Site Suitability Review of the Grand Forks Landfill

by
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and
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Prepared by the
North Dakota State Water Commission
and the
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ND Landfill Site Investigation No. 45

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OF THE
GRAND FORKS LANDFILL

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Bismarck, North Dakota
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TABLE OF CONTENTS

LIST OF FIGURES

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 Grand Forks solid-waste landfill is one of the landfills being evaluated.

Location of the Grand Forks Landfill

The Grand Forks landfill is located about 4 miles west of Grand Forks in Township 152 North, Range 51 West, N 1/2, Section 35. The Grand Forks landfill encompasses about 180 acres.

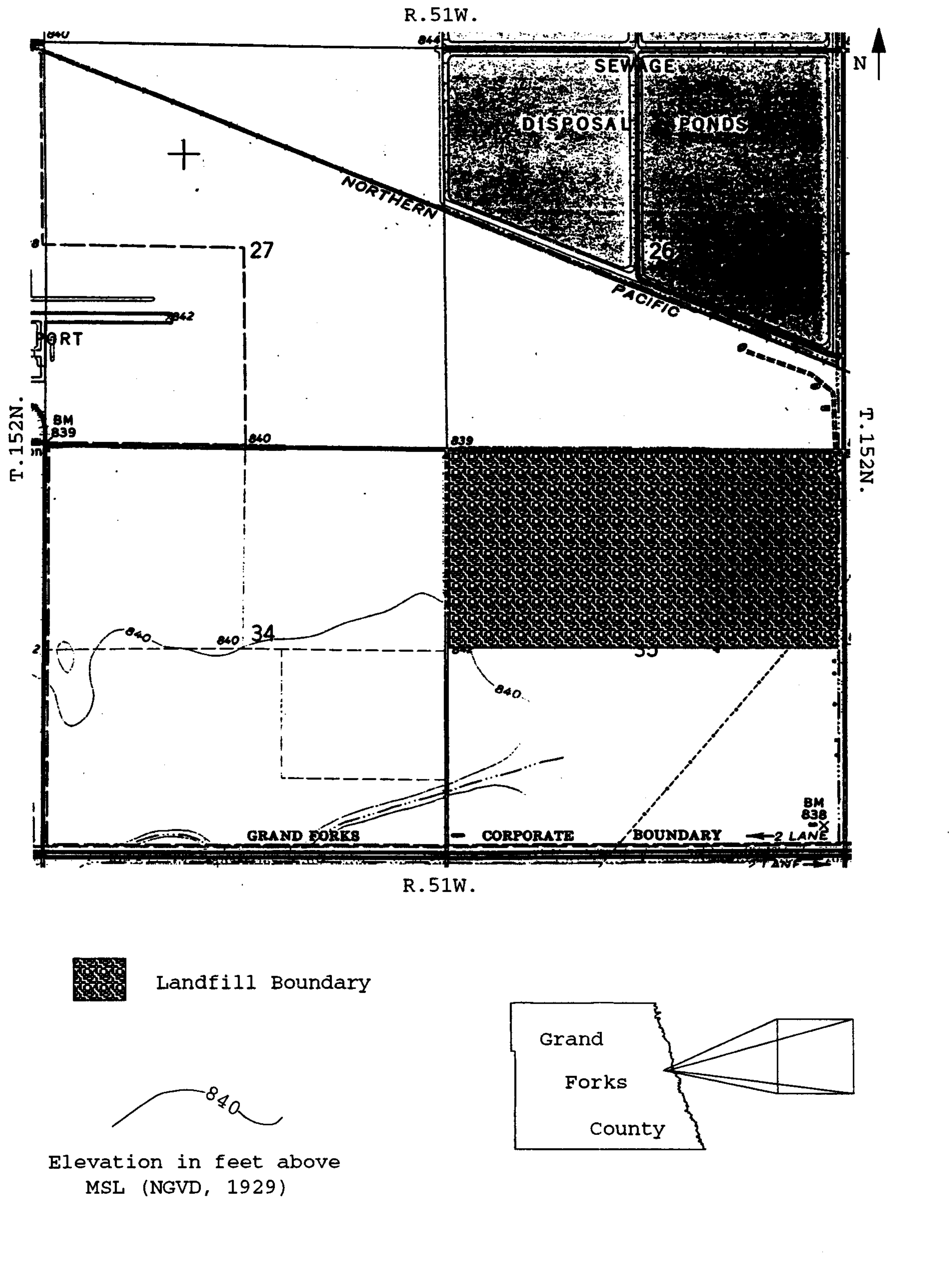


Figure 1. Location of the Grand Forks landfill in the N 1/2, Section 35, T.152N., R.51W.

Previous Site Investigations

Two previous investigations were performed at the Grand Forks landfill. A Master's Thesis was written by John Betcher in December, 1989 titled "The Hydrogeology of a Landfill Located in Fine-Grained Lacustrine Sediments in a Saline Discharge Area West of Grand Forks, North Dakota." Numerous well nests were installed to complete Betcher's study with depths of these wells ranging from 5 to 30 feet. Betcher's study concluded that the lacustrine sediments are saturated to near the land surface with the ground-water flow regime dominated by vertical hydraulic gradients rather than horizontal gradients. The vertical hydraulic gradient fluctuates seasonally with a downward movement during the spring and summer months and upward during the winter months. The upward movement is the result of regional discharge from the underlying bedrock aquifers. The water quality in the shallow ground-water flow system is a mixed cation-chloride type characterized by high dissolved solids concentrations. Betcher's study also detected pH levels ranging from 5.3 to 7.6, with the majority of the measurements near 6.5.

The second investigation was completed by Orr, Schelen, Mayeron, and Associates Inc. (OSM) in February, 1990. OSM installed six monitoring wells and reconditioned six existing monitoring wells from the Betcher study. The depth of the six additional wells ranged from 8 to 42 feet. The OSM investigation concluded that leachate migration from the

Grand Forks landfill does not endanger potable ground-water supplies because of the slow horizontal ground-water velocities and the strong upward flow gradient. OSM stated that contaminant movement may occur as a result of surface runoff through the English Coulee diversion ditch into the Red River. No water quality analyses were conducted in the OSM study.

Methods of Investigation

The current Grand Forks study was accomplished by use of nine existing monitoring wells that are located around the perimeter of the landfill. Water samples and water-level measurements were taken from these monitoring wells.

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

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

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 about 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.

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. 2). 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

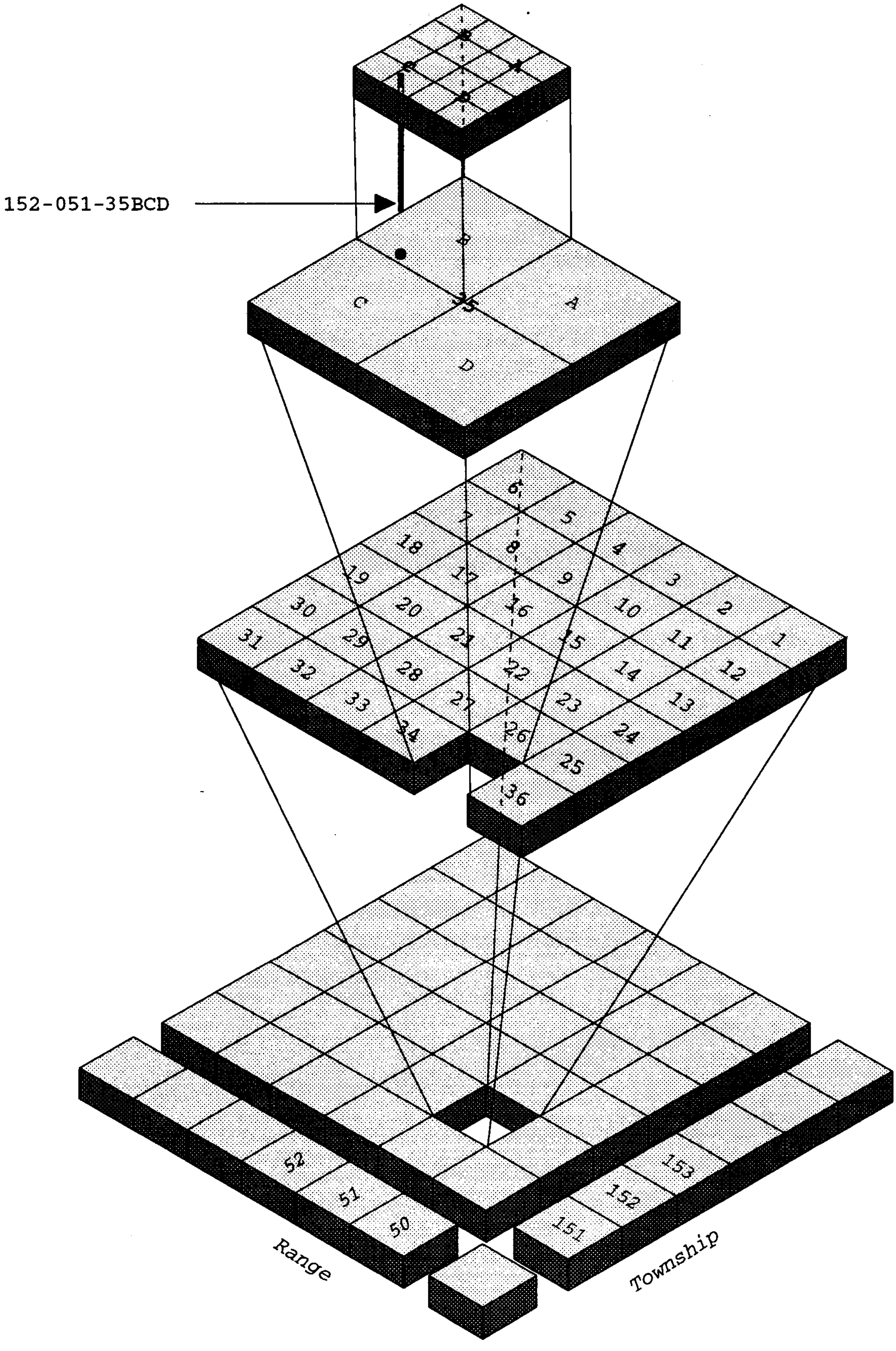


Figure 2. Location-numbering system.

section (40-acre tract), and quarter-quarter-quarter section (10-acre tract). Therefore, a well denoted by 152-051-35BCD would be located in the SE1/4, SW1/4, NW1/4, Section 35, Township 152 North, Range 51 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 152-051-35BCD1 and 152-051-35BCD2.

GEOLOGY

The Grand Forks landfill lies within the Red River Valley physiographic region, a flat plain that was formerly the basin of glacial Lake Agassiz. Surficial deposits in the area consist of offshore lake deposits (mainly clay and silt). A deep test hole drilled 1/2 mile south of the landfill (Kelly, 1968, test hole 151-51-2BBB) penetrated 50 feet of lake sediments overlying 164 feet of glacial till. Bedrock of the Ordovician Red River Formation was encountered at a depth of 215 feet.

A short distance to the west the Dakota Group overlies the Red River Formation and comprises the uppermost bedrock unit. The eastern edge of the Dakota Group subcrop may be a mile or less from the landfill, according to bedrock geologic maps of the area (Hansen and Kume, 1970, Bluemle, 1983).

The landfill is located in a flat, low-lying area that slopes gradually northeastward. Drainage ditches have been constructed on the north and west sides of the landfill and a large diversion canal runs along the south side of the landfill (Fig. 3).

The earlier refuse trenches at the landfill were dug 8 to 10 feet below the ground surface. The bases of these trenches were below the water table, allowing ground-water to seep in to a depth of 2 to 3 feet (Betcher, 1989). Since 1991 the trenches have been constructed in areas with artificial fill, so that all of the refuse is above the water table.

Geologic sampling by Betcher (1989) and Orr, Schelen and Mayeron (1990) shows that the near-surface stratigraphy at the landfill is remarkably uniform. The upper 5 to 6 feet of sediments are composed of laminated silt and silty clay. From a depth of approximately 6 feet to 28 feet the sediments are mostly clay with lenses and laminae of silt. A dark gray, massive clay is present at a depth of approximately 28 feet (Figs. 4 and 5, lithologic logs in Appendix C).

HYDROLOGY

Surface-Water Hydrology

A canal that diverts flow from the English Coulee into the Red River is located along the southern boundary. This canal may function as a discharge area for leachate from the

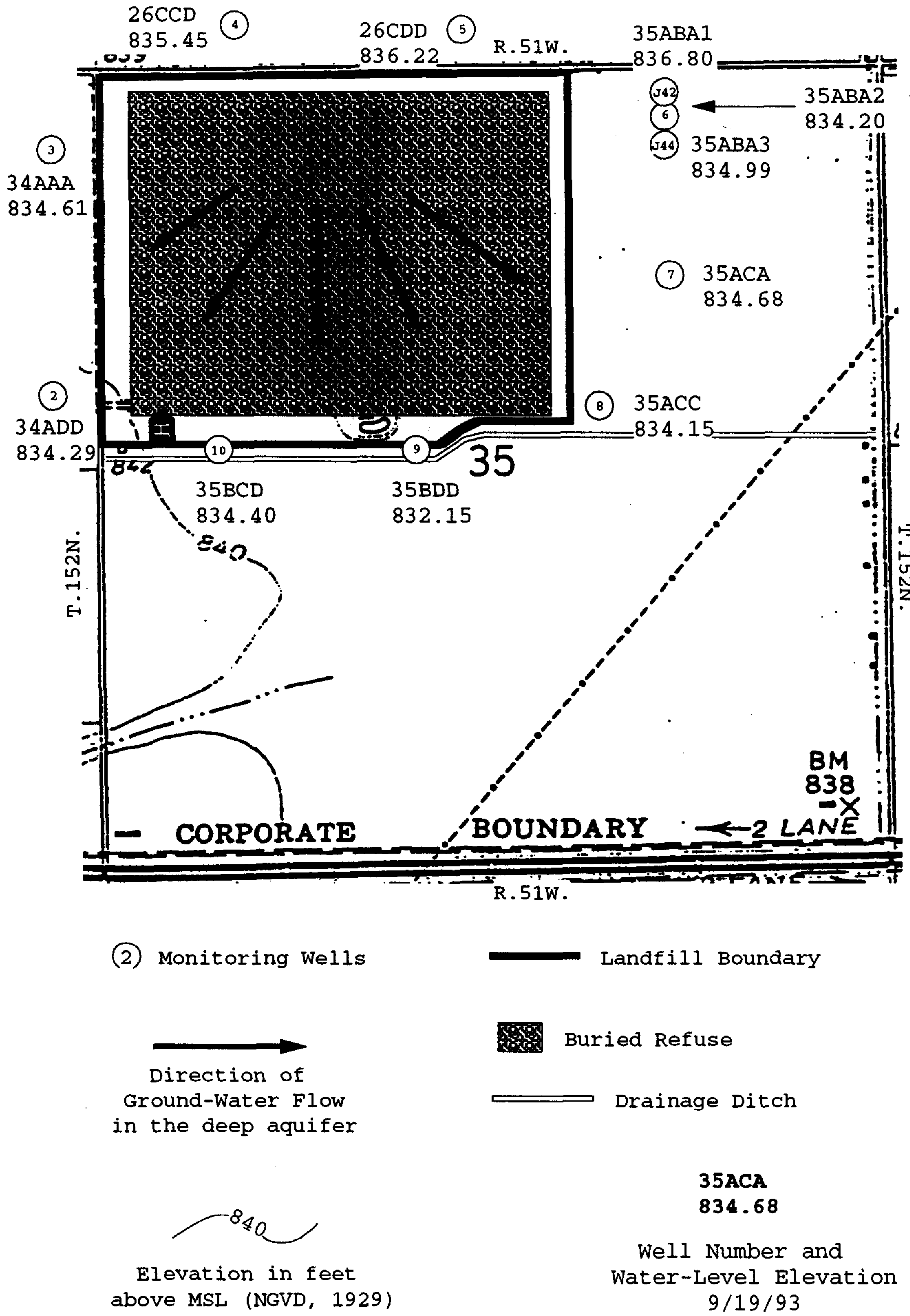


Figure 4. Location of monitoring wells and the direction of ground-water flow.

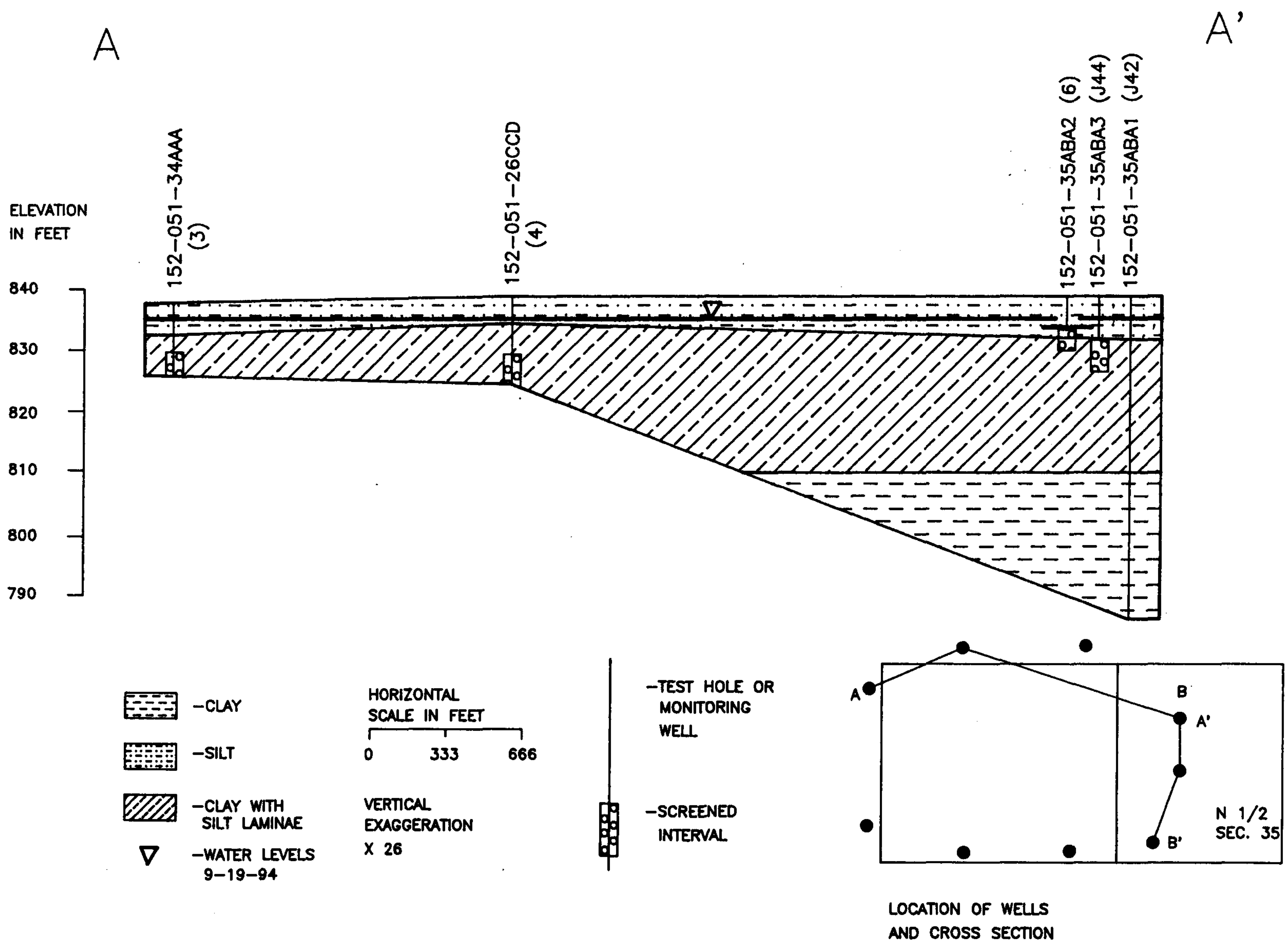


Figure 4: Geohydrologic section A–A' in the Grand Forks landfill.

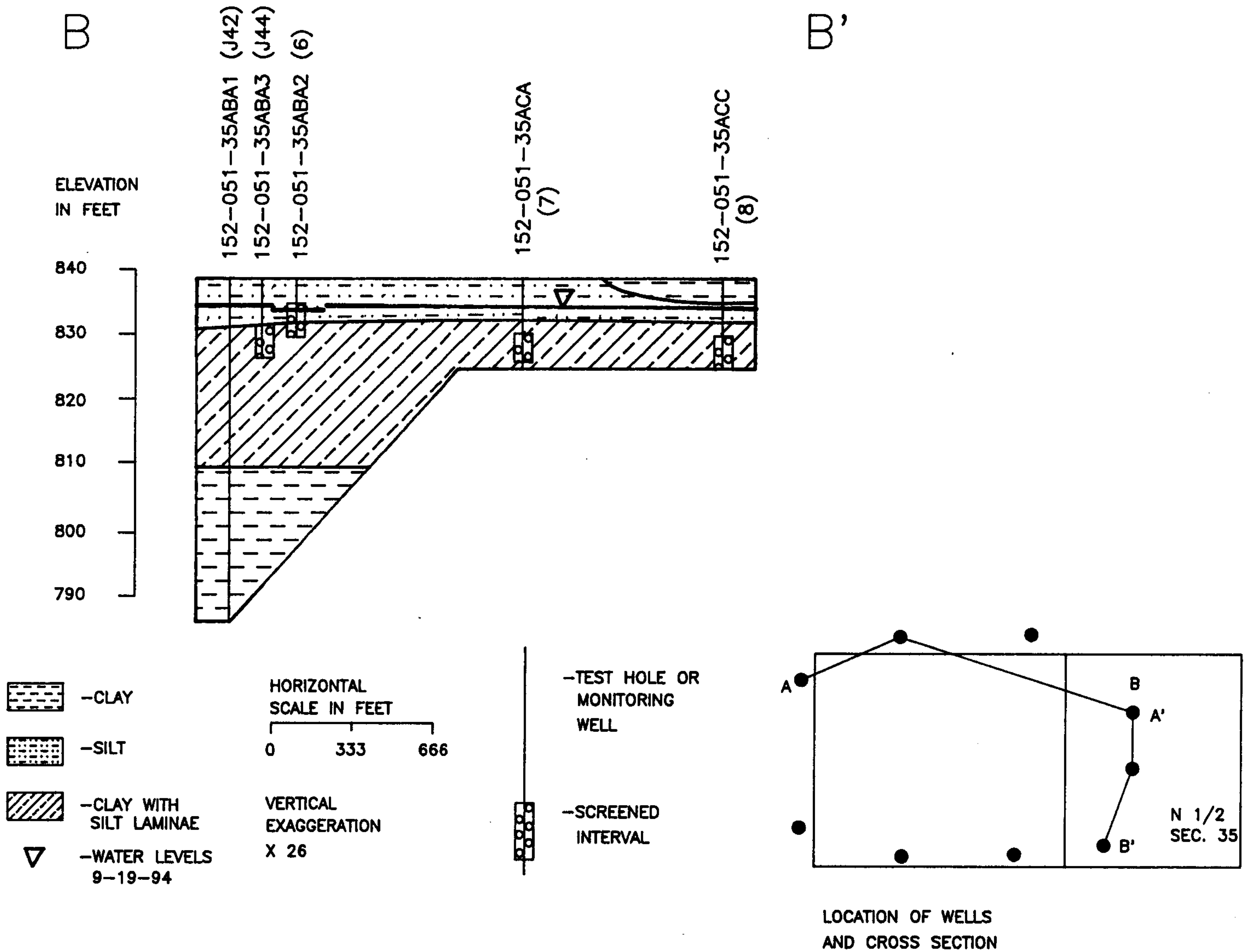


Figure 5: Geohydrologic section B–B' in the Grand Forks landfill.

buried refuse. This canal is also susceptible to contaminant migration from surface-water runoff from the landfill.

Due to the upward movement of ground water, the area surrounding the landfill is characterized by a very shallow water table. As a result, surface ponding commonly occurs during spring snow-melt and periods of above-normal precipitation. Ponding may increase the likelihood of surface runoff causing leachate to migrate laterally into the diversion canal. The city sewage lagoons are located north of the landfill. Ground-water mounding may be present beneath the lagoons creating a ground-water barrier for ground-water flow to the north from the landfill. The lagoons should not affect the area beneath the landfill because of the presence of the lacustrine clay and a natural ground-water flow to the east.

Regional Ground-Water Hydrology

The Dakota Formation, which directly underlies the glacial deposits, appears to "pinch out" near the Grand Forks landfill at a depth ranging from 100-200 feet below land surface (Kelly and Paulson, 1970). The recharge area for the Dakota Formation is at a higher elevation than the landfill thus, causing upward water movement at the landfill. The Dakota aquifer is characterized by a sodium-chloride type water (Kelly and Paulson, 1970) and the saline soils in the landfill area can be attributed to flow of this saline water from the Dakota aquifer. Increased soil salinity may reduce infiltration capacity. The Dakota aquifer should not be susceptible to contaminant migration due to the upward hydraulic gradient between the aquifer and the shallow water table.

The Grand Forks aquifer, a glacial aquifer, is located about two miles east of the landfill at a depth of about 200 feet. This aquifer is characterized by a sodium-chloride type water which appears to have originated from the Dakota aquifer. Very few production wells have been constructed in this aquifer because of its low permeability. The confining lithologies overlying the Grand Forks aquifer consist of lacustrine clay and till. The Grand Forks aquifer should not be susceptible to contaminant migration because of the upward ground-water flow and it is not directly connected hydraulically to the sediments comprising the aquitard in the landfill area.

The glacial aquifers near the Grand Forks landfill consist of undifferentiated sand and gravel lenses interbedded with the lacustrine deposits (Kelly and Paulson, 1970). Most of these aquifers are not very extensive and they contain only small quantities of water. It is not known if any undifferentiated aquifers occur near the Grand Forks landfill.

Local Ground-Water Hydrology

Due to wet conditions, no additional monitoring wells were installed for this study. Nine monitoring wells from the OSM and Betcher investigations were used to complete this study. These wells are located on all sides of the landfill with wells 152-051-34AAA and 34ADD being topographically up-gradient from the landfill (Fig. 3).

Locally, ground water near the Grand Forks landfill is influenced by upward movement of ground water from the Dakota and Red River Formations. This upward movement probably contributes to the maintenance of the shallow water table.

Four water-level measurements were taken over an eight-week period (Appendix D). The ground-water flow direction appears to radiate to the southwest, south, and southeast beneath the landfill (Fig. 3). Ground-water mounding beneath the buried refuse probably created the radial pattern of flow. Locally, ground-water flow surrounding the landfill appears to be to the east toward the Red River. The rate of ground-water velocity is low due to the low hydraulic conductivity of the lacustrine clays. OSM (1990) measured vertical hydraulic conductivities of five cores using a falling head permeameter. Hyraulic conductivities ranged from 2.7×10^{-6} cm/sec to 2.1×10^{-8} cm/sec.

Water Quality

Chemical analyses of water samples are shown in Appendix E. Anomalously high chloride concentrations were detected in all nine wells used in this study. The chloride concentrations ranged from 6,850 mg/L to 24,100 mg/L (Fig. 6) which exceeded the SMCL of 250 mg/L. Based on Kelly (1968) the water quality from two bedrock aquifer wells, about one mile west of the landfill, detected chloride concentrations of 1,170 mg/L. Two of Kelly's (1968) shallow wells (20 to 30 feet deep), located about 2 miles west and 3 miles east of the landfill, indicated chloride concentrations of about 100 mg/L. Based on Kelly's findings and the results of this study, the high chloride concentrations detected near the landfill may be due to the concentrating effect of evaporation near land surface and/or contaminant migration from the landfill.

Seven of the nine monitoring wells detected concentrations of iron that exceeded the SMCL of 0.3 mg/L (Fig. 6). These iron concentrations appear to be typical for the area.

The pH readings indicate that an acidic condition exists beneath the landfill. The pH readings ranged from 5.4 to 6.3 (Fig. 7). Previous studies (Betcher, 1989) indicated pH ranging from 5.3 to 7.6 near the landfill. Typical pH readings for this area range from 7.5 to 8.5. Betcher (1989) indicated that the bulk minerology at the landfill consisted

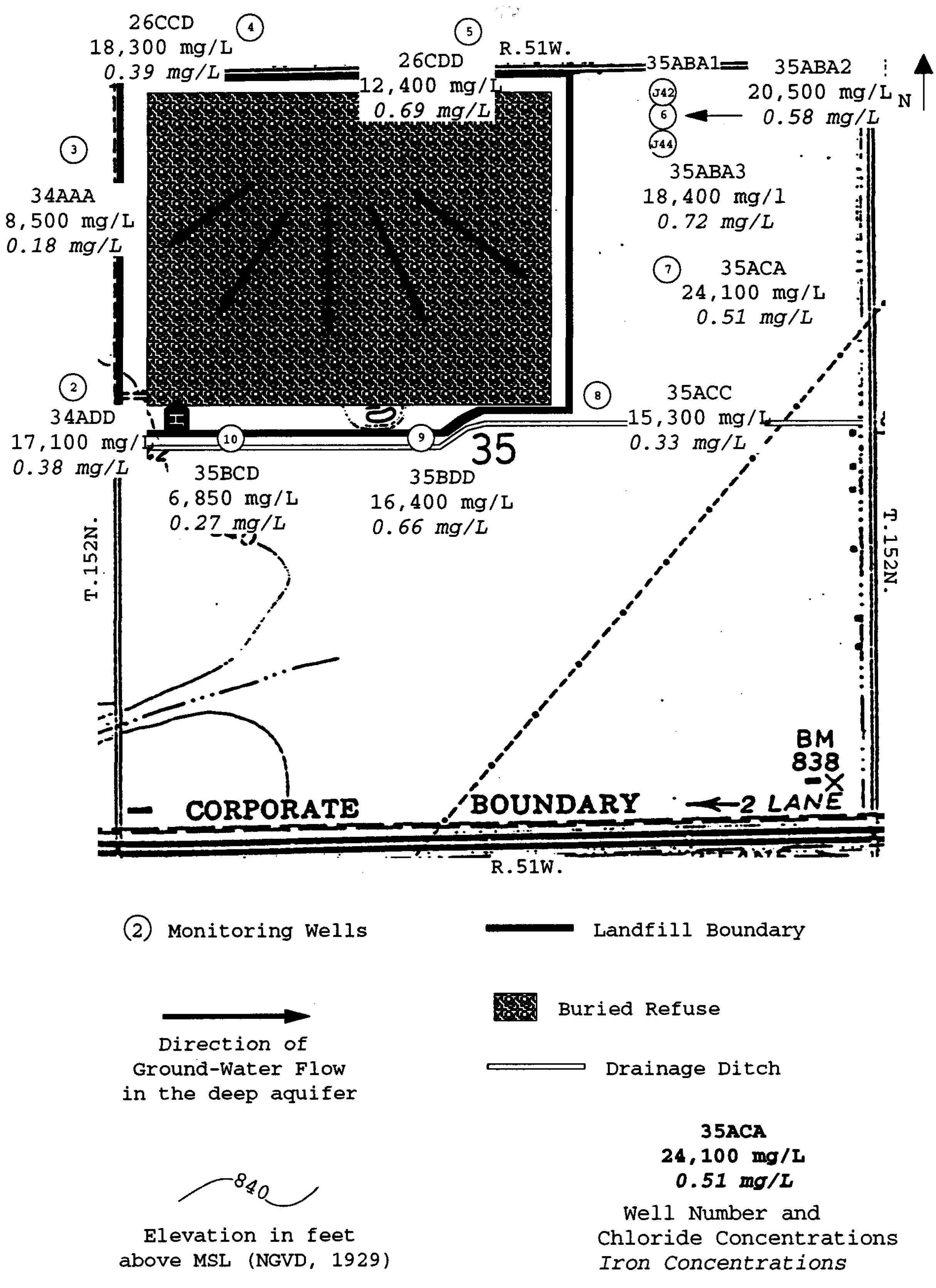
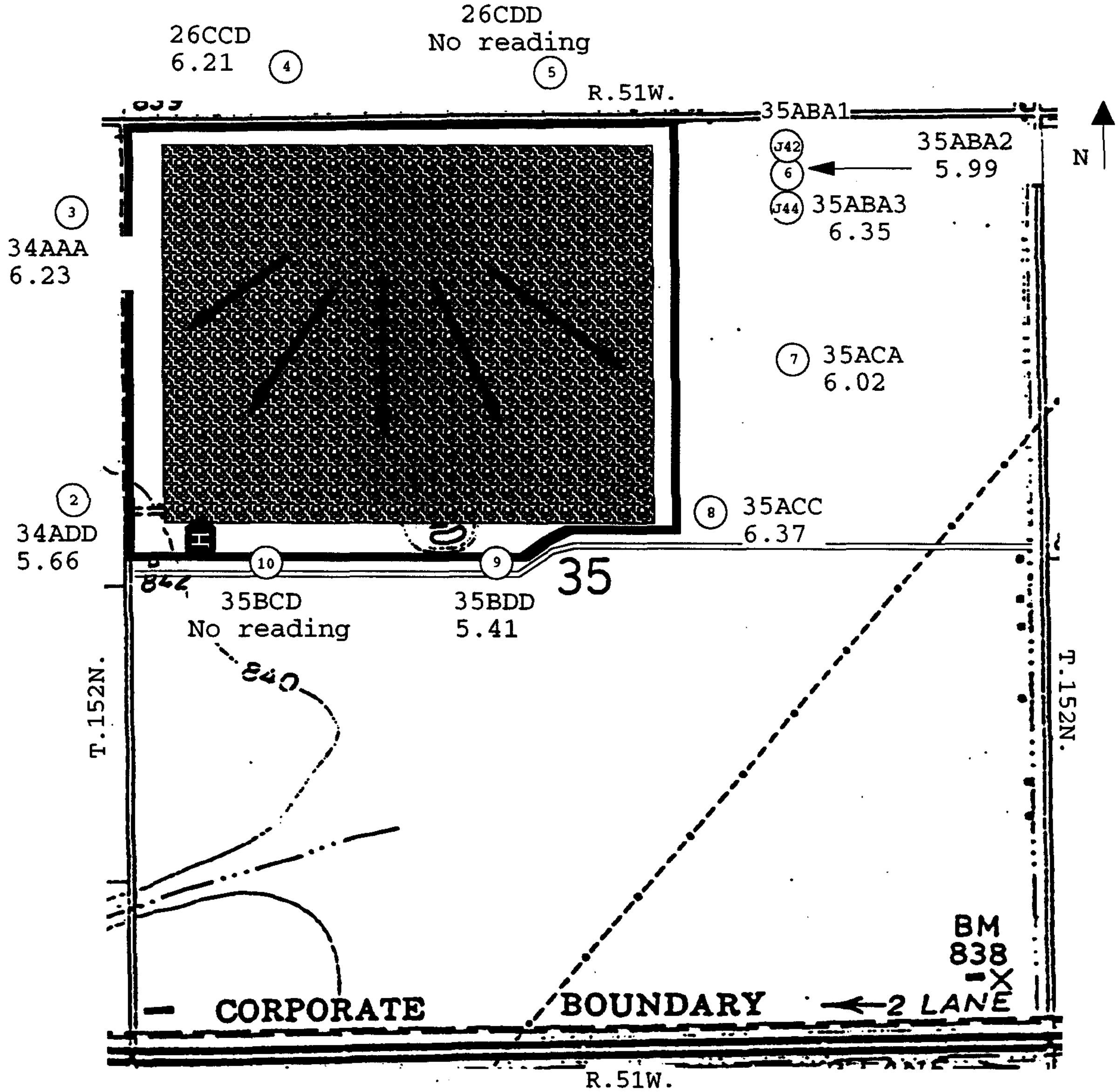


Figure 6. Location of monitoring wells and chloride and iron concentrations.



(2) Monitoring Wells

Landfill Boundary

Buried Refuse

Direction of Ground-Water Flow in the deep aquifer

Drainage Ditch

840 Elevation in feet above MSL (NGVD, 1929)

35ACA
6.02
Well Number and pH levels

Figure 7. Location of monitoring wells and pH levels.

of carbonaceous minerology. The carbonate minerology creates good buffering potential in the soil. This type of minerology at the landfill indicates the source of the low pH levels may be caused by leachate migration from the landfill. The low pH may result in mobilization of trace metals into the local ground-water flow system.

The trace element analyses detected anomalously high selenium and mercury concentrations in most of the monitoring wells. Betcher (1989) detected selenium concentrations of 0 to 1 µg/L and mercury concentrations ranging from 0.1 to 0.9 µg/L. Selenium concentrations measured during this study ranged from 0 µg/L to 94 µg/L (Fig. 8). The MCL of selenium is 10 µg/L. The source of the selenium may be due to bedrock influences and/or contaminant migration from the landfill.

The mercury concentrations at the Grand Forks landfill ranged from 0 µg/L to 20 µg/L (Fig. 8). The MCL of mercury is 2 µg/L. The source of the mercury may be due to contaminant migration from the landfill.

Three monitoring wells detected elevated cadmium concentrations of 3 to 4 µg/L (Fig 7). These concentrations are below the MCL of 10 µg/L, but they are higher than typical ground-water concentrations and may also may be due to contaminant migration from the landfill.

The results of the VOC analyses, from well 152-051-35BDD, are shown in Appendix F. The VOC analyses detected a VOC concentration of dichloromethane (1.18 µg/L). It is inconclusive whether the source of this VOC compound is

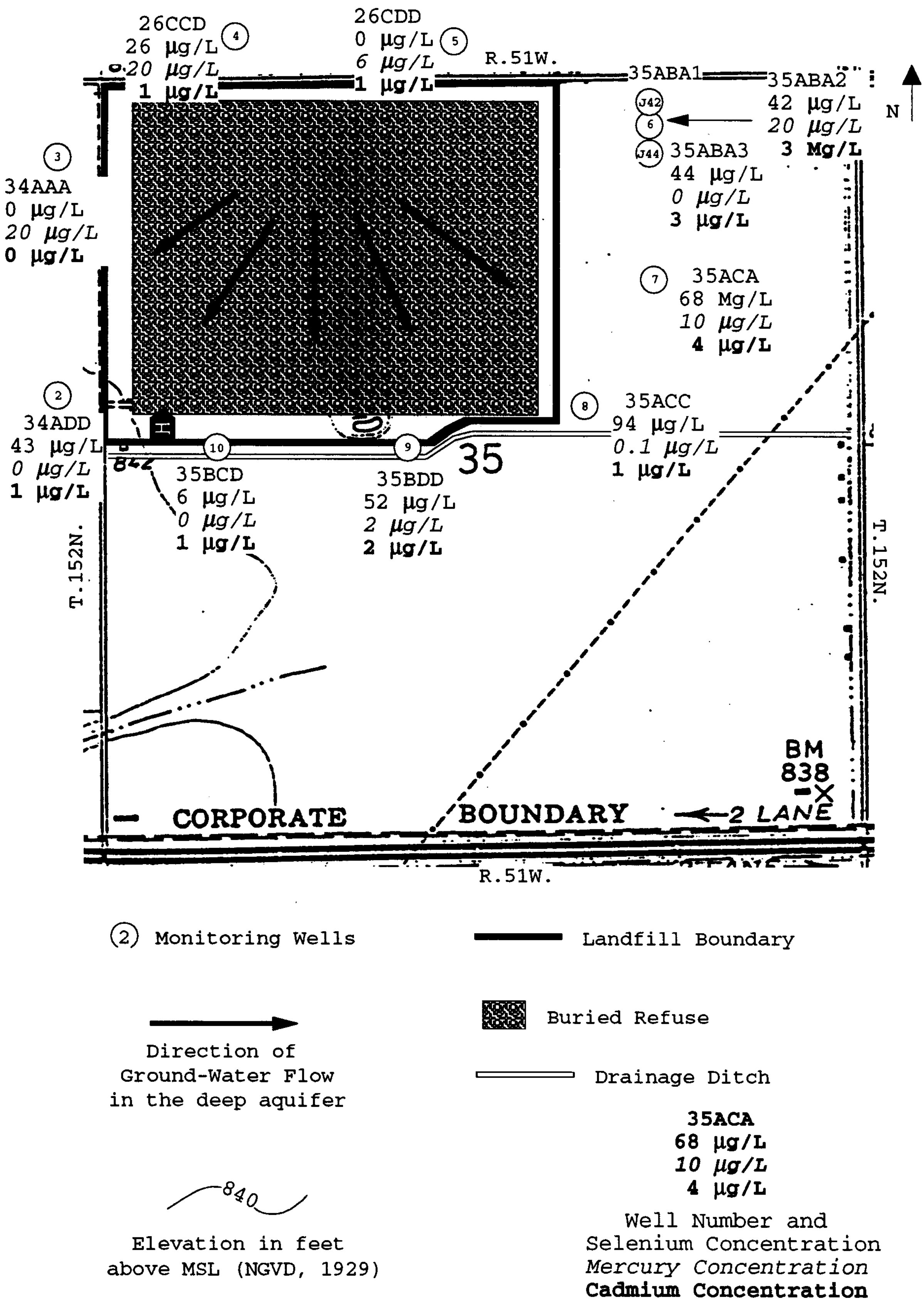


Figure 8. Location of monitoring wells and selenium, mercury, and cadmium concentrations

the result of laboratory contamination[†] or migration from the landfill.

CONCLUSIONS

The Grand Forks landfill is located in a flat, low-lying area that slopes gradually northeastward. This area lies within the Red River Valley physiographic region, the floor of glacial Lake Agassiz. Surficial deposits consist mainly of offshore clay and silt deposits. Near-surface stratigraphy consists of uniform laminated silt and silty clay sediments in the upper 5 to 6 feet. The stratigraphy from 6 to 28 feet is mainly clay with lenses and lamina of silt. Dark gray massive clay is present at a depth of about 28 feet.

Earlier refuse trenches at the landfill were dug to depths of 8 to 10 feet and were located below the water table. Later disposal practices involved constructing trenches with artificial fill to prevent the water table from intersecting buried refuse.

The surface-water hydrology consists of a diversion canal located along the southern boundary of the landfill. This canal may function as a discharge area for leachate from the landfill. The landfill area is usually under near-

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

saturated conditions due to the upward movement of ground water from the bedrock aquifer. Saturated conditions reduce infiltration and create surface ponding, which may increase the likelihood of surface-water runoff into the diversion canal.

Due to the wet conditions, nine monitoring wells from previous investigations were used to complete this study. No additional monitoring wells were installed. The local ground water near the landfill may be influenced by upward movement from the Dakota and Red River Formations.

A ground-water mound may have been created within and beneath the landfill locally, creating a radial pattern of ground-water flow. Ground-water velocity is low due to the low hydraulic conductivities of the lacustrine clays.

Water quality results indicated anomalously high chloride concentrations 27 to 96 times higher than the SMCL. The chloride concentrations are higher than determined from previous studies for ground-water in this area. The high chloride concentrations detected near the landfill may be due to the concentrating effect of evaporation near land surface and/or contaminant migration from the landfill. Iron concentrations above the SMCL were also detected in seven of the nine monitoring wells but such concentrations are typical for this area.

Acidic conditions were detected beneath the landfill. The low pH levels occur in a highly buffered environment, indicating leachate migration from the landfill. The acidic condition may also be a factor in mobilizing trace metals into the local ground-water flow system.

The trace-element analyses detected anomalously high selenium and mercury concentrations. Selenium concentrations ranged from 0 to 9 times higher than the MCL established by the Environmental Protection Agency. The source of the selenium may be due to bedrock influences and/or contaminant migration from the landfill. Mercury concentrations ranged from 0 to 10 times higher than the MCL established by the Environmental Protection Agency. The source of the mercury may be due to contaminant migration from the landfill.

Elevated cadmium concentrations detected in three of the monitoring wells, were below the MCL but higher than would be expected for ground water in this area.

The VOC analyses detected the compound dichloromethane. It is inconclusive 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.

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 EXISTING WELLS

MIDWEST TESTING LABORATORY

26CCD

JOB NO. G039 LOG OR TEST BORING NO. P-7 VERTICAL SCALE 1"=2'

PROJECT Grand Forks Municipal Landfill, Grand Forks, North Dakota

DEPTH IN FEET	SOIL DESCRIPTION SURFACE ELEV.	SAMPLE NO.	SAMPLE TYPE	N VALUE	MOISTURE	DENSITY	LL/PL	Qu
	FAT CLAY-black (CH/OH)							
6"	FAT CLAY-brownish gray to brown	1	SS	7				
2'	SILT-brown to brown mottled & grayish brown, loose (ML)	2	SS	5				
4	LEAN CLAY-brown, medium, with lenses of silt (CL/CH)	3	SS	5				
		4	SS	5				
8	FAT CLAY-gray, medium to soft, with lenses of silt (CH/MH)	5	SS	3				
13½	END OF BORING							

WATER LEVEL DATA

DATE	TIME	CAVE IN DEPTH	WATER LEVEL
11-1-89		HSA 4½'	Wet 5'
11-1-89	1148	HSA 13½'	None
11-1-89	1206	*	None

*Set monitoring well at 13 feet. See attached "Well Driller's Report".

BORING DATA

STARTED 11-1-89 COMPLETED 11-1-89 @ 1148

METHOD USED:

3-1/4" HSA 0-13½'

CREW CHIEF D. Roberson

MIDWEST TESTING LABORATORY

34AAA

JOB NO. G039 LOG OR TEST BORING NO. P-6 VERTICAL SCALE 1"=2'

PROJECT Grand Forks Municipal Landfill, Grand Forks, North Dakota

DEPTH IN FEET	SOIL DESCRIPTION SURFACE ELEV.	SAMPLE NO.	SAMPLE TYPE	N VALUE	LABORATORY TESTS MOISTURE	DENSITY	LL/PL	Qu
	FAT CLAY-black (CH/OH)							
7"	FAT CLAY-brownish gray to brown, rather stiff, with lenses of silt (CH)	1	SS	9				
1½'	SILT-brown mottled, medium dense (ML)	2	SS	9				
4	FAT CLAY-grayish brown, medium, with lenses of silt (CH)	3	SS	7				
		4	SS	5				
9	FAT CLAY-gray, soft, with lenses of silt (CH/MH)	5	SS	3				
11	END OF BORING							

WATER LEVEL DATA

DATE	TIME	CAVE IN DEPTH	WATER LEVEL
11-1-89		HSA 7'	Wet 8'
11-1-89	1348	HSA 13½'	None
11-1-89	1412	*	None

*Set monitoring well at 13 feet. See attached "Well Driller's Report".

BORING DATA

STARTED 11-1-89 COMPLETED 11-1-89 @ 1348

METHOD USED:

3-1/4" HSA 0-13½'

CREW CHIEF D. Roberson

MIDWEST TESTING LABORATORY

34ADD

JOB NO. G039 LOG OR TEST BORING NO. P-5 VERTICAL SCALE 1"=2'

PROJECT Grand Forks Municipal Landfill, Grand Forks, North Dakota

DEPTH IN FEET	SOIL DESCRIPTION SURFACE ELEV.	SAMPLE NO.	SAMPLE TYPE	N VALUE	MOISTURE	DENSITY	LL/PL	Qu
	FAT CLAY-black (CH/OH)							
6"	FAT CLAY-brownish gray (CH)	1	SS	6				
1'	SILT-brown mottled to brown & brownish gray, loose to very loose, with seams and layers of clay below 5 feet (ML)	2	SS	7				
		3	SS	4				
6½	LEAN CLAY-brown, medium, with lenses of silt (CL)	4	SS	5				
9	FAT CLAY-gray, soft, with lenses of silt (CH/MH)	5	SS	3				
13½	END OF BORING							

WATER LEVEL DATA

DATE	TIME	CAVE IN DEPTH	WATER LEVEL
11-1-89		HSA 4½'	Wet 5'
11-1-89	1448	HSA 13½'	None
11-1-89	1512	*	None

*Set monitoring well at 13 feet. See attached "Well Driller's Report".

BORING DATA

STARTED 11-1-89 COMPLETED 11-1-89 @ 1448

METHOD USED:

3-1/4" HSA 0-13½'

CREW CHIEF D. Roberson

MIDWEST TESTING LABORATORY

35ABA1

JOB NO. G039 LOG OR TEST BORING NO. P-1 (page 1) VERTICAL SCALE 1"-4'

PROJECT Grand Forks Municipal Landfill, Grand Forks, North Dakota

DEPTH IN FEET	SOIL DESCRIPTION SURFACE ELEV.	SAMPLE NO.	SAMPLE TYPE	N VALUE	MOISTURE	DENSITY	LL/PL	Qu
7"	FAT CLAY-black (CH/OH)	1	SS	11				
1'	FAT CLAY-light brownish gray (CH)							
	SILT-brown, medium dense to very loose, with lenses and seams of clay (ML)	2	3TW					MA / Perm
		3	SS	4				
6½	FAT CLAY-brown, soft (CH)	4	SS	4				
9	FAT CLAY-gray, soft, with lenses and seams of silt (CH/MH)	5	3TW					MA / Perm
		6	SS	3				
		7	SS	4				
		8	SS	4				
28	FAT CLAY-dark gray, blocky structure (CH)	9	3TW					MA / Perm
32	(continued on next page)							

MIDWEST TESTING LABORATORY

35ABA1 cont.

JOB NO. G039 LOG OR TEST BORING NO. P-1 (page 2) VERTICAL SCALE 1"=4'

PROJECT Grand Forks Municipal Landfill, Grand Forks, North Dakota

DEPTH IN FEET	SOIL DESCRIPTION SURFACE ELEV.	SAMPLE NO.	SAMPLE TYPE	N VALUE	MOISTURE	DENSITY	LL/PL	Qu
	(continued from page 1)							
32	FAT CLAY-dark brownish gray, soft (CH)							
		10	SS	3				
		11	3TW					MA / Perm
		12	SS	3				
		13	3TW					MA / Perm
52	END OF BORING							

WATER LEVEL DATA

DATE	TIME	CAVE IN DEPTH	WATER LEVEL
11-2-89		HSA 4½'	Wet 5'
11-2-89	1106	HSA 49½'	None
11-2-89	1236	*	None

*Set monitoring well at 42 feet. See attached "Well Driller's Report".

BORING DATA

STARTED 11-2-89 COMPLETED 11-2-89 @ 1106

METHOD USED:

3-1/4" HSA 0-49½'

CREW CHIEF D. Roberson

MIDWEST TESTING LABORATORY

JOB NO. G039 LOG OR TEST BORING NO. 35ACA P-2 VERTICAL SCALE 1"=2'

PROJECT Grand Forks Municipal Landfill, Grand Forks, North Dakota

DEPTH IN FEET	SOIL DESCRIPTION SURFACE ELEV.	SAMPLE NO.	SAMPLE TYPE	N VALUE	MOISTURE	DENSITY	LL/PL	Qu
5"	FAT CLAY-black (CH/OH)	1	SS	5				
1'	FAT CLAY-brownish gray (CH)							
	SILT-brown, loose (ML)	2	SS	8				
4	LEAN CLAY-brown, medium, with lenses of silt (CH)	3	SS	5				
7	FAT CLAY-grayish brown, medium (CH)	4	SS	6				
9	FAT CLAY-gray, soft, with lenses of silt (CH/MH)	5	SS	4				
		6	SS	3				
13½	END OF BORING							

WATER LEVEL DATA

DATE	TIME	CAVE IN DEPTH	WATER LEVEL
11-1-89		HSA 2'	Wet 3'
11-1-89	0918	HSA 12'	None
11-1-89	0948	*	None

*Set monitoring well at 12 feet. See attached "Well Driller's Report".

BORING DATA

STARTED 11-1-89 COMPLETED 11-1-89 @ 0918

METHOD USED:

3-1/4" HSA 0-12'

CREW CHIEF D. Roberson

MIDWEST TESTING LABORATORY

JOB NO. G039 LOG OR TEST BORING NO. P-3 35ACC VERTICAL SCALE 1"=2'

PROJECT Grand Forks Municipal Landfill, Grand Forks, North Dakota

DEPTH IN FEET	SOIL DESCRIPTION SURFACE ELEV.	SAMPLE NO.	SAMPLE TYPE	N VALUE	MOISTURE	DENSITY	LL/PL	Qu
	FAT CLAY-black (CH/OH)	1	SS	10				
9"	FAT CLAY-brownish gray (CH)							
2½'	SILT-brown (ML)							
5	LEAN CLAY-brown, soft, with lenses of silt (CL)	2	SS	4				
9	FAT CLAY-gray, soft, with lenses of silt (CH/MH)	3	SS	2				
13	END OF BORING							

WATER LEVEL DATA

DATE	TIME	CAVE IN DEPTH	WATER LEVEL
11-1-89		HSA 4½'	Wet 5'
11-1-89	1030	HSA 13'	None
11-1-89	1054	*	None

*Set monitoring well at 13 feet. See attached "Well Driller's Report".

BORING DATA

STARTED 11-1-89 COMPLETED 11-1-89 @ 1030

METHOD USED:

3-1/4" HSA 0-13'

CREW CHIEF D. Roberson

City of GF
#10

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.

MW#4A

1. WELL OWNER

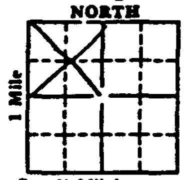
Name: City of Grand Forks

Address: PO Box 1518 Grand Forks, ND 58206

2. WELL LOCATION

Sketch map location must agree with written location.

35BCD



County: Grand Forks

____ ¼ ____ ¼ NW ¼ Sec. 35 Twp. 152 N. Rg. 51 W.

3. PROPOSED USE

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

4. METHOD DRILLED

☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ 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 8 inches. Depth 20 feet.

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

If other, specify ____

Pipe Weight:	Diameter:	From:	To:
Sch 40 lb/ft.	2 inches	0 feet	8 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 (stainless steel, bronze, etc.) Diameter 2 inches

Slot size .010 set from 8 feet to 18 feet

Slot size ____ set from ____ feet to ____ feet

Was a packer or seal used? ☒ Yes ☐ No

If so, what material Bentonite Depth 4-6 Ft.

Type of well: Straight screen ☐ Gravel packed ☒

Depth grouted: From 0' To 4'

Grouting Material: Cement ____ Other XX

If other explain: Bentonite & cement

Well head completion: Pitless unit ____

12" above grade ____ Other XX

If other, specify 2' above grade; Steel protective casing with locking cap

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
CLAY fill, brown/gray	0	2
SILTY CLAY, brown	2	6 1/2
SILTY CLAY, gray, with sand seams at 8½' and 10½'	6 1/2	12
SILT, gray	12	19

(Use separate sheet if necessary.)

10. DATE COMPLETED 10-1-91

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ____

12. REMARKS:

13. DRILLER'S CERTIFICATION

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

MIDWEST TESTING LABORATORY, INC 407
Driller's or Firm's Name Certificate No.

3042 7th Ave N Fargo, ND 58108
Address

Signed by [signature] 10-14-91
Date

City of GF #9

MW#4B

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 Grand Forks

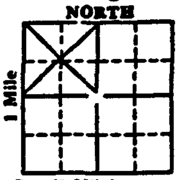
Address PO Box 1518 Grand Forks, ND 58206

2. WELL LOCATION

Sketch map location must agree with written location.

35BDD

NORTH



1 Mile

Sec. (1 Mile) ______

County Grand Forks

____ ¼ ____ ¼ NW ¼ Sec. 35 Twp. 152 N. Rg. 51 W.

3. PROPOSED USE

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

4. METHOD DRILLED

☐ Cable ☐ Forward Rotary ☐ Reverse Rotary ☐ Jetted ☐ Bored ☒ 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 8 inches. Depth 20 feet.

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

If other, specify ______

Pipe Weight:	Diameter:	From:	To:
Sch 40 lb/ft.	2 inches	0 feet	8 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 .010 set from 8 feet to 18 feet

Slot size ______ set from ______ feet to ______ feet

Was a packer or seal used? ☒ Yes ☐ No

If so, what material Bentonite Depth 4'-6' Ft.

Type of well: Straight screen ☐ Gravel packed ☒

Depth grouted: From 0' To 4'

Grouting Material: Cement ______ Other xx

If other explain: Benonite & Cement

Well head completion: Pitless unit ______

12" above grade ______ Other XX

If other, specify 2' above grade; Steel protective casing with locking cap

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
SANDY CLAY, fill, brown	0	2
SILTY CLAY, brown	2	7
SILTY CLAY, dark brown	7	9
SILT, gray	9	19

(Use separate sheet if necessary.)

10. DATE COMPLETED 10-1-91

11. WAS WELL PLUGGED OR ABANDONED?

☐ Yes ☒ No

If so, how ______

12. REMARKS:

13. DRILLER'S CERTIFICATION

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

MIDWEST TESTING LABORATORY, INC — 407

Driller's or Firm's Name — Certificate No.

3802 7th Ave N Fargo, ND 58108

Address

Signed by [signature] — Date 10-14-91

APPENDIX D

WATER-LEVEL TABLES

Grand Forks Water Levels
8/25/94 to 10/06/94

152-051-26CCD MP Elev (msl,ft)=840.45
Undefined Aquifer SI (ft.)=8-13

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/25/94	5.14	835.31	09/19/94	5.00	835.45
09/08/94	5.42	835.03	10/06/94	4.83	835.62

152-051-26CDD MP Elev (msl,ft)=840.54
Undefined Aquifer SI (ft.)=10-15

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/25/94	4.75	835.79	09/19/94	4.32	836.22
09/09/94	4.74	835.80	10/06/94	4.61	835.93

152-051-34AAA MP Elev (msl,ft)=839.45
Undefined Aquifer SI (ft.)=8.8-13.8

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/08/94	5.38	834.07	10/06/94	4.10	835.35
09/19/94	4.84	834.61			

152-051-34ADD MP Elev (msl,ft)=840.57
Undefined Aquifer SI (ft.)=7.96-12.96

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/25/94	6.82	833.75	09/19/94	6.28	834.29
09/08/94	6.94	833.63	10/06/94	6.29	834.28

152-051-35ABA1 MP Elev (msl,ft)=839.3
Undefined Aquifer SI (ft.)=37-42

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/08/94	2.54	836.76	09/19/94	2.50	836.80

152-051-35ABA2 MP Elev (msl,ft)=840.29
Undefined Aquifer SI (ft.)=6.3-8.3

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/25/94	6.48	833.81	09/19/94	6.09	834.20
09/08/94	6.75	833.54	10/06/94	6.04	834.25

152-051-35ABA3 — MP Elev (msl,ft)=840.74

Undefined Aquifer — SI (ft.)=10.8-15.8

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/25/94	5.87	834.87	09/19/94	5.75	834.99
09/08/94	6.52	834.22	10/06/94	5.48	835.26

152-051-35ACA — MP Elev (msl,ft)=840.34

Undefined Aquifer — SI (ft.)=7.9-11.9

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/25/94	5.63	834.71	09/19/94	5.66	834.68
09/08/94	6.34	834.00	10/06/94	5.48	834.86

152-051-35ACC — MP Elev (msl,ft)=840.1

Undefined Aquifer — SI (ft.)=8.2-13.2

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/25/94	6.37	833.73	09/19/94	5.95	834.15
09/08/94	6.62	833.48	10/06/94	6.33	833.77

152-051-35BCD — MP Elev (msl,ft)=840

Undefined Aquifer — SI (ft.)=8-18

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/25/94	3.44	836.56	09/19/94	5.60	834.40
09/08/94	5.69	834.31	10/06/94	3.61	836.39

152-051-35BDD — MP Elev (msl,ft)=840

Undefined Aquifer — SI (ft.)=8-18

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
08/25/94	9.43	830.57	09/19/94	7.85	832.15
09/08/94	7.24	832.76	10/06/94	7.07	832.93

APPENDIX E

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Grand Forks Landfill Water Quality
Major Ions

Location	Screened Interval (ft)	Date Sampled	SiO_2 (milligrams per liter)	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness as $CaCO_3$	as NCH	% Na	SAR	Spec Cond (µmho)	Temp (∞C)	pH
152-051-26CCD	8-13	08/03/94	16	0.39	0.98	2100	2500	5300	13	230	0	2600	18300	0.2	3.2	0.16	30900	16000	15000	43	18	49200	13	6.21
152-051-26CDD	10-15	08/03/94	15	0.69	2.2	1700	1400	3700	15	293	0	1100	12400	0.2	1.6	0.18	20500	10000	9800	45	16	37500	11	
152-051-34AAA	8.8-13.8	08/03/94	18	0.18	0.11	1200	1200	2700	21	274	0	2400	8500	0.3	0.7	0.12	16200	7900	7700	42	13	32100	13	6.23
152-051-34ADD	7.96-12.96	08/03/94	18	0.38	0.39	1900	2500	5000	12	219	0	2600	17100	0.2	4	0.14	29200	15000	15000	42	18	48200	13	5.66
152-051-35ABA2	6.3-8.3	08/03/94	13	0.58	1.4	3200	3100	4600	18	190	0	1700	20500	0.1	1.9	0.1	33200	21000	21000	33	14	50500	13	5.99
152-051-35ABA3	10.8-15.8	08/03/94	15	0.72	0.87	3000	3000	4700	17	178	0	1700	18400	0.1	2.2	0.1	30900	20000	20000	34	14	49600	13	6.35
152-051-35ACA	7.9-11.9	08/03/94	14	0.51	1.3	2500	2600	8400	18	220	0	2200	24100	0.1	1.7	0.15	39900	17000	17000	52	28	56900	13	6.02
152-051-35ACC	8.2-13.2	08/03/94	19	0.33	0.24	970	2100	7400	25	333	0	5800	15300	0.3	3	0.15	31800	11000	11000	59	31	51100	14	6.37
152-051-35BCD	8-18	08/04/94	32	0.27	17	1000	820	2500	53	997	0	790	6850	0.1	0	0.58	12600	5900	5100	48	14	24700	12	
152-051-35BDD	8-18	08/04/94	17	0.66	1.6	2600	2000	4000	17	436	0	1200	16400	0.1	3	0.19	26500	15000	14000	37	14	45700	11	5.41

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
152-051-26CCD	8/04/94	26	9	1	20	6	0	17000
152-051-26CDD	8/04/94	0	0	1	6	6	0	10000
52-051-34AAA	8/04/94	0	0	0	20	0	1	7100
152-051-34ADD	8/04/94	43	2	1	0	0	10	17000
152-051-35ABA2	8/04/94	42	6	3	20	10	2	16000
152-051-35ABA3	8/04/94	44	5	3	0	5	6	16000
152-051-35ACA	8/04/94	68	11	4	10	0	8	16000
152-051-35ACC	8/04/94	94	4	1	0.1	5	16	12000
152-051-35BCD	8/04/94	6	0	1	0	0	10	7600
152-051-35BDD	8/04/94	52	1	2	2	0	5	15000

APPENDIX F

VOLATILE ORGANIC COMPOUNDS
FOR WELL 152-051-35BDD

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	<0.5
Bromodichloromethane	<0.5
Chlorodibromomethane	<0.5
Bromoform	<0.5
trans1,2-Dichloroethylene	<0.5
Chlorobenzene	<0.5
m-Dichlorobenzene	<0.5
Dichloromethane	1.18*
cis-1,2-Dichloroethylene	<0.5
o-Dichlorobenzene	<0.5
Dibromomethane	<0.5
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