Site Suitability Review of the Hazen Landfill

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

ND Landfill Site Investigation No. 5

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OF THE
HAZEN LANDFILL

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

Location

The Hazen municipal solid waste landfill is located four miles north and one mile west of the city of Hazen in Township 145 North, Range 86 West, SE 1/4 Section 20 (Fig. 1). The landfill occupies about 40 acres of an abandoned lignite strip mine.

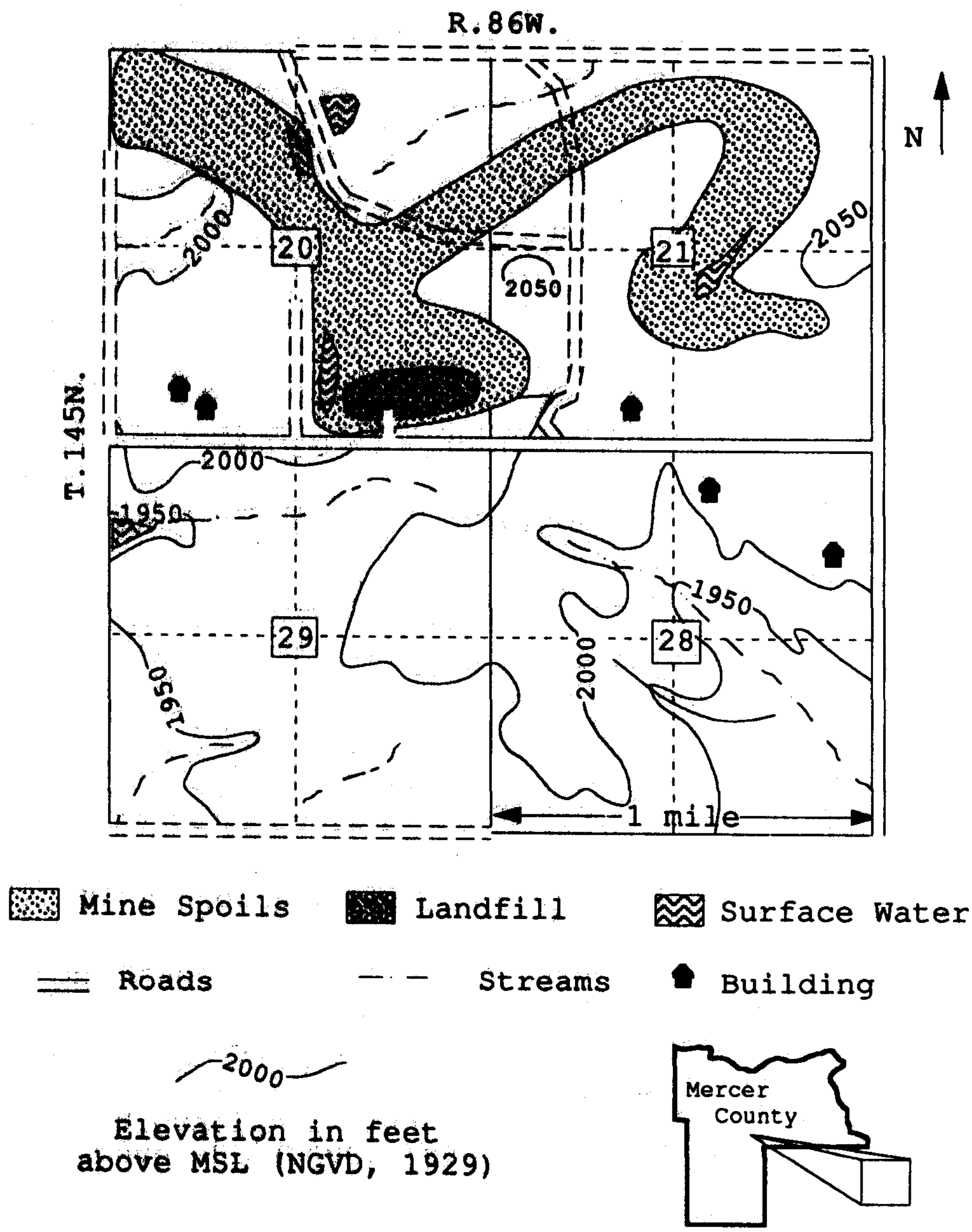

Figure 1. Location of the Hazen landfill in the SE 1/4 of section 20.

Previous Site Investigations

Soil Exploration Company drilled a stratigraphic test hole at the Hazen landfill in 1980. Their lithologic log recorded lignite and clay for the first 11 feet and clay from 11 to 50 feet below land surface. The water level was within a lignite bed nine feet below land surface. The exact location of the test hole was not reported.

Coteau Properties recently completed a geologic and hydrologic study of the area north and east of the site for a mine-permit application. The nearest test hole from this study area is about 1/4 mile from the landfill.

Methods of Investigation

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

Monitoring Well Construction and Development

Six test holes were drilled at the Hazen landfill, and monitoring wells were installed in five of the test holes. The number and placement of the wells installed was based on the geologic and topographic characteristics of the site. Mine tailings adjacent to the refuse cell prevented drilling on the north and west sides of the landfill. Wells were placed on the southwest, south, southeast, east and near the center of the landfill. The wells were screened to monitor the top of the uppermost aquifer.

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

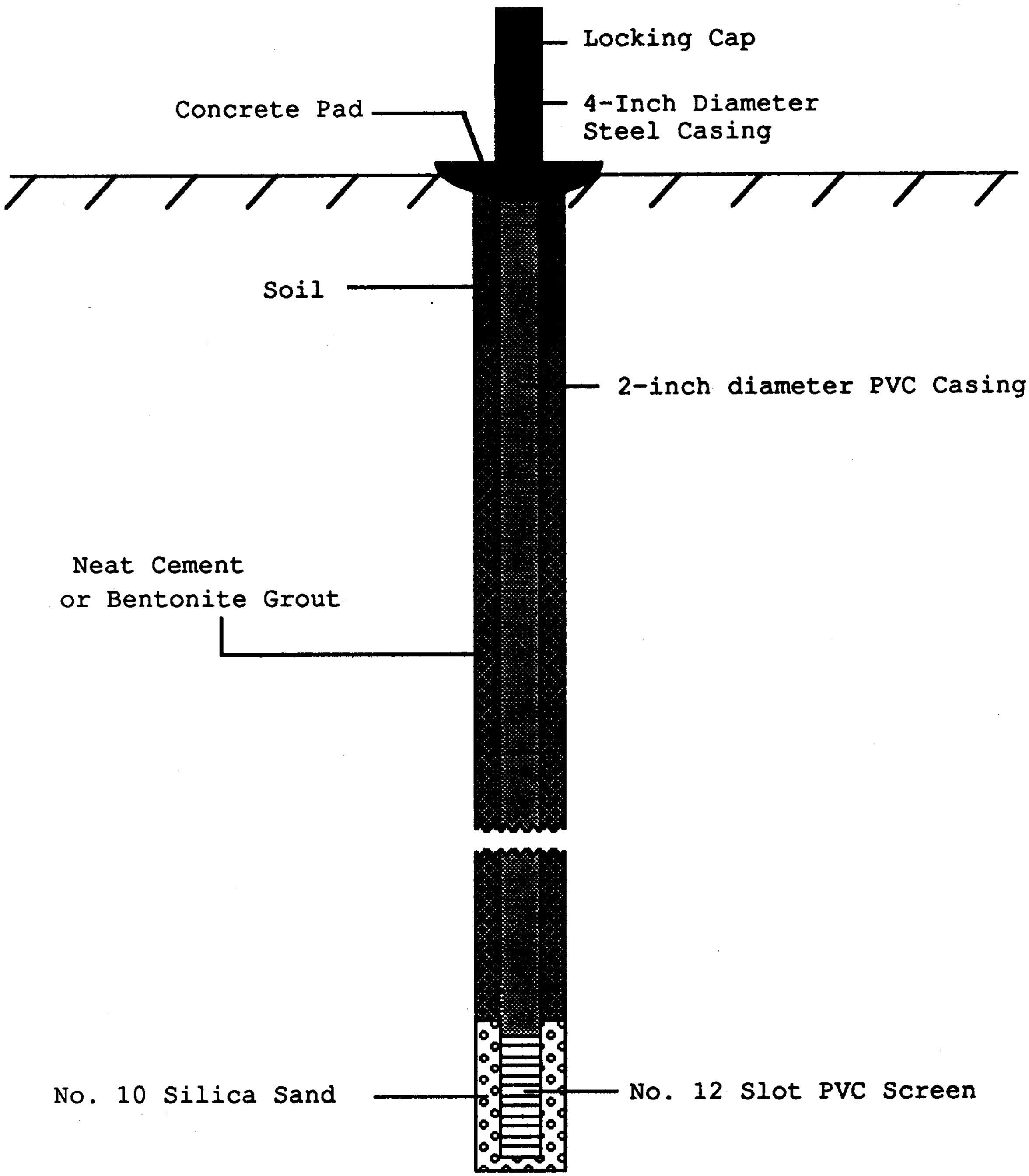

Figure 2. Construction design used for monitoring wells installed at the Hazen landfill.

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 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

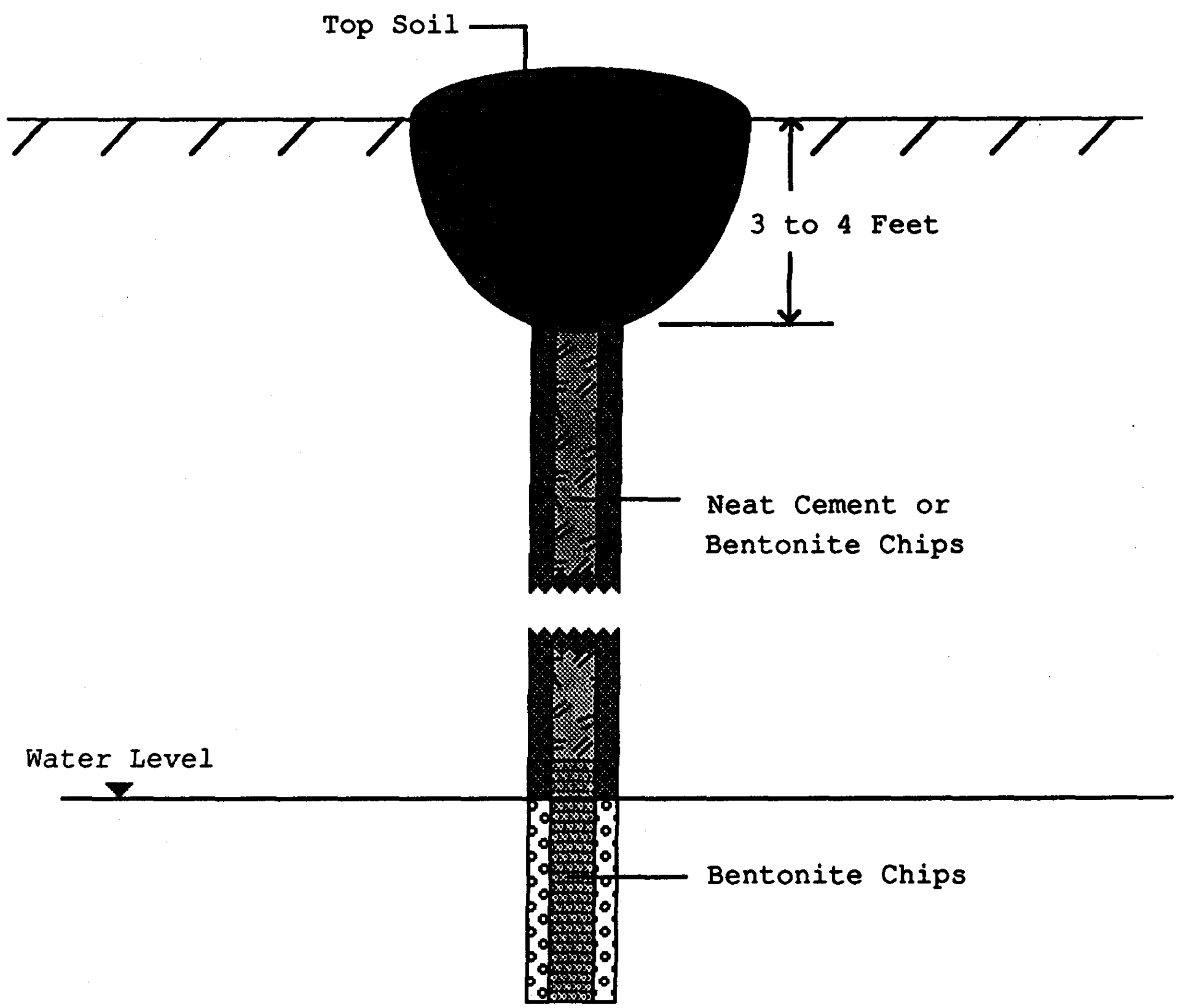

Figure 3. Monitoring well abandonment procedure.

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 145-086-20DDA would be located in the NE1/4, SE1/4, SE1/4 Section 20, Township 145 North, Range 86 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 145-086-20DDA1 and 145-086-20DDA2.

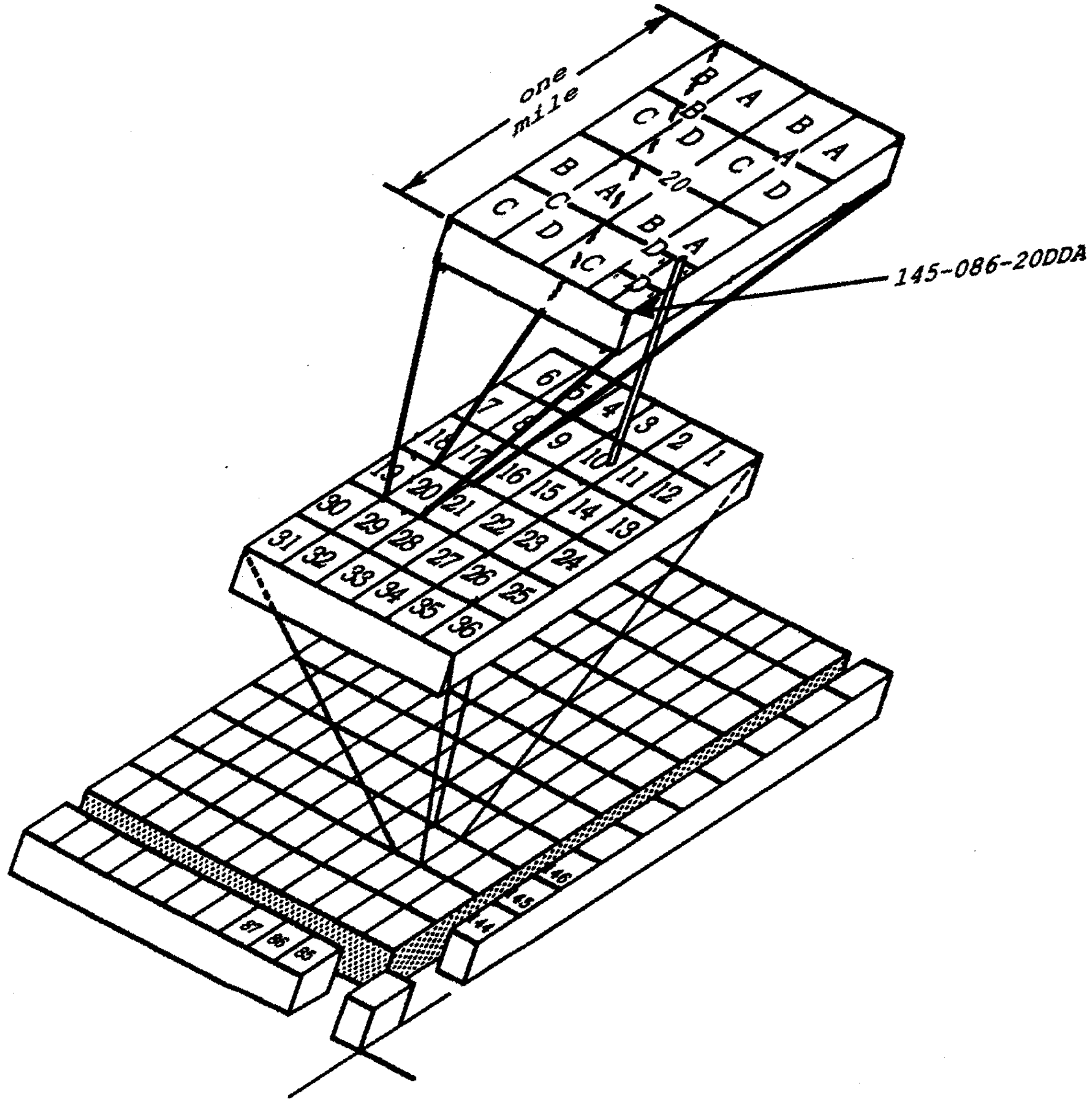

Figure 4. Location-numbering system for the Hazen landfill.

GEOLOGY

Regional Geology

The geologic materials in the vicinity of the Hazen landfill include glacial sediments and bedrock. A layer of till, ranging from 5 to 45-feet thick, covers the region except in the deeper ravines where bedrock is commonly exposed. The till is predominantly clay or sandy clay with traces of gravel (Coteau Properties, 1991).

The area is considered to be glacially modified bedrock topography (Carlson, 1973). The layer of till generally follows the pre-existing topography, modifying it only slightly. The major drainages and their tributaries are pre-glacial bedrock valleys.

The bedrock in the Hazen area is assigned to the Sentinel Butte and Bullion Creek Formations. These formations are Paleocene in age and were deposited in deltaic environments (Jacob, 1976). They are composed of sand, sandstone, silt, clay, lignite, and limestone. The formations are similar in appearance, their main distinguishing characteristic being a difference in color in weathered exposures: the Sentinel Butte Formation is usually dark gray or brown; the Bullion Creek Formation is light gray. It has generally "brighter" hues than does the Sentinel Butte Formation.

Local Geology

The Hazen landfill is located in an abandoned lignite strip mine in an area of moderate relief (Fig. 5). The lignite and overburden have been removed from the mined area and the tailings have been piled in high rows around the site. Refuse has been placed in the large open pit that remained following the mining operation. The refuse pit appears to be underlain by clay and completely surrounded by mine tailings.

The main lignite bed at the site, the Beulah-Zap bed, is part of the Sentinel Butte Formation (Coteau Properties, 1991). Four test holes were drilled outside the mined area and two were drilled within the mine pit (lithologic logs in Appendix C). In the test holes where the Beulah-Zap lignite bed is intact, it is 10 to 15 feet thick. The elevation of the lignite is about 10 feet lower on the west side of the site than on the east side (Fig. 6).

A layer of clay, 8 to 10 feet thick, underlies the Beulah-Zap lignite bed and a one-foot-thick bed of lignite underlies this clay. Below this interval several thin beds of lignite and sandstone are interbedded with thick layers of clay. The contact between the Sentinel Butte Formation and the underlying Bullion Creek Formation has not been established in the subsurface in this area. The county geologic map places the contact at an elevation of about 1860 feet, which would be between 100 and 200 feet below the land

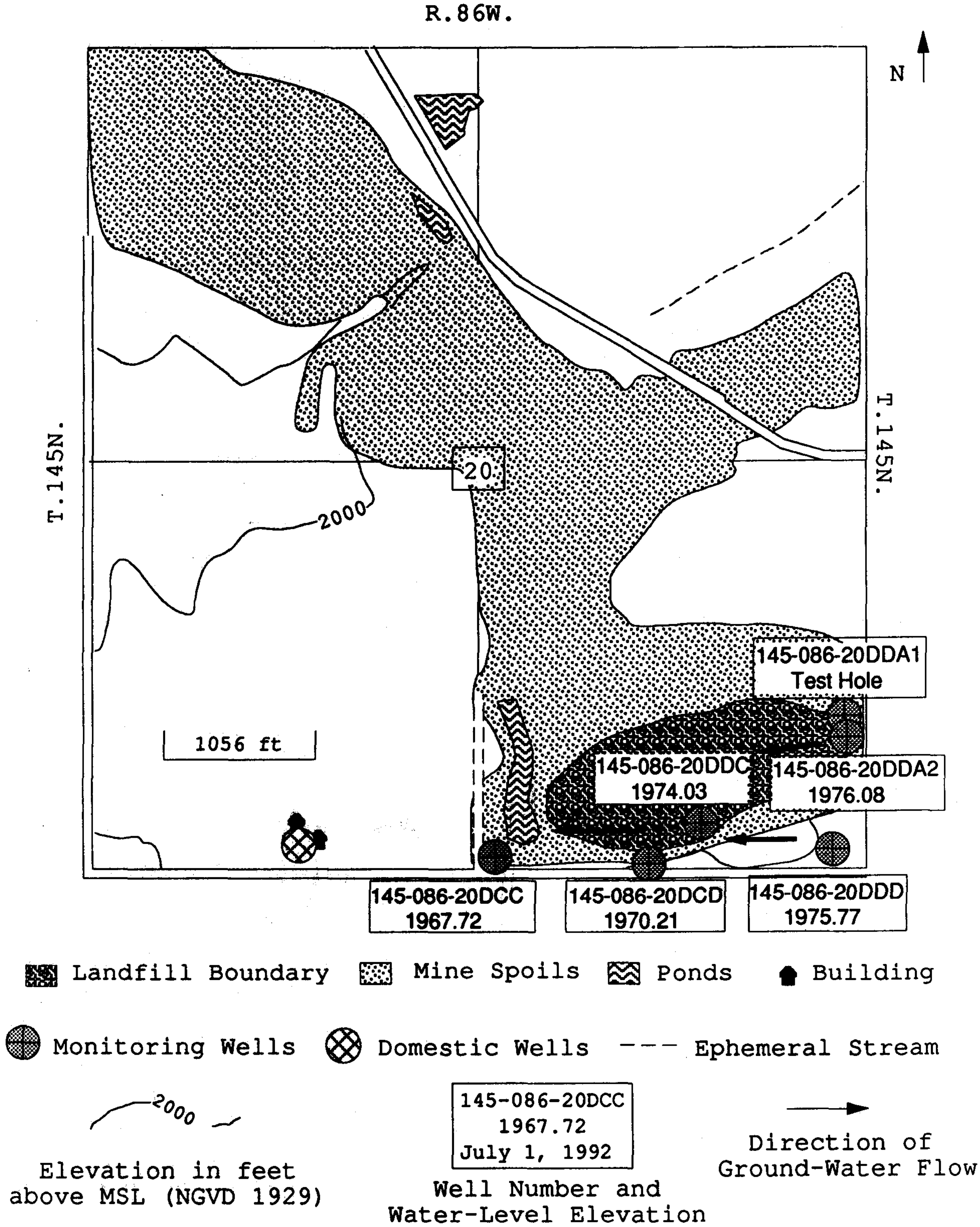

Figure 4. Location of monitoring wells and the direction of ground-water flow at the Devils Lake landfill.

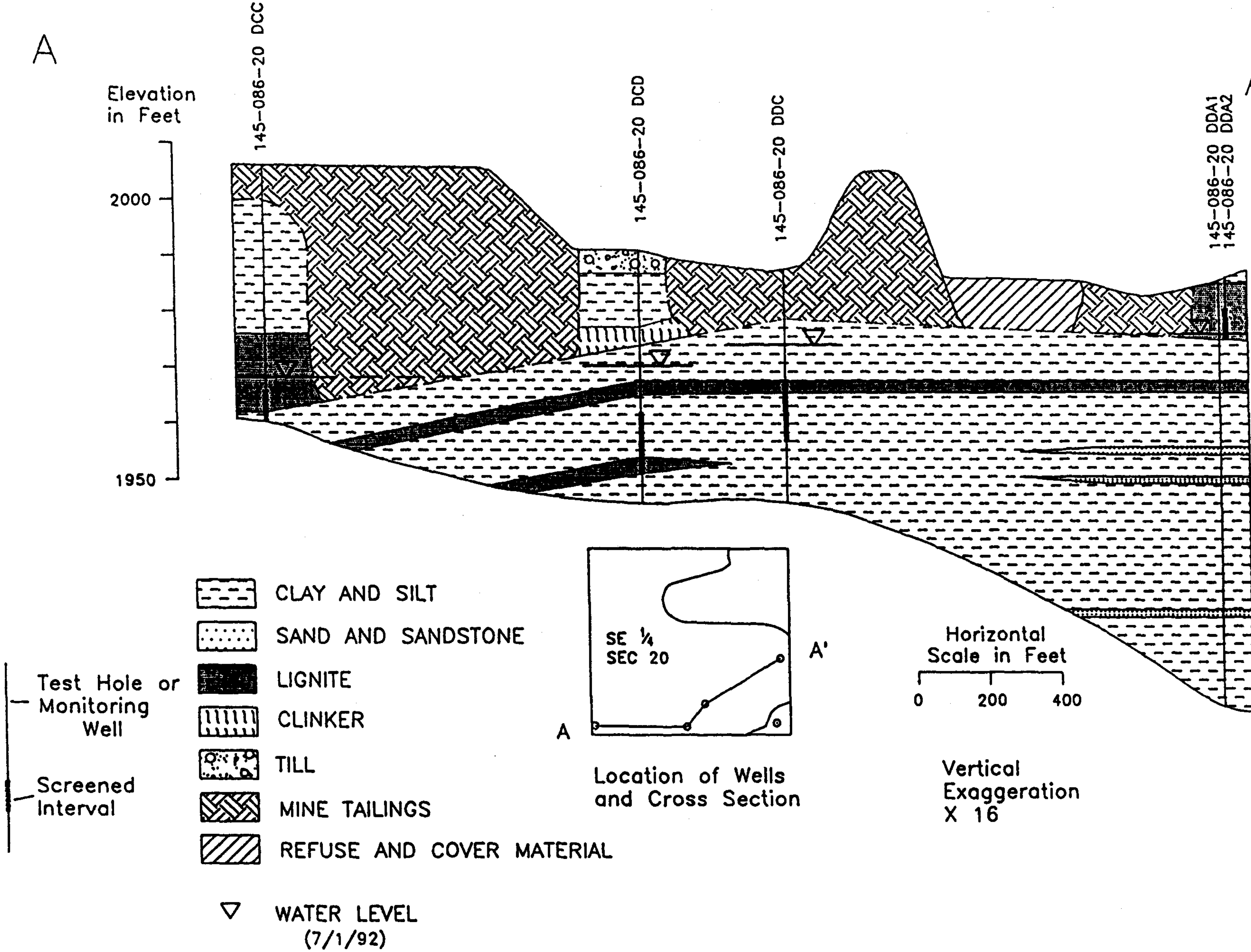

Figure 6. Geohydrologic section A–A' in the Hazen landfill

surface at the mine site (Carlson, 1973).

In the unmined areas the sediments above the lignite consist of bedrock clay and glacial till. The original thickness of these units is not known because none of the test holes were placed in a completely undisturbed area. For example, one test hole was placed in a road ditch and one on an abandoned railroad grade. Lithologic logs from test holes drilled by Coteau Properties (1991) north and east of the landfill indicate that 30 to 60 feet of bedrock clay and up to 25 feet of till overlie the Beulah-Zap lignite.

Throughout the mine site the surficial materials consist of tailings from the mining operation. The tailing piles have a maximum thickness of about 50 feet. They are believed to be composed mainly of clay with relatively small percentages of silt, sand, and gravel. This conclusion is based on visual observations at the site and on the inference that the original overburden was composed primarily of bedrock clay and till.

HYDROLOGY

Surface-Water Hydrology

A pond is located at the west end of the mine boundary (Fig. 5). This pond has permanent cattail growth which indicates a constant supply of water into the pond. The surface of the pond is at the same elevation as the water table.

An ephemeral stream located about 1/4 mile south of the landfill flows to the southwest. A second ephemeral stream located about 1/2 mile southeast of the landfill flows southeast and a third ephemeral stream located north of the mine flows northward. The flow of these streams indicate that the landfill is located on a surface-water divide.

Surface-water runoff is not significant at the landfill. Some ponding, from precipitation, occurs in the landfill may increase infiltration into the refuse.

Regional Ground-Water Hydrology

There are no glacial aquifers within a two-mile radius of the Hazen landfill. Bedrock aquifers are contained within the Sentinel Butte and Bullion Creek Formations. The domestic wells within a one-mile radius of the landfill are screened in the Sentinel Butte Formation. One well located 1/4 mile west of the landfill is screened in the same Beulah-Zap lignite bed aquifer that was monitored at the landfill. A water-quality sample taken from this well did not indicate any contamination of the lignite aquifer.

Local Ground-Water Hydrology

Five monitoring wells were installed in and around the landfill (Fig. 5). The well screens were placed near the top of the uppermost lignite aquifer. Three wells were screened within the Beulah-Zap lignite bed and two wells within thin lignite/clay and silt beds below the upper Beulah-Zap lignite bed. Four water-level measurements were taken over a seven-week period (Appendix D). These measurements were used to determine the direction of ground-water flow.

Local ground-water hydrology is difficult to evaluate within a disturbed mine area because of the complexities of the mining operation and the distribution of mine tailings. Adding refuse to this situation complicates the ground-water flow because of the increased porosity of the refuse. The uppermost lignite aquifer (Beulah-Zap lignite) is unconfined and varies in thickness from 10 to 15 feet. The direction of ground-water flow in the uppermost aquifer appears to follow the dip of the lignite layer to the west-northwest. Vertical flow through the base of the lignite bed probably is negligible because a layer of clay underlies the lignite. The lower clay-lignite aquifer appears to be confined under the Beulah-Zap lignite aquifer. It is not known if the two aquifers are hydraulically connected. The thickness of the clay layer, separating the two aquifers, was not determined at all of the well locations.

Water Quality

Chemical analyses of water samples are shown in Appendix E. Well 145-086-20DDA2 was used as an up-gradient well.

This well was located inside the mine spoils on the east end of the landfill boundary. The results from this well show high concentrations of five analytes. They are manganese (0.43mg/L), calcium (230 mg/L), magnesium (200 mg/L), sodium (260 mg/L), and sulfate (1500 mg/L). All five of these analytes are above their MCL's. These high concentrations appear to be due to the oxidation and leaching of the mine spoils. The chloride concentration in all wells was low. This suggests that there does not appear to be any leachate migration from the landfill into the uppermost lignite aquifer at this site.

Trace element analyses indicate high concentrations of strontium in all wells (Appendix E). Skoustad and Horr (1963, in Hem, 1989) found median concentrations of strontium for large U.S. public water supplies to be 110 µg/L. Increased strontium can result from incineration ash, municipal waste ash, or burning pile ash. Increased concentrations of strontium can also be a result of the weathering of overburden.

The results of the VOC analysis, from well 145-086-20DDC, are shown in Appendix F. This analysis did not detect any VOC compounds.

CONCLUSIONS

The Hazen landfill is located in an abandoned lignite strip mine. The refuse has been placed in a large open pit, which remained following the cessation of mining operations. Around the perimeter of the mine the main lignite bed (the Beulah-Zap bed) is 10 to 15 feet thick. The elevation of the lignite is approximately 10 feet lower on the west side of the site than on the east side. The Beulah-Zap lignite is underlain by an 8 to 10-foot-thick layer of clay and a 1-foot-thick layer of lignite. The sediments below the second lignite consist of clay with thin beds of lignite and sandstone.

In the unmined areas the sediments above the lignite consist of bedrock clay and glacial till. Within the mine site the original sediments have been reworked and the refuse cell is surrounded by the spoil material. On-site observations, as well as information from surrounding test wells, indicate that the tailings are composed primarily of clay with smaller percentages of silt, sand, and gravel. The high proportion of clay in the Sentinel Butte Formation in the area is conducive to low ground-water velocities which will retard leachate migration.

The mine site is located in an area of moderate relief. Ephemeral streams occur south, southeast, and north of the site. Because the site is on a surface-water divide, there is minimal runoff from the surrounding area. However, some ponding occurs from precipitation within the mine pit. This could increase infiltration into the refuse.

Local ground-water hydrology is difficult to evaluate because of the complexities of the mining operation and the distribution of mine tailings. The uppermost Beulah-Zap lignite aquifer is unconfined around the perimeter of the mine site. The direction of ground-water flow follows the dip of the lignite bed to the west-northwest. Vertical flow through the base of the lignite bed probably is negligible because a layer of clay underlies the Beulah-Zap lignite bed.

A water sample from the up-gradient well (145-086-20DDA2) contained high concentrations of manganese, calcium, magnesium, sodium, and sulfate. This well is east of the mined area, but within the area where mine tailings were placed. The high concentrations may result from the oxidation and leaching of the tailings. High concentrations of strontium, found in both up-gradient and down-gradient wells, can result from ashes or from the weathering of reworked materials. Concentrations of chloride, which is commonly an indicator of leachate migration, were low in all of the wells. No VOC's were detected in the VOC analysis from well 145-086-20DDC. These water quality results suggest that there has been no leachate migration from the landfill into the upper lignite aquifer at this time.

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Jacob, A.f., 1976, Geology of the upper part of the Fort Union Group (Paleocene), Williston Basin, with reference to uranium: North Dakota Geological Survey, Report of Investigation No. 58, 49 p.

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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. 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

145-086-20DCC
NDSWC

Date Completed:	5/7/92	Well Type:	P2
Depth Drilled (ft):	48	Source of Data:	
Screened Interval (ft):	41-46	Principal Aquifer :	Undefined
Casing size (in) & Type:P2		L.S. Elevation (ft)	2007.98
Owner: Hazen			

Lithologic Log

Unit	Description	Depth (ft)
CLAY	SANDY, TRACE GRAVEL, PALE BROWN, 5YR5/2 (MINE SPOILS)	0-9
CLAY	LIGHT OLIVE GRAY, 5Y6/1 (SENTINEL BUTTE FORMATION)	9-15
CLAY	SILTY, PALE BROWN, 5YR5/2	15-18
CLAY	PALE BROWN, 5YR5/2	18-23
CLAY	GRAYISH BROWN, 5YR3/2	23-26
CLAY	MEDIUM GRAY, N5	26-32
LIGNITE		32-46
CLAY	MEDIUM GRAY, N5	46-48

145-086-20DCD
NDSWC

Date Completed:	5/7/92	**Well Type:**	**P2**
Depth Drilled (ft):	45	**Source of Data:**	
Screened Interval (ft):	30-40	**Principal Aquifer :**	**Undefined**
Casing size (in) & Type:		**L.S. Elevation (ft)**	**1991.38**
Owner: Hazen			

Lithologic Log

Unit	Description	Depth (ft)
CLAY	**TRACE GRAVEL, PALE BROWN, 5YR5/2 (GLACIAL DRIFT)**	**0-4**
CLAY	**MODERATE YELLOWISH BROWN, 10YR7/4 (SNTINEL BUTTE FORMATION)**	**4-14**
SCORIA	**MODERATE REDDISH ORANGE, 10R6/6**	**14-17**
CLAY	**MEDIUM GRAY, N5**	**17-24**
LIGNITE		**24-26**
SILT	**SANDY, CLAYEY, MEDIUM GRAY, N5**	**26-38**
LIGNITE		**38-40**
CLAY	**GRAYISH BROWN, 5YR3/2**	**40-45**

145-086-20DDA1
NDSWC

Date Completed:	5/7/92	Purpose:	Test Hole
Depth Drilled (ft):	160	Source of Data:	
L.S. Elevation (ft)	1987.04	Owner: Hazen	

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
LIGNITE	(SENTINEL BUTTE FORMATION AND BULLION CREEK FORMATION)	2-12
CLAY	MEDIUM LIGHT GRAY, N6	12-20
LIGNITE		20-21
CLAY	MEDIUM LIGHT GRAY	21-24
SILT	SANDY, CLAYEY, MEDIUM LIGHT GRAY, N6	24-29
CLAY	SILTY, MEDIUM LIGHT GRAY, N6	29-30
SANDSTONE	VERY FINE GRAINED, WELL CEMENTED, LIGHT BROWN, 5YR6/4	30-31
CLAY	MEDIUM LIGHT GRAY, N6	31-36
SANDSTONE	FINE GRAINED, WELL CEMENTED, LIGHT BROWN, 5YR6/4	36-37
CLAY	DUSKY BROWN, 5YR2/2	37-39
CLAY	GREENISH GRAY, 5GY6/1	39-42
CLAY	PALE BROWN	42-44
CLAY	SILTY, LIGHT OLIVE GRAY, 5Y6/1	44-46
CLAY	GREENISH GRAY, 5GY6/1	46-52
CLAY	SILTY, LIGHT OLIVE GRAY, 5Y6/1	52-54
SANDSTONE	FINE GRAINED, WELL CEMENTED, LIGHT BROWN, 5YR6/4	54-55
CLAY	LIGHT OLIVE GRAY, 5Y6/1	55-61
CLAY	DUSKY BROWN, 5YR2/2	61-62
CLAY	LIGHT OLIVE GRAY, 5Y6/1	62-64
SANDSTONE	FINE GRAINED, WELL CEMENTED, LIGHT BROWN, 5YR6/4	64-64.5
CLAY	GREENISH GRAY, 5GY6/1	64.5-67
SILT	CLAYEY, TRACE SAND, GREENISH GRAY, 5GY6/1	67-74
CLAY	GRAYISH BROWN, 5YR3/2	75-80
CLAY	DUSKY BROWN, 5YR2/2	80-84
CLAY	SILTY, PALE BROWN, 5YR5/2	84-87
LIGNITE		87-92

CLAY	PALE BROWN, 5YR5/2	92-104
SANDSTONE	FINE GRAINED, WELL CEMENTED, MEDIUM LIGHT GRAY, N6	104-107
SILT	TRACE FINE SAND, MEDIUM LIGHT GRAY, N6	107-118
LIGNITE		118-124
CLAY	PALE BROWN, 5YR5/2	124-125
CLAY	MEDIUM GRAY, N5	125-135
CLAY	INTERBEDDED BROWN AND GRAY CLAY	135-141
CLAY	SILTY, LIGHT GRAY, N6	141-146
CLAY	PALE BROWN, 5YR2/2	146-152
CLAY	GRAYISH BROWN, 5YR3/2	152-156
CLAY	MEDIUM LIGHT GRAY, N6	156-160

145-086-20DDA2

NDSWC

Date Completed:	5/7/92	Well Type:	P2
Depth Drilled (ft):	15	Source of Data:	
Screened Interval (ft):	8-13	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	1987.04
Owner: Hazen			

Lithologic Log

Unit	Description	Depth (ft)
CLAY	GRAYISH BROWN, 5YR3/2 (SENTINEL BUTTE FORMATION)	0-4
LIGNITE		4-13
CLAY	MEDIUM GRAY, N5	13-15

145-086-20DDC
NDSWC

Date Completed:	5/7/92	**Well Type:**	P2
Depth Drilled (ft):	40	**Source of Data:**	
Screened Interval (ft):	20-30	**Principal Aquifer :**	**Undefined**
Casing size (in) & Type:		**L.S. Elevation (ft)**	**1987.16**
Owner: Hazen			

Lithologic Log

Unit	Description	Depth (ft)
CLAY	SANDY, MODERATE YELLOWISH BROWN (MINE SPOILS)	0-9
CLAY	MEDIUM GRAY, N5 (SENTINEL BUTTE FORMATION)	9-20
LIGNITE		20-21
CLAY	GREENISH GRAY, 5G6/1	21-24
SILT	SANDY, CLAYEY, MEDIUM GRAY, N5	24-29
CLAY	GRAYISH BROWN, 5YR3/2	29-40

145-086-20DDD

NDSWC

Date Completed:	5/7/92	Well Type:	P2
Depth Drilled (ft):	39	Source of Data:	
Screened Interval (ft):	25-35	Principal Aquifer :	Undefined
Casing size (in) & Type:		L.S. Elevation (ft)	2004.87

Owner: Hazen

Lithologic Log

Unit	Description	Depth (ft)
SAND	MEDIUM TO FINE GRAINED, TRACE GRAVEL, CLAYEY, MEDIUM YELLOWISH BROWN (OLD RAILROAD BED)	0-4
CLAY	LIGHT OLIVE GRAY, 5Y6/1 (SENTINEL BUTTE FORMATION)	4-8
CLAY	PALE BROWN, 5YR3/2	8-18
CLAY	GRAYISH BROWN, 5YR3/2	18-20
LIGNITE		20-35
CLAY	GRAYISH BROWN, 5YR3/2	35-39

APPENDIX D

WATER-LEVEL TABLES

Hazen Landfill Water Levels
5/27/92 to 7/15/92

145-086-20DCC LS Elev (msl,ft)=2007.98
Undefined Aquifer SI (ft.)=41-46

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/27/92	39.86	1968.12	07/01/92	40.26	1967.72
06/19/92	40.17	1967.81	07/15/92	40.32	1967.66

145-086-20DCD LS Elev (msl,ft)=1991.38
Undefined Aquifer SI (ft.)=30-40

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/27/92	25.26	1966.12	07/01/92	21.17	1970.21
06/19/92	21.26	1970.12	07/15/92	21.35	1970.03

145-086-20DDA2 LS Elev (msl,ft)=1987.04
Undefined Aquifer SI (ft.)=8-13

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/27/92	10.89	1976.15	07/01/92	10.96	1976.08
06/19/92	10.93	1976.11	07/15/92	11.14	1975.90

145-086-20DDC LS Elev (msl,ft)=1987.16
Undefined Aquifer SI (ft.)=20-30

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/27/92	13.34	1973.82	07/01/92	13.13	1974.03
06/19/92	13.08	1974.08	07/15/92	13.40	1973.76

145-086-20DDD LS Elev (msl,ft)=2004.87
Undefined Aquifer SI (ft.)=25-35

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
05/27/92	29.14	1975.73	07/01/92	29.10	1975.77
06/19/92	29.10	1975.77	07/15/92	29.14	1975.73

APPENDIX E

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Hazen Water Quality

Major Ions 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)																					
145-086-20DCC	41-46	07/15/92	22	0.05	1.5	180	120	190	18	741	0	750	54	0.3	3.5	0.47	1700	940	340	30	2.7		10	7.01
145-086-20DCD	30-40	05/27/92	9.4	0.04	0.2	88	61	340	15	863	0	470	25	0.3	0	0.45	1430	470	0	60	6.8	2140	13	7.46
145-086-20DDA2	8-13	05/27/92	18	0.13	0.43	230	200	260	11	263	0	1500	30	0.1	0	1.6	2380	1400	24	29	3	3090	9	5.87
145-086-20DDC	20-30	05/27/92	11	0.4	0.21	110	88	340	14	825	0	680	31	0.1	0	0.52	1680	640	0	53	5.8	2420	13	6.8
145-086-20DDD	25-35	05/27/92	15	0.09	0.38	100	67	88	5.7	485	0	340	17	0.1	7.3	0.37	880	530	130	26	1.7	1572	10	5.92

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
145-086-20DCD	5/27/92	0	0	0	0	3	8	2500
1405-086-20DDC	5/27/92	1	0	0	0	1	1	3700
1405-086-20DDA2	5/27/92	1	0	0	0	2	0	4200
145-86-20DDD	5/27/92	3	0	0	0	3	6	1600
145-086-20DCC	5/27/92	4	0	0	0	2	5	1710

APPENDIX F

VOLATILE ORGANIC COMPOUNDS FOR WELL 145-086-20DDC

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