STATE OF SOUTH DAKOTA
George S. Mickelson, Governor

DEPARTMENT OF WATER AND NATURAL RESOURCES
Floyd Matthew, Secretary

DIVISION OF GEOLOGICAL SURVEY
Merlin J. Tipton, State Geologist

Open-File Report 57-UR

INVESTIGATION OF THE GROUND-WATER QUALITY
NEAR AURORA, SOUTH DAKOTA

by

Patricia Dawson Hammond

Science Center
University of South Dakota
Vermillion, South Dakota

1989
INTRODUCTION .......................................................... 1
Land use and the Aurora water supply .................................. 1

METHODS AND PROCEDURES .............................................. 6
Drilling and well installation ............................................. 6
Surveying ........................................................................ 6
Water-level measurements .................................................. 6
Well development and water sampling ................................... 8

HYDROGEOLOGIC SETTING ................................................ 8
General geology ............................................................... 8
Big Sioux aquifer ............................................................. 8

RESULTS OF INVESTIGATION ............................................. 8
Buried outwash ................................................................ 8
Big Sioux aquifer ............................................................. 9

CONCLUSIONS AND RECOMMENDATIONS .............................. 14

REFERENCES .................................................................. 14

FIGURES
1. Location of the study area .................................................. 2
2. Locations of test holes, municipal, private, and observation wells; extent of the Big Sioux aquifer; and locations of geologic cross sections ......................................................... 3
3. Nitrate-nitrogen concentrations in the Aurora municipal well ........................................................................ 5
4. Geologic cross section A-A’ ................................................. 8
5. Geologic cross section B-B’ ................................................ 8
   Following ....................................................................... 8
6. Distribution of total-dissolved solids and hardness in the buried outwash ......................................................... 10
7. Distribution of iron and manganese concentrations in the buried outwash ....................................................... 11
INTRODUCTION

The investigation was conducted by the South Dakota Geological Survey (SDGS), at the request of the city of Aurora, South Dakota, to assist the city in locating a future drinking water supply. The purpose of the study was to determine if water of acceptable quantity and quality containing less than 10 milligrams per liter (mg/L) nitrate could be located near the city for municipal use. The investigation was financed by the city of Aurora, the East Dakota Water Development District, and the state of South Dakota. This report contains the results of the investigation, which was conducted in the Aurora area (fig. 1).

Land Use and the Aurora Water Supply

The city of Aurora (population 507) is located 3 miles east of Brookings, South Dakota, in Brookings County. Land in the vicinity of Aurora is used for agriculture and nearly all is irrigated. Irrigation is heavily concentrated in a 2-mile radius around the city and is less concentrated farther to the east, west, and south. All irrigation wells in the study area are completed in the Big Sioux aquifer. The application of nitrogen-based fertilizers in this area is a common farming practice.

Until 1984, a feedlot containing approximately 150 head of cattle was located adjacent to the northwest side of Aurora (fig. 2) and may have contributed nitrate to the ground water. This feedlot was in operation for about 30 years. Actual contribution of nitrate from this source, either in the past or the present, is undocumented.

The Aurora sewage lagoon is located southwest of Aurora (fig. 2) and downgradient from the present municipal well. An earlier report (South Dakota Department of Water and Natural Resources, undated, appendix A, Aurora Sewage Lagoon section) presented data which show that the sewage lagoon leaks and his contaminated ground water with nitrate. The sewage lagoon was not included in the current investigation, however, it is a documented point-source for nitrate contamination.

Elevated nitrate concentrations were known to exist in the ground water on the northwest side of Aurora as early as 1971 (water-quality analyses were performed by South Dakota State University Water Analysis Testing Laboratory and the State Testing Laboratory and are on file at the South Dakota Department of Health, and the SDGS). At that time, individual homes and businesses in Aurora were served by private wells. However, because nitrate-nitrogen concentrations in private wells within the city limits were above the South Dakota drinking water standard of 10 mg/L, a municipal well was drilled.

This municipal well, drilled in 1972, is located on the west side of town, and is completed in the Big Sioux aquifer. The depth of the well is 66 feet and, at this site, the top and bottom of the outwash are 2 and 64 feet, respectively, below land surface. The well is downgradient from the location of the discontinued feedlot and from irrigated agricultural land, and upgradient from the sewage lagoon (fig. 2).

The nitrate-nitrogen concentration in water collected from the municipal well on September 13, 1988, was 10.6 mg/L. This is in excess of the South Dakota drinking water standard of 10 mg/L. With one exception, a water sample collected on April 23, 1984, water-quality analyses have shown nitrate-nitrogen concentrations of 6.3 mg/L or higher since 1974 (table 1 and fig. 3). Figure 3 shows that while nitrate
Figure 1. Location of the study area.
Figure 2. Locations of test holes, municipal, private and observation wells; extent of the Big Sioux aquifer; and locations of geologic cross sections.
### Table 1. Nitrate-nitrogen data for the Aurora municipal well

<table>
<thead>
<tr>
<th>Date collected</th>
<th>Nitrate-nitrogen concentrations (milligrams per liter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-27-73</td>
<td>0</td>
</tr>
<tr>
<td>10-17-74</td>
<td>7.4</td>
</tr>
<tr>
<td>10-28-75</td>
<td>8.73</td>
</tr>
<tr>
<td>07-21-76</td>
<td>10.6</td>
</tr>
<tr>
<td>08-23-76</td>
<td>10.8</td>
</tr>
<tr>
<td>02-13-78</td>
<td>7.3</td>
</tr>
<tr>
<td>01-16-80</td>
<td>6.5</td>
</tr>
<tr>
<td>04-07-81</td>
<td>7.5</td>
</tr>
<tr>
<td>01-27-82</td>
<td>7.7</td>
</tr>
<tr>
<td>09-13-83</td>
<td>6.7</td>
</tr>
<tr>
<td>04-23-84</td>
<td>4.7</td>
</tr>
<tr>
<td>10-02-85</td>
<td>8</td>
</tr>
<tr>
<td>03-30-87</td>
<td>9.3</td>
</tr>
<tr>
<td>05-05-87</td>
<td>9</td>
</tr>
<tr>
<td>07-07-87</td>
<td>8.9</td>
</tr>
<tr>
<td>08-10-87</td>
<td>8.4</td>
</tr>
<tr>
<td>09-08-87</td>
<td>8.7</td>
</tr>
<tr>
<td>10-19-87</td>
<td>9</td>
</tr>
<tr>
<td>11-09-87</td>
<td>9.3</td>
</tr>
<tr>
<td>12-08-87</td>
<td>9</td>
</tr>
<tr>
<td>01-19-88</td>
<td>9.6</td>
</tr>
<tr>
<td>02-08-88</td>
<td>10.4</td>
</tr>
<tr>
<td>03-07-88</td>
<td>9.7</td>
</tr>
<tr>
<td>04-04-88</td>
<td>9.6</td>
</tr>
<tr>
<td>05-09-88</td>
<td>9.8</td>
</tr>
<tr>
<td>06-06-88</td>
<td>10.2</td>
</tr>
<tr>
<td>07-18-88</td>
<td>10.9</td>
</tr>
<tr>
<td>08-08-88</td>
<td>11.5</td>
</tr>
<tr>
<td>09-13-88</td>
<td>10.6</td>
</tr>
</tbody>
</table>

Analyses performed by the South Dakota Department of Health, Pierre, South Dakota.
Figure 3. Nitrate-nitrogen concentrations in the Aurora municipal well.
concentrations in the municipal water supply fluctuate, they have generally increased from 1984 to the present. The city of Aurora contemplates to use water from this municipal well.

METHODS AND PROCEDURES

Drilling and Well Installation

Drilling occurred during two periods: from June 6, 1988, through June 21, 1988, and from November 21, 1988, through November 22, 1988. Drilling was performed using the mud rotary and hollow stem auger drilling methods. The drill bit diameter was 4 3/4 inches on the mud rotary drilling rig and 13 1/2 inches on the hollow stem auger rig. Fourteen test holes were drilled for this investigation; map locations (ML) 1, 2, 3, 4, 9, 10, 12, 14, 16, 17, 18, 19, 20, and 21, fig. 2, app. A). Ten of these holes were completed as observation wells (ML 4, 9, 10, 12, 14, 16, 17, 19, 20, and 21). Six wells were completed in the surficial Big Sioux aquifer (ML 9, 10, 12, 16, 19, and 21) and four were completed in an unnamed (Pleistocene Series) buried outwash (ML 4, 14, 17, and 20). Geophysical logs are available at the SDGS; for three test holes drilled into the buried outwash (ML 3, 18, and 29) and include the parameters: single-point resistivity and natural gamma (app. A).

Observation wells were constructed using 2-inch diameter, schedule 80, threaded, polyvinyl chloride (PVC) casing and screen. Data on screen length and well depth are presented in appendix A. Filter pack, (Grand Island sand, a well sorted, coarse sand), was placed around the outside of the screen up to at least 2 feet above the top of the screen. Bentonite grout was then pumped into the remaining annular space (from the bottom up to land surface) around the outside of the casing. At a later date, an upper portion of the annular space was filled with cement grout and finally topped with soil. These data are on file at the SDGS.

Of the six observation wells installed for this investigation in the Big Sioux aquifer, three wells (ML 16, 19, and 21) were screened within 5 feet of the bottom of the aquifer and had screen tops positioned greater than 11 feet below the water table, and three wells (ML 9, 16, and 12) had screens which intersected the water table. The importance of the positioning of the screens will be discussed later.

Surveying

Casing-top elevations of seven observation wells, and land-surface next to these wells, were surveyed to the nearest 0.01 foot. The bench mark used as a datum was a U.S. Coast and Geodetic Survey bench mark located in NE1/4 NE1/4 SE1/4 section 34, T. 110 N., R. 49 W. The bench mark is stamped "UU 95 1934" and has an elevation of 1,624.485 feet above mean sea level.

Water-Level Measurements

The depth in water in the observation wells was measured on three occasions (table 2) to the nearest 0.01 foot. Measurements were made using a fiber glass tape measure with a concave-shaped device on the end which mates an audible sound upon impact with the water.
<table>
<thead>
<tr>
<th>Map Location No.</th>
<th>Location 2</th>
<th>Well ID</th>
<th>Aquifer 3</th>
<th>Casing Top Elevation 4</th>
<th>Depth to water and date of measurements 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>109N-49W-03ADAA</td>
<td>CO-88-15</td>
<td>Buried</td>
<td>1621.73</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>109N-49W-04AAAA</td>
<td>BK-7-79</td>
<td>Big Sioux</td>
<td>1616.60</td>
<td>T</td>
</tr>
<tr>
<td>6</td>
<td>109N-49W-05BBBB</td>
<td>BK-6-79</td>
<td>Big Sioux</td>
<td>1610.40</td>
<td>T</td>
</tr>
<tr>
<td>7</td>
<td>109N-49W-08BBBB</td>
<td>R1-87-69</td>
<td>Big Sioux</td>
<td>1603.00</td>
<td>T</td>
</tr>
<tr>
<td>8</td>
<td>110N-48W-31BBBB</td>
<td>BG-771</td>
<td>Big Sioux</td>
<td>1654.10</td>
<td>T</td>
</tr>
<tr>
<td>9</td>
<td>110N-49W-26CCCC</td>
<td>R2D-88-65</td>
<td>Big Sioux</td>
<td>1635.50</td>
<td>T</td>
</tr>
<tr>
<td>10</td>
<td>110N-49W-27DCCC</td>
<td>R2D-88-64</td>
<td>Big Sioux</td>
<td>1634.50</td>
<td>T</td>
</tr>
<tr>
<td>11</td>
<td>110N-49W-29AAAA</td>
<td>BG-79D</td>
<td>Big Sioux</td>
<td>1626.20</td>
<td>T</td>
</tr>
<tr>
<td>12</td>
<td>110N-49W-32AAAA</td>
<td>R2D-88-66</td>
<td>Big Sioux</td>
<td>1634.50</td>
<td>T</td>
</tr>
<tr>
<td>13</td>
<td>110N-49W-33CCCC</td>
<td>BG-77R</td>
<td>Big Sioux</td>
<td>1611.40</td>
<td>T</td>
</tr>
<tr>
<td>14</td>
<td>110N-49W-34DDBC</td>
<td>CO-88-09</td>
<td>Buried</td>
<td>1624.22</td>
<td>I</td>
</tr>
<tr>
<td>15</td>
<td>110N-49W-35BBBB</td>
<td>R2-85-61</td>
<td>Buried</td>
<td>1637.00</td>
<td>T</td>
</tr>
<tr>
<td>16</td>
<td>110N-49W-35BCCB</td>
<td>CO-88-18</td>
<td>Big Sioux</td>
<td>1631.62</td>
<td>T</td>
</tr>
<tr>
<td>17</td>
<td>110N-49W-35BCCB1</td>
<td>CO-88-19</td>
<td>Buried</td>
<td>1631.62</td>
<td>T</td>
</tr>
<tr>
<td>18</td>
<td>110N-49W-35CBBCC</td>
<td>CO-88-17</td>
<td>Big Sioux</td>
<td>1621.56</td>
<td>I</td>
</tr>
<tr>
<td>19</td>
<td>110N-49W-35CCBCC</td>
<td>CO-88-13</td>
<td>Buried</td>
<td>1630.32</td>
<td>I</td>
</tr>
<tr>
<td>20</td>
<td>110N-49W-35CCBCC</td>
<td>CO-88-14</td>
<td>Big Sioux</td>
<td>1630.22</td>
<td>I</td>
</tr>
<tr>
<td>21</td>
<td>110N-49W-36DDDD</td>
<td>BG-771</td>
<td>Big Sioux</td>
<td>1629.30</td>
<td>T</td>
</tr>
</tbody>
</table>

1 Map-Location Number - corresponds to number on figure 2 and in appendix A.
2 See appendix A for explanation of location format.
3 Big Sioux = Big Sioux aquifer; buried = an unnamed buried outwash in the study area.
4 Presented in feet above mean sea level; T = the estimated ground-surface elevation from a topographic map plus the length of casing extending above ground surface; I = elevation surveyed with instrument. (See logs in appendix A.)
5 All water levels are presented in feet below top of casing.
Well Development and Water Sampling

All observation wells were developed by pumping with compressed air. A minimum of 70 well volumes of water was removed from each well during this process.

All water samples from observation wells were collected with a bladder pump or, when that was not possible, with a bailer. A minimum of three well volumes of water were evacuated before a simple was collected. Water samples were collected from the 10 observation wells installed for this investigation, four observation wells controlled by the Division of Water Rights, four observation wells drilled previously by the SDGS for other studies, and 14 private wells. Water-quality analyses (table 5) were performed by the South Dakota Geological Survey.

HYDROGEOLOGIC SETTING

General Geology

The study area is underlain by Pleistocene drift (Barazi, 1968; Tomhave, 1988). The drift is composed of till and outwash, both of which are present in the study area. Till consists of a heterogeneous mixture of boulders, gravel, sand, clay, and silt. The till matrix is composed predominantly of clay and silt. Outwash consists primarily of sand and gravel that has been washed, sorted, and deposited by flowing meltwater. Varying amounts of less permeable materials, silt and clay, may be dispersed throughout the outwash matrix. One particular outwash, named the Big Sioux aquifer, is the source of water for the city of Aurora. The top of the deeper, buried outwash is found approximately 20 to 92 feet below the bottom of the Big Sioux aquifer. Separating the outwash units is a clayey till unit which is weathered in some locations and unweathered in others (see xpp. A for site specific lithologic descriptions).

Big Sioux Aquifer

The Big Sioux aquifer (fig. 2) is an unconfined, surficial aquifer composed of sand and gravel (outwash). The predominant grain size of the aquifer material ranges from very coarse sand to very coarse gravel. Ground-water recharge in the Aurora area is thought to be from (1) downward percolation of water from precipitation and excess irrigation, and (2) lateral inflow of water in transient storage (Barazi, 1968). Surface water may also infiltrate into the aquifer when surface-water elevations are higher than adjacent ground water elevations. Average depth to water is approximately 12 feet below the ground surface, and ground water flow direction in the study area is generally to the southwest.

RESULTS OF INVESTIGATION

Buried Outwash

Two cross sections, whose locations are shown in figure 2, illustrate the spatial distribution of outwash units in the study area (figs. 4 and 5). Of the 10 observation wells installed for this investigation, four were
<table>
<thead>
<tr>
<th>Well ID No.</th>
<th>Location 2</th>
<th>Aquifer 3</th>
<th>Date Sampled</th>
<th>Well Depth (ft) 4</th>
<th>Conductivity (mhos) 5</th>
<th>Hardness as CaCO₃</th>
<th>Fe</th>
<th>Mn</th>
<th>SO₄-N</th>
<th>NO₃-N</th>
<th>Na</th>
<th>Ca</th>
<th>Mg</th>
<th>K</th>
<th>Cl</th>
<th>F</th>
<th>Alk T</th>
<th>HCO₃</th>
<th>Field pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>109N-49W-03ADAA</td>
<td>CO-88-15</td>
<td>Buried</td>
<td>06-16-88</td>
<td>114.7</td>
<td>1022</td>
<td>668</td>
<td>473</td>
<td>0.05</td>
<td>1.76</td>
<td>230</td>
<td>&lt;0.04</td>
<td>50</td>
<td>122</td>
<td>41</td>
<td>3.1</td>
<td>1</td>
<td>0.47</td>
<td>351</td>
</tr>
<tr>
<td>6</td>
<td>109N-49W-05BBB</td>
<td>BB-6-79</td>
<td>Big Sioux</td>
<td>09-20-88</td>
<td>18.6</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>7</td>
<td>109N-49W-08BBB</td>
<td>R1-87-69</td>
<td>Big Sioux</td>
<td>09-20-88</td>
<td>70.0</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>8</td>
<td>109N-49W-31BBB</td>
<td>BG-771</td>
<td>Big Sioux</td>
<td>09-20-88</td>
<td>34.3</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>9</td>
<td>109N-49W-26C3CC</td>
<td>R20-88-65</td>
<td>Big Sioux</td>
<td>11-22-88</td>
<td>26.7</td>
<td>851</td>
<td>562</td>
<td>417</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>97</td>
<td>27.2</td>
<td>23</td>
<td>101</td>
<td>40</td>
<td>7.5</td>
<td>10</td>
<td>0.34</td>
<td>260</td>
</tr>
<tr>
<td>10</td>
<td>109N-49W-27D3CC</td>
<td>R20-88-64</td>
<td>Big Sioux</td>
<td>11-22-88</td>
<td>28.4</td>
<td>638</td>
<td>426</td>
<td>342</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>64</td>
<td>14.9</td>
<td>8</td>
<td>81</td>
<td>34</td>
<td>1.9</td>
<td>6</td>
<td>0.26</td>
<td>238</td>
</tr>
<tr>
<td>12</td>
<td>109N-49W-33AAA</td>
<td>R20-88-66</td>
<td>Big Sioux</td>
<td>11-22-88</td>
<td>30.0</td>
<td>722</td>
<td>466</td>
<td>365</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>43</td>
<td>25.5</td>
<td>9.2</td>
<td>85</td>
<td>37</td>
<td>2.5</td>
<td>8</td>
<td>0.24</td>
<td>242</td>
</tr>
<tr>
<td>13</td>
<td>109N-49W-33C3CC</td>
<td>BG-77T</td>
<td>Big Sioux</td>
<td>09-20-88</td>
<td>18.5</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>14</td>
<td>109N-49W-34DBB</td>
<td>CO-88-09</td>
<td>Buried</td>
<td>06-14-88</td>
<td>115.9</td>
<td>2285</td>
<td>1765</td>
<td>1130</td>
<td>4.46</td>
<td>0.94</td>
<td>918</td>
<td>0.04</td>
<td>119</td>
<td>296</td>
<td>95</td>
<td>7.5</td>
<td>4</td>
<td>0.30</td>
<td>486</td>
</tr>
<tr>
<td>15</td>
<td>109N-49W-35BBB</td>
<td>R2-83-61</td>
<td>Buried</td>
<td>06-14-88</td>
<td>118.0</td>
<td>961</td>
<td>588</td>
<td>454</td>
<td>1.13</td>
<td>0.69</td>
<td>179</td>
<td>&lt;0.04</td>
<td>47</td>
<td>116</td>
<td>40</td>
<td>3.3</td>
<td>2</td>
<td>0.32</td>
<td>381</td>
</tr>
<tr>
<td>16</td>
<td>109N-49W-35C3CB</td>
<td>CO-88-18</td>
<td>Big Sioux</td>
<td>06-22-88</td>
<td>53.4</td>
<td>780</td>
<td>482</td>
<td>365</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>67</td>
<td>15.2</td>
<td>23</td>
<td>85</td>
<td>37</td>
<td>2.2</td>
<td>10</td>
<td>0.31</td>
<td>285</td>
</tr>
<tr>
<td>18</td>
<td>109N-49W-35C3CC</td>
<td>CO-88-19</td>
<td>Big Sioux</td>
<td>06-22-88</td>
<td>112.5</td>
<td>970</td>
<td>604</td>
<td>431</td>
<td>0.28</td>
<td>0.72</td>
<td>172</td>
<td>0.17</td>
<td>48</td>
<td>110</td>
<td>38</td>
<td>3.6</td>
<td>2</td>
<td>0.23</td>
<td>374</td>
</tr>
<tr>
<td>19</td>
<td>109N-49W-35C3CC</td>
<td>CO-88-17</td>
<td>Big Sioux</td>
<td>06-21-88</td>
<td>38.6</td>
<td>790</td>
<td>496</td>
<td>346</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>141</td>
<td>7.76</td>
<td>38</td>
<td>81</td>
<td>35</td>
<td>2.5</td>
<td>4</td>
<td>0.33</td>
<td>268</td>
</tr>
<tr>
<td>20</td>
<td>109N-49W-35C3CA</td>
<td>CO-88-13</td>
<td>Buried</td>
<td>06-15-88</td>
<td>109.7</td>
<td>2523</td>
<td>2090</td>
<td>1276</td>
<td>1.06</td>
<td>1.63</td>
<td>1210</td>
<td>0.06</td>
<td>154</td>
<td>333</td>
<td>108</td>
<td>9.4</td>
<td>4</td>
<td>0.42</td>
<td>390</td>
</tr>
<tr>
<td>21</td>
<td>109N-49W-35C3CA</td>
<td>CO-88-14</td>
<td>Big Sioux</td>
<td>06-15-88</td>
<td>34.6</td>
<td>703</td>
<td>454</td>
<td>337</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>76</td>
<td>12.5</td>
<td>18</td>
<td>84</td>
<td>31</td>
<td>1.5</td>
<td>2</td>
<td>0.26</td>
<td>249</td>
</tr>
<tr>
<td>22</td>
<td>109N-49W-43DBDD</td>
<td>BG-77T</td>
<td>Big Sioux</td>
<td>09-20-88</td>
<td>45.4</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

---

1 TDS - total dissolved solids; Fe - iron; Mn - manganese; SO₄ - sulfate; NO₃-N - nitrate-nitrogen; NA - sodium; CA - calcium; MG - magnesium; K - potassium; O - chloride; F - fluoride; Alk T - total alkalinity; HCO₃ - bicarbonate.

2 See appendix A for explanation of location format and map location (ML) number.

3 Big Sioux = Big Sioux aquifer; buried = an unlined buried outwash in the study area.

4 Well depth is presented in feet below top of casing and excludes any blank casing below the screen.

5 mhos = microhoms.

6 U.S. Environmental Protection Agency recommended maximum limit (U.S. Environmental Protection Agency, 1985a).

7 U.S. Environmental Protection Agency enforceable maximum limit (U.S. Environmental Protection Agency, 1985a).
Figure 4. Geologic cross section A-A'.
(for location see figure 2)

- Outwash, Big Sioux aquifer (includes 2 to 3 feet of topsoil)
- Buried outwash
- Non-aquifer sediment (primarily till)
- Well (ML18 is test hole)
- \ldots\ldots Approximate water level in Big Sioux aquifer, 9/21/88, 11/22/88 for ML9.
- \ldots\ldots Lithologic contact. Dashed where approximate. A "?" indicates lateral extent is very uncertain.

Vertical exaggeration = 100X.
Figure 5. Geologic cross section B-B'.
(for location see figure 2)

- Alluvial clay
- Outwash, Big Sioux aquifer (includes 2 to 3 feet of topsoil)
- Buried outwash
- Non-aquifer sediment (primarily till)
- Well (ML8 is test hole)

--- Approximate water level in Big Sioux aquifer, 9/21/88.

Lithologic contact. Dashed where approximate. An "?" indicates lateral extent is very uncertain.

Vertical exaggeration = 100X.
drilled into a buried, confined outwash unit (ML 4, 14, 17, and 20). Data were also gathered from one observation well previously installed in buried outwash (ML 15).

The top of the buried outwash ranges approximately from 70 to 105 feet below the ground surface and 20 to 90 feet below the bottom of the Big Sioux aquifer, and consists predominantly of medium size gravel. The average static water level, in the observation wells installed in the buried outwash, is approximately 12 feet below land surface and the direction of ground-water flow is generally to the southwest. All five observation wells installed in the buried outwash are completed in the same outwash unit. Figures 4 and 5 illustrate that buried outwash occurs throughout the study area, however, additional drilling is necessary to determine the areal extent of this outwash.

Water produced from the wells mentioned above is generally of varying quality (table 3, figs. 6 and 7). Figure 6 illustrates that the total dissolved solids content varies from 588 mg/L (ML 15) to 2,090 mg/L (ML 20) and the hardness concentration varies from 431 mg/L (ML 17) to 1,276 mg/L (ML 20). Iron and manganese concentrations also vary throughout the outwash. Figure 7, illustrates that iron concentrations vary from 0.05 mg/L (ML 4) to 4.46 mg/L (ML 14) and manganese concentrations vary from 0.07 mg/L (ML 15) to 1.63 mg/L (ML 20). Sulfate concentrations are also variable (table 3) and range from 172 mg/L (ML 17) to 1,210 mg/L (ML 20). Because of the variable water quality in this outwash and the unknown areal extent, the buried outwash was not considered as a potential source of municipal water for the city of Aurora.

Big Sioux Aquifer

The Big Sioux aquifer underlies the entire area around Aurora except in the southeast corner of the study area where the aquifer is absent (fig. 2). In the Aurora area, the top of the Big Sioux aquifer is generally within 3 feet of the land surface and lies directly below the soil profile. The saturated thickness of the Big Sioux aquifer in the Aurora area varies from approximately 16 feet (ML 6) to 70 feet (ML 7).

Holm and others (1986) found that nitrate concentrations will tend to decrease with depth. This means that observed nitrate concentrations may be higher in wells which were screened at the water table. Of the six observation wells installed in the Big Sioux aquifer for this investigation, three wells (ML 16, 19, and 21) were screened within 5 feet of the bottom of the aquifer and had screen tops positioned greater than 11 feet below the water table, and three wells (ML 9, 10, and 12) had screens which intersected the water table. Table 3 shows elevated nitrate concentrations in all six of the wells, with the highest concentrations generally found in those wells having screens which intersect the water table. However, the fact that nitrate concentrations are found to be high at the water table and below the water table near the bottom of the aquifer suggests that nitrate contamination is not limited solely to the upper portion of the aquifer.

This investigation found high nitrate concentrations in the Big Sioux aquifer in the vicinity of Aurora (fig. 8 and table 4). As shown in figure 8, 13 wells are observation wells, 14 are private wells, and one is the Aurora municipal well. Six of the 13 observation wells (46 percent) exceed the drinking water standard of 10 mg/L for nitrate-nitrogen, and eight of the 13 observation wells sampled (62 percent) have nitrate-nitrogen concentrations greater than 5 mg/L. Of the 14 private wells sampled, 10 (71 percent) exceed the drinking water standard of 10 mg/L, and 12 (86 percent) have nitrate-nitrogen concentrations greater than
Figure 6. Distribution of total-dissolved solids and hardness in the buried outwash.
Figure 8. Nitrate-nitrogen concentrations in the Big Sioux aquifer.
<table>
<thead>
<tr>
<th>ML Number</th>
<th>Location</th>
<th>Well Depth (feet)</th>
<th>Nitrate-Nitrogen (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private</td>
<td>109N-49W-03BBAB</td>
<td>22.2</td>
<td>10.9</td>
</tr>
<tr>
<td>5</td>
<td>109N-49W-04AAAA</td>
<td>26.2</td>
<td>8.42</td>
</tr>
<tr>
<td>6</td>
<td>109N-49W-05BBBB</td>
<td>18.6</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>Private</td>
<td>109N-49W-05CCCD</td>
<td>14.0</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>7</td>
<td>109N-49W-08BBBB</td>
<td>70.0</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>Private</td>
<td>109N-49W-09AABA</td>
<td>32.0</td>
<td>19.8</td>
</tr>
<tr>
<td>8</td>
<td>110N-48W-31BBBB</td>
<td>34.3</td>
<td>16.9</td>
</tr>
<tr>
<td>9</td>
<td>110N-49W-26CCCCC</td>
<td>26.7</td>
<td>27.2</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-26CCCD</td>
<td>20.0</td>
<td>30.1</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-27CDDD</td>
<td>31.6</td>
<td>16.3</td>
</tr>
<tr>
<td>10</td>
<td>110N-49W-27DDDC</td>
<td>28.4</td>
<td>14.9</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-28AAAD</td>
<td>30.0</td>
<td>19.5</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-28DDDC</td>
<td>30.0</td>
<td>16.4</td>
</tr>
<tr>
<td>11</td>
<td>110N-49W-29AAAA</td>
<td>36.7</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-32BAAB</td>
<td>15.0</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>12</td>
<td>110N-49W-33AAAA</td>
<td>30.0</td>
<td>25.5</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-33ABDD</td>
<td>50.0</td>
<td>14.3</td>
</tr>
<tr>
<td>13</td>
<td>110N-49W-33CCCC</td>
<td>18.5</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-33CDDD</td>
<td>20.0</td>
<td>15.7</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-33CDDD</td>
<td>20.0</td>
<td>11.9</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-34CADD</td>
<td>58.0</td>
<td>6.49</td>
</tr>
<tr>
<td>City</td>
<td>110N-49W-34DDBB</td>
<td>66.0</td>
<td>10.6</td>
</tr>
<tr>
<td>16</td>
<td>110N-49W-35BCBB</td>
<td>53.4</td>
<td>15.1</td>
</tr>
<tr>
<td>19</td>
<td>110N-49W-35CCB</td>
<td>38.6</td>
<td>7.76</td>
</tr>
<tr>
<td>21</td>
<td>110N-49W-35CBB</td>
<td>34.6</td>
<td>12.5</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-35CDD</td>
<td>10.2</td>
<td>9.87</td>
</tr>
<tr>
<td>Private</td>
<td>110N-49W-36BBB</td>
<td>34.2</td>
<td>16.8</td>
</tr>
<tr>
<td>22</td>
<td>110N-49W-36DDDD</td>
<td>45.4</td>
<td>&lt;0.04</td>
</tr>
</tbody>
</table>

1 See appendix A for explanation of location format and map-location (ML) number. Private = sample collected from private well; City = sample from Aurora municipal well.
2 Well depth is presented in feet below top of casing and excludes any blank casing below the screen.
3 mg/L - milligrams per liter.
5 mg/L. The Aurora municipal well had nitrate-nitrogen concentrations above 10 mg/L since June, 1988, and with one exception, consistently above 5 mg/L since 1974.

Figure 8 shows high nitrate concentrations in the Big Sioux aquifer near the city of Aurora. It is likely that point-source pollution, such as the previously mentioned Aurora sewage lagoon, is a factor in some wells in the Aurora area but due to the large areal extent of nitrate contamination (fig. 8), non-point-source pollution must also be considered and examined.

CONCLUSIONS AND RECOMMENDATIONS

Much of the Big Sioux aquifer near the city of Aurora contains nitrate in excess of drinking water standards. Currently, it is not possible to recommend a location for a municipal well in the Big Sioux aquifer, near the city, with the assurance that it will produce water with an acceptable nitrate concentration after prolonged pumping. Before a well site near the city can be recommended it will be necessary to have a better understanding of (1) the extent and severity of the contamination, and (2) the mechanisms of the contaminant transport. Because high nitrate concentrations were found to be extensive in the Big Sioux aquifer in the Aurora area, a more detailed study is needed in order to address the above-mentioned points.

As a result of the high nitrate concentrations found in the Big Sioux aquifer near Aurora, it is recommended that the city use water produced from an area, or aquifer, where nitrate contamination is not a problem. Possible options to improve water quality are to obtain water from (1) the rural-water system nearest the city, or (2) the city of Brookings, and (3) to drill a well at some location where nitrate is not a problem. Before the last option is implemented, additional testing is required.

REFERENCES


U.S. Environmental Protection Agency, 1985a, National interim primary drinking water regulations - maximum contaminant levels for inorganic chemicals: Code of Federal Regulations, Title 40, Part 141, Section 141.11, p. 523-524.


14
APPENDIX A

Logs of test holes and observation wells

MAP LOCATION (ML)

A number arbitrarily assigned to the log according to the order in which it is listed (see Legal Location and Location). This number corresponds to the numbers listed on figure 2.

LEGAL LOCATION and LOCATION

The logs are listed by smallest township number, then the smallest range number, the smallest section number, and then by quarter section: NE = A; NW = B; SW = C; SE = D. A comparison of Legal Location and Location is as follows. A Legal Location of SW 1/4 NW 1/4 SE 1/4 SE 1/4 sec 34, T. 110 N., R. 49 W., is the same as a Location of 110N-49W-34DDBC. In several Locations, the smallest quarter section is followed by the number 1 or 2 which indicates that more than one log may exist for that particular location.

LATITUDE and LONGITUDE

The format is DD.MMSS where D is degrees, M is minutes, and S is seconds.

DRILLING COMPANY

SDGS is an abbreviation for South Dakota Geological Survey.

TOTAL DRILL HOLE DEPTH, SCREEN LENGTH, TOTAL CASING AND SCREEN, and CASING STICK-UP

The numbers are presented in feet.

SCREEN TYPE and CASING TYPE

PVC is an abbreviation for polyvinyl chloride. NTG is an abbreviation for manufactured and indicates a product that is commercially available. HIM is an abbreviation for homemade and indicates a hacksaw-slotted casing.

CASING DIAMETER

The numbers are presented in inches.

CASING TOP ELEVATION and GROUND SURFACE ELEVATION

The numbers are presented in feet above mean sea level. 1 - the elevation was determined using a surveying instrument. 2 - the elevation was estimated from 7½ minute series topographic map.

Appendix A-17
ABANDONED HOLE DUE TO RIG BREAKDOWN, LOST 10 FEET OF DRILL STEM IN HOLE (ONE DRILL STEM PLUS BIT).

0 - 2.0 TOPSOIL, BLACK
2.0 - 10.0 GRAVEL, MEDIUM TO VERY COARSE PEBBLE GRAVEL, OXIDIZED
10.0 - 25.0 CLAY, LIGHT-BROWN, SANDY, PEBBLY (TILL)
25.0 - 47.0 CLAY, LIGHT-GRAY, VERY CLAYEY, STICKY (TILL)
47.0 - 67.0 CLAY, LIGHT-BROWN, VERY CLAYEY, PEBBLY, STICKY (TILL)

* * *
7.0 - 27.0 CLAY, LIGHT-BROWN, SANDY, PEBBLY; STICKY (TILL)
27.0 - 53.0 CLAY, GRAY; VERY STICKY (TILL)
53.0 - 117.0 CLAY, LIGHT-BROWN, PEBBLY; STICKY (TILL)

County: BROOKINGS
Map Location: 3
Latitude: 44.1654
Land Owner: Project: AURORA CITY STUDY-1988
Drilling Company: SDGS
Driller: D. JACOBSON
Geologist: P. DAWSON
Date Drilled: 06-13-1988
Ground Surface Elevation: 1650.00'
Total Drill Hole Depth: 147.00
USGS Hydrological Unit Code: 10170203

Excav Log Information:
Spontaneous Potential: Single Point Resistivity: X
Natural Gamma: X
Extra:
Samples:
0 - 2.0 TOPSOIL, BLACK
2.0 - 8.0 GRAVEL, MEDIUM TO VERY COARSE PEBBLE
GRAVEL; OXIDIZED
8.0 - 36.0 CLAY, LIGHT-BROWN, PEBBLY; STICKY (TILL)
36.0 - 37.0 CLAY, GRAY; VERY STICKY (TILL)
37.0 - 47.0 CLAY, LIGHT-GRAY; VERY STICKY (TILL)
47.0 - 60.0 CLAY, LIGHT-BROWN; STICKY (TILL)
60.0 - 62.0 CLAY, BLACK; DRY
62.0 - 98.0 CLAY, LIGHT-BROWN; STICKY (TILL)
98.0 - 108.0 GRAVEL, MEDIUM TO COARSE PEBBLE GRAVEL
108.0 - 147.0 CLAY, TAN, SANDY (TILL)

LITHOLOGIC DESCRIPTION BASED ON ELECTRIC LOG INTERPRETATION.

County: BROOKINGS
Map Location: 4
Latitude: 44.2643
Land Owner: Project: AURORA CITY STUDY-1988
Drilling Company: SDGS
Driller: D. JACOBSON
Geologist: P. DAWSON
Date Drilled: 06-15-1988
Ground Surface Elevation: 1650.04'
Total Drill Hole Depth: 117.0
Water Rights Well: 

Location: 109N-49W-02ABBD 4
Longitude: 96.4037

Appendix A-17
SCREEN FROM 107 TO 112 FEET:

- 0.0 - 2.0 TOPSOIL, BLACK
- 2.0 - 13.0 GRAVEL, MEDIUM TO VERY COARSE PEBBLE
  GRAVEL, OXIDIZED
- 13.0 - 25.0 CLAY, LIGHT-BROWN, PEBBLY; STICKY (TILL)
- 25.0 - 105.0 CLAY, LIGHT-GRAY; VERY STICKY (TILL)
- 105.0 - 116.0 GRAVEL, MEDIUM TO COARSE PEBBLE GRAVEL;
  OXIDIZED
- 116.0 - 118.0 CLAY, GRAY, SANDY, PEBBLY (TILL)

COUNTY: BROOKINGS
Location: 109N-49W-04AAAA

Driller's Log:
Test Hole Number: BK-7-79
SDGS Well Name: BK-7-79

Geologist's Log: X
Drilling Method: ROTARY

Aquifer: BIG SIoux
Screen Length: 8.0
Casing Diameter: 2.0
Total Casing and Screen: 26.2

DEPTH TO WATER: 6 FEET. CASING SLOTTED 5 FEET
ABOVE A 3-FOOT SANDPOINT.

0 - 1.0 TOPSOIL, BLACK, CLAYEY
1.0 - 8.0 CLAY, BROWN TO GRAY, VERY SANDY
8.0 - 28.0 SAND, FINE, WELL-ROUNDED, TO GRAVEL

***

County: BROOKINGS
Map Location: 6
Location: 109N-49W-05BBBB
Latitude: 44.1656
Longitude: 96.4450
Land Owner:
Project: BROOKINGS OBS WELLS-1979
Driller: K. CARTER
Geologist: K. CARTER
Date Drilled: 06-13-1979
Ground Surface Elevation: 1608.00 T
Total Drill Hole Depth: 30.0
Water Rights Well:
Other Well Name:
Driller's Log:
Geologist's Log: X
Drilling Method: ROTARY
Test Hole Number: BK-6-79
SDGS Well Name: BK-6-79
Aquifer: BIG SIOUX
Screen Type: PVC, MFG. AND HM.
Screen Length: 8.0
Casing Type: PVC
Casing Diameter: 2.0
Casing Stick-up:
Total Casing and Screen: 18.6
Well Maintenance Date:
USGS Hydrological Unit Code: 10170202
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:

DEPT TO WATER: 6.27 FEET. CASING SLOTTED 5 FEET
ABOVE A 3-FOOT SANDPOINT.

0 - 2.0 TOPSOIL, BLACK, VERY GRAVELY
2.0 - 24.0 SAND, FINE, WELL-ROUNDED, TO MEDIUM GRAVEL
24.0 - 30.0 CLAY, BROWN TO GRAY, SANDY, SILTY, PEBBLY (TILL)

***

County: BROOKINGS
Map Location: 7
Location: 109N-49W-06BBBB
Legal Location: NW NW NW SEC. 08, T. 109 N., R. 49 W.
Latitude: 44.1603
Longitude: 96.4344
Land Owner:
Project: KINGSBURY-BROOKINGS STUDY
Drilling Company: SDGS
Driller: G. JENSEN, L. HELSETH
Geologist: L. HAMILTON
Driller's Log:
Geologist's Log: X
Appendix A-19
Date Drilled: 06-26-1987
Ground Surface Elevation: 1600.00 T
Total Drill Hole Depth: 95.0
Water Rights Well: 
Other Well Name: 
Basin: BIG SIOUX
Management Unit: AURORA
Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation: 1603.00 T
Casing Stick-up: 3.00
Well Maintenance Date: 
USGS Hydrological Unit Code: 10170202
Electric Log Information:
Spontaneous Potential: 
Neutral Gamma: 
Samples:

LOG WRITTEN BY J.D. LEHR FROM DRILLER'S AND HAMILTON'S LOGS.
0 - 4.0 CLAY, GRAY (TOPSOIL)
4.0 - 75.0 SAND AND GRAVEL, GRAYISH-BROWN, FINE TO VERY COARSE SAND, VERY FINE TO MEDIUM PEBBLE GRAVEL
75.0 - 95.0 CLAY, GRAY, SILTY, SANDY, PEBBLY (TILL)

County: BROOKINGS
Map Location: 
Legal Location: NW NW NW NW SEC. 31, T. 110 N., R. 48 W.
Latitude: 44.1746
Land Owner: 
Project: USGS
Drilling Company: HURON DRILLING
Driller: 
Geologist: J. GOODMAN
Date Drilled: 08-11-1977
Ground Surface Elevation: 1651.00 T
Total Drill Hole Depth: 50.0
Water Rights Well: BG-771
Other Well Name: 
Basin: BIG SIOUX
Management Unit: AURORA
Screen Type: PVC
Casing Type: PVC
Casing Top Elevation: 
Casing Stick-up: 3.10
Well Maintenance Date: 06-23-1982
USGS Hydrological Unit Code: 10170202
Electric Log Information:
Spontaneous Potential: 
Neutral Gamma: 
Samples:

Drilling Method: ROTARY
Test Hole Number: R1-87-69
SDGS Well Name: R1-87-69
Aquifer: BIG SIOUX
Screen Length: 5.0
Casing Diameter: 2.0
Total Casing and Screen: 70.0
Single Point Resistivity: 
Extra:

County: BROOKINGS
Map Location: 
Legal Location: NW NW NW NW SEC. 31, T. 110 N., R. 48 W.
Latitude: 44.1746
Land Owner: 
Project: USGS
Drilling Company: HURON DRILLING
Driller: 
Geologist: J. GOODMAN
Date Drilled: 08-11-1977
Ground Surface Elevation: 1651.00 T
Total Drill Hole Depth: 50.0
Water Rights Well: BG-771
Other Well Name: 
Basin: BIG SIOUX
Management Unit: AURORA
Screen Type: PVC
Casing Type: PVC
Casing Top Elevation: 
Casing Stick-up: 3.10
Well Maintenance Date: 06-23-1982
USGS Hydrological Unit Code: 10170202
Electric Log Information:
Spontaneous Potential: 
Neutral Gamma: 
Samples:

Drilling Method: ROTARY
Test Hole Number: R1-87-69
SDGS Well Name: R1-87-69
Aquifer: BIG SIOUX
Screen Length: 5.0
Casing Diameter: 2.0
Total Casing and Screen: 70.0
Single Point Resistivity: 
Extra:

Location: 10N-46W-31BBBB
Longitude: 96.3846
Driller's Log:
Geologist's Log: X
Drilling Method: ROTARY
Test Hole Number: 
SDGS Well Name:
Aquifer: BIG SIOUX
Screen Length: 5.0
Casing Diameter: 2.0
Total Casing and Screen: 34.3
Single Point Resistivity: 
Extra:

Appendix A-20
0 -  1.0  TOPSOIL, BLACK
1.0 -  9.0  SAND AND GRAVEL, BROWN, MEDIUM TO COARSE
9.0 -  15.0  CLAY, YELLOW-BROWN, SILTY, FEBBLY (TILL)
15.0 -  45.0  SAND AND GRAVEL, BROWN TO GRAY, MEDIUM
    TO COARSE
45.0 -  50.0  CLAY, GRAY, Silt, Ty, Febbly (TILL)

County: BROOKINGS
Map Location: 9
Legal Location: SW SW SW SE Sec. 26, T. 110 N., R. 49 W.
Latitude: 44.1748
Land Owner:
Project: AURORA CITY STUDY-1988
Drilling Company: SDGS
Driller: D. IVESON
Geologist: K. WILKIE/I. DAWSON
Date Drilled: 11-21-1988
Ground Surface Elevation: 1633.00 T
Total Drill Hole Depth: 35.0
Water Rights Well:
Other Well Name:
Bassin: BIG SIOUX
Management Unit: AURORA
Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation: 1635.50 T
Casing Stick-up: 2.57
Well Maintenance Date: USGS Hydrological Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:
Extra:

10 FEET OF BLANK CASING (OPEN TO SCREEN) FROM 34
TO 24 FEET; SCREEN FROM 24 TO 9 FEET; WATER
LEVEL IS 11 FEET BELOW GROUND SURFACE.

0 -  1.0  TOPSOIL, BLACK
1.0 -  2.0  CLAY, YELLOW-BROWN
2.0 -  4.0  SAND, FINE TO MEDIUM
4.0 -  35.0  GRAVEL, MEDIUM TO VERY COARSE PEbble
GRAVEL, SATURATED AT 14 FEET

County: BROOKINGS
Map Location: 10
Legal Location: SW SW SW SE Sec. 27, T. 110 N., R. 49 W.
Latitude: 44.1747
Land Owner:
Project: AURORA CITY STUDY-1988
Appendix A-21
Drilling Company: SDGS
Driller: D. IVESON
Geologist: K. WILKIE/E. DAWSON
Date Drilled: 11-21-1988
Ground Surface Elevation: 1632.00 T
Total Drill Hole Depth: 40.0
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX
Management Unit: AURORA
Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation: 1634.50 T
Casing Stick-up: 2.40
Well Maintenance Date:
USGS Hydrological Unit Code: 1070203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:

10 FEET OF BLANK CASING (OPEN TO SCREEN) FROM 36 TO 26 FEET, SCREEN FROM 26 TO 11 FEET. WATER LEVEL IS 13 FEET BELOW GROUND SURFACE.

0 - 1.0 TOPSOIL, BLACK
1.0 - 2.0 CLAY, YELLOW-BROWN
2.0 - 40.0 GRAVEL, MEDIUM TO VERY COARSE PEBBLE GRAVEL, SATURATED AT 15 FEET

County: BROOKINGS
Map Location: 11
Legal Location: NE NE NE NE SEC. 29, T. 110 N., R. 49 W.
Latitude: 44.1840
Land Owner:
Project: BROOKINGS CITY STUDY-1979
Drilling Company: SDGS
Driller: T. KENYON
Geologist: K. CARTER
Date Drilled: 06-18-1979
Ground Surface Elevation: 1623.00 T
Total Drill Hole Depth: 50.0
Water Rights Well: BG-79D
Other Well Name:
Basin: BIG SIOUX
Management Unit: AURORA
Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation:
Casing Stick-up: 3.20
Well Maintenance Date: 06-23-1982
USGS Hydrological Unit Code: 1070203
Electric Log Information:

Location: 110N-49W-29AAAA
Longitude: 96.4343

Appendix A-22
Spontaneous Potential:
Natural Gamma: "Extra:

Samples:

CASING SLOTTED 5 FEET ABOVE A 3-FOOT SANDPOINT.  

0   -  1.0  TOPSOIL, BLACK, CLAYEY 
1.0  -  18.0  SAND AND GRAVEL; OXIDIZED 
18.0 -  28.0  SAND, FINE, SILT 
28.0 -  42.0  SAND AND GRAVEL; UNOXIDIZED 
42.0 -  50.0  CLAY, BROWN TO GRAY; SANDY, SILTY, PEBBLY 

(TILL)

County: BROOKINGS  
Location: N10N-49W-33AAAA 1  
Map Location: 12  
Longitude: 96.4227  
Legal Location: NE NE NE SEC. 33 T. 110 N., R. 49 W.  
Latitude: 44.1748  
Land Owner:  
Project: AURORA CITY STUDY-1988  
Driller’s Log:  
Geologist: K. WILKIE/P. DAWSON  
Drilling Company: SDGS  
Date Drilled: 11-21-1988  
Drilling Method: HOLLOWSTEM  
Ground Surface Elevation: 1632.00 T  
Total Drill Hole Depth: 45.0  
Test Hole Number: R20-88-66  
Water Rights Well:  
SDGS Well Name: R20-88-66  
Other Well Name:  
Basin: BIG SIOUX  
Aquifer: BIG SIOUX  
Management Unit: AURORA  
Screen Type: PVC, MFG.  
Geologist’s Log: X  
Casing Type: PVC  
Drilling:  
Casing Top Elevation: 1634.50 T  
Screen Length: 15.0  
Casing Stick-up: 2.50  
Casing Diameter: 2.0  
Total Casing and Screen: 40.0  
Well Maintenance Date:  
USGS Hydrotopical Unit Code: 10170203  
Electric Log Information:

Spontaneous Potential:
Natural Gamma: "Extra:

Samples:

10 FEET OF BLANK CASING (OPEN TO SCREEN) FROM 37 TO 27.5 FEET, SCREEN FROM 27.5 TO 12.5 FEET. WATER LEVEL IS 18.5 FEET BELOW GROUND SURFACE.  

0   -  1.0  TOPSOIL, BLACK  
1.0  -  13.0  SAND, MEDIUM  
13.0 -  45.0  GRAVEL, MEDIUM TO COARSE PEBBLE GRAVEL; SATURATED AT 21 FEET  

County: BROOKINGS  
Location: N10N-49W-33CCCC  
Map Location: 13  

Appendix A-23
Legal Location: SW SW SW SEC. 33, T. 110 N., R. 49 W.
Latitude: 44.1655
Land Owner: Project: USGS
Drilling Company: HURON DRILLING
Driller: E. LOOMEL
Geologist: J. GOEDMAN
Date Drilled: 08-11-1977
Ground Surface Elevation: 1610.00 T
Total Drill Hole Depth: 20.0
Water Rights Well: BG-77R
Other Well Name: BGGS-8
Basin: BIG SIOUX
Management Unit: AURORA
Screen Type: PVC
Casing Type: PVC
Casing Top Elevation: 0
Casing Stick-up: 0
Well Maintenance Date: 06-23-1982
USGS Hydrological Unit Code: 10170202
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:

0 - 1.0 TOPSOIL, BLACK
1.0 - 20.0 SAND AND GRAVEL, COARSE

County: BROOKINGS
Map Location: 14
Legal Location: SW NW SE SE SEC. 34, T. 110 N., R. 49 W.
Latitude: 44.1704
Land Owner: Project: AURORA CITY STUDY-1988
Drilling Company: SDGS
Driller: D. JACOBSON
Geologist: P. DAWSON
Date Drilled: 06-07-1988
Ground Surface Elevation: 1621.37 I
Total Drill Hole Depth: 122.0
Water Rights Well: 
Other Well Name: 
Basin: BIG SIOUX
Management Unit: 
Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation: 1624.22 I
Casing Stick-up: 2.85
Well Maintenance Date: 
USGS Hydrological Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma: Longtitude: 96.4338
Driller's Log: 
Geologist's Log: X
Drilling Method: ROTARY
Test Hole Number: SDGS Well Name: Aquifer: BIG SIOUX
Screen Length: Casing Diameter: 1.5
Total Casing and Screen: 15.5
Single Point Resistivity: Extra:

Location: 110N-49W-34DB
Longtitude: 96.4133
Driller's Log: 
Geologist's Log: X
Drilling Method: ROTARY
Test Hole Number: CO-48-09 SDGS Well Name: CO-48-09
Aquifer: PLEISTOCENE SERIES
Screen Length: 10.0
Casing Diameter: 2.0
Total Casing and Screen: 122.9
Single Point Resistivity: Extra:

Appendix A-24
Samples:

7 FEET OF BLANK CASING (CLOSED TO SCREEN) FROM 120 TO 113 FEET, SCREEN FROM 113 TO 103 FEET.

0 - 2.0 TOPSOIL, BLACK
2.0 - 64.0 GRAVEL, COARSE TO VERY COARSE PEBBLE GRAVEL, COARSE SAND LAYER FROM 40 TO 50 FEET; HIT ROCK AT 56 FEET; OXIDIZED
64.0 - 104.0 CLAY, GRAY, SANDY, PEBBLY (TILL)
104.0 - 115.0 GRAVEL, MEDIUM TO VERY COARSE PEBBLE GRAVEL, OXIDIZED
115.0 - 122.0 CLAY, GRAY, SANDY, PEBBLY; CALCAREOUS (TILL)

* * * *

PRELIMINARY LOG -- SUBJECT TO CHANGE

County: BROOKINGS
Map Location: 15
Legal Location: NW NW NW SEC 35, T. 110 N., R. 49 W.
Latitude: 44.1743
Longitude: 96.4112

Land Owner:

Project: KINGSBURY-BROOKINGS STUDY
Drilling Company: SDGS
Driller: C. SCHMIG
Geologist: G. JOHNSON
Date Drilled: 07-04-1985

Ground Surface Elevation: 1633.00 T
Total Drill Hole Depth: 118.0
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX
Management Unit:
Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation: 1637.00 T
Casing Stick-up: 4.00
Well Maintenance Date:
USGS Hydrological Unit Code: 10170202
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Extra: X
Samples:

NO E-LOG.

0 - 3.0 CLAY, LIGHT-BROWN, SILTY (TOPSOIL)
3.0 - 48.0 SAND AND GRAVEL, COARSE SAND TO VERY COARSE PEBBLES
48.0 - 104.0 CLAY, LIGHT-GRAY, SILTY, SANDY, PEBBLY; CALCAREOUS (TILL)
104.0 - 115.0 SAND AND GRAVEL; COARSEST FRACTION NEAR BASE OF UNIT

Appendix A-25
DESCRIPTION BASED ON LOGS FROM DRILLER AND FIELD ASSISTANT (KATHY MARTIN); CUTTINGS EXAMINED

County: BROOKINGS
Map Location: 16
Legal Location: NW SW NW SEC. 35, T. 110 N., R. 49 W.
Latitude: 44.1727
Land Owner:
Project: AURORA CITY STUDY-1988
Drilling Company: SDSG
Driller: D. JACOBSON
Geologist: P. DAWSON
Date Drilled: 06-21-1988
Ground Surface Elevation: 1629.10 I
Total Drill Hole Depth: 57.0
Water Rights Well:
Other Well Name:
Basin: BG SIOUX
Management Unit: AURORA
Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation: 1631.62 I
Casing Stick-up: 2.39
Well Maintenance Date:
USGS Hydrological Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:
SCREEN FROM 41 TO 51 FEET:

0 - 2.0 TOPSOIL, BLACK
2.0 - 50.0 GRAVEL, MEDIUM PEBBLE GRAVEL FROM 2 TO 30 FEET, COARSE PEBBLE GRAVEL FROM 30 TO 50 FEET, OXIDIZED
50.0 - 57.0 CLAY, GRAY, STICKY (TILL)

County: BROOKINGS
Map Location: 17
Legal Location: NW SW SW SEC. 35, T. 110 N., R. 49 W.
Latitude: 44.1727
Land Owner:
Project: AURORA CITY STUDY-1988
Drilling Company: SDSG
Driller: D. JACOBSON
Geologist: P. DAWSON

Location: 110N-49W-35BCCB
Longitude: 96.4113
Driller's Log:
Geologist's Log: X
Drilling Method: ROTARY
Test Hole Number: CO-88-18
SDGS Well Name: CO-88-18
Aquifer: BIG SIOUX
Screen Length: 10.0
Casing Diameter: 2.0
Total Casing and Screen: 53.4
Single Point Resistivity: Extra:

Appendix A-26
Date Drilled: 06-21-1988
Ground Surface Elevation: 1629.10 I
Total Drill Hole Depth: 127.0
Water Rights Well: 1
Other Well Name: Basin: BIG SIOUX
Management Unit: Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation: 1631.62 I
Casing Stick-up: 2.52
Well Maintenance Date: USGS Hydrological Unit Code: 10170203
Electric Log Information: Spontaneous Potential:
Natural Gamma: Samples:

SCREEN FROM 115 TO 120 FEET.

0 - 2.0 TOPSOIL, BLACK
2.0 - 50.0 GRAVEL, MEDIUM TO VERY COARSE PEBBLE
     GRAVEL; OXIDIZED
50.0 - 70.0 CLAY, GRAY; STICKY (TILL)
70.0 - 84.0 GRAVEL, FINE TO COARSE PEBBLE GRAVEL;
     OXIDIZED
84.0 - 87.0 CLAY, GRAY; STICKY (TILL)
87.0 - 92.0 GRAVEL STRINGER, FINE TO COARSE PEBBLE
     GRAVEL; OXIDIZED
92.0 - 100.0 CLAY, GRAY; STICKY (TILL)
100.0 - 103.0 GRAVEL STRINGER, FINE TO COARSE PEBBLE
     GRAVEL; OXIDIZED
103.0 - 112.0 CLAY, GRAY; STICKY (TILL)
112.0 - 121.0 GRAVEL, MEDIUM TO COARSE PEBBLE GRAVEL;
     OXIDIZED
121.0 - 127.0 CLAY, GRAY; STICKY (TILL)

*****

County: BROOKINGS
Map Location: 18
Legal Location: SW SW NW SE. 35, T. 110 N., R. 49 W.
Latitude: 44.1712
Land Owner:
Project: AURORA CITY STUDY-1988
Drilling Company: SDGS
Driller: D. JACOBSON
Geologist: P. DAWSON
Date Drilled: 06-16-1988
Ground Surface Elevation: 1620.00 T
Total Drill Hole Depth: 147.0
USGS Hydrological Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma: X

Location: 110N-49W-35CBCC
Longitude: 96.4113
Driller's Log:
Geologist's Log: X
Drilling Method: ROTARY
Test Hole Number: CO-88-16
Single Point Resistivity: X
Extra:

Appendix A-27
Samples:

<table>
<thead>
<tr>
<th>Depth</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.0</td>
<td>TOPSOIL, BLACK</td>
</tr>
<tr>
<td>2.0</td>
<td>41.0</td>
<td>GRAVEL, MEDIUM TO VERY COARSE PEBBLE GRAVEL, OXIDIZED</td>
</tr>
<tr>
<td>41.0</td>
<td>70.0</td>
<td>CLAY, LIGHT-GRAY; STICKY, ROCK A' 67 FEET (TILL)</td>
</tr>
<tr>
<td>70.0</td>
<td>85.0</td>
<td>GRAVEL, FINE TO COARSE PEBBLE GRAVEL; OXIDIZED</td>
</tr>
<tr>
<td>85.0</td>
<td>90.0</td>
<td>CLAY, LIGHT-GRAY; STICKY (TILL)</td>
</tr>
<tr>
<td>90.0</td>
<td>98.0</td>
<td>GRAVEL, FINE TO COARSE PEBBLE GRAVEL; OXIDIZED</td>
</tr>
<tr>
<td>98.0</td>
<td>147.0</td>
<td>CLAY, LIGHT-GRAY; STICKY (TILL)</td>
</tr>
</tbody>
</table>

LITHOLOGIC DESCRIPTION BASED ON ELECTRIC LOG INTERPRETATION.

* * * *

County: BROOKINGS
Map Location: 19
Legal Location: SW SW NW SW SEC. 35, T. 110 N., R. 49 W.
Latitude: 44.1712
Land Owner:
Project: AURORA CITY STUDY-1988
Drilling Company: SDGS
Driller: D. JACOBSON
Geologist: P. DAWSON
Date Drilled: 06-20-1988
Ground Surface Elevation: 1619.98 I
Total Drill Hole Depth: 47.0
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX
Management Unit: AURORA
Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation: 1621.56 I
Casing Stick-up: 1.63
Well Maintenance Date:
USGS Hydrological Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:

SCREEN FROM 27 TO 37 FEET.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.0</td>
<td>TOPSOIL, BLACK</td>
</tr>
<tr>
<td>2.0</td>
<td>41.0</td>
<td>GRAVEL, MEDIUM TO VERY COARSE PEBBLE GRAVEL, OXIDIZED</td>
</tr>
<tr>
<td>41.0</td>
<td>47.0</td>
<td>CLAY, LIGHT-GRAY; STICKY (TILL)</td>
</tr>
</tbody>
</table>

* * * *

Location: 118N-49W-35CBCC 1
Longitude: 96.4113
Diaper's Log: X
Test Hole Number: CO-88-17
SDGS Well Name: CO-88-17
Geologist's Log: ROTARY
Aquifer: BIG SIOUX
Screen Length: 10.0
Casing Diameter: 2.0
Total Casing and Screen: 38.6
Single Point Resistivity: Extra:

Appendix A-28
County: BROOKINGS
Map Location: 20
Legal Location: NE NE SW SW SEC. 35, T. 110 N., R. 49 W.
Latitude: 44.1708
Longitude: 96.4057
Land Owner:
Project: AURORA CITY STUDY-1988
Drilling Company: SDGS
Driller: D. JACOBSON
Geologist: P. DAWSON
Date Drilled: 06-14-1988
Ground Surface Elevation: 1627.64
Total Drill Hole Depth: 137.0
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX
Management Unit:
Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation: 1630.32
Casing Stick-up: 2.68
Well Maintenance Date:
USGS Hydrological Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma: X
Single Point Resistivity: X
Exits:
Samples:
29 FEET OF BLANK CASING (CLOSED TO SCREEN) FROM 136 TO 107 FEET, SCREEN FROM 107 TO 97 FEET.
0 - 2.0 TOPSOIL, BLACK
2.0 - 37.0 GRAVEL, MEDIUM TO VERY COARSE PEBBLE
GRAVEL, OXIDIZED
37.0 - 94.0 CLAY, GRAY, SILTY, SANDY, PEBBLY (TILL)
94.0 - 110.0 GRAVEL, FINE TO COARSE PEBBLE GRAVEL
OXIDIZED
110.0 - 137.0 CLAY, GRAY, SILTY, SANDY, PEBBLY (TILL)

County: BROOKINGS
Map Location: 21
Legal Location: NE NE SW SW SEC. 35, T. 110 N., R. 49 W.
Latitude: 44.1708
Longitude: 96.4057
Land Owner:
Project: AURORA CITY STUDY-1988
Drilling Company: SDGS
Driller: D. JACOBSON
Geologist: P. DAWSON
Date Drilled: 06-13-1988
Ground Surface Elevation: 1627.63
Total Drill Hole Depth: 42.0
Water Rights Well:
Other Well Name:
Basin: BIG SIOUX
Aquifer: PLEISTOCENE SERIES
Appendix A-29
Management Unit: AURORA
Screen Type: PVC, MFG.
Casing Type: PVC
Casing Top Elevation: 1630.22 I
Casing Stick-up: 2.59
Well Maintenance Date:
USGS Hydrological Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:

SCREEN FROM 22 TO 32 FEET.

0 - 2.0 TOPSOIL, BLACK
2.0 - 37.0 GRAVEL, MEDIUM TO VERY COARSE PEBBLE GRAVEL; OXIDIZED
37.0 - 42.0 CLAY, GRAY, SILTY, PEBBLY; VERY STICKY (TILL)

* * *

County: BROOKINGS
Map Location: 22
Legal Location: SE SE SE SEC. 36, T. 110 N., R. 49 W.
Latitude: 44.1656
Land Owner:
Project: USGS
Drilling Company: HURON DRILLING
Driller:
Geologist: J. GOODMAN
Date Drilled: 08-11-1977
Ground Surface Elevation: 1628.00 T
Total Drill Hole Depth: 50.0
Water Rights Well: BG-77J
Other Well Name:
Basin: BIG SIOUX
Management Unit: AURORA
Screen Type: PVC
Casing Type: PVC
Casing Top Elevation:
Casing Stick-up: 1.90
Well Maintenance Date: 06-23-1982
USGS Hydrological Unit Code: 10170203
Electric Log Information:
Spontaneous Potential:
Natural Gamma:
Samples:

0 - 4.0 TOPSOIL, BLACK
4.0 - 45.0 SAND AND GRAVEL, BROWN, MEDIUM TO COARSE
45.0 - 50.0 CLAY, GRAY, SILTY, PEBBLY (TILL)

* * *

Location: 110N-49W.36DDDD
Longitude: 96.3851
Driller's Log:
Geologist's Log: X
Drilling Method: ROTARY
Test Hole Number:
SDGS Well Name:
Aquifer: BIG SIOUX
Screen Length: 5.0
Casing Diameter: 2.0
Total Casing and Screen: 45.4
Single Point Resistivity:
Extra:

Appendix A-30