Site Suitability Review of the Jamestown Municipal Landfill

by
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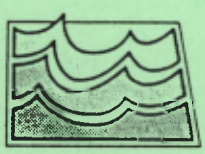

Prepared by the
North Dakota State Water Commission
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ND Landfill Site Investigation No. 17

SITE SUITABILITY REVIEW OF THE JAMESTOWN MUNICIPAL LANDFILL

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

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. Additional studies may be necessary to meet the requirements of the NDSDHCL for continued operation of solid waste landfills. The Jamestown municipal solid waste landfill is one of the landfills being evaluated.

Location of the Jamestown Landfill

The Jamestown municipal solid waste landfill is located eight miles east of the City of Jamestown in Township 140 North, Range 63 West, NE 1/4 Section 36 (Fig. 1). The landfill site encompasses approximately 80 acres, of which 40 acres has been used.

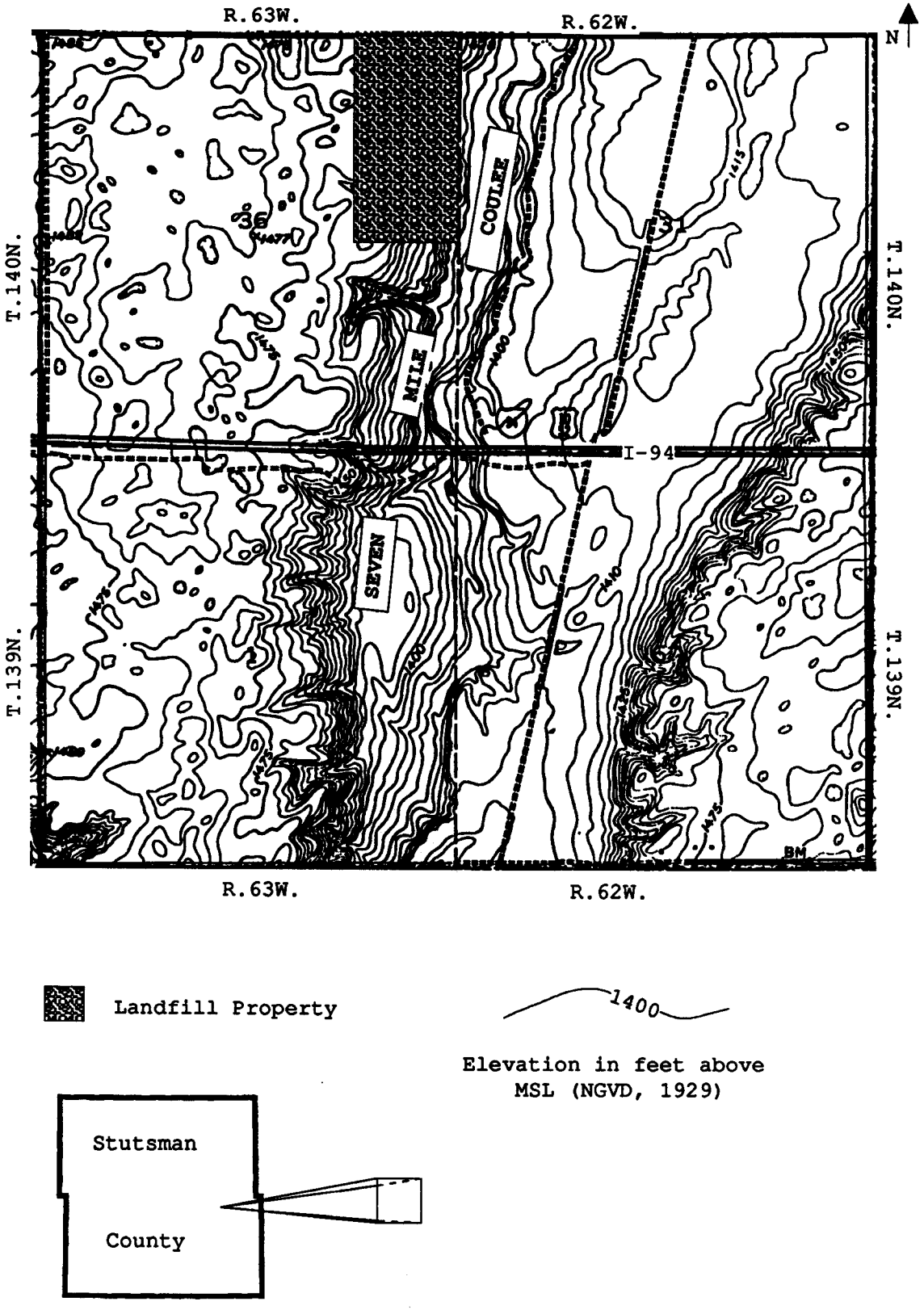


Figure 1. Location of the Jamestown landfill in the northeast quarter of section 36, T.140N., R.63W.

Previous Site Investigations

A hydrogeologic investigation of the site was completed in May, 1991 by Donohue and Associates. Monitoring wells were installed around the perimeter of the landfill boundaries. Deficencies were found in this report and additional wells were installed in August, 1992. Six monitoring wells and three piezometers were installed to determine the ground-water depth and flow direction. Six soil borings were drilled to determine the geologic characteristics of the site. The 1991 study determined that the ground-water flow was toward the Seven-Mile Coulee aquifer and Midway aquifer, both of which are located along the east boundary of the landfill. There was no indication of leachate migration from the landfill into the Seven-Mile Coulee and Midway aquifers in the 1991 report.

The soil borings indicated a thin layer of topsoil underlain by glacial till that varied in thickness across the landfill. A thick layer of glacial outwash underlies the till.

Methods of Investigation

The Jamestown study was accomplished by means of: 1) drilling test holes; 2) constructing and developing of monitoring wells; 3) collecting and analyzing water samples; and 4) measuring water levels.

Test-Drilling Procedure

The drilling method at the Jamestown landfill was based on the site's geology and depth to ground water, as determined by the preliminary evaluation. A hollow-stem auger was used at the Jamestown landfill because the sediments were poorly consolidated and because the depth to the water table was expected to be less than 70 feet. The lithologic descriptions were determined from the drill cuttings.

Monitoring Well Construction and Development

Ten test holes were drilled at the Jamestown landfill, and monitoring wells were installed in nine of the test holes. Ten existing monitoring wells installed by Donohue and Associates, Water Supply Inc., and the ND State Water Commission were also used in this study. The number of wells installed at the Jamestown landfill was based on the geologic and topographic characteristics of the site. The depth and intake interval of each well was selected to monitor the water level at the top of the uppermost aquifer. The wells were located within a one-half mile radius of the active area of the landfill.

Wells were constructed following a standard design (Fig. 2) intended to comply with the construction regulations of

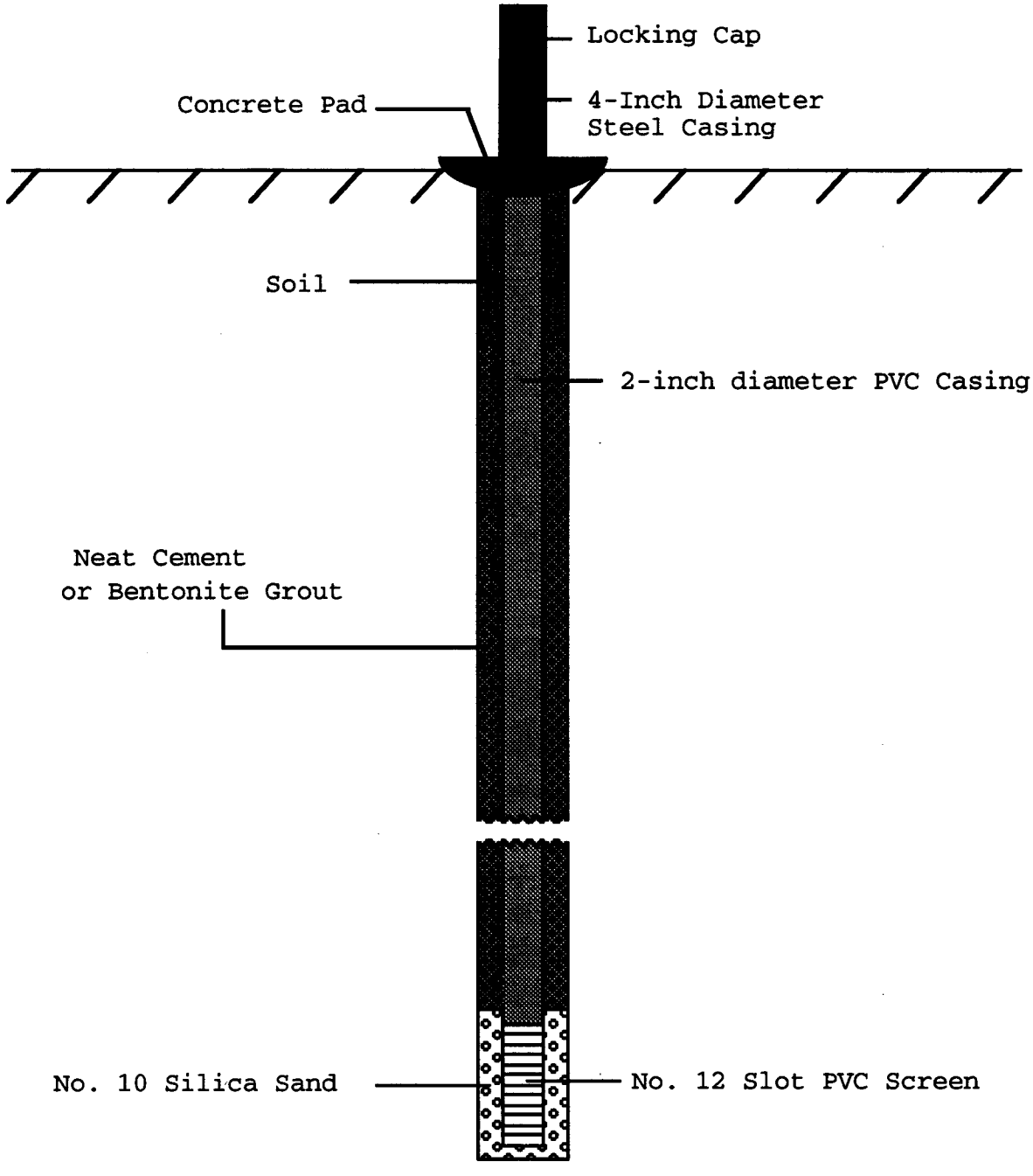


Figure 2. Construction design used for monitoring wells installed at the Jamestown landfill.

the NDSDHCL and the North Dakota Board of Water Well Contractors (North Dakota Department of Health, 1986). The wells were constructed using a 2-inch diameter, SDR21, polyvinyl chloride (PVC) well casing and a PVC screen, either 5 or 10 feet long, with a slot-opening size of 0.012 or 0.013 inches. The screen was fastened to the casing with stainless steel screws (no solvent weld cement was used). After the casing and screen were 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 with their Maximum Contaminant Levels (MCL). MCLs are enforcable drinking water standards that represent the maximum permissible level of a contaminant as stipulated by the U.S. Environmental Protection Agency (EPA).

Water samples were collected using a bladder pump constructed of stainless steel with a teflon bladder. A teflon bailer was used in monitoring wells with limited transmitting capacity. Before sample collection, three to four well volumes were extracted to insure that unadulterated formation water was sampled. Four samples from each well were collected in high density polyethylene plastic bottles as follows:

1) Raw (500 ml)
2) Filtered (500 ml)
3) Filtered and acidified (500 ml)
4) Filtered and double acidified (500 ml)

The following parameters were determined for each sample. Specific conductance, pH, bicarbonate, and carbonate were analyzed using the raw sample. Sulfate, chloride, nitrate*,

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

and dissolved solids were analyzed using the filtered sample. Calcium, magnesium, sodium, potassium, iron, and manganese were analyzed from the filtered, acidified sample. Cadmium, lead, arsenic, and mercury were analyzed using the filtered double-acidified samples.

One well was sampled for Volatile Organic Compounds (VOC) analysis. This sample was collected at a different time than the standard water-quality sample. The procedure used for collecting the VOC sample is described in Appendix B. Each sample was collected with a plastic throw-away bailer and kept chilled. These samples were analyzed within the permitted 14-day holding period. The standard water-quality analyses were performed at the North Dakota State Water Commission (NDSWC) Laboratory and VOC analyses were performed by the NDSDHCL.

Water-Level Measurements

Water-level measurements were taken at least three times at a minimum of two-week intervals. The measurements were taken using a chalked-steel tape or an electronic (Solnist 10078) water-level indicator. These measurements were used to determine the shape and configuration of the water table.

Location-Numbering System

The system for denoting the location of a test hole or observation well is based on the federal system of rectangular surveys of public land. The first and second numbers indicate Township north and Range west of the 5th Principle Meridian and baseline (Fig. 3). The third number indicates the section. The letters A, B, C, and D designate, respectively, the northeast, northwest, southwest, and southeast quarter section (160-acre tract), quarter-quarter section (40-acre tract), and quarter-quarter-quarter section (10-acre tract). Therefore, a well denoted by 140-063-36ADD1 would be located in the SE1/4, SE1/4, NE1/4, Section 36, Township 140 North, Range 63 West. Consecutive numbers are added following the three letters if more than one well is located in a 10-acre tract, e.g. 140-063-36ADD1 and 140-063-36ADD2.

GEOLOGY

Regional Geology

The Jamestown landfill is situated within the glaciated plains, a region of relatively thick glacial sediments with a gently sloping topography (Bluemle, 1991). Three major types

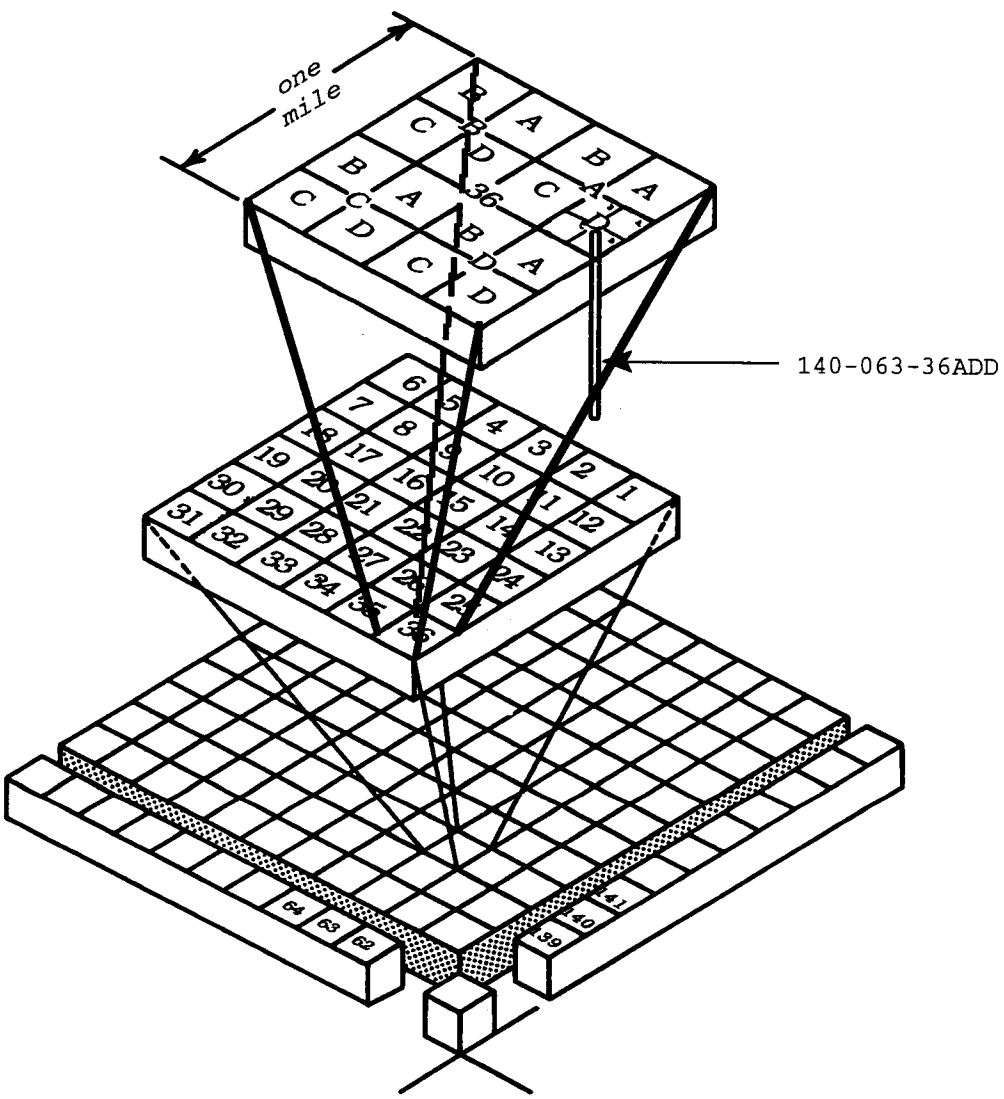


Figure 3. Location-numbering system for the Jamestown landfill.

of sediment are included in the glacial materials: till, glaciofluvial, and glaciolacustrine. Till was deposited directly by glacial ice and is composed of pebbly, sandy, silty clay. Glaciofluvial sediment, or outwash, was deposited by glacial meltwater and is composed mainly of sand and gravel. Glaciolacustrine sediment accumulated in lakes that formed on or near the glacier and is composed mainly of clay and silt (Bluemle, 1991). Till and glaciofluvial sediments are the dominant sediment types in the vicinity of the Jamestown landfill.

Glaciofluvial sediments are contained in three meltwater channels near the landfill. Seven Mile Coulee, located directly east of the landfill, is one of the meltwater channels in the region. The surface topography in this channel consists of a narrow valley occupied by a small stream and flanked by broad terraces of Pleistocene age. The valley fill consists of a thin layer of Holocene alluvium overlying glaciofluvial sand and gravel.

The James River Valley, located two miles south of the landfill, is another meltwater channel. A third meltwater channel, the Midway channel, is a buried valley located directly beneath the landfill. This channel is part of an older extensive Pleistocene drainage system (Christensen and Miller, 1988). All three meltwater channels serve as aquifers for the region.

The Cretaceous Pierre Formation underlies the glacial sediments in the area of the Jamestown landfill. This

formation consists of light gray to dark gray shale, clay, and bentonite. The top of the Pierre Formation ranges generally from 100 to 300 feet below the surface (Christensen and Miller, 1988).

Local Geology

The Jamestown landfill is located on the western edge of Seven Mile Coulee (Fig. 4) with most of the landfill property situated on the slope of the coulee. Surface elevations range from about 1,400 to 1,475 feet. Two ravines trend east-west across the landfill property and intersect Seven Mile Coulee. One of these ravines has been filled with refuse and cover material and subsequently capped.

The stratigraphy of the site includes surficial Holocene clays and Pleistocene deposits of the Coleharbor Group, which consists of till, sand and gravel, and silt and clay. These textural facies are separated by wavy lines on geohydrologic cross sections A-A' and B-B' (Figs. 5 and 6). The Midway channel consists of glaciofluvial sand of the Coleharbor Group which was deposited over pre-existing till or bedrock. The Midway sands were covered by till as a glacier advanced over the region. Glaciofluvial sediments of the Coleharbor Group also were deposited in the Seven Mile Coulee channel. Holocene alluvium (clay) was deposited in the bottom of Seven Mile Coulee.

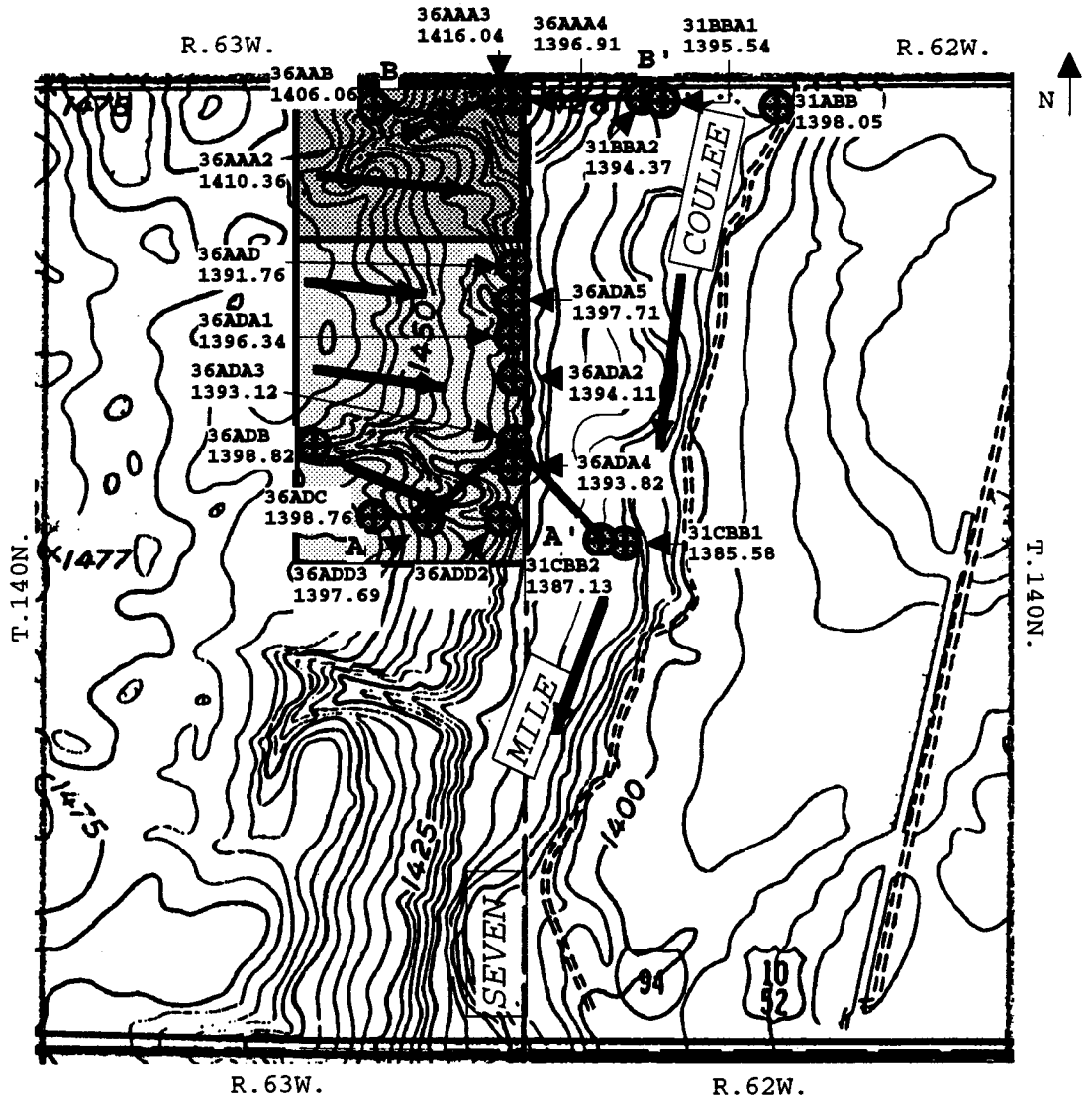


Figure 4. Location of monitoring wells and the direction of ground-water flow at the Jamestown landfill.

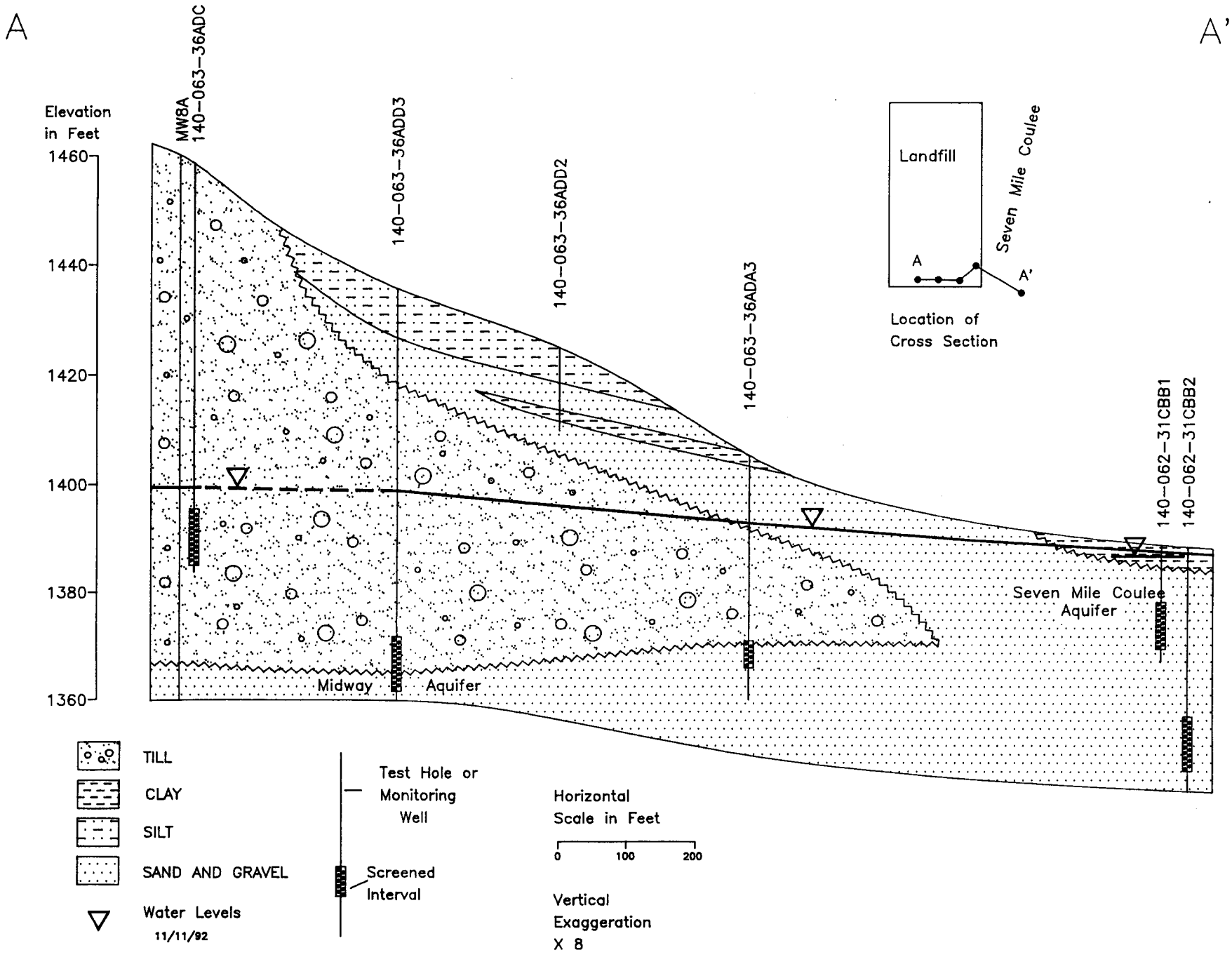


Figure 5. Geohydrologic cross section A–A' in the Jamestown landfill.

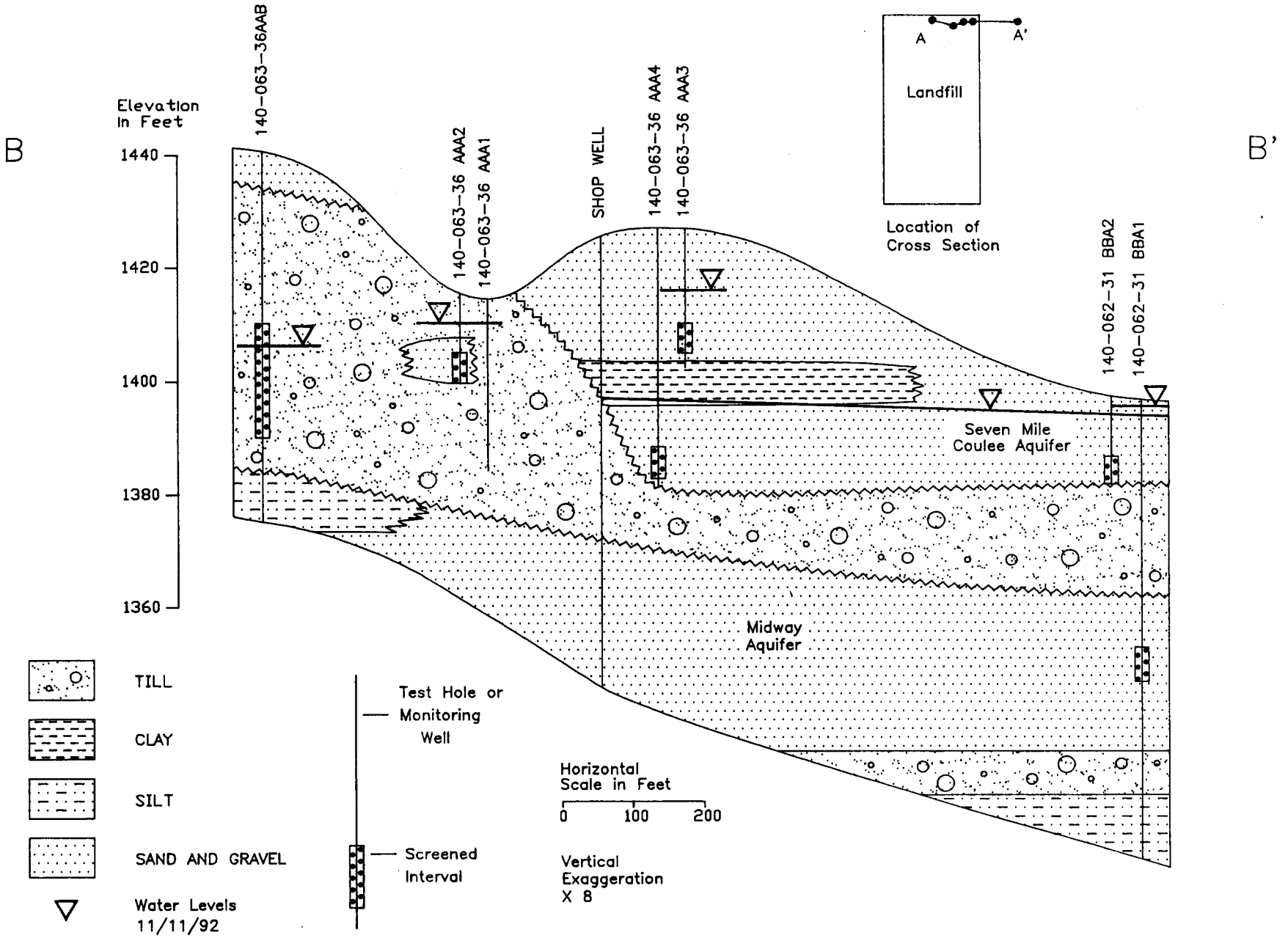


Figure 6. Geohydrologic section B–B' in the Jamestown landfill.

The sand, gravel, and silt occurring near the surface in test holes 140-063-36AAA3, AAA4, AAB, ADA3, ADD2, and ADD3 (Fig. 5 and 6) represent terrace deposits associated with Seven-Mile Coulee. These deposits range from a few feet to about 20 feet in thickness.

The glaciofluvial sediments of the Seven Mile Coulee and Midway channels appear to be lithologically continuous near the south end of the landfill in Seven-Mile Coulee (Fig. 5). However, near the north end of the landfill a 15- to 25-foot-thick layer of till separates the glaciofluvial deposits of the Seven Mile Coulee and Midway channels (Fig. 6).

HYDROLOGY

Surface-Water Hydrology

The Jamestown landfill is located along the eastern flank of Seven-Mile Coulee (Fig. 7), a perennial stream that discharges into the James River. Seven-Mile Coulee is down-gradient from the landfill and may be susceptible to leachate migration. The James River is located about three miles south of the landfill and may be susceptible to leachate migration through the Seven-Mile Coulee. No other surface-water are located near the Jamestown landfill.

Regional Ground-Water Hydrology

Regional aquifers near the Jamestown landfill consist of bedrock and glacial aquifers. Bedrock aquifers underlying the Jamestown landfill are in the Dakota and Pierre Formations. The Dakota aquifer occurs from 1,250 feet below land surface near the eastern part of the county to 2,250 feet below land surface near the western edge of the county (Huxel, et.al, 1965). The Dakota aquifer is characterized by a sodium-sulfate type water.

The Pierre Formation overlies the Dakota aquifer and directly underlies glacial sediments near the Jamestown landfill. The shale of the Pierre Formation may supply small quantities of water to wells screened in areas of extensive fracturing. The Pierre aquifer is characterized by a sodium-bicarbonate to a sodium-sulfate type water. Neither the Dakota nor Pierre aquifers appear to be susceptible to contamination from the landfill due to their depths, the low hydraulic conductivity of the overlying till ($K= 10^{-7}$ to 10^{-8} cm/sec, Donohue, 1991), and the existence of a local discharge area (Seven-Mile Coulee).

Five major glacial aquifers occur within a four-mile radius of the Jamestown landfill (Fig. 7). The closest is the Seven-Mile Coulee aquifer located along the eastern edge of the landfill. The Seven-Mile Coulee aquifer extends from about 4 miles north of the landfill to about two miles south of it and is part of the James River aquifer system. The

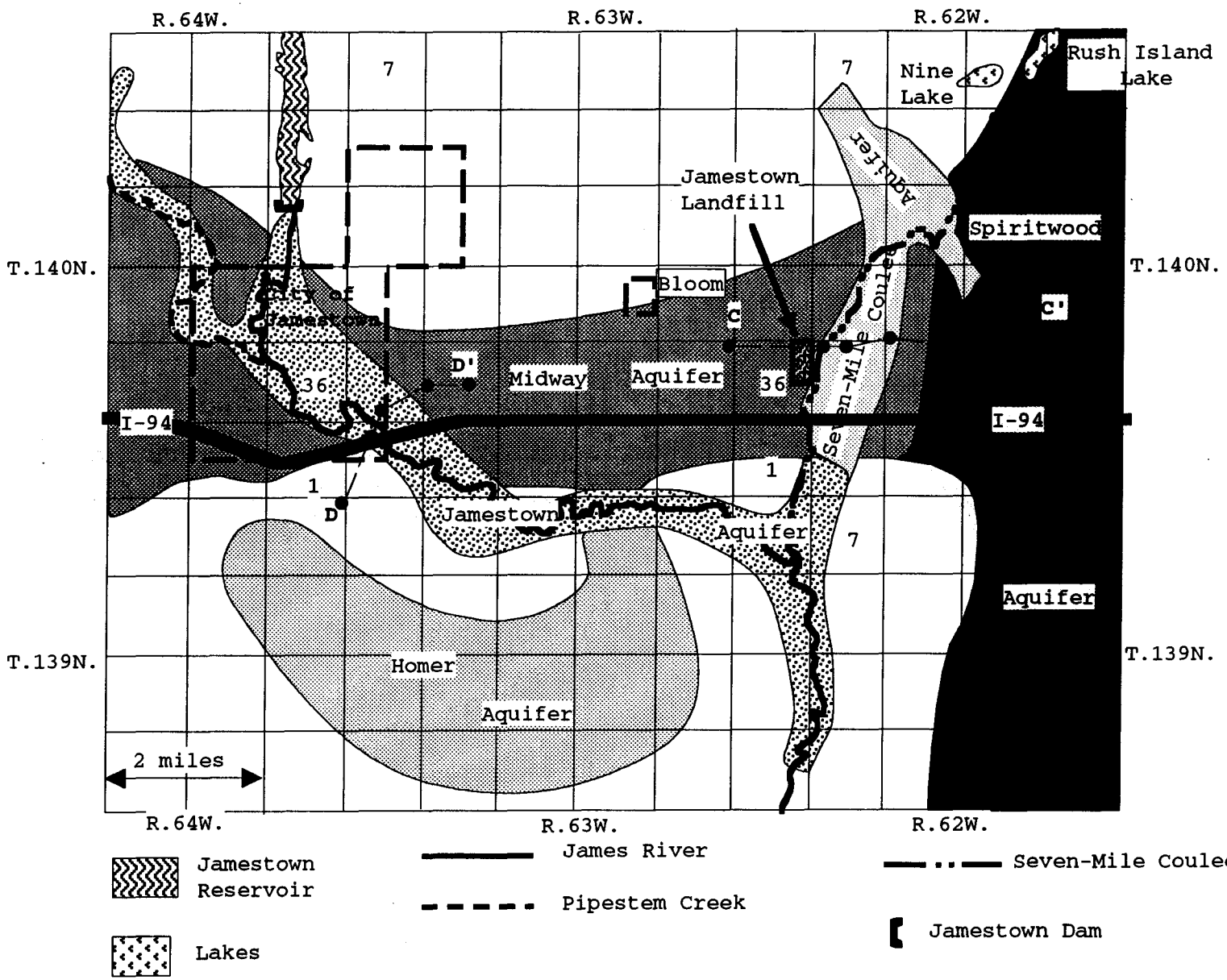


Figure 7. Hydrogeology of the lower James River area, modified from Christensen, P.K., 1988.

Seven-Mile Coulee aquifer consists of glacial outwash deposited in Seven-Mile Coulee. Water levels in the Seven-Mile Coulee aquifer range from land surface to about 25 feet below land surface. The direction of ground-water flow is to the south. Recharge to the Seven-Mile Coulee aquifer is by precipitation, leakage from the Pierre Formation, and the Midway aquifer (Christensen, 1988). Discharge from the Seven-Mile Coulee aquifer is mainly by pumping and evapotranspiration. Discharge also occurs by ground-water movement into the Jamestown aquifer (Christensen, 1988).

The most extensive aquifer in the area is the Spiritwood aquifer, which is located about 1.5 miles east of the landfill (Fig. 7). The Spiritwood aquifer is generally confined except locally near the James River (Christensen, 1988). Recharge to the Spiritwood aquifer is by precipitation and leakage from adjacent undifferentiated aquifers and the Pierre Formation. Discharge from the Spiritwood aquifer is by pumping and leakage into the Midway aquifer and the James River. The Spiritwood aquifer is characterized by a sodium-bicarbonate type water in the area of the landfill.

The Midway aquifer, which extends from Pipestem Lake, west of the City of Jamestown, to the Seven-Mile Coulee (Christensen, 1988, Fig. 7), appears to be hydraulically connected to the Spiritwood aquifer (Fig. 8). Water levels in the Midway aquifer range from land surface in Seven-Mile Coulee stream channel to 110 feet below land surface.

Recharge to the Midway aquifer is by precipitation, leakage from the Spiritwood aquifer and seepage from Pipestem Lake. Discharge from the Midway aquifer is by pumping and ground-water movement into the Jamestown and Seven-Mile Coulee aquifers. The water in the Midway aquifer is characterized by a mixed cation-bicarbonate type.

The Jamestown aquifer is located in the valleys of the James River, Pipestem Creek, and Seven-Mile Coulee (Christensen, 1988, Fig. 7). Water levels indicate the depth of the Jamestown aquifer ranging from 2 to 40 feet below land surface. Recharge to the Jamestown aquifer is by precipitation, and leakage from the Pierre Formation, Midway, Homer, and Seven-Mile Coulee aquifers (Christensen, 1988, Fig. 9). A zone of low transmissivity material slows the ground-water movement from the Seven-Mile Coulee aquifer into the Jamestown aquifer. Discharge from the Jamestown aquifer is mainly by pumping. The Jamestown aquifer is characterized by a calcium-magnesium-bicarbonate type water.

The Homer aquifer is located south-southeast of the City of Jamestown in a buried valley (Christensen, 1988, Fig. 7). The Homer aquifer is confined in most places except locally near the James River valley where it is about 10 feet below the base of the valley. Recharge to the Homer aquifer is by precipitation. Discharge from the Homer aquifer is by ground-water movement into the James aquifer. The Homer aquifer is characterized by a calcium-bicarbonate type water.

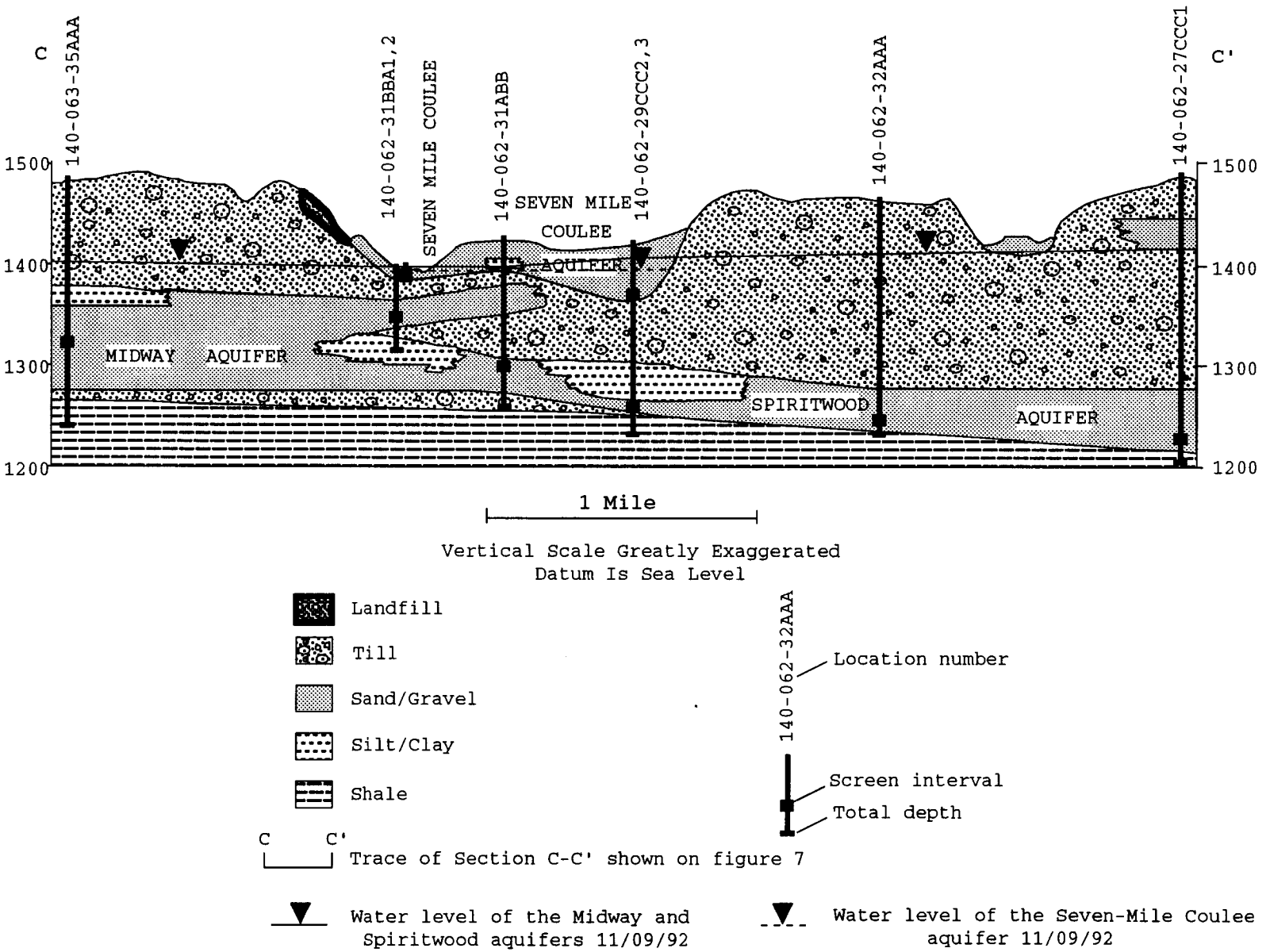


Figure 8. Hydrogeologic section C-C' of the Midway aquifer, Spiritwood aquifer, and Seven-Mile Coulee aquifer modified from Christensen, P.K., 1988.

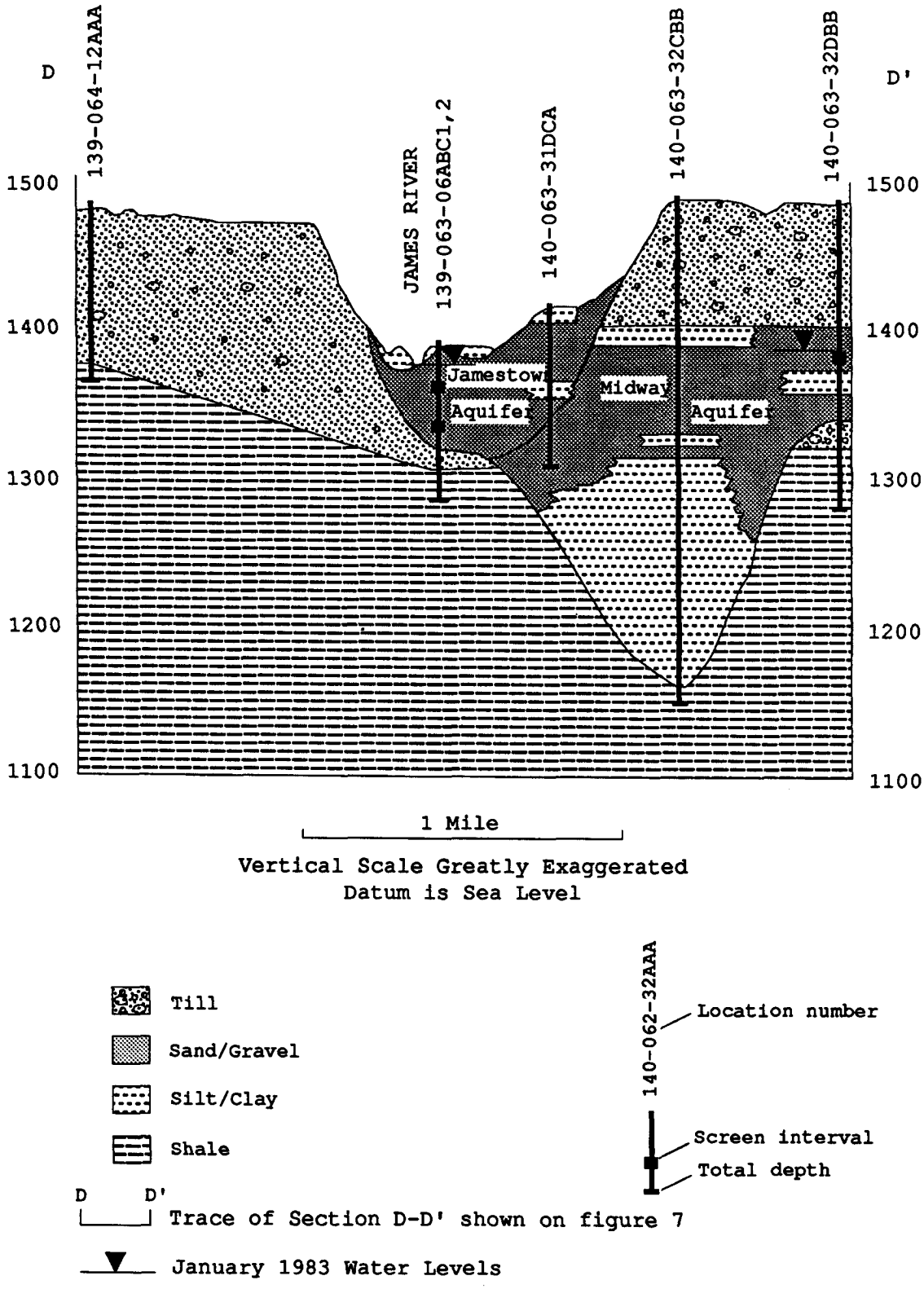


Figure 9. Hydrogeologic section D-D' of the Midway and Jamestown aquifers near Jamestown, modified from Christensen, P.K., 1988.

Undifferentiated aquifers are present in isolated sand and gravel deposits. These aquifers are generally small in size and contain small amounts of water. The ground-water chemistry in these aquifers is variable.

Local Ground-Water Hydrology

Eight test holes were drilled at the Jamestown landfill with monitoring wells installed at six of the sites. Three additional monitoring wells were installed within Seven-Mile Coulee. Eight on-site and two off-site pre-existing monitoring wells were also included in this study. Six water-level measurements were taken over a ten-week period (Appendix D). Off-site monitoring wells were monitored to determine the hydraulic connection between the Seven-Mile Coulee and Midway aquifers. Wells 140-062-31BBA1 and BBA2 are located 0.25 miles east of the north end of the landfill. Water levels indicate an upward movement of water from the Midway aquifer to the Seven-Mile Coulee aquifer. These two aquifers are separated by about 25 feet of till at this location (Christensen, 1988). Wells 140-062-31CBB1 and CBB2 are located 0.25 miles east of the southern boundary of the landfill. Water levels in these wells also indicate an upward movement of water from the Midway aquifer to the Seven-Mile Coulee aquifer (Fig. 6).

The wells along the eastern boundary of the landfill (Fig. 4) appear to penetrate the gravel terrace deposits of

the Seven-Mile Coulee aquifer and the Midway aquifer. Near the eastern boundary of the landfill water occurs in the Seven-Mile Coulee aquifer under unconfined conditions. The Seven-Mile Coulee aquifer is susceptible to contamination from the landfill.

The Midway aquifer directly underlies the landfill at a depth of about 50 to 60 feet on the west side of the landfill boundary. Near the landfill the direction of ground-water flow in the Midway aquifer is east toward the Seven-Mile Coulee aquifer (Fig. 5). A layer of low conductivity till (K= 10^{-7} to 10^{-8} cm/sec, Donohue, 1991) separates the Midway aquifer and the original refuse cells. The thickness of the till decreases to the east where the Seven-Mile Coulee aquifer truncates the Midway aquifer (Fig. 5). The Midway aquifer may be susceptible to contamination where the overlying till is relatively thin, fractured, or was excavated for cell construction.

Water Quality

Chemical analyses of water samples are shown in Appendix E. Wells located along the northern boundary of the landfill were used for background water chemistry for this study because they are up-gradient from the landfill. An anomalously high pH (pH=11.9) value was measured in well 140-063-36ADB. This well is located at the west end of the

original cells and screened in the Midway aquifer. The source of this high pH was not determined.

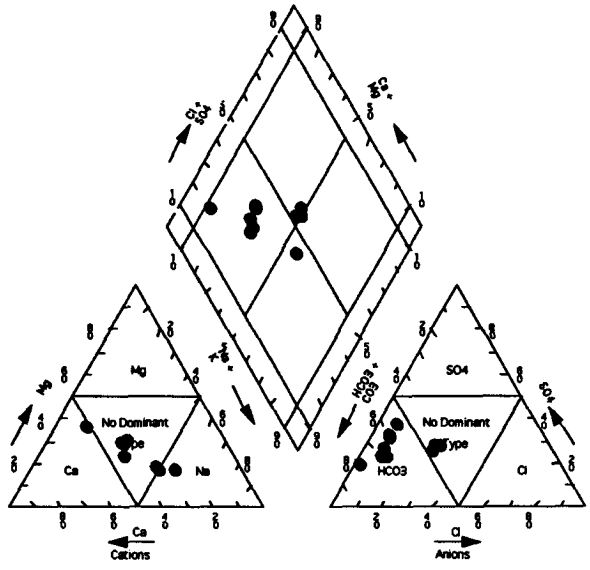
Beneath the landfill the Seven-Mile Coulee aquifer is characterized by a calcium-mixed cation-sulfate-bicarbonate type water (Fig. 10). Away from the landfill the Seven-Mile Coulee aquifer is characterized by a mixed cation-sodium-bicarbonate type water. Some of the differences in hydrochemical facies (relative concentrations of major ions) may be caused by leachate migration from the landfill. The Midway aquifer is characterized by a mixed cation-sodium-bicarbonate type water near and away from the landfill (Fig. 11).

Well 140-063-36AAB indicated an elevated concentration of chloride (100 mg/L, Appendix E) and selenium (21 µg/L). The source of the chloride and selenium was not determined.

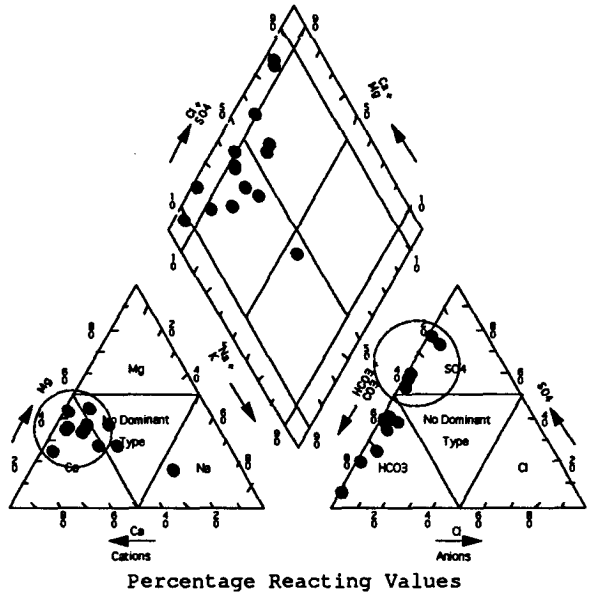
The results of the VOC analyses, from wells 140-062-31CBB1 and 140-063-36ADD1, are shown in Appendix F. The analyses did not detect any VOC compounds.

CONCLUSIONS

The Jamestown landfill is located in a region of relatively thick glacial sediments with gently sloping topography. In the landfill area the glacial deposits consist of till, glaciofluvial (sand and gravel), and

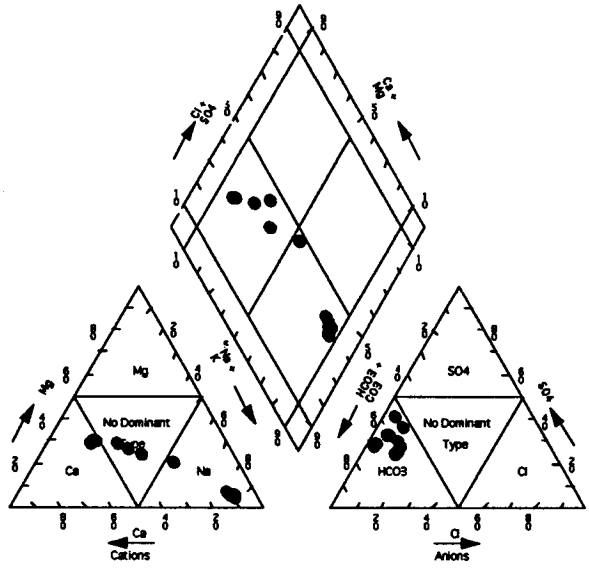


Regional Analysis

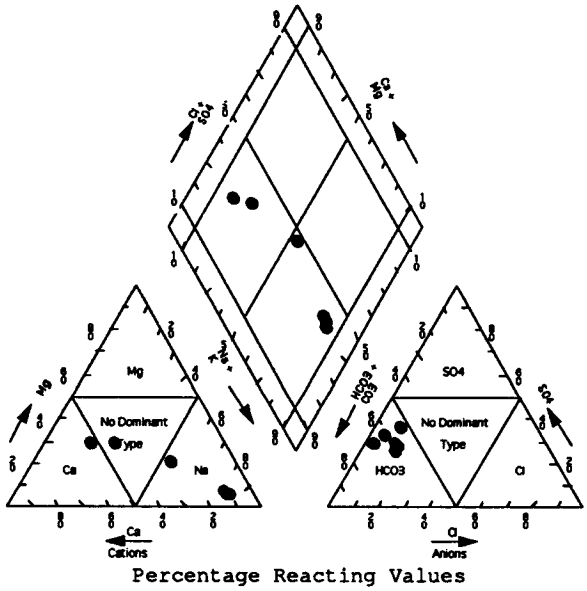


Local Analysis
(Beneath the landfill)

Figure 10. Piper diagrams showing the general ground-water chemistry for the Seven-Mile Coulee aquifer beneath the landfill and regionally.



Regional Analysis



Local Analysis
(Beneath the landfill)

Figure 11. Piper diagrams showing the general ground-water chemistry for the Midway aquifer beneath the landfill and regionally.

glaciolacustine (sand, silt, and clay). Till and glaciofluvial sands predominate.

Three Pleistocene meltwater channels are located near the Jamestown landfill. The Midway channel underlies the landfill, Seven-Mile Coulee is located along the eastern boundary of the landfill, and the James River valley is located about two miles south of the landfill.

The stratigraphy near the Jamestown landfill includes four stratigraphic sequences representing distinct depositional events. These sequences include the glaciofluvial sand of the Midway aquifer, till that buried the Midway aquifer, glaciofluvial sediments of the Seven-Mile Coulee aquifer, and Holocene alluvium in the bottom of Seven-Mile Coulee.

Five major glacial aquifers occur within a four-mile radius of the Jamestown landfill. These glacial aquifers include the Seven-Mile Coulee, Midway, Spiritwood, Jamestown, and Homer aquifers. Based on local hydrogeologic setting, the Seven-Mile Coulee and Midway aquifers appear to be the most susceptible to contamination from the landfill. The Midway aquifer appears to be more susceptible to contamination in the south part of the landfill study area where till does not occur between the Seven-Mile Coulee and Midway aquifers.

Beneath the landfill, the Seven-Mile Coulee aquifer is characterized by a calcium-mixed cation-sulfate-bicarbonate type water. Away from the landfill the Seven-Mile Coulee

aquifer is characterized by a mixed cation-sodium-bicarbonate type water. Some of the differences in hydrochemical facies (relative concentrations of major ions) may be caused by leachate migration from the landfill. The Midway aquifer is characterized by a mixed cation-sodium-bicarbonate type water near and away from the landfill.

Well 140-063-36ADB shows an anomalously high pH value. The source of this pH was not determined. The elevated chloride and selenium concentrations at well 140-063-36AAB do not appear to originate from the landfill as this well is located north (up-gradient) of the active cells. VOC analyses did not detect any VOC compounds.

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APPENDIX A

WATER QUALITY STANDARDS AND CONTAMINANT LEVELS

Water Quality Standards and Contaminant Levels

Field Parameters	
appearance	color/odor
pH	6-9 (optimum)
specific conductance	-----
temperature	-----

Constituent	MCL (µg/L)
Arsenic	50
Cadmium	10
Lead	50
Molybdenum	100
Mercury	2
Selenium	10
Strontium	*

*EPA has not set an MCL for strontium. The median concentration for most U.S. water supplies is 100 µg/L (Hem, 1989).

	SMCL (mg/L)
Chloride	250
Iron	>0.3
Nitrate	50
Sodium	20-170
Sulfate	300-1000
Total Dissolved Solids	>1000

	Recommended Concentration Limits (mg/L)
Bicarbonate	150-200
Calcium	25-50
Carbonate	150-200
Magnesium	25-50
Hardness	>121 (hard to very hard)

APPENDIX B

SAMPLING PROCEDURE FOR VOLATILE ORGANIC COMPOUNDS

SAMPLING PROCEDURE FOR 40ML AMBER BOTTLES

Sample Collection for Volatile Organic Compounds

by
North Dakota Department of Health
and Consolidated Laboratories

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

2. A blank will be sent along. Do Not open this blank and turn it in with the other three samples.

3. Adjust the flow so that no air bubbles pass through the sample as the bottle is being filled. No air should be trapped in the sample when the bottle is sealed. Make sure that you do not wash the ascorbic acid out of the bottle when taking the sample.

4. The meniscus of the water is the curved upper surface of the liquid. The meniscus should be convex (as shown) so that when the cover to the bottle is put on, no air bubbles will be allowed in the sample.

convex meniscus

5. Add the small vial of concentrated HCL to the bottle.

6. 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

140-062-31ABB

Date Completed:	7/15/82	Purpose:	Observation Well
L.S. Elevation (ft):	1421.88	Well Type:	1.25" PVC
Depth Drilled (ft):	127	Aquifer:	Midway
Screened Interval (ft):	122-127	Source:	
		Owner:	SWC

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	DARK BROWN, SILTY, 4'-5' GRANITE BOULDERS AT 2'-2.5'	0-2
SAND	FONE TO VERY COARSE-GRAINED, PREDOMINANTLY COARSE, ANGULAR TO ROUNDED, PREDOMINANTLY SUBROUNDED	2-4
GRAVEL	FINE SAND TO VERY COARSE GRAVEL, PREDOMINANTLY COARSE TO VERY COARSE GRAVEL, ANGULAR TO ROUNDED, PREDOMINANTLY SUBANGULAR, POSSIBLY INTERBEDDED WITH CLAY FROM 13'	4-16
CLAY?	NO SAMPLE, BOULDER AT 24'	16-24
SAND	COARSE-GRAINED SAND TO FINE GRAVEL, >50% COARSE SAND, PREDOMINANTLY SUBROUNDED, A LOT OF ROUNDED SHALE GRAVEL 26'-27'	24-27
TILL	MEDIUM GREENISH-GRAY, CLAYEY, SLIGHTLY SANDY, COHESIVE	27-50
SAND	VERY FINE-GRAINED, WELL SORTED, ANGULAR, CLAYEY, SLIGHTLY COHESIVE, SLIGHTLY CALCAREOUS, (FLUVIAL), SOME INTERBEDDED GRAVEL AROUND 68'	50-72
TILL	OLIVE GRAY, SANDY, PEBBLES, COHESIVE	72-87
SAND & GRAVEL	VERY COARSE SAND TO GRAVEL, ANGULAR	87-91
TILL	AS ABOVE, INTERBEDDED WITH SAND AND GRAVEL, COMPOSED OF COARSE SAND AND FINE GRAVEL	91-96

GRAVEL	NO SAMPLE, INTERBEDDED WITH TILL	96-104
TILL	AS ABOVE, SOME INTERBEDDED FINE GRAVEL AND COBBLES	104-127

140-062-31BBA
NDSWC 6066

Date Completed:	7/15/82	Purpose:	Observation Well
L.S. Elevation (ft):	1397.49	Well Type:	1.25" PVC
Depth Drilled (ft):	60	Aquifer:	Midway
Screened Interval (ft):	45-50	Source:	
		Owner:	SWC

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	NO SAMPLE	1-5
SAND & GRAVEL	VERY COARSE SAND TO MEDIUM GRAVEL, PREDOMINANTLY VERY COARSE SAND AND FINE GRAVEL, ANGULAR TO ROUNDED, PREDOMINANTLY SUB-ROUNDED	5-10
TILL	MEDIUM GRAY TO GREENISH GRAY, SILTY AND SLIGHTLY SANDY, POORLY COHESIVE, INTERBEDDED WITH SAND 22'-30', FINE TO COARSE GRAVEL, PREDOMINANTLY ANGULAR	10-35
GRAVEL	FINE TO VERY COARSE GRAVEL AND COBBLES, PREDOMINANTLY FINE GRAVEL, INTERBEDDED WITHGRAVELLY CLAY, BELOW 40' PREDOMINANTLY VERY COARSE GRAVEL AND COBBLES, SUBROUNDED	35-50

140-062-31BBA2
NDSWC

Date Completed:	9/15/92	Purpose:	Observation Well
L.S. Elevation (ft):	1397.43	Well Type:	2" PVC
Depth Drilled (ft):	15	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	10-15	Source:	
		Owner:	SWC

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-2
CLAY	Trace of sand and gravel, medium gray N5.	2-4
CLAY	With sand and gravel, moderate yellow-brown 10YR5/4.	4-8
GRAVEL	Medium to fine grain, moderate yellow-brown 10YR5/4.	8-15
		0-0

140-062-31CBB1
NDSWC

Date Completed:	7/16/92	Purpose:	Observation Well
L.S. Elevation (ft):	1386.94	Well Type:	2" PVC
Depth Drilled (ft):	15	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	7-12	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	GRAYISH BLACK (N2), (GLACIAL DRIFT)	1-3
SAND	SAND, FINE TO VERY COARSE-GRAINED, AND GRANULE SIZE, (OLIVE GRAY 5Y 4/1)	3-15

140-062-31CBB2
NDSWC

Date Completed:	7/16/92	Purpose:	Observation Well
L.S. Elevation (ft):	1387.46	Well Type:	2" PVC
Depth Drilled (ft):	45	Aquifer:	Midway
Screened Interval (ft):	31-41	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	GRAYISH BLACK (N2), (GLACIAL DRIFT)	1-4
SAND	FINE TO VERY COARSE-GRAINED, SILTY, TRACE PEBBLES AND COBBLES, OLIVE GRAY (5Y 4/1)	4-9
SAND	FINE TO VERY COARSE-GRAINED TO GRANULE SIZE, SILTY, OLIVE GRAY (5Y 4/1)	9-28
SAND	CLAYEY, TRACE GRAVEL, OLIVE GRAY (5Y 4/1)	28-34
SAND	CLAYEY, WITH GRAVEL AND ROCKS, OLIVE GRAY (5Y 4/1)	34-45

140-063-36AAA1

NDSWC

Date Completed:	7/15/92	Purpose:	Test Hole
L.S. Elevation (ft):		Well Type:	
Depth Drilled (ft):	30		
		Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	TRACE SAND AND PEBBLES, GRAYISH BROWN (5YR 3/2), (GLACIAL DRIFT)	1-7
CLAY	TRACE SAND AND GRAVEL, MODERATE YELLOWISH-BROWN (10YR 5/4)	7-11
CLAY	TRACE GRAVEL, OLIVE BLACK (5Y 2/1)	11-18
CLAY	TRACE SAND AND PEBBLES, OLIVE GRAY (5Y 4/1), DAMP, MOST PEBBLES IGNEOUS, A FEW SHALE AND LIGNITE, HIT HARD ROCK AT 30' AND COULD NOT DRILL FURTHER, DRY HOLE	18-30

140-063-36AAA2

NDSWC

Date Completed:	7/15/92	Purpose:	Observation Well
L.S. Elevation (ft):	1414.41	Well Type:	2" PVC
Depth Drilled (ft):	15	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	10-15	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	TRACE SAND AND PEBBLES, GRAYISH BROWN (5YR 3/2)	1-7
SAND	COARSE-GRAINED, SILTY, TRACE PEBBLES, MODERATE YELLOWISH-BROWN (10YR 5/4)	7-15

140-063-36AAA3

NDSWC

Date Completed:	9/15/92	Purpose:	Observation Well
L.S. Elevation (ft):	1427	Well Type:	2" PVC
Depth Drilled (ft):	25	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	17-21	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
GRAVEL	Fill material.	0-1
SAND	Fine grain with a trace of pebbles, moderate yellow-brown 10YR5/4.	1-9
SAND	Fine grain with a trace of silt, moderate yellow-brown 10YR5/4.	9-17
SAND	Medium to coarse grain with fine gravel (up to 5mm), dark yellow-brown 10YR4/2.	17-23
CLAY	Trace of fine sand, dark green-gray 5G4/1.	23-25

140-063-36AAA4
NDSWC

Date Completed:	9/15/92	Purpose:	Observation Well
L.S. Elevation (ft):	1427.22	Well Type:	2" PVC
Depth Drilled (ft):	45	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	38-43	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
GRAVEL	Fill material.	0-2
SAND	Fine grain, moderate yellow-brown 10YR5/4.	2-16
SAND	Coarse to very coarse grain with fine gravel (up to 5mm), dark yellow-brown 10YR4/2.	16-24
CLAY	Dark green-gray 5G4/1.	24-27
CLAY	Sandy, dark green-gray 5G4/1.	27-31
SAND	Medium to coarse grain, olive gray 5Y4/1.	31-39
SAND	Fine to medium grain, olive gray 5Y4/1.	39-45

140-063-36AAB
NDSWC

Date Completed:	10/29/90	Purpose:	Observation Well
L.S. Elevation (ft):	1441.34	Well Type:	2" PVC
Depth Drilled (ft):	57	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	30-50	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	SILT WITH SAND, VERY DARK BROWN	0-1
SAND	SILTY, LIGHT GRAYISH BROWN TO LIGHT BROWN, COARSE TO MEDIUM TO FINE-GRAINED, MEDIUM DENSE TO DENSE, WITH A TRACE OF GRAVEL, AND WITH A LAYER OF FINE SILTY SAND AT ABOUT 5', DRY	1-7
CLAY	SANDY LEAN CLAY, GRAYISH BROWN, STIFF TO RATHER STIFF TO STIFF, WITH A TRACE TO A LITTLE GRAVEL, AND WITH A LAYER OF SAND AT ABOUT 15.5'	7-29
CLAY	SANDY LEAN CLAY, GRAY, VERY STIFF TO STIFF, WITH A TRACE OF GRAVEL	29-38
CLAY	SANDY LEAN CLAY , GRAY, STIFF TO VERY STIFF, WITH A TRACE OF GRAVEL, ALSO SAND OR GRAVEL LAYER ENCOUNTERED AT 56.5'	38-57

140-063-36AAD

NDSWC

Date Completed:	10/26/90	Purpose:	Observation Well
L.S. Elevation (ft):	1410.04	Well Type:	2" PVC
Depth Drilled (ft):	22	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	12-22	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	LEAN CLAY, VERY DARK BROWN	0-2
CLAY	LEAN CLAY WITH SAND, LIGHT GRAYISH BROWN, STIFF, WITH A TRACE OF GRAVEL	2-4
CLAY	SANDY LEAN CLAY, LIGHT GRAYISH BROWN TO GRAYISH BROWN, VERY STIFF TO STIFF TO RATHER STIFF, WITH A TRACE OF GRAVEL	4-15.5
CLAY	SANDY LEAN CLAY, GRAY, RATHER STIFF TO STIFF TO VERY STIFF, WITH A TRACE OF GRAVEL	15.5-22

140-063-36ADA1
NDSWC

Date Completed:	7/15/92	Purpose:	Observation Well
L.S. Elevation (ft):	1409.25	Well Type:	2" PVC
Depth Drilled (ft):	40	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	20-30	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	SAND AND GRAVEL, GRAYISH-BROWN (5YR 3/2), (GLACIAL DRIFT)	1-8
CLAY	SANDY, TRACE PEBBLES AND COBBLES, MODERATE YELLOWISH-BROWN (10YR 5/4)	8-16
CLAY	TRACE SAND AND PEBBLES, OLIVE GRAY	16-23
CLAY	TRACE SAND AND PEBBLES, OLIVE BLACK (5Y 2/1)	23-30
GRAVEL		30-32
SAND	MEDIUM-GRAINED, SILTY, OLIVE GRAY	32-40

140-063-36ADA2
NDSWC

Date Completed:	7/16/92	Purpose:	Observation Well
L.S. Elevation (ft):	1409.34	Well Type:	2" PVC
Depth Drilled (ft):	28	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	22-27	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	SILTY, WITH SAND, PEBBLES AND COBBLES, GRAYISH BROWN (5YR 3/2), (GLACIAL DRIFT)	1-5
GRAVEL	SMALL PEBBLE SIZE, WITH MEDIUM TO VERY COARSE-GRAINED SAND, DARK YELLOWISH-BROWN (10YR 4/2)	11-23
GRAVEL	SMALL PEBBLE SIZE, WITH SAND, DARK YELLOWISH-BROWN (10YR 4/2), WET, SAND AND GRAVEL COLLAPSED AROUND SCREEN	23-28
GRAVEL	PEBBLE SIZE	5-11

140-063-36ADA3

NDSWC

Date Completed:	0	Purpose:	Observation Well
L.S. Elevation (ft):	1404.99	Well Type:	2" Steel
Depth Drilled (ft):	45	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	34-39	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	SILTY, BLACK	0-1
CLAY	SILTY, YELLOWISH-BROWN, TILL	1-2
GRAVEL	FINE, MEDIUM TO COARSE WITH LOTS OF ROCKS	2-14
CLAY	SILTY, YELLOWISH-BROWN, TILL	14-16
CLAY	SILTY, WITH A FEW ROCKS, OLIVE GRAY, TILL	16-21
CLAY	SILTY, OLIVE GRAY	21-34
SAND	FINE, MEDIUM TO COARSE-GRAINED	34-45

140-063-36ADA4
NDSWC

Date Completed:	7/10/84	Purpose:	Observation Well
L.S. Elevation (ft):	1404.95	Well Type:	2" Steel
Depth Drilled (ft):	35	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	23-28	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
CLAY	SANDY, SILTY, TILL, YELLOWISH-BROWN	1-10
GRAVEL	AND ROCKS	10-11
CLAY	SILTY, TILL, OLIVE GRAY	11-21
GRAVEL	AND ROCKS	21-22
CLAY	SILTY, TILL, OLIVE GRAY	22-23
GRAVEL	FINE, MEDIUM, TO COARSE, LOTS OF WATER, MIXED 3 MUD FROM 23'-35'	23-26
SAND	FINE, MEDIUM TO COARSE-GRAINED	26-35

140-063-36ADA5

NDSWC

Date Completed:	10/25/90	Purpose:	Observation Well
L.S. Elevation (ft):	1410.49	Well Type:	2" PVC
Depth Drilled (ft):	20	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	10-20	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	SILT, BLACK TO VERY DARK BROWN	0-2
CLAY	SANDY LEAN CLAY, LIGHT GRAYISH BROWN, STIFF, WITH A TRACE OF GRAVEL, BOULDER ENCOUNTERED AT 3'	2-5
SAND	SILTY, WITH GRAVEL, LIGHT BROWN, COARSE TO MEDIUM TO FINE-GRAINED, DENSE TO VERY DENSE, COBBLES PRESENT AT ABOUT 7'-10', DRY	5-10.5
CLAY	SANDY LEAN CLAY, BROWN TO GRAYISH BROWN, STIFF TO RATHER STIFF, WITH A TRACE OF GRAVEL, AND WITH LENSES AND SEAMS OF SAND	10.5-18
CLAY	SANDY LEAN CLAY, GRAY, MEDIUM TO STIFF, WITH A TRACE TO A LITTLE GRAVEL	18-20

140-063-36ADB
NDSWC

Date Completed:	0	Purpose:	Observation Well
L.S. Elevation (ft):	1466.27	Well Type:	2" PVC
Depth Drilled (ft):	110	Aquifer:	Undefined
Screened Interval (ft):	91-96	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	SILTY, BLACK	0-1
CLAY	SILTY, GRAVELLY, YELLOWISH-BROWN, TILL	1-41
CLAY	SILTY, WITH A FEW ROCKS, OLIVE GRAY, TILL	41-91
GRAVEL	CLAY AND SAND	91-100
SAND	FINE TO MEDIUM-GRAINED, GRAY	100-110

140-063-36ADC
NDSWC

Date Completed:	10/23/90	Purpose:	Observation Well
L.S. Elevation (ft):	1463.59	Well Type:	2" PVC
Depth Drilled (ft):	76	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	65-75	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-0.33
CLAY	LEAN CLAY, GRAYISH BROWN TO LIGHT GRAYISH BROWN, RATHER STIFF TO VERY STIFF, WITH LENSES OF SILT, LARGE COBBLE OR BOULDER ENCOUNTERED AT 2.5'	0.33-4
CLAY	SANDY LEAN CLAY, GRAYISH BROWN TO DARK GRAYISH BROWN BELOW 20', VERY STIFF TO STIFF, WITH A TRACE OF GRAVEL	4-38
CLAY	SANDY LEAN CLAY, DARK GRAYISH BROWN, VERY STIFF TO STIFF, WITH A TRACE OF GRAVEL	38-50.5
CLAY	SANDY LEAN CLAY, GRAY, STIFF AND VERY STIFF, WITH A TRACE OF GRAVEL	50.5-73
CLAY	SANDY LEAN CLAY, GRAY, VERY STIFF TO STIFF, WITH A TRACE OF GRAVEL	73-76

140-063-36ADD1
NDSWC

Date Completed:	10/25/90	Purpose:	Observation Well
L.S. Elevation (ft):	1399.72	Well Type:	2" PVC
Depth Drilled (ft):	16	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	6-16	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL	LEAN CLAY, BLACK TO VERY DARK BROWN	0-1
CLAY	LEAN CLAY, GRAYISH BROWN, RATHER STIFF TO MEDIUM, WITH SEAMS OF SILT	1-7
CLAY	FAT CLAY, GRAYISH BROWN TO DARK BROWNISH GRAY MOTTLED, MEDIUM TO RATHER STIFF, WITH LENSES AND SEAMS OF SAND, COBBLES ENCOUNTERED AT ABOUT 11'	7-12
SILT	SANDY, GRAY, MEDIUM DENSE	12-16

140-063-36ADD2
NDSWC

Date Completed:	7/16/92	Purpose:	Test Hole
L.S. Elevation (ft):		Well Type:	
Depth Drilled (ft):	15		
		Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SILT	WITH COBBLES, DARK YELLOWISH-BROWN (10YR 4/2), (GLACIAL DRIFT)	1-7
SAND	FINE TO MEDIUM-GRAINED, SILTY, DARK YELLOWISH-ORANGE (10YR 6/6)	7-12
CLAY	SANDY, TRACE PEBBLES, MODERATE YELLOWISH-BROWN (10YR 5/4)	12-14
GRAVEL	PEBBLE AND COBBLE SIZE, WITH SAND, MODERATE YELLOWISH-BROWN (10YR 5/4), STOPPED DRILLING AT 15' BECAUSE IT WAS TOO ROCKY TO DRILL	14-15

140-063-36ADD3
NDSWC

Date Completed:	7/17/92	Purpose:	Observation Well
L.S. Elevation (ft):	1435.92	Well Type:	2" PVC
Depth Drilled (ft):	76	Aquifer:	Seven Mile Coulee
Screened Interval (ft):	64-74	Source:	
		Owner:	Jamestown

Lithologic Log

Unit	Description	Depth (ft)
TOPSOIL		0-1
SILT	WITH SAND AND GRAVEL, DARK YELLOWISH-BROWN 10YR 4/2, (GLACIAL DRIFT)	1-10
SAND	MEDIUM TO VERY COARSE-GRAINED, DARK YELLOWISH-ORANGE (10YR 6/6)	10-15
GRAVEL	PEBBLE SIZE, WITH SAND AND CLAY, DARK YELLOWISH-BROWN (10YR 4/2)	15-18
CLAY	TRACE SAND AND PEBBLES, DARK YELLOWISH-BROWN (10YR 4/2)	18-35
CLAY	TRACE SAND AND [EBBLES, MEDIUM BLUISH-GRAY (5B 5/1)	35-37
CLAY	TRACE SAND AND PEBBLES, OLIVE GRAY (5Y 4/1)	37-42
CLAY	TRACE SAND AND PEBBLES, DARK GREENISH-GRAY (5GY 4/1)	42-66
CLAY	SANDY, DARK GREENISH-GRAY (5GY 4/1)	66-72
SAND	SILTY, DARK GREENISH-GRAY (5GY 4/1)	72-76

APPENDIX D

WATER-LEVEL TABLES

Jamestown Water Levels
7/22/92 to 12/03/92

140-062-31ABB LS Elev (msl,ft)=1421.88
Midway Aquifer SI (ft.)=122-127

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/23/92	25.09	1396.79	09/16/92	25.32	1396.56
07/21/92	28.05	1393.83	10/15/92	24.46	1397.42
07/24/92	28.32	1393.56	11/09/92	23.87	1398.01
08/19/92	27.87	1394.01	11/11/92	23.83	1398.05
09/02/92	26.56	1395.32	12/03/92	23.53	1398.35
09/15/92	25.37	1396.51			

140-062-31BBA LS Elev (msl,ft)=1397.49
Midway Aquifer SI (ft.)=45-50

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
06/23/92	2.87	1394.62	09/16/92	2.76	1394.73
07/21/92	4.62	1392.87	10/15/92	2.64	1394.85
07/23/92	4.81	1392.68	11/09/92	2.03	1395.46
08/19/92	4.95	1392.54	11/11/92	1.95	1395.54
09/02/92	3.38	1394.11	11/19/92	2.04	1395.45
09/15/92	2.91	1394.58	12/03/92	1.90	1395.59

140-062-31BBA2 LS Elev (msl,ft)=1397.43
Seven Mile Coulee Aquifer SI (ft.)=10-15

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/25/92	3.53	1393.90	11/19/92	3.06	1394.37
10/12/92	3.89	1393.54	12/03/92	3.12	1394.31
11/11/92	3.06	1394.37			

140-062-31CBB1 LS Elev (msl,ft)=1386.94
Undefined Aquifer SI (ft.)=7-12

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/23/92	3.15	1383.79	09/02/92	0.73	1386.21
07/24/92	3.26	1383.68	09/15/92	1.54	1385.40
07/29/92	3.46	1383.48	11/11/92	1.36	1385.58
08/19/92	3.52	1383.42			

140-062-31CBB2 LS Elev (msl,ft)=1387.46
Undefined Aquifer SI (ft.)=31-41

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/23/92	3.45	1384.01	09/15/92	1.68	1385.78
08/19/92	3.76	1383.70	11/11/92	0.33	1387.13

09/02/92	1.32	1386.14	12/03/92	0.89	1386.57

140-063-36AAA2 LS Elev (msl,ft)=1414.41
Seven Mile Coulee Aquifer SI (ft.)=10-15

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	5.85	1408.56	09/15/92	3.10	1411.31
08/19/92	6.16	1408.25	11/11/92	4.05	1410.36
09/02/92	1.19	1413.22	12/03/92	4.30	1410.11

140-063-36AAA3 LS Elev (msl,ft)=1427
Seven Mile Coulee Aquifer SI (ft.)=17-21

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/25/92	10.69	1416.31	11/19/92	11.01	1415.99
10/12/92	10.86	1416.14	12/03/92	11.10	1415.90
11/11/92	10.96	1416.04			

140-063-36AAA4 LS Elev (msl,ft)=1427.22
Seven Mile Coulee Aquifer SI (ft.)=38-43

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
09/25/92	30.53	1396.69	11/19/92	30.24	1396.98
10/12/92	30.54	1396.68	12/03/92	30.19	1397.03
11/11/92	30.31	1396.91			

140-063-36AAB LS Elev (msl,ft)=1441.34
Undefined Aquifer SI (ft.)=30-50

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	35.05	1406.29	09/15/92	38.45	1402.89
08/19/92	35.72	1405.62	11/11/92	35.28	1406.06
09/02/92	40.94	1400.40	12/03/92	35.00	1406.34

140-063-36AAD LS Elev (msl,ft)=1410.04
Undefined Aquifer SI (ft.)=12-22

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	13.44	1396.60	09/15/92	19.58	1390.46
08/19/92	14.92	1395.12	11/11/92	18.28	1391.76
09/02/92	18.97	1391.07	12/03/92	17.78	1392.26

140-063-36ADA1 LS Elev (msl,ft)=1409.25
Undefined Aquifer SI (ft.)=20-30

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	13.64	1395.61	09/15/92	13.18	1396.07
08/19/92	13.94	1395.31	11/11/92	12.91	1396.34
09/02/92	13.39	1395.86	12/03/92	12.82	1396.43

140-063-36ADA2 LS Elev (msl,ft)=1409.34
Undefined Aquifer SI (ft.)=22-27

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	15.25	1394.09	09/15/92	15.45	1393.89
08/19/92	15.54	1393.80	11/11/92	15.23	1394.11
09/02/92	15.60	1393.74	12/03/92	15.11	1394.23

140-063-36ADA3 LS Elev (msl,ft)=1404.99
Undefined Aquifer SI (ft.)=34-39

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	10.07	1394.92	09/15/92	12.06	1392.93
08/19/92	12.30	1392.69	11/11/92	11.87	1393.12
09/02/92	12.24	1392.75	12/03/92	11.82	1393.17

140-063-36ADA4 LS Elev (msl,ft)=1404.95
Undefined Aquifer SI (ft.)=23-28

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	11.11	1393.84	09/15/92	11.35	1393.60
08/19/92	11.44	1393.51	11/11/92	11.13	1393.82
09/02/92	11.50	1393.45	12/03/92	11.01	1393.94

140-063-36ADA5 LS Elev (msl,ft)=1410.49
Undefined Aquifer SI (ft.)=10-20

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	12.65	1397.84	09/15/92	12.76	1397.73
08/19/92	12.82	1397.67	11/11/92	12.78	1397.71
09/02/92	12.89	1397.60	12/03/92	12.44	1398.05

140-063-36ADB LS Elev (msl,ft)=1466.27
Undefined Aquifer SI (ft.)=91-96

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	68.66	1397.61	09/15/92	68.14	1398.13
07/29/92	68.16	1398.11	11/11/92	67.45	1398.82
08/19/92	68.68	1397.59	12/03/92	67.40	1398.87
09/02/92	68.38	1397.89			

140-063-36ADC LS Elev (msl,ft)=1463.59

Undefined Aquifer SI (ft.)=65-75

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	62.37	1401.22	09/15/92	70.47	1393.12
08/19/92	62.35	1401.24	11/11/92	64.83	1398.76
09/02/92	71.00	1392.59	12/03/92	61.88	1401.71

140-063-36ADD1 LS Elev (msl,ft)=1399.72

Undefined Aquifer SI (ft.)=6-16

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/22/92	7.28	1392.44	09/15/92	5.49	1394.23
08/19/92	7.43	1392.29	11/11/92	6.61	1393.11
09/02/92	4.47	1395.25	12/03/92	6.34	1393.38

140-063-36ADD3 LS Elev (msl,ft)=1435.92

Undefined Aquifer SI (ft.)=64-74

Date	Depth to Water (ft)	WL Elev (msl, ft)	Date	Depth to Water (ft)	WL Elev (msl, ft)
07/21/92	38.47	1397.45	09/15/92	38.65	1397.27
08/19/92	38.07	1397.85	11/11/92	38.23	1397.69
09/02/92	38.83	1397.09	12/03/92	38.17	1397.75

APPENDIX E

MAJOR ION AND TRACE-ELEMENT CONCENTRATIONS

Jamestown Water Quality
Major Ion Analyses

Location	Screened Interval (ft)	Date Sampled	(milligrams per liter) SiO_2	Fe	Mn	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	NO_3	B	TDS	Hardness $CaCO_3$	as NCH	% Na	SAR	Spec Cond (µmho)	Temp (°C)	pH
140-062-31ABB	122-127	08/18/87	26	0.05	0.45	28	13	260	9.9	511	0	210	61	0.5	4.3	0.29	865	120	0	81	10			
140-062-31ABB	122-127	06/07/91	27	0.07	0.27	27	12	300	6.8	572	0	200	76	0.4	7.1	0.52	939	120	0	84	12	1572	10	
140-062-31ABB	122-127	07/23/92	29	0.05	0.2	30	12	300	7.6	563	0	220	75	0.4	5.8	0.41	957	120	0	83	12		9	7.67
140-062-31BBA	45-50	08/11/82	27	0.96	0.39	89	38	63	10	395	0	170	21	0.3	0	0.23	615	380	55	26	1.4	970	10	
140-062-31BBA	45-50	08/18/87	32	2.1	0.38	99	37	38	8.2	399	0	140	11	0.3	4.6	0.16	570	400	72	17	0.8			
140-062-31BBA	45-50	06/07/91	30	1.4	0.3	97	36	37	6.6	420	0	140	14	0.3	1	0.24	571	390	46	17	0.8	875	9	
140-062-31BBA	45-50	07/23/92	32	1.2	0.28	99	35	37	7.4	413	0	140	14	0.3	4.3	0.19	574	390	53	17	0.8		8	7.02
140-062-31BBA2	10-15	10/12/92	23	0.04	1	110	50	29	6.6	524	0	110	6.8	0.3	2.1	0.17	597	480	51	11	0.6	908	10	7.85
140-062-31CBB1	7-12	07/29/92	26	0.02	0.34	72	31	180	10	507	0	280	41	0.5	7.1	0.49	898	310	0	55	4.4		12	7.62
140-062-31CBB2	31-41	07/23/92	20	0.43	0.34	64	33	150	10	413	0	230	49	0.6	5.1	0.25	766	300	0	51	3.8		15	8.41
140-063-36AAA2	10-15	07/22/92	31	0.13	0.26	100	37	9	3.1	459	0	32	5.3	0.2	17	0.04	461	400	26	5	0.2		11	7.64
140-063-36AAA3	17-21	10/12/92	25	0.02	0.05	77	46	19	2.7	273	0	160	9	0.5	28	0.07	501	380	160	10	0.4	731	10	7.73
140-063-36AAA4	38-43	10/12/92	20	0.04	0.09	64	34	33	3.7	293	0	84	14	0.5	29	0.13	426	300	60	19	0.8	635	8	8.14
140-063-36AAB	30-50	07/22/92	23	0.07	2.5	600	130	40	16	534	0	1600	100	0.2	3.3	0.14	2780	2000	1600	4	0.4		11	6.81
140-063-36AAD	12-22	07/22/92	16	0.23	2.8	330	130	39	11	377	0	1100	17	0.2	1.4	0.26	1830	1400	1100	6	0.5		9	7.12
140-063-36ADA1	20-30	07/22/92	21	0.03	0.97	130	43	57	11	465	0	220	26	0.4	2.7	0.22	741	500	120	19	1.1		10	7.66
140-063-36ADA2	22-27	07/22/92	27	0.06	1.3	140	54	35	9.7	483	0	270	7	0.3	5.3	0.31	788	570	180	12	0.6		11	7.39
140-063-36ADA3	34-39	07/22/92	24	0.02	0.11	100	49	6	1.5	458	0	97	4.5	0.1	0.5	0.03	509	450	76	3	0.1		11	7.78
140-063-36ADA4	23-28	07/22/92	26	1.9	0.62	140	58	36	9.1	512	0	270	6.3	0.2	6.3	0.34	807	590	170	12	0.6		10	7.33
140-063-36ADA5	10-20	07/22/92	24	0.08	2.2	150	89	35	5.2	390	0	500	12	0.5	0.9	0.23	1010	740	420	9	0.6		8	7.55
140-063-36ADB	91-96	07/22/92	1.7	0.04	0.01	170	0	25	6.9	0	0	160	6	0.1	0	0.32	370	420	100	11	0.5		11	11.9
140-063-36ADB	91-96	07/29/92	29	0.18	0.28	98	40	31	8.7	359	0	200	5.9	0.2	7.8	0.29	598	410	120	14	0.7		11	8.05
140-063-36ADC	65-75	07/22/92	23	3	2.7	250	88	120	19	667	0	770	14	0.2	0.4	0.74	1620	990	440	21	1.7		9	6.96
140-063-36ADD1	6-16	07/22/92	26	2	0.51	120	50	90	9.1	504	0	290	20	0.3	4.4	0.38	861	510	92	28	1.7		9	6.93
140-063-36ADD3	64-74	07/21/92	25	0.04	0.62	180	59	82	17	474	0	480	17	0.2	0.1	0.43	1090	690	300	20	1.4		11	7.27

Trace Element Analyses

Location	Date Sampled	Selenium	Lead	Cadmium	Mercury	Arsenic	Molybdenum	Strontium
		(micrograms per liter)						
140-062-31ABB	7/23/92	1	0	0	0	3	5	300
140-062-31BBA1	7/23/92	2	0	0	0	7	2	720
140-062-31BBA2	10/12/92	2	0	0	0	12	11	720
140-062-31CBB1	7/29/92	0	0	0	0	5	15	560
140-062-31CBB2	7/23/92	0	0	0	0	3	16	510
140-062-36AAA2	7/22/92	4	0	0	0	1	5	290
140-062-36AAA3	10/12/92	3	0	0	0.1	2	20	310
140-062-36AAA4	10/12/92	3	0	0	0.1	1	16	300
140-062-36AAB	7/22/92	21	0	1	0	2	6	2000
140-062-36AAD	7/22/92	4	0	1	0	2	15	1600
140-062-36ADA1	7/22/92	0	0	0	0	5	10	840
140-062-36ADA2	7/22/92	0	0	0	0	1	12	850
140-062-36ADA3	7/22/92	0	0	0	0	0	0	200
140-062-36ADA4	7/22/92	0	0	0	0	5	2	970
140-062-36ADA5	7/22/92	1	0	0	0	0	17	720
140-062-36ADB	7/22/92	2	0	0	0	0	7	810
140-062-36ADB	7/29/92	0	0	0	0	2	4	810
140-062-36ADC	7/22/92	3	0	0	0	3	6	1700
140-062-36ADD1	7/22/92	0	0	0	0	2	7	860
140-062-36ADD3	7/21/92	0	0	0	0	8	15	1300

APPENDIX F

VOLATILE ORGANIC COMPOUNDS FOR WELL 140-063-36ADD1

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

APPENDIX G

VOLATILE ORGANIC COMPOUNDS FOR WELL 140-062-31CBB1

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