Site Suitability Review of the Minot Municipal Landfill

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

ND Landfill Site Investigation No. 33

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OF THE
MINOT MUNICIPAL LANDFILL

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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 Minot municipal solid waste landfill is one of the landfills being evaluated.

Location of the Minot Landfill

The Minot solid waste landfill is located about two miles southwest of the City of Minot in Township 155 North, Range 83 West, NW 1/4 Section 33 and S 1/2, S 1/2, Section 28. The active area of the landfill is designated Area B and includes approximately 80 acres (Fig. 1). Areas A and

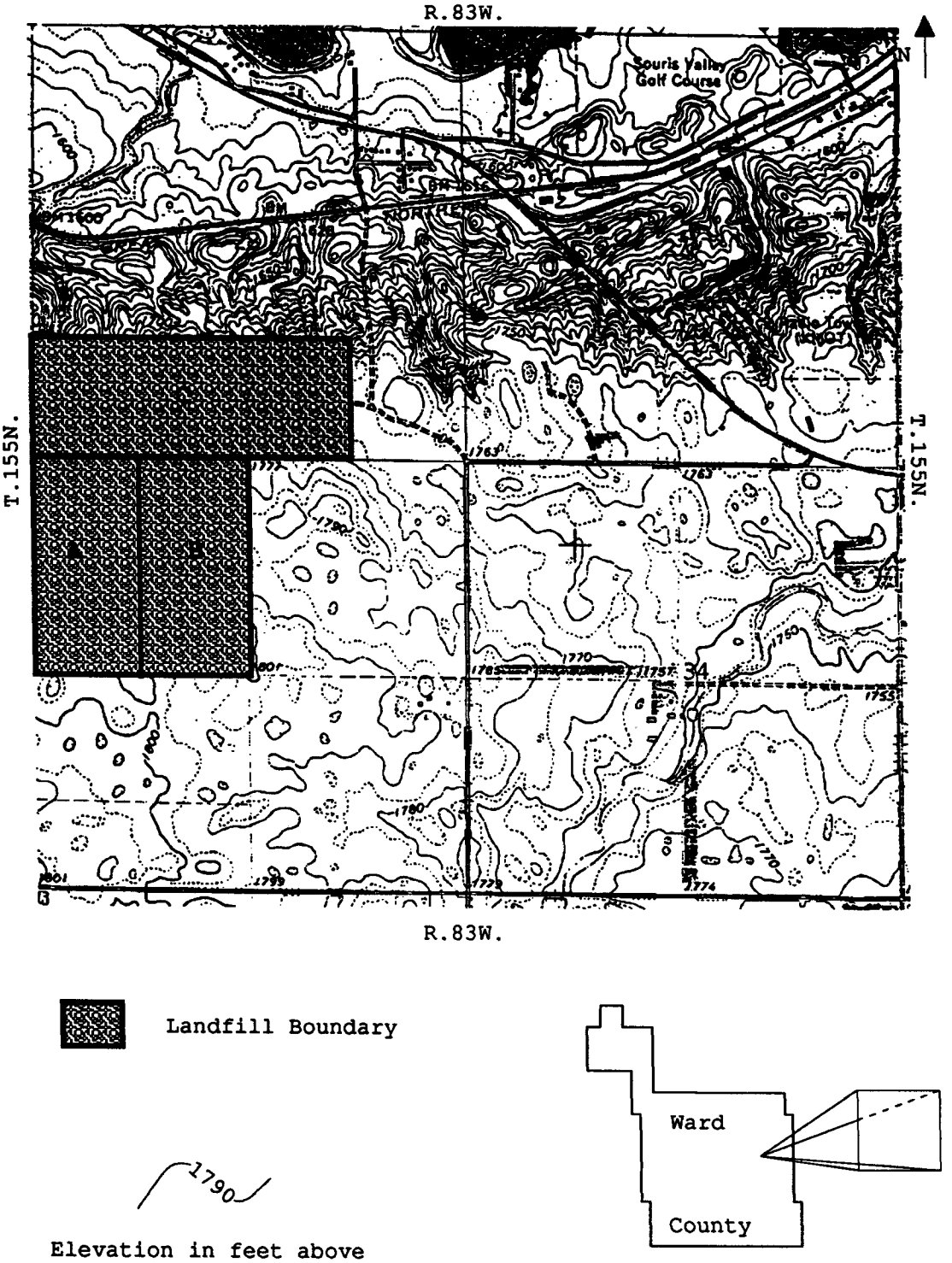

Figure 1. Location of the Minot municipal landfill in the NW 1/4, NW 1/4 of section 33 and S 1/2, S 1/2, of section 28, T155N, R83W.

C are now closed. The entire site encompasses about 270 acres.

Previous Site Investigations

Dakota Testing Laboratory drilled six soil borings at the Minot landfill in 1981 and four additional borings in 1986. Two borings on the east end of Area C encountered predominantly sand, making that area unsuitable for landfill use. The borings in Areas A and B intersected till with lenses of sand.

Donohue and Associates completed a hydrogeological study of the landfill in 1989 and 1990. The study included 14 test borings and the installation of 15 monitoring wells. Test drilling data indicated the site was underlain mainly by glacial till with lenses of sand and gravel.

The ground water within the glacial sediments was interpreted as a perched water system. Upward vertical gradients were observed at two locations where wells were nested. Chemical analyses revealed elevated concentrations of chloride and sulfate in wells adjacent to the landfill. Volatile organic compounds (dichlorofluoromethane and dichlorodifluoromethane) were also detected in well OW-106A.

Methods of Investigation

The Minot 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 was based on the site's geology and depth to ground water, as determined by the preliminary site evaluation. A forward rotary rig was used at the Minot landfill because the depth to the water table was expected to be more than 70 feet. The lithologic descriptions were determined from the drill cuttings. The water used with the rig was obtained from municipal water supplies.

Monitoring Well Construction and Development

Two test holes were drilled at the Minot landfill, and monitoring wells were installed in both test holes. Water samples and water level measurements were also taken on four existing wells installed by Donohue (1990). These wells were located around the perimeter of the active area of the landfill (Area B). Logs of test holes in the closed areas of the landfill were also reviewed to provide a more comprehensive analysis of the site geology and hydrogeology.

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 inserted 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. High-solids bentonite grout and/or neat cement was placed above the silica sand 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.

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.

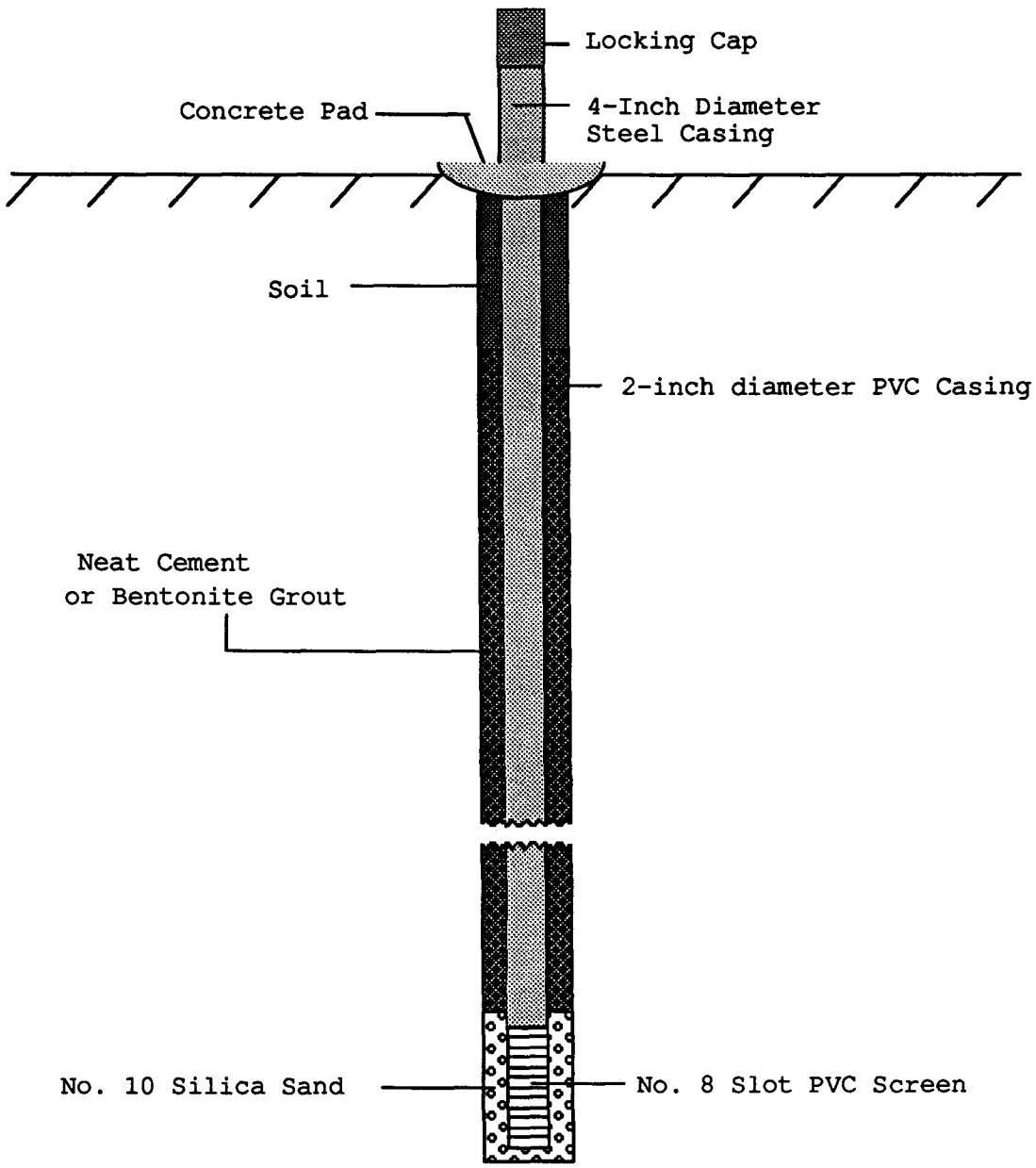

Figure 2. Construction design used for monitoring wells installed at the Minot municipal landfill.

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

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

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 155-083-33BAC would be located in the SW1/4, NE1/4, NW1/4, Section 33, Township 155 North, Range 83 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 155-083-33BAC1 and 155-083-33BAC2.

GEOLOGY

Regional Geology

The Minot landfill is located about a mile south of the Souris River. The topography of the region is characterized by the broad, relatively flat Souris River floodplain with steep valley walls (Pusc, 1987). The upland area to the south of the Souris River Valley consits of gently sloping

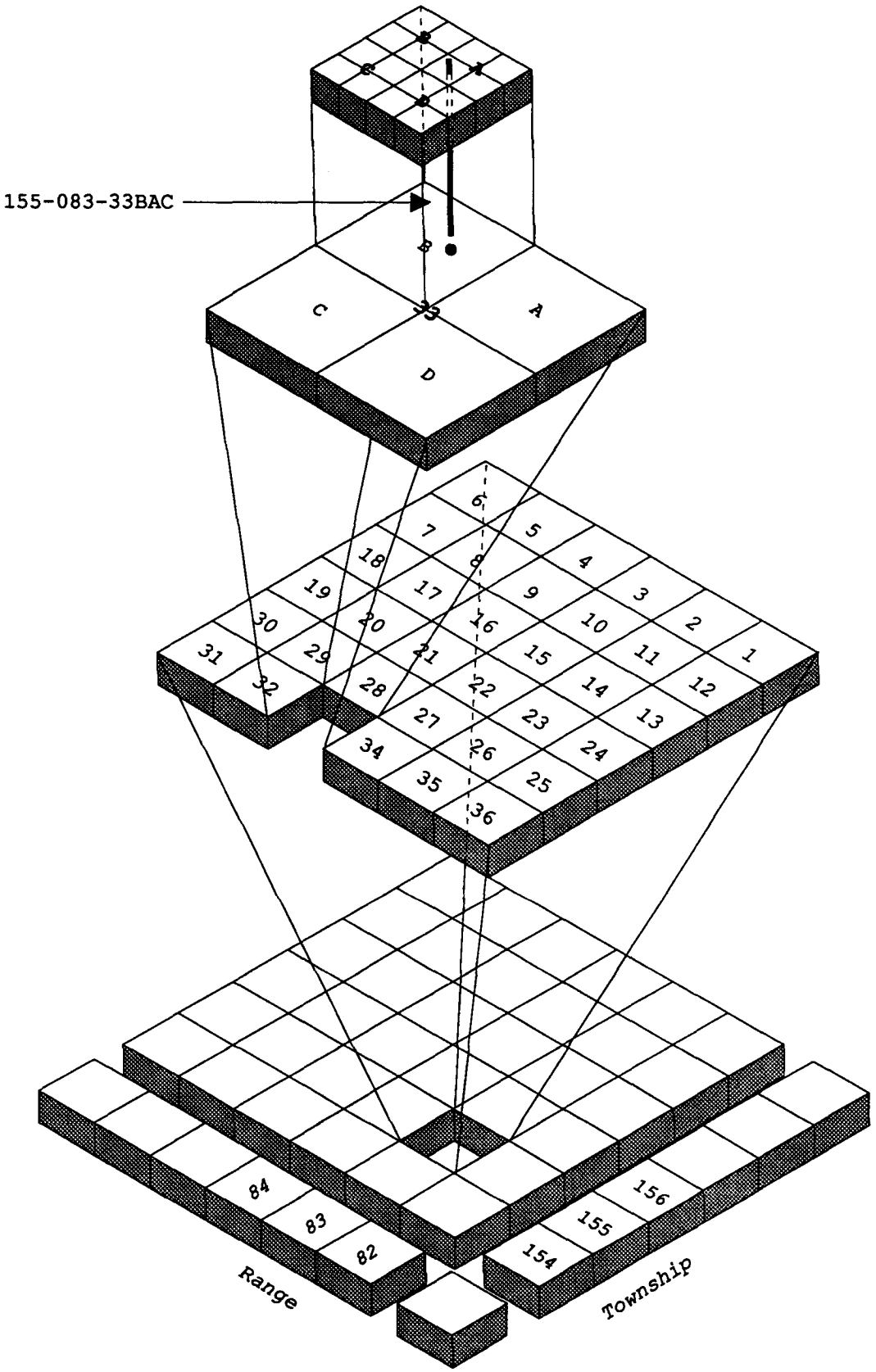

Figure 3. Location-numbering system for the Minot municipal landfill.

topography. Small, closed depressions are common within this area. The upland area is dissected by ravines of intermittent streams which drain northward toward the Souris River.

The near-surface geologic materials in the region are represented by glacial sediments of the Coleharbor Group except for small outcrops of Paleocene bedrock along the valley walls. The thickness of glacial sediments in Ward County generally ranges from 0 to 400 feet (Bluemle, 1989). These sediments include till, glaciofluvial, and lacustrine deposits. The uppermost bedrock formation is the Bullion Creek Formation, which is composed of interbedded clay, silt, sand, lignite, and limestone. The Bullion Creek Formation was deposited in deltaic, fluvial, and lacustrine environments.

Local Geology

The landfill is located on the upland area near the bluff overlooking the Souris Valley (Fig. 1). A deep ravine is located along the west edge of Areas C and A with several smaller ravines located on the north side of Area C. Elevations within the landfill boundaries range from about 1650 to 1800 feet.

Refuse at the landfill was initially placed within the ravines in Areas C and A. These ravines are susceptible to erosion during periods of heavy rainfall such as the summer

of 1993. Beginning in 1980 the refuse was placed further east in Area A using the trench method. In 1990 operations were moved to Area B (Donohue, 1990).

The elevation of the bedrock surface beneath the site has not been determined. Donohue's test hole OW-101A, located in the northwest corner of Area C, encountered black clay, gray sand, and a thin lignite seam from 17 feet to the bottom of the hole at 65 feet (elevation 1588 to 1630 feet). Donohue interpreted this interval as a Pleistocene lacustrine deposit, but it could also be a Paleocene sand and carbonaceous clay of the Bullion Creek Formation.

The glacial sediments at the landfill consist of sandy clay till with relatively thin and probably discontinuous layers of sand and gravel. A thicker sand occurs in test holes B-108, B-112, B-113, and 155-083-33BADB at elevations of about 1740 to 1760 feet (Fig.4 and 5, lithologic logs in Appendicies C and D). In test holes B-114 and 33BAC a thin (5-foot-thick) sand occurs at about the same elevation. This sand may underlie much of Area B. Many of the test holes in the south end of the site (for example, 107A, 109A, and 110A) are too shallow to determine whether the sand is present in this area.

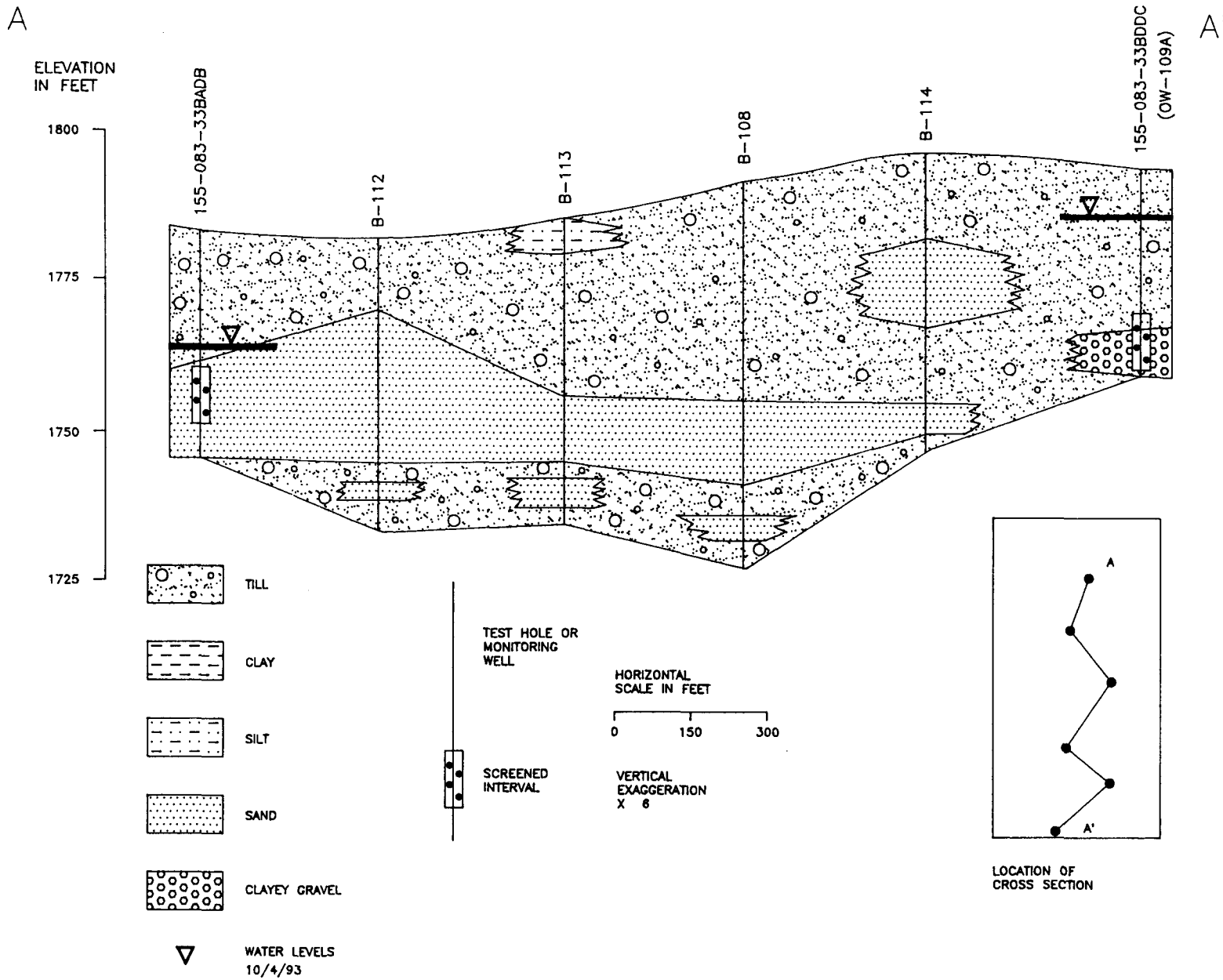

Figure 4. Geohydrologic section A–A' in the Minot landfill.

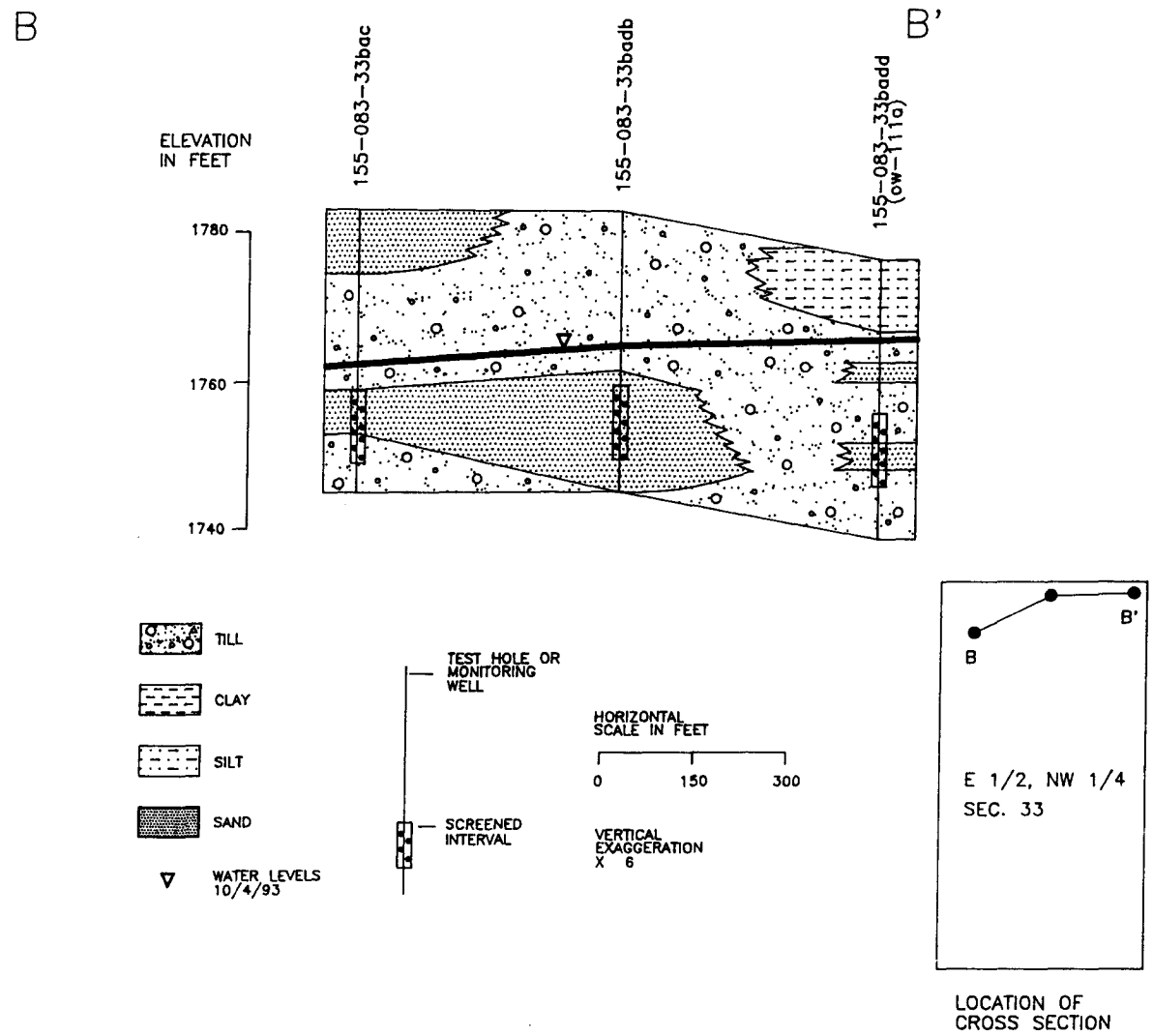

Figure 5. Geohydrologic section B–B' in the Minot landfill.

HYDROLOGY

Surface-Water Hydrology

An intermittent stream located along the western boundary of the landfill site follows a ravine that discharges into the Souris River (Fig. 6). The stream may receive contaminated runoff from the landfill. Springs may also occur along the face of the ravine. These springs may discharge contaminated ground water from the landfill area.

The Souris River is located about one mile north of the landfill. The Souris River valley is a major regional discharge area for both streams and aquifers and numerous springs are found along the valley walls. The Souris River flows north to southeast through the City of Minot and back north into Canada. The Souris River may be susceptible to contamination from the landfill.

Regional Ground-Water Hydrology

About fifty percent of the water used in Ward county is obtained from bedrock aquifers (Pettyjohn and Hutchinson, 1971). These aquifers occur in the Dakota Group, Fox Hills Formation, Hell Creek Formation, Bullion Creek Formation, and the Sentinel Butte Formation. The Dakota Formation, which is located about 3,000 feet below land surface, is characterized by a sodium-chloride type water. The Dakota aquifer should

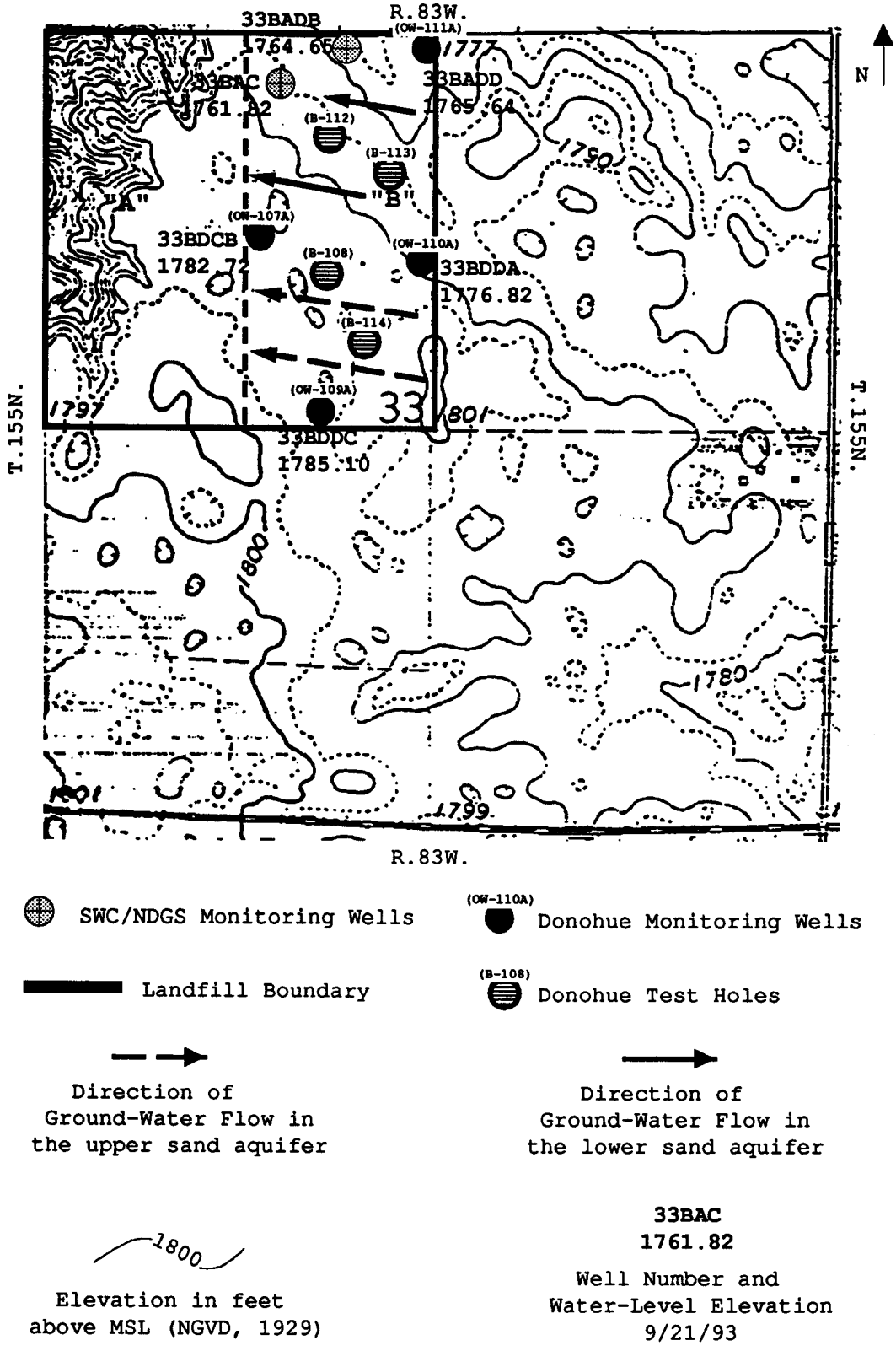

Figure 6. Location of monitoring wells and the direction of ground-water flow.

not be susceptible to contaminant migration from the landfill due to its depth and intervening low transmissivity clay and shale of the Pierre Formation.

The Fox Hills-Hell Creek aquifer overlies the Pierre Formation and is comprised of sandstone at a depth of about 900 feet (Pettyjohn and Hutchinson, 1971). The Fox Hills-Hell Creek aquifer is characterized by a sodium-bicarbonate type water. This aquifer should not be susceptible to contaminant migration due to its depth and intervening low transmissivity clay layers.

The uppermost bedrock aquifer is found in the Bullion Creek Formation, which overlies the Fox Hills Formation. The Bullion Creek aquifer is comprised of sandstone and fractured lignite that directly underlies the glacial drift in the vicinity of the landfill. Recharge to this aquifer is generally from precipitation and from lateral flow from adjacent undifferentiated glacial aquifers. This aquifer is characterized by a sodium-sulfate type water (Pettyjohn and Hutchinson, 1971). The Bullion Creek aquifer may be susceptible to contaminant migration from the landfill in areas where the overlying till contains sand and gravel layers.

The Burlington aquifer, of glaciofluvial origin, is located about one-mile north-northwest of the landfill. This aquifer is comprised of sand and gravel along the Souris and Des Lacs River valleys. The Burlington aquifer is characterized by a mixed cation-bicarbonate type water

(Pettyjohn and Hutchinson, 1971). This aquifer should not be susceptible to contaminant migration from the landfill due to its up-gradient location.

The Minot aquifer is located about 1.5 miles northeast of the landfill and occurs in buried sand and gravel outwash within the Souris River valley. The Minot aquifer is recharged by various adjacent glacial and bedrock aquifers and by leakage of the Souris River (Pettyjohn and Hutchinson, 1971). The water quality of the Minot aquifer is variable due to mixing of water from the adjacent aquifers (Pettyjohn and Hutchinson, 1971). Runoff from the landfill may be directed locally along ravines toward the Souris River valley. Springs may occur in these ravines. As a result the Minot aquifer may be susceptible to contaminant migration from the landfill.

The South Hill aquifer is located about 2.5 miles east of the landfill. This aquifer is comprised of sand and gravel deposits that occupy a buried valley. The South Hill aquifer is characterized by a sodium-bicarbonate type water. This aquifer should not be susceptible to contaminant migration from the landfill.

Local Ground-Water Hydrology

Two monitoring wells were installed at the Minot landfill and four existing wells (Donohue, 1990; logs in Appendix D) were also used to evaluate the site suitability.

At least four water-level measurements were taken over a seven-week period (Appendix E). Water-level measurements indicate two undifferentiated glacial aquifers occur beneath the landfill. The two aquifers are separated by about a 10- to 20-foot layer of clay. Monitoring wells along the southern boundary (Fig. 6) indicate the upper-shallow aquifer composed of sand and gravel at a depth of 8 to 10 feet. The ground-water flow direction in this aquifer appears to be to the west-northwest. This aquifer may discharge in springs along the western boundary of the landfill or it may have been excavated from area "A" and replaced with buried refuse.

Monitoring wells along the northern boundary (Fig. 6) indicate the deeper aquifer composed of fine to medium grained sand at a depth of about 11 to 20 feet. The direction of ground-water flow in this aquifer also appears to be to the west-northwest and may discharge in springs along the ravine west of the landfill.

Water Quality

Chemical analyses of water samples are shown in Appendix F. The major ion analyses indicated an anamolously high chloride (340 mg/L) concentration in well 33BDCB that exceeded the SMCL of 250 mg/L. This well is located along the southwest corner of disposal site "B" and adjacent to disposal site "A". Well 33BDCB is screened in the upper-shallow sand aquifer.

Wells 33BAC and 33BADB detected a chloride concentration of 120 mg/L, which is significantly higher than other chloride concentrations reported for ground water in the study area. These wells are screened in the lower sand aquifer at the north end of disposal site "B". Donohue (1990) also indicated elevated chloride concentrations and attributed these concentrations to contaminant migration from the landfill.

The major ion analysis, from well 33BDCB, detected anomalously higher concentrations of total dissolved solids (7,000 mg/L), sulfate (4400 mg/L), sodium (1100 mg/L), and magnesium (500 mg/L) that exceeded concentrations reported for ground water in the study area. The concetrations are indicative of leachate migration from the landfill. The major ion analyses detected an iron concentration of 1.5 mg/L in well 33BDDC, a level that exceeds the SMCL of 0.3 mg/L. The source of the iron concentration was not determined from this study.

Trace element analyses detected selenium concentrations of 54 µg/L and 29 µg/l from wells 33BADB and BDCB, respectively. These concentrations exceed the MCL of 10 µg/L and are higher than other concentrations reported for ground water in the study area. The elevated selenium concentration may be indicative of leachate migration from the landfill.

The results of the VOC analysis, from well 155-083-33BAC, are shown in Appendix G. The analysis detected the compound tetrahydrofuran (97.4 µg/L), a man-made compound

used in glues and liquid cements for fabricating packages and polyvinyl-chloride materials. The source of the tetrahydrofuran may be due to contaminant migration from the landfill or from well construction.

CONCLUSIONS

The Minot landfill is located in an upland area overlooking the Souris River Valley. A deep ravine along the west edge of the landfill property drains northward to the Souris River. Refuse was initially placed in ravines and later in trenches in the old areas of the landfill (Areas C and A). The ravines are susceptible to erosion during periods of heavy rainfall. The present landfill site (Area B) was opened in 1990.

The near-surface materials at the landfill consist of glacial sediments comprised of sandy clay till with layers of sand and gravel. Although many of the sand and gravel layers are thin and appear to be discontinuous, a thicker sand is present at elevations of about 1740 to 1760 feet. This sand may underlie much of Area B.

An intermittent stream is located in a ravine along the western boundary of the landfill. This stream may receive discharge from springs located along the face of the ravine. The intermittent stream discharges into the Souris River, which is located about one mile north of the landfill. The

Souris River valley is a regional discharge area for both streams and aquifers. The intermittent stream and the Souris River may be susceptible to contamination from the landfill.

Regional aquifers are located in glacial and bedrock lithologies. There are three major glacial aquifers located within a two-mile radius of the landfill. Runoff from the landfill may be directed locally along ravines toward the Souris River valley. Springs may occur in these ravines. As a result the Minot aquifer may be susceptible to contaminant migration from the landfill.

The uppermost bedrock aquifer occurs in the Bullion Creek Formation. The Bullion Creek aquifer is recharged by precipitation and lateral flow from undifferentiated aquifers. This aquifer may be susceptible to contamination from the landfill where the till contains sand and gravel layers.

Two undifferentiated sand layers form the uppermost aquifers beneath the landfill. These aquifers are separated by a 10- to 20-foot thick layer of clay. The extent of these aquifers is not known. The direction of ground-water flow in both aquifers is to the north-northwest toward the ravine. These sand aquifers may be susceptible to contamination from the landfill.

Water quality analyses indicated elevated chloride concentrations in wells 33BDCB, 33BAC, and 33BADB. A previous investigation by Donohue (1990) also detected elevated chloride concentrations. The major ion analysis,

from well 33BDCB, detected anomalously higher concentrations of total dissolved solids, sulfate, sodium, and magnesium that exceeded concentrations reported for ground water in the study area. These concentrations are indicative of contaminant migration from the landfill.

Trace element analyses detected selenium concentrations above the MCL from wells 33BADB and 33BDCB. These concentrations exceed the MCL and are higher than other concentrations reported for ground water in the study area. The elevated selenium concentration may be indicative of leachate migration from the landfill.

A VOC analysis from well 33BAC detected the compound tetrahydrofuran. The source of the tetrahydrofuran may be due to leachate migration from the landfill or from well construction.

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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

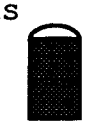
1. Three samples must be collected in the 40ml bottles that are provided by the lab. One is the sample and the others are duplicates.

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

155-083-33BAC

NDSWC

Date Completed:	8/11/93	Purpose:	Observation Well
L.S. Elevation (ft):		Well Type:	2" PVC
Depth Drilled (ft):	38	Aquifer:	UND
Screened Interval (ft):	25-35	Source:	
		Owner:	MINOT LANDFILL

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND	SILTY, VERY FINE GRAIN, YELLOWISH-BROWN	1-7
SAND	CLAYEY, SILTY, YELLOWISH-BROWN, TILL, FINE GRAIN WITH YELLOWISH-ORANGE MOTTLES	7-25
SAND	MEDIUM TO COARSE GRAIN, OLIVE, TRACE OF CLAY, LIGNITE CHIPS	25-30
SAND	CLAYEY, YELLOWISH-BROWN, TILL	30-38

155-083-33BADB

NDSWC

Date Completed:	8/11/93	Purpose:	Observation Well
L.S. Elevation (ft):		Well Type:	2" PVC
Depth Drilled (ft):	38	Aquifer:	UND
Screened Interval (ft):	24-34	Source:	
		Owner:	MINOT LANDFILL

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SAND	FINE TO COARSE GRAIN, YELLOWISH-BROWN, TILL	1-6
SAND	FINE GRAIN, SILTY, CLAYEY, YELLOWISH-BROWN, TILL	6-21
SAND	FINE TO MEDIUM GRAIN, OLIVE	21-22
SAND	SILTY, CLAYEY, FINE GRAIN, OLIVE	22-27
SAND	MEDIUM GRAIN, CLAYEY, OLIVE	27-29
SAND	CLAYEY, FINE GRAIN, BLUEISH-GRAY	29-38

APPENDIX D

Previous Lithologic Logs

LOG OF BORING

BRUNS ENGINEERING TESTING

PROJECT: BND-89-105 Subsurface Exploration
Minot Landfill
Minot, North Dakota

BORING: B 107

LOCATION: N 8.665.4
E 11,356.5

DATE: 10-24-89 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
1792.8	0					
1791.8	1	ML	SANDY SILT, very low plasticity*			*roots, dark brown, dry (Topsoil)
		CL	SANDY, SILTY CLAY, low plasticity trace of gravel, trace of lignite olive mottled white (Glacial Till)			TW#1 9'-11' LL-34 PL=15 PI-19
1777.8	15					
1776.8	16	SM	SILTY SAND, fine, brown, moist **			**(Glacial Till)
		CL	SANDY CLAY, medium plasticity trace of lignite, trace of gravel olive, moist (Glacial Till)			TW#2 19'-21' LL-38, PL-15, PI-23
			3" seam of medium gravel water-bearing			
1762.8	30					
			con't			

LOG OF BORING

ENGINEERING TESTING

PROJECT:	BORING: B 107 con't
BND-89-105 Subsurface Exploration Minot Landfill Minot, North Dakota	LOCATION: N 8,665.4 E 11,356.5
	DATE: 10-24-89 SCALE: 1"=4'

Elev.	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
1762.8	30					
			2" silty sand, waterbearing			
1760.9	32					
		CL	SILTY CLAY, medium plasticity trace of lignite, trace of gravel moist (Glacial Till)			
1767.8	35					
			End of Boring			

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

MONITORING WELL FIELD DATA SHEET

Client Donahue Proj. No. BND89-105 Location Minot Landfill

Well Number OW-107A Well Location _____ Date of Installation 10-25-89

Date of Revision _____ Crew BR/LH/DM B.M. Location & Elev. (±0.01) _____

Stick up above ground (to 0.1') _____

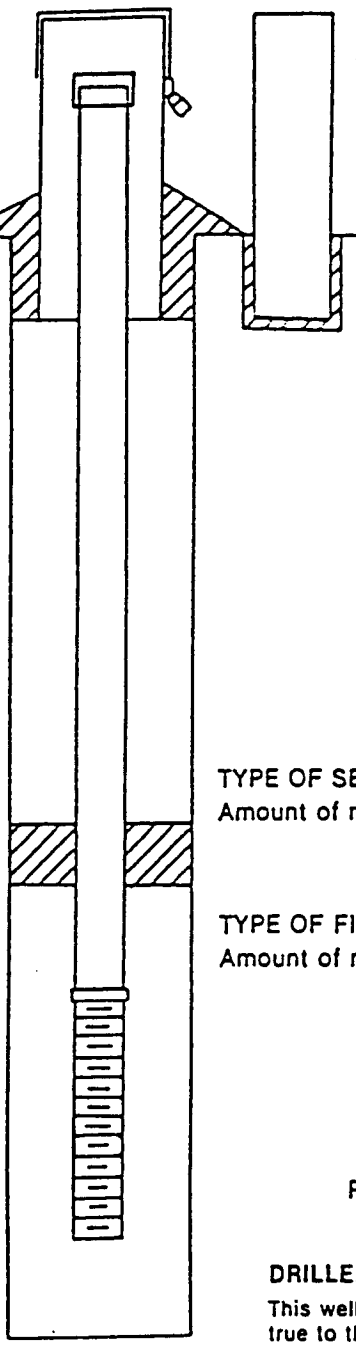
Top of riser pipe (w/o cap) Elev. (±0.01') 3'

Ground surface Elev. (±0.1') _____

Depth to bottom of surface seal _____

Approximate water level before installation 0

Approximate depth to first water encountered in drilling 24'



BUMPER POST:
4" x 4" x 7' Wood _____
4" x 7' black
capped steel _____

Protective Cover:
Type Steel
Length 5'
Lock # 2106

Type of sealing material _____

RISER PIPE:
Type PVC
Diameter 2"
Total Length 23'
Sections Used 2-10' 1-3'
Couplings --
Cap Yes X No _____

NEAT CEMENT GROUT ABOVE SEAL
Amount of material used _____
Proportions _____

Depth to top of seal 15'
Depth to bottom of seal 17'

TYPE OF SEALING MATERIAL: Volclay Chips
Amount of material used 1½ bags

Depth to top of screen 20'

TYPE OF FILTER MATERIAL: Frac Sand 12/30
Amount of material used 9 bags

SCREEN: Timco
Type PVC
Slot Size .01
Length 10'
Diameter 2"
Plug/Point Plug

Depth to bottom of screen 30'

Depth to bottom of boring 34'

Method of advance:
HSA X I.D. 6¼
Casing _____ I.D. _____
Auger _____ O.D. _____

Method of development:
Air _____
Jet _____ Surge _____ Bail _____

DRILLER'S CERTIFICATION

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

Braun Engineering Testing — 406
Driller's or Firm's Name — Certificate No.

P. O. Box 2379, Bismarck, ND 58502
Address

Signed by _____ Date _____

BRAUN

LOG OF BORING

ENGINEERING TESTING

PROJECT:	BORING: B 108
END-89-105 Subsurface Exploration Minot Landfill Minot, North Dakota	LOCATION: N 8,230.8 E 11,747.8
	DATE: 10-18-89 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
1790.0	0					
1789.0	1	ML	SILT, very low plasticity, rooted*			*black, dry (Topsoil)
		CL	SANDY CLAY, low plasticity, trace of gravel, trace of lignite, brown, dry. (GLacial Till)			
1782.0	8					
		CL	SANDY CLAY, medium plasticity trace of gravel, trace of lignite brown, moist (Glacial Till)			LL-35 PL-15 PI-20
1769.0	21					
		CL	SANDY CLAY, medium plasticity trace of gravel, gray, moist (Glacial Till)			
1763.0	27					
		SP	SAND, fine, brown, waterbearing (Glacial Till)			
1761.0	29					
1760.0	30	CL	SILTY CLAY, low plasticity, **			**trace of gravel, lenses of silt, gray. moist (Glacial Till)
			Con't			

LOG OF BORING

BRAUN ENGINEERING TESTING

PROJECT: BND-89-105 Subsurface Exploration
Minot Landfill
Minot, North Dakota

BORING: B 108 Con't

LOCATION: N 8,230.8
E 11,754.8

DATE: 10-18-89

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
1760.0	30					
1754.0	36	SC	CLAYEY SAND, fine-medium, trace of gravel, gray, waterbearing (Glacial Outwash)	15		
1740.0	50	CL	SANDY CLAY, medium plasticity, trace of gravel, trace of lignite, dark gravel, moist (Glacial Till)	15		
1735.0	55	SP	SAND, fine-medium, gray, water-bearing (Glacial Outwash)			
1731.0	59	CL	SILTY CLAY, medium plasticity, trace of gravel, gray, moist (Glacial Till) CON'T			LL-38 PL-14 PI-24
	60					

LOG OF BORING

ENGINEERING TESTING

PROJECT:	BORING: B 108 Con't
END-89-105 Subsurface Exploaration Minot Landfill Minot, North Dakota	LOCATION: N 8,230.8 E 11,747.8
	DATE: 10-18-89 SCALE: 1"=4'

Elev.	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
1730.0	60					
			6" seam of waterbearing sand			
1704.5	75.5	SP	SAND, fine, gravel, waterbearing (Glacial Outwash)			
1701.0	79		End of Boring Boring grouted			

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

LOG OF BORING

ENGINEERING TESTING

PROJECT:	BORING: B 109
BND-89-105 Subsurface Exploration Minot Landfill Minot, North Dakota	LOCATION: N 7,377.2 E 11,904.6
	DATE: 10-24-89 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
1793.1	0					
1792.1	1	ML	CLAYEY SILT, very low plasticity*			*rooted black, dry (Topsoil)
		CL	SILTY CLAY, low plasticity, black, damp (Glacial Till)			
1790.1	3					
		CL	SANDY, SILTY CLAY, low plasticity, trace of gravel, light brown mottled white, dry (Glacial Till)			
1785.1	8					
		CL	SANDY, SILTY CLAY, low to medium plasticity, trace of gravel, trace of lignite, gray, moist (Glacial Till)			TW#1 9'-11' LL-35 PL-16 PI-19
						TW#2 19'-21' LL-34 PL-15 PI-19 S.P.G.-2.628
1766.1	27					
		GP-GC	CLAYEY GRAVEL, fine-coarse, dark brown, waterbearing (Glacial Outwash)			
1763.1	30					
			con't			

LOG OF BORING

ENGINEERING TESTING

PROJECT: END-89-105 Subsurface Exploration Minot Landfill Minot, North Dakota	BORING: B 109 con't LOCATION: N 7,377.2 E 11,904.6
	DATE: 10-24-89 SCALE: 1"=4'

Elev.	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
1763.1	30					
1758.1	35		End of Boring			

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

MONITORING WELL FIELD DATA SHEET

Client Donahue Proj. No. BND89-105 Location Minot Landfill

Well Number OW-109A Well Location _____ Date of Installation 10-24-89

Date of evision _____ Crew BR/LH/DM B.M. Location & Elev. (±0.01) _____

Stick up above ground (to 0.1') _____

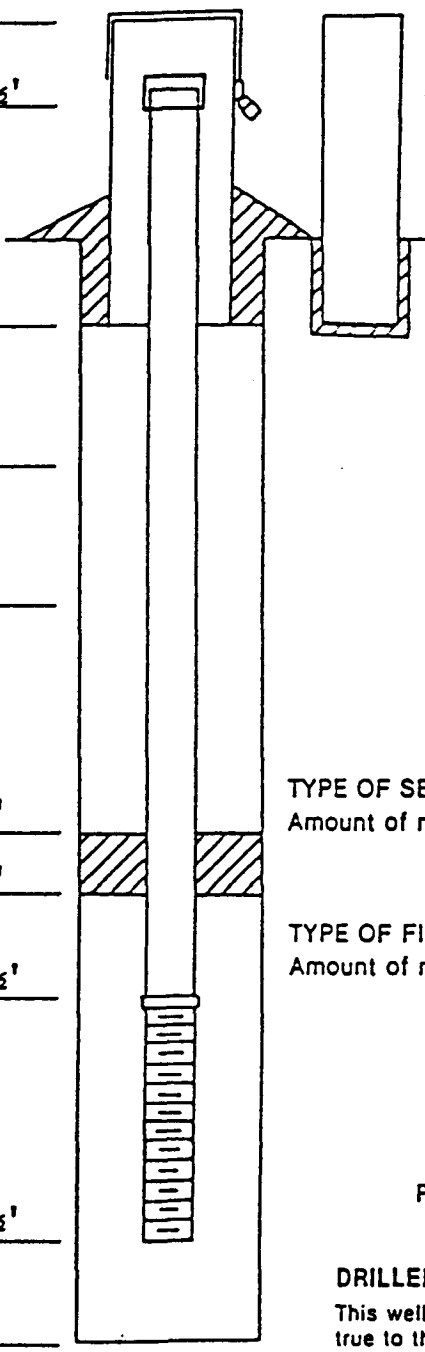
Top of riser pipe (w/o cap) Elev. (±0.01') 2½'

Ground surface Elev. (±0.1') _____

Depth to bottom of surface seal _____

Approximate water level before installation _____

Approximate depth to first water encountered in drilling _____



Depth to top of seal 18'

Depth to bottom of seal 21'

Depth to top of screen 24½'

Depth to bottom of screen 34½'

Depth to bottom of boring 35'

BUMPER POST:
4" x 4" x 7' Wood _____
4" x 7' black _____
capped steel _____

Protective Cover:
Type Steel
Length 5'
Lock # 2106

Type of sealing material _____

RISER PIPE:
Type PVC
Diameter 2"
Total Length 27'
Sections Used 2-10' 1-7'
Couplings --
Cap Yes X No _____

NEAT CEMENT GROUT ABOVE SEAL
Amount of material used _____
Proportions _____

TYPE OF SEALING MATERIAL: Volclay Chips
Amount of material used 1½ bags

TYPE OF FILTER MATERIAL: Frac Sand
Amount of material used 4½ bags

SCREEN: Timco
Type PVC
Slot Size .01
Length 10'
Diameter 2"
Plug/Point Plug

Method of advance:
HSA X I.D. 6¼
Casing _____ I.D. _____
Tricone _____ O.D. _____

Method of development:
Air _____
Jet _____ Surge _____ Bail _____

DRILLER'S CERTIFICATION

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

Braun Engineering Testing 406
Driller's or Firm's Name Certificate No.

P. O. Box 2379, Bismarck, ND 58502
Address

Signed by _____ Date _____

BRAUN

LOG OF BORING

ENGINEERING TESTING

PROJECT:	BORING: B 110
BND-89-105 Subsurface Exploration Minot Landfill Minot, North Dakota	LOCATION: N 8,565.9 E 12,630.5
	DATE: 10-23-89 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
1787.0	0					
1786.0	1	ML	SILT, very low plasticity*			*rooted, black, dry (Topsoil)
1784.5	2.5	ML	SILT, very low plasticity, brown, damp (Glacial Outwash)			
1779.0	8	SM	SILTY SAND, fine, brown, damp (Glacial Outwash)			
1775.0	12	CL	SANDY, SILTY CLAY, low plasticity seam of sand, light brown mottled white, moist (Glacial Till)			
1773.0	14	SM	SILTY SAND. fine-medium, brown*			*waterbearing (Glacial Outwash) TW#1 14'-16' LL-35, PL-15, PI-20
1771.0	16	CL	SILTY CLAY, low plasticity, trace of gravel, trace of lignite, brown moist (Glacial Outwash)			
1766.0	21	ML	SILT, very low plasticity, gray, moist, (GLacial Outwash)			
17762.0	24	SM	SILTY SAND. fine brown, moist (GLacial Outwash)			
			End of Boring			

MONITORING WELL FIELD DATA SHEET

Client Donahue Proj. No. BND89-105 Location Minot Landfill

Well Number OW-110A Well Location _____ Date of Installation 10-23-89

Date of Revision _____ Crew BR/LH/DM B.M. Location & Elev. (±0.01) _____

Stick up above ground (to 0.1') _____

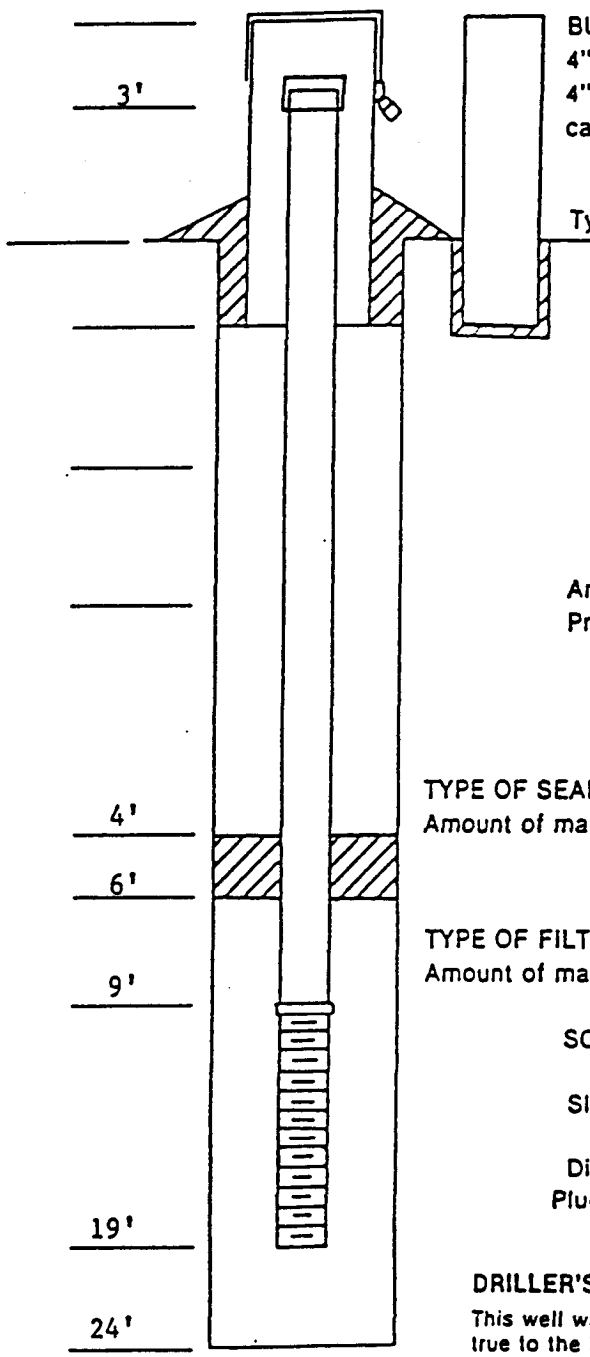
Top of riser pipe (w/o cap) Elev. (±0.01') 3'

Ground surface Elev. (±0.1') _____

Depth to bottom of surface seal _____

Approximate water level before installation _____

Approximate depth to first water encountered in drilling _____



Depth to top of seal 4'

Depth to bottom of seal 6'

Depth to top of screen 9'

Depth to bottom of screen 19'

Depth to bottom of boring 24'

BUMPER POST:
4" x 4" x 7' Wood _____
4" x 7' black capped steel _____

Protective Cover:
Type Steel
Length 5'
Lock # 2106

Type of sealing material _____

RISER PIPE:
Type PVC
Diameter 2"
Total Length 12'
Sections Used 1-10' 1-2'
Couplings --
Cap Yes X No _____

NEAT CEMENT GROUT ABOVE SEAL
Amount of material used _____
Proportions _____

TYPE OF SEALING MATERIAL: Volclay Chips
Amount of material used 1½ bags

TYPE OF FILTER MATERIAL: Frac Sand 12/30
Amount of material used 8 bags

SCREEN: Timco
Type PVC
Slot Size .01
Length 10'
Diameter 2"
Plug/Point Plug

Method of advance:
HSA X I.D. 6¼
Casing _____ I.D. _____
Tricone _____ O.D. _____

Method of development:
Air _____
Jet _____ Surge _____ Bail _____

DRILLER'S CERTIFICATION

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

Braun Engineering Testing (Driller's or Firm's Name) 406 (Certificate No.)

P. O. Box 2379, Bismarck, ND 58502 (Address)

Signed by _____ Date _____

BRAUN

LOG OF BORING

ENGINEERING TESTING

PROJECT: BND-89-105 Subsurface Exploration
Minot Landfill
Minot, North Dakota

BORING: B 111

LOCATION: N 9,963.9
E 12,612.5

DATE: 10-23-89 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
1777.0	0					
1775.5	1.5	ML	SILT, very low plasticity, rooted black, dry, (Topsoil)			
1767.0	10	ML	CLAYEY SILT, very low plasticity brown, dry (Glacial Till)			
1766.0	11	SP	SAND, fine, light brown, damp *			*(Glacial Outwash)
1762.0	15	CL	SILTY CLAY, low plasticity, trace of gravel, gray mottled to rust (Glacial Till)			
1761.0	16	SP	SAND, fine, light brown, water-**			**bearing (Glacial Outwash)
1755.0	22	CL	SANDY CLAY, low plasticity, trace of gravel, trace of lignite, brown, moist (Glacial Till)			
1754.0	23	SP	SAND, fine, brown, waterbearing*			
1749.0	28	CL	SITLY CLAY, medium plasticity, trace of lignite, dary gray, moist (Glacial Till)			
1747.5	29.5	SP	SAND, fine, gray, waterbearing*			
1747.0	30	CL	SILTY CLAY, medium plasticity***			***dark gray, moist (Glacial Till)
			Con't			

LOG OF BORING

ENGINEERING TESTING

PROJECT:	BORING: B 111 con't
BND-89-105 Subsurface Exploration Minot Landfill Minot, North Dakota	LOCATION: N 9,963.9 E 12,612.5
	DATE: 10-23-89 / SCALE: 1"-4'

Elev.	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
747.0	30					
1738.0	39		End of Boring			

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

MONITORING WELL FIELD DATA SHEET

Client Donahue Proj. No. BND89-105 Location Minor Landfill

Well Number OW-111A Well Location _____ Date of Installation _____

Date of Revision _____ Crew BR/LH/DM B.M. Location & Elev. (±0.01) _____

Stick up above ground (to 0.1') _____

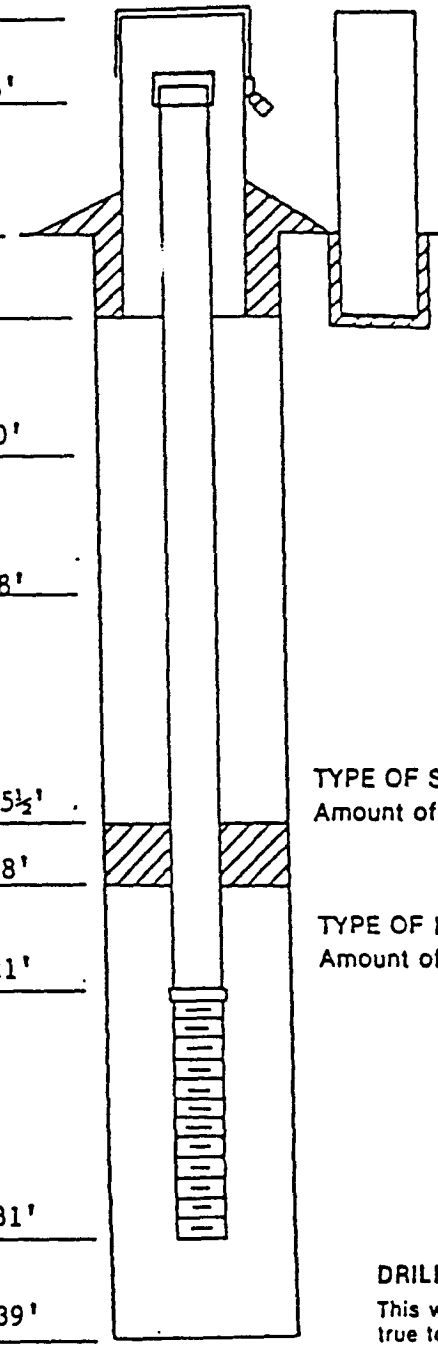
Top of riser pipe (w/o cap) Elev. (±0.01') 3'

Ground surface Elev. (±0.1') _____

Depth to bottom of surface seal _____

Approximate water level before installation 30'

Approximate depth to first water encountered in drilling 28'



Depth to top of seal 15½'

Depth to bottom of seal 18'

Depth to top of screen 21'

Depth to bottom of screen 31'

Depth to bottom of boring 39'

BUMPER POST:
4" x 4" x 7' Wood _____
4" x 7' black capped steel _____

Protective Cover:
Type Steel
Length 5'
Lock # 2106

Type of sealing material _____

RISER PIPE:
Type PVC
Diameter 2"
Total Length 24'
Sections Used 2-10' 1-4'
Couplings --
Cap Yes X No _____

NEAT CEMENT GROUT ABOVE SEAL
Amount of material used _____
Proportions _____

TYPE OF SEALING MATERIAL: Volclay
Amount of material used 1 3/4 bags

TYPE OF FILTER MATERIAL: Frac Sand 12/30
Amount of material used 10 3/4 bags

SCREEN: Timco
Type PVC
Slot Size .01
Length 10'
Diameter 2"
Plug/Point Plug

Method of advance:
HSA X I.D. 6½
Casing _____ I.D. _____
Tricone _____ O.D. _____

Method of development:
Air _____
Jet _____ Surge _____ Bail _____

DRILLER'S CERTIFICATION

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

Braun Engineering Testing 406
Driller's or Firm's Name Certificate No.

P. O. Box 2379, Bismarck, ND 58502
Address

Signed by _____ Date

BRAUN

LOG OF BORING

ENGINEERING TESTING

PROJECT:

BND-89-105 Subsurface Exploration
Minot Landfill
Minot, North Dakota

BORING: B 112

LOCATION:
N 9,541.9
R 11,754.5

DATE: 10-21-89

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
1781.8	0					
1781.3	.5	ML	SILT, non plastic, rooted, dark*			*brown, dry
		CL	SILTY CLAY, low plasticity, trace of gravel, trace of lignite, brown, dry to moist (Glacial Till)			(Topsoil)
1769.3	12.5					
		SP	SAND, fine-medium, brown, damp to waterbearing (Glacial Outwash)			
1764.8	17					
		SM	SAND, very fine with seams of silt, olive, wet to waterbearing (Glacial Outwash)			
1758.8	23					NP
1757.8	24	ML	SILT, no plasticity, light brown **			** moist
		SM	SILTY SAND, very fine with seams of silt, olive wet to water bearing (Glacial Outwash)			(Glacial Till)
1751.8	30					
			con't			

LOG OF BORING

BRAUN ENGINEERING TESTING

PROJECT: BND-89-105 Subsurface Exploration
Minot Landfill
Minot, North Dakota

BORING: B 112 con't

LOCATION: N 9,540.9
E 11,754.5

DATE: 10-21-89

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
1751.8	30					
1743.8	38					LL-43 PL-18 PI-25
1741.8	40	CL	SILTY CLAY, medium plasticity trace of gravel, gray, moist (Glacial Till)			
1739.8	42.5	SP	SAND, fine-medium, trace of lignite, gray, waterbearing (Glacial Outwash)			
1732.9	49	CL	SILTY CLAY, medium plasticity, trace of gravel, gray, moist (Glacial Till)			
			End of Boring Boring grouted			

LOG OF BORING

ENGINEERING TESTING

PROJECT: BND-89-105 Subsurface Exploration Minot Landfill Minot, North Dakota	BORING: B 113 LOCATION: N 9,140.0 E 12,322.5
	DATE: 10-20-89 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
1785.4	0					
1784.4	1	ML	SILT, nonplastic, rooted, black*			*dry (Topsoil)
1783.4	2	CL	SANDY, SILTY CLAY, low plasticity**			**trace of gravel, moist (Glacial Till)
1779.4	6	ML	SILT, nonplastic, white, dry (Glacial Till)			
1769.4	16	CL	SANDY CLAY, low plasticity, trace of gravel, brown, moist (Glacial Till)			
1766.4	19	ML	SILT, nonplastic, brown, moist (GLacial Till)			
1762.4	23	CL	SANDY CLAY, medium plasticity alternating layers of silty sand and silty gravel, gray, moist to wet (Glacial Till)			
1761.4	24	ML	SANDY SILT, non plastic, brown***			NP *** waterbearing
1756.4	29	CL	SANDY CLAY, medium plasticity gray, wet (Glacial Till)			
1755.4	30	SP-SM	SILTY SAND, fine-medium, gray****			****waterbearing (Glacial Outwash)
			con't			

LOG OF BORING

ENGINEERING TESTING

PROJECT:
BNB-89-105 Subsurface Exploration
Minot Landfill
Minot, North Dakota

BORING: B 113
LOCATION:
N 9,140.0
E 12,322.5
DATE: 10-20-89
SCALE: 1"=4'

Elev.	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
1755.4	30					
1743.4	42	CL	SILTY CLAY, medium plasticity, trace gravel, dark gray. moist, (Glacial Till)			
1743.4	45	SP	SAND, medium, gray, waterbearing (Glacial Outwash)			
1736.4	49	CL	SILTY CLAY, medium plasticity trace of gravel, gray, moist (Glacial Till)	75		*(Glacial Outwash)
1733.9	51.5		End of Boring			

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

LOG OF BORING

BMTH ENGINEERING TESTING

PROJECT: BND-89-105 Subsurface Exploration
Minot Landfill
Minot, North Dakota

BORING: B 114
LOCATION: N 7,961.8
E 12,289.4
DATE: 10-20-89
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
1795.7	0					
1794.7	1	ML	SILT, no plasticity, rooted,*			*black dry (Topsoil)
		CL	SANDY, SILTY CLAY, low plasticity trace of gravel, trace of lignite, brown, moist (GLacial Till)			
1781.7	14					
		SM	SILTY SAND, fine-coarse, 1" layer of sandy clay @ 15'-15.5' brown, waterbearing (Glacial Outwash)			
1775.7	20					
		SM	SILTY SAND, fine, trace of gravel brown, waterbearing (Glacial Outwash)			
1766.7	29					
1765.7	30	CL	SILTY CLAY, medium plasticity**	16		**gray, moist (Glacial Till)
			con't			

LOG OF BORING

ENGINEERING TESTING

PROJECT:	BORING: B 114 con't
BND-89-105 Subsurface Exploration Minot Landfill Minot, North Dakota	LOCATION: N 7,961.8 E 12,289.4
	DATE: 10-20-89 SCALE: 1"=4'

Elev.	Depth	ASTM D2487 Symbol	Description of Materials (ASTM D2488)	BPF	WL	Tests or Notes
1765.7	30					
1762.7	33	ML	CLAYEY SILT, very low plasticity trace of gravel, trace of lignite gray, moist (Glacial Outwash)			
1759.7	36	CL	SANDY CLAY, medium plasticity trace of gravel, dark gray, moist (Glacial Till)			
1754.7	41	SP	SAND, fine-medium, trace of gravel, brown, waterbearing (Glacial Outwash			
1749.7	46	CL	SANDY CLAY, medium plasticity, trace of gravel, gray, moist (Glacial Till)			
1746.7	49		End of Boring Boring grouted			

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

APPENDIX E

WATER-LEVEL TABLES

Minot Municipal Landfill Water Levels
8/17/93 to 10/04/93

155-083-33BAC LS Elev (msl,ft)=1783.07
UND Aquifer SI (ft.)=25-35

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/17/93	21.06	1762.01	09/21/93	21.25	1761.82
08/26/93	21.52	1761.55	10/04/93	21.43	1761.64
09/09/93	21.38	1761.69			

155-083-33BADB LS Elev (msl,ft)=1783.06
UND Aquifer SI (ft.)=24-34

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/17/93	18.82	1764.24	09/21/93	18.41	1764.65
08/26/93	19.02	1764.04	10/04/93	18.41	1764.65
09/09/93	18.80	1764.26			

155-083-33BADD LS Elev (msl,ft)=1777.43
Undefined Aquifer SI (ft.)=21-31

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/27/93	12.33	1765.10	09/21/93	11.79	1765.64
09/09/93	12.03	1765.40	10/04/93	11.77	1765.66

155-083-33BDCB LS Elev (msl,ft)=1793.54
Undefined Aquifer SI (ft.)=20-30

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/27/93	11.10	1782.44	09/21/93	10.82	1782.72
09/09/93	10.75	1782.79	10/04/93	11.22	1782.32

155-083-33BDDA LS Elev (msl,ft)=1787.55
Undefined Aquifer SI (ft.)=9-19

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/27/93	10.46	1777.09	09/21/93	10.73	1776.82
09/09/93	10.63	1776.92	10/04/93	11.03	1776.52

155-083-33BDDC LS Elev (msl,ft)=1793.78
Undefined Aquifer SI (ft.)=24.5-34.5

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/27/93	9.17	1784.61	09/21/93	8.68	1785.10
09/09/93	8.83	1784.95	10/04/93	8.29	1785.49

APPENDIX F

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Minot Municipal Landfill Water Quality
Major Ions Analyses

Location	Screened Interval (ft)	Date Sampled	(milligrams per liter) 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
155-083-33BAC	25-35	08/26/93	20	0.08	7	510	340	530	23	717	0	3100	120	0.2	2.7	0.15	5010	2700	2100	30	4.4	4970	8	6.44
155-083-33BADB	24-34	08/26/93	19	0.07	1.7	440	210	480	22	537	0	2400	120	0.3	6.9	0.3	3970	2000	1500	34	4.7	4160	8	6.71
155-083-33BADD	21-31	08/27/93	18	0.03	1.5	480	250	450	21	500	0	2800	39	0.2	6.4	0.34	4310	2200	1800	30	4.2	4420	8	6.6
155-083-33BDCB	20-30	08/27/93	21	0.08	1.7	480	500	1100	30	890	0	4400	340	0.2	2.5	0.19	7310	3300	2500	42	8.3	7220	8	6.5
155-083-33BDDA	9-19	08/27/93	21	0.09	2.1	450	150	28	11	335	0	1500	13	0.1	2.7	0.02	2340	1700	1500	3	0.3	2470	8	6.69
155-083-33BDDC	24.5-34.5	08/27/93	24	1.5	3	440	150	360	19	655	0	1900	44	0.1	0	0.42	3270	1700	1200	31	3.8	3660	8	6.44

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
155-083-33BAC	8/26/93	2	0	1	0	1	1	3400
155-083-33BADB	8/26/93	54	0	0	0	1	3	2500
155-083-33BADD	8/26/93	2	0	1	0	2	0	3100
155-083-33BDCB	8/26/93	29	0	1	0.1	1	0	4800
155-083-33BDDA	8/26/93	0	0	0	0	2	2	810
155-083-33BDDC	8/26/93	0	0	0	0	3	0	2300

APPENDIX G

VOLATILE ORGANIC COMPOUNDS FOR WELL 155-083-33BAC

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	<2
Vinyl Chloride	<1
Carbon Tetrachloride	<2
1,2-Dichlorethane	<2
Trichloroethylene	<2
1,1-Dichloroethylene	<2
1,1,1-Trichloroethane	<2
para-Dichlorobenzene	<2
Acetone	<50
2-Butanone (MEK)	<50
2-Hexanone	<50
4-Methyl-2-pentanone	<50
Chloroform	<5
Bromodichloromethane	<5
Chlorodibromomethane	<5
Bromoform	<5
trans1,2-Dichloroethylene	<2
Chlorobenzene	<2
m-Dichlorobenzene	<5
Dichloromethane	<5
cis-1,2-Dichloroethylene	<2
o-Dichlorobenzene	<2
Dibromomethane	<5
1,1-Dichloropropene	<5
Tetrachlorethylene	<2
Toluene	<2
Xylene(s)	<2
1,1-Dichloroethane	<5
1,2-Dichloropropane	<2
1,1,2,2-Tetrachloroethane	<5
Ethyl Benzene	<2
1,3-Dichloropropane	<5
Styrene	<2
Chloromethane	<5
Bromomethane	<5
1,2,3-Trichloropropane	<5
1,1,1,2-Tetrachloroethane	<5
Chloroethane	<5
1,1,2-Trichloroethane	<5

* Constituent Detection

VOC Constituents cont.

2,2-Dichloropropane	<5
o-Chloroluene	<5
p-Chlorotoluene	<5
Bromobenzene	<5
1,3-Dichloropropene	<5
1,2,4-Trimethylbenzene	<5
1,2,4-Trichlorobenzene	<5
1,2,3-Trichlorobenzene	<5
n-Propylbenzene	<5
n-Butylbenzene	<5
Naphthalene	<5
Hexachlorobutadiene	<5
1,3,5-Trimethylbenzene	<5
p-Isopropyltoluene	<5
Isopropylbenzene	<5
Tert-butylbenzene	<5
Sec-butylbenzene	<5
Fluorotrichloromethane	<5
Dichlorodifluoromethane	<5
Bromochloromethane	<5
Allylchloride	<5
2,3-Dichloro-1-propane	<5
Tetrahydrofuran	97.4*
Pentachloroethane	<5
Trichlorotrofluoroethane	<5
Carbondisufide	<5
Ether	<5

* Constituent Detection