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GEOLOGICAL SURVEY
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TASK I - COMPLETION REPORT
BIG SIOUX AQUIFER STUDY, EASTERN SOUTH DAKOTA

by

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INTRODUCTION

The Big Sioux Aquifer is a shallow glaciofluvial aquifer associated with the Big Sioux River system. This system drains the easternmost tier of counties in the State (fig. 1) with the aquifer underlying several thousand square miles of this area. This aquifer is the major source of water within the basin, serving municipal, industrial, rural and irrigation needs. Overall, the ground-water quality is excellent and ranks among the highest quality water in the State. Because the surface water supplies within the basin are insufficient for existing needs and the water quality of the bedrock aquifers is generally poor, the Big Sioux Aquifer is the only major source of good quality water within the basin.

The Big Sioux Aquifer consists of interlayered glacial and alluvial sediments with numerous tributaries to the main body of the aquifer. As a result, the aquifer is not a single, simple system but rather is composed of a number of smaller flow systems with varying degrees of interconnection.

Although a large amount of geohydrologic and water quality data exist for the Big Sioux Basin, it is poorly organized and has various degrees of reliability. To correct this deficiency the current project was initiated at the request of the East Dakota Conservancy Sub-District. The data compilation was done by personnel of the South Dakota Geological Survey with funding provided by a section 208 waste treatment management planning grant.

The current project was undertaken as a preliminary effort to compile and evaluate existing data. These data are presented in the various plates, figures, and appendices. This report is intended to be a summary of existing data and, as such, is intended for usage by geologists and hydrologists. The various plates and figures are hopefully self-explanatory.

PHYSICAL PARAMETERS OF THE BIG SIOUX AQUIFER

A large body of data exists for the aquifer. The most abundant data are in the form of drillers logs and geologic maps. The major step in the project was to determine the areal extent of the Big Sioux Aquifer. For the majority of the area geologic maps from the Geologic Map Series of the South Dakota Geological Survey were used. In areas of the aquifer not covered by the Geologic Map Series, a regional geologic map (Flint, 1955) was used. The areal extent of the outwash and alluvium was scaled to county maps (approximately 1/2 inch = 1 mile).

After scaling the geologic maps to the county base maps, drilling data were compiled from test holes, observation wells and irrigation wells. The main source of the test hole data was

the South Dakota Geological Survey. Observation well and irrigation well data were obtained from the South Dakota Office of Water Rights. The compiled data extend from the early 1950's to the present and have a wide range of reliability. Test hole data were evaluated and placed in three subjective categories. The first category contains test holes that are obviously worthless and are discarded. Category two contains those data of questionable reliability which are included in the basic data appendices but are not included in the plates. The third category contains what are judged to be reliable data. These data were used to construct aquifer isopachs, water table surface maps, and sand and gravel isopachs. Since the areal extent of the aquifer was determined from surficial geologic maps, a number of areas are found where the subsurface data indicate a greater extent for the aquifer than does the surficial geology. In those areas where the data are good and only minor corrections are needed the aquifer boundaries have been adjusted. In other areas the aquifer obviously extends beyond the mapped boundaries; however, the lack of data precludes the establishment of new boundaries. In these situations the old boundaries were left intact as it was felt little was to be gained by "guesstimates" of where the boundaries actually are. In addition to areal extent, problems may exist with respect to defining the vertical extent of the aquifer. Many of the data are logs from auger test holes which are quite old. The problem with auger tests is that they are usually unreliable below 50 feet and are even more unreliable after penetrating saturated sand and gravel. Combined with this, and in a large part because of this unreliability, most of the auger tests stopped after penetrating the surface sand and gravel bodies. Recent work has shown that in some areas there are more deeply buried aquifers which are hydraulically connected to the Big Sioux Aquifer. Because of the lack of data the extent and complexity of these interconnections are largely unknown.

CHEMICAL PARAMETERS OF THE BIG SIOUX AQUIFER

Figures 1 through 12 comprise a series of frequency diagrams used to graphically display the relative abundance of various chemical constituents present in water from the Big Sioux Aquifer. When viewed individually (see app.) these chemical data may indicate a low degree of reliability because of the lack of quality assurances in both the sampling techniques and chemical analyses. Chemical analyses date from the early 1950's to the present; however, continuity of sampling does not exist for the aquifer as a whole. This results from the fact that a majority of the analyses were performed for smaller individual study areas throughout the past three decades. Such a long time range of sampling will obviously cause anomalies to appear in the data compilation. However, by displaying the data on frequency diagrams, it is possible to show at a glance the wide range of data while still indicating the most probable average concentrations of a particular constituent.

It is currently impossible to make a definitive statement concerning degradation of ground water quality in the Big Sioux Aquifer. Certain general statements with regard to water quality are, however, worth mentioning. In terms of overall water quality, as measured by total dissolved solids, the water quality within the aquifer is good. In contrast, based on those data presently available, concern must be expressed regarding high concentrations of nitrate in several sectors. Of 370 nitrate analyses, 53 (14 percent) exceed the drinking water standards of 10 parts per million (ppm). Locations of immediate concern are indicated by the concentration of high nitrate values in the following areas of the aquifer.

1. A large part of the Big Sioux Aquifer between Castlewood and Bruce.
2. Several small areas in the vicinity of Elkton.
3. The entire aquifer between Egan and Flandreau.
4. Numerous other highly isolated instances of individually high nitrate concentrations as shown on Plate 2.

These high nitrate values may represent only limited, isolated occurrences or, in fact, indicate high concentrations in larger areas which are currently undefined because of a lack of information concerning the following factors.

1. Seasonal fluctuations in nitrate values.
2. Inconsistency of sampling techniques.
3. Lack of quality assurance in the chemical analyses.
4. A large time gap between sampling of adjacent points.
5. Lack of vertical control with respect to where the sample was collected within the aquifer.
6. A general absence of data for large segments of the aquifer.

Data for trace elements are almost totally absent. Other than for nitrate, no public drinking water supply is known to be in violation of drinking water standards; however, there are 25 selenium analyses which are known to be anomalously high. Coupled with this are previous findings which indicate a tendency for high selenium values to accompany high nitrate values (Stach, in preparation). This suggests that future sampling will find selenium values in excess of the drinking water standard of 10 parts per billion (ppb).

RECOMMENDATIONS

As is true of any preliminary investigation, definite conclusions are impossible to obtain. Large gaps in the data exist because data are either insufficient or totally lacking; an obvious need for further research is indicated. Problem areas with many unanswered questions indicate that further study of the entire Big Sioux Aquifer is justified.

A suggested approach would be to split any future research into two general catagories. The first would be the establishment of a statistical sampling network to construct a baseline for the aquifer as a whole; the second would delineate and concentrate on specific problem areas.

Data from the two categories would reinforce one another as sampling would overlap.

Specific problem areas suggested for study are:

1. Castlewood - Bruce vicinity
2. Elkton area
3. Entire aquifer between Flandreau and Egan
4. Selected sanitary landfills
5. Selected sewage lagoons

Chemical parameters suggested for study are:

1. Common ions: Ca, Na, Mg, K, Fe, Mn, F, NO3, Cl, and SO4.
2. Trace elements: Hg, Ba, Ag, Se, As, Cr, Zn, Cu, and Cd.
3. Organic compounds such as commonly used pesticides and herbicides.

In addition to the above, future studies should include a compilation of possible point sources--sanitary landfills, sewage lagoons, manufacturing sources, and stockyards. This portion of the study would be used for selecting the specific problem areas mentioned above.

REFERENCES CITED

Adolphson, D. G., and Ellis, M. J., 1964, Basic hydrogeologic data, Skunk Creek-Lake Madison drainage basin, South Dakota: South Dakota Geol. Survey and South Dakota State Water Resources Commission Water Resources Rept. no. 3, 68 p.

Baker, G. K., 1963, Water supply for the city of Beresford: South Dakota Geol. Survey Spec. Rept. no. 22, 34 p.

Barari, A., 1967, Ground-water supply for the city of Dell Rapids: South Dakota Geol. Survey Spec. Rept. no. 39, 70 p.

------ 1968, Ground-water investigation for the city of Brookings: South Dakota Geol. Survey Spec. Rept. no. 45, 51 p.

------ 1971, Hydrology of Lake Poinsett: South Dakota Geol. Survey Rept. Inv. no. 102, 69 p.

------ 1971, Hydrology of Lake Kampeska: South Dakota Geol. Survey Rept. Inv. no. 103, 84 p.

------ 1971, Ground-water investigation for the city of Volga: South Dakota Geol. Survey Spec. Rept. no. 51, 33 p.

------ 1972, Ground-water investigation for the city of Baltic: South Dakota Geol. Survey Spec. Rept. no. 56, 19 p.

------ 1979, Ground-water study in the vicinity of Brandon: South Dakota Geol. Survey Open-File Report 27-UR, 27 p.

Barari, A., and Beissel, D., 1976, Ground-water study for the Brookings-Deuel rural water system: South Dakota Geol. Survey Open-File Report 7-UR, 113 p.

Barari, A, and Green, Susan, in preparation, Ground-water study for the city of Fairview, open-file report.

Beffort, J. D., 1969, Ground-water investigation for the city of Lennox: South Dakota Geol. Survey Spec. Rept. 46, 44 p.

Beffort, J. D., and Hedges, L. S., 1967, Ground-water supply for the city of Waubay: South Dakota Geol. Survey Spec. Rept. no. 40, 40 p.

Division of Sanitary Engineering, South Dakota Department of Health, 1959, South Dakota Public Water Supply Data, 31 p.

Ellis, M. J., and Adolphson, D. G., 1969, Basic hydrogeologic data for a part of the Big Sioux drainage basin, eastern South Dakota: South Dakota Geol. Survey and South Dakota Water Resources Commission Water Resources Rept. no. 5, 124 p.

Flint, R. F., 1955, Pleistocene geology of eastern South Dakota: U.S. Geol. Survey Prof. Paper 262, pl. no. 1.

Iles, D., in preparation, Ground-water study for the Sioux Falls-Brandon area: South Dakota Geol. Survey open-file report.

Jorgenson, D. G., 1960, Geology and shallow ground water resources of the Missouri valley between North Sioux City and Yankton, South Dakota: South Dakota Geol. Survey Rept. Inv. no. 86, 54 p.

------ 1966, Ground water supply for the city of Lake Norden: South Dakota Geol. Survey Spec. Rept. no. 34, 37 p.

Leap, D., in preparation, Geology and water resources of Day County, South Dakota: South Dakota Geol. Survey Bull. no. 24.

Lee, K. Y., 1958, Geology and shallow ground-water resources of the Brookings area, Brookings County, South Dakota: South Dakota Geol. Survey Rept. Inv. no. 84, 62 p.

------ 1958, Geology of the Brookings quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.

------ 1958, Geology of the White quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.

------ 1960, Geology of the Flandreau quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.

------ 1960, Geology of the Rutland quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.

Lee, K. Y., and Powell, J. E., 1961, Geology and ground water resources of glacial deposits in the Flandreau area, Brookings, Moody, and Lake Counties, South Dakota: South Dakota Geol. Survey Rept. Inv. no. 87, 117 p.

McMeen, J. A., 1964, Ground water supply for the city of Canton: South Dakota Geol. Survey Spec. Rept. no. 31, 40 p.

------ 1964, Ground water supply for the city of Harrisburg: South Dakota Geol. Survey Spec. Rept. no. 26, 27 p.

Office of Water Hygiene, South Dakota Department of Environmental Protection, 1979, South Dakota Public Water Supply Chemical Data. unpaginated.

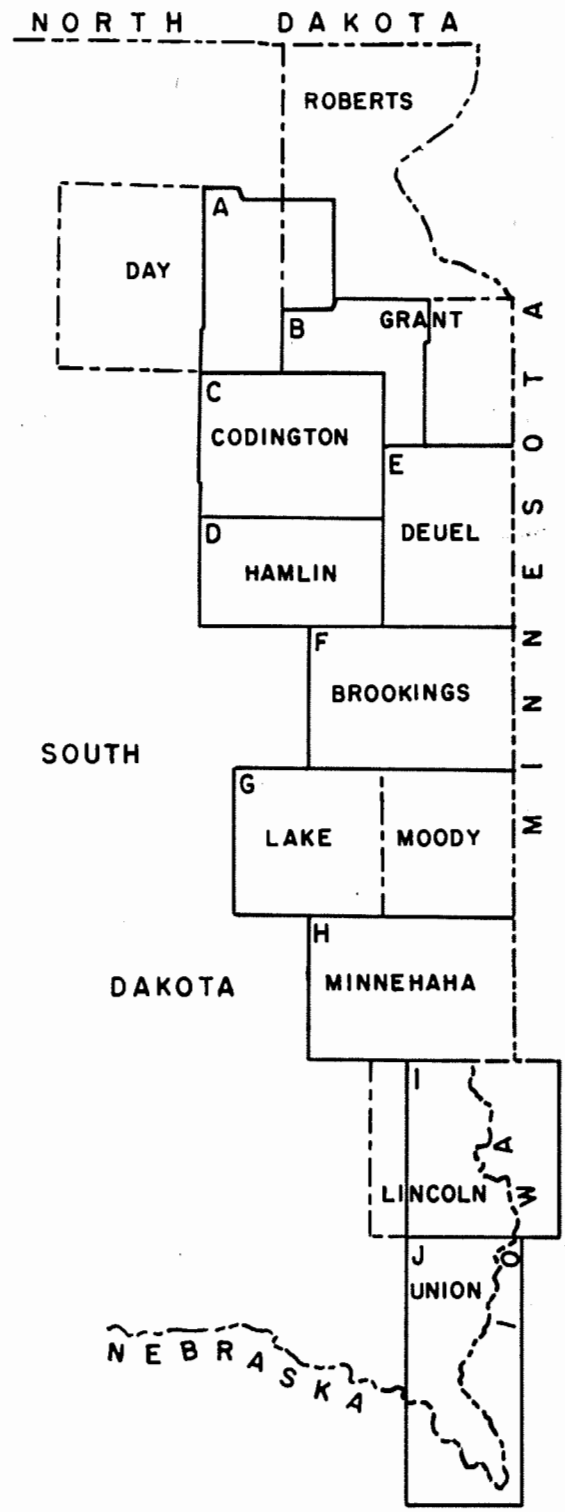
Rukstad, L. R., and Hedges, L. S., 1964, Ground water supply for

the city of Watertown: South Dakota Geol. Survey Spec. Rept. no. 28, 32 p.
Schroeder, W., 1976, Sand and gravel resources in Deuel County, South Dakota: South Dakota Geol. Survey Inf. Pamphlet no. 9, 20 p.
------ 1976, Sand and gravel resources in Hamlin County, South Dakota: South Dakota Geol. Survey Inf. Pamphlet no. 10, 29 p.
South Dakota Water Rights Commission, 1975, Observation well report, 94 p.
Steece, F. V., 1958, Geology and shallow ground water resources of the Watertown-Estelline area, South Dakota: South Dakota Geol. Survey Rept. Inv. no. 85, 36 p.
------ 1958, Geology of the Estelline quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.
------ 1958, Geology of the Hayti quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.
------ 1958, Geology of the Watertown quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.
------ 1959, Geology of the Hartford quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.
------ 1959, Geology of the Sioux Falls quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.
Tipton, M. J., 1958, Geology of the Florence quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.
------ 1958, Geology of the Henry quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.
------ 1958, Geology of the South Shore quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.
------ 1958, Geology of the Still Lake quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.
------ 1959, Geology of the Chester quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.
------ 1959, Geology of the Dell Rapids quadrangle, South Dakota: South Dakota Geol. Survey Geol. Quad. map with text.

PLATE 1(A-J)

Maps displaying concentrations of total solids in ground water from the Big Sioux Aquifer.

INDEX MAP



T124N

T123N

T122N

T121N

T120N

GRENVILLE

WAUBAY

ORTLEY

SUMMIT

264

364

372

304

316

491

444

696

460

528

1368

R52W

R51W

R55W

R54W

R53W

ROBERTS COUNTY

DAY COUNTY

TOTAL SOLIDS

PLATE 1A

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

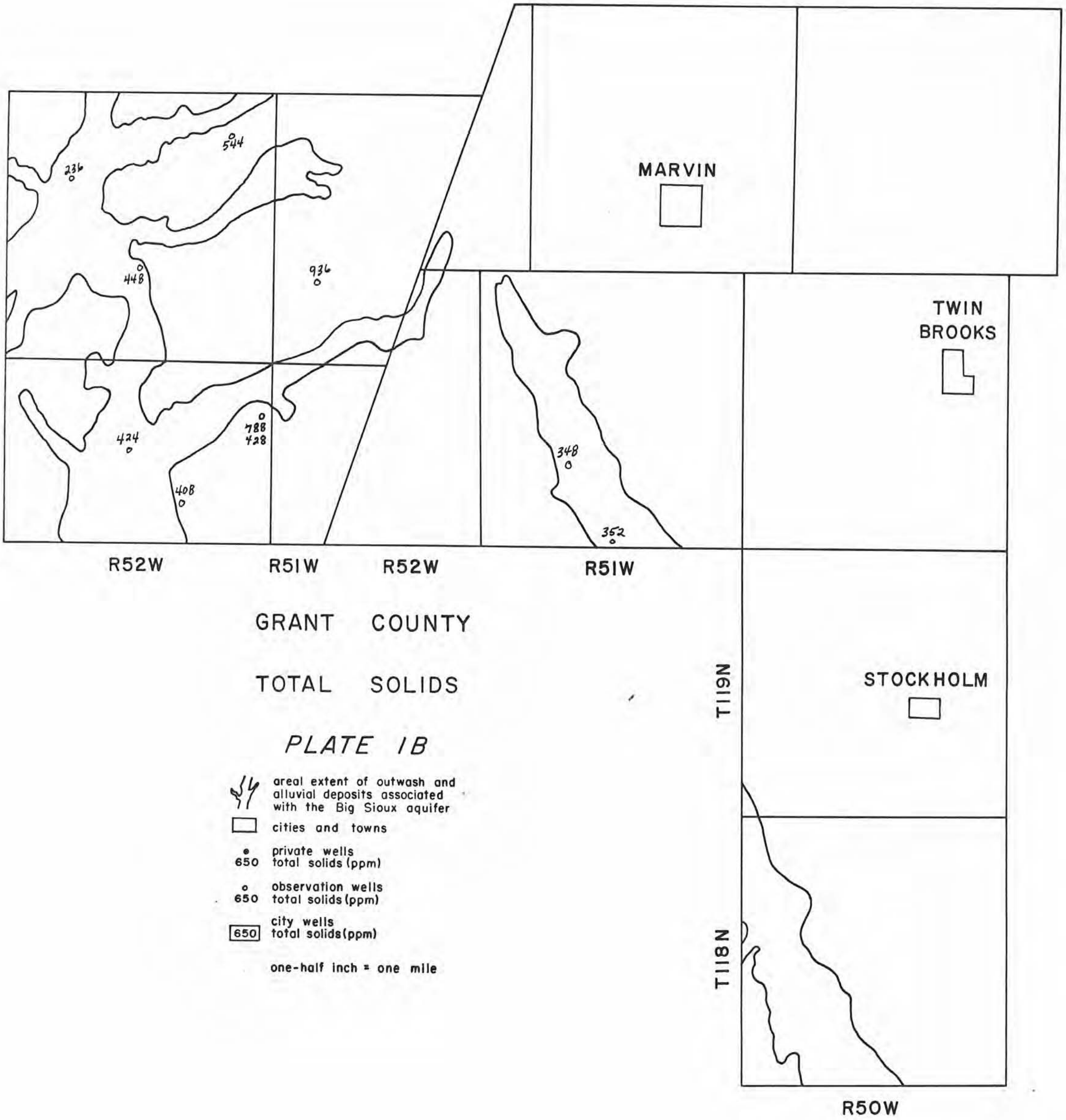
cities and towns

• 650 private wells total solids (ppm)

o 650 observation wells total solids (ppm)

[650] city wells total solids (ppm)

one-half inch = one mile



GRANT COUNTY

TOTAL SOLIDS

PLATE 1B

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 650 private wells total solids (ppm)

o 650 observation wells total solids (ppm)

[650] city wells total solids (ppm)

one-half inch = one mile

R55W

R54W

R52W

R52W

T120N

T119N

T118N

T117N

T116N

R53W

R51W

WALLACE

FLORENCE

SOUTH SHORE

WATERTOWN

KRANZBURG

HENRY

CODINGTON COUNTY

TOTAL SOLIDS

992

648

620 544

892

680

1556

344

712

520

512

660

614

1140, 1612

400 352

638

682 1184

642

648 488

672 1147

1147

458

487 776
421 776
333
574 333

852

1040

907

573

1084

600 454, 497

2335

1365

618
718
752

PLATE IC

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

650 private wells total solids (ppm)

650 observation wells total solids (ppm)

650 city wells total solids (ppm)

one-half inch = one mile

PLATE ID

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

650 private wells total solids (ppm)

650 observation wells total solids (ppm)

650 city wells total solids (ppm)

one-half inch = one mile

T115N

T114N

T113N

R55W

R54W

R53W

R52W

R51W

CASTLEWOOD

HAYTI

LAKE NORDEN

ESTELLINE

HAMLIN COUNTY TOTAL SOLIDS

PLATE IE

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

private wells
650 total solids (ppm)

observation wells
650 total solids (ppm)

city wells
650 total solids (ppm)

one-half inch = one mile

T117N

T116N

T115N

T114N

T113N

GOODWIN

ALTAMONT

1568

396

520

523

596 340

418
350
446

CLEAR LAKE

252
689
633

693

990

666

1020

920

696
1090

872

990

790

1980

BRANT

624

1368

480

692

420

296

TORONTO

R50W R49W R48W R47W

DEUEL COUNTY TOTAL SOLIDS

T112N

T111N

T110N

T109N

PLATE 1F

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 650 private wells total solids (ppm)

o 650 observation wells total solids (ppm)

[650] city wells total solids (ppm)

one-half inch = one mile

BRUCE

WHITE

VOLGA

BROOKINGS

BUSHNELL

AURORA

SINAI

ELKTON

R52W R51W R50W R49W R48W R47W

BROOKINGS COUNTY TOTAL SOLIDS

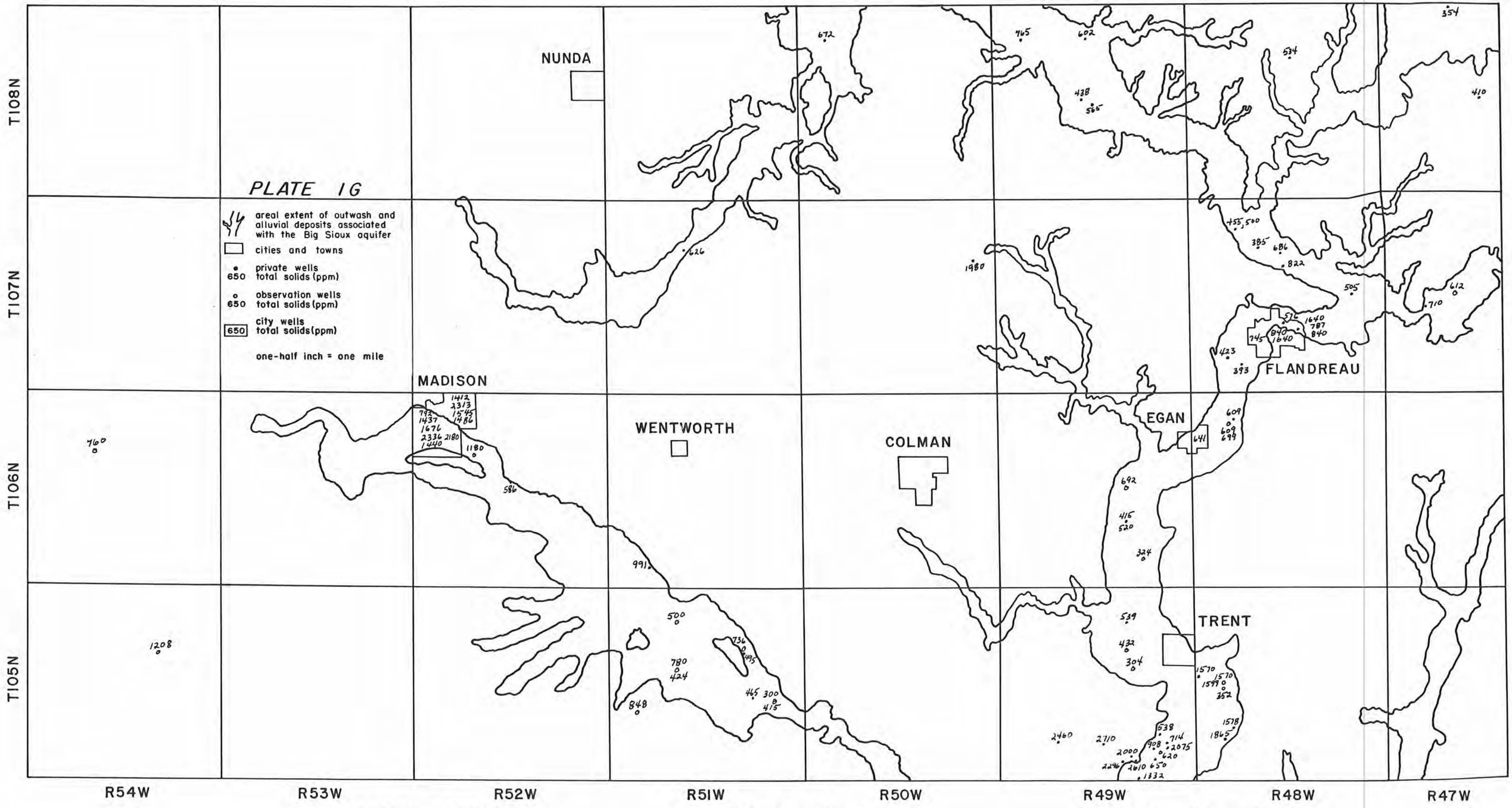


PLATE 1G
areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer
cities and towns
private wells
650 total solids (ppm)
observation wells
650 total solids (ppm)
city wells
650 total solids (ppm)
one-half inch = one mile
NUNDA
MADISON
WENTWORTH
COLMAN
EGAN
FLANDREAU
TRENT
T108N
T107N
T106N
T105N
R54W
R53W
R52W
R51W
R50W
R49W
R48W
R47W
LAKE COUNTY
TOTAL SOLIDS
MOODY COUNTY

T104N

T103N

T102N

T101N

COLTON

790
633
1087

532
478

584
632

536

910

423

692
542

986

269

448
425
382

HUMBOLDT

1038
1028

HARTFORD

DELL RAPIDS

600
1320
2000
1115
1542

1430

617

1130

428
523
474

1970
874

2740

473
356

BALTIC

606
676
638
926
522
676
2323

870

404
310

980

550

1532

1265

668

1580

SHERMAN

568

GARRETSON

1120
520
540
500

BRANDON

416

640

340
616

668

VALLEY SPRINGS

704

1460

660

652 (avg.)

SIOUX FALLS

1396

1450

379

414

PLATE IH

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 650 private wells total solids (ppm)

○ 650 observation wells total solids (ppm)

[650] city wells total solids (ppm)

one-half inch = one mile

R52W R51W R50W R49W R48W R47W

MINNEHAHA COUNTY TOTAL SOLIDS

T100N
T99N
T98N
T97N
T96N
R50W
R49W
R48W
R47W
HARRISBURG
WORTHING
CANTON
FAIRVIEW
HUDSON
BERESFORD
LINCOLN COUNTY
LYON COUNTY
SIOUX COUNTY
TOTAL SOLIDS
1525
2605
1212
3100
3320
1800
2470
2728
2620
2800
1720
715
2620
1580
2330
878
1355
1970
1562
3090
386
1603
2372
500
734
656
1442
600
1290
1208
2218
2754
2810
3942
3718
2410
1074
526
PLATE II
areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer
cities and towns
• 650 private wells total solids (ppm)
○ 650 observation wells total solids (ppm)
650 city wells total solids (ppm)
one-half inch = one mile

BERESFORD

ALCESTER

SIOUX COUNTY

PLYMOUTH COUNTY

ELK POINT

JEFFERSON

NORTH SIOUX CITY

UNION COUNTY

WOODBURY COUNTY

T95N

T94N

T93N

T92N

T91N

T90N

T89N

R50W

R49W

R48W

1170
1618
859
2205
402
3086
490
2672
512
592
549
472
1824
325
1434
769
1804
748
388
1436
1494
636
328
632
307
488
582
824
684
688

PLATE IJ

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 650 private wells total solids (ppm)

○ 650 observation wells total solids (ppm)

[650] city wells total solids (ppm)

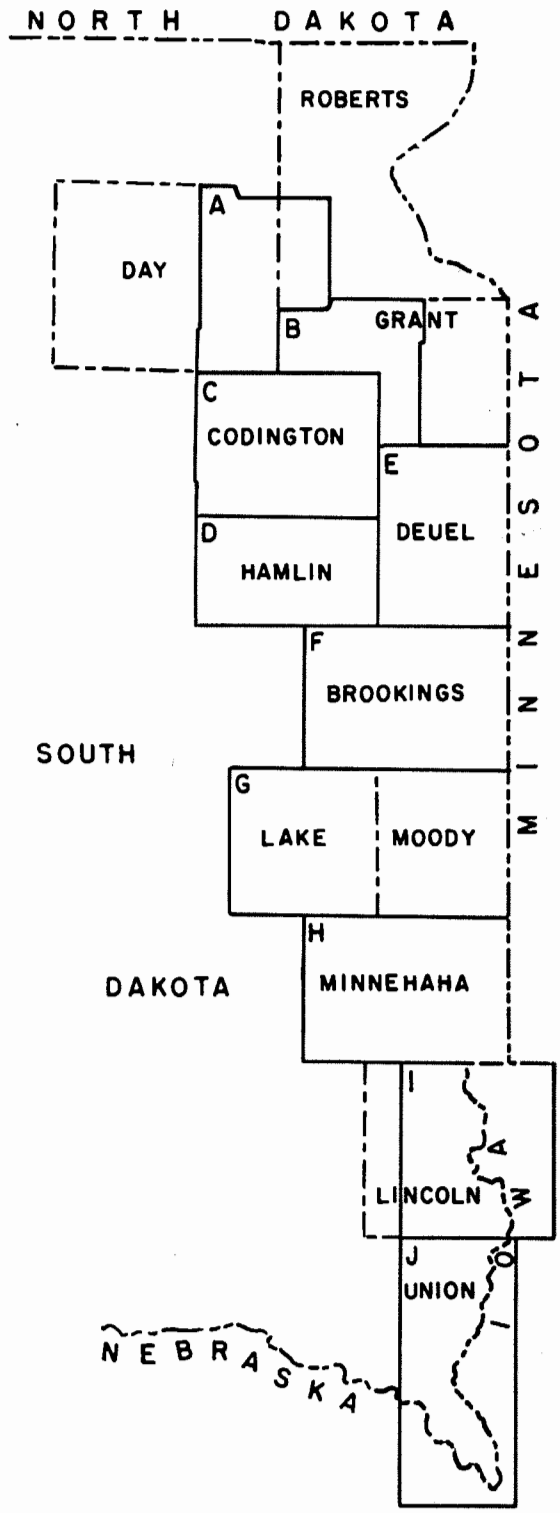
one-half inch = one mile

TOTAL SOLIDS

PLATE 2(A-J)

Maps displaying nitrate-nitrogen values in ground water from the Big Sioux Aquifer.

INDEX MAP



T124N

T123N

T122N

T121N

T120N

GRENVILLE

4.5

WAUBAY

0.0
0.0

9.70

8.20

1.53

3.50

2.30

ORTLEY

10.25

SUMMIT

0.42

0.65

0.49

0.91

R55W

R54W

R53W

R52W

R51W

DAY COUNTY

ROBERTS COUNTY

NITRATE LEVELS

PLATE 2A

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 0.01 private wells nitrate concentration (ppm)

o 0.01 observation wells nitrate concentration (ppm)

[0.01] city wells nitrate concentration (ppm)

one-half inch = one mile

MARVIN

TWIN BROOKS

STOCKHOLM

T121N

T120N

T119N

T118N

R52W R51W R52W R51W R50W

1.75
4.8
3.00
2.60
0.43
0.45
0.79
0.66
0.0
0.06

GRANT COUNTY

NITRATE LEVELS

PLATE 2B

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 0.01 private wells nitrate concentration (ppm)

o 0.01 observation wells nitrate concentration (ppm)

[0.01] city wells nitrate concentration (ppm)

one-half inch = one mile

R55W

R54W

R52W

R52W

T120N

T119N

T118N

T117N

T116N

WALLACE

FLORENCE

SOUTH SHORE

WATERTOWN

KRANZBURG

HENRY

CODINGTON COUNTY

NITRATE LEVELS

R53W

R51W

0.32

6.90

0.0

0.52

19.0

3.30

0.0

0.32

0.0

2.56

0.0

5.75

0.20

0.07

Tr

3.80

5.0

0.65

0.07

0.0

7.3

0.0

0.0

0.0

2.0

0.0

0.0

0.79

0.2

1.0

1.68

0.22

PLATE 2C

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

0.01 private wells nitrate concentration (ppm)

0.01 observation wells nitrate concentration (ppm)

[0.01] city wells nitrate concentration (ppm)

one-half inch = one mile

PLATE 2D

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 0.01 private wells nitrate concentration (ppm)

○ 0.01 observation wells nitrate concentration (ppm)

[0.01] city wells nitrate concentration (ppm)

one-half inch = one mile

T115N

T114N

T113N

R55W R54W R53W R52W R51W

CASTLEWOOD

HAYTI

LAKE NORDEN

ESTELLINE

5.0

5.0
16.0

0.0

0.0

0.0

20.1

57.0

2.4

0.0

0.22

0.0

0.0

0.02

2.0

0.0

4.7

4.5

0.62

0.13

0.0

0.0

20.0

0.11

0.0

0.07

0.00

17.0

12.0

0.00

0.40

0.03

HAMLIN COUNTY NITRATE LEVELS

PLATE 2E

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

private wells
0.01 nitrate concentration (ppm)

observation wells
0.01 nitrate concentration (ppm)

city wells
[0.01] nitrate concentration (ppm)

one-half inch = one mile

T117N

T116N

T115N

T114N

T113N

GOODWIN

ALTAMONT

CLEAR LAKE

BRANT

TORONTO

0.04

2.8

0.05

1.7

2.4
7.9
17.2

18.0 1.5

1.5
0.4

13.4 1.5

33.0

.0.5

2.0

2.8
0.5

10.0

0.09

4.0

2.0

4.7

14.0

0.03 0.09

7.8

R50W R49W R48W R47W

DEUEL COUNTY NITRATE LEVELS

T112N

T111N

T110N

T109N

PLATE 2F

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

private wells
0.01 nitrate concentration (ppm)

observation wells
0.01 nitrate concentration (ppm)

city wells
0.01 nitrate concentration (ppm)

one-half inch = one mile

BRUCE

WHITE

VOLGA

BROOKINGS

BUSHNELL

AURORA

SINAI

ELKTON

R52W R51W R50W R49W R48W R47W

BROOKINGS COUNTY NITRATE LEVELS

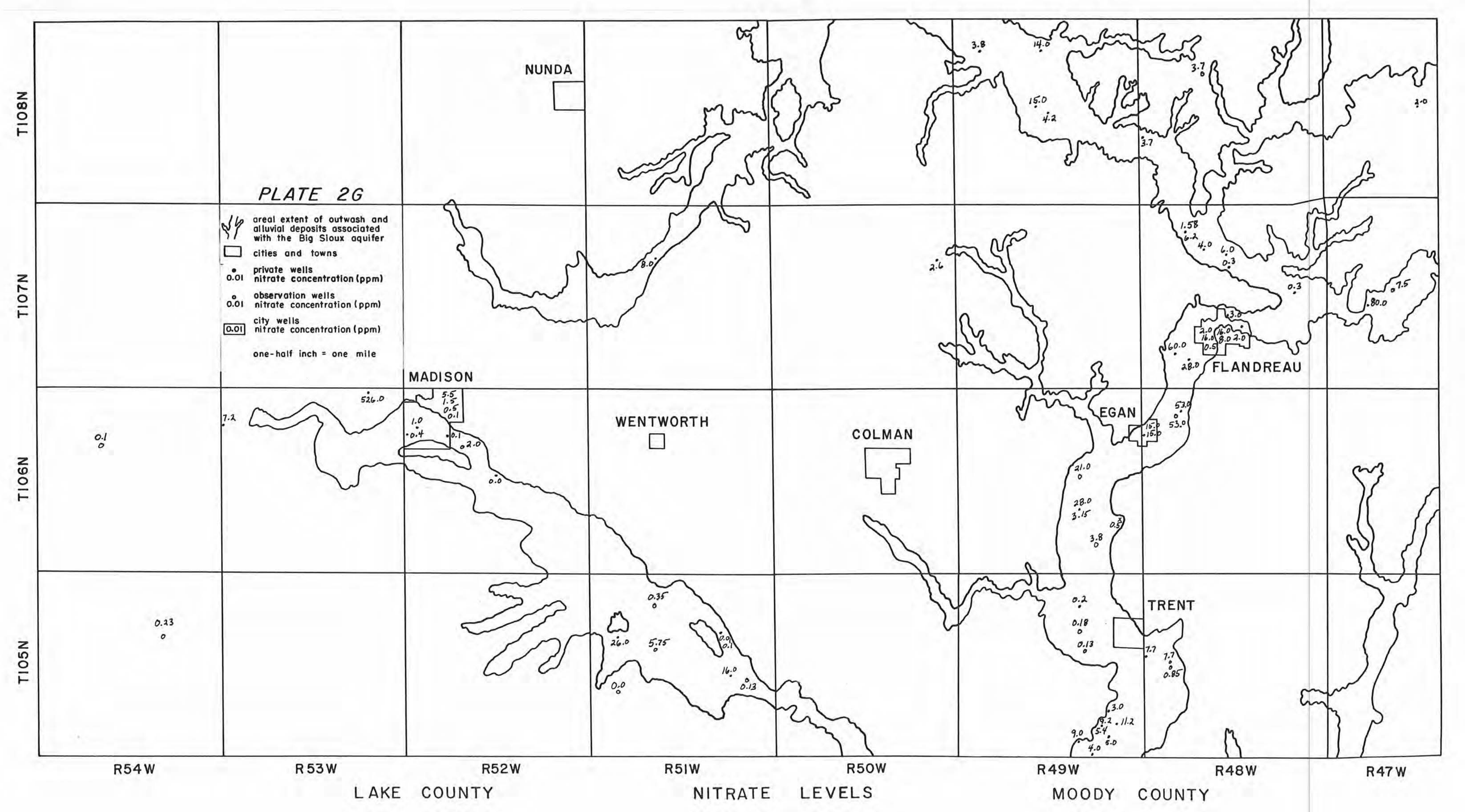


PLATE 2G
areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer
cities and towns
private wells nitrate concentration (ppm)
observation wells nitrate concentration (ppm)
city wells nitrate concentration (ppm)
one-half inch = one mile
NUNDA
MADISON
WENTWORTH
COLMAN
EGAN
FLANDREAU
TRENT
T108N
T107N
T106N
T105N
R54W
R53W
R52W
R51W
R50W
R49W
R48W
R47W
LAKE COUNTY
NITRATE LEVELS
MOODY COUNTY

T104N

T103N

T102N

T101N

COLTON

DELL RAPIDS

BALTIC

SHERMAN

GARRETSON

HUMBOLDT

HARTFORD

BRANDON

VALLEY SPRINGS

SIOUX FALLS

PLATE 2H

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

0.01 private wells nitrate concentration (ppm)

0.01 observation wells nitrate concentration (ppm)

[0.01] city wells nitrate concentration (ppm)

one-half inch = one mile

R52W R51W R50W R49W R48W R47W

MINNEHAHA COUNTY NITRATE LEVELS

T100N

T99N

T98N

T97N

T96N

HARRISBURG

WORTHING

CANTON

FAIRVIEW

HUDSON

BERESFORD

LINCOLN COUNTY

LYON COUNTY

SIOUX COUNTY

NITRATE LEVELS

PLATE 2I

0.8
0.08
0.3
5.0
0.7
0.3
25.0
3.6
0.0
11.0
26.0
0.0
0.8
1.2

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 0.01 private wells nitrate concentration (ppm)

o 0.01 observation wells nitrate concentration (ppm)

[0.01] city wells nitrate concentration (ppm)

one-half inch = one mile

R50W

R49W

R48W

R47W

T95N

T94N

T93N

T92N

T91N

T90N

T89N

R50W

R49W

R48W

BERESFORD

ALCESTER

ELK POINT

JEFFERSON

NORTH SIOUX CITY

0.3

0.0

0.8

0.07

1.4

0.85

1.17

2.7

0.55

1.45

1.48

0.01

4.6

0.0

1.61

1.75

0.01

1.20

0.84

1.28

0.59

0.85

1.36

0.23

0.0

0.77

1.91

1.48

SIOUX COUNTY

PLYMOUTH COUNTY

UNION COUNTY

WOODBURY COUNTY

PLATE 2J

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

private wells
0.01 nitrate concentration (ppm)

observation wells
0.01 nitrate concentration (ppm)

city wells
0.01 nitrate concentration (ppm)

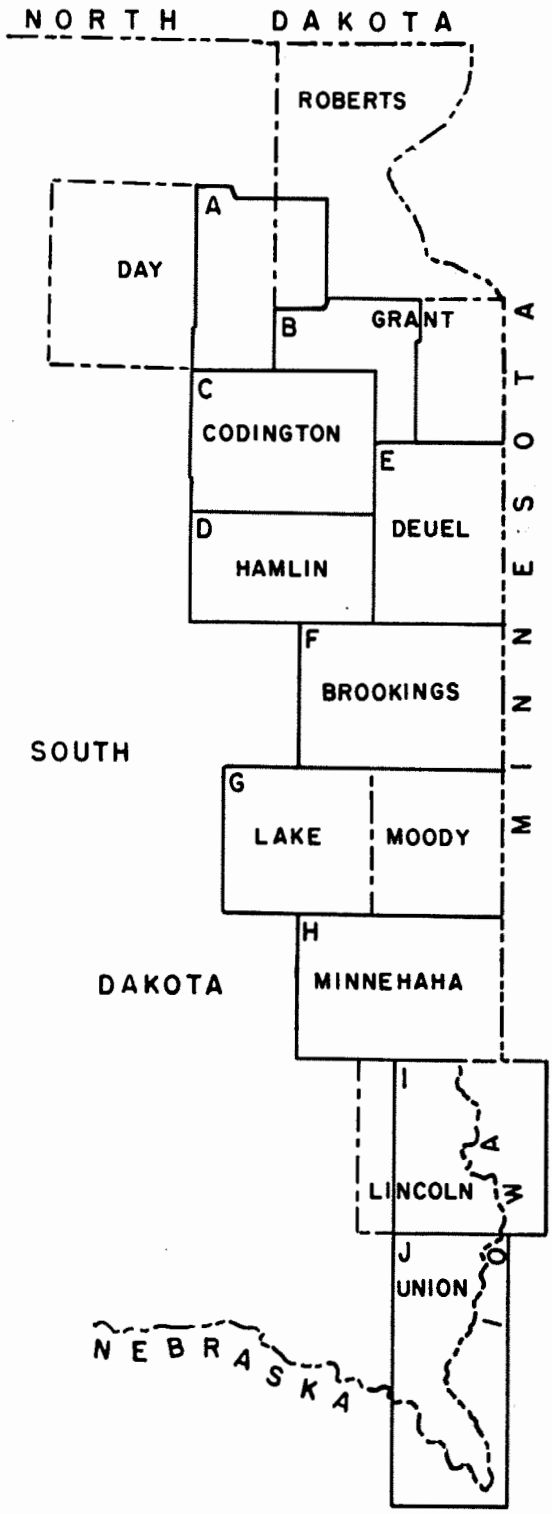
one-half inch = one mile

NITRATE LEVELS

PLATE 3(A-J)

Maps displaying contours on the water table surface in the Big Sioux Aquifer.

INDEX MAP



T124N

T123N

T122N

T121N

T120N

GRENVILLE

WAUBAY

ORTLEY

SUMMIT

R55W R54W R53W R52W R51W

ROBERTS COUNTY

DAY COUNTY

Possible ground water divide

WATER TABLE

PLATE 3A

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 1250 test hole water level (msl elevation)

o 1250 observation well water level (msl elevation)

x 1250 irrigation well water level (msl elevation)

contour interval - 20 feet

one-half inch = one mile

MARVIN

TWIN BROOKS

STOCKHOLM

T121N

T120N

T119N

T118N

R52W R51W R52W R51W R50W

GRANT COUNTY

WATER TABLE

PLATE 3B

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 1250 test hole water level (msl elevation)

o 1250 observation well water level (msl elevation)

x 1250 irrigation well water level (msl elevation)

contour interval - 20 feet

one-half inch = one mile

R55W

R54W

R52W

R52W

T120N

T119N

T118N

T117N

T116N

T119N

T118N

WALLACE

FLORENCE

SOUTH SHORE

WATERTOWN

KRANZBURG

HENRY

CODINGTON COUNTY

WATER TABLE

R53W

R51W

PLATE 3C

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 1250 test hole water level (msl elevation)

o 1250 observation well water level (msl elevation)

x 1250 irrigation well water level (msl elevation)

contour interval - 20 feet

one-half inch = one mile

PLATE 3D

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

test hole
1250 water level (msl elevation)

observation well
1250 water level (msl elevation)

irrigation well
1250 water level (msl elevation)

contour interval - 20 feet

one-half inch = one mile

CASTLEWOOD

HAYTI

LAKE NORDEN

ESTELLINE

T115N

T114N

T113N

R55W

R54W

R53W

R52W

R51W

HAMLIN COUNTY WATER TABLE

PLATE 3E

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 1250 test hole water level (msl elevation)

○ 1250 observation well water level (msl elevation)

X 1250 irrigation well water level (msl elevation)

contour interval - 20 feet

one-half inch = one mile

T117N

T116N

T115N

T114N

T113N

GOODWIN

ALTAMONT

CLEAR LAKE

BRANT

TORONTO

R50W

R49W

R48W

R47W

DEUEL COUNTY WATER TABLE

PLATE 3F

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 1250 test hole water level (msl elevation)

○ 1250 observation well water level (msl elevation)

× 1250 irrigation well water level (msl elevation)

contour interval - 20 feet

one-half inch = one mile

BRUCE

WHITE

VOLGA

BROOKINGS

BUSHNELL

AURORA

SINAI

ELKTON

T112N

T111N

T110N

T109N

R52W

R51W

R50W

R49W

R48W

R47W

BROOKINGS COUNTY WATER TABLE

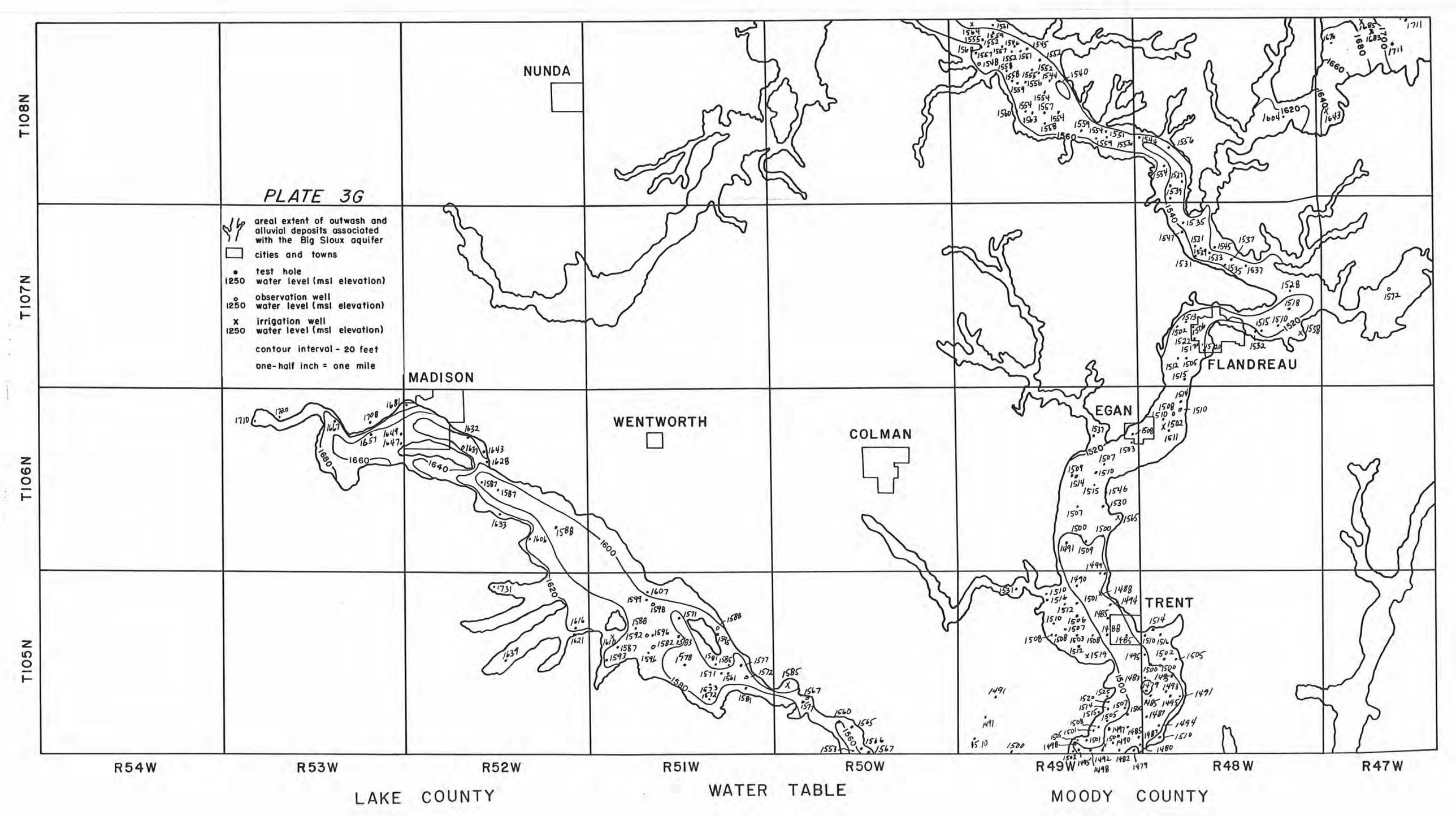


PLATE 3G
areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer
cities and towns
test hole
1250 water level (msl elevation)
observation well
1250 water level (msl elevation)
irrigation well
1250 water level (msl elevation)
contour interval - 20 feet
one-half inch = one mile
NUNDA
MADISON
WENTWORTH
COLMAN
EGAN
FLANDREAU
TRENT
T108N
T107N
T106N
T105N
R54W
R53W
R52W
R51W
R50W
R49W
R48W
R47W
LAKE COUNTY
WATER TABLE
MOODY COUNTY

T104N

T103N

T102N

T101N

COLTON

DELL RAPIDS

BALTIC

SHERMAN

GARRETSON

HUMBOLDT

HARTFORD

BRANDON

VALLEY SPRINGS

SIOUX FALLS

PLATE 3H

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 1250 test hole water level (msl elevation)

o 1250 observation well water level (msl elevation)

x 1250 irrigation well water level (msl elevation)

contour interval - 20 feet

one-half inch = one mile

R52W R51W R50W R49W R48W R47W

WATER TABLE

MINNEHAHA COUNTY

T100N
T99N
T98N
T97N
T96N
R50W
R49W
R48W
R47W
HARRISBURG
WORTHING
CANTON
FAIRVIEW
BERESFORD
HUDSON
LYON COUNTY
SIOUX COUNTY
LINCOLN COUNTY WATER TABLE
PLATE 3I
areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer
cities and towns
• 1250 test hole water level (msl elevation)
o 1250 observation well water level (msl elevation)
x 1250 irrigation well water level (msl elevation)
contour interval - 20 feet
one-half inch = one mile

BERESFORD

ALCESTER

SIOUX COUNTY

PLYMOUTH COUNTY

ELK POINT

JEFFERSON

NORTH SIOUX CITY

UNION COUNTY WATER TABLE

WOODBURY COUNTY

T95N

T94N

T93N

T92N

T91N

T90N

T89N

R50W

R49W

R48W

1354 1352 1338 1324 1320 1312 1300 1302 1295 1289 1280 1324 1160 1154 1331 1140 1130 1133 1128 1160 1120 1112 1109 1129 1110 1108 1104 1119 1115 1111 1110 1105 1107 1107 1098 1103 1104 1099 1103 1102 1095 1100 1100 1098 1099 1106 1103 1097 1095 1098 1087 1091 1087 1088 1097 1088 1082 1080

PLATE 3J

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

• 1250 test hole water level (msl elevation)

○ 1250 observation well water level (msl elevation)

× 1250 irrigation well water level (msl elevation)

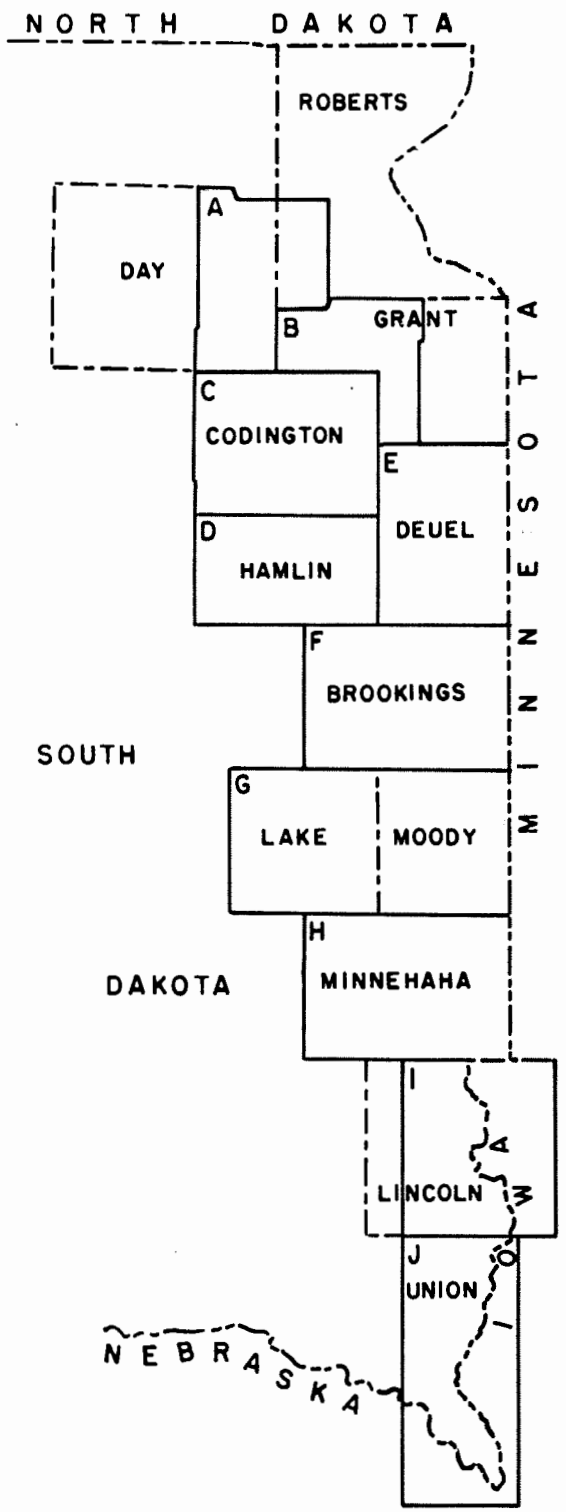
contour interval - 20 feet

one-half inch = one mile

PLATE 4(A-J)

Isopach maps showing thickness of saturated material in the Big Sioux Aquifer.

INDEX MAP



T124N

T123N

T122N

T121N

T120N

GRENVILLE

WAUBAY

ORTLEY

SUMMIT

R52W

R51W

ROBERTS COUNTY

R55W

R54W

R53W

DAY COUNTY

SATURATED THICKNESS

PLATE 4A

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

20 • thickness of saturated sand and gravel in test holes, observation wells, and irrigation tests

contour interval - 20 feet

one-half inch = one mile

MARVIN

TWIN BROOKS

STOCKHOLM

T121N

T120N

T119N

T118N

R52W R51W R52W R51W R50W

GRANT COUNTY

SATURATED THICKNESS

PLATE 4B

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

20 thickness of saturated sand and gravel in test holes, observation wells, and irrigation tests

contour interval - 20 feet

one-half inch = one mile

R55W

R54W

T120N

R52W

R52W

T119N

T119N

T118N

T118N

T117N

T116N

SOUTH SHORE

WALLACE

FLORENCE

WATERTOWN

KRANZBURG

HENRY

CODINGTON COUNTY

SATURATED THICKNESS

R53W

R51W

PLATE 4C

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

20 thickness of saturated sand and gravel in test holes, observation wells, and irrigation tests

contour interval - 20 feet

one-half inch = one mile

PLATE 4D

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

20 thickness of saturated sand and gravel in test holes, observation wells, and irrigation tests

contour interval - 20 feet

one-half inch = one mile

T115N

T114N

T113N

R55W R54W R53W R52W R51W

CASTLEWOOD

HAYTI

LAKE NORDEN

ESTELLINE

HAMLIN COUNTY SATURATED THICKNESS

PLATE 4E

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

20 thickness of saturated sand and gravel in test holes, observation wells, and irrigation tests

contour interval - 20 feet

one-half inch = one mile

GOODWIN

ALTAMONT

CLEAR LAKE

BRANT

TORONTO

T117N

T116N

T115N

T114N

T113N

R50W

R49W

R48W

R47W

DEUEL COUNTY SATURATED THICKNESS

PLATE 4F

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

20 thickness of saturated sand and gravel in test holes, observation wells, and irrigation tests

contour interval - 20 feet

one-half inch = one mile

BRUCE

WHITE

VOLGA

BROOKINGS

BUSHNELL

AURORA

SINAI

ELKTON

T112N

T111N

T110N

T109N

R52W

R51W

R50W

R49W

R48W

R47W

BROOKINGS COUNTY SATURATED THICKNESS

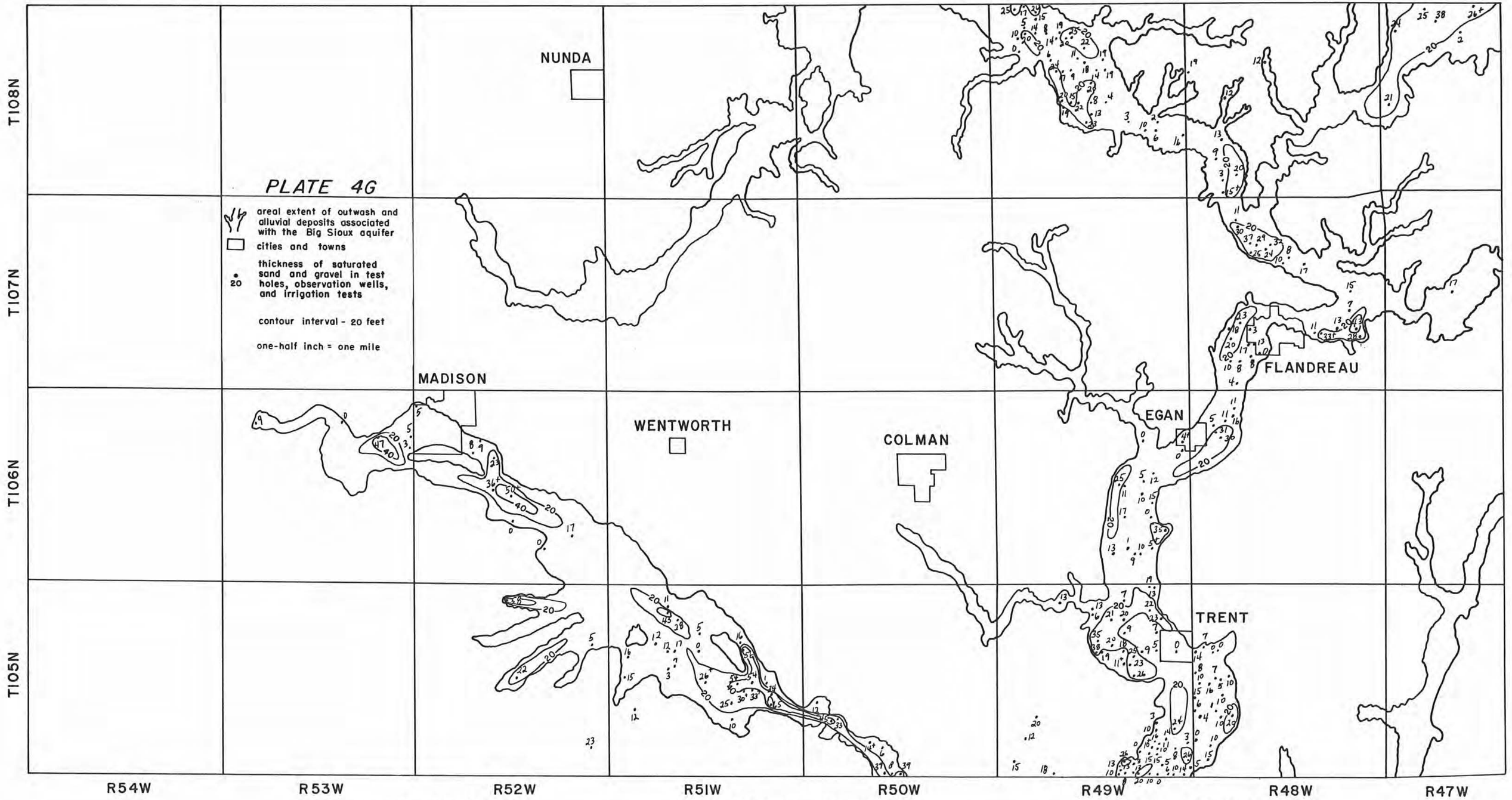


PLATE 4G
areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer
cities and towns
thickness of saturated sand and gravel in test holes, observation wells, and irrigation tests
20
contour interval - 20 feet
one-half inch = one mile
NUNDA
MADISON
WENTWORTH
COLMAN
EGAN
FLANDREAU
TRENT
T108N
T107N
T106N
T105N
R54W
R53W
R52W
R51W
R50W
R49W
R48W
R47W
LAKE COUNTY
SATURATED THICKNESS
MOODY COUNTY

T104N

T103N

T102N

T101N

COLTON

DELL RAPIDS

BALTIC

SHERMAN

GARRETSON

HUMBOLDT

HARTFORD

BRANDON

VALLEY SPRINGS

SIOUX FALLS

PLATE 4H

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

20 thickness of saturated sand and gravel in test holes, observation wells, and irrigation tests

contour interval - 20 feet

one-half inch = one mile

R52W R51W R50W R49W R48W R47W

MINNEHAHA COUNTY SATURATED THICKNESS

T100N

T99N

T98N

T97N

T96N

HARRISBURG

WORTHING

CANTON

FAIRVIEW

HUDSON

BERESFORD

LYON COUNTY

LINCOLN COUNTY

SIOUX COUNTY

SATURATED THICKNESS

PLATE 4I

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

20 thickness of saturated sand and gravel in test holes, observation wells, and irrigation tests

contour interval - 20 feet

one-half inch = one mile

R50W R49W R48W R47W

BERESFORD

ALCESTER

SIOUX COUNTY

PLYMOUTH COUNTY

UNION COUNTY

WOODBURY COUNTY

ELK POINT

JEFFERSON

NORTH SIOUX CITY

T95N

T94N

T93N

T92N

T91N

T90N

T89N

R50W

R49W

R48W

PLATE 4J

areal extent of outwash and alluvial deposits associated with the Big Sioux aquifer

cities and towns

20 thickness of saturated sand and gravel in test holes, observation wells, and irrigation tests

contour interval - 20 feet

one-half inch = one mile

SATURATED THICKNESS

FIGURE 1

FREQUENCY DIAGRAM FOR TOTAL DISSOLVED SOLIDS IN GROUNDWATER OF THE BIG SIOUX AQUIFER

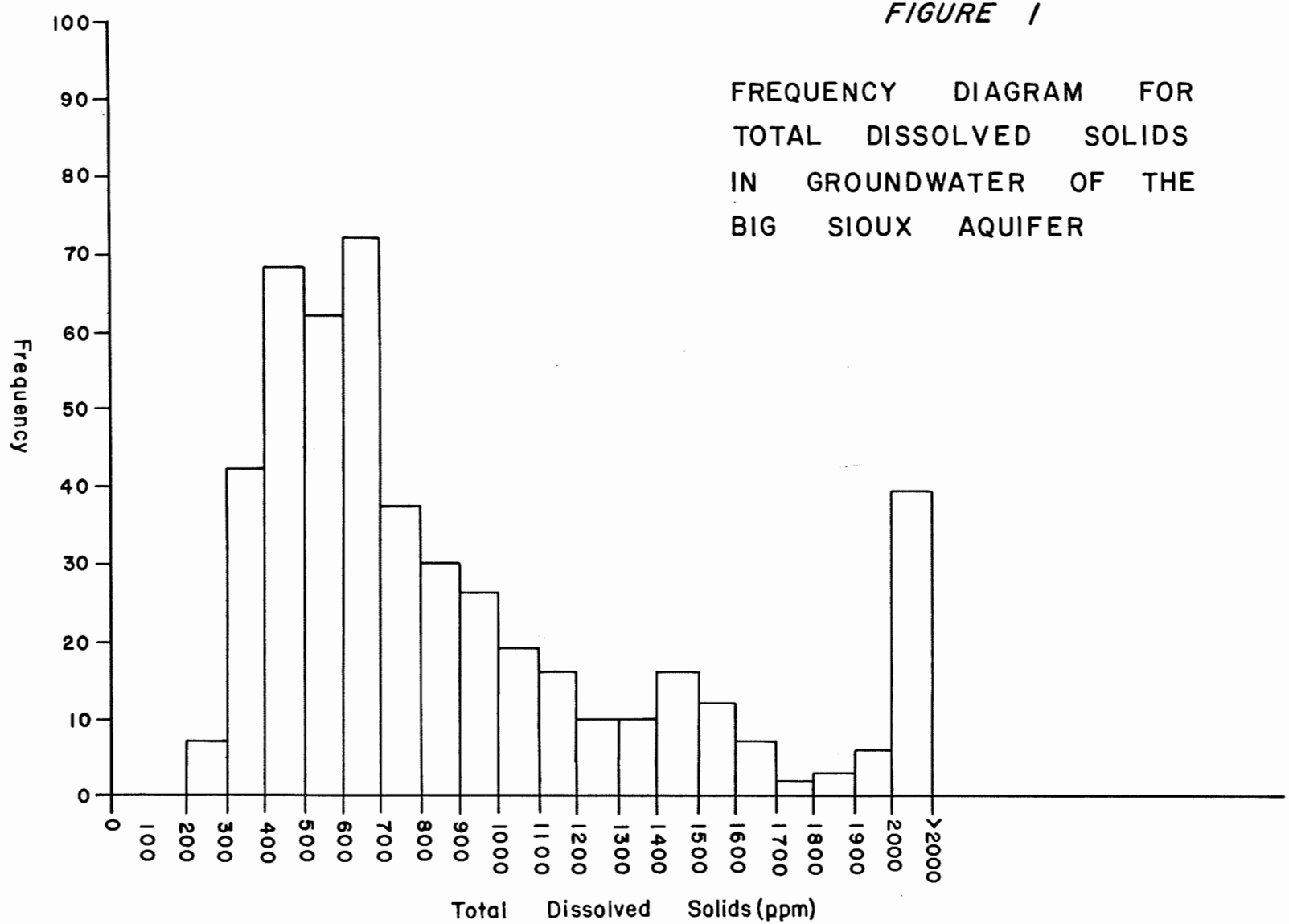


FIGURE 2

FREQUENCY DIAGRAM FOR SODIUM IN GROUNDWATER OF THE BIG SIOUX AQUIFER

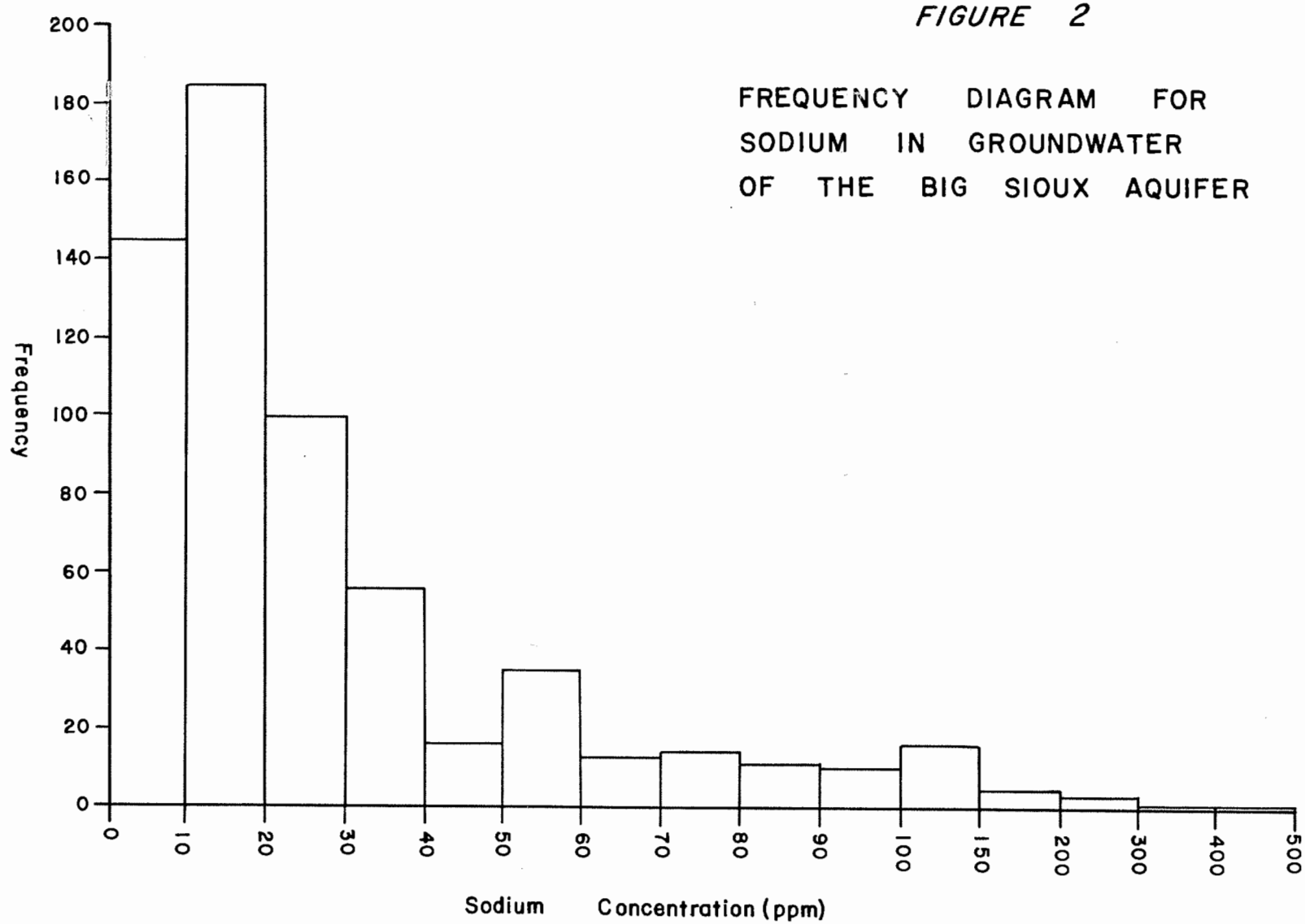


FIGURE 3

FREQUENCY DIAGRAM FOR MAGNESIUM IN GROUNDWATER OF THE BIG SIOUX AQUIFER

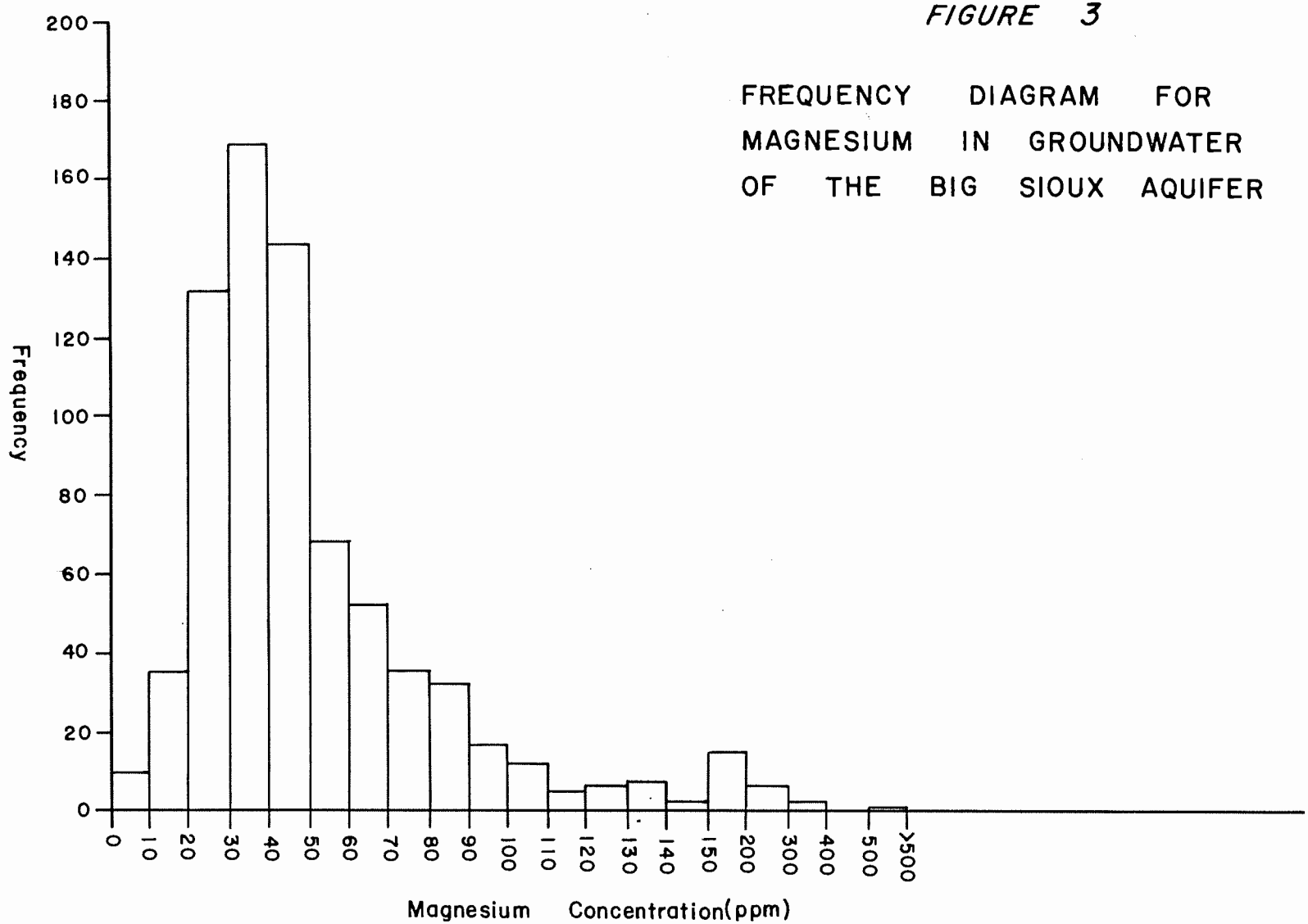


FIGURE 4

FREQUENCY DIAGRAM FOR CALCIUM IN GROUNDWATER OF THE BIG SIOUX AQUIFER

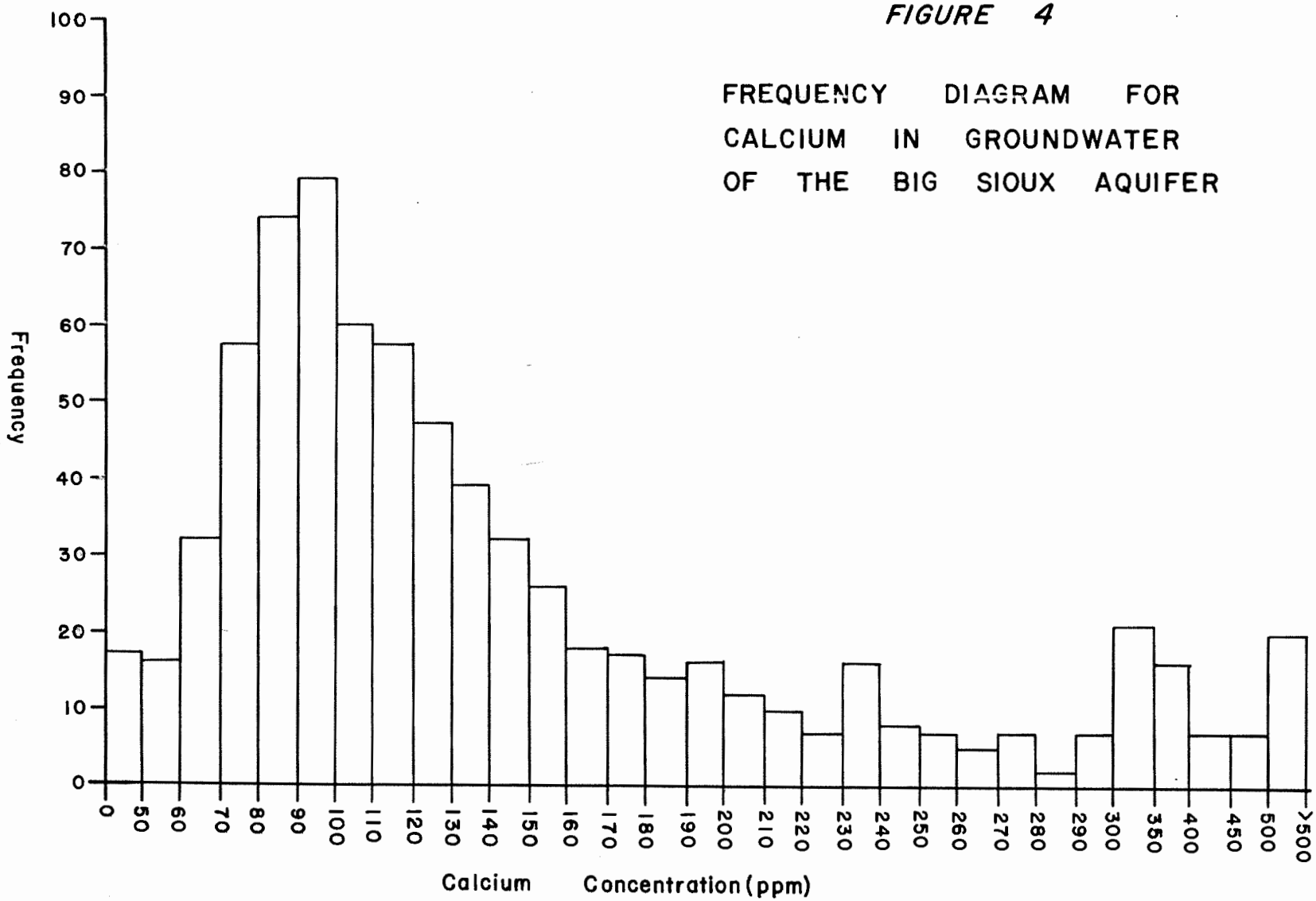


FIGURE 5

FREQUENCY DIAGRAM FOR CHLORIDE IN GROUNDWATER OF THE BIG SIOUX AQUIFER

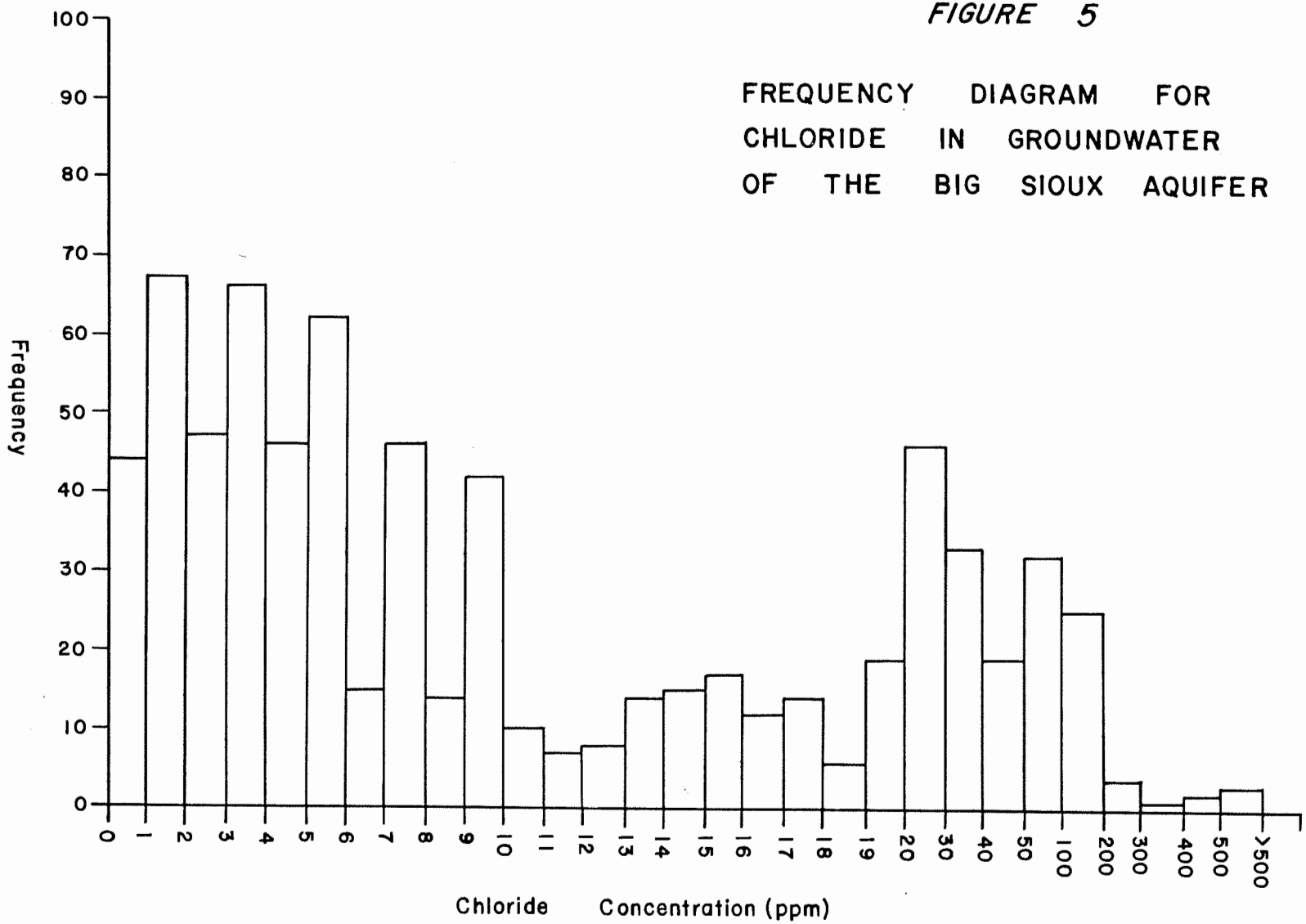


FIGURE 6

FREQUENCY DIAGRAM FOR IRON IN GROUNDWATER OF THE BIG SIOUX AQUIFER

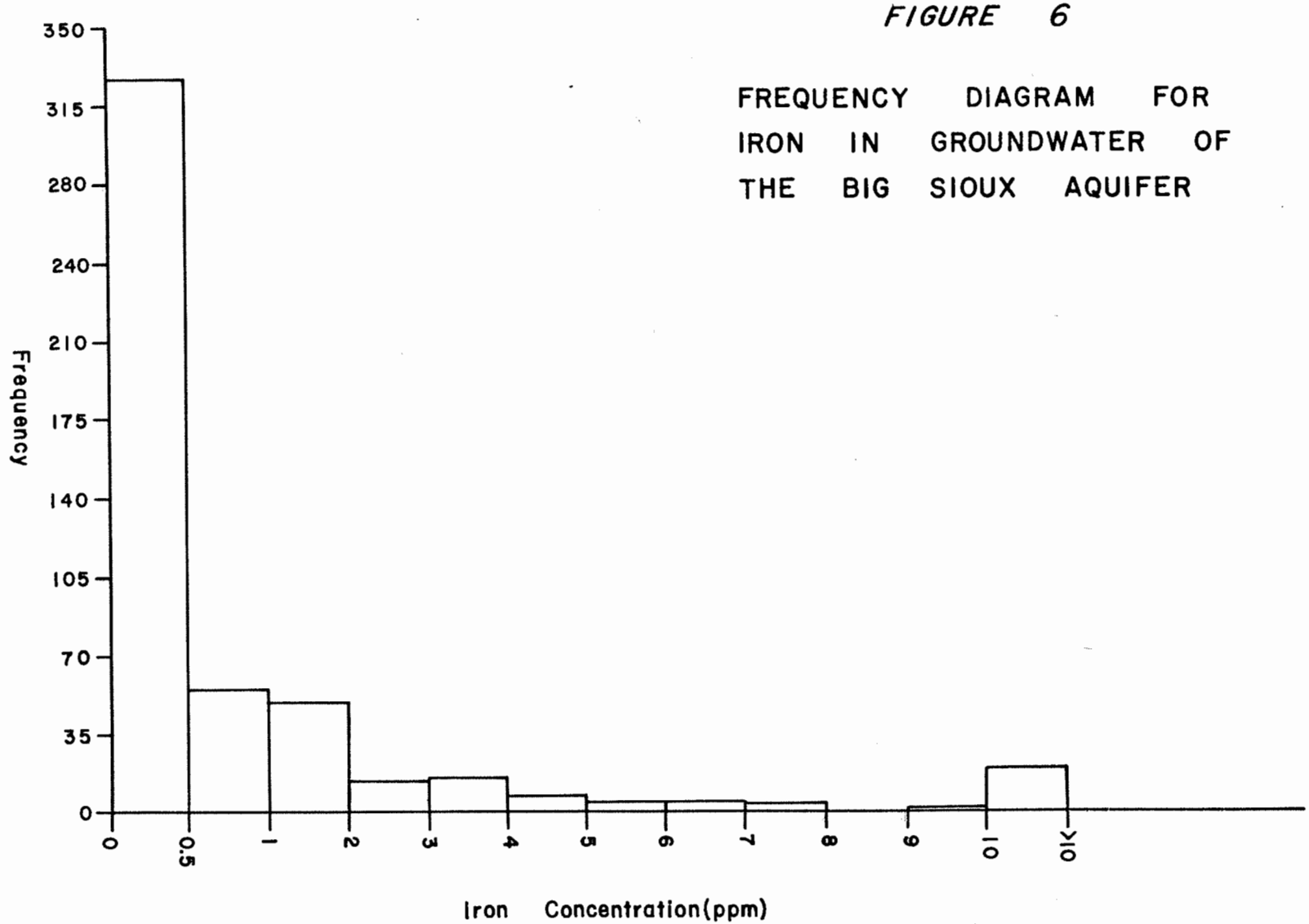


FIGURE 7

FREQUENCY DIAGRAM FOR MANGANESE IN GROUNDWATER OF THE BIG SIOUX AQUIFER

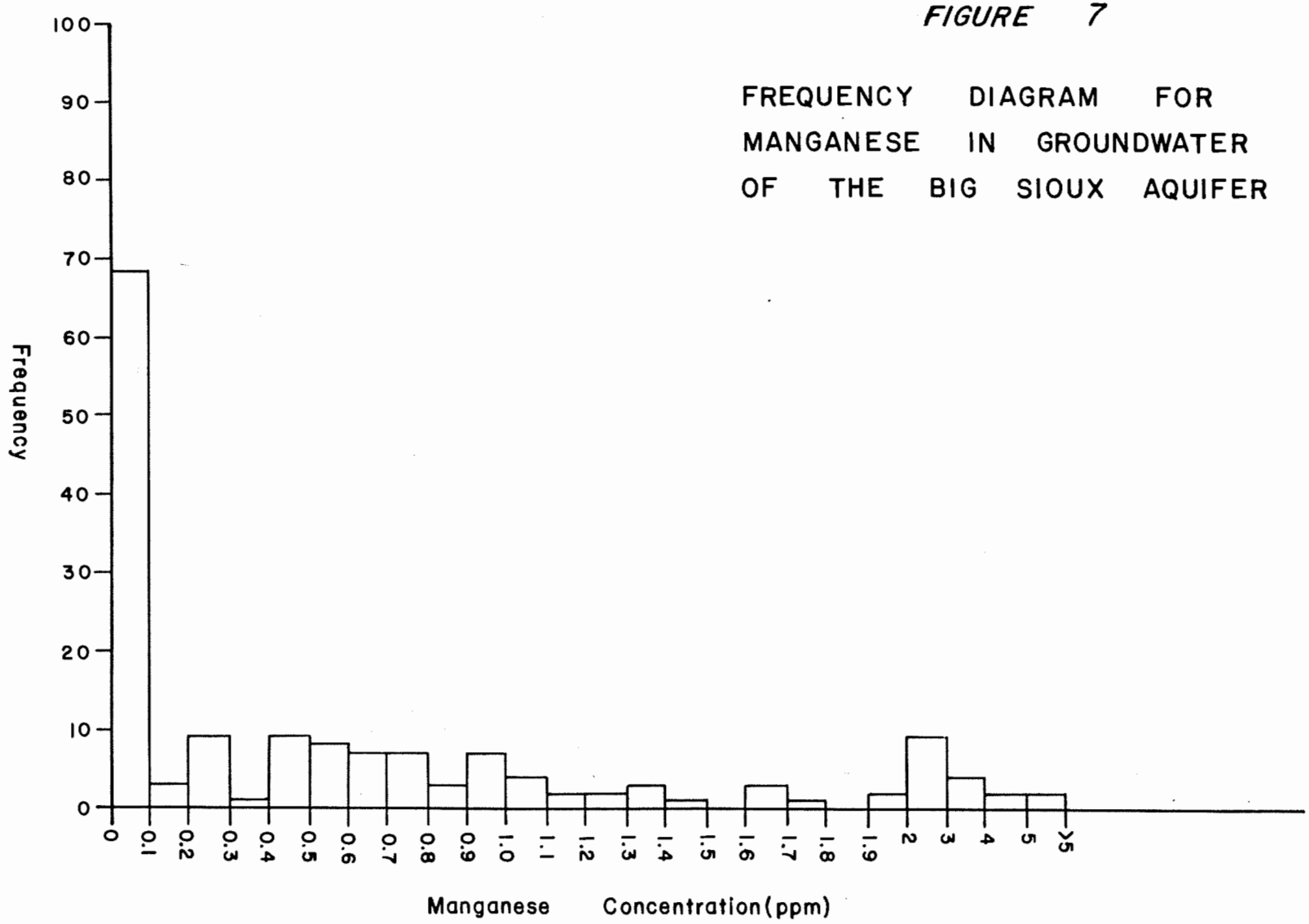


FIGURE 8

FREQUENCY DIAGRAM FOR POTASSIUM IN GROUNDWATER OF THE BIG SIOUX AQUIFER

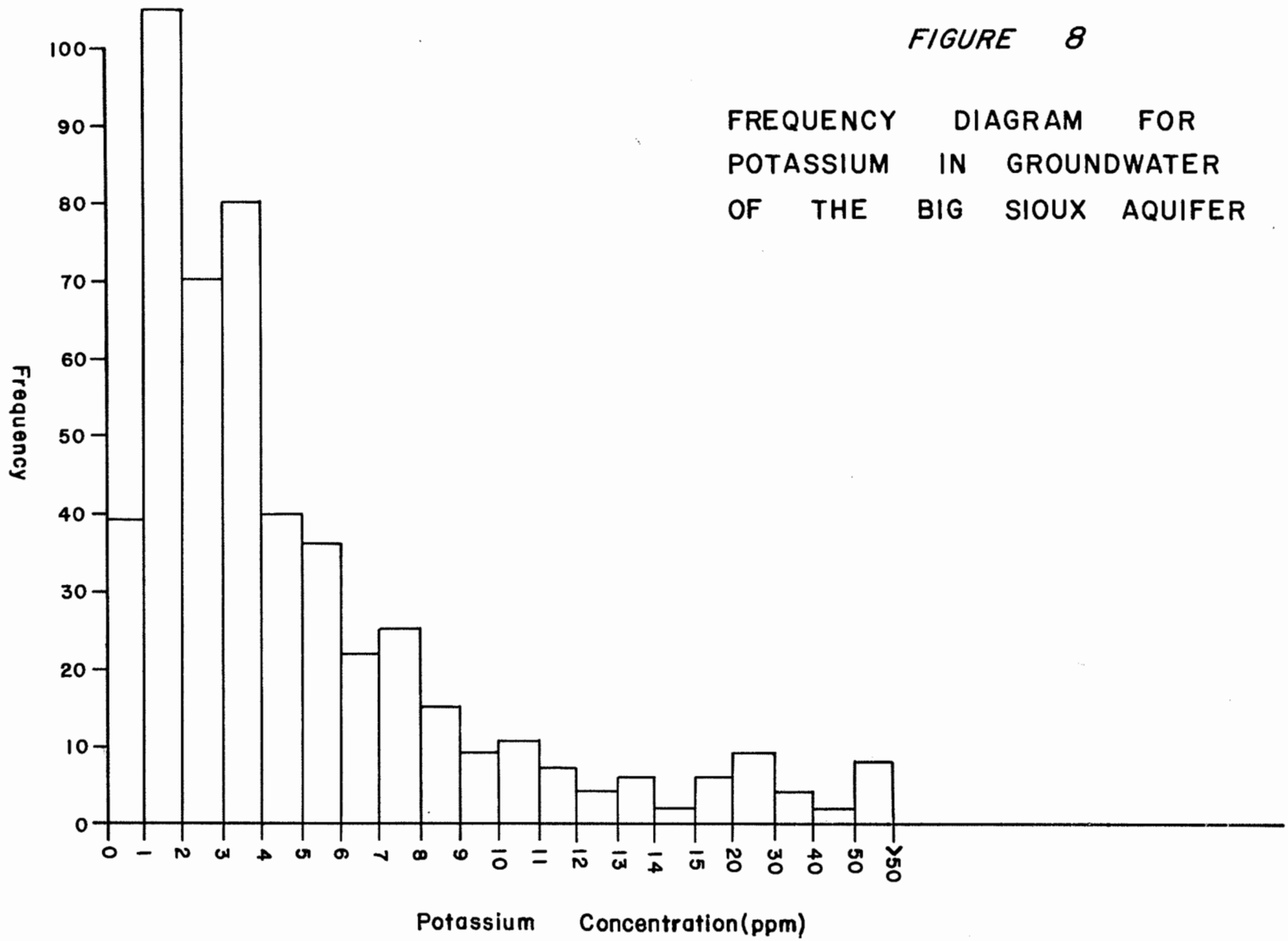


FIGURE 9

FREQUENCY DIAGRAM FOR SULFATE IN GROUNDWATER OF THE BIG SIOUX AQUIFER

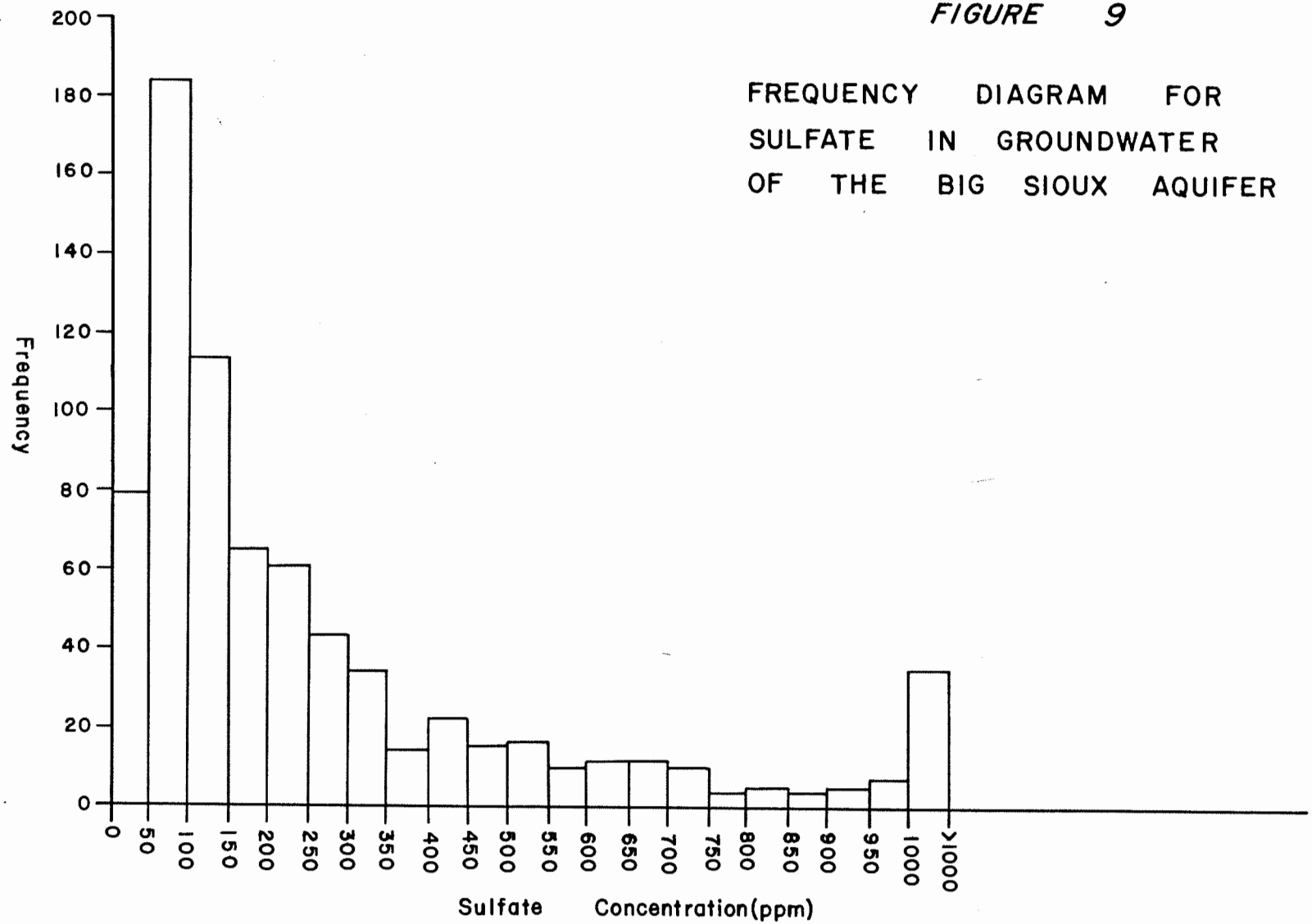


FIGURE 10

FREQUENCY DIAGRAM FOR BICARBONATE IN GROUNDWATER OF THE BIG SIOUX AQUIFER

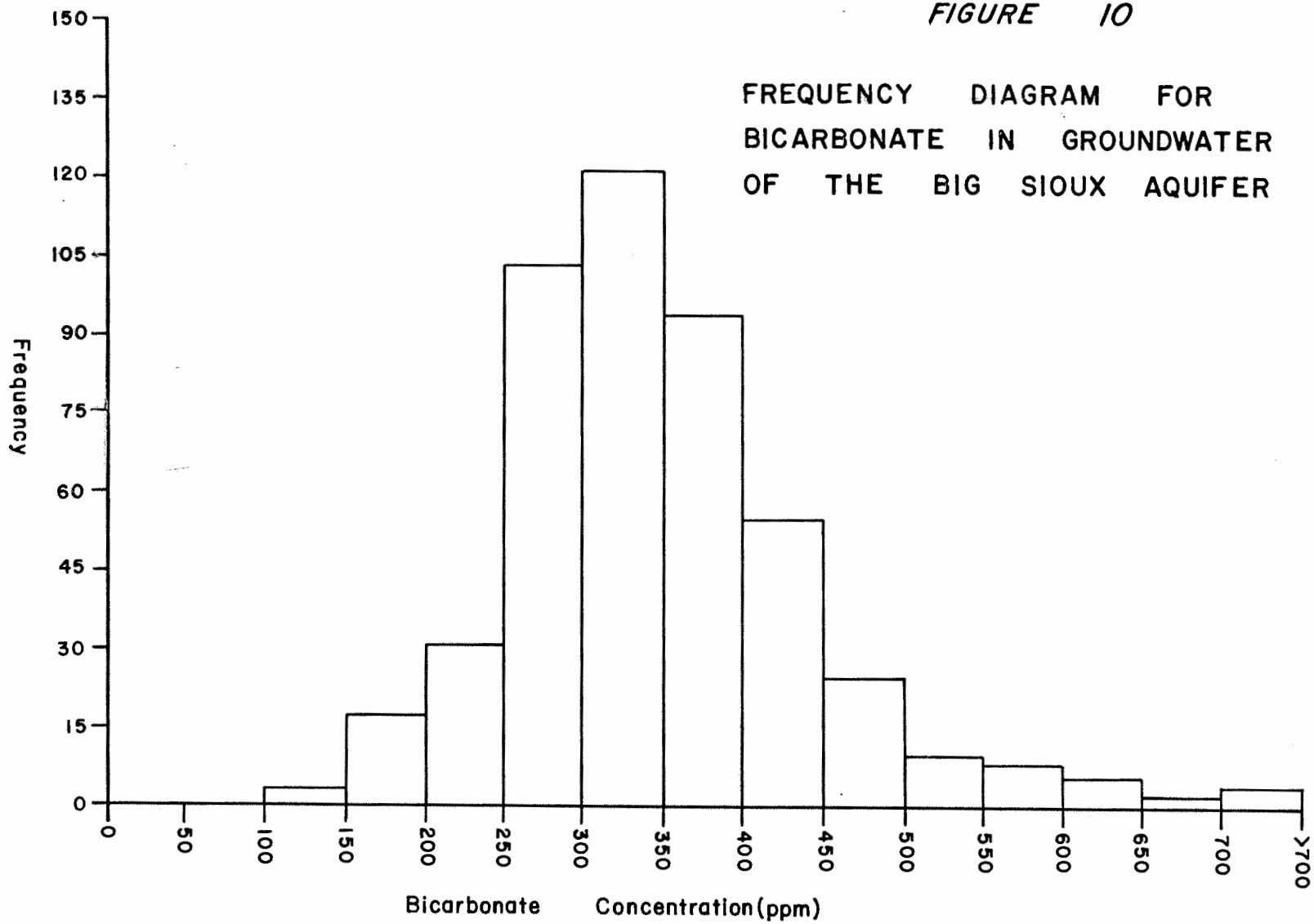


FIGURE 11

FREQUENCY DIAGRAM FOR FLUORIDE IN GROUNDWATER OF THE BIG SIOUX AQUIFER

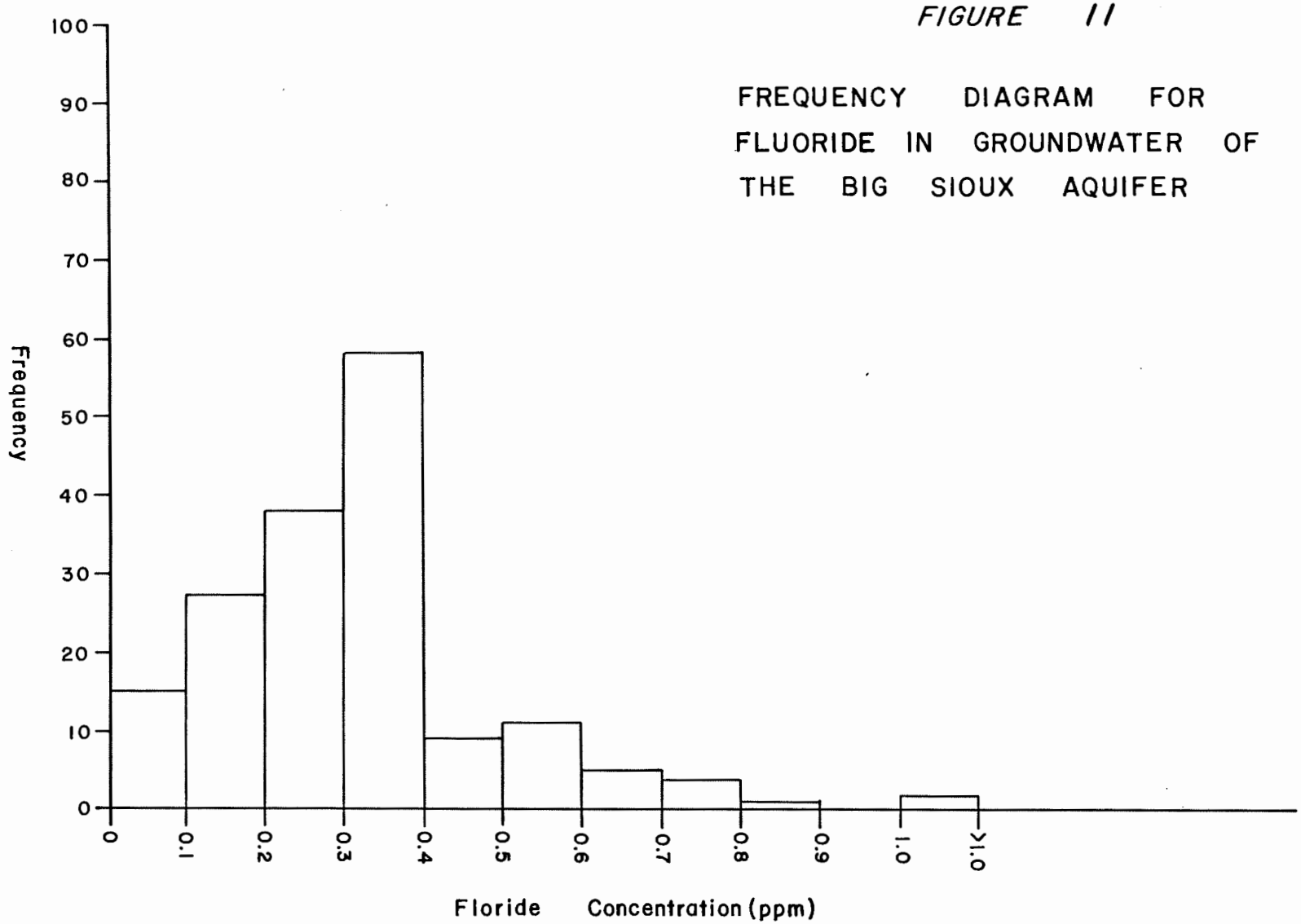


FIGURE 12

FREQUENCY DIAGRAM FOR NITRATE-NITROGEN IN GROUNDWATER OF THE BIG SIOUX AQUIFER