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DEPARTMENT OF WATER AND NATURAL RESOURCES
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SCOTLAND GASOLINE SPILL

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INTRODUCTION

A gasoline spill occurred at the Kronaizl Oil Company located at 840 Washington Street in Scotland, South Dakota, on February 24, 1983. Dan Kronaizl, owner, reported a loss of 2,085 gallons of Amoco regular gasoline from a hole in a rusted-out above ground storage tank. A total of 13 test holes were drilled in the area adjacent to the storage tank with observation wells installed in 9 of them. Casing top altitudes for the wells were determined by surveying and water level measurements were made on eight occasions. This report contains the findings and conclusions of an investigation conducted under the supervision of the South Dakota Geological Survey.

GEOLOGY

The City of Scotland is underlain by late Wisconsin age, light yellow-brown to dark olive-gray till. The till is calcareous, friable, locally sandy, and ranges in thickness from 50 to 90 feet. The bedrock units underlying the till, in descending order, are the Niobrara Formation, Codell Sandstone Member of the Carlile Shale, Carlile Shale, Greenhorn Limestone, Graneros Shale, Dakota Formation, and the Sioux Quartzite Formation (Christensen, 1963, 1974 and Jorgensen, 1971).

The four Scotland municipal wells are developed in the Codell Sandstone. According to Otto Bjorum, a local well driller, three of the wells are cased from land surface to the top of the Niobrara Formation below which uncased hole exists to the bottom of the Codell Sandstone. The other well is cased from land surface to the top of the Codell Sandstone below which uncased hole exists to the bottom of the Sandstone (personal communication, Otto Bjorum, April 2, 1983).

SUMMARY OF EVENTS

On the day of the gasoline spill, February 24, 1983, Mr. Kronaizl notified the Division of Water Quality of the State Department of Water and Natural Resources. The next day the South Dakota Geological Survey was contacted by the Division of Water Quality and asked to investigate. Two Geological Survey representatives, Assad Barari and the writer, visited the spill site and discussed evaluation and cleanup procedures with Mr. Kronaizl. Assad Barari reviewed the responsibilities of Kronaizl Oil Company and the responsibility and concerns of the State of South Dakota with regard to the evaluation and cleanup of the gasoline spill. It was recommended that the services of a private company that specializes in petroleum recovery be contracted to evaluate and conduct the cleanup operations. It was also emphasized that the Geological Survey staff would be available to provide any necessary consultation or technical help in the recovery operations. The names of several private companies were provided by

Dr. Barari. Mr. Kronaizl subsequently hired Mr. Peltier of Sioux Equipment Company of Sioux Falls, South Dakota.

Mr. Peltier visited the site around March 10, 1983, and recommended augering three 20-inch diameter holes to a depth of 10 feet near the spill site (fig. 1, test holes A1, A2, and A3). This work was completed on March 22, 1983, by Gene Bender, a private contractor, from Menno, South Dakota. For a period of several months after the holes were augered, Mr. Kronaizl reported that a combined total of 200 to 300 gallons of water was pumped from the holes every other day. However, no free gasoline was ever found in any of the holes.

On April 20, 1983, the site was inspected by the writer and having found no gasoline in the holes or nearby wells and no evidence of gasoline movement to nearby basements, it was decided to continue the pumping. On April 29, 1983, Mr. Kronaizl reported that no gasoline had yet been recovered, so it was recommended by the Geological Survey that more test holes be drilled in an attempt to locate the areal extent of the gasoline spill. Mr. Kronaizl made arrangements with Koranda Well Drilling for five more test borings. These holes were drilled on May 10, 1983, (fig. 1, test holes A4, A5, A6, A7, and A8) to a depth of 20 feet and left as open holes except for a short (approximately 0.5 feet) temporary surface casing.

The altitudes of the test hole sites were surveyed by Geological Survey personnel on May 26, 1983. It was also noted, at that time, that two of the holes (A5 and A8) were dry and the others showed no signs of gasoline except hole A6 which had a gasoline odor.

The holes were inspected again on May 31, 1983, and it was found that hole A7 had approximately one-eighth inch of free gasoline (measured with a sampling device) on top of the water. None of the other holes had any evidence of liquid gasoline, but a slight gasoline odor and a slight oil film was detected in holes A1, A3, and A5 (table 1).

A trench approximately 15 feet deep, 10 feet long, and 5 feet wide was dug next to hole A7 on June 3, 1983, and then enlarged to include hole A7 several days later. No water or gasoline entered the trench during or after excavation. On July 15, 1983, and September 6, 1983, Mr. Kronaizl reported by telephone that no change had occurred in the trench conditions.

On September 16, 1983, the area was again inspected and it was found that all holes installed for the investigation were dry except for A6 which may have contained surface runoff from a recent rain (table 1). Again, no evidence of gasoline odors were reported in basements or nearby domestic wells.

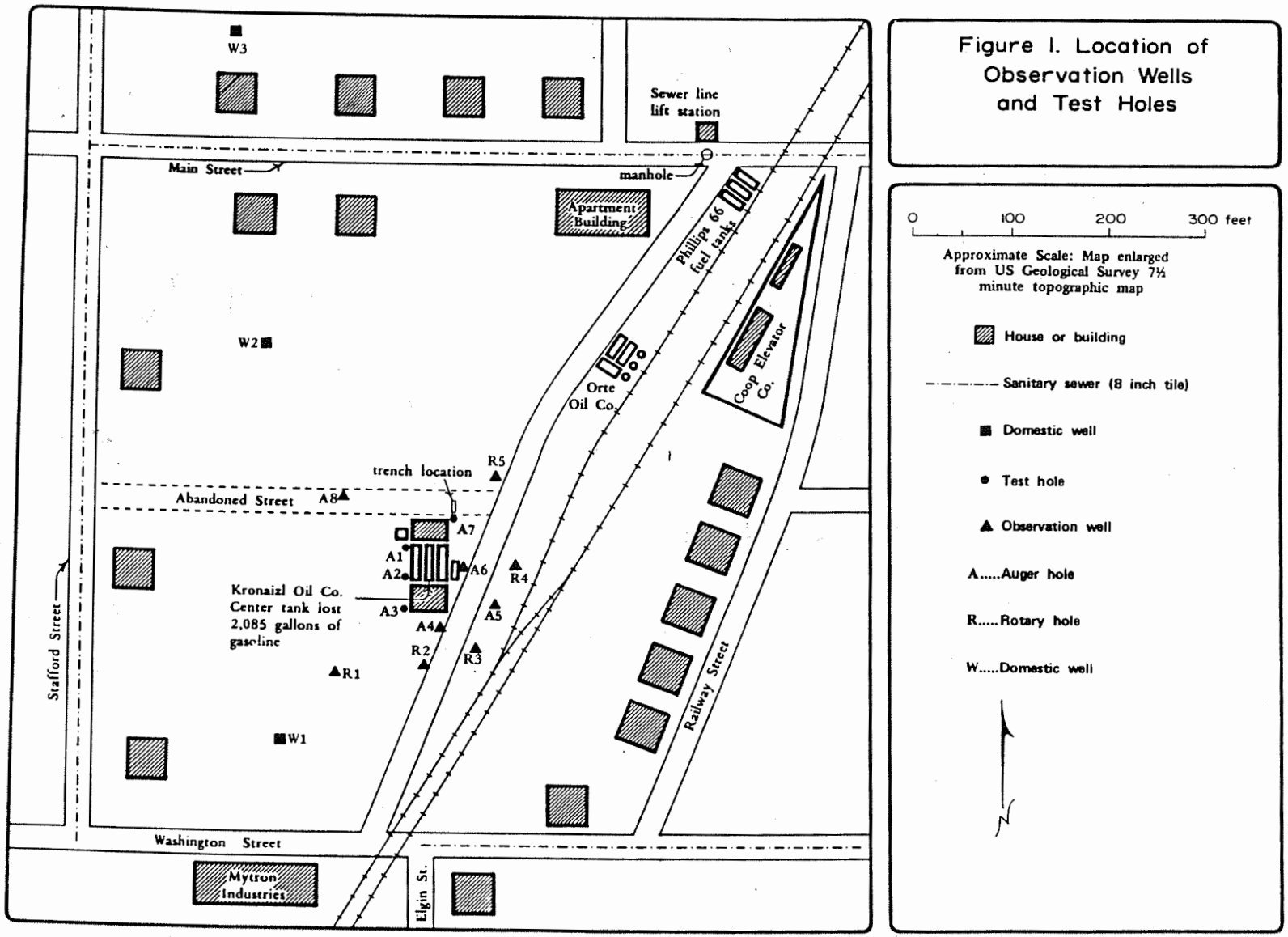

Figure 1. Location of Observation Wells and Test Holes

Table 1. Observation well depths, surveyed altitudes, water-level measurements, and indication of contamination.

Hole Number	Depth, in Feet	Measuring point above ground surface, in feet	Measuring point altitude, in feet	Depth to Water, in Feet							
				Apr. 21, 1983	May 9, 1983	May 31, 1983	Sept. 16, 1983	Nov. 3, 1983	Jan. 18, 1984	May 23, 1984	Aug. 16, 1984
A1	8.1*	0.0	1350**	4.00[1,2]	3.91[1,2]	5.52[1,2]	Dry[1]	Filled	–	–	–
A2	6.5*	0.0	1350**	3.56[1,2]	3.35[1,2]	5.15[1,2]	Dry[1]	Filled	–	–	–
A3	7.8*	0.0	1350**	4.42	5.15[2]	7.04	Dry	Filled	–	–	–
A4	13.4	2.0	1350.57	–	–	11.30	Dry	Dry	–	Dry	Dry
A5	13.9	2.0	1350.68	–	–	Dry[1]	Dry	Dry	–	13.70	Dry
A6	12.8	2.0	1350.49	–	–	8.16	8.60[1]	11.80[1]	–	6.10	7.40
A7	12.1*	0.0	1350.47	–	–	8.94[1,3]	Dry	Filled	–	–	–
A8	11.6	2.0	1350.38	–	–	Dry	Dry	Dry	–	7.50	10.10
R1	35.1	1.3	1350.43	–	–	–	–	–	32.23	21.72	20.40
R2	31.1	1.1	1349.58	–	–	–	–	–	30.50	22.90	21.95
R3	36.3	0.8	1349.43	–	–	–	–	–	36.35	20.40	21.50
R4	33.9	0.8	1349.21	–	–	–	–	–	24.78	13.90	16.30
R5	31.4	0.8	1348.76	–	–	–	–	–	25.20[1]	10.92	13.15[1]
W1	41.0	0.6	1350.48	31.90	31.00	31.20	30.10	31.10	32.60	26.70	24.30
W2	39.0	1.4	1349.35	26.30	28.30	29.10	30.10	39.80	31.80	25.60	25.40
W3	33.0	0.6	1348.52	11.60	12.60	16.40	20.10	32.40	24.30	8.10	10.30

*Test hole was not cased

**Altitude estimated from 7½ minute topographic map

[1] Gasoline odor present

[2] Oil film on water

[3] Free gasoline present on water

It was recommended that because the existing observation holes were dry it was necessary to install a minimum of four more observation wells at greater depths in order to monitor the water table. Subsequently, five observation wells were installed by Koranda Well Drilling on October 19-20, 1983 (fig. 1, test holes R1, R2, R3, R4, and R5, and app. A). The well driller reported the brief presence of a gasoline odor when R4 was drilled; otherwise, no evidence of gasoline contamination was reported.

During the last week in October, 1983, the trench was backfilled along with test holes A1, A2, and A3 since they represented a potential safety hazard to the local population. No evidence of gasoline was present in any when they were abandoned.

On November 3, 1983, the newly installed wells were surveyed by the Geological Survey. No evidence of gasoline was noted in any of the wells except for hole A6 which had a slight gasoline odor.

The wells were again checked for depth to water and presence of gasoline on January 18, May 23, and August 16, 1984, and no indication of gasoline was found except for well R5 which had a slight gasoline odor but no free gasoline. City of Scotland Water and Sewer official, Jim Sedlacek, was contacted and he related that no gasoline odors have ever been detected in the sanitary sewer system or water system. Likewise, residents nearest the gasoline spill had not experienced any unusual odors in their basements.

On August 20, 1984, open holes A4, A5, A6, and A8 were cased, gravel packed, and sealed. All wells that contained water were developed with a bailer and air in an effort to induce the flow of gasoline to the wells. No indications of gasoline were found except for a slight gasoline odor again in well R5. Finally, the wells were inspected on September 7, 1984, and no indication of gasoline contamination was found.

OBSERVATION-WELL CONSTRUCTION

Observation holes A1, A2, and A3 were drilled with a 20-inch diameter auger and were not cased. Holes A4, A5, A6, A7, and A8 were drilled with a 5-inch auger and left as open holes, except for surface casing that was installed, until August, 1984. They were then cased with 2-inch PVC casing joined by slip-fit, glued couplings with a cap on the bottom. Manufactured horizontal slots were located from 5 feet below the land surface to the bottom of the wells. The wells were gravel packed with concrete sand to 1 foot above the screen and then sealed with powdered bentonite to the ground surface. Wells R1, R2, R3, R4, and R5 (fig. 2) were drilled by the mud circulating rotary method with a 6.75-inch diameter bit and cased with 2.5-inch PVC casing joined by slip-fit glued couplings with a cap on the bottom. From 5 feet below the land surface to the bottom of the well, vertical overlapping

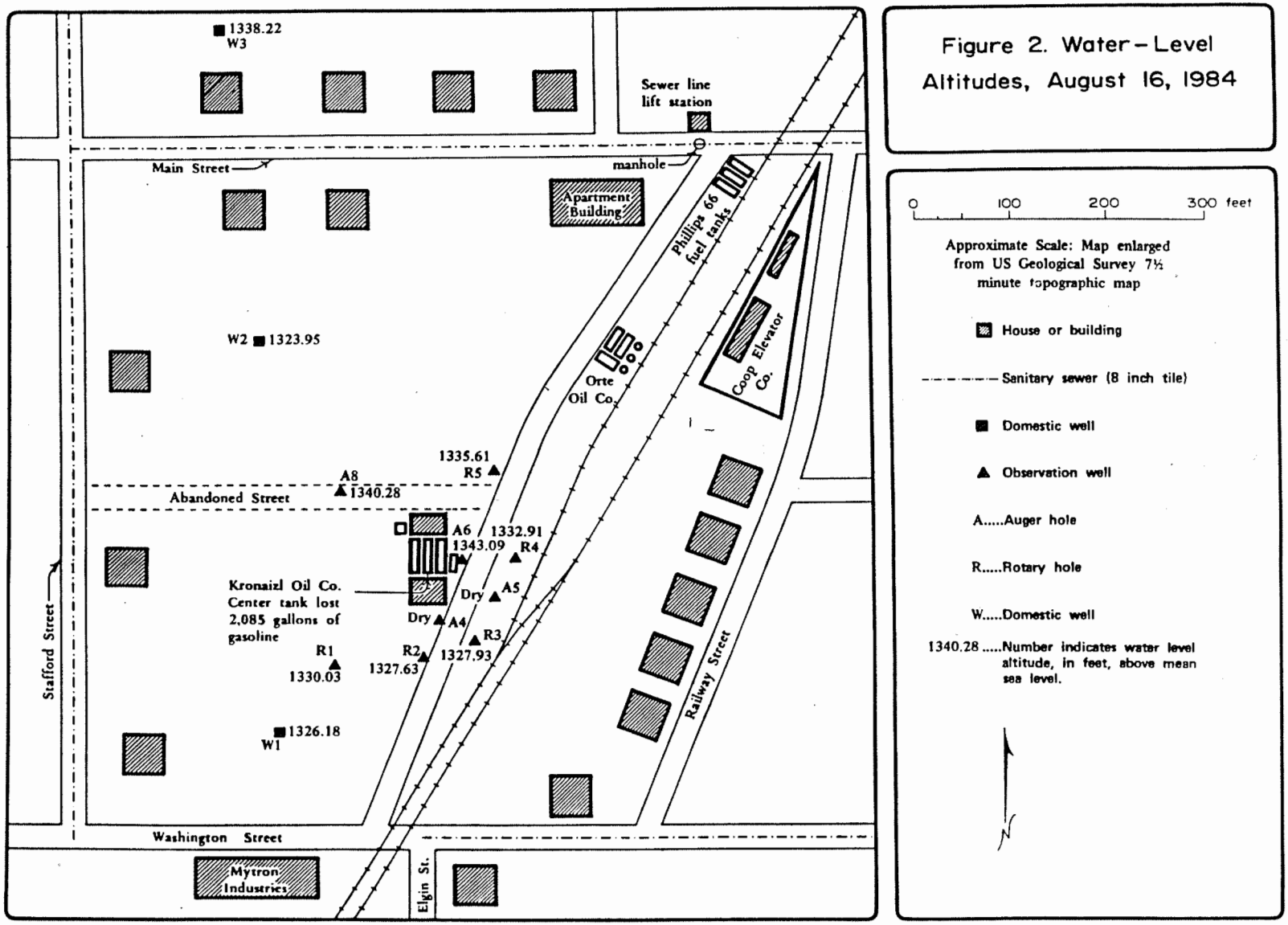

Figure 2. Water-Level Altitudes, August 16, 1984

slots were cut in the casing. These wells were also gravel packed to 1 foot above the slotted casing and then sealed with bentonite to the land surface. The wells were then evacuated with a cylinder pump to remove the drilling fluid.

HYDROGEOLOGIC EVALUATION

The depths to water were measured in the available observation wells a total of 8 times during the 21-month period following the gasoline spill. These data are shown on table 1. The water level altitudes for the observation wells on August 16, 1984 are shown on figure 2.

Local inconsistencies in the lithologic properties of till and the hydraulic conductivities make evaluation of the water-level altitudes difficult to interpret in terms of predicting which direction the contaminant would migrate. However, the general direction of ground-water movement appears to be from northwest to southeast in the area (fig. 2). Thus, the majority of the contamination would be expected to also move in that direction.

No free gasoline was encountered in any of the observation wells during the 21-month period of monitoring. As discussed in a previous section, one-eighth-inch of free gasoline was measured in a product sampling bailer in well A7. A trench next to the well yielded no free gasoline nor was water ever encountered in the trench which was maintained for a 5-month period. Apparently, the gasoline in observation well A7 was the result of movement along an individual fracture and represented only a small quantity of gasoline which was subsequently lost to evaporation in the trench.

The only other observation wells that suggested the presence of any contamination were A6 and R5 which had intermittent gasoline odors and R4 which emitted a brief odor when drilled. Auger holes A1 and A2 also exhibited an odor along with a black oily film. The water in these holes was evacuated for a period of several months and no free gasoline was ever recovered.

The movement of ground water through till deposits is at the present time under much scrutiny. Suffice it to say that till does not necessarily transmit ground water in the same fashion as do other porous granular mediums. It is instead suggested that most of the movement may occur along a system of fractures. Thus, it becomes extremely difficult to predict the lateral movement of the ground water and; therefore, gasoline on the surface of the ground water. The gasoline, except for the part that becomes immoblized by the sediments, follows the same path as the ground water. The immobilized gasoline will remain in the sediments for an extended period of time and is subject to movement after significant precipitation events occur. Microbial action will likely degrade portions of the gasoline over time.

Because no significant quantities of free gasoline have been encountered or recovered, and the amount lost to evaporation is assumed to be small, gasoline must still be in the ground. As the gasoline moves downward and laterally through the sediments toward the water table, small amounts are retained. Eventually, a point may be reached when all the gasoline may be retained by the sediments and will cease to migrate (except during periods of high precipitation and subsequent raising of the water levels). This is referred to as "exhaustion to immobility" by the American Petroleum Institute (1972). They present the following equation to calculate the amount of soil required to attain immobile saturation:

$$\text{cubic yards of soil required to attain immobile saturation} = \frac{0.20\ (\text{volume of oil in barrels})}{(\text{soil porosity})\ (\text{residual saturation})}$$

where

Vs = volume of soil required in cubic yards,
Vo = volume of oil in barrels
P = porosity of the soil
Sr = residual saturation

$$Vs = \frac{0.20\ (Vo)}{(P)\ (Sr)}$$

Assuming a soil porosity of 30 percent, a residual saturation of 0.10 (for gasoline), and volume of spill equal to 49.6 barrels (1 barrel = 42 gallons), then

$$Vs = \frac{(0.20)\ (49.6)}{(0.30)\ (0.1)}$$

$$Vs = 331 \text{ cubic yards} = 8936 \text{ cubic feet}$$

This demonstrates that the spilled gasoline may be immobilized to exhaustion in an area 30 feet by 30 feet of the spill site and 10 feet deep. The equation assumes a granular porous medium and does not represent conditions for flow through a fractured medium; however, as previously mentioned, fracture flow may be a component in the overall flow system. Thus, the figure calculated represents only an estimate of the immobilization potential.

CONCLUSIONS

It was reported by Dan Kronaizl that on February, 1983, 2,085 gallons of gasoline were spilled onto the ground from a leak in an above ground storage tank in Scotland, South Dakota. As of August, 1984, no significant quantities of gasoline have been recovered or located in observation wells around the site. Calculations using the American Petroleum Institute equation for

exhaustion to immobility indicates that the gasoline may be immobilized in the sediments immediately around the spill site, and therefore subjected to continuing biodegradation. Hence, the gasoline should not present any immediate hazard to the local population. It should be emphasized, however, that even though the gasoline has apparently been immobilized in the soil within the spill site area, precipitation events resulting in water percolating into the ground will cause portions of the gasoline to be released and it will mix with or migrate with the ground water. Therefore, during periods of high rainfall, the potential exists for the migration of either free gasoline or vapors into basements, sewer lines, or along any buried cables.

It is recommended that the observation wells be maintained and monitored periodically (especially during early spring and after major precipitation events) for the presence of gasoline. If gasoline is found in any of the observation wells, additional observation wells should be installed. Also, any potential buyer of the property should be made aware of the gasoline spill so that necessary precautions can be taken if any excavations are made on the site.

REFERENCES

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APPENDIX A

Well-Drillers Report

Location: 96N-58W-08accd

Project: Scotland Gasoline Spill

County: Bon Homme

Legal Location: SE SW SW NE sec. 8, T. 96 N., R. 58 W.

Land Owner: Dan Kronaizl

Driller: Koranda Well Company

Date Drilled: 10-25-1983

Drilling Method: Rotary

Hole Diameter: 6.75 inches

Ground-Surface Elevation: 1350 (from 7.5 minute topographic map)

Remarks: Six wells were drilled; five to 40 feet and one to 60 feet. Screen was 2.5-inch PVC with continuous vertical 0.125-inch slots from 5 to 40 feet. Bottom and top were capped. Pea rock from 5 to 40 feet, clay from 0 to 5 feet. Wells were pumped with a 2-inch cylinder pump. Static water level was 22 feet.

Depth, in feet	Drilling Log
0- 5	Topsoil and yellow clay
5- 60	Clay and gray shale