Site Suitability Review of the Mandan Landfill

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

ND Landfill Site Investigation No. 1

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OF THE
MANDAN 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 a site-suitability review of the municipal 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. Additional studies may be necessary to meet the requirements of the NDSDHCL for continued operation of municipal solid waste landfills. The Mandan municipal solid waste landfill is one of the landfills being evaluated.

Location of the Mandan Landfill

The Mandan municipal solid waste landfill is located 4 1/2 miles west and 2 miles south of the City of Mandan in Township 139 North, Range 82 West, NE 1/4 Section 35 (Fig. 1). The landfill site encompasses approximately 88 acres,

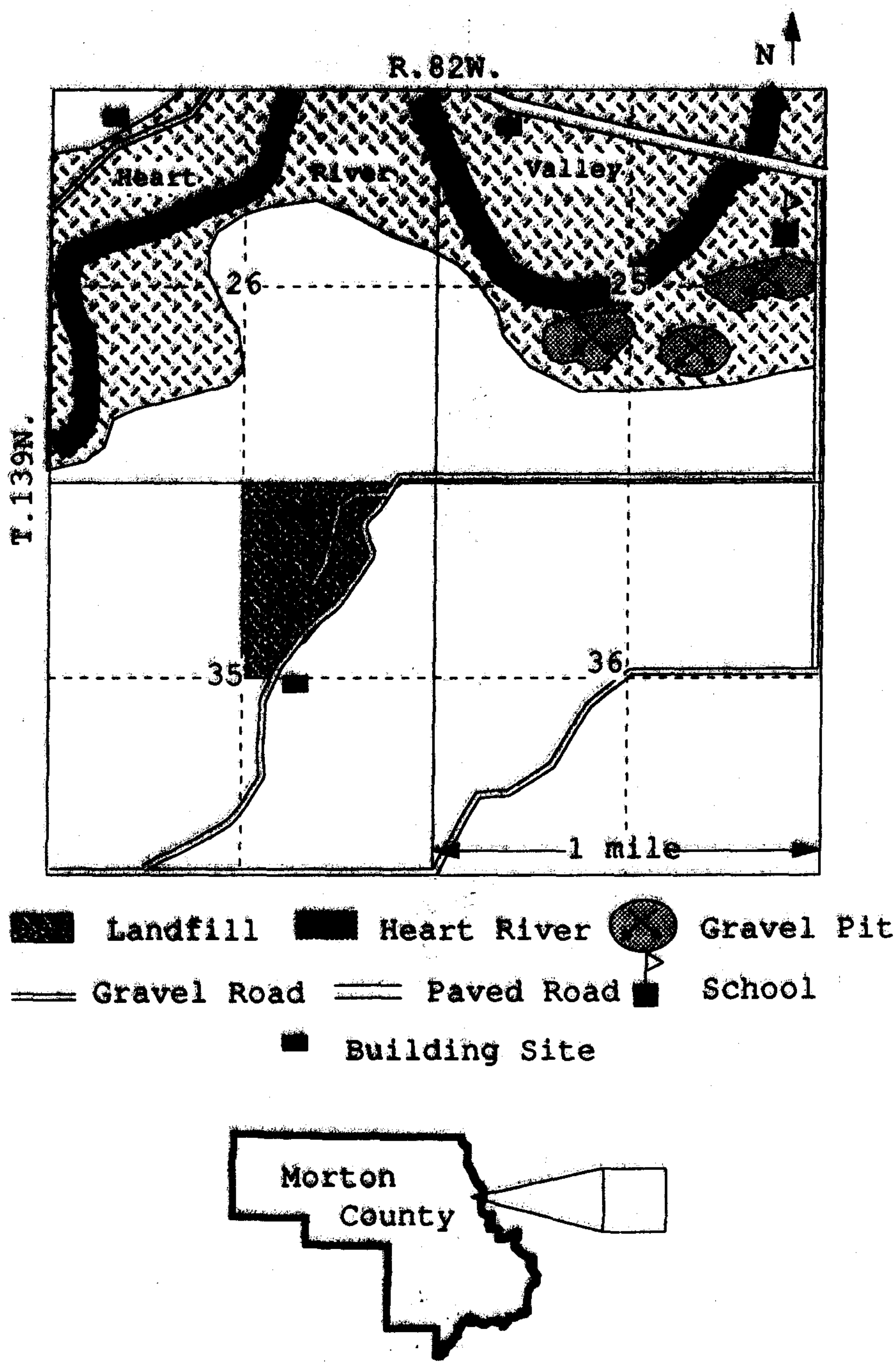

Figure 1. Location of the Mandan landfill in NE 1/4 section 35.

of which approximately 40 acres are actively being used.

Previous Site Investigations

A construction and operating report on the Mandan landfill was completed in May, 1981 by Toman Engineering Company. This report was based on twelve test holes drilled at 50-foot depths throughout the landfill property. The results indicated a surficial layer of clay and a water-table depth below 50 feet. It was recommended that the depth of the refuse cells not exceed 8 feet because test holes indicated a continuous layer of indurated sandstone at depths ranging from 4 to 30 feet below land surface. A thick layer of medium-grained sand underlies the indurated sandstone. The direction of ground-water movement through the site was not determined during the 1981 study. Surface drainage is toward the ravines located at the northwest corner and along the east side of the landfill property.

Methods of Investigation

The current Mandan landfill study was accomplished by: 1) test drilling; 2) construction and development of monitoring wells; 3) collecting and analyzing water samples; and (4) measuring water-levels. Well abandonment procedures were followed for non-permanent monitoring wells.

Test Drilling Procedure

The drilling method at the Mandan landfill was based on the site's geology and depth to ground water, as determined by the preliminary site evaluation. A forward-rotary drilling rig was used at the Mandan landfill because prior work in the area had shown the presence of a layer of indurated sandstone and because the depth to the water table was anticipated to be greater than 70 feet. The lithologic descriptions were determined from drill cuttings. The water used with the forward rotary rig was obtained from the Mandan municipal water system.

Monitoring Well Construction and Development

The number of wells installed at the Mandan landfill was based on the geologic and topographic characteristics of the landfill. Six test holes were drilled at the Mandan landfill. Monitoring wells were installed at five of the six locations. 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 near the active area of the landfill.

Wells were constructed following a standard design (Fig. 2) and comply with the construction regulations of the NDSDHCL and the North Dakota Board of Water Well

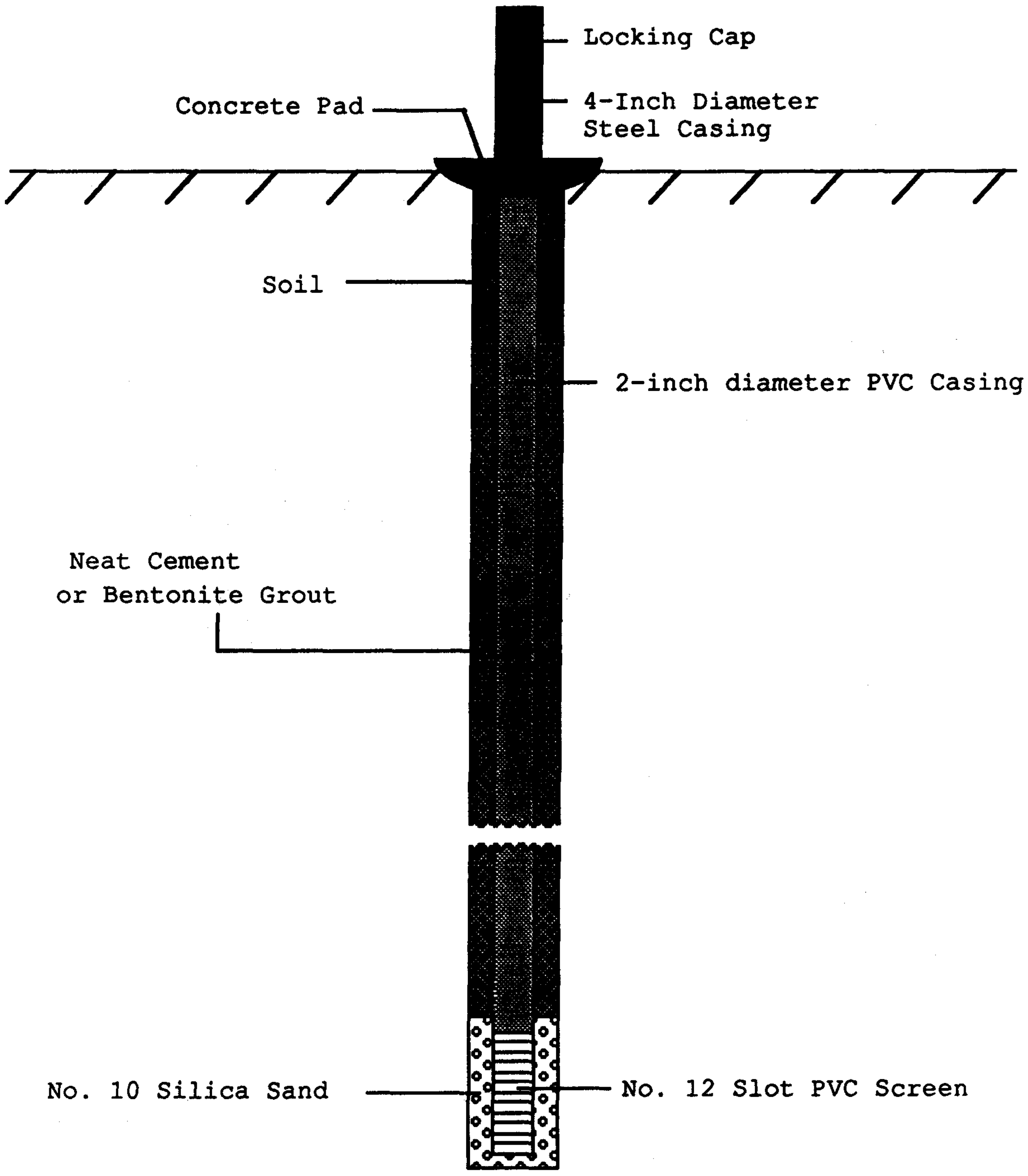

Figure 2. Construction design used for monitoring wells installed at the Mandan landfill.

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 later sampled for Volatile Organic Compounds (VOC) analysis. 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.

Well-Abandonment Procedure

The test holes and monitoring wells that were not permanent were abandoned according to NDSDHCL and Board of Water Well Contractors regulations (North Dakota Department Health, 1986). The soil around the well was dug to a depth

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 and 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.

Contractors (North Dakota Department 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. 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. 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.

of approximately three to four feet below land surface (Fig. 3) to prevent disturbance of the sealed wells. The screened interval of the well was plugged with bentonite chips to a height of approximately one foot above the top of the screen and the remaining well casing was filled with neat cement. The upper three to four feet was then filled with cuttings and the disturbed area was blended into the surrounding land surface. Test holes were plugged with high-solids bentonite grout and/or neat cement to a depth approximately five feet below land surface. The upper five feet of the test hole was filled with soil cuttings.

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. 4). 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 139-82-35ABC would be located in the SW1/4, NW1/4, NE1/4 Section 35,

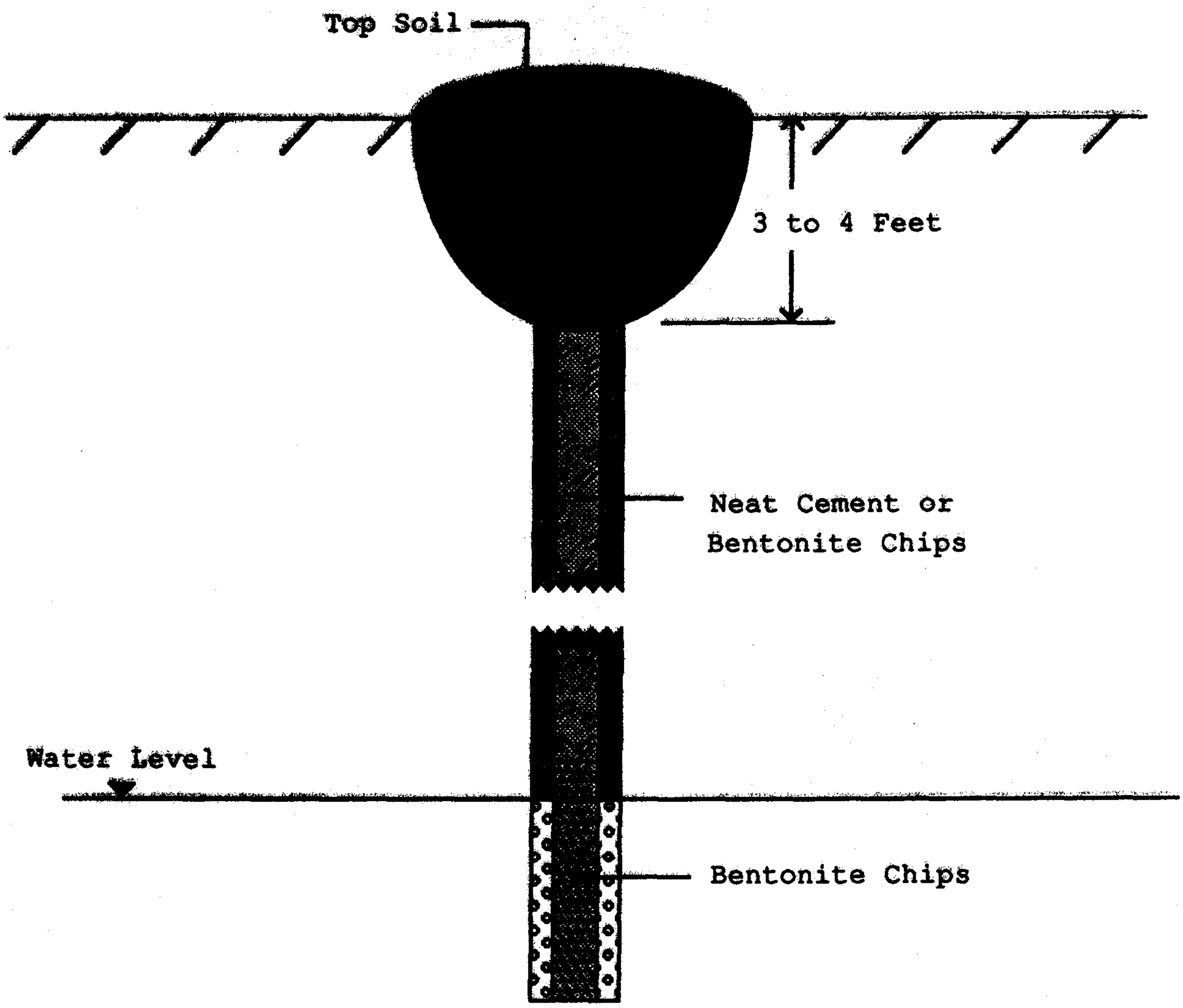

Figure 3. Monitoring well abandonment procedure.

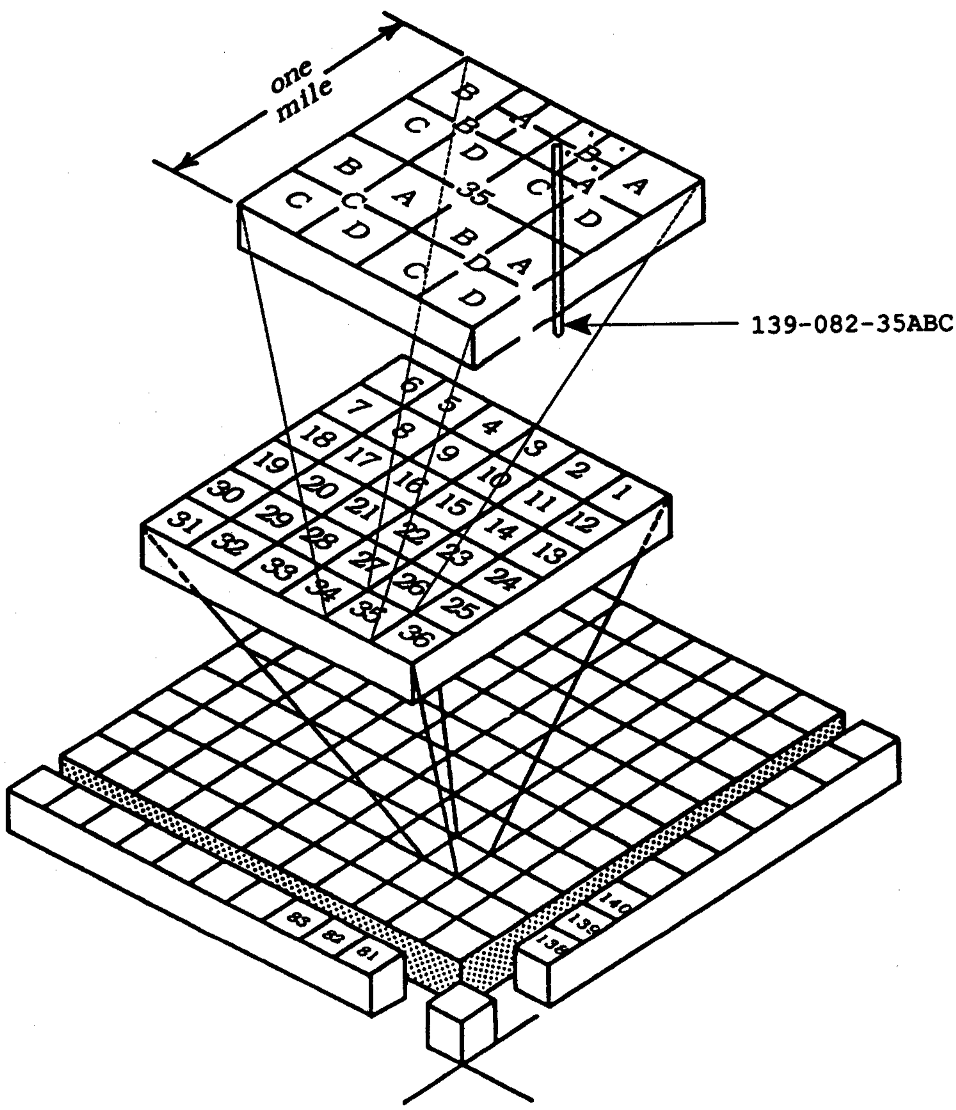

Figure 4. Location-numbering system.

Township 139 North, Range 82 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 139-82-35ABC1 and 139-82-35ABC2.

GEOLOGY

Regional Geology

The Mandan landfill is located on a bluff a mile south of the Heart River in an upland area with rolling topography. Near the river a row of steep, dissected slopes drops about 100 feet to the valley below. The landfill is situated directly above one of these slopes.

The surface material in the vicinity of the landfill, including the uplands and the bluffs above the river, consist of poorly consolidated bedrock of the Cannonball Formation. The Cannonball Formation is a marine sequence of Paleocene age (Cvancara, 1976). The lithology of the Cannonball Formation includes sand, sandstone, silt, and clay.

The Heart River Valley is a pre-glacial valley partially filled with deposits of alluvium. Judging from limited test hole data (Ackerman, 1977), these deposits are approximately 50 to 100 feet thick and consist predominantly of sand and gravel. The nearest of these alluvial deposits is approximately one-half mile north of the landfill.

Local Geology

Some areas of the Mandan landfill site are strongly eroded, whereas others have a more gentle surface typical of the upland area to the south. Surface elevations range from 1750 feet to 1950 feet. Two deep ravines in the northwest corner of the landfill drain toward the Heart River (Fig. 5). A shallower ravine occurs at the northeast corner of the site, and a deep ravine is present southeast of the site.

The lithologic logs from this study (Appendix C), as well as those from Toman (1981), reveal a layer of clay at the surface over most of the landfill area. Below the clay there is a layer of sand and sandstone, and below the sand is another layer of clay. The clay intervals are composed primarily of silty clay, but they also contain thin beds and lenses of silt and sand. The thickness of the upper clay interval varies from a few feet to about 30 feet because of variations in surface elevation.

The sand and sandstone layer is exposed at the surface in the ravines and along the side of the bluff north of the landfill. This unit is 35 to 40 feet thick and is composed of fine-grained sand. The upper foot consists of indurated sandstone, while the remainder is unconsolidated or slightly consolidated sand. The upper indurated layer forms a ledge wherever it outcrops.

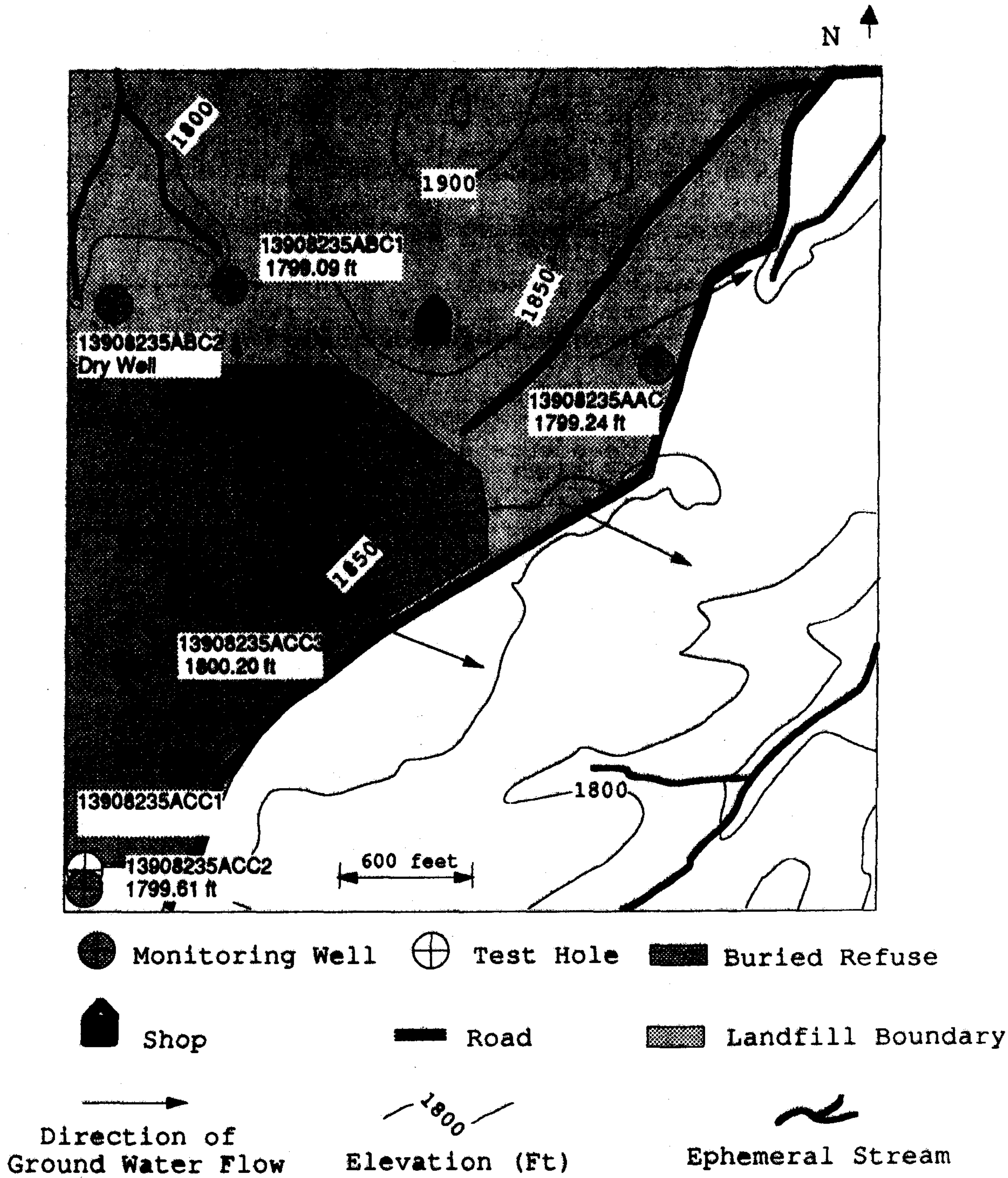

Figure 5. Location of monitoring wells and test holes at the Mandan landfill with 7/2/92 ground-water levels.

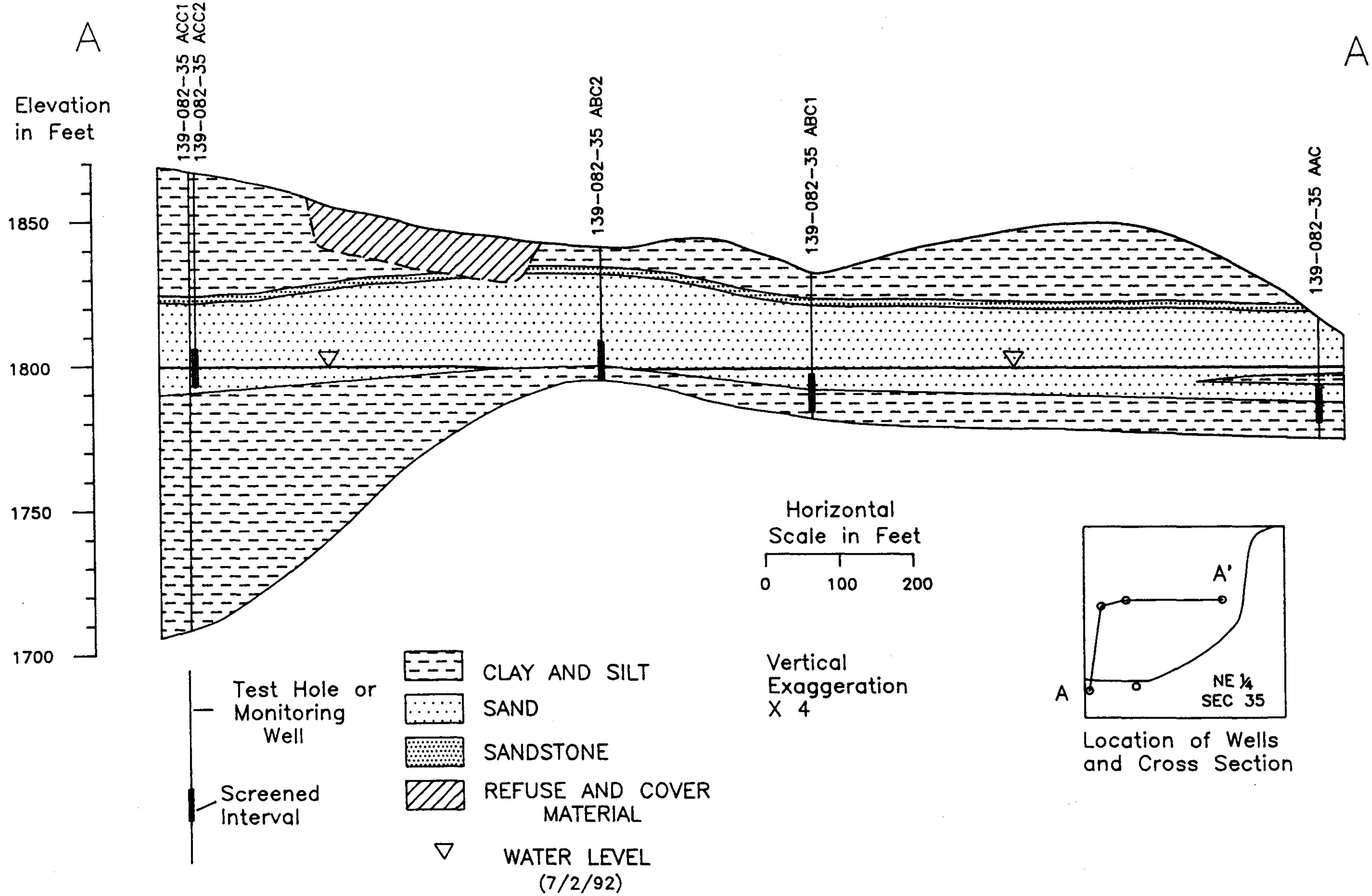

Figure 6. Geohydrologic section A–A' in the Mandan landfill

Geohydrologic-section A-A' through the landfill (Fig. 6) shows that the sand is at a constant elevation except in well 139-082-35ABC2, where it is about 10 feet higher than in the other wells. The base of the landfill cell currently in use is about 10 feet below the top of the sand. The earlier cells did not intersect the sand as they were at higher elevations.

The two ravines in the northwest corner of the site are eroding directly toward the landfill cells. These ravines are about 100 feet deep. As mentioned earlier, the bedrock is poorly consolidated except for the uppermost ledge-forming layer of sandstone. The sand below the uppermost layer erodes easily and undercuts the ledge in the ravines. The ravines have eroded down through the ledge less than 100 feet away from the nearest refuse cell.

HYDROLOGY

Surface Water Hydrology

The regional surface drainage flows towards the Heart River, which is located approximately one mile north of the landfill. Surface water runoff from the landfill flows through the ravines located near the site. The surface water entering the landfill property is intercepted and diverted around the site by drainage ditches and diversion dikes towards the ravines at the northwest corner of the site. The road ditch along the eastern boundary also diverts surface water away from the landfill.

Regional Ground-Water Hydrology

Little information is available on the regional ground-water flow system. Domestic wells within a one-mile radius of the landfill are screened in a lower aquifer in the Cannonball Formation. The bedrock aquifer is approximately 100 to 200 feet below land surface.

The Heart River aquifer is located approximately one-half mile north-northwest of the landfill. The Heart River aquifer consists mainly of alluvial sands and gravels (Ackerman, 1980). It is possible that ground water in the deep bedrock aquifer may be hydraulically connected to the Heart River aquifer.

Local Ground-Water Hydrology

Five monitoring wells were installed in and around the landfill boundaries (Fig. 5). The wells were screened near the base of the unconsolidated bedrock sand. The unconsolidated bedrock sand, below the surficial clay, is partially saturated and is the uppermost aquifer beneath the landfill.

Monitoring well 139-083-35ACC2 is located at the southern boundary of the study area for up-gradient information of the water table. The other four wells are located at or near the heads of the four ravines near the landfill. These ravines are located near the southeastern, northeastern and northwestern corners of the property. Well 139-082-35ABC2, located in the northwest corner, was dry throughout the study period.

Four water-level measurements were made in each of the five monitoring wells over a six-week period (Appendix D). In the uppermost unconsolidated sand, the direction of ground-water flow is to the north.

The landfill is located on a ground-water divide. The eastern part of the landfill drains towards the southeastern and northeastern ravines and the remainder of the landfill drains towards the northwestern ravines.

Water Quality

Chemical analyses of water samples are shown in Appendix E. Chloride, a conservative ion, can be an indicator of leachate migration. Well 139-082-35ACC3 indicates a chloride concentration, 58 milligrams per liter (mg/L) that is significantly larger than the 6.3 mg/L concentration in the up-gradient well (139-082-35ACC2) (Fig.7). This concentration (58 mg/L) is less than the MCL for chloride (250 mg/L).

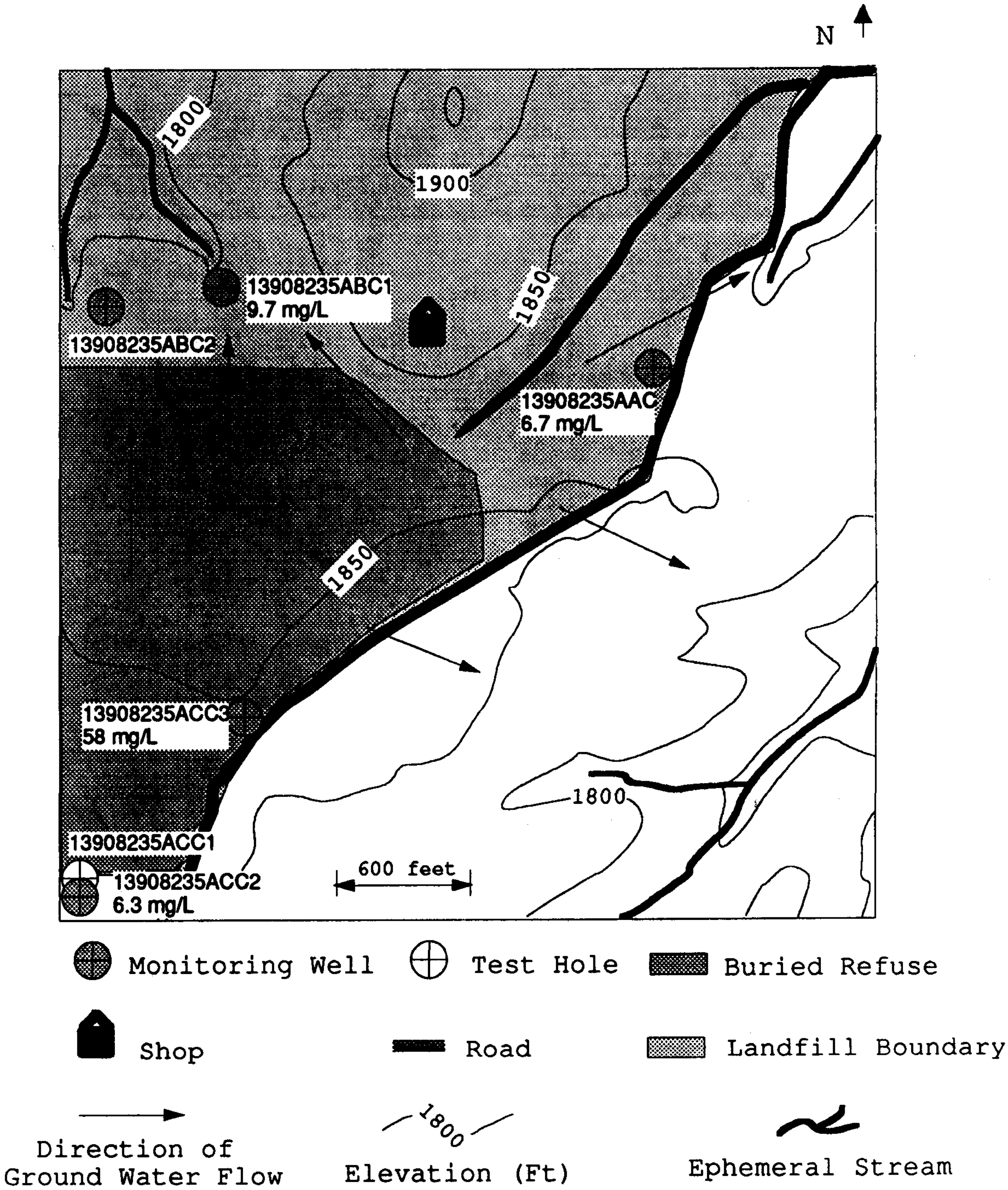

Figure 7. Chloride concentrations (mg/L) at the Mandan landfill.

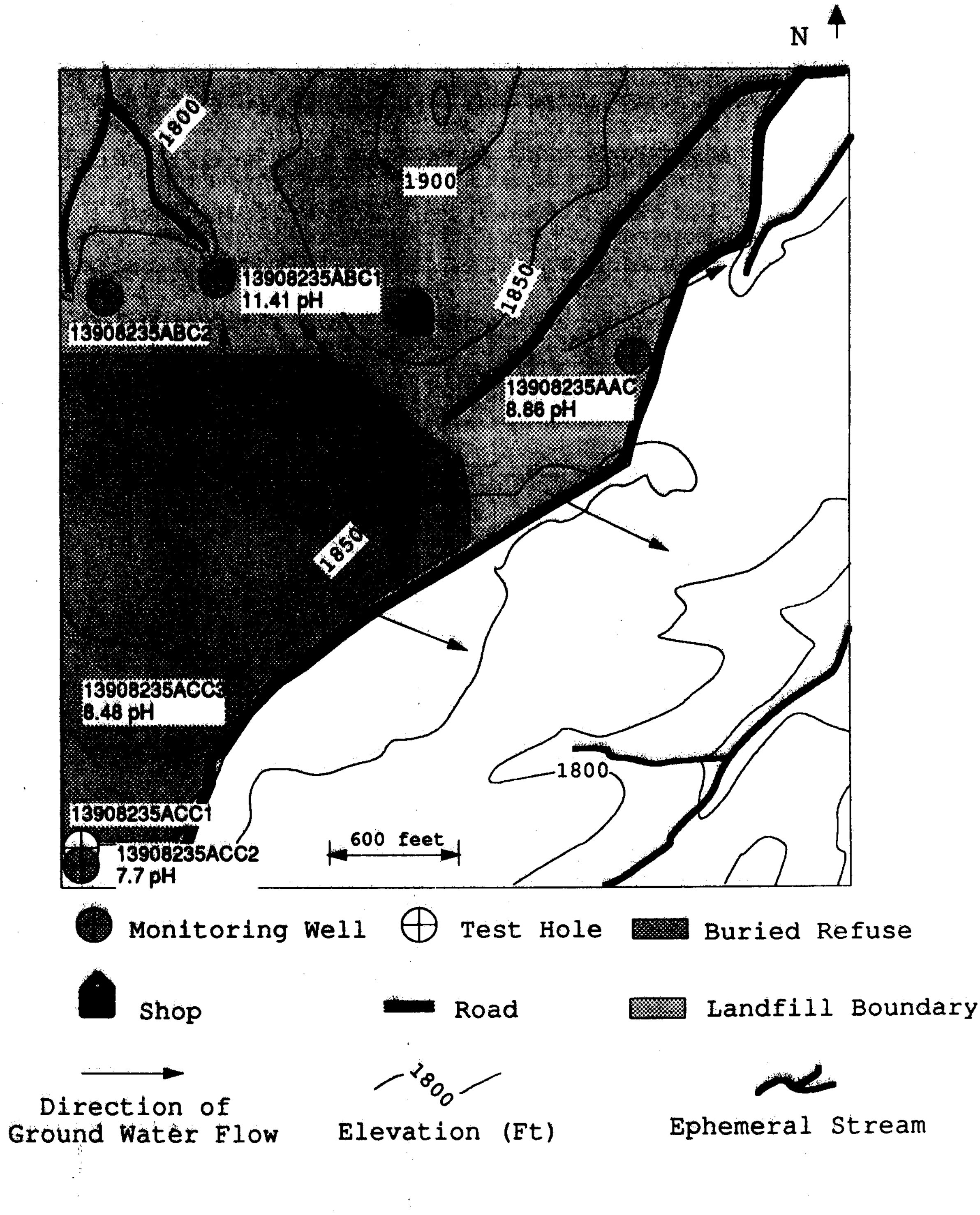

Figure 8. Ground-water pH at the Mandan landfill.

Well 139-082-35ABC1 indicates a pH level of 11.41 compared to 7.7 in the up-gradient well (Fig.8). The pH of 11.41 indicates a strong reducing environment that may be caused by leachate migration. The slightly higher pH values of wells 139-082-35ACC3 and 139-082-35AAC are probably due to their proximity to the disposal area of the water treatment sludge.

The increased pH at well 139-082-35ABC1 also coincides with an increase in molybdenum concentration (69 µg/L) compared to 6 µg/L in the up-gradient well (139-082-35ACC2). Well 139-082-35AAC also indicated a high molybdenum concentration (74 µg/L) with a pH of 8.86. Elevated molybdenum concentrations may be due to the increased mobility of molybdenum in high pH environments. The molybdenum reservoir may be the local sedimentary sequence or the influence of the landfill.

A VOC sample was collected from well 139-082-35ABC1. The results of the VOC analysis are shown in Appendix F. The VOC analysis indicates a detection of 2-Butanone (MEK). This compound is found in most solvents and its detection may indicate the presence of leachate. The increase in pH at this well may be related to the detection of MEK.

CONCLUSIONS

The city of Mandan landfill is located on a topographic upland area that is covered by a thin layer of bedrock clay.

The clay overlies a thin layer of indurated sandstone and a thick layer of unconsolidated sand. The sand and sandstone layers are extensive across the landfill property and outcrop at the heads of the ravines located in the vicinity of the landfill. The ravines in the northwest corner of the property are eroding headward into the active landfill area. Because of their proximity and depth, and because of the non-resistant character of the formation, these ravines may present a serious erosion problem and expose the buried cells to surface runoff.

The presence of the bedrock sand at a relatively shallow depth and the high permeability of the sand are conducive to leachate migration into the uppermost sand aquifer. Elevated chloride, pH, and 2-Butanone detections suggest the presence of leachate in the uppermost sand aquifer at two well locations.

The direction of ground-water flow in the uppermost sand aquifer appears to be toward the ravines in the northwest corner of the landfill. The domestic water supply in the deeper bedrock aquifer should not be affected by the landfill because the uppermost sand aquifer may discharge into the two ravines at the northwest corner of the landfill. Leachate migration into the Heart River or the Heart River Aquifer is possible from the two ravines.

REFERENCES

Ackerman, D.J. 1977. Ground-water basic data for Morton County, North Dakota: North Dakota Geological Survey, Bulletin 72, North Dakota State Water Commission, County Ground-Water Studies 27, Part II, 592 p.

Ackerman, D.J. 1980. Ground-water resources of Morton County, North Dakota: North Dakota Geological Survey, Bulletin 72, North Dakota State Water Commission, County Ground-Water Studies 27, Part III 51, p.

Cvancara, A.M.. 1976. Geology of the Cannonball Formation (Paleocene) in the Williston Basin, with reference to uranium potential: North Dakota Geological Survey, Report of Investigation 57, 22 p.

Hem, J.D., 1989, Study and interpretation of the chemical characteristics of natural water: United States Geological Survey Water-Supply Paper 2254, 263 p.

Toman Engineering Company, 1981, Report for Mandan Solid Waste Disposal Facility.

North Dakota Department of Health, 1986, Water well construction and water well pump installation: Article 33-18 of the North Dakota Administrative Code.

APPENDIX A

WATER QUALITY STANDARDS AND MAXIMUM CONTAMINANT LEVELS

Water Quality Standards and Maximum Contaminant Levels

Field Parameters	MCL (mg/L)
appearance	color/odor
pH	6-8(optimum)
specific conductance	-----
temperature	-----
water level	-----
Geochemical Parameters	
iron	>0.3
calcium	25-50
magnesium	25-50
manganese	>0.05
potassium	------
total alkalinity	------
bicarbonate	150-200
carbonate	150-200
chloride	250
fluoride	0.7-1.2
nitrate+nitrite (N)	10
sulfate	300-1000
sodium	20-170
total dissolved solids (TDS)	>1000
cation/anion balance	------
hardness	>121 (hard to very hard)
Heavy Metals (µg/L)	
arsenic	50
cadmium	10
lead	50
molybdenum	100
mercury	2
selenium	10
strontium	*

* EPA has not set a MCL for strontium. The median concentration for most U.S. water supplies is 110 µg/L (Hem, 1989).

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

139-082-35AAC

NDSWC

Date Completed:	4/30/92	Well Type:	P2
Depth Drilled (ft):	40	Source of Data:	
Screened Interval (ft):	24-34	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1816.62

Owner: Mandan

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	SILTY, SANDY, GRAYISH-ORANGE, 10YR7/4	2-9
SAND	FINE GRAINED, YELLOWISH-BROWN, 10YR5/4, (CANNONBALL FORMATION)	9-17
CLAY	SILTY, MODERATE YELLOWISH-BROWN, 10YR5/4	17-22
SAND	FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4	22-24
SAND	FINE GRAINED, DARK MEDIUM GRAY, N4	24-28
SAND	FINE GRAINED, SILTY AND CLAYEY, DARK MEDIUM GRAY, N4	28-31
SILT	SANDY, CLAYEY, DARK MEDIUM GRAY, N4	31-36
CLAY	SILTY, DARK MEDIUM GRAY, N4	36-40

139-082-35ABC1

NDSWC

Date Completed:	4/30/92	Well Type:	P2
Depth Drilled (ft):	50	Source of Data:	
Screened Interval (ft):	35-45	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1832.24

Owner: Mandan

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SILT	CLAYEY AND SANDY, MODERATE YELLOWISH-BROWN, 10YR5/4, (CANNONBALL FORMATION)	1-4
SANDSTONE	FINE GRAIN, MEDIUM DARK GRAY, N4, WELL CEMENTED	4-6
SAND	FINE TO MEDIUM GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4	6-27
CLAY	MODERATE REDDISH-BROWN, 10R4/6	27-29
SANDSTONE	FINE GRAINED, LIGHT BROWN, 5Y5/6, MODERATELY CEMENTED	29-36
SAND	FINE GRAINED, MEDIUM DARK GRAY, N4	36-38
SAND	SILTY, MEDIUM DARK GRAY, N4,	38-42
SAND	SILTY AND CLAYEY, MEDIUM DARK GRAY, N4	42-44
CLAY	SILTY, MEDIUM DARK GRAY, N4	44-50

139-082-35ABC2

NDSWC

Date Completed:	4/30/92	Well Type:	P2
Depth Drilled (ft):	45	Source of Data:	
Screened Interval (ft):	39-44	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1840.73

Owner: Mandan

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	GRAYISH-ORANGE, 10YR7/4, (CANNONBALL FORMATION)	1-2
SAND	FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4	2-4
SANDSTONE	FINE GRAINED, LIGHT BROWN, 5YR5/6 AND DARK MEDIUM GRAY, N4, WELL CEMENTED	4-6
SAND	FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4	6-12
SILTSTONE	SANDY, MODERATELY REDDISH-BROWN, 10YR5/4, MODERATELY CEMENTED	12-16
SAND	FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4	16-36
SAND	SILTY, LIGHT OLIVE GRAY, 5Y6/1	36-41
SAND	SILTY AND CLAYEY, DARK MEDIUM GRAY, N4	41-43
CLAY	LIGHT GRAY, N7	43-45

139-082-35ACC1

NDSWC 12936

Date Completed:	4/29/92	Purpose:	Test Hole
Depth Drilled (ft):	160	Source of Data:	
L.S. Elevation (ft)	1868.58	Owner: Mandan	

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	PALE YELLOWISH BROWN, 10YR6/2, (CANNONBALL FORMATION)	1-11
CLAY	LIGHT OLIVE GRAY, 5Y6/1	11-21
CLAY	GRAYISH-ORANGE, 10YR7/4	21-31
CLAY	LIGHT OLIVE GRAY, 5Y6/1	31-35
CLAY	SANDY, PALE YELLOWISH-BROWN, 10YR6/2	35-41
SANDSTONE	FINE GRAINED SILTY, MEDIUM GRAY, N5, WELL CEMENTED	41-42
SAND	FINE-GRAINED, MOTTLED, YELLOWISH-BROWN, 10YR5/4	42-62
SANDSTONE	FINE-GRAINED, WELL CEMENTED, DARK YELLOWISH-ORANGE, 10YR6/6	61-61.5
SAND	FINE-GRAINED, MEDIUM GRAY, N5	61.5-69
SAND	FINE GRAINED SILTY, MEDIUM DARK GRAY, N4	69-75
CLAY	SANDY, SILTY, DARK MEDIUM GRAY, N4	75-80
SILTSTONE	CLAYEY, LIGHT OLIVE GRAY, 5Y6/1, MODERATELY CEMENTED	80-96
CLAY	SILTY, LIGHT OLIVE GRAY, 5Y6/1	96-144
CLAY	SILTY AND SANDY, OLIVE GRAY, 5Y4/1	144-151
CLAY	SILTY, OLIVE GRAY, 5Y4/1	151-160

139-082-35ACC2

NDSWC 12936A

Date Completed:	4/29/92	Well Type:	P2
Depth Drilled (ft):	80	Source of Data:	
Screened Interval (ft):	68-78	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1868.58

Owner: Mandan

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		1-3
CLAY	SILTY, PALE YELLOWISH-BROWN, 10YR6/2, (CANNONBALL FORMATION)	3-11
CLAY	SILTY, OLIVE-GRAY, 5Y4/1 WITH LIGHT BROWN, 5YR6/4 MOTTLES	11-32
CLAY	SILTY, OLIVE-GRAY, 5Y4/1	32-35
CLAY	SILTY AND SANDY, DARK YELLOWISH-ORANGE, 10YR6/6	35-41
SANDSTONE	FINE GRAINED, LIGHT-BROWN, 5YR6/4, AT TOP, OLIVE-GRAY, 5Y4/1, BELOW, WELL CEMENTED	41-42
SAND	FINE GRAINED, MODERATE YELLOWISH-BROWN, 10YR5/4	42-51
SAND	FINE GRAINED, DARK YELLOWISH-ORANGE, 10YR6/6	51-55
SAND	FINE GRAINED, DARK YELLOWISH-BROWN, 10YR4/2	55-71
SAND	FINE GRAINED, SILTY, DARK MEDIUM GRAY, N4,	71-76
SILT	SANDY, CLAYEY, DARK MEDIUM GRAY, N4	76-80

139-082-35ACC3

NDSWC

Date Completed:	4/30/92	Well Type:	P2
Depth Drilled (ft):	70	Source of Data:	
Screened Interval (ft):	54-64	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1852.83

Owner: Mandan

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	PALE YELLOWISH-BROWN, 10YR6/2, (CANNONBALL FORMATION)	2-8
CLAY	SILTY, PALE YELLOWISH-BROWN, 10YR6/2	8-13
CLAY	SILTY, OLIVE-GRAY, 5Y4/1	13-16
CLAY	SILTY, OLIVE-GRAY,5Y4/1,, FEW LIGHT BROWN, 5YR5/6 MOTTLES	16-21
CLAY	OLIVE-GRAY, 5Y4/1	21-24
CLAY	SILTY WITH A TRACE OF SAND, LIGHT BROWN, 5YR5/6	24-28
CLAY	SILTY, MODERATE REDDISH-ORANGE, 10R6/6	28-30
SANDSTONE	FINE GRAINED, LIGHT BROWN, 5YR5/6, AT TOP, MEDIUM GRAY, N5 BELOW, WELL CEMENTED	30-31
SAND	FINE GRAINED, DARK YELLOWISH-BROWN, 10YR4/2	31-53
SAND	FINE GRAINED, DARK MEDIUM GRAY, N4	53-61
SILT	SANDY, CLAYEY, DARK MEDIUM GRAY, N4	61-70

APPENDIX D

WATER-LEVEL TABLES

Mandan Landfill Water Level Data
5/5/92 to 7/2/92

139-082-35AAC LS Elev (msl,ft)=1816.62
Undefined Aquifer SI (ft.)=24-34

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/05/92	17.25	1799.37	06/19/92	17.61	1799.01
06/05/92	17.55	1799.07	07/02/92	17.38	1799.24

139-082-35ABC1 LS Elev (msl,ft)=1832.24
Undefined Aquifer SI (ft.)=35-45

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/05/92	33.13	1799.11	06/19/92	33.16	1799.08
06/05/92	33.18	1799.06	07/02/92	33.15	1799.09

139-082-35ACC2 LS Elev (msl,ft)=1868.58
Undefined Aquifer SI (ft.)=68-78

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/29/92	68.87	1799.71	06/19/92	69.10	1799.48
06/05/92	68.95	1799.63	07/02/92	68.97	1799.61

139-082-35ACC3 LS Elev (msl,ft)=1852.83
Undefined Aquifer SI (ft.)=54-64

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/07/92	52.61	1800.22	06/19/92	52.61	1800.22
06/05/92	52.63	1800.20	07/02/92	52.63	1800.20

APPENDIX E

MAJOR ION AND TRACE ELEMENT CONCENTRATIONS

Mandan Landfill Study Area Water Quality

Major Ion Analyses

Location	Date Sampled	SiO_2	Ca	Mg	K	Na	F	HCO_3	CO_3	SO_4	Cl	B	Fe	Mn	Hardness as CO_3	SAR	% Na	Field pH	Temp (°C) (µmho)	Specific Conductance	TDS (mg/L)
		---- milligrams per liter ----																			
13908235ACC3	5/7/92	7.7	25	13	2.7	160	0.6	238	9	170	58	0.08	0.01	0.01	120	6.4	74	8.48	11	937	594
13908235ABC1	5/5/92	14	59	0	7.7	220	0.3	0	13	200	9.7	0.16	0.04	0	150	7.8	75	11.41	14	1942	712
13908235AAC	5/5/92	12	27	6	3.4	72	0.3	192	0	100	6.7	0.06	0.01	0.01	92	3.3	62	8.86	9	501	327
13908235ACC2	5/29/92	12	9.5	4	2	120	0.6	253	0	120	6.3	0.11	0.04	0.07	40	8.2	86	7.7	9	748	400

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		---- micrograms per liter ----						
13908235ACC3	5/7/92	3	0	0	0	2	21	410
13908235ABC1	5/5/92	1	0	0	0	2	69	370
13908235AAC	5/5/92	1	0	0	0	4	74	310
13908235ACC2	5/29/92	1	0	0	0	3	6	170

APPENDIX F

VOLATILE ORGANIC COMPOUNDS FOR WELL 139-082-35ABC1

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)	228*
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	<50
Pentachloroethane	<5
Trichlorotrofluoroethane	<5
Carbondisufide	<5
Ether	<5

* Constituent Detection