Site Suitability Review of the Beulah 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. 4

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OF THE
BEULAH 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 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 Beulah municipal solid waste landfill is one of the landfills being evaluated.

Location

The Beulah municipal solid waste landfill is located three miles north of the city of Beulah in an abandoned lignite strip mine (Fig. 1). The mine site encompasses approximately 100 acres in Township 144 North, Range 88 West, S 1/2 Section 1, and N 1/2 Section 12. The active area of the landfill includes approximately 30 acres.

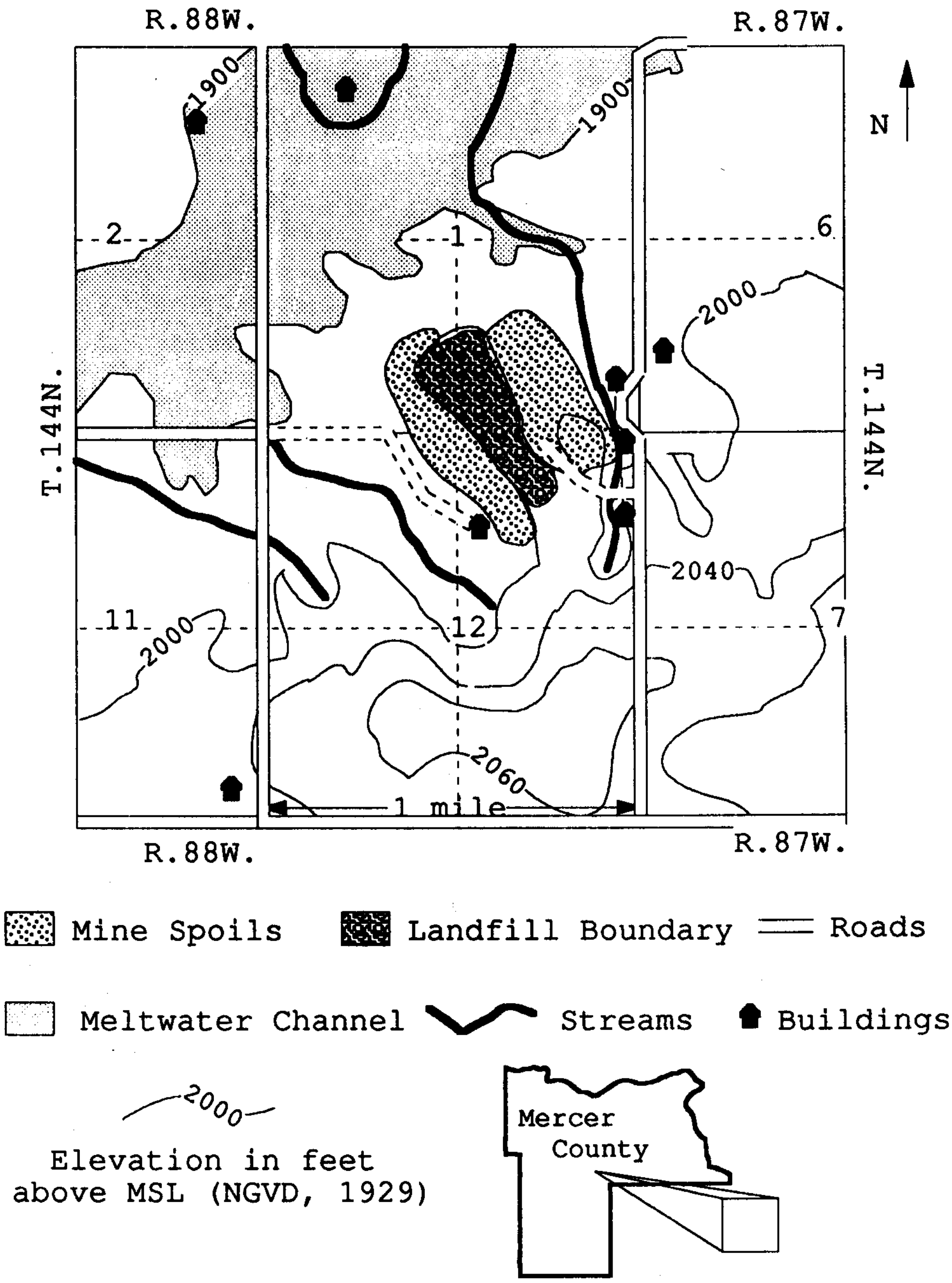

Figure 1. Location of the Beulah landfill in the SE 1/4 of section 1 and the NE 1/4 of section 12.

Previous Site Investigations

The only previous geological or hydrological investigations of the Beulah landfill involved a description of the 64-foot-deep mine trench in 1980. At the same time, a single 21-foot hole was drilled in the bottom of the landfill trench.

Methods of Investigation

The Beulah 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 wells.

Test Drilling Procedure

The drilling procedure used at the Beulah landfill 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 Beulah landfill because of the presence of lignite and clinker at the site. The lithologic descriptions were determined from the drill cuttings. The water used with the drill rig was obtained from the Beulah municipal water system.

Monitoring Well Construction and Development

Six test holes were drilled at the Beulah landfill, and monitoring wells were installed in five of the test holes. The number of wells installed was based on the geologic and topographic characteristics of the site. The wells were screened to monitor the top of the uppermost aquifer.

The choice of drilling locations was limited by poor access at the site. Mine tailings surrounding the landfill were generally inaccessible to the drill rig, making it impractical to place the wells adjacent to the landfill. A thick layer of clinker on the north end of the site also hindered drilling operations. In test hole 144-088-01DBC the drill rig lost circulation due to the high porosity of the clinker and drilling was terminated well above the target horizon.

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

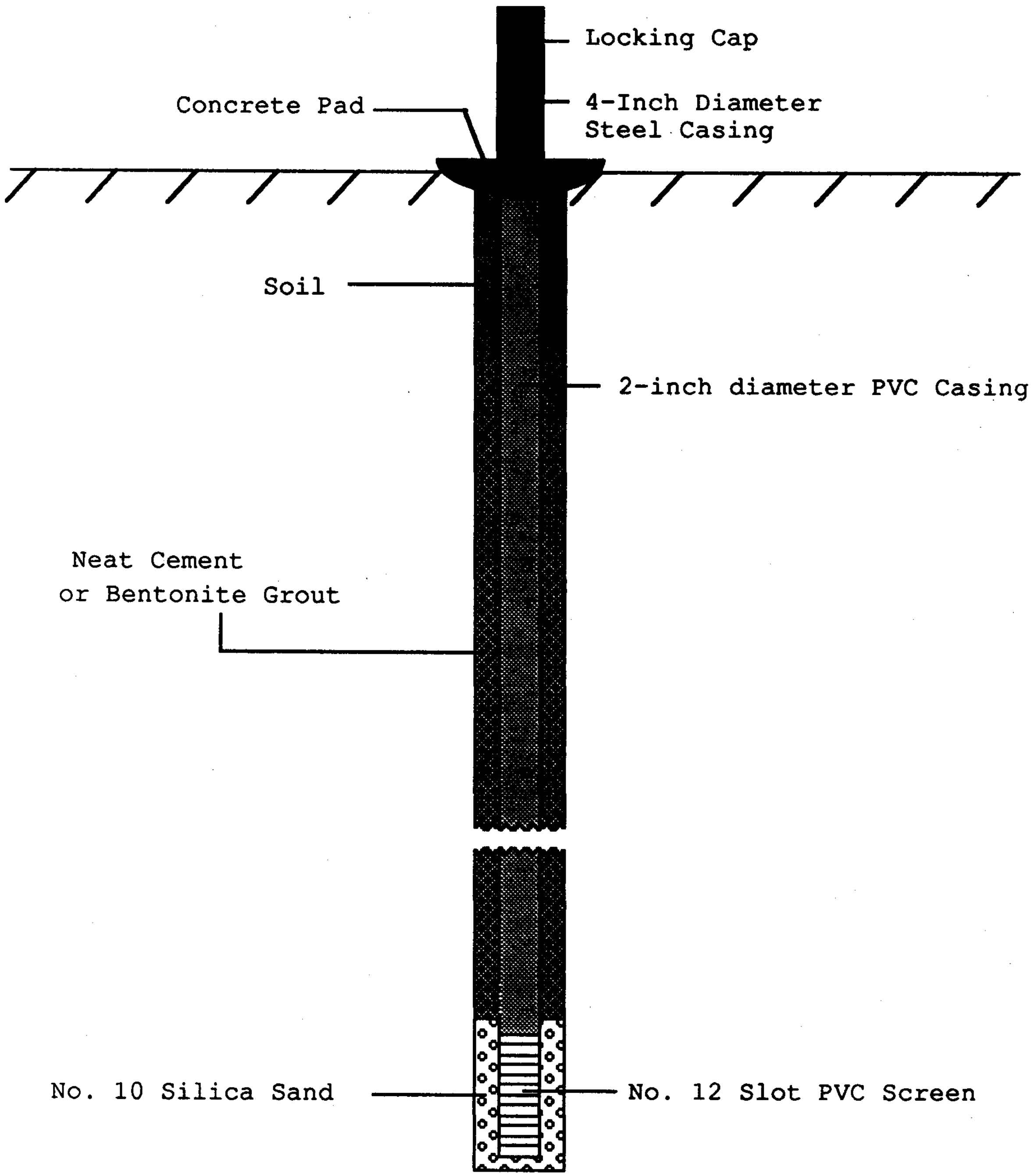

Figure 2. Construction design used for monitoring wells installed at the Beulah landfill.

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. 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.

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 along with their Maximum Contaminant Levels (MCL). MCLs are enforcable 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. Calcium, magnesium, sodium, potassium, iron, and manganese were analyzed using 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.

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 of Health, 1986). The soil around the well was dug to a depth 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

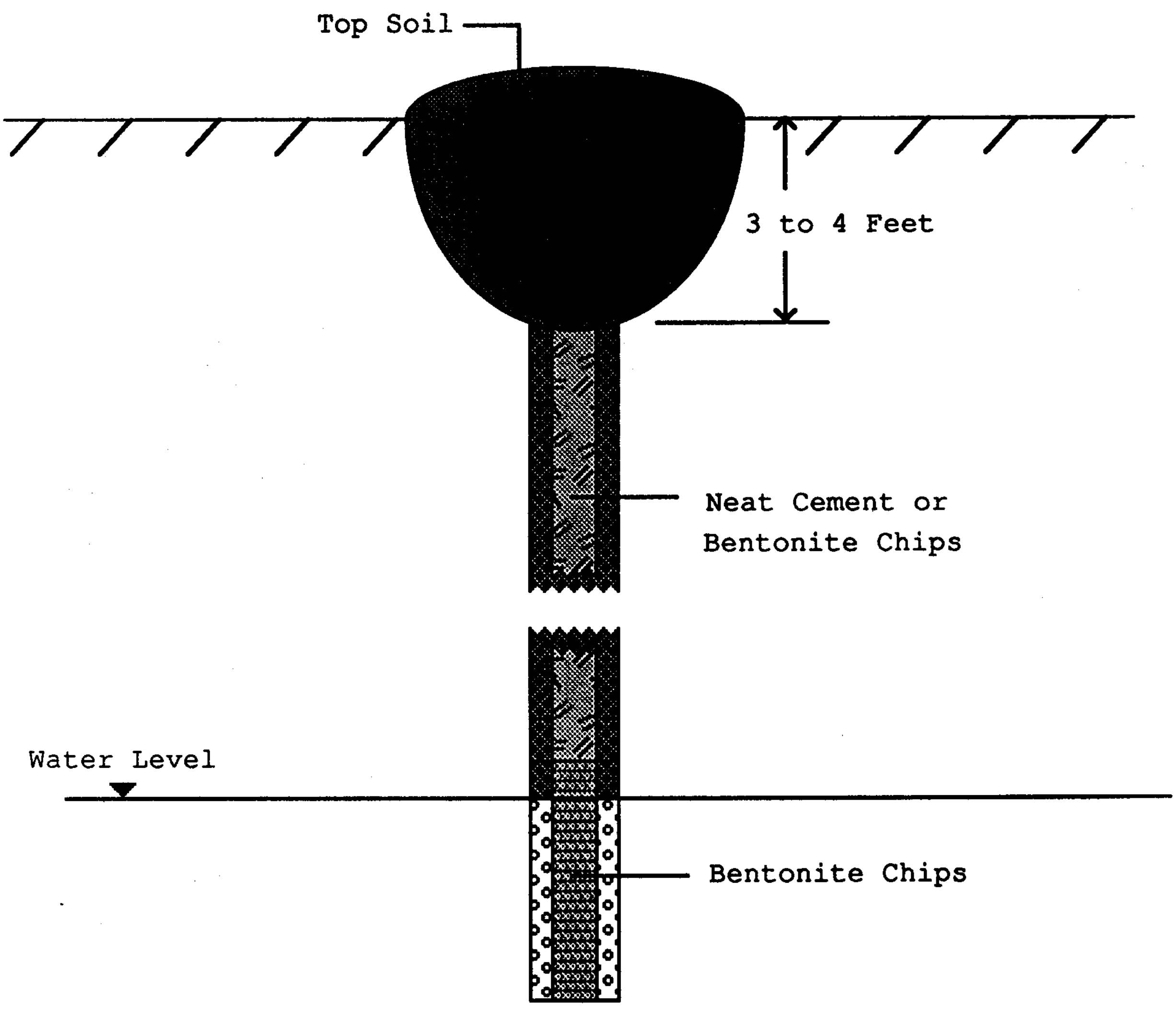

Figure 3. Monitoring well abandonment procedure.

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 144-088-01DDB would be located in the NW1/4, SE1/4, SE1/4 Section 1, Township 144 North, Range 88 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 144-088-01DDB1 and 144-088-01-DDB2.

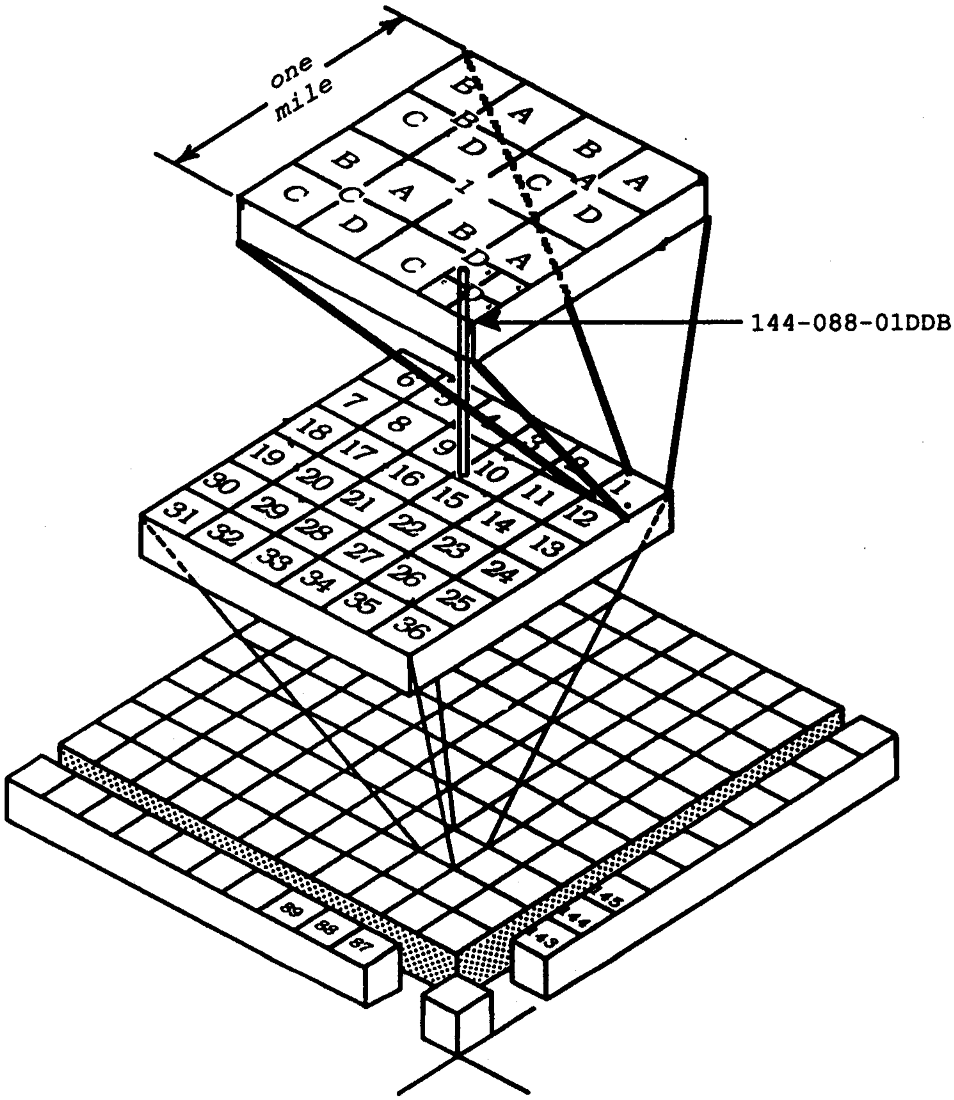

Figure 4. Location-numbering system for the Beulah landfill.

GEOLOGY

Regional Geology

The materials in the vicinity of the Beulah landfill include both bedrock and glacial sediments. The bedrock at or near the surface is included in the Sentinel Butte Formation, a nonmarine, Paleocene unit that was deposited in a deltaic environment (Jacob, 1976). The Sentinel Butte Formation is composed of sand, sandstone, silt, clay, lignite, and limestone. Most sand in the formation is fine-grained, with infrequent occurrences of medium-grained sand. With few exceptions, the Sentinel Butte sediments are poorly consolidated. A thin layer of Pleistocene till covers the Paleocene bedrock in some areas (Carlson, 1973).

A meltwater channel that occurs about 1/4 mile northwest of the Beulah landfill connects Lake Sakakawea with the Knife River (Fig. 1). In Sections 1 and 2, T144N, R88W, the channel bifurcates with one branch extending eastward to Hazen and the other branch extending southwestward to Zap. The glacial outwash deposits in the channel are approximately 250 feet thick and consist of sand and gravel with interbedded silt and clay (Croft, 1973). Fifteen to 30 feet of Holocene alluvium overlies the outwash deposits.

Local Geology

The Beulah landfill is located in an abandoned lignite strip mine, on a ridge overlooking the meltwater channel. Ephemeral streams are present on the southwest and northeast sides of the site (Fig. 5). The erosion of the ephemeral streams and of the meltwater channel have created relatively steep slopes on three sides of the site.

The mine site contains a variety of sediments - sand, clay, lignite, clinker, and till - as well as tailings from the mining operation. The tailings consist of a variable mixture of sand, silt, and clay. Test hole 144-088-12AAC1, on the south end of the site, intersected the lignite bed (Appendix C). The lignite bed is 18 feet thick, and its top is 44 feet below the ground surface. On the north end of the site the lignite has been replaced by clinker, which outcrops along the side of the ridge (Fig. 6).

The lignite and clinker are overlain by a layer of fine-grained sand except in well 144-088-12Baa, where clay overlies the lignite. A layer of clay 6 to 12-feet thick underlies the lignite and clinker. Another layer of fine-grained sand about 60 feet thick is present below the clay. The lower sand outcrops on the slopes below the site and along the ephemeral streams on either side of the site. This sand extends to the northwest where it probably was truncated by the meltwater channel.

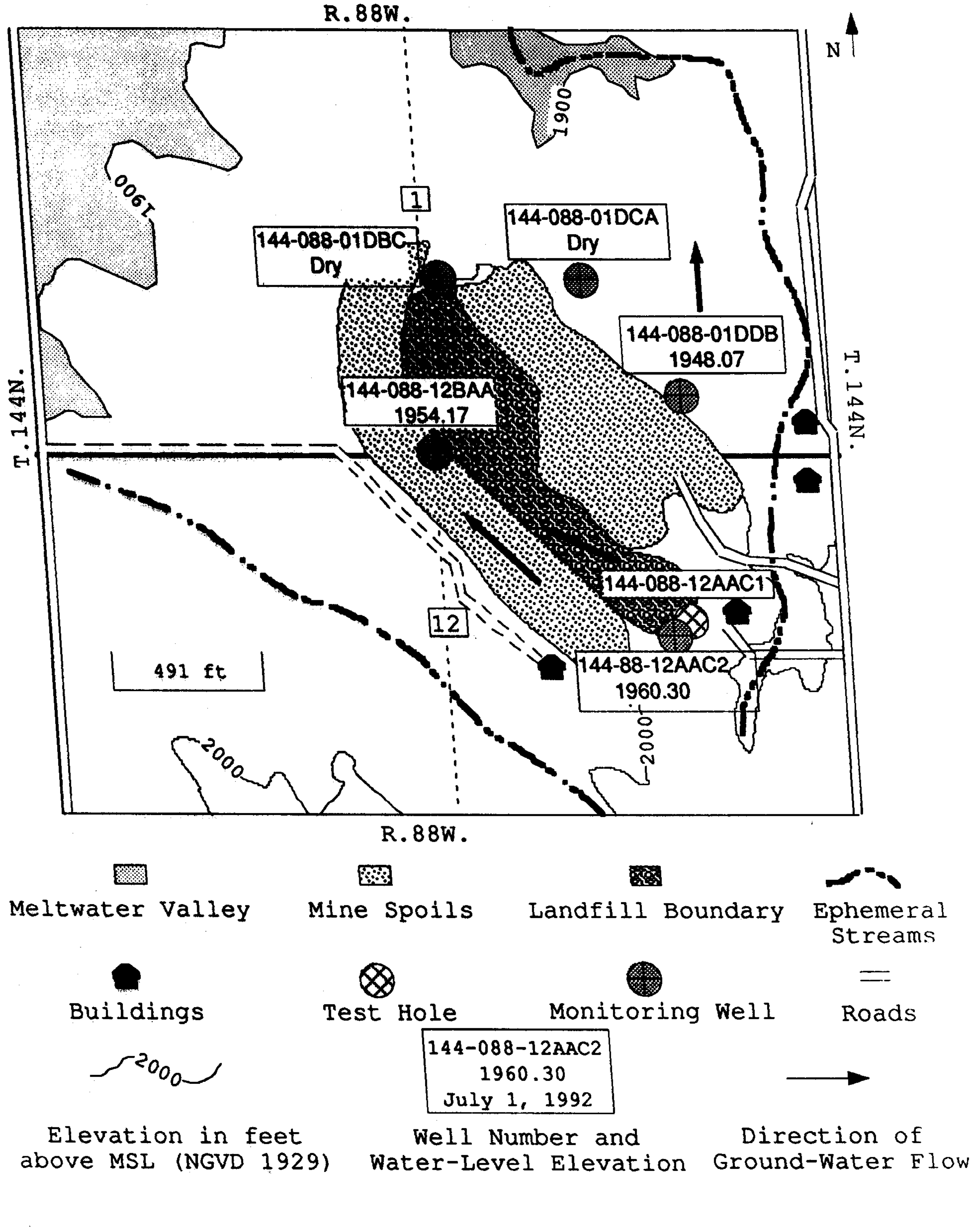

Figure 5. Location of monitoring wells and the direction of ground-water flow at the Beulah landfill.

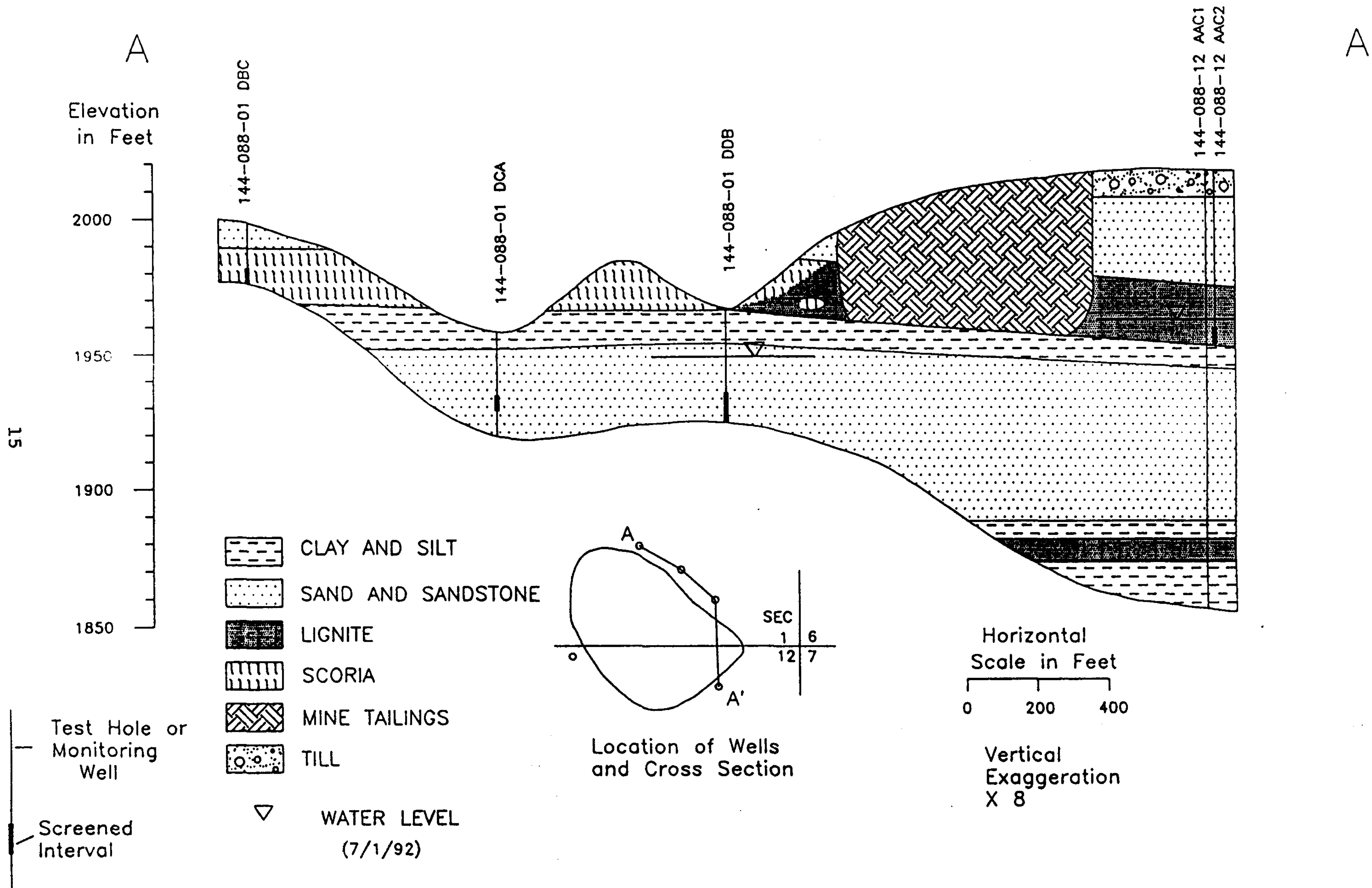

Figure 6. Geohydologic Section A–A' in the Beulah landfill

The mining operation created a large trench, approximately 40 to 60 feet deep, which has been used as a refuse cell. East of the refuse cell the lignite and overburden have been removed and replaced with mine tailings. The sediments west of the cell consist of undisturbed bedrock (lignite, sand, and clay) with a few feet of mine tailings at the surface. The north wall of the cell is composed of clinker and sand. The sediments beneath the refuse cell consist of a thin layer of clay underlain by a thick layer of sand.

HYDROLOGY

Surface-Water Hydrology

Ephemeral streams occur along the northeastern and southwestern boundaries of the landfill. These streams flow north and drain into the Antelope Creek aquifer.

Most surface runoff should not enter the landfill because the landfill is located on a ridge. The surface water, on site, may accumulate in small depressions. This accumulation increases infiltration into the refuse.

Regional Ground-Water Hydrology

The glacialfluvial Antelope Creek aquifer occurs near the Beulah landfill. This aquifer occupies a meltwater channel approximately 1/4 mile north of the Beulah landfill and consists of sand and gravel deposits. The direction of ground-water flow in the Antelope Creek aquifer is to the south from Lake Sakakawea into the Knife River (Croft, 1973). Recharge to the Antelope Creek aquifer is from Lake Sakakawea and bedrock aquifers and discharge is upward into the Knife River. The aquifer is less than a mile wide with a maximum thickness of about 250 feet. Wells within this aquifer typically yield 100 to 500 gallons per minute (Croft, 1973).

The Antelope Creek aquifer is generally characterized by a sodium-bicarbonate type water. This water is very hard (264 to 576 mg/L) with an iron concentration ranging from 2.0 to 8.6 mg/L.

There are also regional bedrock aquifers located in the Sentinel Butte and Bullion Creek Formations. There are numerous domestic wells, east of the landfill, screened within these aquifers.

Local Ground-Water Hydrology

Five monitoring wells were installed around the landfill boundary (Fig. 5). The well screens were placed near the top of the uppermost lignite aquifer and in the sand below the lignite aquifer. Four water-level measurements were taken over a seven-week period (Appendix D). Wells 144-088-01DBC and 144-088-01DCA were dry throughout this study. Because of the two dry wells down gradient, the precise direction of ground-water flow was not determined.

Local ground-water hydrology is difficult to evaluate due to the complexities of the mining operation and the distribution of mine tailings and refuse in the landfill. The uppermost aquifer is an 18-foot thick lignite layer that occurs along the south and the west sides of the landfill. The direction of ground-water flow in this aquifer probably is north-northwest and discharges through seeps along the flanks of the ridge. It appears that the west boundary of the refuse cell intersects the uppermost lignite layer. This would enhance leachate movement into the aquifer.

The lower aquifer occurs in a bedrock sand about 60 feet thick. A saturated thickness of about 25 feet was measured in well 144-088-01DDB. In this area the sand aquifer is unconfined. A 6 to 12-foot thick layer of clay separates the lignite and sand aquifers. Due to uncertainty regarding the continuity of this clay layer, it is not known if the uppermost lignite and the lower sand aquifers are hydraulically connected.

Water Quality

Chemical analyses of water samples are shown in Appendix E. Well 144-088-12AAC2 was used as an up-gradient well in the lignite aquifer. Concentrations of iron (0.87 mg/L; Fig.7), sulfate (2,800 mg/L; Fig.8), and chloride (130 mg/L;

Fig. 9) are higher in well 144-088-12BAA as compared to other monitoring wells. Iron and sulfate concentrations are above the MCL's (Appendix A). The chloride concentration is below the MCL, but is four times higher than the up-gradient analysis. Chloride, a conservative ion, may be a primary indicator for leachate migration. The increased ion concentrations may indicate migration of leachate from the refuse into the uppermost lignite aquifer. High total dissolved solids (TDS) concentrations (5,010 mg/L) were detected in well 144-088-12BAA. This concentration is higher than the up-gradient concentration (3,520 mg/L) but is not unusual in lignite aquifers. Leachate migration into the sand aquifer was not indicated by the water quality analysis at well 144-088-01DDB.

The trace-element analysis shows a concentration of strontium (15,350 µg/L) in well 144-088-12BAA that is four times higher than the concentration up-gradient of the landfill (Fig. 10). Skoustad and Horr (1963, in Hem, 1989) found median concentrations of strontium for large U.S. public supplies to be 110 mg/L. Increased strontium can result from leaching of incineration ash, municipal waste ash, and burning pile ash. These ashes are usually found in municipal waste landfills.

The results of the VOC analysis, from well 144-088-01DDB, are shown in Appendix F. This analysis did not detect any VOC compounds.

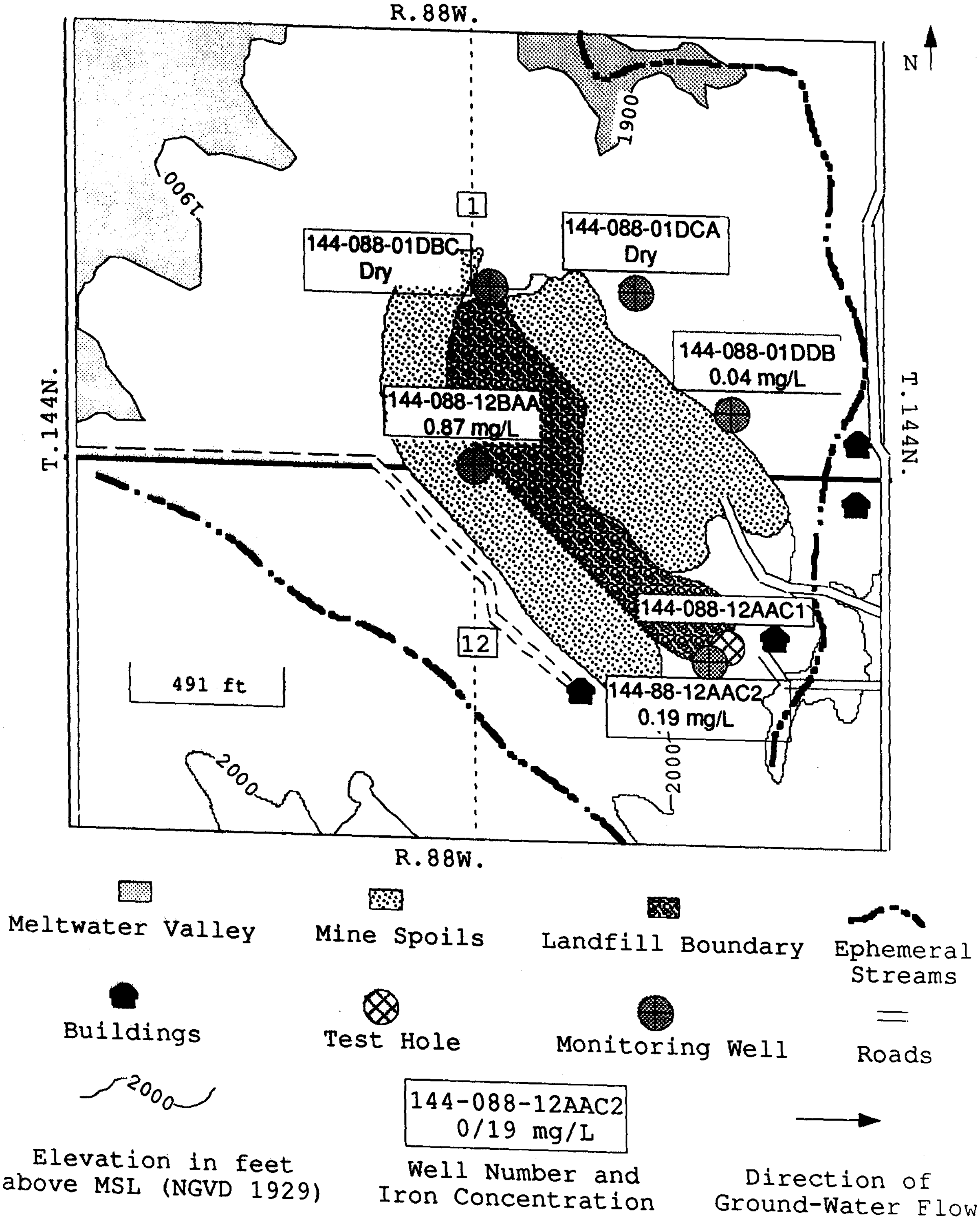

Figure 7. Iron concentrations (mg/L) at the Beulah landfill.

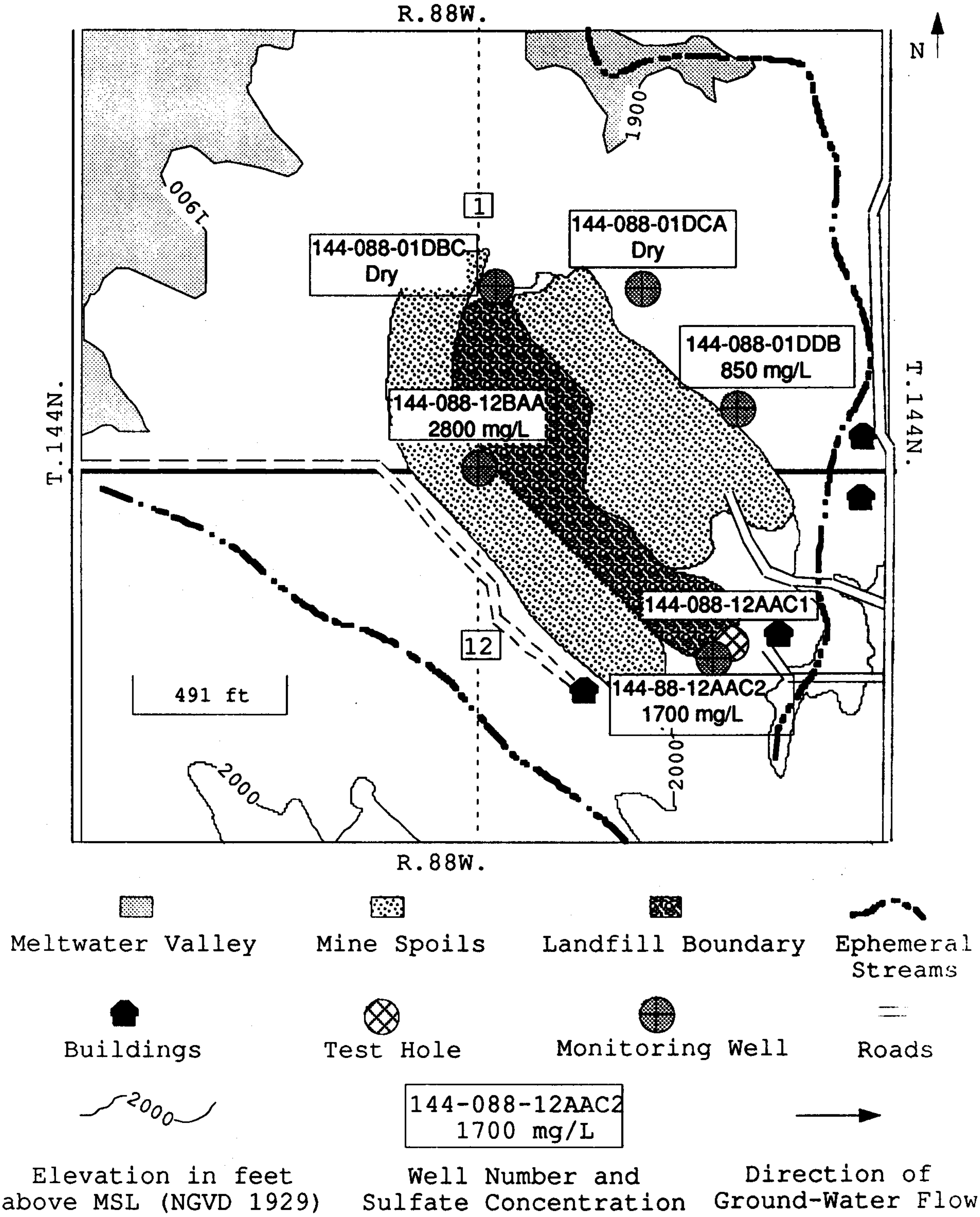

Figure 8. Sulfate concentrations (mg/L) at the Beulah landfill.

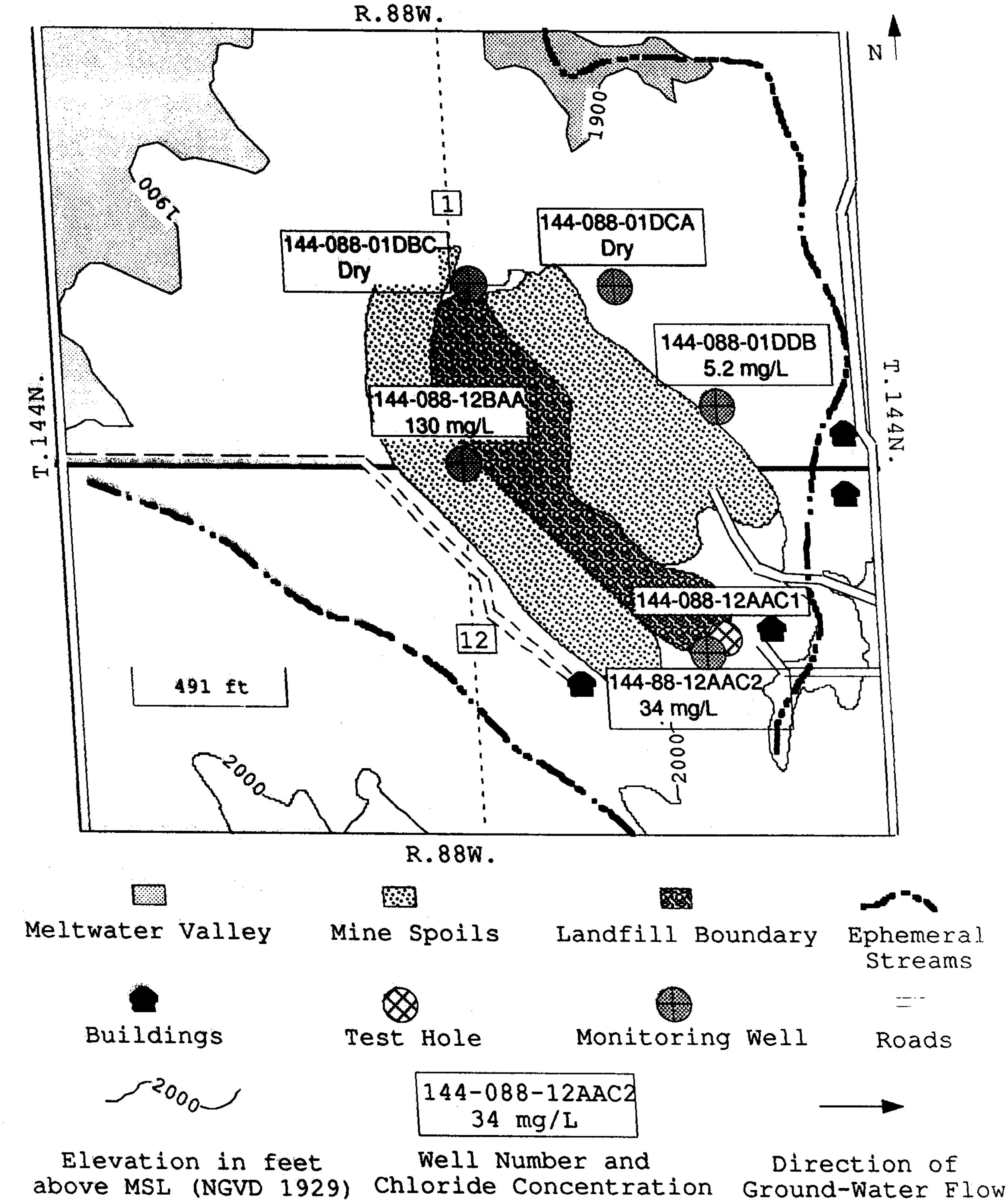

Figure 9. Chloride concentrations (mg/L) at the Beulah landfill.

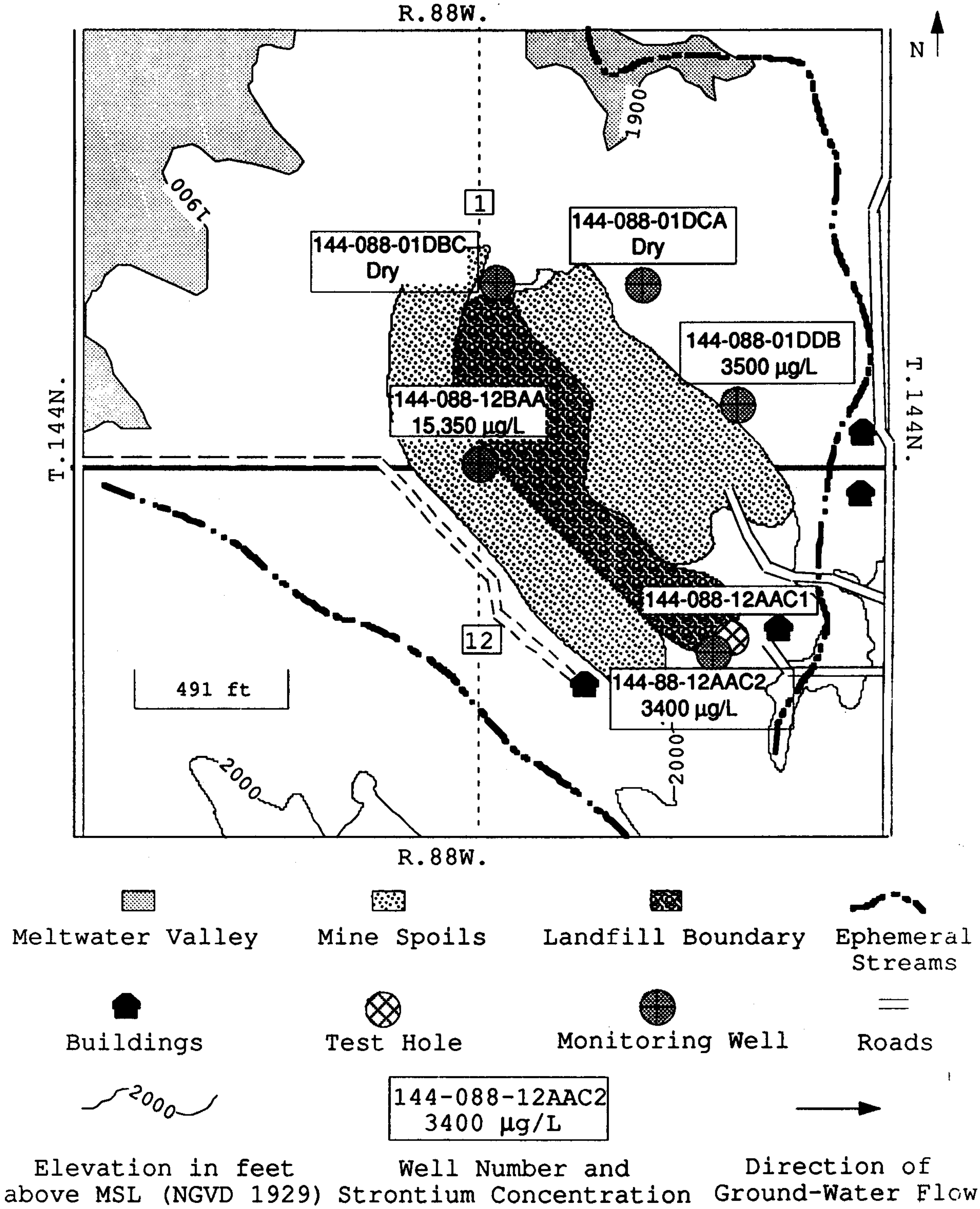

Figure 10. Strontium concentrations (µg/L) at the Beulah landfill.

CONCLUSIONS

The Beulah landfill is located on a ridge in an abandoned lignite strip mine overlooking a meltwater channel. The main lithologies at the landfill are sand, clay, lignite, and clinker. The refuse cell is bounded by lignite, clay, and sand on the west side; by clinker and sand on the north side; and by mine tailings on the east side. The base of the lignite is at the same elevation as the base of the refuse cell. A thin (6 to 12-foot) layer of clay occurs directly below the base of the cell. A 60-foot-thick layer of sand underlies this clay.

Ephemeral streams located east and west of the landfill in the drainage ravines discharge north into the meltwater channel. Runoff onto the Beulah landfill should be minimal because the landfill is located in a local topographic upland.

The local ground-water hydrology was difficult to evaluate due to the complexities of the mining operation and its location on a ridge. The uppermost lignite layer is partially saturated at wells 144-088-12AAC2 and 144-088-12BAA and, as a result, in these areas the lignite aquifer is unconfined. The direction of ground-water flow in this aquifer is probably north-northwest across the ridge. This aquifer appears to discharge through seeps along the flanks of the ridge. A water sample, collected from well 144-088-12BAA indicated high concentrations of strontium (15,350 μg/L) and increased concentrations of chloride (130 mg/L), sulfate (2,800 mg/L), and iron (0.87 mg/L). Increased concentrations of these analytes suggest leachate migration from the landfill into this aquifer.

Well 144-088-01DDB was screened in the bedrock sand east of the landfill. In this area, the sand aquifer is unconfined. A 6 to 12-foot layer of clay separates the uppermost lignite aquifer and this sand. Due to uncertainty with regard to the continuity of the clay layer, it is not known if these two aquifers are hydraulically connected. The direction of ground-water flow in the sand aquifer is probably north toward the Antelope Creek aquifer. The water-quality analysis provides no evidence of leachate migration from the landfill into the aquifer.

This landfill presents site conditions that may be conducive to leachate migration into the ground water. These conditions are: 1)the abundance of permeable sediments; 2) the proximity of the refuse to the water table; and 3) the presence of a shallow bedrock-sand aquifer. Leachate migration from the landfill could affect the Antelope Creek aquifer through the bedrock aquifers.

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APPENDIX A

WATER QUALITY STANDARDS AND MAXIMUM CONTAMINANT LEVELS

Water Quality Standards and Maximum Contaminant Levels

Parameter	MCL (mg/L)
Field Parameters	
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. Scew 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

144-088-01DBC

NDSWC

Date Completed:	5/6/92	Well Type:	P2
Depth Drilled (ft):	20	Source of Data:	
Screened Interval (ft):	15-20	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1996.01
Owner: Beulah			

Lithologic Log

Unit	Description	Depth (ft)
SAND	FINE-GRAINED, CLAYEY, PALE YELLOWISH BROWN, 10YR 6/2	0-9
SANDSTONE	FINE-GRAINED, MODERATE REDDISH ORANGE, 10R 6/6, VERY HARD, ALTERED BY COAL BURN (CLINKER), LOST CIRCULATION AT 20'	9-20

144-088-01DCA

NDSWC

Date Completed:	5/6/92	**Well Type:**	P2
Depth Drilled (ft):	35	**Source of Data:**	
Screened Interval (ft):	25-30	**Principal Aquifer :**	Undefined
Casing size (in) & Type:		**L.S. Elevation (ft)**	1955.92
Owner: Beulah			

Lithologic Log

Unit	Description	Depth (ft)
CLAY	SILTY, DUSKY BROWN, 5YR 2/2	0-3
SAND	FINE-GRAINED, SILTY, MODERATE YELLOWISH BROWN, 10YR 4/2	3-12
CLAY	SANDY, MEDIUM LIGHT GRAY, N6	12-14
SAND	FINE-GRAINED, SILTY, MODERATE YELLOWISH BROWN, 10YR 4/2	14-18
SAND	FINE-GRAINED, SILTY, OLIVE GRAY, 5Y 4/1	18-33
SANDSTONE	WELL CEMENTED, FINE-GRAINED, MEDIUM GRAY, N5	33-35

144-088-01DDB
NDSWC

Date Completed:	5/6/92	Well Type:	P2
Depth Drilled (ft):	40	Source of Data:	
Screened Interval (ft):	30-40	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1967.30
Owner: Beulah			

Lithologic Log

Unit	Description	Depth (ft)
CLAY	SILTY, DUSKY BROWN, 5YR 2/2	0-7
CLAY	SILTY, MODERATE YELLOWISH BROWN, 10YR 5/4	7-8
CLAY	SANDY, MODERATE YELLOWISH BROWN, 10YR 5/4	8-11
CLAY	OLIVE GRAY, 5Y 4/1	11-12
SAND	VERY FINE-GRAINED, SILTY, GRAYISH GREEN, 10GY 5/2	12-17
SAND	FINE-GRAINED, GRAYISH GREEN, 10GY 5/2	17-20
SAND	FINE-GRAINED, SILTY, OLIVE GRAY, 5Y 4/1	20-40

144-088-12AAC1

NDSWC

Date Completed:	5/5/92	Purpose:	Test Hole
Depth Drilled (ft):	160	Source of Data:	
L.S. Elevation (ft)	2017.73	Owner: Beulah	

Lithologic Log

Unit	Description	Depth (ft)
SILT	SANDY, TRACE GRAVEL (TILL), PALE YELLOWISH BROWN, 10YR 6/2	0-9
SAND	POORLY CEMENTED, FINE-GRAINED, SILTY MODERATE YELLOWISH BROWN, 10YR 5/4	9-43
CLAY	DUSKY BROWN, 5YR 2/2	43-44
LIGNITE		44-63
CLAYSTONE	MEDIUM GRAY, N5	63-69
SAND	POORLY CEMENTED, FINE-GRAINED, SILTY, GREENISH GRAY, 5GY 6/1	69-80
SAND	VERY POORLY CEMENTED, FINE-GRAINED, SILTY, GREENISH GRAY, 5GY 6/1	80-106
CLAY	SANDY, VERY LIGHT GRAY, N8	106-107
SANDSTONE	MODERATELY CEMENTED, FINE-GRAINED, SILTY, LIGHT GRAY, N7	107-108
SAND	POORLY CEMENTED, FINE-GRAINED, SILTY, GRAYISH GREEN, 10GY 5/2	108-121
SANDSTONE	WELL CEMENTED, FINE-GRAINEDD, GRAYISH GREEN, 10GY 5/2	121-122
SAND	POORLY CEMENTED, FINE-GRAINED, GRAYISH GREEN, 10GY 5/2	122-129
SANDSTONE	WELL CEMENTED, FINE-GRAINED, GRAYISH GREEN, 10GY 5/2	129-131
CLAY	GRAYISH BROWN, 5YR 3/2	131-132
LIGNITE		132-133
CLAY	MEDIUM GRAY, N5	133-135
CLAY	GREENISH GRAY, 5GY 6/1	135-139
LIGNITE		139-145
CLAY	PALE BROWN 5YR 5/2	145-147
CLAY	GRAYISH GREEN, 10GY 5/2	147-153
CLAY	SILTY, GRAYISH GREEN, 10GY 5/2	153-160

144-088-12AAC2
NDSWC

Date Completed:	5/6/92	**Well Type:**	P2
Depth Drilled (ft):	66	**Source of Data:**	
Screened Interval (ft):	58-63	**Principal Aquifer :**	Undefined
Casing size (in) & Type:		**L.S. Elevation (ft)**	2017.73
Owner: Beulah			

Lithologic Log

Unit	Description	Depth (ft)
SAND	FINE-GRAINED, SILTY, TRACE GRAVEL (TILL)	0-9
SAND	POORLY CEMENTED, FINE-GRAINED, SILTY, MODERATE YELLOWISH BROWN	9-17
SANDSTONE	CEMENTED, WITH WHITE CLAY	17-19
SAND	POORLY CEMENTED, FINE-GRAINED, SILTY, OLIVE GRAY	19-30
SAND	FINE-GRAINED, SILTY, DARK YELLOWISH ORANGE 10YR 6/6	30-34
SAND	POORLY CEMENTED, FINE-GRAINED, SILTY, OLIVE GRAY	34-44
CLAY	GRAYISH BROWN, 5YR 3/2	44-45
LIGNITE		45-63
CLAYSTONE	GRAYISH BROWN, 5YR 3/2	63-65
CLAYSTONE	MEDIUM GRAY, N5	65-66

144-088-12BAA

NDSWC

Date Completed:	5/6/92	**Well Type:**	P2
Depth Drilled (ft):	80	**Source of Data:**	
Screened Interval (ft):	73-78	**Principal Aquifer :**	Undefined
Casing size (in) & Type:		**L.S. Elevation (ft)**	2029.65
Owner: Beulah			

Lithologic Log

Unit	Description	Depth (ft)
CLAY	TOPSOIL	0-4
SANDSTONE	SILTY SAND	4-7
SANDSTONE	YELLOWISH SAND, LITTLE SILT	7-9
CLAYSTONE	HARD YELLOW CLAY	9-16
CLAY	BROWNISH	16-19
LIGNITE		19-20
CLAYSTONE	BROWN	20-21
CLAY	WHITISH GRAY	21-23
CLAY	SILTY, YELLOWISH	23-29
CLAY	DARK BROWN	29-31
CLAY	LIGHT BROWN	31-32
CLAY	YELLOWISH, INTERBEDDED WITH SAND	34-45
CLAYSTONE	DARK BROWN	45-51
SANDSTONE	GREENISH BEDROCK SANDS	51-57
CLAYSTONE	GRAYISH, THIN CEMENTED SANDSTONE AT 58'	57-60
LIGNITE	WITH INTERBEDDED GRAY CLAY	60-62
LIGNITE		62-69
LIGNITE	SOFT	69-70
LIGNITE	HARD	70-78
CLAYSTONE	BROWN, GRAYISH CLAY AT 80'	78-80

APPENDIX D

WATER-LEVEL TABLES

Beulah Landfill Water Level Data
5/29/92 to 7/16/92

144-088-01DDB LS Elev (msl,ft)=1967.3

Undefined Aquifer SI (ft.)=30-40

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/29/92	19.37	1947.93	07/01/92	19.23	1948.07
06/19/92	19.48	1947.82	07/16/92	19.20	1948.10

144-088-12AAC2 LS Elev (msl,ft)=2017.73

Undefined Aquifer SI (ft.)=58-63

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/29/92	57.36	1960.37	07/01/92	57.43	1960.30
06/19/92	57.43	1960.30	07/15/92	57.45	1960.28

144-088-12BAA LS Elev (msl,ft)=2029.65

Undefined Aquifer SI (ft.)=73-78

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/29/92	74.67	1954.98	07/16/92	75.46	1954.19
06/19/92	75.41	1954.24	07/27/92	75.49	1954.16
07/01/92	75.48	1954.17			

APPENDIX E

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Beulah Water Quality

Major Ion Analyses

Location	Screened Interval (ft)	Date Sampled	SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness as $CaCO_3$	NCH	% Na	SAR	Spec Cond (µmho)	Temp (°C)	pH
			(milligrams per liter)																					
144-088-01DDB	30-40	05/29/92	9.4	0.04	0.44	160	110	120	8.8	348		850	5.2	0.2	1.5	0.14	1440	850	570	23	1.8	1761	12	7.34
144-088-12AAC2	58-63	07/15/92	17	0.19	1.6	120	100	940	14	1190	0	1700	34	0.4	8.3	0.64	3520	710	0	74	15		18	8.29
144-088-12BAA	73-78	07/16/92	31	0.87	1.4	370	300	830	21	1050	0	2800	130	0.2	7.2	0.66	5010	2200	1300	45	7.7		13	6.99

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
144-088-01DDB	5/29/92	1	0	0	0	2	20	3500
144-088-12AAC2	7/12/92	4	0	0	0	0	2	3400
144-088-12BAA	7/16/92	7	0	0	0	3	6	15350

APPENDIX F

VOLATILE ORGANIC COMPOUNDS FOR WELL 144-088-01DDB

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	<50
Pentachloroethane	<5
Trichlorotrofluoroethane	<5
Carbondisufide	<5
Ether	<5

* Constituent Detection