Site Suitability Review of the Williston Landfill

by
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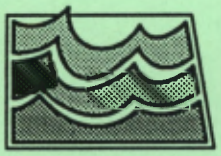

Prepared by the
North Dakota State Water Commission
and the
North Dakota Geological Survey

ND Landfill Site Investigation No. 37

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Bismarck, North Dakota
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INTRODUCTION

Purpose

The North Dakota State Engineer and the North Dakota State Geologist were instructed by the 52nd State Legislative Assembly to conduct site-suitability reviews of the solid waste landfills in the state of North Dakota. These reviews are to be completed by July 1, 1995 (North Dakota Century Code 23-29-07.7). The purpose of this program is to evaluate site suitability of each landfill for disposal of solid waste based on geologic and hydrologic characteristics. Reports will be provided to the North Dakota State Department of Health and Consolidated Laboratories (NDSDHCL) for use in site improvement, site remediation, or landfill closure. A one time ground-water sampling event was performed at each site, and additional studies may be necessary to meet the requirements of the NDSDHCL for continued operation of solid-waste landfills. The Williston solid waste landfill is one of the landfills being evaluated.

Location of the Williston Landfill

The Williston solid-waste landfill is located about one and one-half miles northeast of the city of Williston in Township 154 North, Range 100 West, NW 1/4 Section 17 (Fig. 1). The landfill area encompasses about 100 acres.

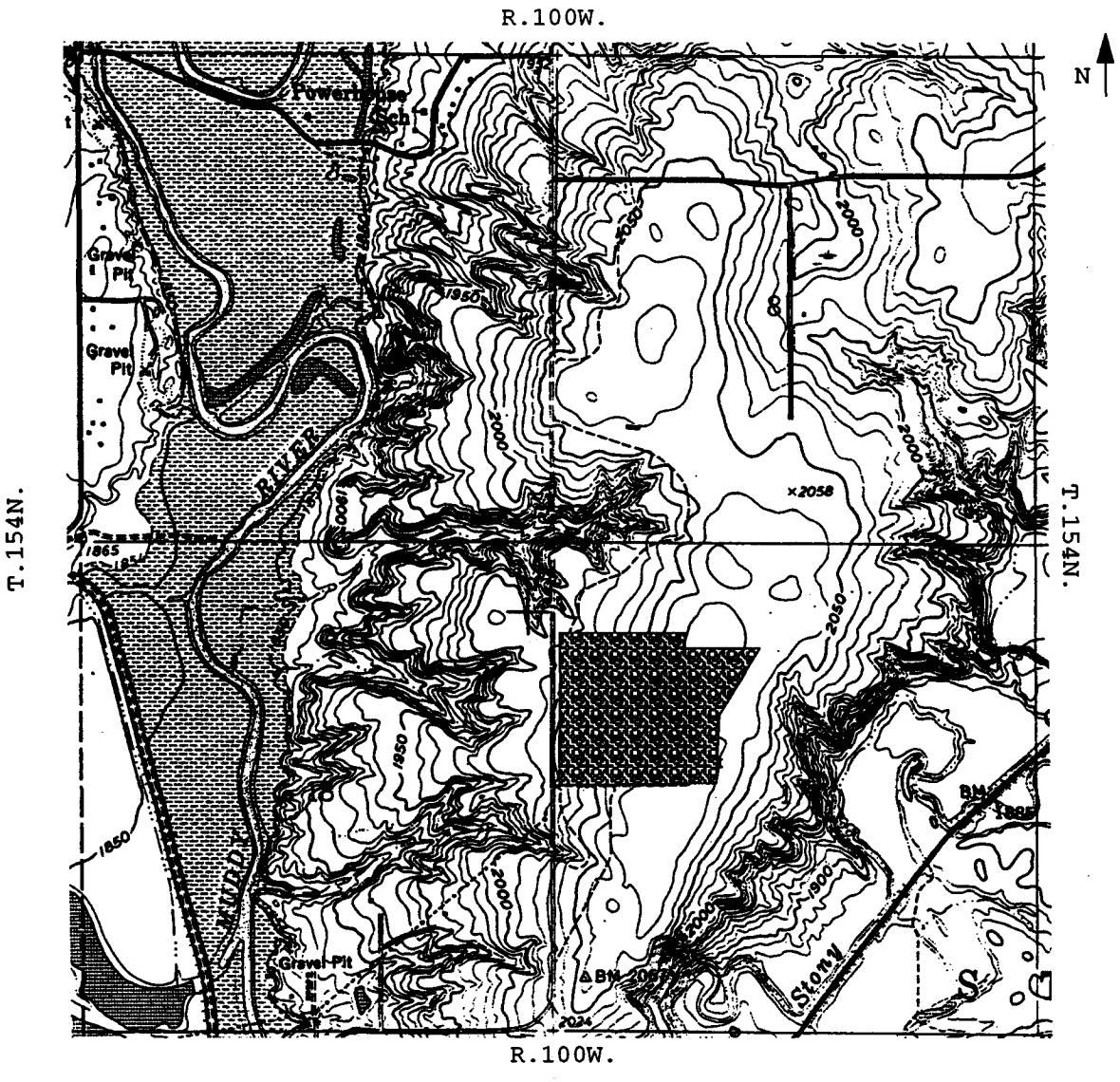

Figure 1. Location of the Williston municipal landfill in the NW 1/4, Section 17, T.154N., R.100W.

Previous Site Investigations

A hydrogeologic investigation was completed at the Williston landfill in 1992 by Water Supply Incorporated (WSI). This investigation included previous information from the original site evaluation (Braun, 1984) and the location of subsurface mine boundaries (Verplanke, 1984).

The WSI investigation identified four hydrologic units at the site. These units consisted of weathered lignite (leonardite), silt, sand, and lignite. WSI determined that ground water occurs under perched conditions in each of the four hydrologic units.

The leonardite unit varies in thickness and areal extent. Water only was found in one well screened in the leonardite. The leonardite has been excavated within the landfill boundary.

The "silty zone" described by WSI was penetrated by one well. This well was found to be dry.

The "sand zone" identified by WSI is separated from the "silty zone" by a 20- to 60-foot thick layer of clay. The sand was found to extend across the site from east to west with a hydraulic gradient to the west. WSI identified the sand unit as the only aquifer at the site.

WSI did not install monitoring wells in the lignite unit.

Methods of Investigation

The Williston study was accomplished by means of: 1) drilling test holes; 2) constructing and developing monitoring wells; 3) collecting and analyzing water samples; and 4) measuring water levels.

Test-Drilling Procedure

The drilling method at the Williston landfill was based on the site's geology and depth to ground water, as determined by the preliminary evaluation. A forward rotary drill rig was used at the Williston landfill because the sediments were consolidated and because the depth to the water table was expected to be greater than 70 feet. The lithologic descriptions were determined from the drill cuttings.

Monitoring Well Construction and Development

Six test holes were drilled at the Williston landfill, and monitoring wells were installed in five of the test holes. Four existing wells from the WSI investigation were also incorporated into this study. The number of wells installed at the Williston landfill was based on the geologic and topographic characteristics of the site. The depth and intake interval of each well was selected to monitor the

water level at the top of the uppermost aquifer. The wells were located within boundaries of the landfill.

Wells were constructed following a standard design (Fig. 2) intended to comply with the construction regulations of the NDSDHCL and the North Dakota Board of Water Well Contractors (North Dakota Department of Health, 1986). The wells were constructed using a 2-inch diameter, SDR21, polyvinyl chloride (PVC) well casing and a PVC screen, either 5 or 10 feet long, with a slot-opening size of 0.012 or 0.013 inches. The screen was fastened to the casing with stainless steel screws (no solvent weld cement was used). After the casing and screen were installed into the drill hole, the annulus around the screen was filled with No. 10 (grain-size diameter) silica sand to a height of two feet above the top of the screen. A two to three-foot bentonite plug was placed above the sand pack using one-half inch bentonite pellets. High-solids bentonite grout and/or neat cement was placed above the bentonite plug to seal the annulus to approximately five feet below land surface. The remaining annulus was filled with drill cuttings. The permanent wells were secured with a protective steel casing and a locking cover protected by a two-foot-square concrete pad.

All monitoring wells were developed using a stainless steel bladder pump or a teflon bailer. Any drilling fluid and fine materials present near the well were removed to insure movement of formation water through the screen.

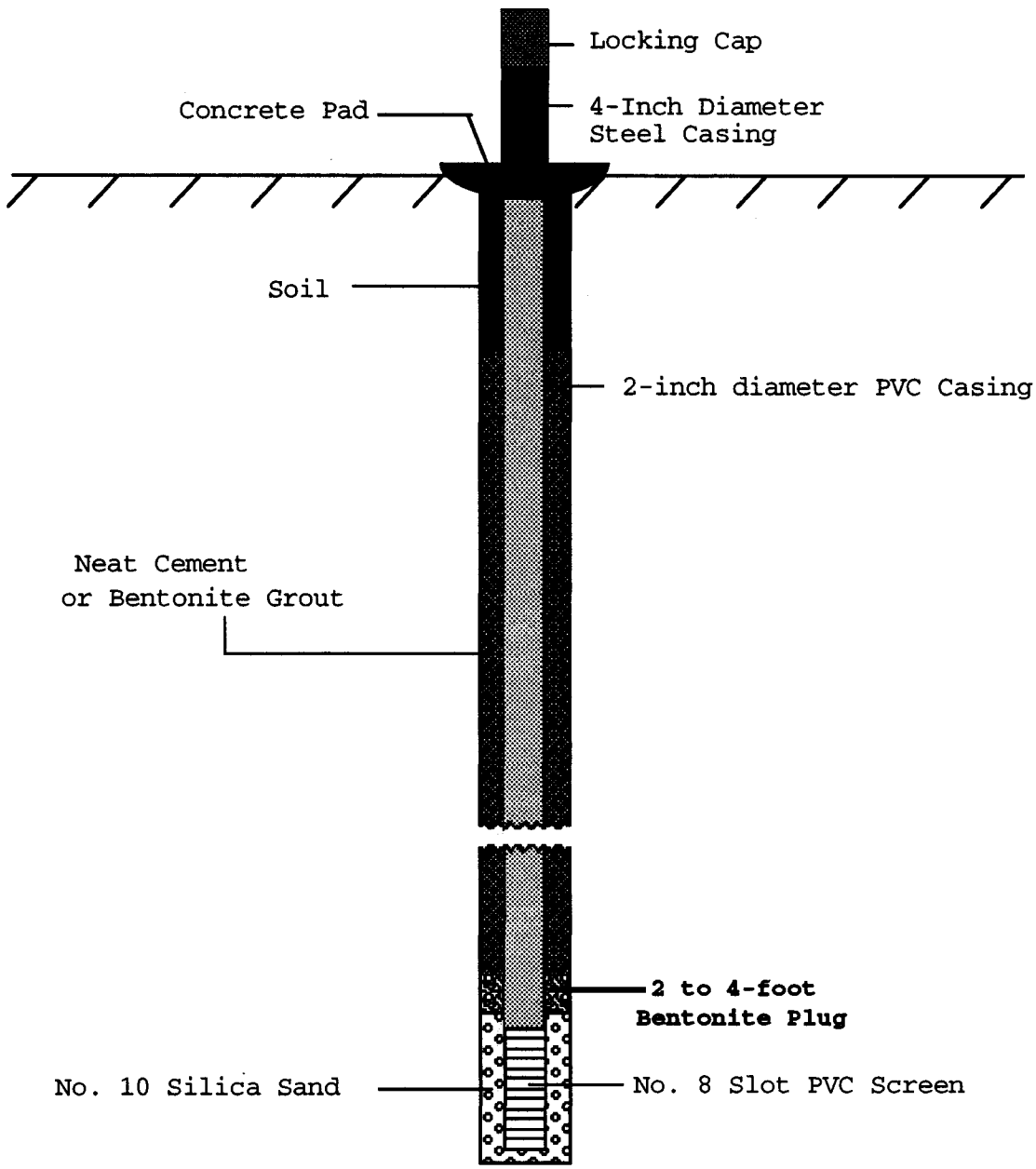

Figure 2. Construction design used for monitoring wells installed at the Williston landfill.

The Mean Sea Level (MSL) elevation was established for each well by differential leveling to Third Order accuracy. The surveys established the MSL elevation at the top of the casing and the elevation of the land surface next to each well.

Collecting and Analyzing Water Samples

Water-quality analyses were used to determine if leachate is migrating from the landfill into the underlying ground-water system. Selected field parameters, major ions, and trace elements were measured for each water sample. These field parameters and analytes are listed in Appendix A with their Maximum Contaminant Levels (MCL). MCLs are enforceable drinking water standards that represent the maximum permissible level of a contaminant as stipulated by the U.S. Environmental Protection Agency (EPA).

Water samples were collected using a bladder pump constructed of stainless steel with a teflon bladder. A teflon bailer was used in monitoring wells with limited transmitting capacity. Before sample collection, three to four well volumes were extracted to insure that unadulterated formation water was sampled. Four samples from each well were collected in high-density polyethylene plastic bottles as follows:

1) Raw (500 ml)

2) Filtered (500 ml)

3) Filtered and acidified (500 ml)

4) Filtered and double acidified (500 ml)

The following parameters were determined for each sample: Specific conductance, pH, bicarbonate, and carbonate were analyzed using the raw sample. Sulfate, chloride, nitrate*, and dissolved solids were analyzed using the filtered sample. Calcium, magnesium, sodium, potassium, iron, and manganese were analyzed from the filtered, acidified sample. Cadmium, lead, arsenic, and mercury were analyzed using the filtered double-acidified samples.

One well was sampled for Volatile Organic Compounds (VOC) analysis. This sample was collected at a different time than the standard water-quality sample. The procedure used for collecting the VOC sample is described in Appendix B. Each sample was collected with a plastic throw-away bailer and kept chilled. These samples were analyzed within the permitted 14-day holding period. The standard water-quality analyses were performed at the North Dakota State Water Commission (NDSWC) Laboratory and VOC analyses were performed by the NDSDHCL.

Water-Level Measurements

Water-level measurements were taken at least three times at a minimum of two-week intervals. The measurements were taken using a chalked-steel tape or an electronic (Solnist

* No special preservative techniques were applied to nitrate samples and as a result reported nitrate concentrations may be lower than actual.

10078) water-level indicator. These measurements were used to determine the shape and configuration of the water table.

Location-Numbering System

The system for denoting the location of a test hole or observation well is based on the federal system of rectangular surveys of public land. The first and second numbers indicate Township north and Range west of the 5th Principle Meridian and baseline (Fig. 3). The third number indicates the section. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section (160-acre tract), quarter-quarter section (40-acre tract), and quarter-quarter-quarter section (10-acre tract). Therefore, a well denoted by 154-100-17BDA would be located in the NE1/4, SE1/4, NW1/4, Section 17, Township 154 North, Range 100 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 154-100-17BDA1 and 154-100-17BDA2.

GEOLOGY

Regional Geology

The Williston landfill is located on a ridge between Little Muddy Creek and Stoney Creek (Fig. 4). The geology of

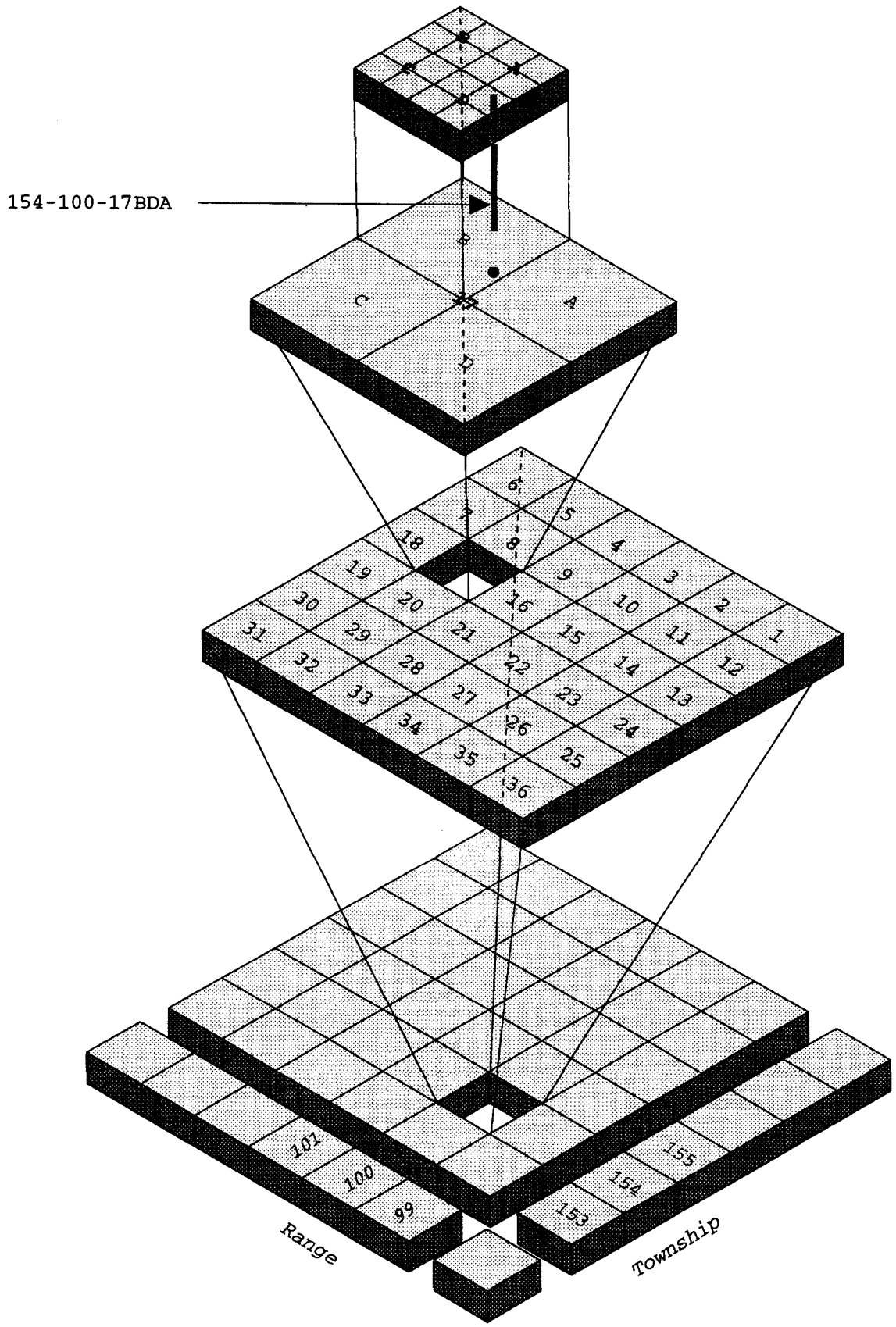

Figure 3. Location-numbering system.

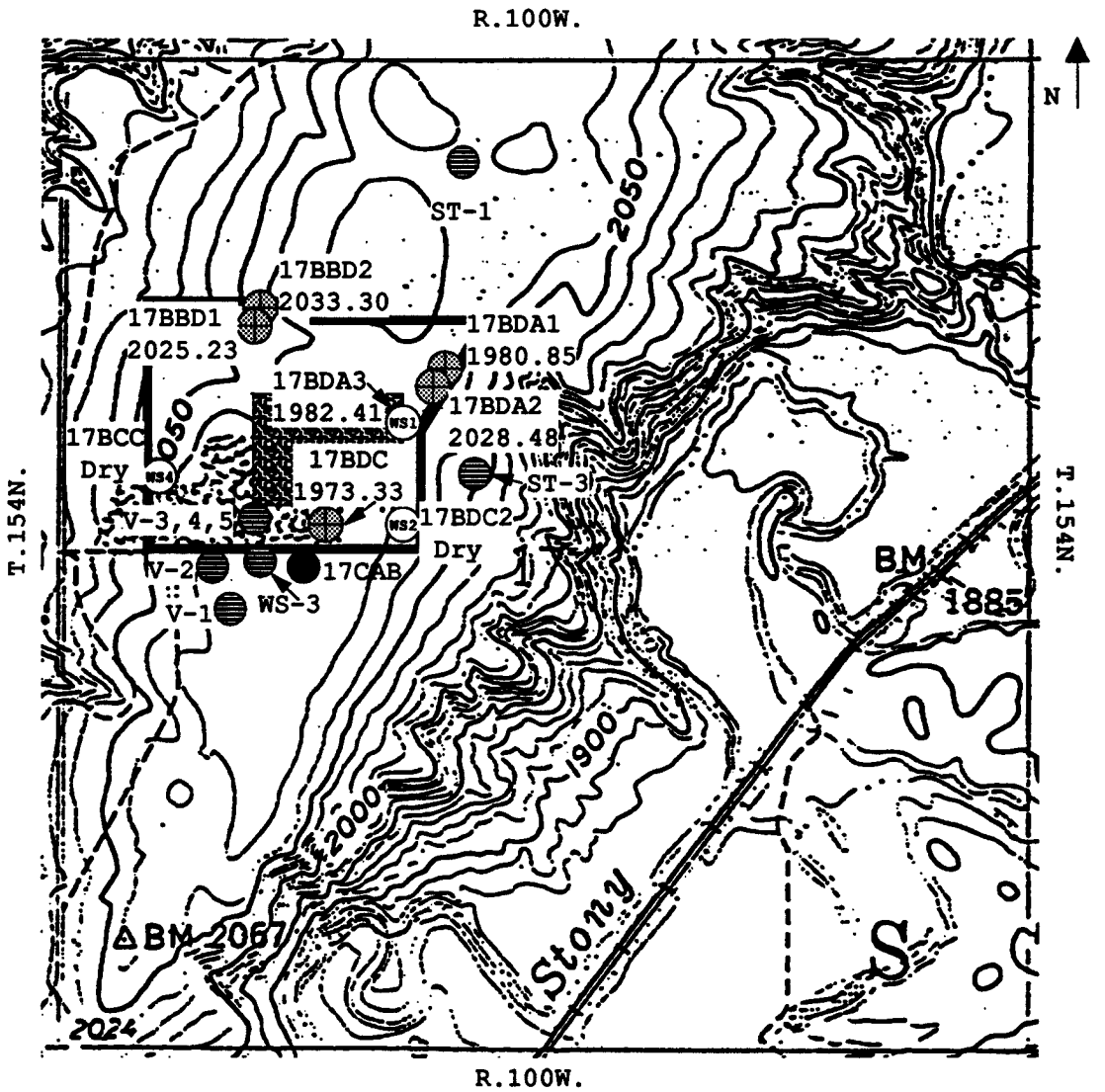

Figure 4. Location of monitoring wells and test holes at the Williston landfill.

the region is characterized by a thin layer of glacial sediments draped over and slightly modifying the pre-existing bedrock topography. The glacial sediments are generally less than 50 feet thick, and in some areas they have been removed by erosion, exposing the underlying Tertiary bedrock (Freers, 1970). The uppermost bedrock unit in the area, the Sentinel Butte Formation, is composed of sand, sandstone, silt, clay, and lignite.

The valleys of Stoney Creek to the east of the landfill and the Little Muddy River to the west contain modest amounts of alluvium and/or glacial outwash. The preglacial Yellowstone River flowed through the west edge of the City of Williston. North of Williston it followed the route of present-day Little Muddy River northward to Divide County. The buried channel of the ancestral Yellowstone is about two miles northwest of the landfill. It is at least 200 feet deep and contains a large quantity of alluvial and glacial sediments (Freers, 1970).

The Missouri River valley south of the landfill also contains alluvial and glacial deposits, consisting of clay, silt, sand, and gravel. The thickest section of these deposits penetrated by a test boring measured 178 feet. This boring was drilled in the floodplain several miles southwest of the City of Williston (Freers, 1970).

Local Geology

The geology at the Williston landfill is illustrated in Figures 5, 6, and 7. A layer of glacial sediment at the surface ranges in thickness from 0 (not present) to 20 feet. These sediments are composed mainly of till, but layers of gravel are also present in test holes ST-1 and 154-100-17BDA2.

The glacial sediments are underlain by a layer of weathered lignite (known as "leonardite") which ranges from 0 (not present) to 20 feet thick. These wide variations in thickness are due mainly to erosion. The leonardite has been removed beneath the active area of the landfill. The leonardite is being mined at the northern boundary of the landfill by GeoResources, Inc. for use as a drilling mud additive (Schmid, 1992). The leonardite is underlain by clay that is generally 5 to 15 feet thick.

The next unit is a sand and silt zone (called the "silty zone" by Schmid, 1992). This unit has a variable composition, ranging from silty sand to sandy silt to clayey silt. The unit is less than 10 feet thick in all areas except on the east side of the landfill, where it is thicker and contains a high proportion of sand. At test hole ST-3 the silty zone consists of 5 feet of silt and 20 feet of fine-grained, silty sand. At test hole 154-100-17BDA1 a layer of sandy silt and a separate layer of sand correlate

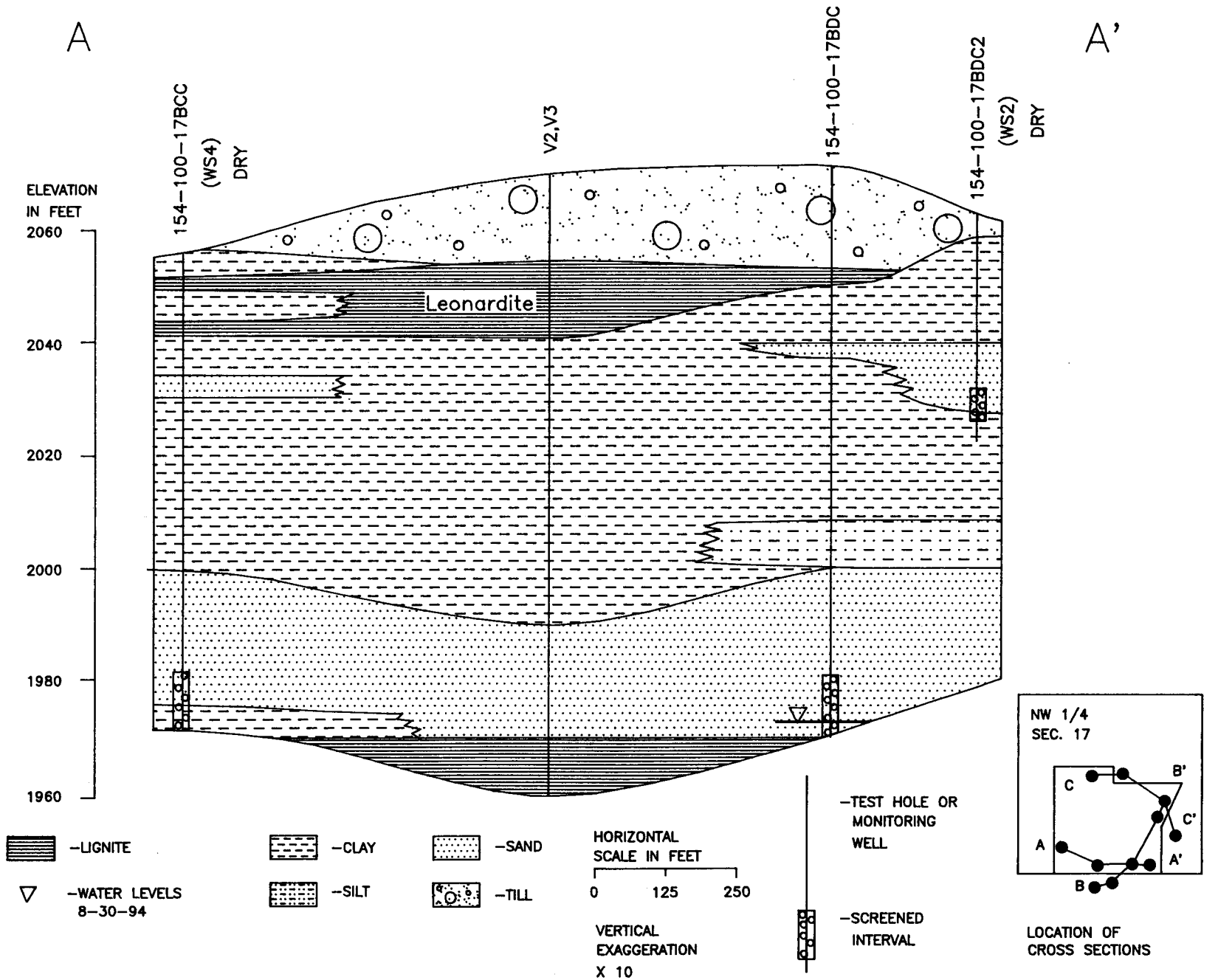

Figure 5. Geohydrologic section A–A' in the Williston landfill.

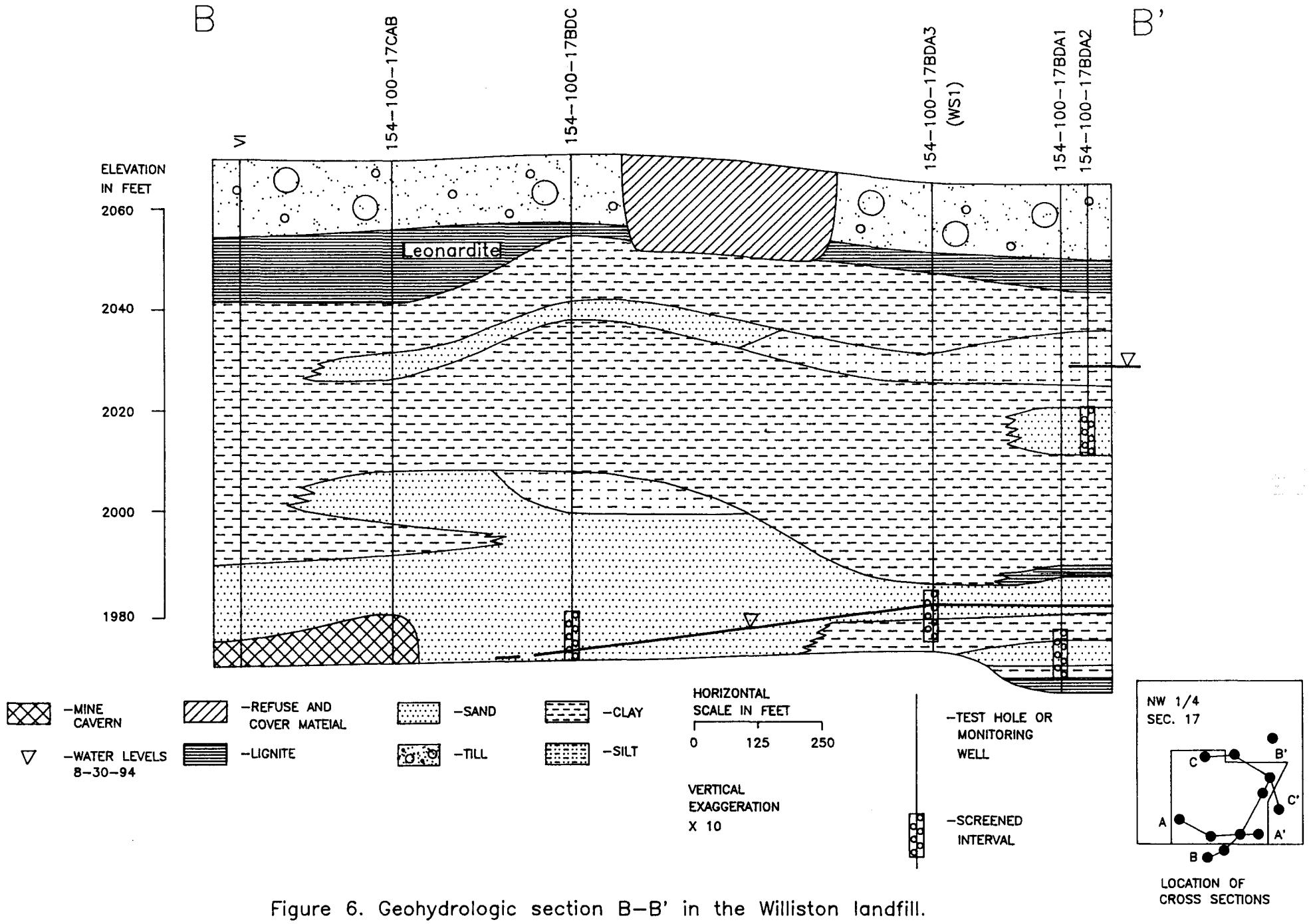

Figure 6. Geohydrologic section B–B' in the Williston landfill.

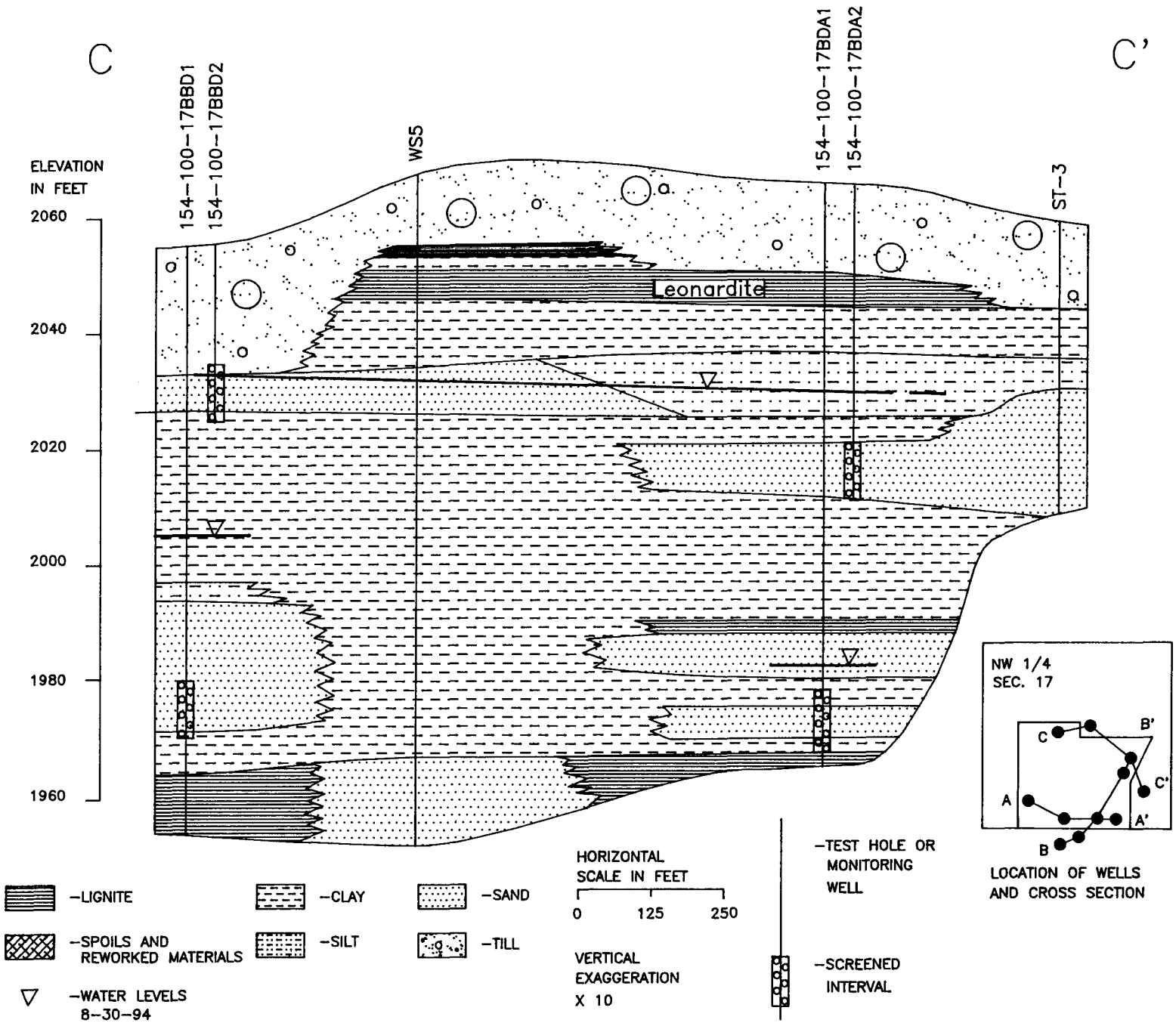

Figure 7. Geohydrologic section C–C' in the Williston landfill.

with the thick layer of silt and sand in test hole ST-3 (Fig. 7).

At test hole ST-1 the silty zone consists of 4 feet of silt and 20 feet of fine-grained, silty sand. ST-1 is located northeast of the landfill in an area slated for future expansion. The silty zone was not reported in test holes V1, V2, or ST-2W.

The silty zone is underlain by a thick (20 feet or more) layer of clay. The clay is underlain by a layer of fine-grained, silty sand that has a maximum thickness of about 30 feet. This sand is absent in test hole WS-5 (Fig. 5). The deep sand at this test hole site appears to be a separate unit (Schmid, 1992).

A lignite bed occurs near the base of many of the deeper test holes. The lignite is about 10 feet thick at test holes V3, V4, V5, and 154-100-17BBD1. The lignite was mined by underground methods in the area south of the landfill. Test holes V1, V2, and 154-100-17CAB encountered caverns and rubble resulting from the underground mining (Fig. 6).

HYDROLOGY

Surface-Water Hydrology

Stony Creek is located about 1/4 mile to the east downslope of the landfill. Stony Creek is an intermittent stream that flows south and discharges into the Missouri River.

Stony Creek may be susceptible to contaminant migration from the landfill if springs are present along the western slope of the valley.

The Little Muddy River is located about 3/4 mile west of the landfill boundary. The Little Muddy River lies in a valley about 200 feet lower in elevation than the landfill (Fig. 1). The valley appears to be inundated throughout the year. The Little Muddy River flows to the south and discharges into the Missouri River. The Little Muddy River should not be susceptible to surface contamination from the landfill.

The Missouri River is located about 3 miles south of the landfill. The Missouri River is down-gradient but should not be susceptible to contaminant migration due to its distance from the landfill.

Regional Ground-Water Hydrology

Regional aquifers near the Williston landfill consist of bedrock and glacial aquifers. Bedrock aquifers are located in the Dakota, Cannonball/Ludlow, and Bullion Creek/Sentinel Butte Formations. The Dakota aquifer is located at a depth of 4,200 to 5,600 feet below land surface (Armstrong, 1969). The Dakota aquifer is characterized by a sodium-chloride type water. This aquifer should not be affected by contaminant migration from the landfill due to its depth and the occurrence of intervening aquitards (clay layers).

The Cannonball/Ludlow aquifer is located at a depth of about 500 feet below land surface (Armstrong, 1969). The Cannonball/Ludlow aquifer is characterized by a sodium-bicarbonate type water. This aquifer should not be affected by contaminant migration from the landfill due to its depth and the occurrence of intervening aquitards.

The Bullion Creek/Sentinel Butte aquifers directly underlie the glacial deposits. The Bullion Creek/Sentinel Butte aquifers consist of very fine grained sand and lignite beds (Armstrong, 1969). Recharge to the Bullion Creek/Sentinel Butte aquifers is by precipitation. Discharge of the Bullion Creek/Sentinel Butte aquifers occurs as springs at outcrops along valley walls and lateral flow into adjacent glacial aquifers. The Bullion Creek/Sentinel Butte aquifers are characterized by a sodium-bicarbonate type water (Armstrong, 1969). The shallow Bullion Creek/Sentinel Butte aquifers may be susceptible to contaminant migration from the landfill in areas that have a thin clay layer separating the aquifer and the refuse.

The regional glacial aquifers consist of glaciofluvial deposits of sand and gravel in buried valleys (Armstrong, 1969). The Little Muddy aquifer is located in the Little Muddy Creek valley about 3/4 mile west of the landfill. This valley is a buried bedrock valley of the ancestral Yellowstone River (Armstrong, 1969). The Little Muddy aquifer has two separate hydrologic units, the lower and upper units (Armstrong, 1969). The lower unit consists of

predominantly gravel deposits with sand and is about 130 below land surface. The upper unit ranges in thickness from 0 to 116 feet and consists of intermixed sand and gravel (Armstrong, 1969). Recharge to the Little Muddy aquifer is by precipitation and lateral flow from adjacent glacial and bedrock aquifers. The Little Muddy aquifer is characterized by a sodium-sulfate, bicarbonate type water. This aquifer may be susceptible to contaminant migration from the landfill if it is hydraulically connected to adjacent bedrock aquifers that underlie the landfill.

Undifferentiated aquifers are present in isolated sand and gravel deposits. These aquifers are generally limited in areal extent and contain small amounts of water. The ground-water chemistry in these aquifers is variable. One such aquifer underlies the southern portion of Stony Creek. This aquifer may be susceptible to contaminant migration from the landfill if it is hydraulically connected to adjacent bedrock aquifers that underlie the landfill.

Local Ground-Water Hydrology

Six test holes were drilled at the Williston landfill with monitoring wells installed at five of the sites (Fig. 4). Three existing monitoring wells were also used for this investigation (WS-1, WS-2, WS-4). Six monitoring wells were located at three separate sites to monitor two separate hydrologic units in the Sentinel Butte Formation. The upper

unit was described by as a "silty zone" and the lower unit was described as a "sand zone" (Schmid 1992). The two hydrologic units are separated by 20 to 60 feet of clay (Figs. 5, 6 and 7).

Four water-level measurements were taken over an eight-week period. The "silty zone" was found to be dry beneath the landfill at well 17BDC2 but shows a ground-water flow to the east in wells 17BBD2 and 17BDA2. This "silty zone" may be susceptible to contaminant migration if it is intersected by the refuse cell.

The lower unit of sand was identified as the uppermost aquifer beneath the landfill. Within the landfill study area the direction of ground-water flow in the deep sand aquifer is to the southeast (Fig 8). The presence of the subsurface mines appears to have an influence in the direction and gradient of the lower sand aquifer at the south property line of the landfill (Fig. 6). This sand layer appears to extend beyond the landfill boundaries and may outcrop along the valley walls on the east and west side of the landfill. This aquifer may be susceptible to contaminant migration where the overlying clay is relatively thin and fractured.

Water Quality

Chemical analyses of water samples are shown in Appendix E. The Williston landfill is located along the north

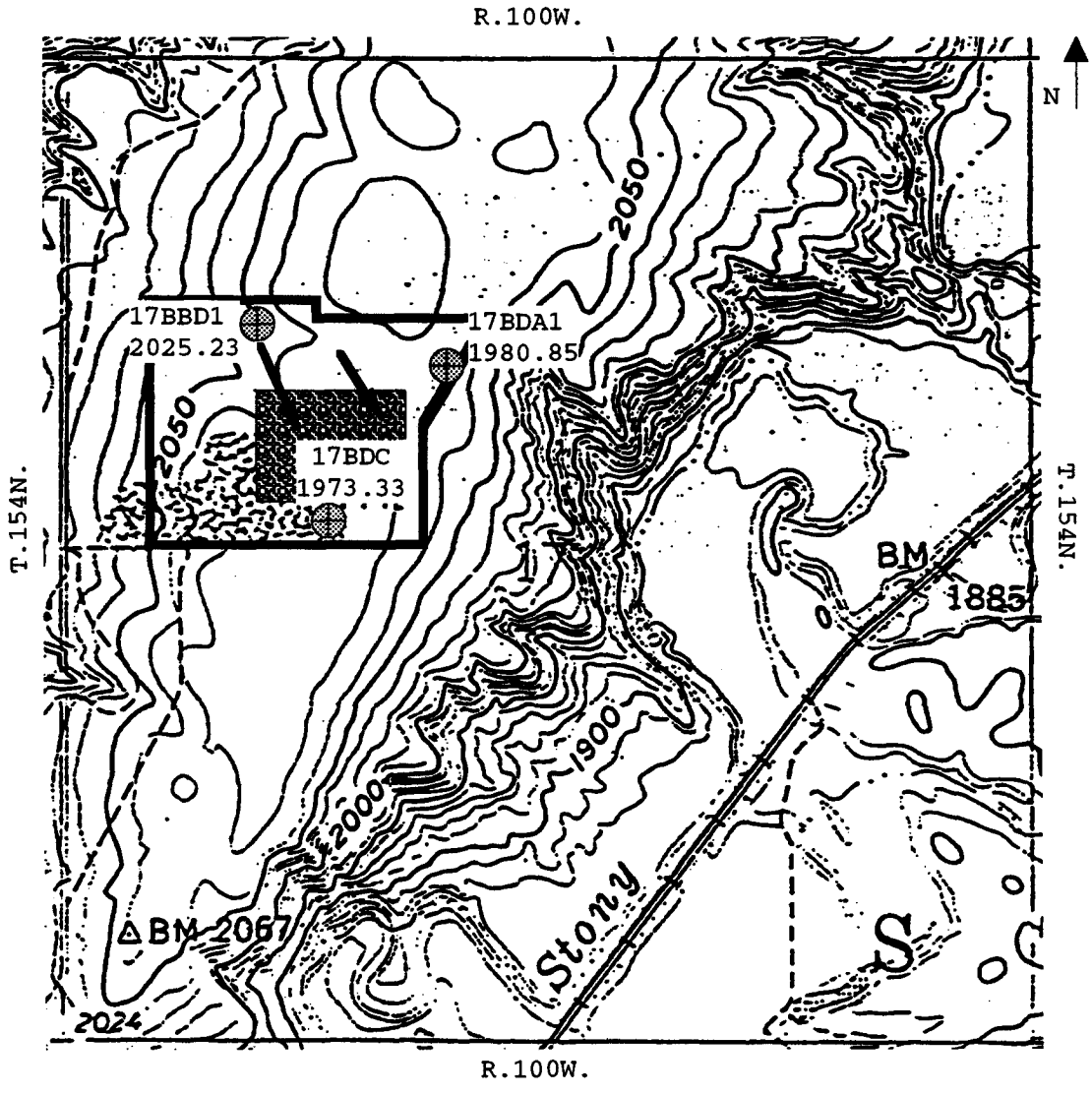

Figure 8. Location of monitoring wells and the direction of ground-water flow in the deep sand aquifer.

boundary of an old landfill where mined salt residue has been disposed.

The water beneath the landfill is characterized by a sodium-bicarbonate to a sodium-sulfate type water. This water is typical of the Sentinel Butte Formation (Armstrong, 1969).

The major ion analyses indicated elevated iron concentrations that exceeded the SMCL in all but one well (Appendix E). The source of the iron was not determined but may be derived from the lignite layer.

The trace element analyses indicated an anomalously high concentration of selenium (19 µg/L) in well 17BBD2 that exceeded the MCL of 10 µg/L. The source of the selenium was not determined. There were no other trace elements detected from other wells.

The VOC analysis, from well 154-100-17BBD2, is shown in Appendix F. The analyses detected concentrations of chloroform (4.82 µg/L), bromodichloromethane (0.79 µg/L), and dichloromethane (1.28 µg/L). It is inconclusive as to whether the source of this VOC compound is the result of laboratory contamination† or migration from the landfill.

† Beginning in September, 1994 the NDSDHCL changed their analytical procedures that lowered detection limits for VOC concentrations by one to two orders of magnitude.

CONCLUSIONS

The Williston landfill is situated on a ridge between the Little Muddy River and Stoney Creek. The site is characterized by a thin layer of glacial sediment ranging from 0 to 20 feet thick overlying the Sentinel Butte Formation. The glacial sediments are composed mainly of till with intermittent layers of gravel. The Sentinel Butte Formation is composed of sand, sandstone, silt, clay, and lignite.

The glacial sediments are underlain by a layer of weathered lignite (leonardite) which ranges from 0 to 20 feet thick. The leonardite has been mined within the landfill boundaries and is presently being mined along the northern edge of the site. The leonardite is underlain by a layer of clay ranging from 5 to 15 feet thick. A unit of sand and silt underlies the clay layer. This unit varies in composition beneath the landfill and ranges from silty sand to sandy silt to clayey silt. This unit is underlain by a layer of clay that has a thickness greater than 20 feet. A layer of fine-grained silty sand underlies this layer of clay. The thickness of this sand is less than 30 feet.

A ten-foot thick lignite bed underlies the lower sand unit. The lignite was mined by underground methods south of the landfill. Underground caverns and rubble were encountered in numerous test holes.

Six monitoring wells were located at three separate sites to monitor two hydrologic units in the Sentinel Butte Formation. These units are the sand and silt unit and the lower sand unit both of which are separated by a layer of clay up to about 30 feet thick. The sand and silt unit was dry beneath the active landfill area, but was partially saturated along the northern and eastern boundaries of the landfill. Water-level measurements indicate the direction of ground-water flow to be toward the east where discharge may occur as springs along the western face of the Stoney Creek valley.

The lower sand unit was identified as the uppermost aquifer beneath the landfill. This sand unit appears to extend beyond the landfill boundaries and may outcrop along the valley walls on the east and west side of the landfill. Within the landfill study area, direction of ground-water flow is to the southeast. The presence of subsurface mines may influence the direction and gradient in the lower sand unit along the southern boundary of the landfill.

Major ion analyses indicated elevated iron concentrations that exceeded the SMCL in all but one monitoring well. The source of the iron concentration was not determined but may derived from the lignite. The trace element analyses indicated an anomalously high selenium concentration in well 17BBD2 that exceeded the MCL. The source of the selenium was not determined.

A VOC analysis, from well 17BBD2, detected concentrations of chloroform, bromodichloromethane, and dichloromethane. It is inconclusive as to whether the source of this VOC compound is the result of laboratory contamination or migration from the landfill.

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APPENDIX A

WATER QUALITY STANDARDS
AND
CONTAMINANT LEVELS

Water Quality Standards and Contaminant Levels

Field Parameters	
appearance	color/odor
pH	6-9 (optimum)
specific conductance	-----
temperature	-----

Constituent	**MCL (µg/L)**
Arsenic	50
Cadmium	10
Lead	50
Molybdenum	100
Mercury	2
Selenium	10
Strontium	*

*EPA has not set an MCL for strontium. The median concentration for most U.S. water supplies is 100 µg/L (Hem, 1989).

	SMCL (mg/L)
Chloride	250
Iron	>0.3
Nitrate	50
Sodium	20-170
Sulfate	300-1000
Total Dissolved Solids	>1000

	Recommended Concentration Limits (mg/L)
Bicarbonate	150-200
Calcium	25-50
Carbonate	150-200
Magnesium	25-50
Hardness	>121 (hard to very hard)

APPENDIX B

SAMPLING PROCEDURE FOR VOLATILE ORGANIC COMPOUNDS

SAMPLING PROCEDURE FOR 40ML AMBER BOTTLES

Sample Collection for Volatile Organic Compounds

by
North Dakota Department of Health
and Consolidated Laboratories

1. Three samples must be collected in the 40ml bottles that are provided by the lab. One is the sample and the others are duplicates.

2. A blank will be sent along. Do Not open this blank and turn it in with the other three samples.

3. Adjust the flow so that no air bubbles pass through the sample as the bottle is being filled. No air should be trapped in the sample when the bottle is sealed. Make sure that you do not wash the ascorbic acid out of the bottle when taking the sample.

4. The meniscus of the water is the curved upper surface of the liquid. The meniscus should be convex (as shown) so that when the cover to the bottle is put on, no air bubbles will be allowed in the sample.

convex meniscus

5. Add the small vial of concentrated HCL to the bottle.

6. Screw the cover on with the white Teflon side down. Shake vigorously, turn the bottle upside down, and tap gently to check if air bubbles are in the sample.

7. If air bubbles are present, take the cover off the bottle and add more water. Continue this process until there are no air bubbles in the sample.

8. The sample must be iced after collection and delivered to the laboratory as soon as possible.

9. The 40 ml bottles contain ascorbic acid as a preservative and care must be taken not to wash it out of the bottles. The concentrated acid must be added after collection as an additional preservative.

APPENDIX C

LITHOLOGIC LOGS OF WELLS AND TEST HOLES

154-100-17BBD1
NDSWC

Date Completed:	5/11/94	Purpose:	Observation Well
L.S. Elevation (ft):	2054.57	Well Type:	2" PVC
Depth Drilled (ft):	100	Aquifer:	Undefined
Screened Interval (ft):	75-85	Source:	
		Owner:	Williston

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	gravelly, trace of sand, moderate yellowish brown, 10YR5/4, till.	1-3
ROCK		3-4
CLAY	sandy, trace of gravel, moderate yellowish brown, 10YR5/4, till.	4-22
SAND	silty, clayey, moderate yellowish brown, 10YR5/4, bedrock.	22-28
CLAY	stiff, dark yellowish brown, 10YR4/2.	28-37
CLAY	stiff, medium gray, N5.	37-58
SILT	clayey, medium gray, N5.	58-61
SAND	fine grained, silty, clayey, medium gray.	61-84
CLAY	silty, olive gray, 5Y4/1.	84-91
LIGNITE		91-100

154-100-17BBD2
NDSWC

Date Completed:	5/17/94	Purpose:	Observation Well
L.S. Elevation (ft):	2054.23	Well Type:	2" PVC
Depth Drilled (ft):	31	Aquifer:	Undefined
Screened Interval (ft):	21-31	Source:	
		Owner:	Williston

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	gravelly, sandy, moderate yellowish brown, 10YR5/4, till.	1-20
SAND	fine grained, silty, clayey, moderate yellowish brown, 10YR5/4, bedrock.	20-23
CLAY	stiff, moderate yellowish brown, 10YR5/4.	23-26
SAND	fine grained, silty, moderate yellowish brown, 10YR5/4.	26-30
CLAY	dark yellowish brown, 10Yr4/2.	30-31

154-100-17BDA1
NDSWC

Date Completed:	5/10/94	Purpose:	Observation Well
L.S. Elevation (ft):	2064.67	Well Type:	2" PVC
Depth Drilled (ft):	100	Aquifer:	Undefined
Screened Interval (ft):	88-98	Source:	
		Owner:	Williston

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	sandy, trace of pebbles, moderate yellowish brown, 10YR5/4, till.	1-4
SAND	fine grained.	4-5
ROCK		5-6
CLAY	sandy, trace of pebbles, moderate yellowish brown, 10YR5/4, till.	6-15
Leonardite	bedrock.	15-21
CLAY	silty, olive gray, 5Y4/1.	21-29
SILT	fine sand and clay, olive gray, 5Y4/1.	29-37
CLAY	silty, dark yellowish brown, 10YR4/2.	37-40
LIGNITE		40-41
CLAY	silty, dark yellowish brown, 10YR4/2.	41-44
CLAY	silty, sandy, olive gray, 5Y4/1.	44-48
SAND	fine grained, silty, medium gray, N5.	48-54

CLAY	stiff, medium gray, N5, interbedded lenses of bentonite	54-58
CLAY	silty, medium gray, N5.	58-60
CLAY	stiff, medium gray, N5.	60-64
CLAY	organic rich, grayish brown, 5YR3/2.	64-66
CLAY	stiff, greenish gray, 5GY6/1.	66-76
LIGNITE		76-78
SANDSTONE	fine grained, medium dark gray, N4, well cemented.	78-83
CLAY	medium gray, N5.	83-90
SAND	fine grained, silty, medium gray, N5.	90-96
CLAY	medium gray, N5.	96-99
LIGNITE		99-100

154-100-17BDA2

NDSWC

Date Completed:	5/11/94	Purpose:	Observation Well
L.S. Elevation (ft):	2065.12	Well Type:	2" PVC
Depth Drilled (ft):	56	Aquifer:	Undefined
Screened Interval (ft):	43-53	Source:	
		Owner:	Williston

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	trace of sand and pebbles, moderate yellowish brown, 10YR5/4, till.	1-14
GRAVEL	fine to medium grained.	14-18
Loenardite	bedrock.	18-20
CLAY	dark yellowish brown, 10YR4/2.	20-27
CLAY	olive gray, 5Y4/1.	27-31
CLAY	silty, dark yellowish brown, 10YR4/2.	31-40
CLAY	olive gray, 5Y4/1.	40-44
SAND	fine grained, silty, medium gray, N5.	44-45
SANDSTONE	fine grained, moderately cemented, medium light gray, N6.	45-47
SAND	fine grained, silty, medium gray, N5.	47-52
CLAY	silty, medium gray, N5.	52-56

154-100-17BDC
NDSWC

Date Completed:	5/12/94	Purpose:	Observation Well
L.S. Elevation (ft):	2070.87	Well Type:	2" PVC
Depth Drilled (ft):	100	Aquifer:	Undefined
Screened Interval (ft):	90-100	Source:	
		Owner:	Williston

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	silty, grayish brown.	1-5
CLAY	sandy, trace of gravel, dark yellowish brown, 10YR4/2, till.	5-19
Loenardite	bedrock.	19-21
CLAY	stiff, medium gray, N5.	21-30
SANDSTONE	fine grained, moderately cemented, medium light gray, N6.	30-32
CLAY	stiff, moderate yellowish brown, 10YR5/4.	32-47
CLAY	stiff, medium gray, N5.	47-63
SILT	sandy, clayey, medium gray, N5.	63-70
SAND	fine grained, silty, medium gray, N5.	70-76
CLAY	medium gray, N5	76-77
SAND	fine grained, silty, medium gray, N5.	77-81
SAND	fine grained, clayey, silty, medium gray, N5.	81-92

SANDSTONE	fine grained, medium light gray, N6.	92-94
SAND	fine grained, silty, medium gray, N5.	94-100

154-100-17CAB
NDSWC

Date Completed:	5/11/94	Purpose:	Test Hole
L.S. Elevation (ft):	2069	Well Type:	
Depth Drilled (ft):	87		
		Source:	
		Owner:	Williston

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	trace of sand and gravel, moderate yellowish brown, 10YR5/4, till.	2-14
LOENARDITE	bedrock.	14-24
CLAY	grayish brown, 5YR3/2.	24-25
LOENARDITE		25-29
CLAY	medium gray, N5.	29-38
SAND	fine grained with silt and clay, dark yellowish brown, 10YR4/2.	38-40
SANDSTONE	fine grained, moderately cemented, medium light gray, N6.	40-42
CLAY	medium light gray, N6	42-62
SANDSTONE	fine grained, well cemented, medium gray, N5.	62-63
CLAY	medium gray, N5.	63-68
SAND	fine grained, silty, clayey, medium gray, N5.	68-72

CLAY	medium gray, N5.	72-77
SAND	fine grained, silty, medium gray, N5.	77-87
UNKNOWN	lost circulation at 87 feet, penetrated void, possible underground mine.	87-100

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

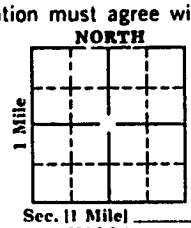
Name City of Williston Landfill

Address Williston, ND 58802

2. WELL LOCATION

Sketch map location must agree with written location.

#1, East side, just south of L3, 154-100-17BDA3



County Williams

NE ¼ SE ¼ NW ¼ Sec. 17 Twp. 154 N. Rg. 100 W.

3. PROPOSED USE

☐ Domestic ☐ Irrigation ☒ Monitoring
☐ Stock ☐ Municipal ☐ Industrial ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☒ Forward Rotary ☐ Jetted ☐ Auger
If other, specify

5. WATER QUALITY

Was a water sample collected for:
Chemical Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent

6. WELL CONSTRUCTION

Diameter of hole 5.75 inches. Depth 92 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete
☐ Threaded ☐ Welded ☒ Other

If other, specify stainless steel screws

Pipe Weight:	Diameter:	From:	To:
SDR-21 lb/ft.	2 inches	+2.0 feet	80 feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ft to feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches
(stainless steel, bronze, etc.)

Slot size 10 set from 80 feet to 90 feet

Slot size set from feet to feet

Was a packer or seal used? ☒ Yes ☐ No

If so, what material bentonite Depth 74 to 77 Ft.

Type of well: Straight screen ☐ Gravel packed ☒

Depth grouted: From 74 To 2

Grouting Material: Cement X Other

If other explain:

Well head completion: Pitless unit

12" above grade X Other

If other, specify 4" sq steel locking protective casing

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level 85.8 feet below land surface

If flowing: closed-in pressure psi

GPM flow through inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

ft. after hrs. pumping gpm

ft. after hrs. pumping gpm

ft. after hrs. pumping gpm

9. WELL LOG

Formation	Depth (ft.) From	To
Sand, fine, yellowish brown	0	5
Clay, silty, yelllowish brown	5	13
Sand, fine to medium, yellowish brown	13	14
Clay, silty, yellowish brown, bedrock	14	15
Leonardite	15	18
Clay, silty, brownish gray	18	26
Clay, silty, medium gray	26	34
Clay, silty to sandy, yellowish brown	34	42
Clay, silty, medium gray	42	52
Rock, limestone	52	52.4
Clay, silty, medium gray	52.4	54
Clay, silty, brownish gray	54	54.5
Clay, silty, medium gray, clay very sticky, drilled with water from 60 feet down, used 2400 gal of water and 5 sxs of mud	54.5	80
Sand, fine, bluish gray, abt 20% clay	80	87
Clay, silty, medium gray	87	92
9 Grab samples from 18 to 80 feet		

(Use separate sheet if necessary.)

10. DATE COMPLETED 8/20/91

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how

12. REMARKS:

Cap on bottom of screen
200# of #10 silica sand to 77 feet
Medium bentonite chips to 74 feet
Redimix neat cement to 2 feet
Medium bentonite chips to 1 foot
Sacrete and PC to surface

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply Inc. 46
Driller's or Firm's Name Certificate No.

Box 1191 - Bismarck, ND 58502
Address

Lewis Knuston 8/22/91
Signed by Lewis Knuston Date

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

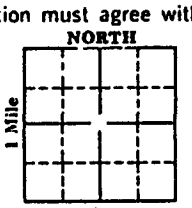
Name City of Williston Landfill

Address Williston, ND 58802

2. WELL LOCATION

Sketch map location must agree with written location.

#2, Southeast corner, 154-100-17BDC2



County

SW ¼ SE ¼ NW ¼ Sec. 17 Twp. 154 N. Rg. 100 W.

3. PROPOSED USE

☐ Domestic ☐ Irrigation ☒ Monitoring
☐ Stock ☐ Municipal ☐ Industrial
☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☒ Forward Rotary ☐ Jetted ☐ Auger
If other, specify

5. WATER QUALITY

Was a water sample collected for:
Chemical Analysis? ☐ Yes ☒ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent

6. WELL CONSTRUCTION

Diameter of hole 5.75 inches. Depth 40 feet.
Casing: ☐ Steel ☒ Plastic ☐ Concrete
☐ Threaded ☐ Welded ☒ Other
If other, specify stainless steel screws

Pipe Weight:	Diameter:	From:	To:
SDR-21 lb/ft.	2 inches	+2.0 feet	33 feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No
Perforated pipe set from ft to feet
Was casing left open end? ☐ Yes ☒ No
Was a well screened installed? ☒ Yes ☐ No
Material PVC Diameter 2 inches
(stainless steel, bronze, etc.)
Slot size 10 set from 33 feet to 38 feet
Slot size set from feet to feet
Was a packer or seal used? ☒ Yes ☐ No
If so, what material bentonite Depth 27 to 30 Ft.
Type of well: Straight screen ☐ Gravel packed ☒
Depth grouted: From 27 To 2
Grouting Material: Cement X Other
If other explain:
Well head completion: Pitless unit
12" above grade X Other
If other, specify 4" sq steel locking protective casing
Was pump installed: ☐ Yes ☒ No
Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level dry feet below land surface
If flowing: closed-in pressure psi
GPM flow through inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other
Pumping level below land surface:
ft. after hrs. pumping gpm
ft. after hrs. pumping gpm
ft. after hrs. pumping gpm

9. WELL LOG

Formation	Depth (ft.) From	To
Sand, fine to coarse	0	2
Clay, silty, yellowish brown	2	4
Sand, fine to medium, yellowish brown, bedrock	4	5
Clay, silty, yellowish brown	5	16
Clay, silty, medium gray	16	24
Sand, fine, yellowish gray	24	36
Clay, silty, yellowish orange	36	37
Clay, silty, medium gray	37	40

(Use separate sheet if necessary.)

10. DATE COMPLETED 8/20/91

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No
If so, how

12. REMARKS:

Cap on bottom of screen
125# of #10 silica sand to 30 feet
Medium bentonite chips to 27 feet
Redimix neat cement to 2 feet
Medium bentonite chips to 1 foot
Sacrete and PC to surface

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply Inc. 46
Driller's or Firm's Name Certificate No.
Box 1191 - Bismarck, ND 58502
Address

Signed by Lewis Knutson 8/22/91
Date

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

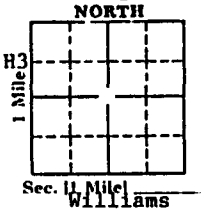
Name City of Williston Landfill

Address Williston, ND 58802

2. WELL LOCATION

Sketch map location must agree with written location.

#3, south side, just north of H3
154-100-17BCD
WS-3



County Williams

SE ¼ SW ¼ NW ¼ Sec. 17 Twp. 154 N. Rg. 100 W.

3. PROPOSED USE

☐ Domestic ☐ Geothermal ☒ Monitoring
☐ Stock ☐ Irrigation ☐ Industrial
☐ Municipal ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☒ Forward Rotary ☐ Jetted ☐ Auger
If other, specify

5. WATER QUALITY

Was a water sample collected for:
Chemical Analysis? ☐ Yes ☐ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent

6. WELL CONSTRUCTION

Diameter of hole 4.75 inches. Depth 33 feet.
Casing: ☐ Steel ☐ Plastic ☐ Concrete
☐ Threaded ☐ Welded ☐ Other
If other, specify

Pipe Weight:	Diameter:	From:	To:
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet

Was perforated pipe used? ☐ Yes ☐ No
Perforated pipe set from ft to feet
Was casing left open end? ☐ Yes ☒ No
Was a well screened installed? ☐ Yes ☐ No
Material Diameter inches
(stainless steel, bronze, etc.)
Slot size set from feet to feet
Slot size set from feet to feet
Was a packer or seal used? ☐ Yes ☐ No
If so, what material Depth Ft.
Type of well: Straight screen ☐ Gravel packed ☐
Depth grouted: From To
Grouting Material: Cement Other
If other explain:
Well head completion: Pitless unit
12" above grade Other
If other, specify
Was pump installed: ☐ Yes ☐ No
Was well disinfected upon completion? ☐ Yes ☐ No

7. WATER LEVEL

Static water level feet below land surface
If flowing: closed-in pressure psi
GPM flow through inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other
Pumping level below land surface:
ft. after hrs. pumping gpm
ft. after hrs. pumping gpm
ft. after hrs. pumping gpm

9. WELL LOG

Formation	Depth (ft.) From	To
Sand, fine to coarse	0	1
Clay, silty, yellowish brown, till	1	7
Clay, silty, yellowish brown, bedrock	7	12
Leonardite	12	31
Sand, fine, yellowish brown	31	33

(Use separate sheet if necessary.)

10. DATE COMPLETED 8/20/91

11. WAS WELL PLUGGED OR ABANDONED?

☒ Yes ☐ No
If so, how 300# coarse bentonite chips

12. REMARKS:

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply Inc. 46
Driller's or Firm's Name Certificate No.
Box 1191 - Bismarck, ND 58502
Address
Lewis Knutson 8/20/91
Signed by Lewis Knutson Date

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

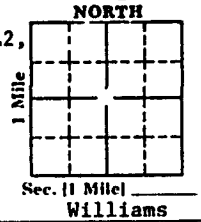
Name: City of Williston Landfill

Address: Williston, ND 58802

2. WELL LOCATION

Sketch map location must agree with written location.

#4, West Side, Just north of L2, 154-100-17BCC



County: Williams

SW ¼ SW ¼ NW ¼ Sec. 17 Twp. 154 N. Rg. 100 W.

3. PROPOSED USE

☐ Domestic ☐ Geothermal ☒ Monitoring
☐ Stock ☐ Irrigation ☐ Industrial
☐ Municipal ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☒ Forward Rotary ☐ Jetted ☐ Auger
If other, specify

5. WATER QUALITY

Was a water sample collected for:
Chemical Analysis? ☐ Yes ☒ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent

6. WELL CONSTRUCTION

Diameter of hole 5.75 inches. Depth 84 feet.

Casing: ☐ Steel ☒ Plastic ☐ Concrete
☐ Threaded ☐ Welded ☒ Other

If other, specify stainless steel screws

Pipe Weight:	Diameter:	From:	To:
SDR-21 PVC ft.	2 inches	+2.0 feet	73 feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No

Perforated pipe set from ft to feet

Was casing left open end? ☐ Yes ☒ No

Was a well screened installed? ☒ Yes ☐ No

Material PVC Diameter 2 inches
(stainless steel, bronze, etc.)

Slot size 10 set from 73 feet to 83 feet

Slot size set from feet to feet

Was a packer or seal used? ☒ Yes ☐ No

If so, what material bentonite Depth 66 to 70 Ft.

Type of well: Straight screen ☐ Gravel packed ☒

Depth grouted: From 66 To 2

Grouting Material: Cement X Other

If other explain:

Well head completion: Pitless unit

12" above grade X Other

If other, specify 4" sq steel locking protective casing

Was pump installed: ☐ Yes ☒ No

Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level 79.9 feet below land surface

If flowing: closed-in pressure psi

GPM flow through inch pipe

Controlled by: ☐ Valve ☐ Reducers ☐ Other

If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other

Pumping level below land surface:

ft. after hrs. pumping gpm

ft. after hrs. pumping gpm

ft. after hrs. pumping gpm

9. WELL LOG

Formation	Depth (ft.) From	To
Clay, silty, brownish gray, bedrock	0	6
Leonardite	6	7
Clay, silty, yellowish brown	7	8
Sand, fine, yellowish brown	8	9
Clay, silty, yellowish brown	9	14
Leonardite	14	15
Clay, silty, medium gray	15	23
Sand, fine to medium, yellowish brown	23	24
Rock, limestone	24	27
Clay, silty, yellowish brown	27	35
Clay, silty, medium gray	35	48
Clay, silty to sandy, bluish gray, abt 30% sand	48	56
Sand, fine, bluish gray	56	81
Clay, silty, medium gray	81	84
11 Grab samples from 15 to 70 feet		
Bulk sample from 15 to 40 feet		

(Use separate sheet if necessary.)

10. DATE COMPLETED 8/21/91

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how

12. REMARKS:

Cap on bottom of screen
150# of #10 silica sand to 70 feet
Medium bentonite chips to 66 feet
Redimix neat cement to 2 feet
Medium bentonite chips to 1 foot
Sacrete and PC to surface

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply Inc. 46
Driller's or Firm's Name Certificate No.
Box 1191 - Bismarck, ND 58502
Address

Lewis Knuston 8/22/91
Signed by Lewis Knuston Date

STATE OF NORTH DAKOTA

BOARD OF WATER WELL CONTRACTORS

900 E. BOULEVARD • BISMARCK, NORTH DAKOTA 58501

WELL DRILLER'S REPORT

State law requires that this report be filed with the State Board of Water Well Contractors within 30 days after completion or abandonment of the well.

1. WELL OWNER

Name: City of Williston Landfill

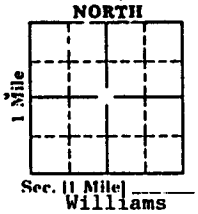
Address: Williston, ND 58802

2. WELL LOCATION

Sketch map location must agree with written location.

#5, North Side, East of Maint Bldg, East Well, 154-100-17BBD

WS-5



County: Williams

SE ¼ NW ¼ NW¼ Sec. 17 Twp. 154 N. Rg. 100 W.

3. PROPOSED USE

☐ Domestic ☐ Geothermal ☒ Monitoring
☐ Stock ☐ Irrigation ☐ Industrial
☐ Municipal ☐ Test Hole

4. METHOD DRILLED

☐ Cable ☐ Reverse Rotary ☐ Bored
☒ Forward Rotary ☐ Jetted ☐ Auger
If other, specify

5. WATER QUALITY

Was a water sample collected for:
Chemical Analysis? ☐ Yes ☒ No
Bacteriological Analysis? ☐ Yes ☐ No
If so, to what laboratory was it sent

6. WELL CONSTRUCTION

Diameter of hole 5.75 inches. Depth 116 feet.
Casing: ☐ Steel ☒ Plastic ☐ Concrete
☐ Threaded ☐ Welded ☐ Other
If other, specify stainless steel screws

Pipe Weight:	Diameter:	From:	To:
SDR-21 ~~XXX~~ lb/ft.	2 inches	+2.0 feet	100 feet
lb/ft.	inches	feet	feet
lb/ft.	inches	feet	feet

Was perforated pipe used? ☐ Yes ☒ No
Perforated pipe set from ft to feet
Was casing left open end? ☐ Yes ☒ No
Was a well screened installed? ☒ Yes ☐ No
Material PVC Diameter 2 inches
(stainless steel, bronze, etc.)
Slot size 10 set from 100 feet to 115 feet
Slot size set from feet to feet
Was a packer or seal used? ☒ Yes ☐ No
If so, what material bentonite Depth 94 to 99 Ft.
Type of well: Straight screen ☐ Gravel packed ☒
Depth grouted: From 94 To 2
Grouting Material: Cement X Other
If other explain:
Well head completion: Pitless unit
12" above grade X Other
If other, specify 4" sq steel locking protective casing
Was pump installed: ☐ Yes ☒ No
Was well disinfected upon completion? ☐ Yes ☒ No

7. WATER LEVEL

Static water level 111.6 feet below land surface
If flowing: closed-in pressure psi
GPM flow through inch pipe
Controlled by: ☐ Valve ☐ Reducers ☐ Other
If other, specify

8. WELL TEST DATA

☐ Pump ☐ Bailer ☐ Other
Pumping level below land surface:
ft. after hrs. pumping gpm
ft. after hrs. pumping gpm
ft. after hrs. pumping gpm

9. WELL LOG

Formation	Depth (ft.) From	To
Topsoil, silty, black	0	1
Clay, silty, yellowish brown, Till	1	8
Clay, silty, yellowish brown, Bedrock	8	12
Leonardite	12	14
Clay, silty, brownish gray	14	16
Leonardite	16	21
Clay, silty to sandy	21	34
Clay, silty, yellowish brown	34	35
Sand, fine, brownish gray, w/ clay layers	35	40
Clay, silty, brownish gray	40	41
Clay, silty, medium gray	41	58
Lignite	58	58.5
Clay, silty, medium gray	58.5	75
Rock, limestone	75	76
Clay, silty, medium gray, clay very sticky, drilled with water from 80' down, used 7 sxs of mud	76	100
Sand, fine, bluish gray	100	110
Clay, silty	110	112
Sand	112	116
Clay	116	118
12 Grab samples from 21 to 80 feet Attempted thinwall at 40 feet, bent tube		

(Use separate sheet if necessary.)

10. DATE COMPLETED 8/22/91

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No
If so, how

12. REMARKS: Washdown valve on bottom of screen; Backwashed before sand packing well; 225# of #10 silica sand to 97 feet; Medium bentonite chips to 94 feet; Redimix neat cement to 2 feet; Medium bentonite chips to 1 foot; Sacrete and PC to surface

13. DRILLER'S CERTIFICATION

This well was drilled under my jurisdiction and this report is true to the best of my knowledge.

Water Supply Inc. 46
Driller's or Firm's Name Certificate No.
Box 1191 - Bismarck, ND 58502
Address
Lewis Knuston 8/22/91
Signed by Lewis Knuston Date

PROJECT: W84-005 SOIL BORINGS
Proposed City Landfill
Georesources Pit
East of Williston, ND

BORING: ST-1 (Sheet 1 of 3)
LOCATION: see attached sketch
DATE: 2/23 & 24/84 SCALE: 1"=4'

(See Report and Standard Plates for evaluation and descriptive terminology.)

Elev.	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
2065.2						
2063.7	1½	ML-CL	CLAYEY SILT, slightly plastic, trace roots and humus, brown, *	10		*slightly moist, rather stiff (loess topsoil)
2059.2	6	ML-CL	SANDY SILT, slightly plastic, trace gravel and clay, light olive, slightly moist, very stiff (till)	19		
2051.2	14	CL	SANDY SILTY CLAY, low plasticity, a little gravel, olive, moist, very stiff (till)	23		
2047.2	18	SW-SM	SANDY GRAVEL, fine to medium grained, a little silt, very dark brown, moist, medium dense, -loss of wash water- (outwash)	14		
2037.2	28	OL	ORGANIC SILT, trace gravel, black moist, medium dense LEONARDITE (Leonardite)	20 12		
2035.2	30	CH	CLAY, high plasticity, a few lenses silty clay, massive structure, dark gray, moist,**	53		**very hard (clay shale)
			continued on Sheet 2			

PROJECT: W84-005 SOIL BORINGS
Proposed City Landfill
Georesources Pit
East of Williston, ND

BORING: ST-1 (Sheet 2 of 3)
LOCATION: see attached sketch
DATE: 2/23 & 24/84 SCALE: 1"=4'

(See Report and Standard Plates for evaluation and descriptive terminology.)

Elev.	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
2035.2	30					
2034.2	31		Clay - continued from Sheet 1			
		CL	SILTY CLAY, medium plasticity, lenses of lignite, crumbly texture, massive structure, dark gray mottled rust, moist, very stiff*	24		*(claystone)
2031.2	34					
		CL	SILTY CLAY, low plasticity, crumbly texture, massive structure, gray, moist, hard (claystone)	33		
2028.7	36½					
		ML-CL	CLAYEY SILT, slightly plastic, massive structure, gray, moist, very stiff (siltstone)	33		
2026.2	39					
		ML	SANDY SILT, nonplastic, massive structure, gray, moist, medium dense (siltstone)	34		
2022.2	43					
		SM	SILTY SAND, fine grained, massive structure, gray to yellowish gray and brownish gray, moist, very dense	62		
				55		
				51		
2005.2	60		(sandstone)	63		
			continued on Sheet 3			

PROJECT: W84-005 SOIL BORINGS
Proposed City Landfill
Georesources Pit
East of Williston, ND

BORING: ST-1 (Sheet 3 of 3)
LOCATION: see attached sketch
DATE: 2/23 & 24/84 SCALE: 1"=4'

Elev. 2005.2	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
		SM	Silty sand - continued from Sheet 2 - loss of wash water at 60' -			
2002.2	63					
		CH	CLAY, high plasticity, massive structure, dark gray, moist, very stiff	29		
1997.2	68		(clay shale)			
		CL-CH	SILTY CLAY to CLAY, medium to high plasticity, laminated structure, dark gray mottled brown,*	31		*moist, hard (claystone)
1994.7	70½					
			Boring advanced to 9' with 3¼" ID hollow-stem auger, to 20' with wash water and 3" scratch bit. Wash water was lost in gravel from 14 to 18 feet. Hollow-stem auger then advanced to 19'. Boring continued with wash water and scratch bit. Wash water lost into formation at 60'. Boring advanced to 69' with bentonite drilling mud.			
			Boring plugged with grout mixture of drilling mud and portland cement			

(See Report and Standard Plates for evaluation and descriptive terminology.)

ENGINEERING TESTING

PROJECT: W84-005 SOIL BORINGS
Proposed City Landfill
Georesources Pit
East of Williston, ND

BORING: ST-3 (Sheet 1 of 2)
LOCATION: see attached sketch
DATE: 3/19/84 SCALE: 1"=4'

(See Report and Standard Plates for evaluation and descriptive terminology.)

Elev.	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
2058.4						
2056.9	1½	ML-CL	CLAYEY SILT, slightly plastic, trace roots and humus, brown, *	28		*dry, very stiff
		CL	SANDY SILTY CLAY, medium plasticity, a little gravel, olive, slightly moist, hard	36		
				79		
2044.4	14		(till)			Note: No Leonardite was observed in cuttir or samples at this location
		CL	SILTY CLAY, low plasticity, varved with silt, massive structure, light gray, slightly moist	123		
				96		
2035.4	23		(claystone)			
		ML-CL	CLAYEY SILT, some fine sand, massive structure, light gray, moist, very dense	65		
2030.4	28		(siltstone)			
		SM	SILTY SAND, non to slightly plastic, very fine grained, trace clay, massive structure, **			
2028.4	30					**light gray, moist, very dense
				66		
			continued on Sheet 2			

LOG OF BORING

BRAUN ENGINEERING TESTING

PROJECT: W84-005 SOIL BORINGS
Proposed City Landfill
Georesources Pit
East of Williston, ND

BORING: ST-3 (Sheet 2 of 2)

LOCATION: see attached sketch

DATE: 3/19/84

SCALE: 1"=4'

Elev.	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
2028.4			SILTY SAND - continued from Sheet 1			
				100+		
				86		
				72		
2007.9	50½		(siltstone)	68		
			Boring advanced to 19' with 3¼-inch ID hollow-stem auger. Drilling mud and 2-7/8-inch scratch bit used to advance boring to 50.5-foot depth.			
			Water level observations not possible because of drilling mud.			
			Hole grouted with mixture of Portland cement and bentonite drilling mud.			

(See Report and Standard Plates for evaluation and descriptive terminology.)

WELL LOG

Verplancke Drilling Co.
RURAL ROUTE 4 - BOX 192A
WILLISTON, NORTH DAKOTA 58801
(701) 572-7801

DATE Oct 15 1984 HOLE NO. 1

CLIENT City of Williston Dept of Public Works AREA Proposed City Landfill

FROM	TO	FORMATION
0	12	tan Silty Sand & Rocks
12	16	Brown silty clay & Rocks
16	29	oxidised Coal
29	50	tan & Grey Silty clay
50	81	Clean Blue Clay
81	95	Grey fine Sand
95	96	Void
96	100	Rubble (Caved area)
		Hole Diam - 5"
TOTAL DEPTH	100'	

DRILLING SUPPLIES & OTHER MATERIAL USED

BITS USED

MUD USED

CASING SET FT. SIZE

DRILLER P.T.V ASST. DRILLER HELPER

WELL LOG

Verplancke Drilling Co.
RURAL ROUTE 4 - BOX 192A
WILLISTON, NORTH DAKOTA 58801
(701) 572-7801

DATE Oct. 15, 1984 HOLE NO. 2

CLIENT City of Williston Public Works AREA Proposed City Landfill

FROM	TO	FORMATION
0	12	Tan Silty Sand & Rocks
12	16	Brown Silty Clay & Rocks
16	29	Oxidised Coal
29	50	Tan & Grey Silty Clay
50	81	Blue Clay
81	100	Fine Grey Sand
100	107	No Returns Very Loose & Rubbly Formation
107	113	Void
113	118	Very Loose & Rubbly Formation
		Hole Diam - 5"
TOTAL DEPTH	100 ft.	

DRILLING SUPPLIES & OTHER MATERIAL USED

BITS USED

MUD USED

CASING SET FT. SIZE

DRILLER Dahl ASST. DRILLER HELPER

WELL LOG

Verplancke Drilling Co.
RURAL ROUTE 4 - BOX 192A
WILLISTON, NORTH DAKOTA 58801
(701) 572-7801

DATE Oct. 16, 1984 HOLE NO. 3

CLIENT City of Williston Dept of Public Works AREA Proposed City Landfill

FROM	TO	FORMATION
0	99	Overburden
99	109	Coal (Water Seam on top of Coal)
109	110	Blue-Grey Clay
		Hole Diam - 5"
TOTAL DEPTH	110'	

DRILLING SUPPLIES & OTHER MATERIAL USED

BITS USED

MUD USED

CASING SET FT. SIZE

DRILLER RJV ASST. DRILLER HELPER

WELL LOG

Verplancke Drilling Co.
RURAL ROUTE 4 - BOX 192A
WILLISTON, NORTH DAKOTA 58801
(701) 572-7801

DATE Oct 16 - 1984 HOLE NO. 4

CLIENT City of Williston AREA Proposed City Landfill
Dept of Public Works

FROM	TO	FORMATION
0	99	Overburden
99	109	Coal Water (Seam on top of Coal)
109	110	Blue - Grey Clay
		Hole Dia. 5"
TOTAL DEPTH		

DRILLING SUPPLIES & OTHER MATERIAL USED

BITS USED

MUD USED

CASING SET FT. SIZE

DRILLER R & V ASST. DRILLER HELPER

WELL LOG

Verplancke Drilling Co.
RURAL ROUTE 4 - BOX 192A
WILLISTON, NORTH DAKOTA 58801
(701) 572-7801

DATE Oct 16, 1984 HOLE NO. 5

CLIENT City of Williston AREA Proposed City Land Fill
Dept of Public Works

FROM	TO	FORMATION
0	99	Overburden
99	109	Coal (Water Seam on Top of Coal)
109	110	Blue Grey Clay
		Hole Diam - 5"
TOTAL DEPTH		DRILLING SUPPLIES & OTHER MATERIAL USED

BITS USED

MUD USED

CASING SET FT. SIZE

DRILLER RJV ASST. DRILLER HELPER

APPENDIX D

WATER-LEVEL TABLES

Williston Landfill Water Levels
6/21/94 to 8/30/94

154-100-17BBD1 — MP Elev (msl,ft)=2056.79
Undefined Aquifer — SI (ft.)=75-85

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/21/94	60.06	1996.73	08/17/94	51.92	2004.87
07/18/94	52.20	2004.59	08/30/94	51.31	2005.48
08/01/94	31.56	2025.23			

154-100-17BBD2 — MP Elev (msl,ft)=2056.15
Undefined Aquifer — SI (ft.)=21-31

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/21/94	22.65	2033.50	08/17/94	22.71	2033.44
07/18/94	23.00	2033.15	08/30/94	22.74	2033.41
08/01/94	22.85	2033.30			

154-100-17BCC — MP Elev (msl,ft)=2058.76
Undefined Aquifer — SI (ft.)=73-83

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/21/94	Dry		08/17/94	Dry	
07/18/94	Dry		08/30/94	Dry	
08/01/94	Dry				

154-100-17BDA1 — MP Elev (msl,ft)=2066.43
Undefined Aquifer — SI (ft.)=88-98

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/14/94	84.85	1981.58	08/17/94	84.83	1981.60
07/18/94	86.11	1980.32	08/30/94	84.52	1981.91
08/01/94	85.58	1980.85			

154-100-17BDA2 — MP Elev (msl,ft)=2066.9
Undefined Aquifer — SI (ft.)=43-53

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/14/94	38.76	2028.14	08/17/94	38.34	2028.56
07/18/94	38.37	2028.53	08/30/94	38.40	2028.50
08/01/94	38.42	2028.48			

154-100-17BDA3 — MP Elev (msl,ft)=2067.38
Undefined Aquifer — SI (ft.)=80-90

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/14/94	84.41	1982.97	08/17/94	84.61	1982.77
07/18/94	85.57	1981.81	08/30/94	84.43	1982.95
08/01/94	84.97	1982.41			

154-100-17BDC MP Elev (msl,ft)=2072.75

Undefined Aquifer SI (ft.)=90-100

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/21/94	Dry	2072.75	08/17/94	99.83	1972.92
07/18/94	Dry	2072.75	08/30/94	Dry	1972.64
08/01/94	99.42	1973.33			

154-100-17BDC2 MP Elev (msl,ft)=2065.03

Undefined Aquifer SI (ft.)=33-38

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/14/94	Dry		08/17/94	Dry	
07/18/94	Dry		08/30/94	Dry	
08/01/94	Dry				

APPENDIX E

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Williston Landfill Water Quality
Major Ions

Location	Screened Interval (ft)	Date Sampled	SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness $CaCO_3$	as NCH	% Na	SAR	Spec Cond (µmho)	Temp (°C)	pH
			(milligrams per liter)																					
154-100-17BBD1	75-85	08/01/94	11	0.15	0.53	38	20	940	19	1200	0	1200	27	0.5	11	0.16	2860	180	0	91	30	5850	12	7.63
154-100-17BBD1	75-85	06/21/94	12	5.8	0.43	38	20	810	12	1050	0	910	22	0.6	5	0.16	2350	180	0	90	26	4700	15	6.06
154-100-17BBD2	21-31	06/21/94	22	0.81	.16	110	36	180	14	176	0	480	23	0.5	9.4	0.05	3010	420	280	47	3.8	1760	12	8.81
154-100-17BDA1	88-98	06/14/94	10	1.1	0.2	40	18	820	19	1380	24	900	20	0.9	6.3	0.23	2540	170	0	90	27	3500	10	8.97
154-100-17BDA2	43-53	06/14/94	12	0.06	0.76	250	240	1400	28	1370	0	3600	24	0.4	80	0.2	6310	1600	490	65	15	8700	10	7.85
154-100-17BDA3	80-90	06/14/94	12	10	0.31	35	18	1100	14	2420	0	770	17	0.5	38	0.27	3210	160	0	93	38	5900	10	7.81

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
164-100-17BBD1	8/01/94	1	0	0	0	12	131	320
164-100-17BBD2	6/22/94	19	0	0	0.1	1	31	790
164-100-17BDA1	6/22/94	0	20	0	0	3	53	300
164-100-17BDA2	6/22/94	5	0	0	0	2	14	2000
164-100-17BDA3	6/22/94	0	18	0	0	1	26	340

APPENDIX F

VOLATILE ORGANIC COMPOUNDS FOR WELL 154-100-17BBD2

Volatile Organic Compounds
and
Minimum Concentrations

Concentrations are based only on detection limits. Anything over the detection limit indicates possible contamination.

Constituent	Chemical Analysis µg/L
Benzene	<0.5
Vinyl Chloride	<0.5
Carbon Tetrachloride	<0.5
1,2-Dichlorethane	<0.5
Trichloroethylene	<0.5
1,1-Dichloroethylene	<0.5
1,1,1-Trichloroethane	<0.5
para-Dichlorobenzene	<0.5
Acetone	<50
2-Butanone (MEK)	<50
2-Hexanone	<50
4-Methyl-2-pentanone	<50
Chloroform	4.82*
Bromodichloromethane	0.79*
Chlorodibromomethane	<0.5
Bromoform	<0.5
trans1,2-Dichloroethylene	<0.5
Chlorobenzene	<0.5
m-Dichlorobenzene	<0.5
Dichloromethane	<0.5
cis-1,2-Dichloroethylene	<0.5
o-Dichlorobenzene	<0.5
Dibromomethane	1.28*
1,1-Dichloropropene	<0.5
Tetrachlorethylene	<0.5
Toluene	<0.5
Xylene(s)	<0.5
1,1-Dichloroethane	<0.5
1,2-Dichloropropane	<0.5
1,1,2,2-Tetrachloroethane	<0.5
Ethyl Benzene	<0.5
1,3-Dichloropropane	<0.5
Styrene	<0.5
Chloromethane	<0.5
Bromomethane	<0.5
1,2,3-Trichloropropane	<0.5
1,1,1,2-Tetrachloroethane	<0.5
Chloroethane	<0.5
1,1,2-Trichloroethane	<0.5

* Constituent Detection

VOC Constituents cont.

2,2-Dichloropropane	<0.5
o-Chloroluene	<0.5
p-Chlorotoluene	<0.5
Bromobenzene	<0.5
1,3-Dichloropropene	<0.5
1,2,4-Trimethylbenzene	<0.5
1,2,4-Trichlorobenzene	<0.5
1,2,3-Trichlorobenzene	<0.5
n-Propylbenzene	<0.5
n-Butylbenzene	<0.5
Naphthalene	<0.5
Hexachlorobutadiene	<0.5
1,3,5-Trimethylbenzene	<0.5
p-Isopropyltoluene	<0.5
Isopropylbenzene	<0.5
Tert-butylbenzene	<0.5
Sec-butylbenzene	<0.5
Fluorotrichloromethane	<0.5
Dichlorodifluoromethane	<5
Bromochloromethane	<0.5
Allylchloride	<5
2,3-Dichloro-1-propane	<5
Tetrahydrofuran	<50
Pentachloroethane	<5
Trichlorotrifluoroethane	<5
Carbondisufide	<5
Ether	<5
trans-1,3-Dichloropropene	<0.5

* Constituent Detection