SODIUM

The concentration of sodium in water of the High Plains aquifer is shown by the map on this sheet. Several thousand chemical analyses of water samples from the aquifer were used to prepare this map. Each interval on the map shows the range in sodium concentration that predominates in that area. Because of map scale, it is not possible to show small areas within or between intervals where sodium concentration may be more or less than that indicated. More detailed information about the quality of ground water is available in reports from various Federal, State, and County agencies.

Chemical data from 28 water samples from the High Plains aquifer are presented in the table below and located by number on the map. The table includes the data needed to evaluate the salinity and sodium hazards associated with the use of water for irrigation discussed elsewhere on this sheet. These 28 chemical analyses were selected because they are representative of the variations in the concentrations of the cations calcium, magnesium, and sodium found in water from the High Plains aquifer. The sodium hazard associated with the use of water for irrigation is determined by the concentrations of these cations. If the proportion of sodium is large the hazard is high; conversely, if calcium and magnesium predominate, the hazard is low. The U.S. Salinity Laboratory Staff (1954) quotes Scofield and Headley (1921) who summarized the results of a series of alkali reclamation experiments with the statement: "Hard water makes soft land and soft water makes hard land." Alkali soils are formed by accumulation of exchangeable sodium.

The sodium concentration in water from the High Plains aquifer generally increases from north to south and ranges from less than 25 to more than 100 mg/L as shown on the map. The maximum reported sodium concentration in uncontaminated water from the aquifer was 1,151 mg/L (sample 28). About 56 percent of the area of the High Plains aquifer contains water with less than 25 mg/L sodium, 26 percent of the area of the aquifer contains water with 25 to 50 mg/L sodium, and 18 percent of the area of the aquifer contains water exceeding 50 mg/L. Only 3 percent of the area of the aquifer contains water exceeding 100 mg/L sodium, most of which is in Texas.

The concentration of sodium in most of the area of the High Plains aquifer is less than 50 mg/L because the aquifer is composed mainly of sand and gravel deposits that contain few sodium minerals. Where the aquifer is composed of the Arikaree Formation (samples 1, 2, and 3) and the Brule Formation (sample 6), water generally contains larger concentrations of sodium than water from the Ogallala Formation (samples 4 and 7-13) or Quaternary sand and gravel deposits (sample 5). However, the concentration of sodium in ground water in many parts of the High Plains appears to be affected by the bedrock.

In Kiowa County, Colorado, sample 14 from the High Plains aquifer contained 222 mg/L sodium. In this area, the aquifer is underlain by the Smoky Hill Marl Member of the Niobrara Formation which contains marine clays. The sodium concentration in ground water probably is increased in Kiowa County by ion exchange on clays at the weathered surface of the bedrock or on clays in the aquifer derived from reworked bedrock.

In southwestern Kansas, Oklahoma, and northern Texas, the concentration of sodium in samples 20, 22, and 23 ranged from 100 to 240 mg/L. The bedrock underlying the aquifer in this area is of Permian age and contains salt beds and saline water. Relatively large sodium concentrations and equal proportions of sodium and chloride (see pie diagram 11 on sheet 1) indicate that saline water from the Permian rocks may be entering the aquifer.

The sodium concentration exceeds 100 mg/L in parts of the High Plains aquifer in New Mexico and Texas, south of the Canadian River. Sample 27 from the aquifer contained 227 mg/L sodium and sample 28 contained 1,151 mg/L sodium. Most of this area of the aquifer is underlain by Upper Cretaceous rocks containing highly mineralized water that may be entering the aquifer. Also, many saline lakes or playas occur in this area (Reeves and Miller, 1978) and seepage from the playas may contribute to the relatively large concentrations of sodium found in water from the aquifer. In some areas, large concentrations of sodium have been caused by disposal of oil-field brines in surface pits. Rettman and Leggat (1966) reported 5,170 mg/L sodium plus potassium in a water sample contaminated by brine disposal in Gaines County, Texas.

Sodium concentrations in water in the High Plains aquifer near major streams are affected by irrigation practices. In areas of extensive irrigation, sodium is concentrated by evapotranspiration and ion exchange in the soil. In stream valleys where the water table is near land surface, infiltration of irrigation water has resulted in relatively large concentrations of sodium. As shown on the map, the sodium concentration in ground water is 50 to 100 mg/L along part of the Platte and Republican Rivers, and exceeds 100 mg/L along part of the Arkansas River.

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CHEMICAL DATA FROM SELECTED WATER SAMPLES FROM THE HIGH PLAINS AQUIFER

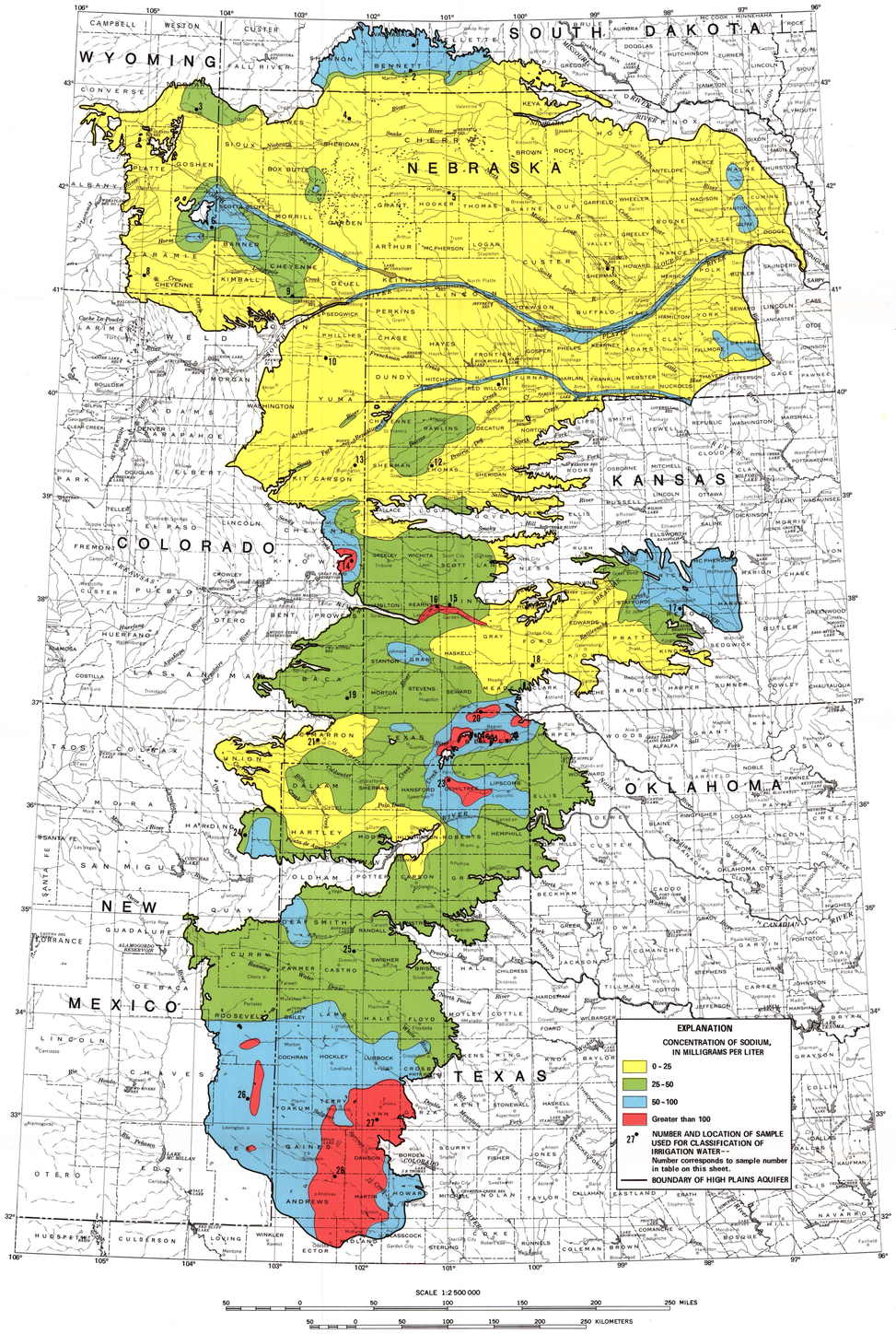
[mg/L = milligrams per liter; meq/L = milliequivalents per liter; µmho = micromhos per centimeter at 25 degrees Celsius]

Sample number	Site number	Geologic unit[1]	Well depth (feet)	Calcium (mg/L)	Calcium (meq/L)	Magnesium (mg/L)	Magnesium (meq/L)	Sodium (mg/L)	Sodium (meq/L)	Specific conductance (µmho)	Sodium adsorption ratio
1	432355101280O	ARKR	150	57	2.84	2.4	0.20	77	3.35	617	2.7
2	431257101281S	ARKR	96	28	1.40	8.3	.68	52	2.26	446	2.2
3	424426104200T	ARKR	100	122	6.09	29	2.39	27	1.17	926	.6
4	424230102183S	OGLL	220	40	2.00	6.7	.55	8.0	.35	305	.3
5	420040100590Z	SDGV	245	20	1.00	3.3	.27	6.6	.29	158	.4
6	413809104060Z	BRUL	150	24	1.20	11	.90	59	2.57	485	2.5
7	411452098472 1	OGLL	200	94	4.69	14	1.15	12	.52	605	.3
8	410939104580 1	OGLL	250	45	2.25	5.5	.45	4.4	.19	281	.2
9	410116103003G	OGLL	153	41	2.05	11	.90	25	1.09	400	.9
10	402324102360O	OGLL	368	29	1.45	9.7	.80	22	.96	328	.9
11	401108100173 4	OGLL	200	56	2.79	15	1.23	9.8	.43	420	.3
12	392303101095 4	OGLL	227	43	2.15	17	1.40	24	1.04	450	1.3
13	391806102141 8	OGLL	321	30	1.50	10	.82	22	.96	325	.9
14	382449102065Z	OGLL	100	228	11.38	114	9.38	222	9.66	2,630	3.0
15	380339100582 4	OGLL	340	110	5.49	48	3.95	47	2.04	1,060	.9
16	380153101071 3	OGLL	320	320	15.97	62	5.10	120	5.22	2,100	1.6
17	375711098032 6	SDGV	70	91	4.54	12	.99	80	3.48	875	2.1
18	372732099515 5	OGLL	180	54	2.69	20	1.65	18	.78	470	.5
19	370908102111 2	OGLL	178	33	1.65	20	1.65	28	1.22	435	1.0
20	370059100342 0	OGLL	260	63	3.14	19	1.56	240	10.44	1,650	6.8
21	364543102362 1	OGLL	230	49	2.45	29	2.39	20	.87	555	.6
22	364119100160 4	OGLL	180	46	2.30	14	1.15	100	4.35	855	3.6
23	362052100554 2	OGLL	560	54	2.69	23	1.89	130	5.66	1,070	4.1
24	354946103262 6	OGLL	120	35	1.75	30	2.47	46	2.00	612	1.4
25	344114102055 6	OGLL	201	38	1.90	16	1.32	47	2.04	475	1.6
26	331529103190 7	OGLL	90	108	5.39	16	1.32	68	2.96	941	1.6
27	330205101475 5	OGLL	95	383	19.11	177	14.56	227	9.87	2,900	2.4
28	322914102182 4	OGLL	101	295	14.72	297	24.43	1,151	50.07	4,250	11.3

[1]ARKR-Arikaree Formation or Group; BRUL-Brule Formation; OGLL-Ogallala Formation; SDGV-Quaternary sand and gravel deposits.

CONVERSION FACTORS

Multiply inch-pound units	*By*	*To obtain SI units*
foot	0.3048	meter
mile	1.609	kilometer
acre	0.4047	square hectometer
square mile	2.590	square kilometer



CONCENTRATION OF SODIUM IN GROUND WATER

SALINITY AND SODIUM HAZARDS

The principal use of ground water in the High Plains is for irrigation. Although many chemical constituents or properties of water affect its suitability for irrigation, the two main criteria for determining the suitability of water for irrigation are dissolved-solids concentration and sodium concentration relative to calcium and magnesium concentrations.

Specific conductance is a convenient measure of the salinity hazard or dissolved-solids concentration of water; specific conductance is the electrical conductivity of water measured in micromhos per centimeter at 25° Celsius (µmho). Typically, the concentration of dissolved solids, in milligrams per liter, can be estimated by multiplying specific conductance by a factor ranging from 0.55 to 0.80 depending on the chemical composition of the water.

Nearly all sources of irrigation water that have been used successfully for a considerable time have specific-conductance values less than 2,250 µmho. Waters with greater specific conductance are used occasionally, but crop production has not been satisfactory, except in unusual situations (U.S. Salinity Laboratory Staff, 1954). Water with specific conductances ranging from 750 to 2,250 µmho commonly is used for irrigation, but satisfactory crop growth is obtained only with good land management and favorable drainage conditions. Saline conditions will develop if leaching and drainage are inadequate (U.S. Salinity Laboratory Staff, 1954). Water with specific-conductance of less than 750 µmho generally is satisfactory for irrigation, but salt-sensitive crops may be adversely affected by the use of irrigation water with specific conductances of 250 to 750 µmho.

Excessive concentrations of sodium are harmful to plants and soil. Accumulation of sodium in soils affects plant growth and decreases soil permeability and siltability. The sodium-adsorption ratio is a means of determining whether the sodium concentration of water is likely to affect soil properties adversely. The U.S. Salinity Laboratory Staff (1954) defined sodium-adsorption ratio (SAR) of water as:

$$SAR = \frac{(Na^{+})}{\sqrt{\frac{(Ca^{++} + (Mg^{++})}{2}}}$$

where ion concentrations are expressed in milliequivalents per liter. The experiments cited by the U.S. Salinity Laboratory show that the SAR predicts reasonably well the degree to which irrigation water tends to enter into cation-exchange reactions in soil. Large SAR values indicate a hazard of sodium replacing adsorbed calcium and magnesium, and this replacement is damaging to soil structure (Hem, 1970).

A diagram for the classification of irrigation waters developed by the U.S. Salinity Laboratory Staff (1954) is shown below. The diagram is based on the specific conductance, in micromhos per centimeter at 25° Celsius, and sodium-adsorption ratio. The salinity hazard is classified on the horizontal scale as low (100 to 250 µmho), medium (250 to 750 µmho), high (750 to 2,250 µmho) or very high (greater than 2,250 µmho). The sodium hazard is classified on the vertical scale, which is divided into four classes with respect to sodium-adsorption ratio. At specific conductance of 100 µmho, the classifications for sodium hazard are low (0 to 10), medium (10 to 18), high (18 to 26), and very high (greater than 26); the classifications change with increasing specific conductance.

Chemical analyses of 28 ground-water samples that are representative of the High Plains aquifer are presented in the table on this sheet and the locations of the wells from which these samples were collected are shown on the sodium-concentration map. The specific conductance and sodium-adsorption ratio from these samples are plotted and identified by number on the diagram below. The following discussion of the classification of these water samples is based on that presented by the U.S. Salinity Laboratory Staff (1954).

The diagram for classification of irrigation waters shows that sample 5 from the sand hills of Nebraska has a low salinity hazard and a low sodium hazard. This type of water can be used for irrigation with most crops on most soils with little likelihood of soil salinity buildup or little danger of the development of harmful levels of exchangeable sodium.

Sixteen samples have low sodium hazard but medium salinity hazard. These samples are all from the Ogallala Formation except for samples 1 and 2 which are from the Arikaree Formation and sample 6 which is from the Brule Formation. This type of water can be used for irrigation if a moderate amount of leaching occurs. Plants with moderate salt tolerances can be grown in most instances without special practices for salinity control. There is little danger of the development of harmful levels of exchangeable sodium.

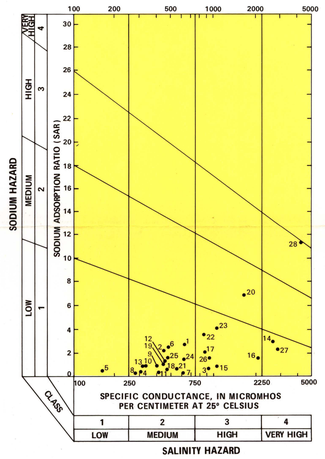
Seven samples have low sodium hazard and high salinity hazard. Exchangeable sodium causes no problem with use of this water; but because of high salinity, this water cannot be used in soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Samples 14 and 27 have low sodium hazard and very high salinity hazard. These samples are from areas where the concentration of dissolved solids in the High Plains aquifer is affected by the underlying bedrock. Use of this type water for irrigation causes no problems related to exchangeable sodium, but it is not suitable for irrigation under ordinary conditions. Because of the very high salinity hazard, its use should be limited to salt-tolerant crops on well-drained permeable soils and with excessive applications of irrigation water.

Sample 20 has high salinity hazard and a medium sodium hazard. This sample was collected from a well in Meade County, Kansas, and its quality probably is affected by water from the underlying Permian age bedrock. Use of this water for irrigation will result in appreciable sodium and salinity hazard to fine-textured soils having high cation-exchange capacity, especially under minimal-leaching conditions, unless gypsum is present in the soil. This water can be used on well-drained, coarse-textured, or permeable organic soils.

Sample 28 has a very high salinity hazard and a high sodium hazard and is generally unsuitable for irrigation. The sample was collected from a well in Andrews County, Texas, and its chemistry may be affected by saline water from Cretaceous marine rocks or seepage from saline playa lakes.

Most of the High Plains aquifer contains water having a low sodium hazard and a medium salinity hazard. Except for areas where the salinity hazard is very high, water from the aquifer generally is suitable for irrigation on most soils in the High Plains. In areas where the salinity hazard is high and soils have poor drainage, water from the High Plains aquifer may not be suitable for irrigation without management for salinity control.



Base from U. S. Geological Survey
United States base map, 1972

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1982—W82171

DISSOLVED SOLIDS AND SODIUM IN WATER FROM THE HIGH PLAINS AQUIFER IN PARTS OF COLORADO, KANSAS, NEBRASKA, NEW MEXICO, OKLAHOMA, SOUTH DAKOTA, TEXAS, AND WYOMING

By
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1982

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