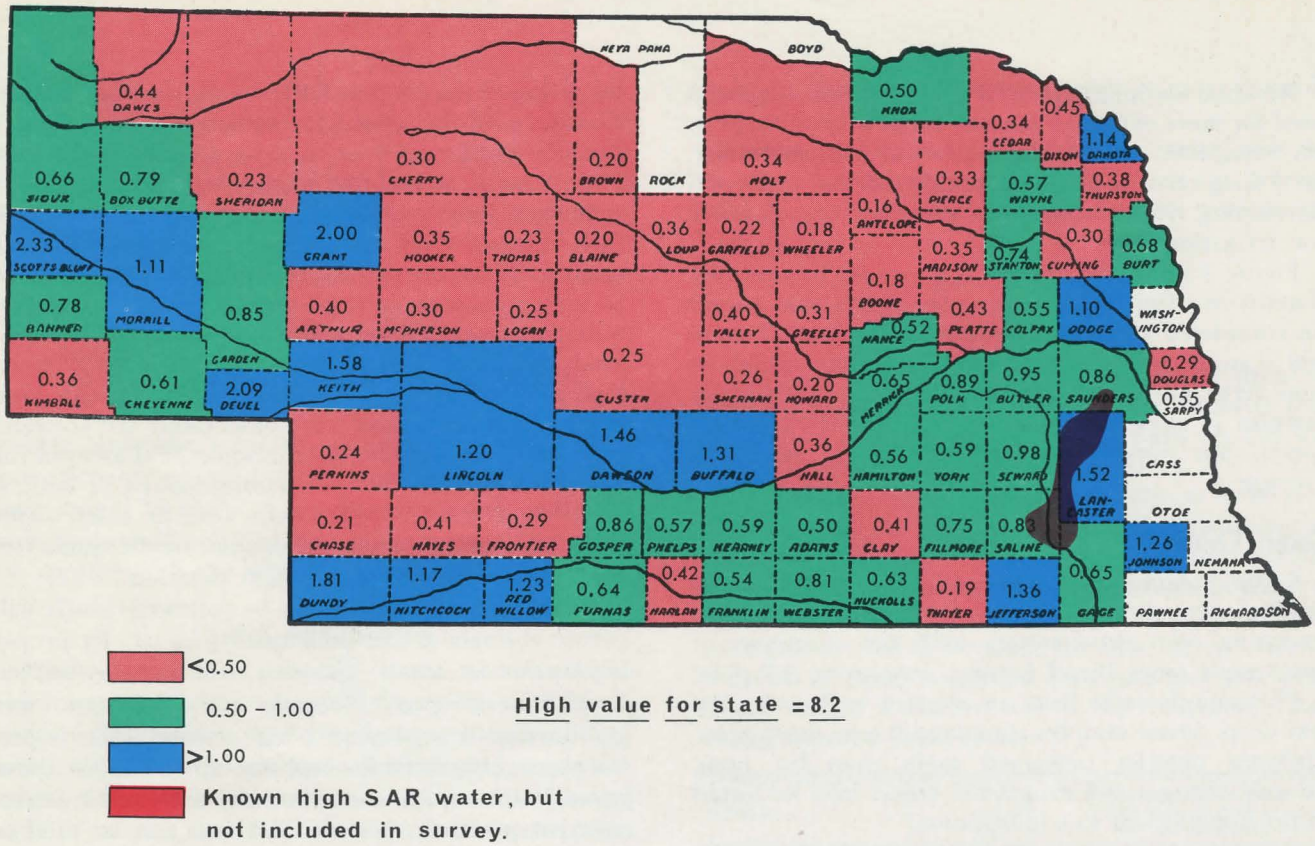


Figure 2. Sodium adsorption averages of water in Nebraska, 1961.

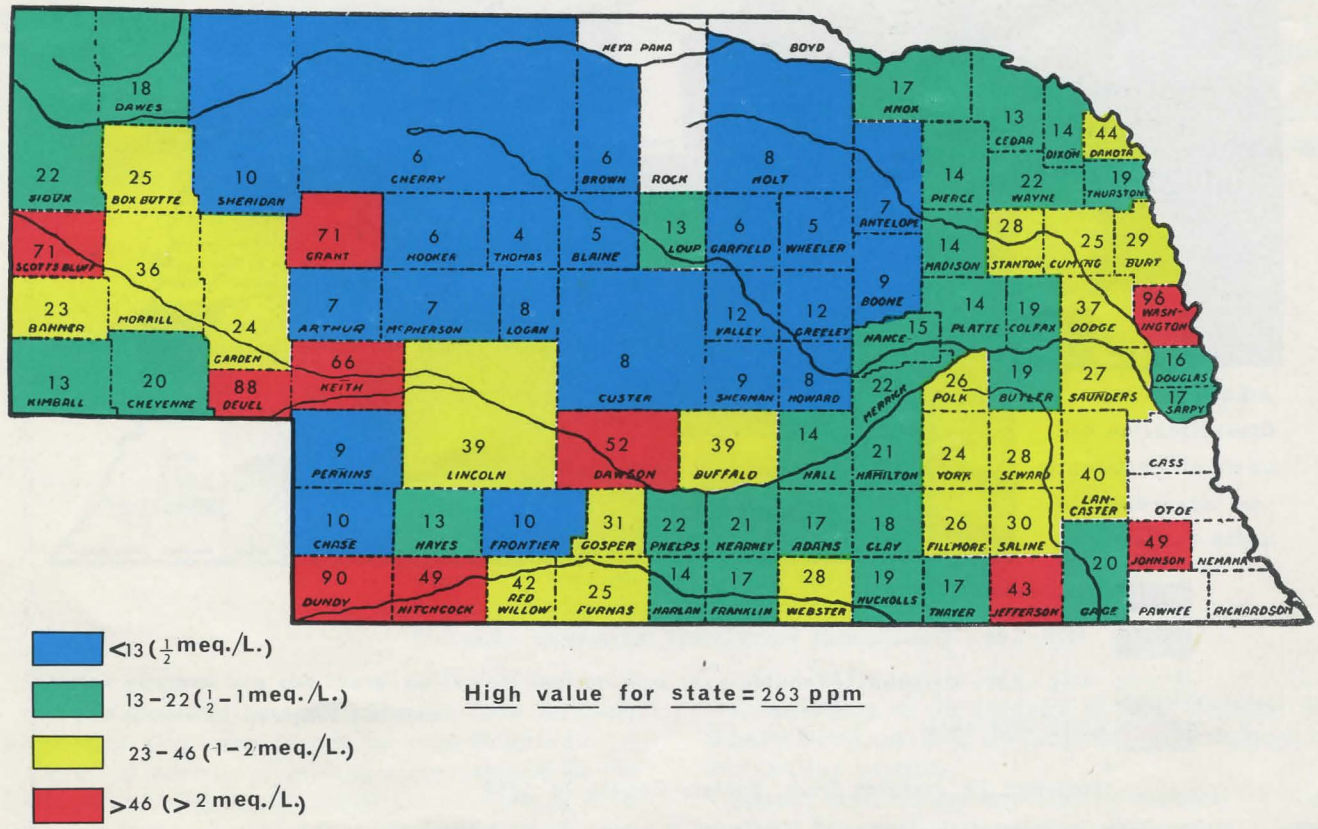


Figure 3. Sodium content of Nebraska ground water, irrigation well survey, 1961, average sodium values in ppm.

Residual sodium carbonate (RSC) values suggest a need for more extensive concern about alkali hazard in the State. RSC values can probably be used to predict, on a long term basis, the possibility of an alkali soil developing from the use of a given quality of water for irrigation.

Figure 4 shows the average RSC values by counties. Twenty-two counties have average values that would be considered marginal if the effective rainfall were less than 10 inches. Nine county averages would be considered unsafe for irrigation. Not all of the water samples in these counties fall in these critical categories, but some were high enough to raise the average.

Boron Content

Boron content of the ground water samples was not high enough to expect toxicity levels to result from irrigating with these waters—with the exception of one sample from Deuel County, containing 2.2 ppm.

This sample came from an artesian well about 500 feet deep. Seven samples contained 0.5 or more ppm. Eighteen samples contained more than 0.3 ppm. County averages and ranges for boron may be found in the appendix of this publication.

Danger Levels in Terms of Water Quality

The U.S.D.A. Salinity Laboratory at Riverside, California, has developed a classification system for irrigation water quality (Figure 1). Sodium adsorption ratio (SAR) is used to evaluate sodium or alkali hazard. Conductivity is used as a measure of total soluble solids to evaluate salinity hazard.

Danger levels will vary somewhat with soil texture, rainfall, crop and water management. Rainfall tends to dilute the salt accumulation in the soil caused by irrigation, making it possible to use poorer quality water in areas of higher effective rainfall. Well-drained sandy soils can often be irrigated with water of quite high salinity since these soils are easily leached. Most crops grown in Nebraska are moderately salt tolerant.

Ground and surface water in some local areas of the state constitute a sodium or salinity hazard, or both, if used for irrigation. Some wells and, in a few cases, lands have been abandoned because of the quality of the water and poor management practices.

Management practices can be followed which will permit the safe use of poor quality water. By proper application of water, excessive salts can be leached from most irrigated Nebraska soils. In some cases gypsum can be applied with high sodium water to permit the sodium to be leached through the soil without harm. Water analyses are necessary to determine management practices. Periodic soil tests can be used to evaluate the build-up of salts or sodium.

Water classified low or medium in salinity or sodium hazard can be used for irrigation on most Nebraska soils unless internal drainage is restricted. High sali-

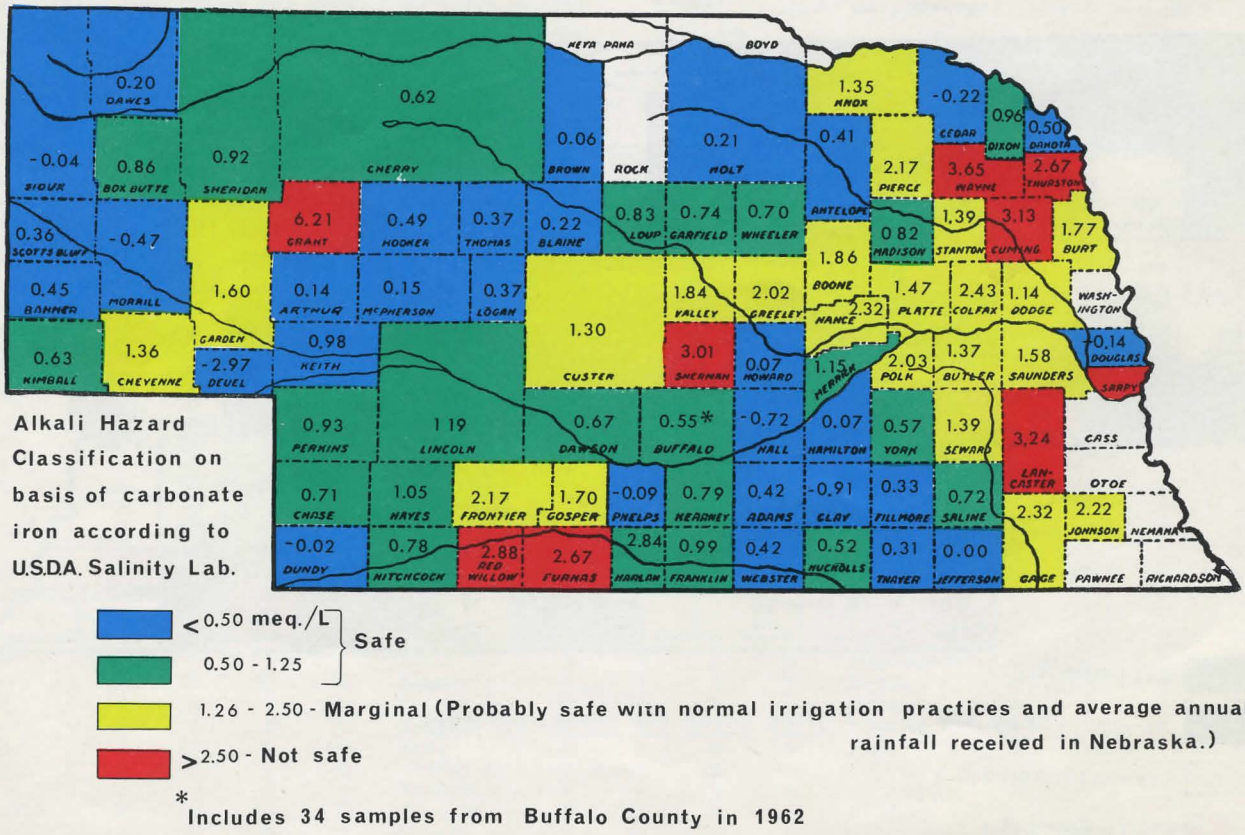


Figure 4. Water quality of Nebraska ground water hazard based on the average residual sodium carbonate values for each county where samples were collected in 1961.

nity or high sodium water should be used only if special management practices are followed. These include meeting the leaching requirement, providing adequate drainage and, in the case of high sodium waters, using chemical amendments such as gypsum. Very high sodium or saline water normally should not be used.

Residual sodium carbonate levels have been classified as follows:

Less than 1.25 meq./liter—safe
1.25 to 2.50 meq./liter—marginal
More than 2.50 meq./liter—unsafe for irrigation.

Under Nebraska rainfall conditions marginal water can probably be used safely. However, periodic soil tests should be made to determine whether exchangeable sodium is building up. If so, gypsum can often be applied with the water to avoid further build-up.

Future Implications

History in parts of the Old World has illustrated the importance of water quality for irrigation. Large areas in Central Asia where irrigated agriculture flourished centuries ago are now essentially barren waste lands. These soils were rendered useless by allowing salts or sodium, or both, to accumulate to the point where soils could be no longer tilled or crops would no longer grow. Undoubtedly this could have been avoided if modern soil and irrigation science had been known and applied.

In general, the quality of Nebraska ground water is good. However, this survey, farmers samples, surveys by the Conservation and Survey Division and the U.S. Geological Survey reveal that in some areas problems will arise from the use of irrigation water unless proper management practices are employed. In certain localities farmers are aware of this. In others, problems may not occur for several years or possibly generations.

By way of illustration, an "average water" was determined for the eight counties in which the average RSC was 2.5 meq./liter or more. Results were as follows:

RSC—2.6 meq./liter
SAR—.84
Sodium—25 ppm

The SAR does not indicate an immediate problem with a sodium hazard. The RSC value indicates that the sodium applied may be readily fixed on the soil surface if other conditions are favorable.

The time required for an alkali condition to develop depends upon the amount of clay and organic matter in the soil, the amount of water applied and whether the sodium is adsorbed on the clay throughout the profile, in the top foot, or at some other depth. Some assumptions need to be made for illustration. Assume 18 inches of water is applied each year and that none of the sodium is leached out of the root zone. Then we can estimate these results:

Soil texture	Cation exchange capacity	Time required to reach 15% sodium saturation in each foot (an alkali situation)
Sandy loam	**8 meq./100 gm**	**10 years**
Silt loam	**16 meq./100 gm**	**20 years**
Clay loam	**24 meq./100 gm**	**25 years**

This illustration is speculative, but indicates that if the proper conditions exist, problems could arise within a lifetime. Problems will arise much sooner for high saline or high sodium waters if improperly used. The high RSC water is much more common in Nebraska. This points up the need for farmers to know the quality of the water being used and the management practices necessary for safe use.

Section 2
Soil Fertility and Nebraska's Ground Water

By Clinton A. Hoover
Formerly Assistant Professor of Agronomy (Agricultural Extension), Now, Head, Hall of Youth, Nebraska Center for Continuing Education

Certain chemicals in ground water have fertilizer value when this water is used for crop irrigation.

Chemical analysis of ground water samples in the 1961–1962 surveys reveals important amounts of some essential plant food elements and insignificant amounts of others.

A knowledge of the presence of these elements and relative levels can help the irrigator better manage his soil fertility program.

Sixteen elements are known to be essential for plant growth. Three of these, carbon, hydrogen and oxygen, come from the air and water, and are usually in

abundant supply even for nonirrigated crops. The remaining 13 elements must be supplied by the soil in adequate amounts for crops to grow well. These elements are:

Primary	*Secondary*	*Trace or Minor*	
nitrogen (N)	**calcium (Ca)**	**zinc (Zn)**	**molybdenum (Mo)**
phosphorus (P)	**magnesium (Mg)**	**iron (Fe)**	**manganese (Mn)**
potassium (K)	**sulfur (S)**	**boron (B)**	**chlorine (Cl)**
			copper (Cu)

The fertilizer value of any one of these elements found in ground water used for irrigation purposes depends on the soil's ability to supply an adequate amount of that element.

Some elements, for example potassium and magnesium, are often found in abundant supply in many Nebraska soils. The presence of these elements in irrigation water generally has little if any beneficial effect on crop production. In some cases, continued application of water containing large amounts of these elements might produce undesirable effects on crops and soils.

On the other hand, some Nebraska soils are deficient in certain elements, such as sulfur. Irrigation water that supplies a generous amount of sulfur will likely help crops to which this water is applied. The need for supplemental fertilizer containing sulfur would be reduced or eliminated.

In still other situations, the chemicals in irrigation water supply maintenance amounts of certain essential elements. The amounts supplied during an irrigation season may be enough to offset the annual crop removal of these elements. This means that the chances of these elements becoming deficient in the soil for good crop production are greatly reduced—so long as the irrigation water continues to supply these elements.

To understand and appreciate the fertilizer value of irrigation water, the irrigator must know something about the chemical nature of his water. Much variation in chemical nature of ground water was found among the water samples analyzed in the 1961–1962 survey.

Results reported in this publication should be used only as a guide. The situation for any one particular irrigation well may be different from the average nutrient content found in the survey of random samples. An irrigator interested in knowing the situation on his particular well or wells should have a complete chemical analysis made on water samples from each well. Along with this should be a complete soil testing program

Appendix Table 1 lists the average content and the range, by county, of each element tested in the survey.

Results of chemical analysis on some 1,100 ground water samples and what these mean in terms of fertilizer value of the water follows. Concentrations of each element tested are reported in the left-hand column in **parts of the element per million parts of water (ppm)**. Percent of samples falling into various concentration levels is also reported. The right-hand column

Zinc deficient corn showing stunted growth and chlorosis (yellowing of lower leaves.

shows the concentration of each element in **pounds per acre foot of water**. These values are calculated by multiplying the value in ppm (left-hand column) by 2.72. An acre foot of water weighs 2.72 million pounds; hence, 1 part per million equals 2.72 pounds per acre foot of water.

Nitrogen

Table 2. Nitrate-nitrogen content of ground water, 1,165 samples.

Nitrogen ppm N	Number of samples	% of samples	Pounds N per acre foot of water
0–0.9	440	38	0– 2.4
1– 9	695	59	2.7–24.5
10–19	24	2	27.2–51.7
more than 19[a]	6	1	more than 51.7

[a] The highest level found was 24.8 ppm (1 sample). This represents 67.5 pounds N per acre foot of water.

Except for a few localized areas, the nitrogen content of Nebraska's ground water is relatively low. The nitrogen in the water is as effective as the nitrogen in commercial inorganic fertilizers. A farmer applying 1½-acre feet of irrigation water containing 5 ppm nitrate-nitrogen is applying about 20 pounds of available nitrogen. In areas where the survey revealed higher concentrations of nitrate-nitrogen, a substantial amount of nitrogen is being applied with the irrigation water.

Associated with these high levels of nitrogen (beneficial from the standpoint of crop production) may in some instances be certain hazards to human and live-

stock health if used for drinking purposes. The health aspects of high nitrate ground water are discussed in Section 3.

Phosphorus

Table 3. Phosphate content of ground water, 1,124 samples.

Phosphate, ppm P	Number of samples	% of samples	Pounds P per acre foot of water
0–0.4	924	82	0–1.1
0.5–0.8	199	17	1.4–2.2
more than 0.8[a]	1		more than 2.2

[a] This sample contained 0.9 ppm. or 2.4 pounds of P per acre foot of water.

The amount of phosphorus in ground water is probably too low to supply any worthwhile amount for crop production.

Potassium

Table 4. Potassium content of ground water, 1,141 samples.

K, ppm	Number of samples	% of samples	Pounds K per acre foot of water
0– 9	576	51	0–24
10–19	437	38	24–52
20–29	108	9	54–79
30–39	12	1	82–106
more than 39[a]	8	less than 1	more than 106

[a] The highest level found was 75 ppm or 204 pounds K per acre foot of water.

Many of the samples appear to contain significant amounts of potassium. The value of the potassium in Nebraska's ground water is questionable in view of the apparent adequate levels existing in most soils of the state.

Excessive accumulations of potassium in soils may interfere with the uptake of such elements as magnesium and calcium, and perhaps other elements.

On the other hand, soils depleted in potassium may be benefited by the potassium added in ground water used to irrigate these soils.

Calcium

Table 5. Calcium content of ground water, 1,085 samples.

Ca, ppm	Number of samples	% of samples	Pounds Ca per acre foot of water	Pounds lime per acre foot of water[a]
0–19	54	5	0– 52	0– 218
20–39	415	38	54–106	227– 445
40–59	384	35	109–160	258– 672
60–79	175	16	163–215	685– 903
80–99	29	3	218–269	916–1130
more than 99[b]	28	3	more than 269	more than 1130

[a] Based on ag lime, 60% effective.
[b] The highest level found was 197 ppm or 536 pounds Ca per acre foot of water. This is equivalent to 2,251 pounds of ag lime per acre foot of water.

The presence of calcium carbonate and bicarbonate in Nebraska's ground water influences the alkalinity of the soil in much the same way as does the addition of ag lime. Most ground water in the state contains appreciable amounts of calcium bicarbonate.

Nearly half of the water samples tested in the survey contained about one-fourth ton of ag lime equivalent per acre foot of water. This is probably about enough lime to correct soil acidity caused by the use of acid-forming commercial fertilizers and by normal decomposition of crop residues.

Some irrigators report that the use of high lime irrigation water for several years has eliminated the need for lime on soils that were initially acid before irrigation began.

Ground water that supplies a considerable amount of calcium bicarbonate may cause a substantial decrease in soil acidity in a few years.

Calcium is an essential plant nutrient in addition to its important role in controlling soil acidity and alkalinity. From a nutrient standpoint, Nebraska soils generally supply adequate amounts of calcium and the value of the calcium in ground water is probably minor.

Magnesium

Table 6. Magnesium content of ground water, 1,083 samples.

Mg, ppm	Number of samples	% of samples	Pounds Mg per acre foot of water	Pounds lime per acre foot of water[a]
0– 9	257	24	0– 24	0–101
10–19	485	45	25– 52	104–218
20–29	212	19	54– 79	227–332
30–39	75	7	82–106	344–445
40–59	43	4	109–160	458–672
more than 59[b]	11	1	more than 160	more than 672

[a] Based on ag lime, 60% effective.
[b] The highest level found was 91.2 ppm or 248 pounds Mg per acre foot of water. This is equivalent to 1,042 pounds of ag lime per acre foot of water.

Magnesium, like calcium, is an essential plant nutrient. The fertility value of magnesium in irrigation water is minor, particularly in central and western Nebraska. The predominant ions on the clay in this region are calcium, magnesium, and potassium. There appears to be little if any need for magnesium fertilizer on these soils.

Some acid soils of eastern Nebraska may benefit from the addition of magnesium in irrigation water. The favorable results of magnesium on soil productivity in these cases would likely be due to the liming effect of the water rather than the plant food contribution of magnesium.

In evaluating the liming effects of irrigation water, you need to consider the total contribution of both calcium and magnesium, in addition to the amounts of

Sulfur

Table 7. Sulfate content of ground water, 1,113 samples.

Sulfate, ppm S	Number of samples	% of samples	Pounds S per acre foot of water
0– 9	449	40	0– 24
10–19	318	29	25– 52
20–29	110	10	54– 79
30–39	73	6	82–106
40–49	50	4	109–133
50–59	41	4	136–160
60–100	41	4	163–272
more than 100[a]	31	3	more than 272

[a] The highest level found was 510 ppm or 1,387 pounds S per acre foot of water.

carbonate and bicarbonate present in the water. These latter constituents were discussed in Section 1.

The amount of sulfur present in the ground water samples tested varied from practically none to over 1,000 pounds per acre foot of water.

Annual applications of one or more acre feet of irrigation water containing 25 pounds of sulfur per acre foot of water can be expected to supply the sulfur needs of most crops grown in Nebraska. Sixty percent of the water samples tested contained 25 pounds or more of sulfur per acre foot of water.

Most ground water of low sulfur content was found in northcentral Nebraska under sandy, low-organic matter soils on which a great deal of sulfur deficiency has been observed on alfalfa.

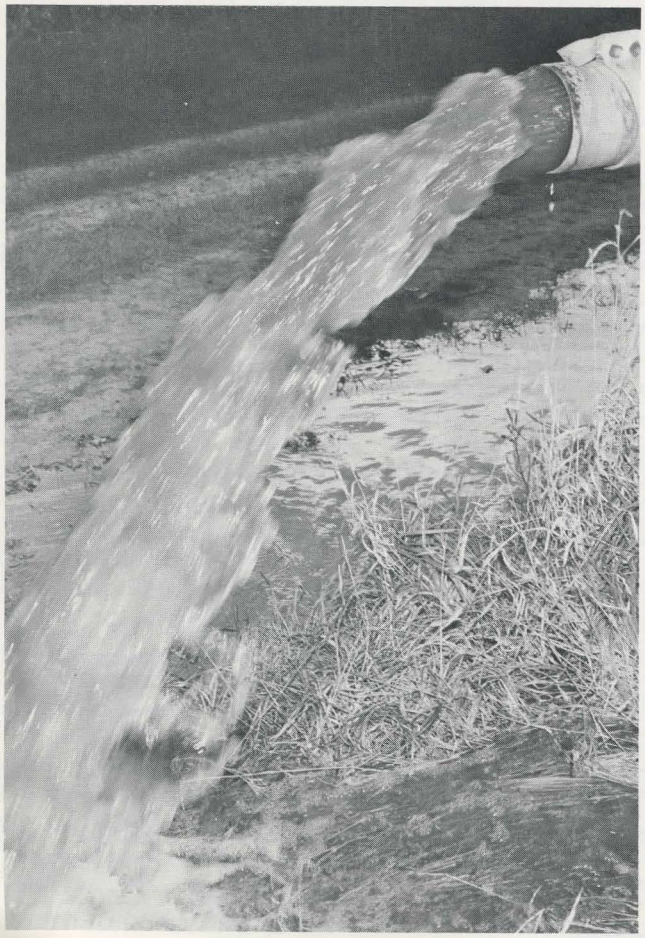
Farmers irrigating soils of this nature should investigate their irrigation water for sulfur content before applying fertilizer sulfur.

Boron

Table 8. Boron content of ground water, 1,025 samples.

B, ppm	Number of samples	% of samples	Pounds B per acre foot of water
0–0.1	390	38	0 –0.27
0.1–0.19	421	41	0.27–0.52
more than 0.19[a]	214	21	more than 0.52

[a] The highest level found was 2.2 ppm. This was the only sample that exceeded 1 ppm.



Boron is an essential trace element for plant growth. According to U.S.D.A. Circular 969 "Classification and Use of Irrigation Water," plants usually show no boron deficiency if irrigated with water containing at least 0.1 ppm boron. Nearly two-thirds of the water samples tested contained at least 0.1 ppm boron. It appears that Nebraska's ground water generally contains enough boron to provide crop needs.

Boron may be toxic if present in excessive amounts. Injury may develop if soils are continually irrigated with water containing more than 1.0 ppm boron. In only one sample was boron high enough to cause concern with respect to the development of toxicity from continued use of the water. This one sample was obtained from Deuel County.

Iron

The iron content of ground water varied from a trace to quantities which may cause incrusting problems in irrigation systems. Iron is an essential trace element for plant growth, but it is doubtful that the iron remains in a soluble form long enough to be available to plants grown on iron deficient soils. Hence, the iron content of irrigation water may have little if any fertilizer value. A discussion of incrustation problems associated with water of high iron content may be found in Section 4.

Section 3
Nitrate Pollution of Ground Water

By Paul Fischbach
Associate Professor of Agricultural Engineering (Agricultural Extension)

Nitrogen, regardless of the form in which it is applied, is ultimately changed to nitrate-nitrogen by soil microbial processes. Sources of nitrogen include crop residues, barnyard manure or commercial fertilizers. The nitrate form of nitrogen is not held by soil clay and organic matter, but instead is soluble and free to move with soil water.

Research has shown that as water moves through the soil from rainfall or irrigation, nitrate present in the soil moves with it. If soil moisture is initially below field capacity, water moving through the soil will carry nitrate and deposit it at the wetting front.

If soil moisture is at field capacity, additional water moving through the soil will carry some nitrate in advance of the wetting front. In either case, if water penetrates below the root zone of the crop, some ni-

trate will be carried below the root zone and lost to the crop.

Nitrate also moves upward and can be deposited on the soil surface under two conditions:

1. Under furrow irrigation, water from the irrigation furrow will move into the dry ridge by capillarity. Since nitrate is soluble, it will be carried into the ridge with the water. As the water is lost from the ridge through evaporation and plant use, nitrate is left behind.

2. When the water table is near the surface and rainfall or irrigation water penetrates to the water table, a saturated soil profile results. As water is lost from the surface of the soil through evaporation and plant use, water carrying nitrate will move upward and the nitrate will be deposited on or near the surface.

Excessive Nitrate-Nitrogen Content

Thirty of the 1,166 samples tested during the 1961 irrigation season had concentrations of 10 ppm or more nitrate-nitrogen (Table 9).

Concentrations of 10 ppm nitrate-nitrogen or greater are considered hazardous to infants if used for their water supply or in their formulas, according to the State Health Department. Seven hundred and thirty-two, or 62% of the samples, had concentrations of less than two ppm nitrate-nitrogen.

Water samples that had concentrations of nitrate-nitrogen greater than 10 ppm were in Seward, Merrick, Sioux, Dawes, Phelps, Fillmore, Nance, Stanton, Dodge, Holt, Knox and Platte Counties (Fig. 5).

Most of the samples containing concentrations greater than 10 ppm nitrate-nitrogen were in Merrick County. Possible reasons for this are:

1. Merrick County has a large number of irrigation wells (1,981 registered on January 1, 1963).

2. About 95 percent of the tillable land in the county is irrigated. The soils are generally medium to coarse textured, underlain with sand and gravel at depths of 2 to 5 feet.

3. Large amounts of commercial fertilizer have been used on the irrigated land since 1950.

4. A considerable acreage of alfalfa is grown on subirrigated land.

5. Many cattle are fed in the county, a situation which creates an opportunity for pollution of ground water by surface runoff from feed yards into wells and the leaching of nitrate through the shallow, sandy soils overlying high water tables.

Table 9. Percent of sample carrying various amounts of nitrate-nitrogen. 1961 Water Quality Survey.

Nitrate-Nitrogen	No. samples	Percent	Ave.
10.0 or more	30	3	15.5
9.9–5.0	91	8	6.6
4.9–2.0	313	27	3.2
2.0 or less	732	62	0.8

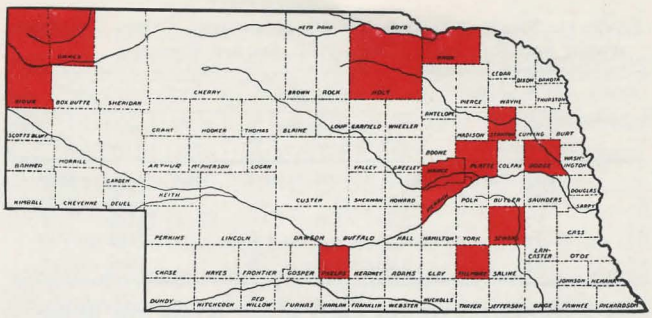


Figure 5. Counties having one or more irrigation water samples with concentrations of nitrate-nitrogen greater than 10.0 ppm, Water Quality Survey, 1961.

Relation of Nitrate-Nitrogen Content to Depth to Ground Water

Data from the 1,166 water samples from irrigation wells in the state show a relationship between the concentration of nitrate-nitrogen in the ground water and the average depth to the static water level (Table 10).

The ground water samples containing concentrations greater than 10 ppm nitrate-nitrogen were collected from wells where the average depth to static water level was 38 feet. Samples containing concentrations of nitrate-nitrogen of less than 2 ppm had an average depth to static water level of 61 feet.

Table 10. The average depth to static level and average depth of well compared to various concentrations of nitate nitrogen. Water Quality Survey, 1961

Nitrate-Nitrogen ppm.	Ave. depth to static water level	Ave. depth of well
10.0 or more	38 feet	103 feet
9.9–5.0	49 feet	114 feet
4.9–2.0	56 feet	135 feet
2.0 or less	61 feet	155 feet

Variations in Nitrate-Nitrogen Content with Season (Seward Co. Study)

Irrigation wells from which water samples were obtained and tested for variation in nitrate-nitrogen concentration during spring, irrigation season, and fall are located in Seward County. This area is bordered by the Blue River on the east, Hiways 2 and 34 on the north, as far west as Utica, Nebraska, and as far south as Goehner, Nebraska.

Well No. 1 is near the center of the area. The surface topography (2) has ill defined drainage which would generally indicate that most of the water that fell as rain or was applied as irrigation water would either percolate into the soil or evaporate.

The ground water gradient tends to level out near the center of the area with the gradients sloping towards Lincoln Creek to the north, Big Blue River to the east, and West Fork of Big Blue River to the south (3).

Changes in ground water levels occur each year. The ground water is usually the highest for any specific year during the spring. At the end of the irrigation

Table 11. Nitrate-nitrogen variations duirng spring, irrigation season and fall during 1960–1962, Seward County.

Well No.	Year 1960		Year 1961			Year 1962		
	Irrig. season	Fall	Sp.	Irrig. season	Fall	Sp.	Irrig. season	Fall
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	14.2	20.5	28.0	14.6	.....	.....	12.8	32.0
2	5.2	4.1	5.2	5.6	17.6	.....	11.6	.....
3	5.4	3.4	8.4	5.4	5.0	.....	4.9	.....
4	3.9	.....	6.0	5.5	3.0	.....	5.4	.....

and growing season, ground water levels are at their lowest. The cones of depression created by pumping the irrigation wells start leveling out after the wells are shut off. If ground water is recharging down through the profile at this time or during the fall months from rain water percolating down through the profile, nitrate may be carried with the recharge water, thus causing some of the fluctuations in concentration of nitrate-nitrogen shown in Table 11.

The concentration of nitrate-nitrogen is much higher in the spring and fall than during the irrigation season in Well No. 1 (Table 11).

More research is needed to determine the causes of fluctuation in concentrations of nitrate-nitrogen in the ground water pumped by irrigation wells. However, there may be some relationship between the fluctuations of the ground water levels measured in irrigation wells and the concentration of nitrate-nitrogen measured in the water samples from irrigation wells.

In Well No. 2, the concentration of nitrate-nitrogen in the ground water remained fairly constant until the sample was taken in the fall of 1961. Then it increased from 5.6 ppm during the irrigation season to 17.6 ppm. During the next irrigation season (1962) the concentration decreased from 17.6 ppm to 11.6 ppm, but had a much higher concentration than during the 1961 irrigation season.

Water Quality Survey 1962

Nebraska ground water samples with a concentration of nitrate-nitrogen exceeding 10.0 ppm in 1961 were resampled during June and again in August, 1962, to study the changes in nitrate-nitrogen concentration. In addition, four irrigation wells and one domestic well surrounding each of the original irrigation wells were selected for sampling and analysis of nitrate-nitrogen. The purpose was to determine the size of the area polluted. The distance of the four surrounding wells sampled in 1962 varied from ¼ to 1 mile on either side of the original irrigation well.

The concentration of nitrate-nitrogen decreased from July, 1961, to August, 1962, in all but one of the original irrigation wells resampled. The high nitrate producing wells in Sioux and Dawes Counties decreased to below 10.0 ppm nitrate-nitrogen (Figs. 5 & 6).

The size of the area with high concentrations of nitrate-nitrogen in the ground water varied considerably. For example, in Stanton County, locations "a, b and f" (Appendix Table 2) show that the area polluted with nitrate to be very limited. Nance County locations "a–f" show that the area polluted is larger than the area sampled—all of the surrounding irrigation wells, the domestic well and the original well contained nitrate-nitrogen exceeding 10.0 ppm.

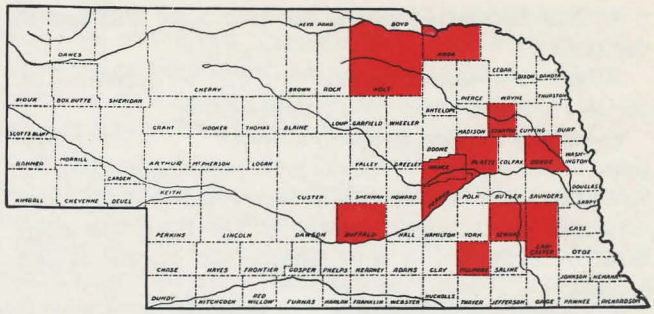


Figure 6. Counties having one or more irrigation water samples with concentrations of nitrate-nitrogen greater than 10.0 ppm, Water Quality Survey, 1962.

In general, irrigation wells in Merrick, Nance, and Platte Counties that had high concentrations of nitrate in 1961 have wells surrounding them with high concentrations of nitrate in the ground water. These areas have sandy soils with comparatively high intake rates. Most of the soils in this area are underlain by sand and gravel at about five feet. The static ground water levels are shallow. The area is intensively irrigated and the main crops are corn, alfalfa, and grain sorghum. Commercial nitrogen fertilizers have been used extensively on corn and grain sorghums since 1950. Many farm cattle feeding operations are also located in these counties. Alfalfa hay is one of the major crops. All of these are possible sources of nitrate which may pollute the ground water. (In the case of alfalfa when grown for green manure.)

Implications

Nitrate is soluble and moves with the water through the soil resulting in economic loss of nitrogen fertilizer out of the root zone. Consequently the nitrate problem has profound implications in irrigation and fertilization management practices. Rain or irrigation water moves down through the soil carrying nitrate with it. Some nitrate may move in advance of the wetting front if the wetting front meets soil that already is wet to field capacity.

Irrigation Management

Excess irrigation water should not be applied unless leaching of harmful salts is required. See Section I, page 6.

If leaching is required to remove excess harmful salts, this should be done after the crop has used most of the nitrate, probably late in the growing season, fall or spring. **Always refill the root zone with water before applying nitrogen fertilizer.**

Irrigation water applied during the growing season should not penetrate below the depth from which

roots have extracted soil moisture. If it does, the water may move most of the nitrate out of the root zone.

To avoid leaching, the irrigator must know when to start and stop irrigating and how much water he is applying each irrigation. The amount of water can be determined by water meters, parshall flume or some water measuring device, and by calculating the area irrigated each irrigation set. When to start and stop irrigating can be determined by placing tensiometer or electrical resistance blocks in the field irrigated.

Nitrogen Fertilizer Management

Delaying the application of nitrogen fertilizer until the crop is growing and roots are actively absorbing nitrogen reduces the time during which applied nitrogen may be subject to leaching. Fertilizer experiments on irrigated corn in Nebraska during 1957–1959 show that better yields are usually obtained from summer side dressing than from either fall or spring preplant application when nitrogen fertilizers are applied at minimum rates (4).

When more nitrogen fertilizer is applied than is needed for top corn yields, the differences between fall, spring and side dressing times of application are usually insignificant.

Applying part of nitrogen fertilizer in the irrigation water may also reduce the hazard of nitrate leaching, especially on sandy soils.

Section 4
Corrosion and Incrustation

By Deon D. Axthelm
Water Resources Specialist
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The extent of corrosion or incrustation as a result of poor water quality cannot be predicted reliably by chemical analysis of water alone. However, analysis can indicate whether water will have a tendency to deposit a layer of minerals that will eventually close well screen and gravel pack openings (incrustation). Analysis can also indicate whether water will have a tendency to erode or remove scale from the surface of a well screen or casing (corrosion).

Data from the water analysis in this study were analyzed to determine a "saturation index" which describes the chemical balance of the water and indicates the tendency and the degree of potential incrustation or corrosion (5). Because of the complexity of chemical interactions in well waters, positive prediction methods have not been developed.

Irrigation pipe column showing incrustation to depth of one half inch.

The total mineral content of each water sample was determined by a conductivity test. Conductivity measures the amount of electrical current the water can carry. Under certain conditions the current carrying capacity of the water promotes the corrosive tendencies in most metals.

How Incrustation Occurs

Incrustation is caused either by the precipitation of certain minerals or by clogging with silt, sands, or other foreign materials. The saturation index indicates the possibility of such incrustation on the screen, the gravel pack or in the water bearing formation by calcium and magnesium carbonates (lime).

These deposits fill the pore spaces and cement the sand and gravel together, to the screen, or both. An impermeable barrier of deposits thus reduces or stops the flow of water into the well. Calcium and magnesium salts are found in abundance in most Nebraska ground waters.

The rate at which minerals may be deposited to form incrustation can be affected by the amount of drawdown in a well during pumping. An excessive amount of drawdown can cause:

1. Reduced pressures on the water.
2. Increased water velocity.
3. Exposed well screen.

Reduced pressures and increased velocities both have the effect of increasing chemical reactions of the minerals in the water with a resulting potential for a higher incrustation rate. Well screens exposed by excessive drawdown permit air to enter the spaces between the gravel or sand of the water bearing materials. The aeration and wetting and drying actions of the water film surrounding the sand and gravel particles may cause incrusting or cementing actions. The result of partially sealed well screens is increased water velocities through remaining openings and a consequent potential increase of incrustation.

Preventing incrustation is not completely possible. A slight amount of incrustation may be desirable since it helps prevent electrolytic corrosion. Incrustation can be reduced by keeping as near normal pressures as possible on the ground water. This is accomplished by maintaining drawdown (lowering of water level) at a minimum during pumping.

Well owners should understand that for a non-artesian well a drawdown of 50 percent results in about 75 percent maximum water yield of the well. Correct installations, correct screen openings and complete development of the well help maintain a reasonable drawdown level (**6**).

Additional wells also could be installed to deliver the amount of water desired to maintain high water levels during pumping. Reducing water velocities by reducing pumping rates minimizes incrustation possibilities.

Wetting and drying actions can be delayed by installing well screens at a depth where pumping levels will not expose the openings.

Incrustation can sometimes be removed from metal cased wells with acid treatments undertaken by reliable drillers or technicians (**7**). Treatment is expensive and results are not always satisfactory. Other clogging material can be removed with other well treatment materials, such as polyphosphates.

How Corrosion Occurs

Corrosion occurs when any material is eaten away or decomposed by chemical action. Causes of corrosion are:

1. Direct chemical or 2. electrolytic actions.

Direct chemical action is the destruction of material by acid solutions. In this survey no ground water tested less than a pH value of 7.0. This value indicates very little potential of corrosion by direct attack (**8**).

There are a few areas in the state in which hydrogen sulfide (H_2S) occurs in well waters. H_2S is acidic and attacks metals. H_2S can be detected readily by the distinctive rotten-egg odor. Where this odor occurs direct chemical attack of metal can be expected from such waters (**9**). Metal equipment used in these wells should be increased in thickness to assure longer life.

Electrolytic or galvanic action occurs when there is a flow of current between two or more different metals submerged in a solution that contains dissolved minerals. The current is self generating as the mineralized water contacts and reacts with a metal. High mineral content in water provides an easier path for electric current than does less mineralized water.

Corrosion has eaten away these irrigation well nuts.

Conductivity values, which are indications of the mineral ions, indicate the current carrying potential of the ground water. The reacting metal must in some way be connected in a circuit with a second metal. An example of such a circuit could be an irrigation pump resting on a metal well casing. The circuit may also be established between two dissimilar metals that are in metal-to-metal contact with each other and submerged. An example is a bolt on a pump column.

A circuit also can be established within a single piece of submerged metal like a pump column or well screen. The impurities, grain boundaries, areas of stress, etc., in the metal all may differ sufficiently from the major portions of the remaining metal to create a galvanic cell and cause electrolytic action.

Each of these circuits is capable of causing corrosion. The more unlike the metals forming the circuit, the greater the voltage potential. Likewise, the greater the salt content of the water, the greater the voltage.

The operation of the galvanic cell or flow of current from one part of metal to another starts when the water (electrolyte) reacts chemically with one of the metals. The reacting metal particles change form, releasing an electric charge. This is electrolytic or galvanic corrosion (**10**). The charge or current travels by metal ions in the solution to the receiving metal. The receiving metal, the cathode, may be plated with either metal or hydrogen. This does not usually injure the receiving metal.

Pitting and build up of materials on the same piece of metal pipe submerged in water, is an excellent illustration of this process. The reacting metal particle completely leaves the anode and in some instances is deposited at the cathode. It is also possible for the

metal particle to be incorporated in some other chemical reaction and never reach the cathode.

Deposits, when sufficiently thick at either the cathode or anode, may insulate the metal and stop current flow. Thus, corrosion may be stopped.

Aeration of water is usually considered a promoter of galvanic corrosion, although air plays a dual role. The cathode in some electrolytic actions receives a plating of hydrogen instead of other mineral materials. Hydrogen plating stops current flow. When extra oxygen is mixed with water, it can combine with the hydrogen and remove this protective plating. The removal of the hydrogen permits the current to flow and corrosion to restart.

In other instances oxygen can retard corrosion by combining with corrosion products at the anode to form a rust-like covering. This covering can effectively shut off current flow, if it is continuous and thick enough to insulate the anode. Oxygen apparently causes, more than inhibits, corrosion. To prevent air and oxygen from mixing with ground water, Nebraska well owners should try to prevent cascading or undue agitation of well waters by correct design and installation of irrigation wells and pumps.

Corrosion, Incrustation at the Same Time

Corrosion and incrustation have more opportunity to occur simultaneously in areas where the saturation index and conductivity are both high. Cracks and chips in mineral deposits can occur or water moving at high velocities can erode protective incrustation coverings exposing the metal surface. High conductivity water encourages corrosion at these points if an electric circuit is established. Wells in such areas should be thoroughly investigated before proceeding with plans.

An example of such a well is in Dundy County. Both corrosion and incrustation were occurring. The saturation index was 2.37 and the conductivity was 2.7. Length of well life may be only 2–5 years with these conditions. Special and heavier materials may be required for use in such areas.

Conductivity values are important in making decisions about type and thickness of metals to use in irrigation wells.

Interpretation of Tests

The range and average saturation indexes from this study are printed in each county of the state map (Figure 7). These figures represent only the limited number of wells sampled in each county.

In each county the saturation index is listed according to the following plan:

High-Low (range in each county)
Average (for the county)

Values represent as many as 71 samples (Hamilton County) to one sample (Grant and McPherson Counties). The map shows only the index for the one sample in those two counties. Two samples only were tested in each of Arthur, Cuming, Dixon, and Hooker Counties. No samples were collected in Boyd, Cass, Keya Paha, Nemaha, Otoe, Pawnee, Richardson, and Washington Counties.

Large red dots in each county locate wells with a saturation index value of a +2.00 or greater.

Conductivity values are shown in Appendix Figure 1. Each shading represents areas of Nebraska having similar conductivity.

For determining saturation index and conductivity values of wells in particular areas refer to specific data available in County Extension Offices.

Saturation Index

A saturation index of zero indicates that the chemical composition of the water is in equilibrium. A positive index indicates a tendency of the water to deposit scale or to incrust (**11**). Higher index numbers show greater deposit potential. An index of +2.00 or higher may be in the high incrustation possibility range. There were 48 readings of +2.00 or higher in 22 counties (Figure 7).

A negative index indicates water that may tend to be corrosive. There were seven negative saturation index readings in six counties: Blaine, Cherry, Garfield, Holt, Merrick, and Thomas. The lowest reading was −0.54 in Holt County. Because of testing procedure inaccuracies no importance should be attached to these negative readings.

The effects of pH levels. In general, a pH value below 7.0 is acid in reaction and tends to be corrosive. Water with a pH value above 7.0 tends to be incrusting. There were no values below pH 7.4.

Unless used in conjunction with other determinations, pH values can be misleading. However, we can infer that there will be little or no corrosion from direct chemical action of Nebraska's water on metals.

Conductivity

Conductivity is the ability of water to carry an electric current. Current-carrying ability is a result of the mineral or salt content of the water. As the amount of dissolved minerals increases, the amount of current the water can carry increases, resulting in higher conductivity values.

As conductivity values rise, the potential for electrolytic (galvanic) corrosion of metals increases. All natural waters contain some dissolved minerals; thus, all ground water holds the possibility of at least encouraging galvanic corrosion if the proper conditions exist. However, the possibility is slight at lower values of conductivity.

Corrosion is not a severe problem in most areas in Nebraska. This indicates that the lower conductivity values for the state are of less concern than higher values when judgments need to be made about corrosive potential. The areas on the map (Appendix Figure 1) shown in white, are considered to be moderately

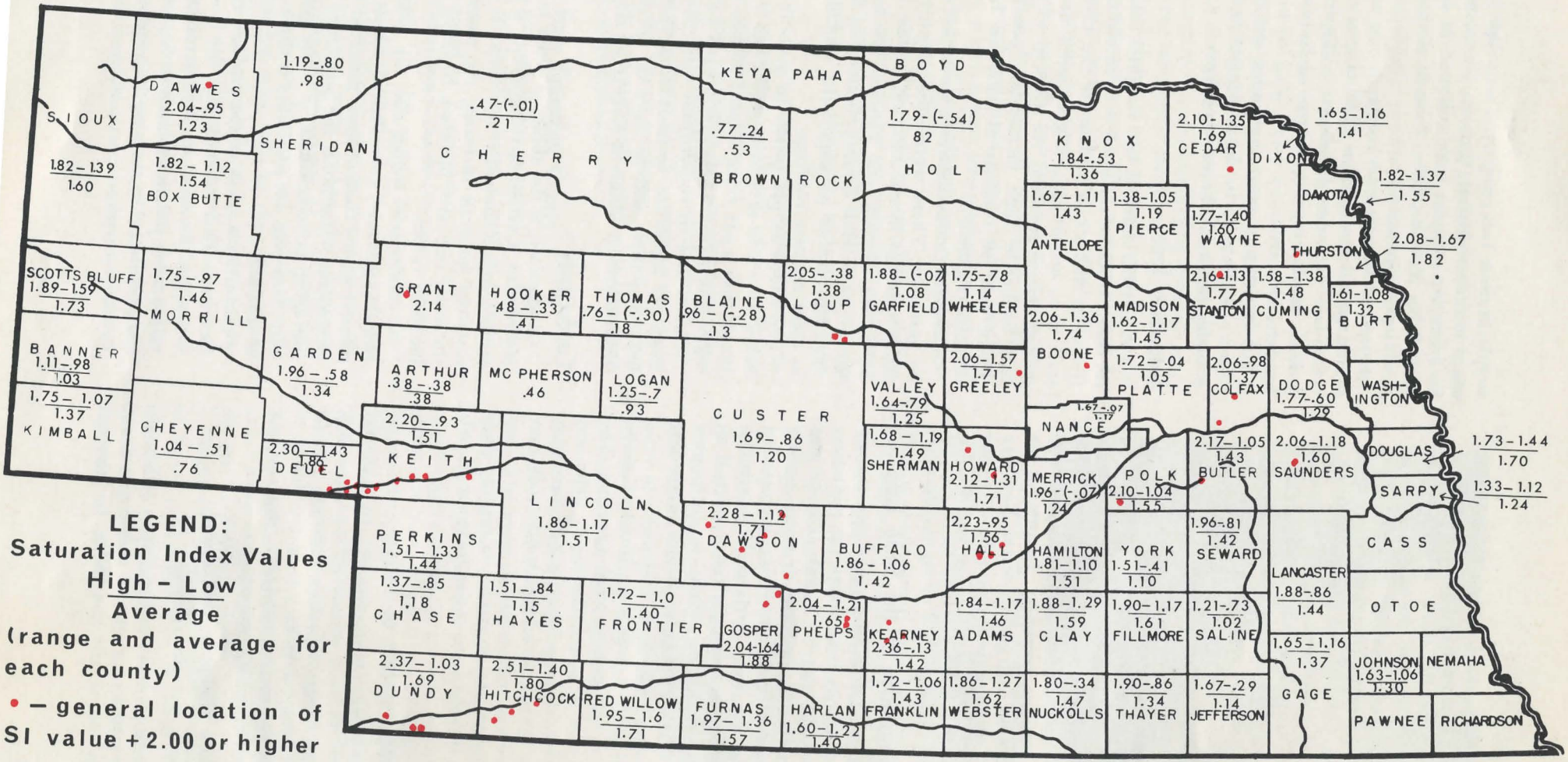


Figure 7. Saturation Index values, Water Quality Survey, 1961.

high. No specific conductivity level can definitely cause corrosion because the kind of well casing and pump metals and the mineral deposits affect the corrosion possibilities.

The important idea is that as conductivity readings increase, corrosion possibilities increase. Also, if the conductivity reading is high and the saturation index is also high, corrosion can in some cases proceed simultaneously with the build-up of incrusting materials.

Implications for the Future

Recommendations for Planning New Irrigation Wells

Check Figure 7 and Appendix Figure 1 for the high saturation index and conductivity readings in your county. Specific well records are in the County Extension offices. If the proposed well is to be located where the index values are near +2.00 or in the area of high conductivity values, investigate the data of specific wells nearest your proposed well.

Check with local well owners for their experiences with incrusting or plugging problems. This will help you decide on types of casings and the type and thickness of metals. In general, well casings in Nebraska do not require anything but the common iron metals or concrete currently used. In some areas, use of thicker or higher quality metals will prolong well and pump life.

The computation of a saturation index for individual water samples is not ordinarily recommended. It is a long and costly procedure. Examination of conductivity readings and mineral content analysis will usually give enough indication of incrustation or corrosion possibilities. In areas where doubt exists, a standard water analysis should be made and competent advice sought.

Special Problems

Tests for iron were inconclusive. Iron content is difficult to determine without special sampling methods. Iron content in most Nebraska ground water is probably not high enough to cause special concern about corrosion problems. There may be sufficient quantities in some wells to cause incrustation problems of a special nature.

The iron occurring naturally in water can be attacked by bacteria. These bacteria convert the soluble iron in the water to iron hydroxides. The hydroxides cover the bacteria cells, resulting in masses of jelly-like, slimy growths in wells. When the proper bacteria and iron are both present the build-up of great masses of jelly-like substances is possible. This may clog well screen openings, pipes, gravel packs, etc., and close water passages. This jelly-like mass quickly forms red or black rust-like material when exposed to air. This also can be a problem in domestic wells and water systems.

These bacteria may be found in many waters and also can be introduced by contaminated well drilling equipment. They are easily killed by chlorination treatments.

Piping systems for irrigation are subject to the same water corrosion problems as wells or pumps. Fortunately, non-conducting materials are used for coupling gaskets. This tends to break some of the possible electrical circuits. Corrosion by electrolytic action can occur, however, within a single pipe length.

Corrosion and incrustation on irrigation piping systems due to water quality usually are not severe in Nebraska. Occasionally, discoloration of pipes causes alarm. Quite often this can be attributed to precipitation of iron which occurs as soon as it comes in contact with air. The discoloration caused by iron oxides is not harmful to pipe.

Conclusion

Corrosion and incrustation due to water quality seldom are serious in Nebraska if wells are properly designed and managed for conditions and chemical nature of the water.

Incrustation appears to be a bigger problem in the future than corrosion.

Positive saturation index values indicate incrustation potentials. The average saturation index values of all counties ranged from 1.88 to 0.13, indicating that if deposits occur they will generally build slowly. There were 22 counties with +2.00 or higher indexes, indicating areas within counties where incrustation may build swiftly.

Slow but eventual build-up of deposits will cause some need for renovation or replacement of wells. Attention should be paid to water quality in locating a well. Well owners should follow reasonable operating practices to prevent incrustation. Drillers should be prepared in the near future to deal with problems of renovation through the use of well cleaning treatments, including acids. Educational institutions and professional associations should take the lead in teaching means and methods of renovation.

Although not extensive, some medium and high conductivities were found. Some weakening of metals from corrosion can be expected from galvanic type actions. Higher quality metals, heavier gauge metals or non-metallic materials, if adaptable, should be used in areas of high conductivity values.

High pH values in Nebraska indicate little potential for direct chemical corrosion.

The standard water analysis can give some indication of corrosion or incrustation potential. It is not generally recommended that a saturation index be computed in Nebraska.

Section 5

Research Needed

The committee has indicated the need to gather new information in the following areas:

1. Nitrate toxicity in foodstuffs associated with a reduction in milk production and the early dropping of calves. It was noted that the dairy husbandry department is currently conducting some investigations in this matter. The University of Missouri was noted to be working rather extensively on this problem.

2. Environmental and physiological factors of plants that influence nitrate accumulation. This area would require a new project in the Nebraska Agricultural Experiment Station.

3. Fate of applied nitrogen. A project covering this matter has been submitted to the Nebraska Agricultural Experiment Station. Although currently not a part of this project, information is also needed on the quantities of nitrogen that are leached with given quantities of irrigation water.

4. Water quality studies in surface waters. The Department of Water Resources of the State of Nebraska has requested funds and plans a new program to establish a rather permanent network of stations for continued sampling and testing of the quality of surface water of the state. It is planned that this program is to be cooperative with the United States Geological Survey. It also appears very desirable that the program of testing quality of surface water should be closely coordinated with the water quality studies of the ground water suggested earlier in this report.

5. Hydrologic conditions required for accumulation of nitrate in ground water. Agricultural Engineering plans to participate in a proposal of this type. It is felt that such a project would cover the gap in information between work currently being done within the rooting zone of the surface soil and the information that is to be gathered concerning the quality of ground water.

6. Management practices for the safe utilization of water of medium and high sodium and salinity hazards. Water of poor quality can be used for irrigation of salt tolerant crops without developing serious soil problems if correct management practices are followed. Studies are needed to determine the right management practices and amendments for various types of soils under climatic conditions of Nebraska. Rainfall undoubtedly has a diluting effect on the need for leaching requirement where medium and high saline water is used and for gypsum when the RSC and SAR values are high.

APPENDIX

Appendix Table 1. Irrigation water quality survey 1961 (expressed in parts per million (ppm).

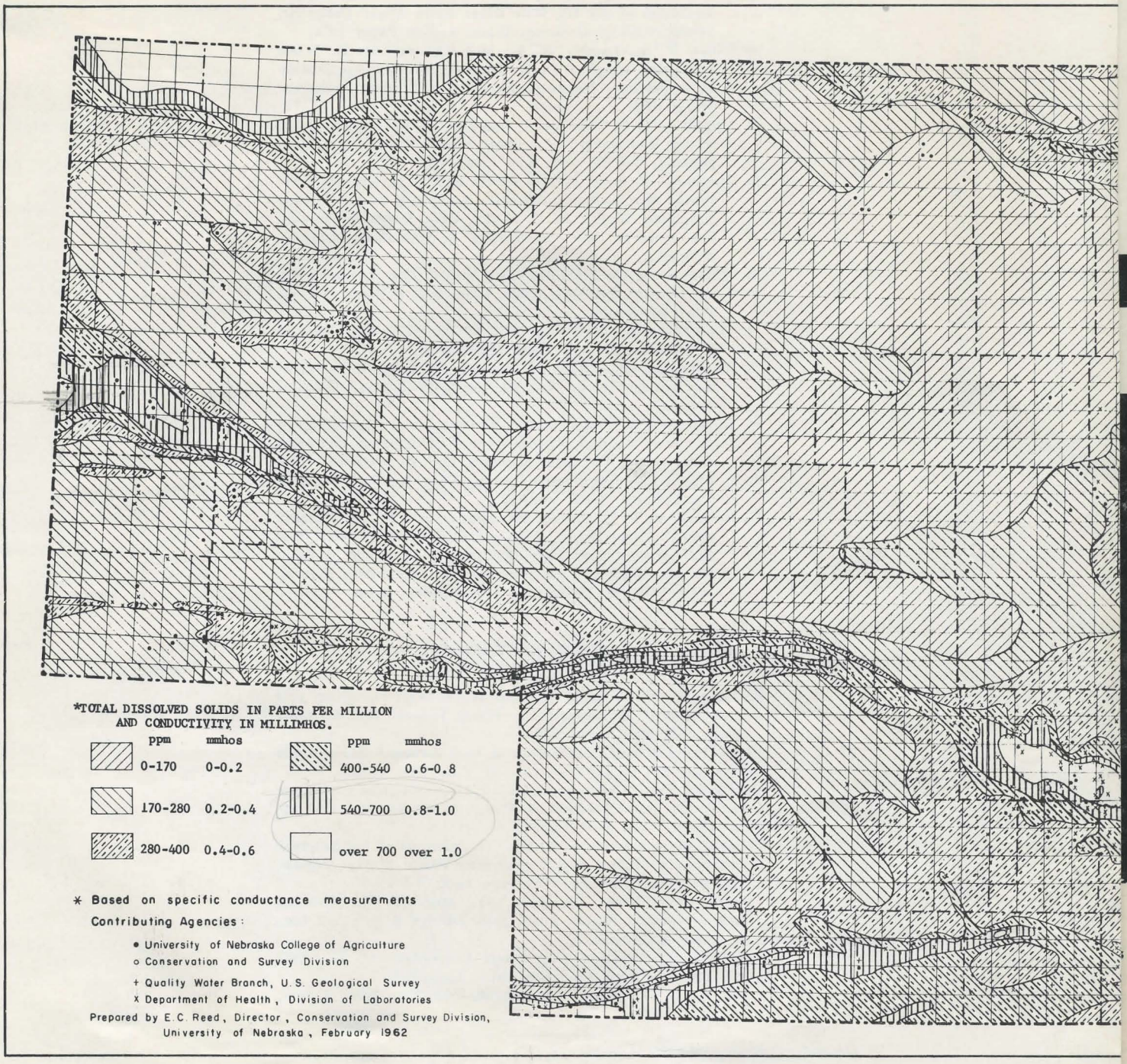
County	N		P		K		Ca		Mg		S		B		Fe		Cl	
	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range
Adams	0.6	0- 3.8	0.24	0- .4	9.0	6-15	46.5	34-65	10.6	2.6-23.4	11.4	0-39	0.14	<.05-0.40	.01	0- .31	2.6	0-15
Antelope	0.5	0- 3.6	.27	.1- .3	9.9	4-15	51.8	30-70	12.8	8.6-19.2	1.8	1-3	0.13	<.05- .25	----	------	3.0	1-9
Arthur	1.6	1.6*	.40	.4	12.0	12	22.0	22	2.0	2.0	1.0	1	.06	.06- .05	----	------	----	-----
Banner	2.3	1.4- 2.8	.10	.1- .1	5.6	5-7	32.4	27-37	14.9	14.4-15.2	5.0	2-7	.11	.10- .15	.02	0- .10	9.6	6-14
Blaine	1.3	0.2- 3.7	.38	.2- .4	8.3	5-15	22.0	12-39	6.6	0.6-12.4	2.5	2-4	.04	<.05- .10	----	------	----	-----
Boone	0.6	0.1- 1.0	.25	.1- .4	10.8	9-12	58.6	28-75	16.9	11.6-26.9	2.5	1-4	.12	.10- .15	----	------	1.2	1-2
Box Butte	1.6	0- 2.7	.15	.1- .3	22.5	7-75	40.3	21-64	19.2	10.8-37.0	16.1	2-53	.25	.10- .50	----	------	5.3	0-31
Brown	2.5	.9- 5.0	.29	.2- .3	6.4	5-9	22.1	15-28	4.7	3.0- 6.3	0.9	0-2	.08	<.05- .15	----	------	0.3	0-1
Buffalo	2.4	0- 9.6	.10	.1- .1	12.9	10-16	47.3	25-77	11.3	4.3-14.9	76.0	52-145	.11	.05- .20	.16	0-1.15	26.6	11-46
Burt	0.1	0- 1.1	.21	.1- .8	8.1	3-14	28.8	18-46	44.5	26.8-91.2	35.9	4-173	.19	<.05- .60	1.49	0-6.70	4.8	1-13
Butler	1.3	0- 7.5	.18	0- .5	9.7	7-14	33.1	20-86	27.5	12.4-59.6	21.6	9-55	.07	<.05- .20	.09	0- .58	5.1	1-10
Cedar	0.5	0- 1.0	.12	.1- .2	6.4	4-9	48.4	21-93	33.0	20.0-65.2	27.4	4-44	.12	.10- .15	.03	0- .16	0.2	0-1
Chase	1.9	1.6- 2.4	.10	.1- .1	11.1	8-16	22.4	15-26	17.3	12.7-23.6	4.3	3-8	.09	<.05- .20	.01	0- .14	5.9	2-9
Cherry	0.6	0- 0.9	.33	.3- .4	5.7	5-6	17.7	14-20	2.3	0.1- 6.1	2.3	1-4	.05	.05- .05	----	------	3.0	2-4
Cheyenne	4.3	2.5- 8.0	.10	.1- .1	9.8	6-20	18.2	13-25	27.2	15.8-44.6	9.4	2-29	.10	<.05- .25	.02	0- .13	9.6	1-25
Clay	1.7	0- 6.2	.26	0- 6	7.7	5-11	46.9	20-76	29.6	1.1-89.5	15.3	0-43	.08	<.05- .45	.01	0- .23	9.1	1-29
Colfax	1.6	0.1- 5.4	.16	.1- .4	8.4	6-17	30.9	14-76	24.6	12.4-49.6	18.6	5-95	.13	<.05- .40	.05	0- .45	3.0	1-8
Cuming	0.4	0- 1.9	.20	0- .4	7.7	4-23	22.7	16-26	25.0	18.6-33.4	10.0	0-14	.05	.05- .05	.36	0-1.80	2.0	0-4
Custer	1.4	0- 3.4	.11	.1- .2	11.4	7-19	32.6	21-56	16.8	6.0-33.8	3.4	1-11	.11	<.05- .30	.02	0- .30	5.9	3-15
Dakota	0.0	0-	.10	.1- .1	17.4	13-22	50.8	30-89	38.4	33.4-44.3	69.0	48-115	.22	.15- .30	1.69	0-6.70	36.6	14-82
Dawes	5.0	0.4-20.0	.10	.1- .1	17.2	7-49	42.8	19-119	26.7	17.9-47.2	16.4	2-69	.08	<.05- .25	.01	0- .05	33.2	5-144
Dawson	1.9	0- 6.9	.13	.1- .6	19.7	7-41	45.8	23-78	23.4	5.0-42.4	45.0	1-165	.13	<.05- .40	.03	0- .34	19.0	1-43
Deuel	3.4	0- 5.9	.10	.1- .1	17.3	12-28	81.0	14-157	45.7	18.8-80.8	32.9	6-69	.19	<.05-2.2	.08	0- .92	33.8	8-66
Dixon	3.2	0- 6.3	.10	.1- .1	6.0	5-7	37.5	25-50	24.8	24.5-25.1	28.5	22-35	.10	.05- .15	1.57	0-3.14	51.0	2-100
Dodge	2.2	0-14.6	.28	.1- .7	10.4	5-24	41.2	12-81	26.0	9.2-48.7	35.3	8-180	.10	<.05- .45	.18	0- .85	13.7	2-73
Douglas	1.4	0- 8.0	.19	0- .4	7.8	5-11	47.1	34-60	14.8	6.4-24.0	19.9	0-52	.05	<.05- .10	.09	0- .73	0.7	0-7
Dundy	0.7	0- 3.1	.10	.1- .1	25.8	12-43	72.2	23-197	43.1	11.2-51.4	167.1	3-510	.24	.05- .50	.18	0- .88	15.9	0-47
Fillmore	1.9	0-13.6	.20	.1- .6	9.0	7-12	51.7	28-108	12.3	2.5-29.2	23.3	9-165	.07	<.05- .15	.02	0- .35	14.9	0-37
Franklin	1.8	0- 3.7	.23	.1- .4	11.8	9-14	39.3	29-60	13.2	6.1-23.6	12.9	4-25	.20	<.05- .30	.07	0- .53	9.4	4-18
Frontier	2.4	0.3- 4.2	.10	.1- .1	15.3	13-21	32.4	26-40	17.3	11.3-27.8	7.8	4-22	.12	<.05- .20	----	------	7.5	1-14
Furnas	2.5	0- 5.8	.11	.1- .2	15.3	11-27	52.6	33-82	18.3	5.2-29.6	18.0	4-40	.14	.10- .20	.07	0- .36	18.3	1-51
Gage	2.1	0.4- 9.6	.20	.1- .5	4.2	3-6	40.4	23-78	14.5	7.0-28.0	8.0	1-21	.08	<.05- .15	----	------	12.4	4-42
Garden	2.6	0.5- 4.9	.13	.1- .3	13.7	7-20	45.3	24-71	9.8	0-18.5	9.9	2-26	.12	.10- .20	----	------	11.3	1-30
Garfield	1.2	0.3- 1.6	.30	.1- .4	8.4	3-14	35.4	14-55	5.7	2.4-10.2	1.2	0-4	.23	.05- .90	----	------	0.6	0-1
Gosper	3.4	1.7- 5.0	.11	.1- .2	17.6	12-26	54.9	26-89	17.9	11.4-31.1	15.6	4-36	.07	<.05- .10	----	------	13.5	1-51
Grant	0.1	0.1*	.40	.4	66.0	66	86.0	86	9.5	9.5	7.0	7	.04	<.05- .10	.07	.07	2.0	2
Greeley	1.1	0- 4.2	.18	.1- .5	15.4	10-20	53.8	34-78	12.2	6.2-20.0	10.3	2-22	.11	<.05- .25	.01	0- .07	1.7	1-4
Hall	1.5	0- 6.9	.21	.1- .7	12.5	5-24	64.9	22-193	18.4	1.7-67.6	52.3	5-270	.17	<.05- .35	.07	0-1.55	12.9	1-58
Hamilton	1.6	0- 8.0	.33	0- .6	8.5	6-12	51.4	24-86	18.6	0-46.8	23.9	0-168	.16	<.05- .30	.003	0- .17	10.6	0-33
Harlan	1.0	0- 6.0	.17	.1- .2	13.9	9-20	35.6	25-59	14.7	5.8-25.3	16.1	6-42	.16	<.05- .20	.09	0- .35	13.3	3-37
Hayes	1.4	0- 2.3	.10	.1- .1	16.7	13-20	28.1	17-40	18.2	14.0-21.8	7.6	3-19	.17	.10- .25	----	------	8.0	4-13
Hitchcock	2.5	0.2- 7.2	.10	.1- .1	22.4	15-39	56.2	32-107	26.0	13.9-41.7	18.2	4-34	.24	.15- .40	----	------	20.9	1-53
Holt	3.5	0-17.6	.17	.1- .4	5.6	3-10	30.2	8-54	2.4	0- 5.9	1.4	0-4	.11	<.05- .20	----	------	1.3	0-5
Hooker	0.2	0.1- 0.2	.25	.2- .3	7.5	6-9	22.0	20-24	3.5	1.6- 5.3	2.0	2-2	.04	<.05- .10	.03	0- .05	----	-----
Howard	0.9	0.1- 2.8	.23	.1- .5	9.1	7-12	57.3	40-94	18.1	6.5-37.2	4.4	0-10	.11	<.05- .20	.11	0-1.20	6.3	3-9
Jefferson	1.1	0.2- 5.0	.30	.2- .4	5.4	4-6	53.2	26-83	11.0	7.6-14.5	9.0	2-19	.14	.05- .20	.01	0- .05	38.3	5-124
Johnson	1.1	0- 5.3	.30	.1- .6	4.0	3-6	43.6	25-73	18.5	10.4-24.5	10.4	4-26	.11	.05- .15	.02	0- .08	51.4	18-143
Kearney	1.9	0.1- 6.7	.20	.1-1.4	12.9	4-24	39.0	9-128	19.1	2.6-29.0	16.7	2-45	.18	<.05- .55	.10	0- .60	13.6	1-55
Keith	2.2	0.2- 6.4	.10	.1- .1	17.4	8-37	82.1	27-154	17.4	2.6-51.2	101.5	2-330	.06	<.05- .25	.01	0- .17	24.2	0-91
Kimball	2.4	0.6- 3.7	.10	.1- .1	6.9	5-8	43.5	34-51	11.9	6.0-17.4	7.2	3-14	.10	<.05- .15	----	------	10.9	3-19

Appendix Table 1. (continued)

County	N		P		K		Ca		Mg		S		B		Fe		Cl	
	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range	Ave	Range
Knox	5.5	0.1-17.6	.16	.1- .3	6.6	6-8	43.8	21-64	14.0	6.5-22.7	11.8	7-19	.11	.05- .15	.02	0- .08	0.4	0-1
Lancaster	2.3	0- 6.2	.32	0- .8	7.0	5-15	39.6	16-69	13.2	7.6-18.5	18.0	4-35	.17	.10- .30	.22	0- .97	20.4	4-57
Lincoln	1.9	0- 4.8	.16	.1- .6	19.1	6-31	41.7	22-115	16.4	0-33.4	34.3	0-175	.16	<.05- .30	.04	0- .87	20.4	4-54
Logan	1.7	1.0- 4.5	.23	.1- .4	6.5	6-7	33.3	24-47	6.9	4.6- 9.4	1.5	1-2	.11	<.05- .15	----	------	3.0	2-5
Loup	0.8	0.2- 1.4	.30	.2- .4	19.6	6-51	42.2	17-70	14.7	6.5-28.1	2.0	1-5	.13	.05- .20	----	------	----	-----
Mc Pherson	1.8	1.8*	.20	.2	6.0	6	26.0	26	4.4	4.4	1.0	1	.11	<.05- .15	----	------	2.0	2
Madison	1.7	0.1- 7.4	.26	.1- .4	8.1	5-12	33.7	27-53	20.3	10.2-34.9	9.4	2-27	.13	<.05- .20	.75	0-2.30	6.3	0-13
Merrick	7.7	0-24.8	.19	0- .5	11.2	5-31	31.5	20-91	17.6	0-72.0	21.3	0-75	.13	<.05- .90	.01	0- .10	[illegible]	0-29
Morrill	1.8	0.4- 2.9	.10	.1- .1	12.9	7-21	42.3	32-66	14.5	5.3-25.2	26.1	2-70	.10	<.05- .25	.02	0- .08	13.8	1-27
Nance	3.9	0.6-13.6	.21	.1- .5	11.4	4-22	33.7	19-65	13.2	3.4-22.7	9.0	1-19	.05	<.05- .10	.02	0- .19	3.8	1-9
Nuckolls	1.3	0- 5.1	.58	.1-4.7	13.5	5-55	45.1	23-55	10.6	4.3-16.7	17.4	4-42	.08	<.05- .15	.08	0- .53	13.4	5-42
Perkins	1.9	1.6- 2.4	.10	.1- .1	16.8	12-19	34.0	29-38	13.6	11.4-14.9	3.6	2-4	.09	<.05- .15	----	------	14.2	10-24
Phelps	3.9	0.1-11.2	.17	0- .6	15.5	8-26	53.6	28-90	18.3	8.2-31.9	32.2	0-85	.09	<.05- .20	----	------	16.3	2-32
Pierce	4.5	0.1- 9.8	.14	.1- .2	6.5	5-11	36.0	22-57	14.4	9.5-20.4	8.0	2-34	.08	<.05- .10	----	------	8.8	7-11
Platte	2.9	0.1-20.0	.18	.1- .4	6.9	3-10	46.8	21-87	10.3	0-16.1	10.4	1-60	.11	<.05- .25	.02	0- .24	4.4	1-22
Polk	2.8	0.6- 7.7	.22	.1- .6	10.2	7-17	46.6	22-88	11.8	0.4-32.8	18.5	4-85	.11	<.05- .45	----	------	9.4	3-38
Red Willow	2.7	0- 5.9	.14	.1- .2	24.0	17-32	47.8	20-68	23.0	16.4-29.2	30.9	6-57	.14	.05- .25	----	------	22.3	11-41
Saline	0.8	0.2- 1.9	.27	.1- .8	6.2	5-7	49.1	25-71	12.6	3.0-21.7	15.3	7-31	.05	<.05- .05	.01	0- .08	22.8	15-81
Sarpy	1.1	0.1- 2.1	.10	.1- .1	5.8	5-8	31.3	21-44	15.7	10.3-20.4	11.0	7-16	.04	<.05- .05	.44	0-1.75	0.5	0-1
Saunders	2.3	0- 4.6	.18	.1- .5	11.1	7-15	50.6	22-98	14.6	7.6-20.5	20.7	4-80	.13	.05- .20	.11	0- .58	8.0	4-17
Scotts Bluff	2.1	0.1- 6.1	.10	.1- .1	18.6	8-29	56.1	40-70	19.5	12.0-34.4	62.5	47-115	.22	.10- .30	.01	0- .05	33.7	11-69
Seward	3.5	0-14.6	.25	.1- .6	8.6	6-16	44.7	19-79	12.5	3.6-22.7	13.2	4-38	.11	<.05- .20	.04	0- .19	20.6	17-38
Sheridan	0.9	0.1- 1.6	.10	.1- .1	10.7	7-18	37.6	29-50	7.5	5.8- 9.2	5.3	3-10	.10	.05- .15	----	------	5.5	1-10
Sherman	0.7	0.3- 1.1	.10	.1- .1	10.0	6-14	28.3	25-34	8.5	6.0-12.1	3.6	2-5	.07	.05- .15	.01	0- .05	3.6	1-7
Sioux	7.8	2.9-14.5	.10	.1- .1	8.4	7-10	58.2	38-87	9.1	6.0-12.8	15.0	3-33	.06	<.05- .10	----	------	9.0	2-19
Stanton	3.3	0.1-14.1	1.14	.1-6.9	11.1	7-16	56.3	32-90	21.7	7.8-42.4	48.7	4-165	.09	<.05- .30	.49	0-2.87	9.6	7-15
Thayer	1.8	0.4- 4.8	.37	.1- .7	7.3	5-10	43.0	29-69	7.5	4.2-15.6	4.5	2-12	.05	<.05- .10	----	------	11.7	2-24
Thomas	1.5	0.6- 2.6	.25	.1- .5	6.5	6-8	22.3	15-32	1.8	1.2- 2.4	2.3	1-4	.04	<.05- .10	----	------	0.5	0-2
Thurston	0.6	0- 2.2	.08	0- .1	7.3	6-9	46.0	32-67	25.9	20.0-28.9	19.5	10-34	.13	.05- .20	.02	0- .05	8.5	4-12
Valley	1.8	0- 8.0	.16	.1- .4	15.2	10-27	44.9	26-69	12.2	6.7-18.7	12.0	4-28	.19	<.05- .60	.03	0- .11	6.7	2-20
Washington	0.1	0.1*	.20	.2	27.0	27	----	-----	----	---------	55.0	55	----	---------	.33	.33	27.0	27
Wayne	1.6	0.1- 4.2	.10	.1- .1	10.0	9-11	38.0	29-43	25.2	22.3-26.8	24.0	5-45	.06	<.05- .10	----	------	8.7	7-10
Webster	1.8	0- 3.8	.18	0- .3	10.7	6-24	55.6	35-102	10.6	1.4-23.0	26.0	5-103	.10	<.05- .15	.02	0- .14	8.1	0-24
Wheeler	0.3	0- 0.6	.32	.2- .5	7.2	4-11	36.4	24-60	3.3	1.2- 5.5	0.6	0-2	.06	<.05- .10	----	------	----	-----
York	1.7	0.1- 5.6	.35	0- .8	11.3	6-14	33.6	10-78	22.8	1.3-54.0	11.3	0-25	.09	<.05- .25	.02	0- .19	9.4	2-19

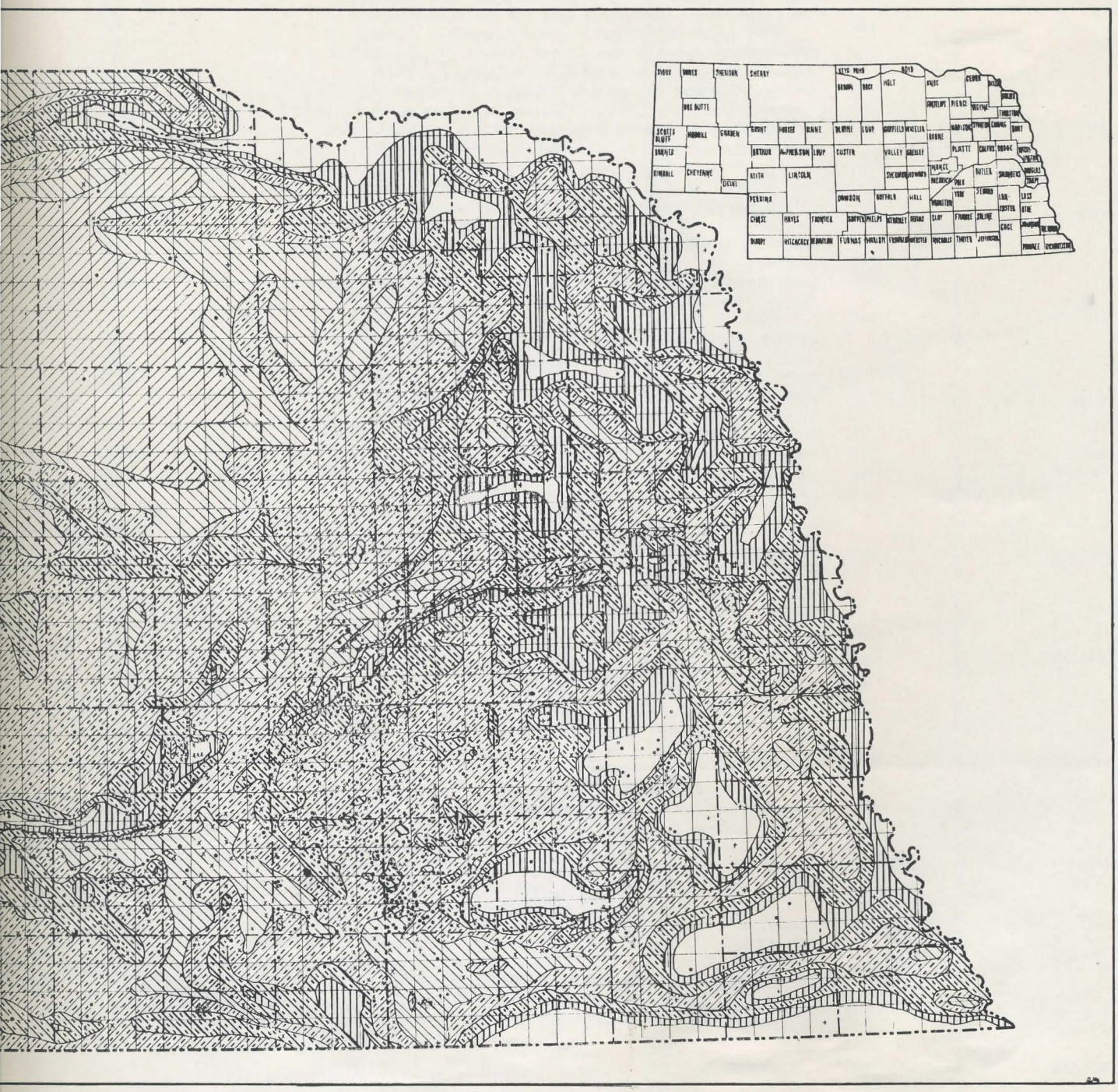
< means "less than"
* only sample obtained for analysis

Appendix Figure 1. Ground



Scale 1,00
0 1 10

quality map of Nebraska.


SIOUX
DAWES
SHERIDAN
SHERRY
KEYA PAHA
BOYD
BROWN
ROCK
HOLT
KNOX
CEDAR
DIXON
DAKOTA
THURSTON
BURT
DODGE
SAUNDERS
DOUGLAS
SARPY
CUMING
STANTON
WAYNE
PIERCE
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NANCE
PLATTS
CALFAX
DOUGLAS
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BUTLER
SAUNDERS
POLK
YORK
SEWARD
LAN-
CASTER
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FILLMORE
SALINE
GAGE
JOHNSON
NEMAHA
PAWNEE
RICHARDSON
THAYER
JEFFERSON
NUCKOLLS
CLAY
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ADAMS
FRANKLIN
HARLAN
FURNAS
GOSPER
PHELPS
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HOWARD
GARFIELD
WHEELER
VALLEY
SHERMAN
GREELEY
LOUP
BLAINE
CUSTER
DAWSON
CHASE
HAYES
FRONTIER
HITCHCOCK
DUNDY
KIMBALL
CHEYENNE
DEUEL
KEITH
LINCOLN
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CUMING
STANTON
WAYNE
PIERCE
BOONE
NANCE
PLATTS
CALFAX
DODGE
WASHINGTON
BURTLER
SAUNDERS

Appendix Table 2. Concentration of nitrate-nitrogen in water from irrigation and domestic wells (by county).[a]

County	Well location[b]	July, 1961	June, 1962	August, 1962
		ppm	ppm	ppm
Dawes	a	20.0		0.9
	b			0.0
	c			8.4
	f			4.8
Dodge	a	14.6	10.0	0.4
	b			0.6
	c			2.3
	d			11.0
	e			9.5
	f			7.7
Fillmore	a	11.2	12.8	9.6
	b			0.6
	c			15.2
	d			4.0
	e			0.2
Fillmore	a	12.1	12.0	9.6
	b			0.2
	c			0.4
	d			10.4
	e			3.3
	f			4.5
Fillmore	a	13.6	13.2	3.2
	b			12.4
	c			0.0
	e			0.2
	f			76.0
Holt	a	17.6		15.2
	b			2.4
	f			9.5
Knox	a	17.6	14.0	
Merrick	a	10.4		8.0
	b			3.3
	c			8.4
	d			8.8
	e			10.0
Merrick	a	10.4		9.6
	b			10.0
	c			8.8
	d			9.6
	e			13.2
	f			8.8
Merrick	a	12.8	4.4	8.0
	b			3.3
	c			8.4
	d			8.8
	e			11.6
	f			2.4
Merrick	a	12.8	16.8	13.6
	b			7.7
	c			13.6
	d			6.2
	e			13.6
	f			7.4
Merrick	a	14.6	12.4	13.6
	b			12.8
	c			13.6
	d			11.6
	e			11.6
	f			16.4
Merrick	a	14.6	14.4	12.8
	b			5.8
	c			11.6
	d			0.0
	e			12.8
	f			16.4
Merrick	a	14.6	10.0	9.6
	b			6.8
	c			8.0
	d			11.6
	e			1.0
	f			16.4
Merrick	a	14.6	10.4	10.0
	b			8.4
	c			8.4
	d			9.6
	e			8.4
	f			10.0
Merrick	a	14.6		
Merrick	a	14.6	10.8	12.8
	b			12.8
	c			9.6
	f			12.8
Merrick	a	20.0	16.0	16.4
	b			13.6
	c			26.0
	d			11.6
	e			6.2
	f			13.6
Merrick	a	20.0	15.6	13.6
	b			10.0
	c			8.8
	d			6.6
	e			26.0
Merrick	a	24.8	18.0	19.6
	b			26.0
	c			16.4
	d			19.6
	e			0.2
	f			19.6
Merrick	a	24.8	2.7	2.8
	b			1.9
	c			1.8
	d			2.4
	e			2.4
	f			0.2
Nance	a	13.6		10.0
	b			14.0
	c			11.0
	d			27.6
	e			14.0
	f			12.4
Phelps	a	10.4		
Phelps	a	11.2	0.5	
Platte	a	20.0	15.2	16.0
	b			10.4
	c			16.8
	d			26.0
	e			30.0
	f			18.4
Seward	a	14.6		12.8
	b	14.6	5.2	4.7
Sioux	a	12.6		2.2
	b			0.2
	f			2.2
Sioux	a	14.5		
Stanton	a	14.1	12.0	10.0
	b			0.0
	f			0.0

[a] Data are not included in this table for water samples from wells that had less than 10.0 ppm on the July, 1961, sampling date.

[b] a—refers to an irrigation well water sample with high nitrate concentration July, 1961.

b, c, d, e } refers to irrigation wells surrounding well "a"

f—refers to domestic well near well "a"

BIBLIOGRAPHY

1. U.S. Department of Agriculture, State and Federal Division of Agricultural Statistics. Nebraska Well Irrigation Statistics, Lincoln, Nebraska, 1963.
2. Marbut, Curtis F., Soil Survey of Seward County, Nebraska.
3. Johnson, C. R. and Keech, C. F. Geology and Ground Water Resources of the Big Blue River Basin Above Crete, Nebrsaka. Geological Survey Water Supply Paper 1474.
4. Olson, R. A., Lamke, W. E., and Rhoades, H. R. When Fertilizing Irrigated Corn—Time of Nitrogen Application Is Important. Nebraska Experiment Station Quarterly, Sring, 1960.
5. Langlier, W. F. "The Analytical Control of Anti-Corrosion Water Treatment," *American Water Works Association Journal*, Vol. 29, 1936, New York, N.Y.
6. Fischbach, P. E., P. E. Schleusener and V. H. Dreezen, "Nebraska Minimum Standards for Artificially Gravel Packed Irrigation Wells," E. C. 57-702, 1957, Extension Service, University of Nebraska, College of Agriculture, Lincoln, Nebraska.
7. "Maintaining the Yield of Water Wells," *The Johnson Drillers Journal*, Jan.–Feb., 1965, Edward E. Johnson, Inc. St. Paul, Minnesota.
8. "The Chemistry of Water," Bulletin No. 1237, 1951. Edward E. Johnson, Inc., St. Paul, Minnesota.
9. Thomas, A. H., "Role of Bacteria in Corrosion," *Water and Sewage Works*, Vol. 89, No. 9, 1942, Sept., Chicago, Illinois.
10. Koehler, W. A. "Fundamentals of Corrosion," *Proceedings of the First Annual Appalachian Underground Corrosion Shortcourse*, Technical Bulletin No. 45, October, 1956, Engineering Experiment Station, West Virginia University, Morgantown, West Virginia.
11. Kendall, V. V., "Corrosion Problems from a Practical Standpoint," *Proceedings of the First Annual Appalachian Underground Corrosion Shortcourse*, Technical Bulletin No. 45, October, 1956, Engineering Experiment Station, West Virginia University, Morgantown, West Virginia.

OTHER REFERENCES

Bennison, E. W. "Fundamentals of Water Well Operation and Maintenance," *American Water Works Journal*, Vol. 45, Jan.–Jnue, 1953, New York, N.Y.

"The Corrosion and Incrustation of Well Screens," Bulletin 834 1955, Edward E. Johnson, Inc., St. Paul, Minnesota.

DeMartini, F. E. "Corrosion and the Langlier Calcium Carbonate Saturation Index," *American Water Works Journal*, Vol. 30, Jan.–June, 1938, New York, N.Y.

Eliassen, R. and James C. Lamb. "Mechanisms of the Internal Corrosion of Water Pipe," *American Water Works Journal*, Vol. 45, July–December, 1953, New York, N.Y.

"Metals That Resist Corrosion Save Money," *The Johnson Drillers Journal*, March–April, 1962, Edward E. Johnson, Inc., St. Paul, Minnesota.

Speller, F. N. *Corrosion, Causes and Prevention*, 3rd Ed., 1951 McGraw-Hill Book Company, New York, N.Y.

Uhlig, H. H., ed. *Corrosion Handbook*, 1948, John Wiley & Sons, Inc. New York.

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