AN OPTIMAL SHALLOW DISPOSAL SITE AND FACILITY FOR HAZARDOUS WASTE IN KANSAS

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for the Master of Science degree in geology.

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ABSTRACT

Effective July 1, 1985, Kansas legislative policy will continue to permit the underground burial of toxic substances only as a final alternative in hazardous waste management. Section 2, T.13S., R.39W. is one of several optimal locations in central Wallace County that satisfies many criteria necessary for the safe, shallow disposal of any non-radioactive waste. This site is a topographic high underlain by about 40 feet of unsaturated loess and/or Ogallala sediments that must be removed to expose the Weskan member of the Pierre Shale. The approximate thickness of 300 feet and 70% total clay content suggest that the Pierre is well-suited for use as a waste repository at this site. The dry sub-humid climate and tectonic stability in northwest Kansas are conducive to shallow disposal practices. A well designed and managed facility includes leachate collection and monitoring systems and should provide future generations of Kansans with the most protection possible from any disposal methodology legal in the state.

ACKNOWLEDGMENTS

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INTRODUCTION

In 1979, 112 cattle on a Kansas farm were destroyed after being contaminated by waste oil used in animal backrubbers. The waste oil was purchased from a salvage yard that was contaminated by improper disposal of polychlorinated biphenols (PCBs). Products from 54 of the cattle were traced and properly disposed of (Environmental Protection Agency (EPA), 1980). Life-threatening incidents such as this are becoming more frequent and receiving increased attention as public outcry for hazardous waste management and environmental protection continues to mount; "Love Canal" and "Times Beach" have become dreaded words in each governor's vocabulary.

Kansas House Bill No. 2740 became law effective July 1, 1984, and defines hazardous waste as "...waste or combination of wastes which because of its quantity, concentration or physical, chemical, biological or infectious characteristics or as otherwise determined by the secretary (of health and environment) to cause, or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness; or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of or otherwise managed. Hazardous waste shall not include: 1) Household waste; 2) agricultural waste returned to the soil as fertilizer; 3) mining waste and overburden from the extraction, beneficiation and processing of ores and minerals, if returned to the mine site; 4) drilling fluids, produced waters and other wastes associated with the exploration, development and production of crude oil, natural gas or geothermal energy; 5) fly ash, bottom ash, slag and flue gas emission control wastes generated primarily from the combustion of coal or other fossil fuels; 6) cement kiln dust; or 7) materials listed in 40 CFR 261.4, as in effect on July 1, 1983."

In this text, I further delineate hazardous waste as chemical products and by-products that have known mutagenic, carcinogenic, or acutely toxic properties, and are generated by manufacturing industries, pesticide applicators, governmental agencies, academic institutions, and hospitals. These wastes may usually be segregated as homogeneous solids, semi-solids, liquids, or contained gasses at the site of generation and generally do not degrade into less toxic compounds under normal conditions. Kansas industry produces between 0.5% and 2.0% of the nation's hazardous waste volume (EPA, 1980), or between about 0.3 million and 5.0 million metric tons annually. EPA (1980) estimates suggest that 10% of all hazardous waste generated in the United States is properly disposed of; over 200 uncontrolled, contaminated dump sites in Kansas qualify for the Hazardous Waste Cleanup Fund under House Bill No. 2726, also enacted in 1984. A list of hazardous compounds found in a typical industrial landfill is provided in Table 1.

TABLE 1

Contents of drums placed in a typical industrial landfill.

(From Anderson and others, 1982)

Dibromo propanol
Methylene chloride bottoms
Pesticides
PCB waste
Oil sludge
Chlorinated still bottoms
Ink sludge
Tank sludge
Organic residues
Laboratory chemicals
Sulfonated still bottoms
Heavy metal sludge
Chlorinated solvent sludge
Mixed solvents
Plating sludge
Acetic acid sludge
Grinding oil sludge
Chlorinated organic residues
Urethane laquer
Toluene still bottoms
Methanol slurry
Phenol tar sludge
Contaminated fuel oil
Glycol waste
Heat transfer oil sludge
Freon bottoms
Oil and grease sludge
Benzyl alcohol bottoms
Chlorinated xylene sludge
Perchlor bottoms
Waste solvents
Fuel oil sludge
Mercury filter press sludge
Phenol sludge
Methyl chloroform bottoms
Fractional bottoms

Kansas legislation permits the secretary of KDHE to authorize the underground burial of toxic substances only as a final alternative in hazardous waste management. Currently, there are no licensed hazardous waste disposal facilities in Kansas. A privately operated facility near Furley (N½ SW¼ section 26, T.25S., R.5E., Sedgwick County) was closed in 1981 after State Geological Survey investigators discovered contaminated ground water and determined the site was geologically unfit for hazardous waste disposal. It appears that the only criterion used to locate the Furley facility was the availability of land (Wilson, written testimony, 1983).

The primary objective of any disposal facility is isolation and protection of buried contaminants from surface and ground water. The technology for safe, shallow disposal begins with the selection of a geologically compatible site. Trenches must be excavated (about 50 feet deep) in a suitable rock formation. Should any leachate escape a properly designed and managed facility, the goal is to minimize the flow rate while maximizing toxic attenuation of percolating fluids (Cartwright and others, 1982).

OBJECTIVES AND METHODS

The objectives of this research are: 1) to identify an optimal location in Kansas (defined to the section, township, and range) suitable for shallow, long-term containment of hazardous, non-radioactive waste; 2) to suggest trench design, leachate collection and monitoring systems; 3) to maintain harmony with local land use at this site. Many emotional, political, and legal aspects of hazardous waste management in Kansas continue to be argued. This study was conducted independent of such concerns.

In the course of this research I utilized maps, well logs, and the geologic literature. The study began with a statewide elimination process based on seismic risk and climate. As favorable regions became apparent, compatible shallow lithostratigraphy, natural hazards, local mineral production, and proximity to communities and thoroughfares were examined. It must be noted that no established formula was used to evaluate this myriad of concerns. Subjective, but seemingly optimal, decisions were made after reviewing the pros and cons of interrelated considerations that cannot all be ideal in any single location. As a result, several locations probably satisfy the criteria outlined in this text and may be as overall suitable as the proposed site for safe, shallow hazardous waste burial. A low altitude aerial reconnaissance flight confirmed the final suitability of the proposed site.

Aspects of engineering geology that were considered at this site include necessary geotechnical surveys, design of a below-ground facility, potential waste-earth and waste-waste interactions and management of such concerns, and environmental monitoring systems.

CONCLUSIONS

The results of this study suggest that section 2, T.13S., R.39W., Wallace County is an optimal location in Kansas for the safe, shallow disposal of any non-radioactive waste (Figures 1 - 3).

The proposed site is a topographic high underlain by about 40 feet of unsaturated loess and/or Ogallala sediments that must be removed to expose the erosional surface of the Weskan member of the Pierre Shale. The 70% total clay composition and approximate thickness of 300 feet of shale below the site suggests that the Pierre is well-suited for use as a waste repository. Should any leachate escape a properly designed and managed facility, the character of the Pierre will incorporate low hydraulic conductivity (about 10^{-10} cm/sec) with the attenuation of percolating contaminants. The close proximity of the site to US-40 highway and the Union Pacific Railroad minimizes the risk of a catastrophe involving the transportation of hazardous materials from these thoroughfares to the site. Local residents and the citizens of Wallace City should not be threatened by this site location owing to the stratigraphic relations in the area and the hundreds of thousands of years required for an increasingly dilute leachate to migrate through the Pierre.

Unavoidable natural hazards that present risk to a disposal facility located anywhere in Kansas include lightning strikes, hail damage, rainstorms, tornadoes,

Figure 1

Wallace County, Kansas.

(Kansas base map from Buchanan and Steeples, 1980)

(County map from Kansas Highway Department, 1965)

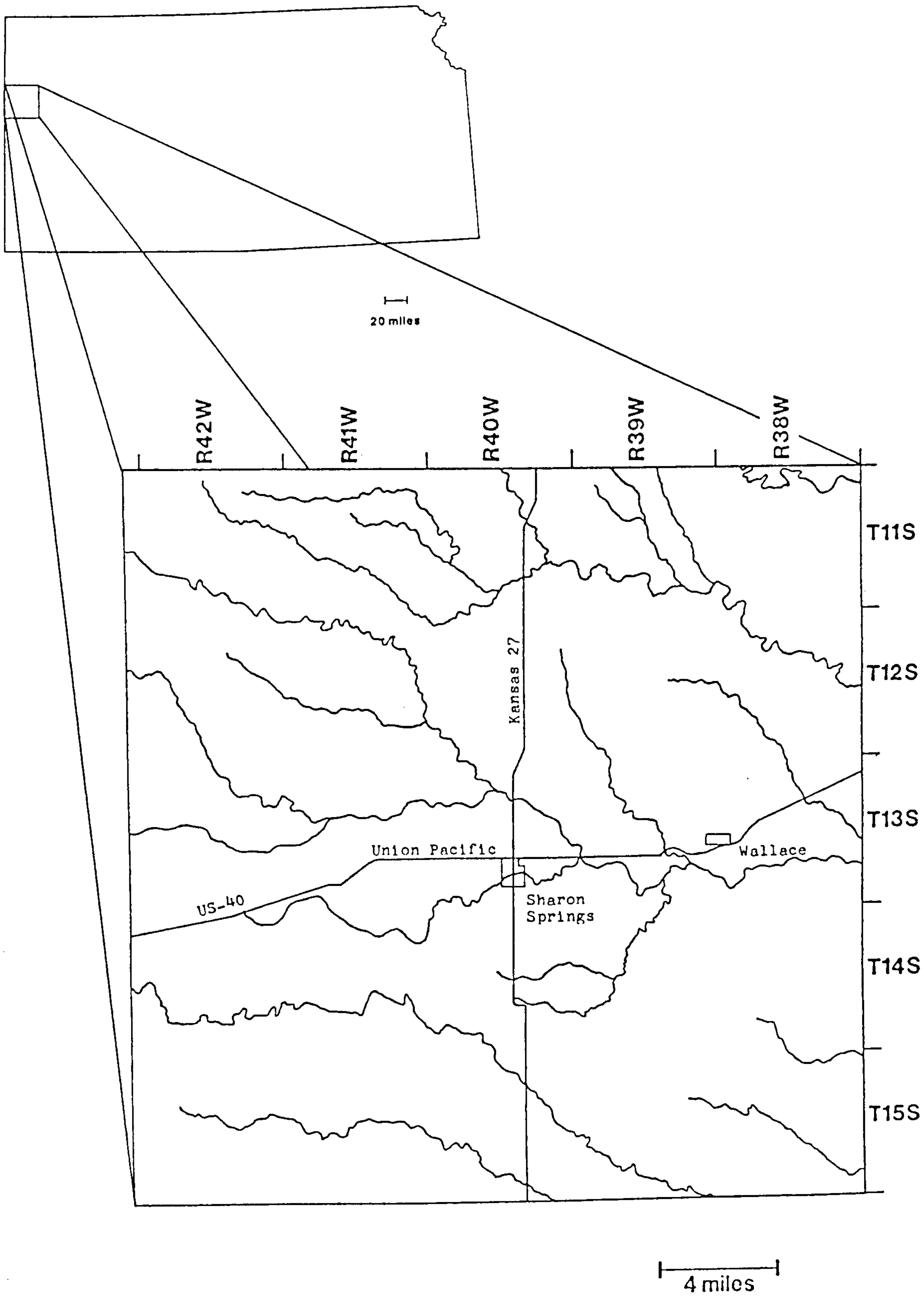

20 miles
R42W
R41W
R40W
R39W
R38W
T11S
T12S
T13S
T14S
T15S
Kansas 27
Union Pacific
Wallace
US-40
Sharon
Springs
4 miles

Figure 2

Drainage north of Wallace City.

(From Wallace Quadrangle,
U.S.G.S. 15 minute series, 1959)

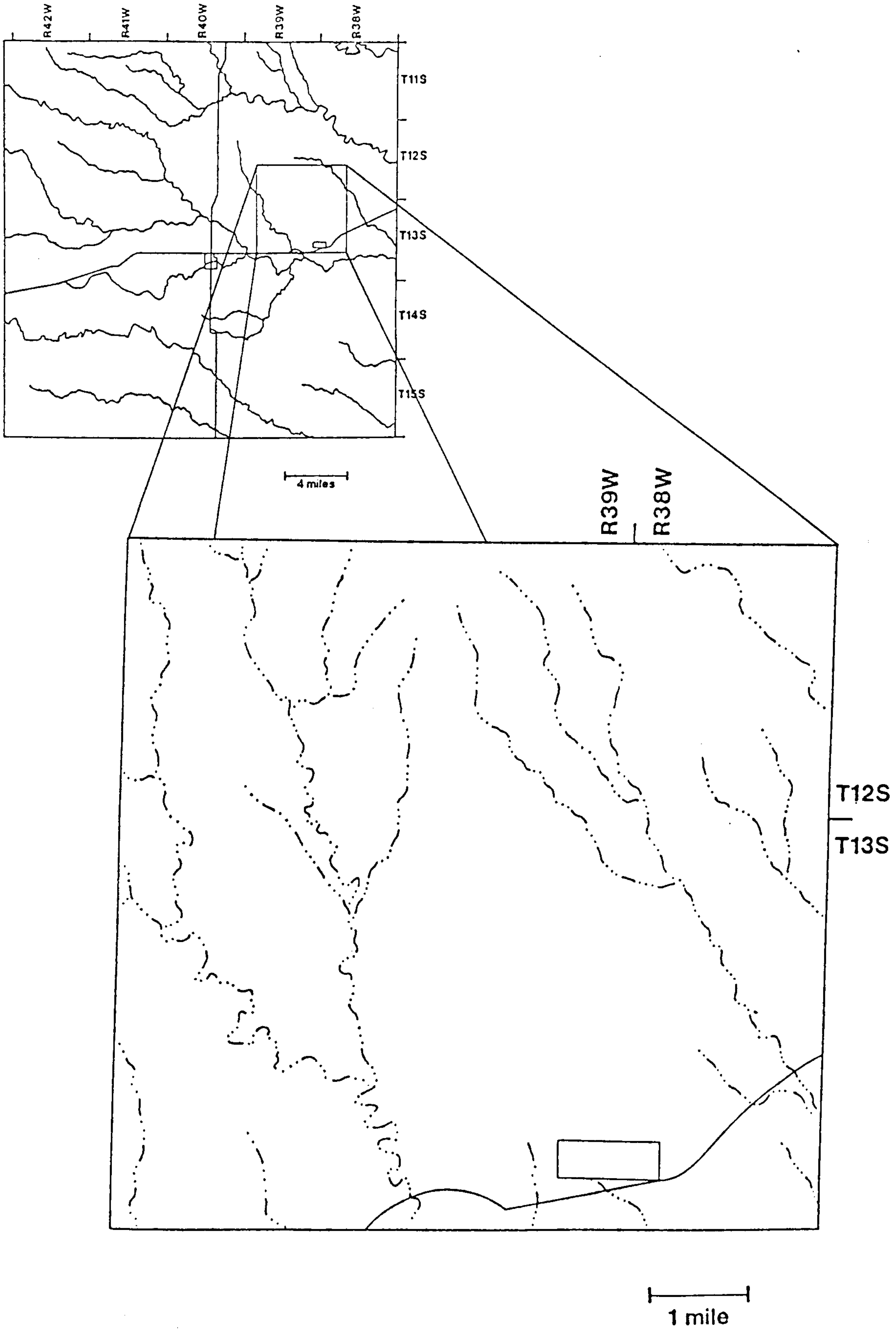

R42W
R41W
R40W
R39W
R38W
T11S
T12S
T13S
T14S
T15S
4 miles
R39W
R38W
T12S
T13S
1 mile

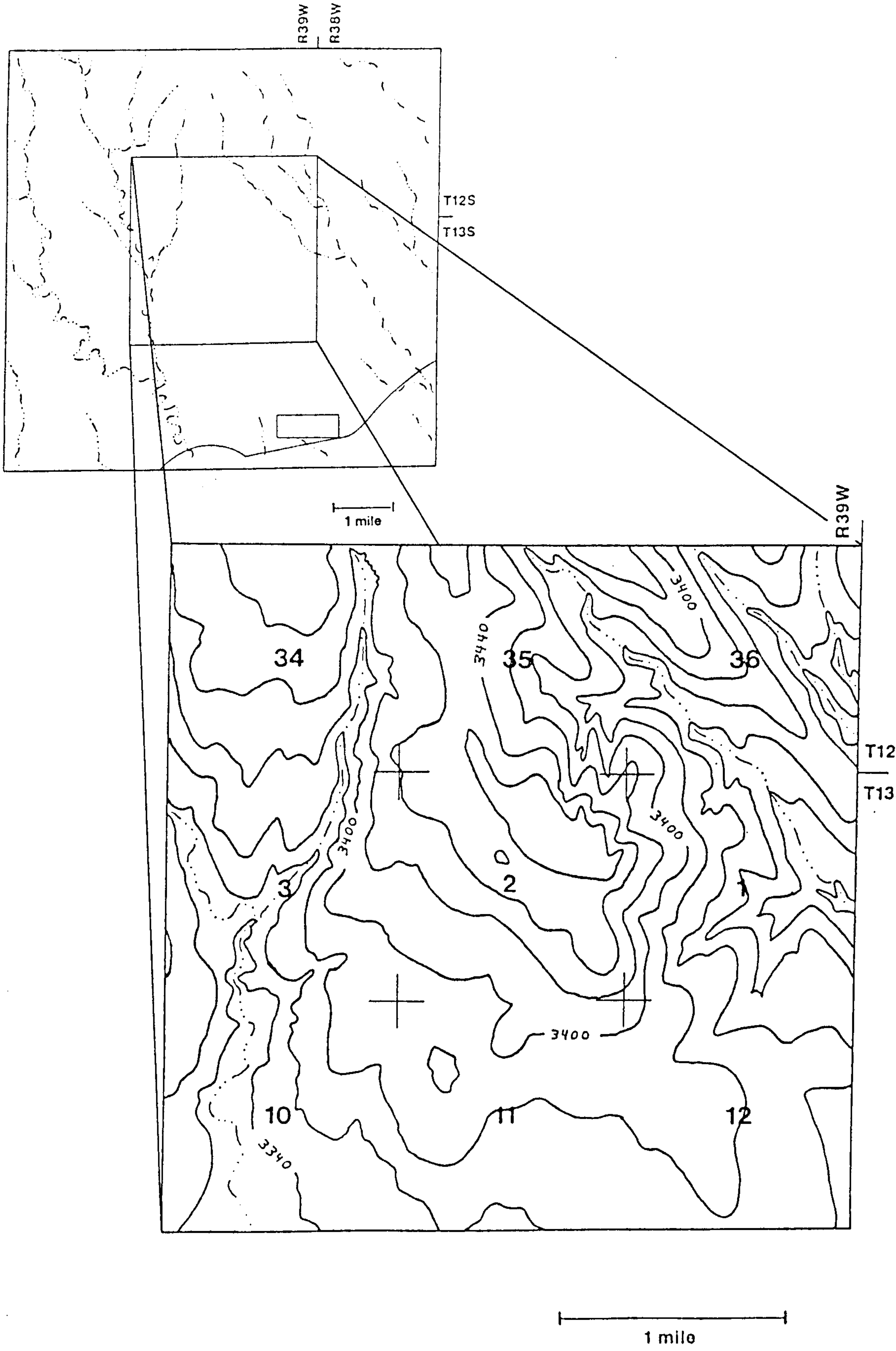
Figure 3

Section 2 T. 13S. R. 39W.

Contour interval 20 feet.

(From Wallace Quadrangle,

U.S.G.S. 15 minute series, 1959)


R39W
R38W
T12S
T13S
1 mile
R39W
34
35
36
3440
3400
T12S
T13S
3400
3400
3
2
1
3400
10
11
12
3340
1 mile

acute winter weather, and drought. Ground water from Lower Cretaceous rocks (e.g. Dakota Formation) occurs some 1400 feet below the surface and may be used, if necessary, to stabilize a final vegetative cover and provide water to wash equipment, flush tank trucks, and other industrial uses. The remote chance for collapse or subsidence under the site is compensated for by the substantial thickness of non-calcareous Pierre that will separate the bottom of the proposed trenches from the top of the Niobrara Chalk. No record of any hole drilled in this section was found, although abandoned oil wells are located within several miles of the site and should be worked over, if necessary, to assure that they are properly plugged.

Precipitation in the dry sub-humid climate of Wallace County likely will not exceed the moisture capacity of surface materials and permit infiltration into buried disposal trenches. Northwest Kansas appears to lack any earthquake-prone structure and presents the lowest overall seismic risk in the state.

Seismic reflection and refraction profiles should be obtained to determine the local dip of the beds and if any faults are present below the site. Core samples should be analyzed in the laboratory for hydraulic conductivity, shrink-swell potential, waste-earth interactions, and other pertinent geotechnical data. Field permeameters should be installed to determine *in situ* hydraulic conductivity of various horizons at several locations.

Trench design should include tile-lined trench bottoms, leachate collection, compacted clay liners, activated charcoal layers, and low permeability caps. The only leachate likely to be generated will be derived from precipitation that falls directly into an open trench. This finite volume of potential leachate will, in accordance with the volume of waste to be buried, determine the dimensions of the trenches and the leachate collection tank. If this entire volume of leachate were to escape the facility, percolating solutions will become increasingly dilute as they migrate hundreds of feet vertically and thousands of feet horizontally through adsorbant Pierre clays before ever becoming a potential problem. Smectites should swell when saturated and retard leachate migration along fractures, bedding planes, and other features. Heavy metals, organics, and incompatible wastes should be segregated before burial to allow more control in analyzing potential waste-earth and waste-waste interactions.

Permanent monitoring systems must evaluate the vertical and horizontal migration of contaminants by core samples and well samples routinely taken equidistant from one another and the center of the facility. Perennial Buffalo grass is indigenous to the High Plains and should be considered for use as a vegetative cover, routinely analyzed for plant uptake, and not permitted to enter the food chain. Only sampling wells and monitoring checks should be permanently foreign to the landscape.

The proposed site was selected in order to minimize the damage that may result if a facility were to completely fail, but a costly cleanup may eventually become necessary if stringent geological, constructional, and operational guidelines are not followed. However, the disposal alternatives to shallow burial that are currently legal in Kansas seem to present higher short and long term risk than disposal by containment and isolation in a suitable environment.

TECTONIC SETTING AND SEISMIC RISK

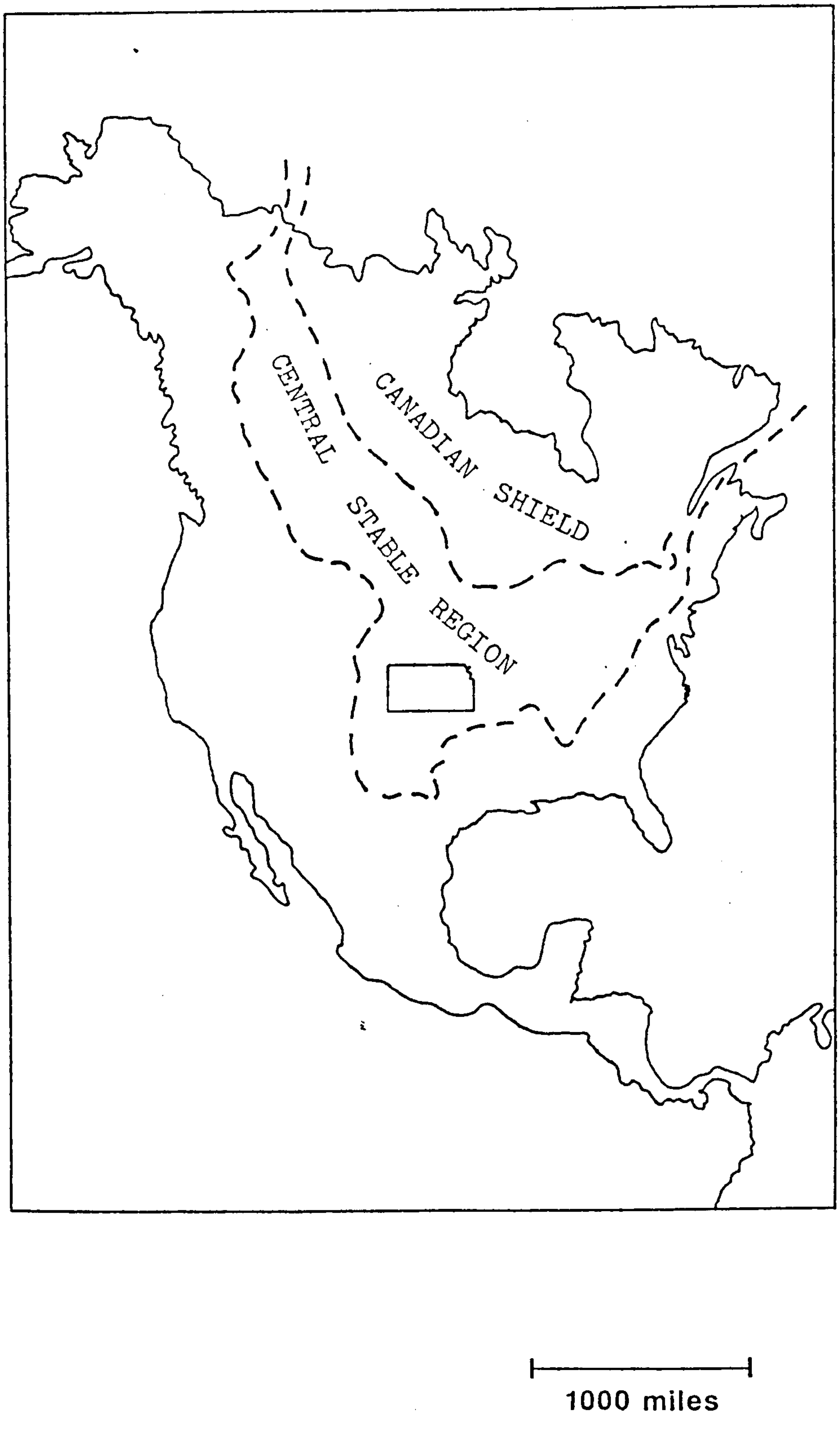
Tectonic stability and minimum siesmic risk are essential in locating a permanent disposal facility. Potential hazards from surface, compressional, and shear wave energies include deformation of trench construction and leachate collection systems, increased permeability of the surrounding earth material by fracture, and change in direction of surface and ground water flow.

Kansas is located on a stable buried southern extension of the Canadian Shield (Merriam, 1963, and Figure 4). The geology is characterized by marine shelf deposits up to 9500 feet in thickness resting non-conformably on crystalline Precambrian basement rock. Although the gentle structure and monotonous stratigraphic succession imply tectonic stability since Precambrian time (Merriam, 1963), 24 earthquakes with epicenters in Kansas have been reported since 1811, and at least 17 others have been felt within

Figure 4

Geologic setting of Kansas.

(From Merriam, 1963)


CENTRAL STABLE REGION
CANADIAN SHIELD
1000 miles

the state (Cole and Van Sickel, 1977). Dubois and Wilson (1978) reported that intensities of events originating in Kansas ranged from Modified Mercalli (MM) II (1903, Douglas County) to MM VIII (1867, near Manhattan) (Table 2). Merriam (1963) reported that focal depths for these earthquakes ranged from approximately 16 to 38 miles, such that the hypocenters were above the Mohorovicic discontinuity within the granitic crust. The relationship between basement structure and epicenter location is well-known (Figure 5). The epicenters of 60 microearthquakes, generally less than Richter magnitude 3.0, were recorded in Kansas from 1977 to 1980 and suggest that tectonic forces continue to affect the state (Buchanan and Steeples, 1980). One cause for these microearthquakes could be the substantial volumes of fluids withdrawn from densely drilled areas which must reduce pore pressures and may promote collapse or slippage along faults that extend into the granite basement. Produced brines that have cooled at the surface, then injected under pressure into formations often deeper than those from which they were removed, may cause contraction and fracture at the warmer, deeper zone of emplacement and promote earth movement (Callahan, 1971). Such may be the case in many Kansas oilfields where Pennsylvanian brines are disposed into Cambro-Ordovician rock and thereby present increased risk to otherwise stable areas.

TABLE 2

Modified Mercalli Intensity Scale of 1931.

(Adapted from Dubois and Wilson, 1978)

I. Not Felt. Marginal and long-period effects of large earthquakes.

II. Felt by persons at rest, on upper floors, or favorably placed.

III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. May not be recognized as an earthquake.

IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Wooden walls and frame creak.

V. Felt outdoors, direction estimated. Sleepers awakened. Liquids disturbed. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Furniture moved or overturned. Trees, bushes shaken.

VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Weak chimneys broken at roof line. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII. Steering of motor cars affected. Fall of some masonary walls. Twisting, fall of chimneys, factory stacks, towers, elevated tanks. Frame houses moved on foundation if not bolted down. Changes in flow or temperature of springs and wells. Cracks in wet ground.

IX. General panic. Ordinary workmanship masonary heavily damaged. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.

X. Most masonary and frame structures destroyed with their foundations. Serious damage to dams, embankments. Large landslides. Rails bent slightly.

XI. Rails bent greatly. Underground pipelines out of service.

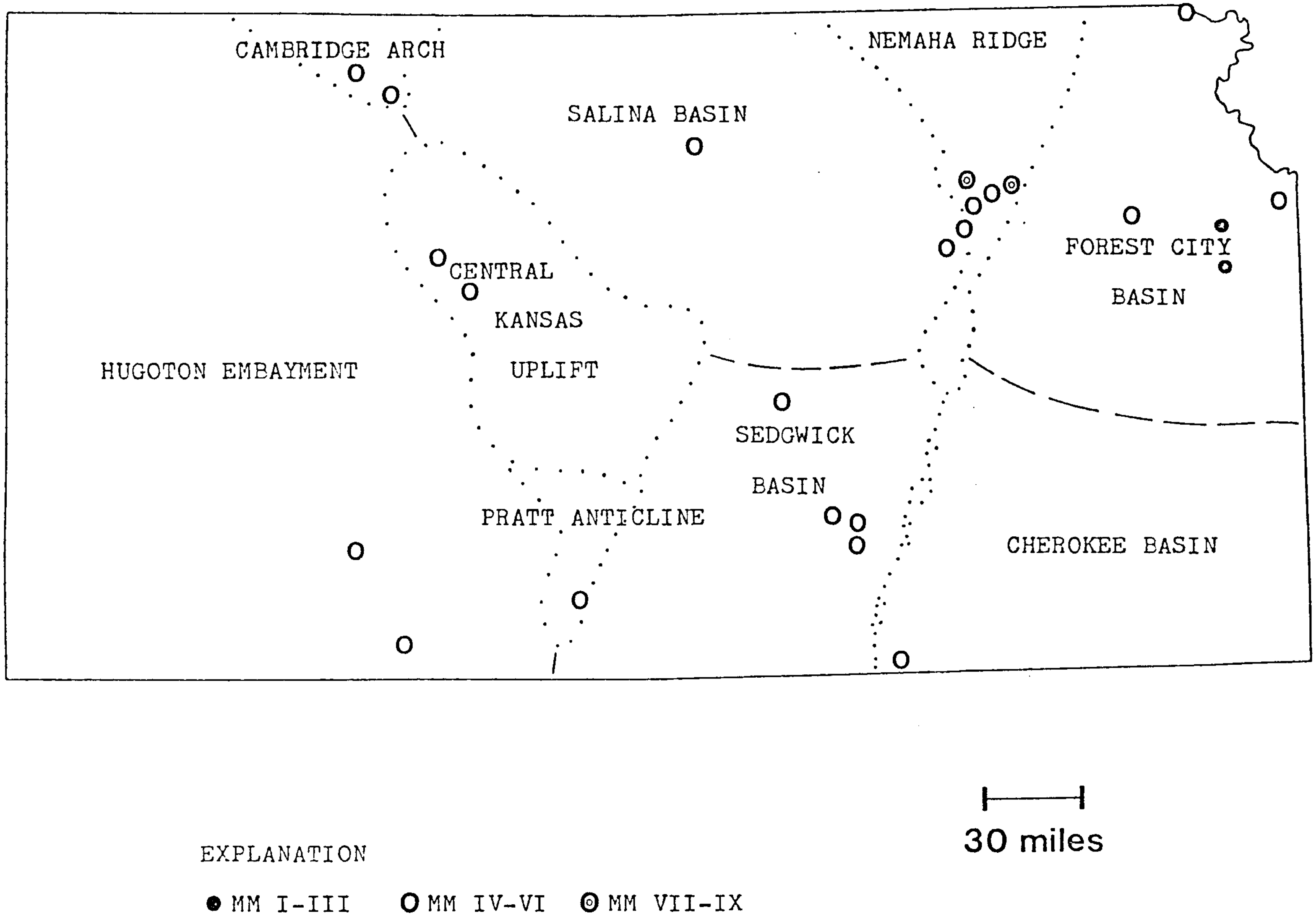
XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Figure 5

Intensities and locations of earthquakes since 1867 with epicenters in Kansas in relation to basement structure.

(Basement structure map from Merriam, 1963)

(Intensities and locations from Dubois and Wilson, 1978)


CAMBRIDGE ARCH
NEMAHA RIDGE
SALINA BASIN
CENTRAL KANSAS UPLIFT
FOREST CITY BASIN
HUGOTON EMBAYMENT
SEDGWICK BASIN
PRATT ANTICLINE
CHEROKEE BASIN
30 miles
EXPLANATION
● MM I-III
O MM IV-VI
◎ MM VII-IX

Eastern Kansas presents the highest seismic risk in the state. The frequency and intensity of earthquakes along the Nemaha Ridge suggests that this feature is tectonically active (Merriam, 1963). High angle normal and reverse faulting have been proposed by numerous investigators; subsurface throws over 1000 feet have been mapped by drilling and geophysical techniques (Fuller, personal communication, 1984). Mineral production and drilling activity along the Nemaha Ridge presents increased risk to an already earthquake-prone area. The active Humboldt Fault Zone borders the Nemaha Ridge to the east near the Nebraska border, and contributes to the elevated seismic risk of eastern Kansas (Dubois and Wilson, 1978).

The deeply buried Midcontinent Geophysical Anomaly (MGA) is a failed rift zone dated over 1 billion years, and trends from central Kansas north to Lake Superior (Buchanan and Steeples, 1980). The margin of the MGA parallels the west flank of the Nemaha Ridge and was probably influential in the MM VII (1906) and MM VIII (1867) events* near Manhattan (Steeples and Stander, 1977). Buchanan and Steeples (1980) reported that a flurry of microearthquakes, including a magnitude 3.1 event that was the first felt by Kansans in 19 years, was probably associated with the northwest flank of the MGA. Long faults occur where younger igneous rock is adjacent to older rock and presents seismic risk along the MGA from central Kansas

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*Intensities modified by Dubois and Wilson, 1978.

to the Great Lakes (Steeples and Stander, 1977).

Since 1867, seismicity associated with the Central Kansas Uplift and adjacent structures has been less frequent and less intense than seismicity along the MGA and Nemaha Ridge. However, the occurrence of previous earthquakes, known faults, and dense mineral exploitation along central Kansas structure presents increased risk to the central third of the state. Lubrication of existing faults by secondary oil recovery methods is believed to have triggered microearthquakes along the Cambridge Arch in southwest Nebraska near a large oilfield (Buchanan and Steeples, 1980).

The geologic literature suggests that western Kansas lacks earthquake-prone basement features and, therefore, is considered the most tectonically stable region in the state. Although numerous shallow faults have been mapped throughout western Kansas, particularily in the Niobrara Chalk, these features show no preferential trend and are believed to result from solution of the buried Niobrara and subsequent slumping of overlying beds (Merriam, 1963). These faults do not appear related to the tectonic framework of western Kansas.

The high density of production from the massive gas fields in the southern Hugoton Embayment presents increased risk to southwest Kansas. The low density of shallow gas and other hydrocarbon production in northwest Kansas presents the lowest risk increase in all of stable western

Kansas due to mineral exploitation. Northwest Kansas is also located equidistant from the troublesome New Madrid Fault Zone (Missouri-Illinois) and Wasatch Fault Zone (Utah) and should experience minimum repercussions if either of these high risk areas produce a sizeable earthquake (Figure 6).

These factors suggest that northwest Kansas presents the lowest overall seismic risk of any area in the state.

CLIMATE

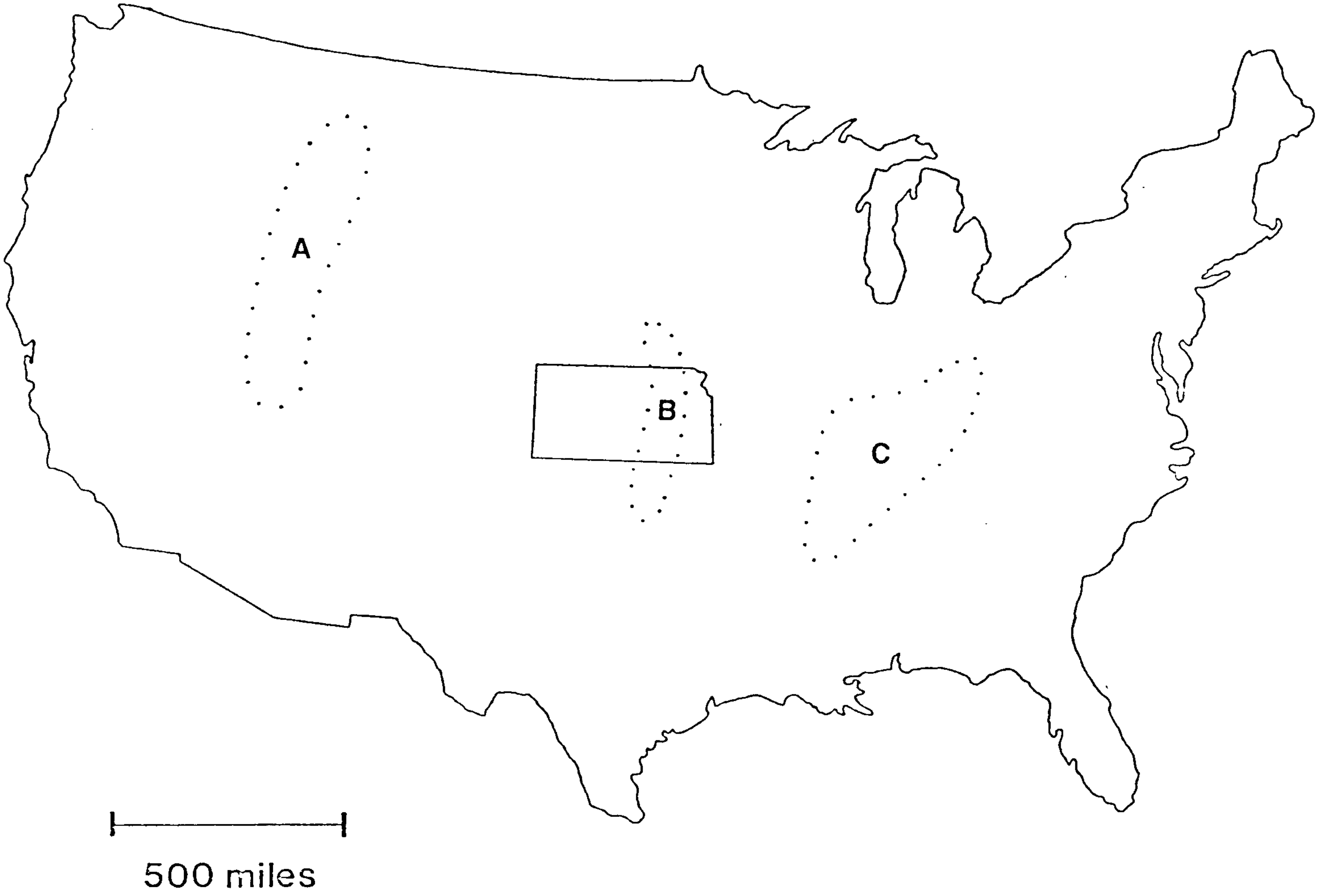
The effect of climate on any landfill is marked. Humid climates generally produce more precipitation than soil and vegetative cover can incorporate, the net result being percolation below the soil horizon and generation of leachate from a buried disposal facility. Where rock of low permeability or synthetic membrane liners underlie landfills in humid climates, effluent streams of leachate can occur when infiltration exceeds the moisture capacity of both the soil cover and compacted fill material and overflows from the site, a phenomena known as "the bathtub effect" (Cartwright and others, 1981). Sub-humid, semi-arid, and arid climates generally have amounts of precipitation that are less than the moisture capacity of surface materials and little, if any, infiltration occurs below the soil horizon.

Robb (1959) provided an excellent summary of climate in Kansas. A condensed version of this summary follows:

Figure 6

Map of conterminous U.S. showing two areas of high probability for earthquakes: A, Wasatch Fault Zone; C, New Madrid Fault Zone; and one of moderate probability: B, Nemaha Ridge.

(From Dubois and Wilson, 1978)


A
B
C
500 miles

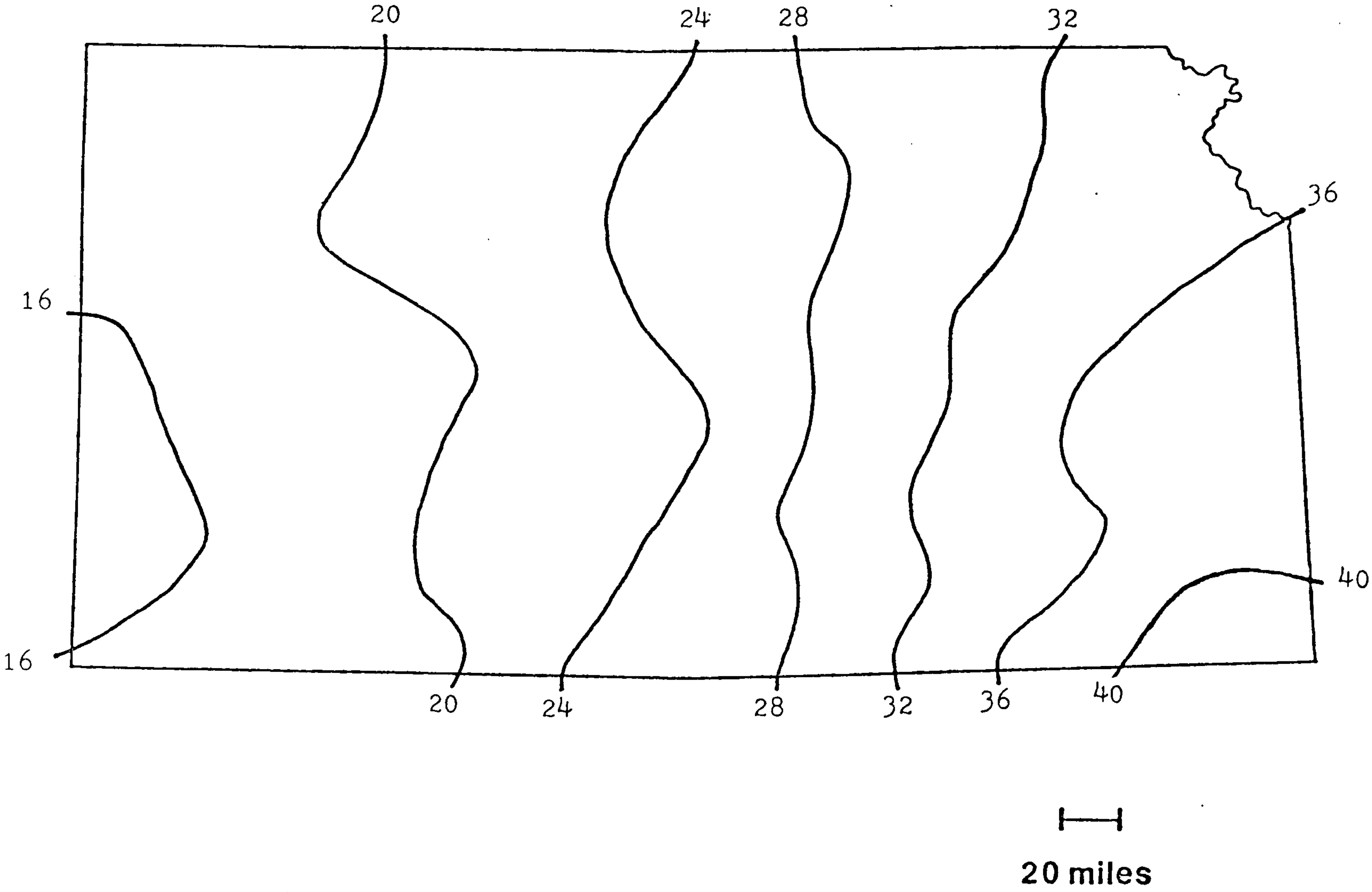
Kansas is located at the center of the 48 contiguous states and is characterized by major fluctuations in temperature and precipitation. Kansas weather is largely influenced by the Gulf of Mexico, a source of moisture from the south, and by the Rocky Mountains to the west, which prevents importation of Pacific Ocean moisture. Differences in elevation affect climate; eastern Kansas at 800-1000 feet MSL receives about 10 inches of snow per year. This amount gradually increases to the west where the largest average of 24 inches per year is reached along the 3500 feet MSL Colorado border. However, the overall mean annual precipitation is highest in southeast Kansas at over 40 inches per year and gradually decreases westward to 16 to 18 inches per year along the Colorado border (Figure 7). Coincident with this precipitation gradient is humid climate in the extreme east to dry sub-humid climate in the west with extreme southwest Kansas being designated semi-arid. However, any part of Kansas may receive a 24-hour rainfall of 5 to 10 inches (end Robb, 1959).

Temperatures below 0° F and above 100° F generally occur throughout the state on an annual basis. This wide range in temperature will primarily affect the management of the facility and cannot be avoided anywhere in the state. Winter temperatures may create icy conditions and forbid the usage of conventional earth-moving equipment. Extreme summer temperatures may exceed the flash points of certain hazardous wastes and ignite the vapor surrounding a leaky

Figure 7

Mean annual precipitation in Kansas in inches.

(From Cole and Van Sickel, 1977)


20
24
28
32
36
16
16
20
24
28
32
36
40
40
20 miles

drum from the spark of an internal combustion engine, or from a struck match of a careless worker.

Kansas is somewhat unique in having a major climatic change between the humid eastern border and semi-arid western border. Based on mean annual precipitation, the farther west-southwest a disposal site is located, the smaller the volume of leachate that should be generated. Although a northwest location will receive a bit more annual precipitation than a southwest location (about 1 to 2 inches more per year), this difference is negligible and does not offset the combination of low seismic risk and compatible shallow lithostratigraphy in northwest Kansas.

COMPATIBLE SHALLOW LITHOSTRATIGRAPHY

In the event that any leachate should escape a properly designed and managed facility, the character of the disposal medium must protect ground water from contamination. Fine-grained rock with high percentages of clay particles provide low flux of solutions and gasses and long contact time between adsorbing earth material and percolating contaminants (Cartwright, Gilkeson, and Johnson, 1981). Minimum U.S. EPA guidelines require that a hydraulic conductivity of 10^{-7} cm/sec exist, 5 feet between the base of any artificial liner or trench bottom and the water table, and 500 feet from any functioning public or private water supply. In addition, no site may be located in contact with surface water, on a wetland, on a floodplain, or in the recharge zone of a sole aquifer (Cartwright and others, 1981).

Of the strata that occur in the shallow subsurface in dry, stable northwest Kansas (Figure 8), the clay-rich Pierre Shale best satisfies the previously described criteria for a disposal medium. The Pierre occurs at or near the surface in Cheyenne, Gove, Logan, and Wallace counties where drainage has partially or completely removed overlying Cenozoic deposits (Jewett, 1964). Outcrops are generally limited to low-lying areas adjacent to drainage and would be subject to water gathering, flash flooding, and further erosion. An optimal location for disposal into the Pierre should, therefore, be an upland area where thin (not greater than 50 or so feet) Cenozoic overburden may be easily removed by conventional means to expose the erosional surface of the thick shale sequence. An isopach map indicates that the Pierre thickens northwesterly to 1600 feet in extreme northwest Cheyenne County (Figure 9a). However, the Pierre in this area is coincident with badland topography (Prescott, 1952), a condition that is not conducive to shallow disposal and negates this optimal thickness. Other than Cheyenne County, the thinnest Tertiary deposits that overlie the thickest Cretaceous Pierre Shale will occur in Wallace County (Figures 9a and 9b). An optimal upland disposal site in Wallace County would be located where thin, removeable overburden is chiefly unsaturated (Figure 10). The discontinuous water

Figure 8

Generalized shallow
stratigraphy in northwest Kansas.

(Adapted from Elias, 1931; Gill and others, 1972;
Hodson, 1963; and Zeller, 1968)

SYSTEM	SERIES	STRATIGRAPHIC UNIT	MAXIMUM THICKNESS	PHYSICAL CHARACTER AND WATER SUPPLY
Quaternary	Pleistocene	Alluvium	about 100 feet	Stream-laid deposits of gravel, sand, silt, and clay that occur along drainage valleys and ravines. Generally somewhat saturated and yields water to wells.
		Peoria and Loveland Formations	about 100 feet	Silt, mostly eolian. May become sandy near the base. Most deposits are above the water table and generally yield no water to wells.
Tertiary	Miocene	Ogallala Formation	350 feet	Gravel, sand, silt, and clay. Unconsolidated, or locally cemented by calcium carbonate or silica. The most important aquifer in northwest Kansas; yields up to 2000 gpm to irrigation wells.
Cretaceous	Upper Cretaceous	*Pierre Shale	1600 feet	Clayey, fissle, fossiliferous, dark-grey shale. Concretions of various sizes and composition. Thin beds of grey-green to brown bentonite are common. Yields no water to wells.
		Niobrara Chalk	600 feet	Soft, light-grey calcareous shale and chalk. Yields no water to wells.

*Pierre Shale

Thickness	Member	Character
100 ft	Beecher Island	Light-grey, sandy, silty shale; transitional with Fox Hills Sandstone throughout Great Plains (removed in northwest Kansas). Limonite and calcareous concretions present.
500-600 ft	Undifferentiated	Grey to black clayey shale. Limestone concretions in upper 90 feet or so.
60 ft	Salt Grass	Grey, clayey shale. Numerous thin bentonite beds. Limonite and calcareous concretions common.
200 ft	Lake Creek	Dark-grey, thin bedded, flaky, clayey shale. Contains calcareous and limonite concretions. Gypsum locally abundant.
170 ft	Weskan	Grey, clayey shale. Bentonite beds common in lower part. Calcareous concretions common.
225 ft	Sharon Springs	Dark, organic-rich, flaky, clayey, bituminous shale. Clay-ironstone septarian and calcareous concretions common in upper part.

Figure 9a

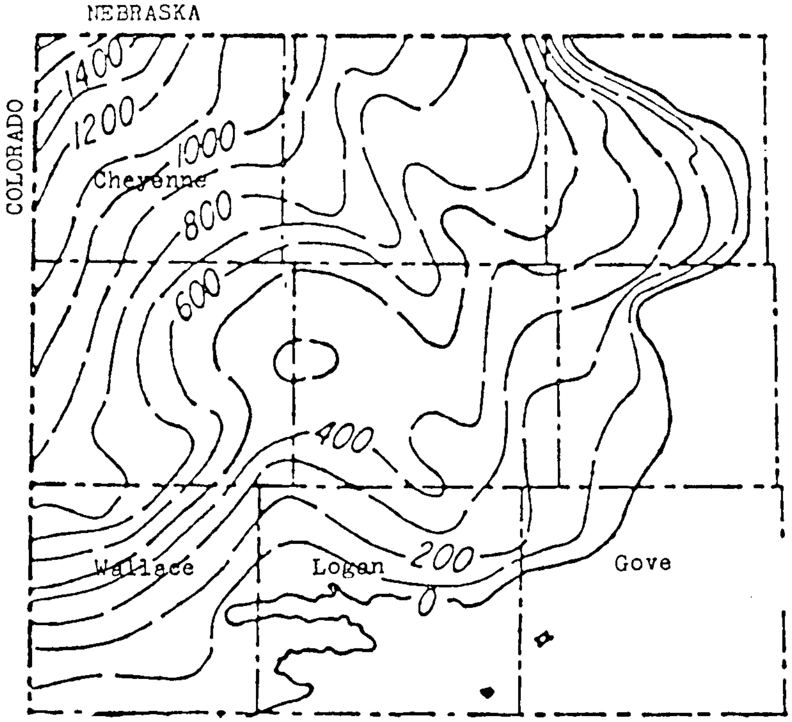
Isopach map of Pierre Shale
in northwest Kansas.
Contour interval 100 feet.

(From Merriam, 1963)

Figure 9b

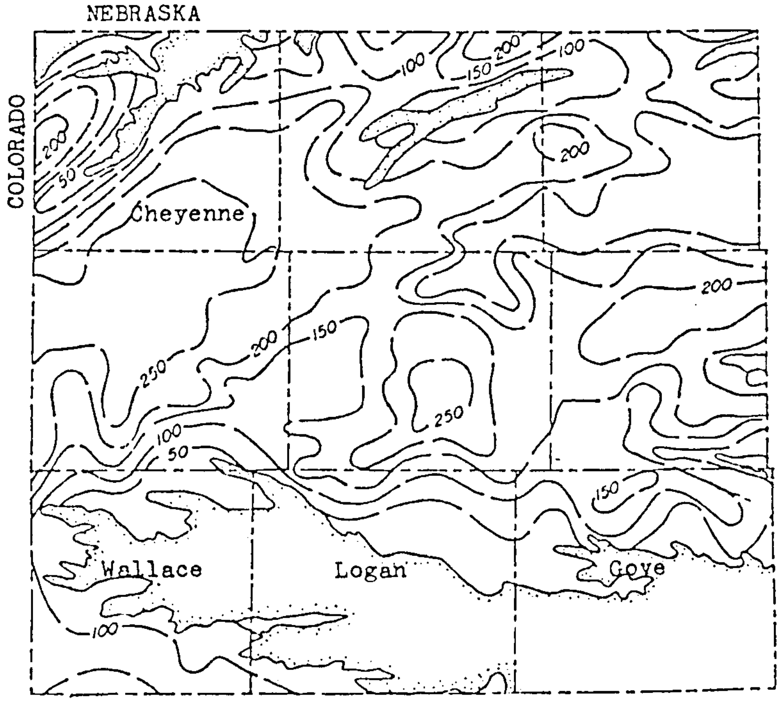
Isopach map of Ogallala Formation
in northwest Kansas.
Contour interval 50 feet.
▨ pre-Ogallala

(From Merriam, 1963)



A

Approximately 30 miles

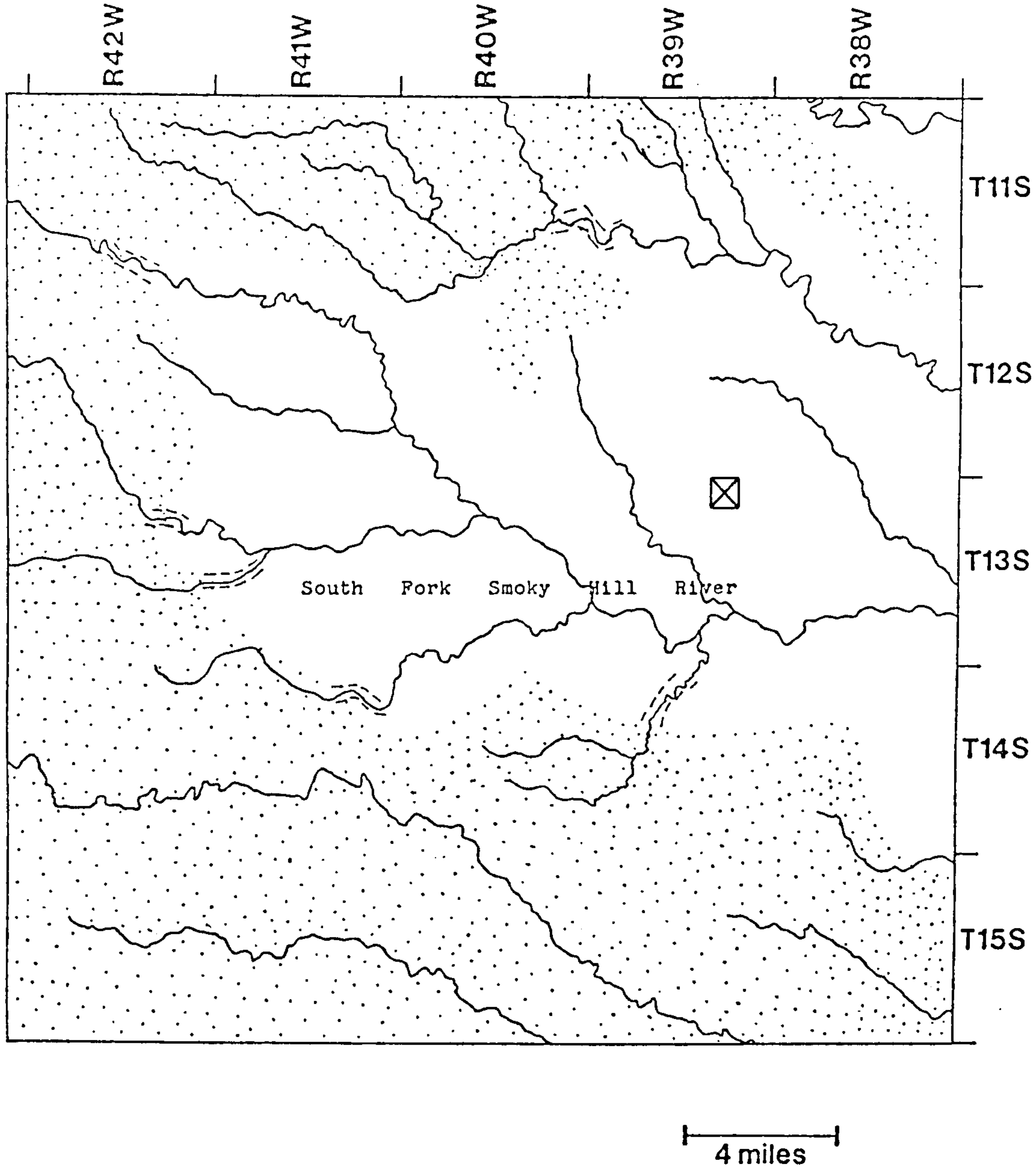


B

Figure 10

Saturated and unsaturated
Cenozoic deposits in Wallace County.
Box shows the location of the proposed site.

(From Hodson, 1963)



EXPLANATION

◌ Saturated Cenozoic deposits.

○ Unsaturated Cenozoic deposits; dashed where intersected by stream valleys.

table throughout central Wallace County is confined largely to fill deposits where South Fork Smoky Hill River and its tributaries have partially or completely replaced Tertiary and Upper Cretaceous deposits with Pleistocene alluvium. The thickness of loess at the surface is of less concern due to the unsaturated nature of these deposits and the ease in which they may be removed or terraced by conventional earth-moving equipment.

The Sharon Springs, Weskan, Lake Creek, and Salt Grass members of the Pierre occur in Wallace County (Elias, 1931). Gill and others (1972) reported an increase in montmorillonite and a decrease in kaolinite above the basal Sharon Springs member (Table 3). The increased percentage of montmorillonite in the upper members implies greater swelling potential and lower hydraulic conductivity, in addition to a general increase in cation exchange capacity over the kaolinite-rich Sharon Springs member. These considerations suggest that the optimal disposal medium within the Pierre is any member younger than the Sharon Springs. Numerous bentonite beds are present in the lower part of the Weskan and in the Sharon Springs, and the composition of these clay-rich layers contributes to the assurance of low permeability rock in the lower Pierre (Table 4).

Elias (1931) mapped the contacts between members of the Pierre in Wallace County within an admitted error of plus or minus 10 feet, and this work was used to identify the

TABLE 3

Composition of samples from the Pierre Shale in northwest Kansas.

(From Gill and others, 1972)

*Sample location shown in Figure 11.

Member	Clay mineral, as percentage of total clay						Composition of sample, in percent						
	Montmorillonite	Mixed layer	Illite	Chlorite	Kaolinite	Total clay	Quartz	Plagioclase	K-feldspar	Dolomite	Gypsum	Jarosite	Total
Salt Grass	35	41	17	0	7	70	19	3	0	0	0	0	92
Lake Creek	28	52	13	1	7	60	19	2	0	3	0	0	84
Weskan	41	25	31	2	1	75	25	2	0	0	2	0	104
..do...	31	36	20	4	9	65	27	tr	0	9	0	0	101
*..do...	37	40	18	0	5	80	19	2	0	0	0	0	101
..do...	36	41	17	2	4	75	18	2	?	0	0	0	95
Sharon Springs	8	52	20	0	20	30	10	0	50	0	0	0	90
..do...	15	53	17	3	12	55	27	1	1	0	tr	0	84
..do...	20	41	22	0	17	70	28	0	1	0	0	0	99
..do...	15	45	14	3	23	60	20	1	0	2	0	tr	85
..do...	0	69	19	0	12	60	21	0	1	0	2	0	84
..do...	16	52	19	0	13	65	20	1	tr	0	5	5	96
..do...	17	53	15	0	15	50	20	1	1	0	10	7	89
..do...	8	53	21	0	18	75	28	1	1	0	?	0	105

tr., trace; ?, presence doubtful

TABLE 4

Composition of bentonite samples from the Pierre Shale in northwest Kansas.

(From Gill and others, 1972)

*Sample location shown in Figure 11.

	Clay mineral, as percentage of total clay			Nonclay mineral as percentage of sample	
Member	Nonexpanded montmorillonite	Expanded beidellite	Kaolinite	Quartz	Other
		SURFACE SAMPLES			
Weskan	90	10	3	0	
*..do...	95	5	0	0	
..do...	85	15	0	0	Plagioclase 2
..do...	100	0	0	0	
Sharon Springs	25	75	45	3	
		SAMPLE CUTTINGS			
Sharon Springs	50	50	10	0	Pyrite 3
..do...	Nd	Nd	90	0	
..do...	50	50	15	2	..do... 10
..do...	25	75	10	0	
..do...	0	0	100	0	..do... 15

Nd., not determined

near-surface occurrence of the members of the Pierre. Well logs indicate that about 40 feet of loess and/or Ogallala rests unconformably on Weskan shale at the proposed site (Figure 11). Some 300 feet of Pierre should separate the bottom of the proposed trenches from the top of the shaly Niobrara Chalk.

Hydraulic conductivity of 10^{-10} cm/sec in Pierre Shale has been reported in the northern Great Plains (Shurr and Bredehoeft, 1977), and given the generally uniform composition of the Pierre throughout the Cretaceous Western Interior Basin (Tourtelot, 1962), the anticipated hydraulic conductivity under the proposed site should have a similar value. Hydraulic conductivity in the basal Sharon Springs member should be slightly greater than in the overlying Weskan due to the difference in clay mineral percentages. Smectites in the Pierre should swell and heal joints and fractures when saturated and retard leachate migration along bedding planes and other features (Wilson, personal communication, 1985). The Pierre lacks ground water resources (Johnson, 1958; Hodson, 1963).

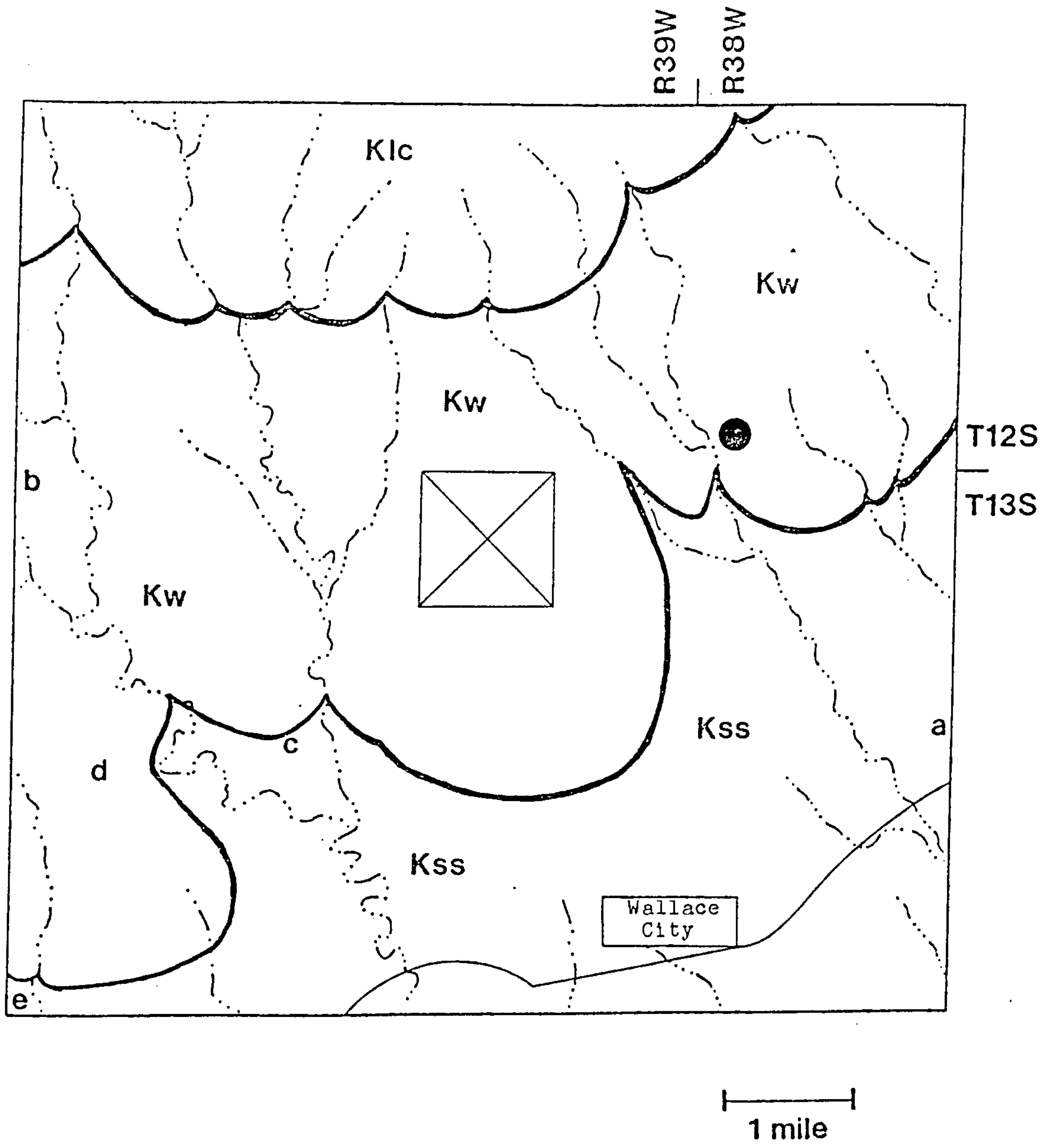
NATURAL HAZARDS

Natural hazards, other than earthquakes, that present risk to a disposal facility in the unsaturated near-surface formations of Wallace County include flash flooding, tornadoes and storms, drought, surface depressions, and collapse subsidence. Of these hazards, only flash flooding

Figure 11

Geologic map of the vicinity of the proposed site. Overlying Cenozoic deposits are omitted from this map.

(Geologic contacts from Elias, 1931)



EXPLANATION

a–e Location of well logs provided in appendix.

● Location for sample with asterisk (*) in Table 3 and 4.

Pierre Shale (Upper Cretaceous)

Klc Lake Creek member

Kw Weskan member

Kss Sharon Springs member

may be alleviated by virtue of the site location and may only be achieved on a topographic high away from South Fork Smoky Hill River flood plains and intermittent tributary ravines.

Much of central Wallace County is mapped on the Sharon Springs and Wallace 15-minute series quadrangles, and these maps were used to evaluate topographical relations in areas of unsaturated Cenozoic deposits. West-central Wallace County is heavily dissected by rills, creeks, and ravines that feed South Fork Smoky Hill River, and the topography is characterized by steep-sided canyons and bluffs adjacent to flatlands peppered with surface depressions that are characteristic of the High Plains. East of Sharon Springs, the canyon and flatland topography is predominantly confined to areas south of Smoky Hill River, whereas gently rolling valley and ridge terrain is characteristic north of the river channel. The area north of Smoky Hill River, within a 6 mile radius of Wallace City, contains numerous local topographic highs that are generally at least 1 mile from the nearest intermittent drainage ravine and should not be subject to flash flooding. Only those topographic highs in this area underlain by the Weskan or younger members of the Pierre were considered as potential sites. The northeast part of T.13S. R.39W. was selected because the topographic highs in sections 2, 11, and 12 are underlain by Weskan shale and are collectively farther from the nearest drainage than any other local highs in the region. Although section 2 is closer to drainage than section 11 or 12 (Figure 3), section 2 is at a higher elevation and the surface drainage will direct runoff from precipitation away from the center of the section in near-radial pattern. Hodson (1963) reported that the width of South Fork Smoky Hill River flood plain varies from a quarter of a mile to slightly greater than a mile. Section 2 is located about 3 miles from the north edge of the river valley in an upland area and is considered safe from Smoky Hill flash flooding; flood levels over 100 feet above the elevation of Wallace City would be necessary in order for section 2 to be reached by Smoky Hill flood waters.

Tornadoes, lightning, hail, sleet, and blizzards are annual occurrences throughout the state. Potential hazards to a disposal facility include destruction from tornado winds, combustion and deformation of waste drums in open trenches from cloud to ground lightning and hail, and other operational/management aspects of the facility that are governed by the phase and intensity of falling precipitation. No county in Kansas is immune from severe weather, but the dry western counties generally experience less threatening weather than the rest of the state due to the lack of available moisture in the atmosphere necessary to spawn intense weather. From 1950 to 1980, 1553 tornadoes were reported in Kansas, and only 10 of these sitings occurred in Wallace County (Kansas Division of Emergency Preparedness, 1981). However, electrical storms, heavy and prolonged rains, and acute winter weather may be expected annually in Wallace County.

Drought conditions are common in Kansas. A potential hazard that drought presents to shallow disposal is insufficient moisture to stabilize a final vegetative cover. Although Smoky Hill alluvium provides water for Wallace City and local residents, Lower Cretaceous rocks (e.g. Dakota Formation and Cheyenne Sandstone) have long provided water to western Kansas for irrigation and stock, and this resource is potentially available at the site for additional usage to wash equipment, flush tank trucks, and other industrial needs. Keene and Bayne (1977) reported that the approximate depth to the top of Lower Cretaceous rocks in the vicinity of the proposed site is 1400 feet, and water quality of roughly 1000 ppm total dissolved solids occurs in the area, based on samples from two Dakota wells about 12 miles southeast of Wallace City. To minimize the risk of leachate percolating down well holes, all water wells should be drilled off the premises as far from the facility as local considerations will allow.

Surface depressions in Wallace County are generally confined to flatland areas where drainage is poorly developed. Depressions less than 10 feet deep may have been caused by animal and/or wind action, whereas deeper depressions may have occurred from the seepage of water causing mechanical compaction and solution in the underlying Tertiary rocks (Hodson, 1963). The proposed site is located in a well-drained upland area with no surface depressions in the vicinity. The removal of Tertiary overburden in addition to a well vegetated surface cover should eliminate the hazard of these shallow depressions developing over the trenches. Where Tertiary rocks are thin or absent, Russell (1929) believed that deep, steep-sided, almost circular sinks and basins were caused by collapse of cavities that developed between the walls of tensional faults in the Niobrara, and could not have resulted from Niobrara subcrop solutions because of the impervious nature of the shaly chalk. He reported that a normal fault with a throw of at least 50 feet cuts the north wall of Smoky Basin Cave-In near Sharon Springs, and that this and other similar deep cave-ins formed by a series of sudden collapses rather than by a single collapse or slow subsidence. Elias (1931) believed that if the underground dip of the fault exposed in Smoky Basin Cave-In does not differ appreciably from the surficial dip, then the supposed tensional cavity in the Niobrara should be west of the center of the present cave-in, and that cavities produced by such faulting could not possibly collapse without the action of some undermining waters. The uppermost formation below the Niobrara that would be subject to solution is some 2000 feet below the surface and likely would not produce such steep-sided collapse areas at the surface (Hodson, 1963). No collapse basins are located in the terrain immediately north of Wallace City. Seismic profiles are necessary at the proposed site to determine if any faults exist in the Pierre and Niobrara below the site. There is no record of any hole drilled in the proposed section, eliminating the chance for artificially-induced solution of any formation beneath section 2. The remote chance for any collapse or subsidence under the site by any means is compensated for by the substantial thickness of non-calcareous Pierre that will separate the bottom of the proposed trenches from the top of the Niobrara Chalk.

LOCAL MINERAL PRODUCTION

Hydrocarbon wells and other drill holes may act as conduits to other strata and allow contaminants to migrate vertically as dictated by the pressure gradient. Limestone cement and iron surface casings set through Pierre Shale should not be expected to resist solution and corrosion from toxic leachate.

Wallace County is not densely drilled, although petroleum and shallow Niobrara gas are locally produced. Although the proposed site is located in the most densely drilled township in Wallace County (Fuller, personal communication, 1984), the locations of the few mineral exploration holes drilled in the vicinity should not threaten the integrity of the site (Figure 12). The well southeast of the site (NE¼ SW¼ NW¼ section 12, T.13S., R.39W.) was drilled and abandoned in 1926 to a Cretaceous total depth and is sufficiently close to section 2 to

Figure 12

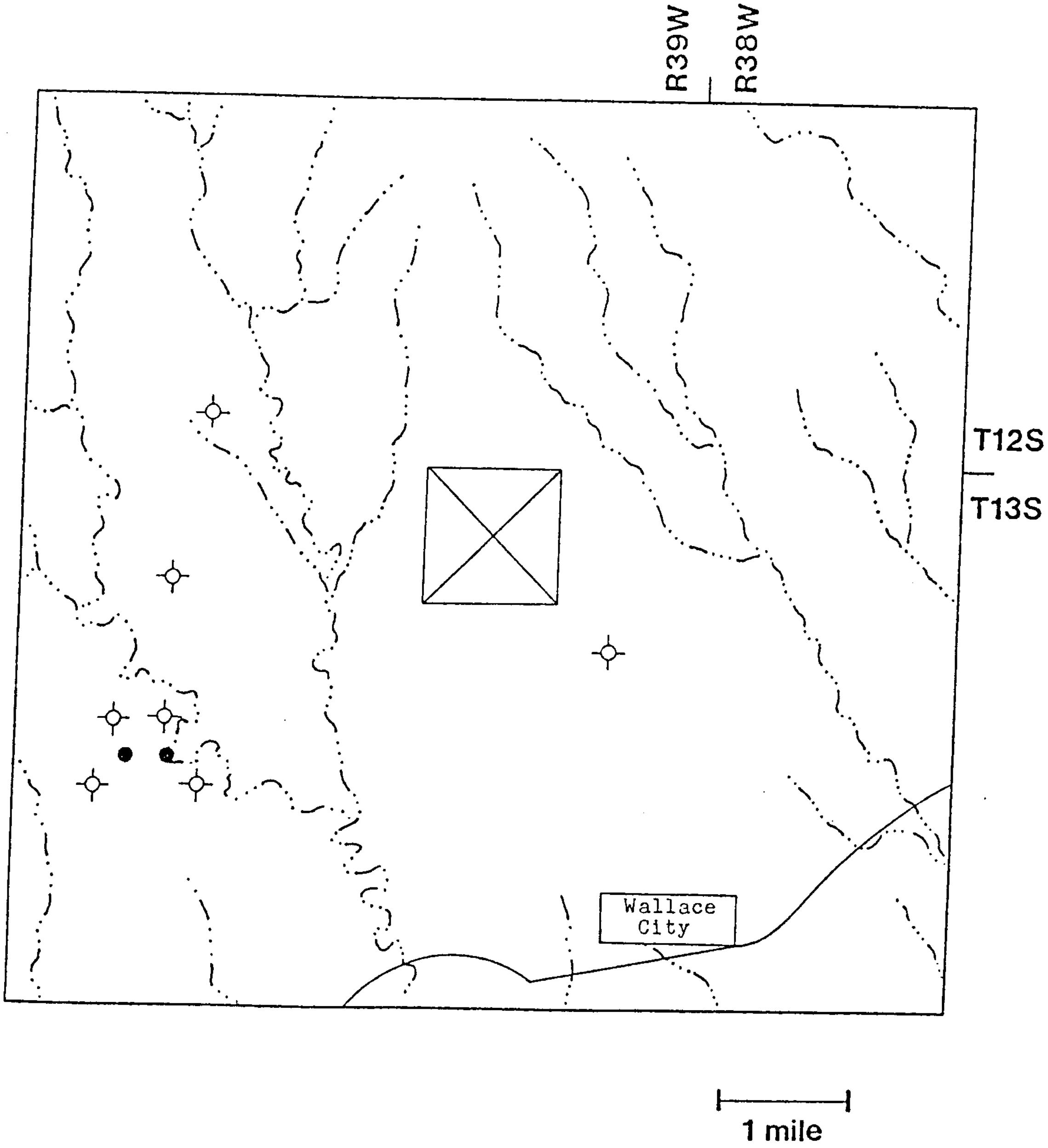
Location of mineral exploration wells in the vicinity of the proposed site.

(Locations from Fuller, 1984)

EXPLANATION

⌖ drilled and abandoned

● petroleum producer


R39W
R38W
T12S
T13S
Wallace City
1 mile

warrant workover to assure it is properly plugged. The well should be drilled out to total depth, all casings pulled, and filled to the surface with smectite-rich clay and fresh water slurry that should seal the contact between the strata and the hole. Should waste-earth interactions increase the hydraulic conductivity in the Pierre to a uniform 10^{-7} cm/sec, some 100 thousand years will be required for leachate to migrate to the nearest well other than section 12 located west northwest of the site, and this allows ample time for potential workover procedures to be completed, if ever necessary.

PROXIMITY TO COMMUNITIES AND THOROUGHFARES

From 1972 to 1980, 137 vehicular fatalities involving hazardous materials occurred in Kansas (Kansas Division of Emergency Preparedness, 1981). Although air carriers boast the safest transportation record, major highways and railroads provide safe and economical means of transporting large volumes of hazardous waste over long distances. Locating a disposal facility near major thoroughfares should minimize the risk of a catastrophe from the thoroughfare to the site, but should not compromise the safety of near-by residents and communities from possible contamination.

The proposed site is located about four miles north of US-40 highway and the Union Pacific Railroad and should be readily accessible from either of these thoroughfares (Figures 1 - 3). After waste is safely placed in a Pierre repository, any leachate that escapes from the facility will require between 0.2 and 200 million years to reach Wallace City, based on hydraulic conductivity values from 10^{-7} cm/sec to 10^{-10} cm/sec and providing the dip and pressure head creates movement to the south. This slow permeability, combined with toxic attenuation from contaminants interacting with earth material, seems more than adequate protection of domestic and public concerns from percolating fluids.

AERIAL RECONNAISSANCE

Aerial reconnaissance was made of the proposed site on the morning of November 4, 1984.* Ed Glassman, a geologist and pilot from Hays, Kansas flew left seat while I photographed the landscape at high oblique angles with a 35 mm camera (Plates 1 and 2).

Wallace City is a very small community situated in a typical High Plains setting. Trees are locally confined to Smoky Hill River valley where adequate ground water is available. The gently rolling dryland slopes have been terraced to minimize runoff; milo was being grown in S½ section 2 and accounts for the distinguishing reddish-brown color noticed in every photograph. No central pivot or other irrigation facilities were seen from 2100 feet AGL.

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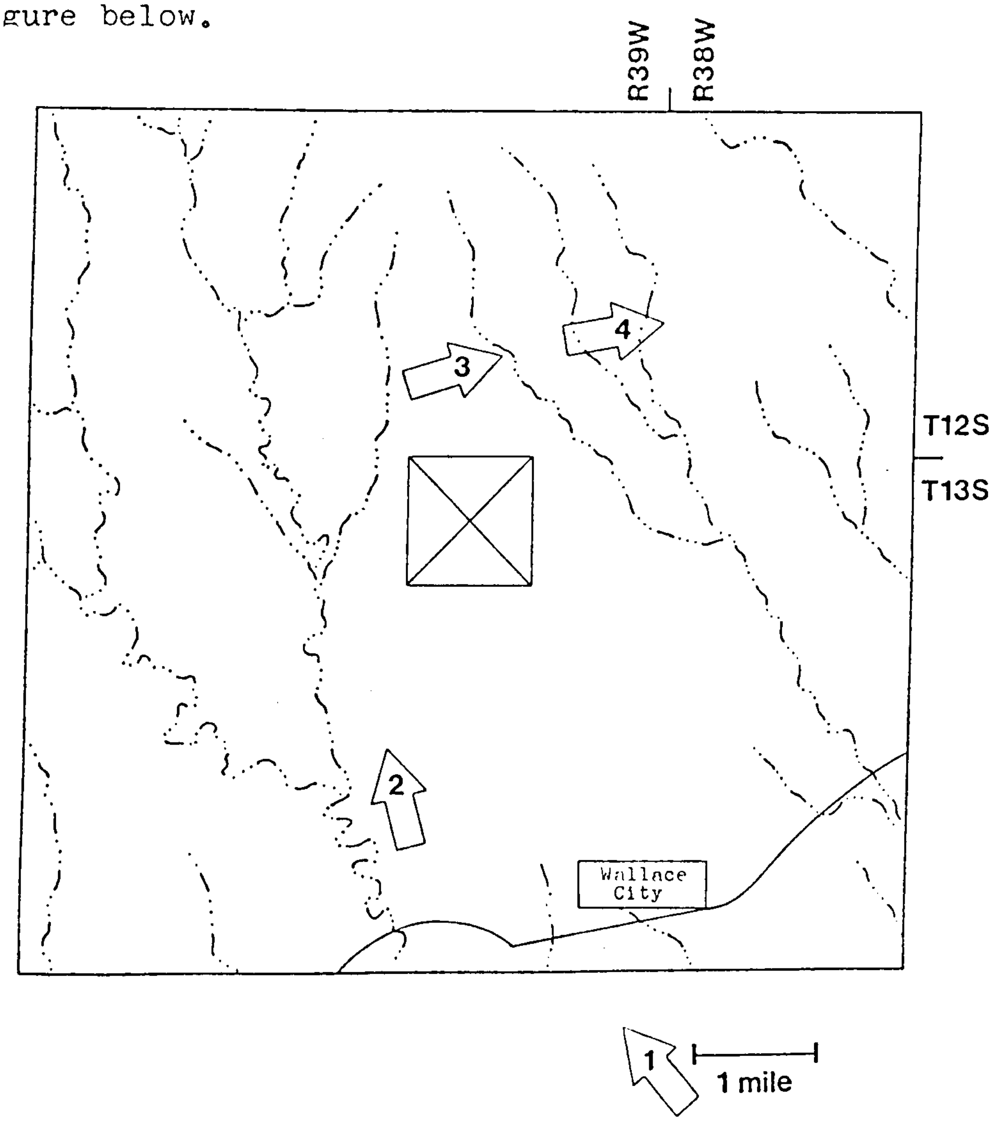
*Cessna 152, N4782B, Hays Municipal Airport.
Cruise altitude 5500 feet MSL, 2100 feet AGL.

Plates 1 & 2

Photographs taken during the aerial reconnaissance flight at 9:00 AM November 4, 1984.

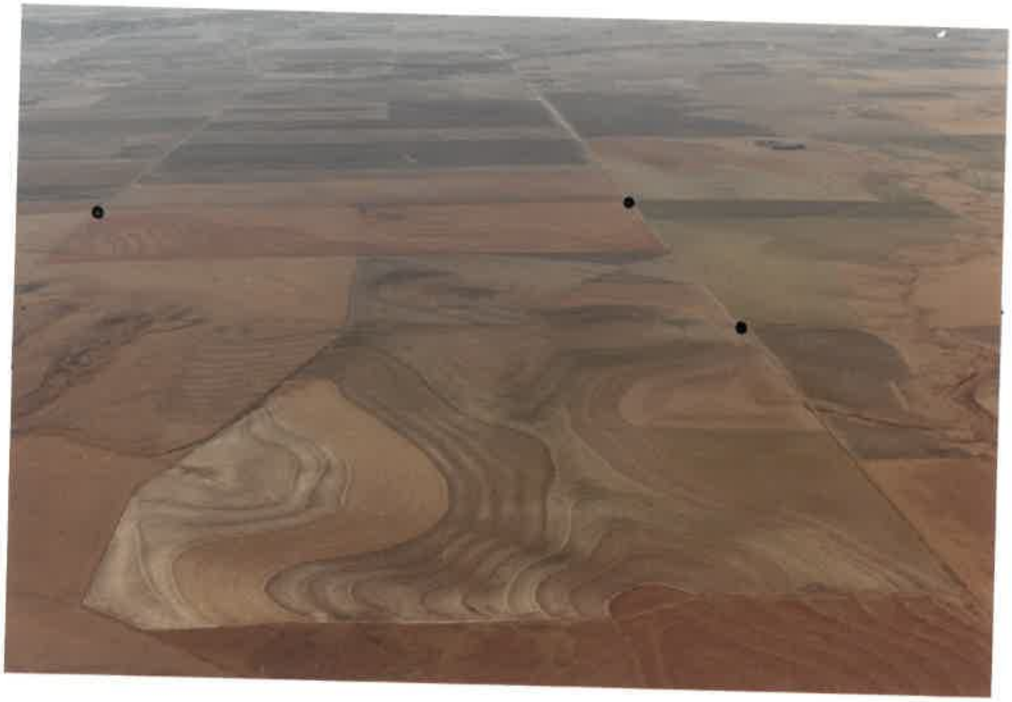
Corners of the proposed site are indicated by the black dots, and the reddish-brown color observed in the S½ of the section is dryland milo crop.

The location and orientation of the aircraft when each photograph was taken is illustrated in the figure below.

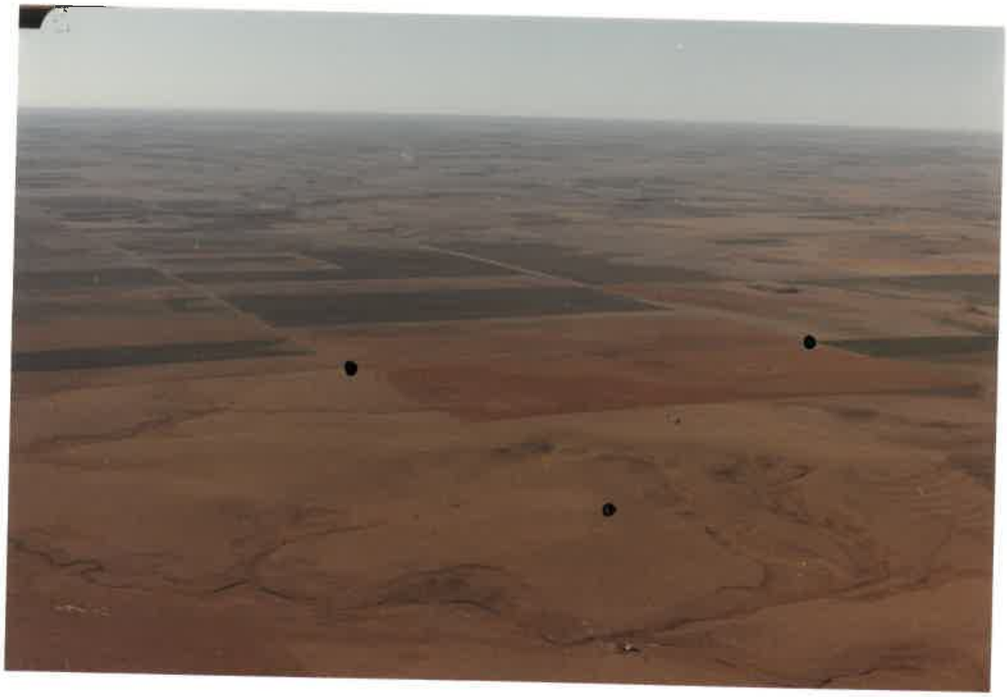


Photograph #1; looking north northwest.

Photograph #2; looking north.



Photograph #3; looking south.



Photograph #4; looking southwest.

Photograph #4 shows that $S\frac{1}{2}$ section 2 is a bit more removed from surface erosion and drainage than the $N\frac{1}{2}$ and should probably be considered first for trench locations. However, loess at the surface anywhere in the section may easily be terraced to alter drainage patterns, and irrigation from Lower Cretaceous rocks should be available, if necessary, to stabilize a vegetative cover.

NECESSARY GEOTECHNICAL SURVEYS

Seismic reflection and refraction profiles at the proposed site should confirm the depths, thickness, and local dip of the buried units, and the presence of faulting beneath the site that may promote solution and collapse. Cores of Pierre should be sampled and the hydraulic conductivity, shrink-swell potential, waste-earth interactions, and other geotechnical information determined in the laboratory. Field permeameters should be drilled at several locations and the *in situ* hydraulic conductivity of various horizons should be determined.

FACILITY DESIGN

The below-ground facility illustrated in Figures 13 and 14 is adapted from Brown (1982), who suggested this design for an above-ground landfill and championed the idea of ease with which repairs may be made for centuries to come. This above-ground concept seems valid for locations in humid climates where large volumes of leachate may continously be

Figure 13

Plan view schematic of a

below-ground disposal facility.

Not drawn to scale.

PLAN VIEW

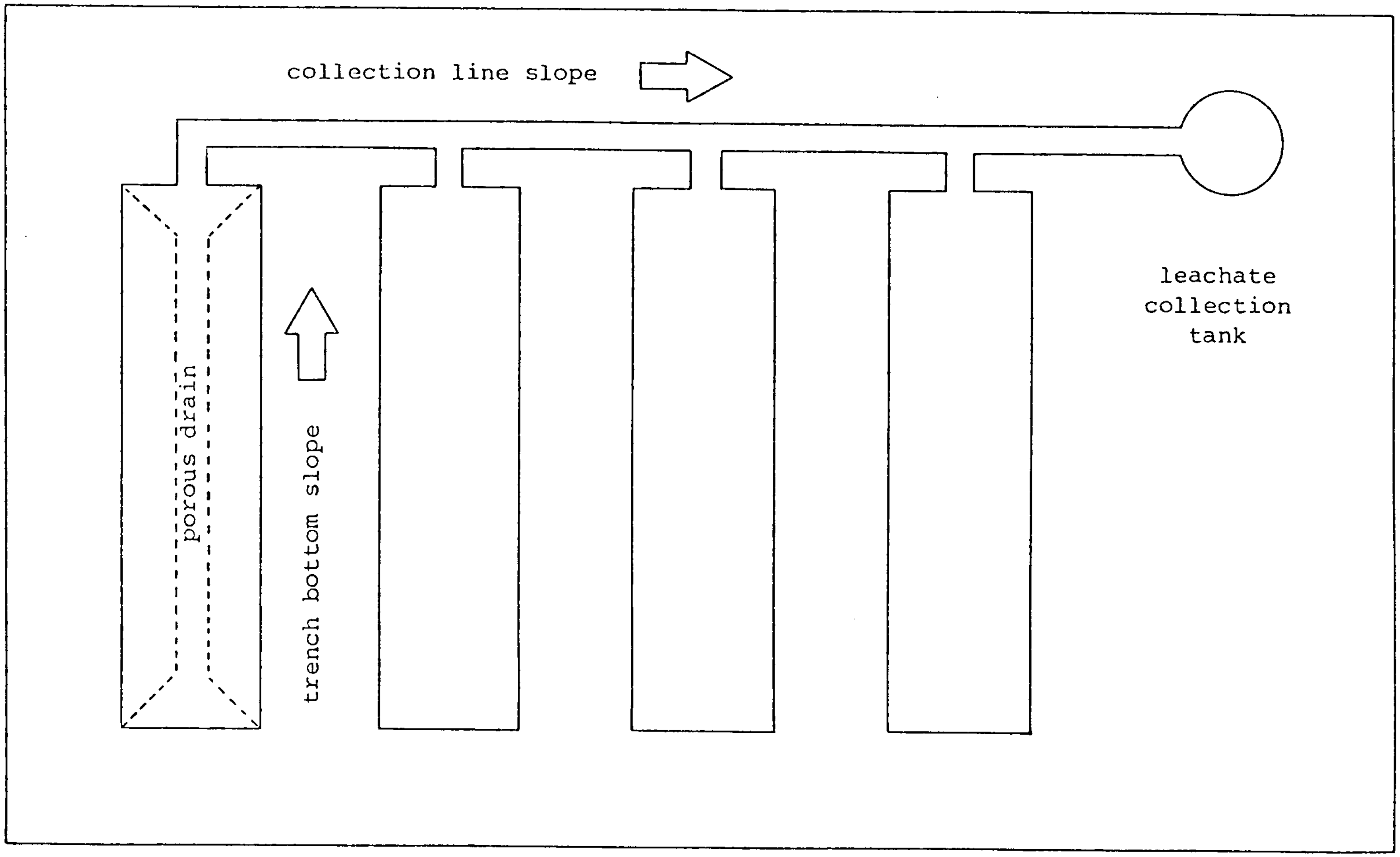

collection line slope
leachate collection tank
porous drain
trench bottom slope

Figure 14

Schematic cross section of a disposal trench at the proposed site. Arbitrary trench dimensions illustrated are 55 feet deep into Weskan shale by 100 feet wide.

Vertical scale 1:550
Horizontal scale 1:857
Vertical exaggeration 1.6X

Explanation

Quaternary System

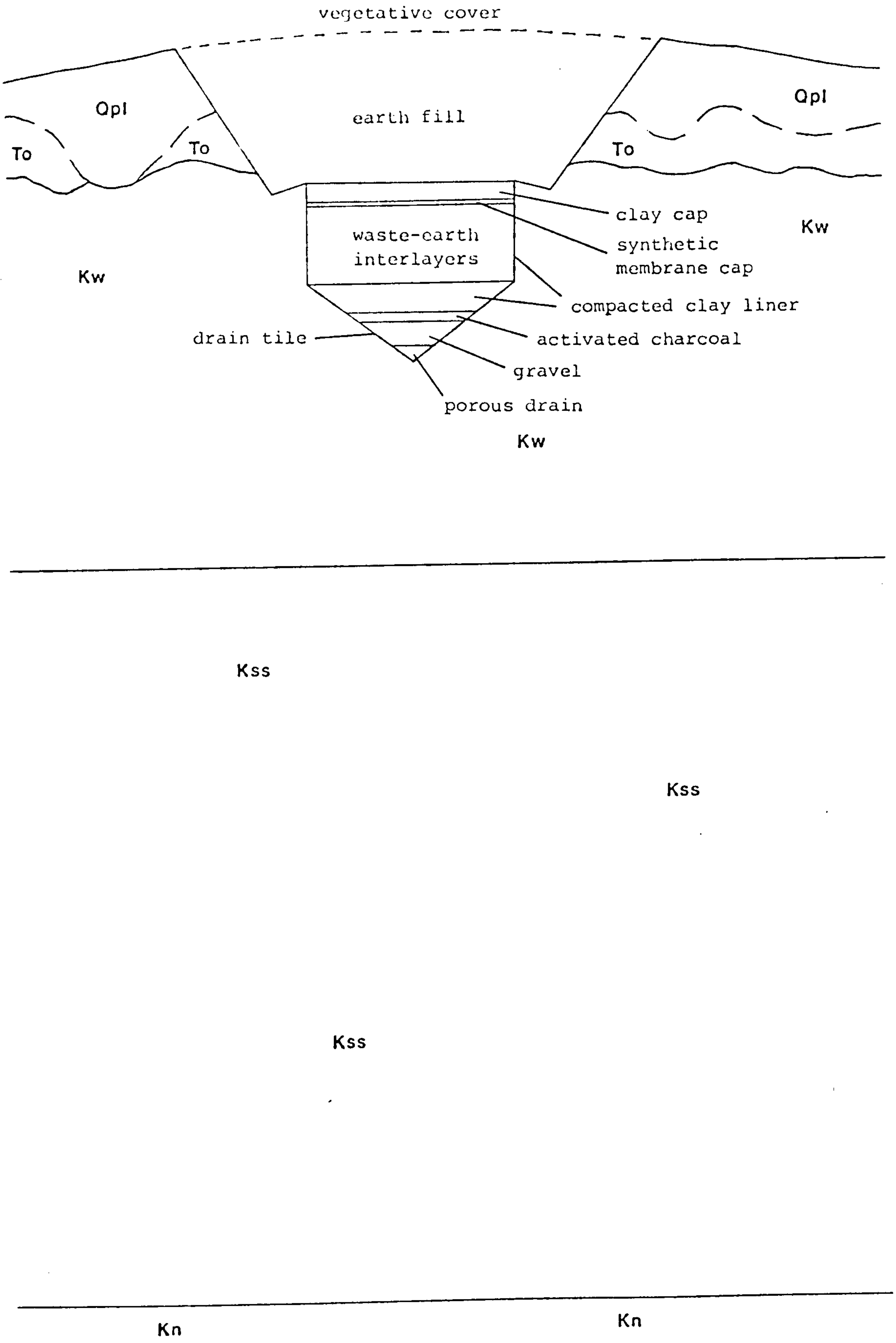
Qpl	Peoria and Loveland Formations

Tertiary System

To	Ogallala Formation

Cretaceous System

Kw	Weskan shale
Kss	Sharon Springs shale
Kn	Niobrara Chalk


vegetative cover
Qpl
earth fill
Qpl
To
To
To
clay cap
Kw
synthetic
membrane cap
waste-earth
interlayers
Kw
compacted clay liner
drain tile
activated charcoal
gravel
porous drain
Kw
Kss
Kss
Kss
Kn
Kn

generated and create the need for frequent repairs. However, in sub-humid Wallace County where recharge is absent or negliglible (Garland and Mosher, 1975), the only leachate likely to be generated will be derived from precipitation falling directly into an open trench. This volume of precipitation may be sufficiently small to remain trapped in earth fill material for centuries before migrating to the leachate collection tank. If this entire finite volume of leachate were to escape the facility, the low risk of contamination from fluids that have become increasingly dilute as they slowly percolate through great distances of Pierre Shale offsets the need for an above-ground landfill to collect leachate, only to again be confronted with a disposal problem.

The projected volume of precipitation that will enter a facility will be determined by the surface areas of open, in-use trenches and, in accordance with the volumes of waste drums to be buried, will dictate the dimensions of the trenches and leachate collection tank. For comparison, the surface area of the closed Furley, Kansas facility was less than one quarter section.

The materials that may come into contact with leachate must be highly resistant to organic and heavy metal-rich solutions at various pH; compacted pure clay liners, teflon, and fiberglass products should be considered for trench liners, bottom tiles, and leachate collection owing to their low permeability, resistent nature, and economic feasibility.

Most leachate can be expected to migrate vertically downward within a trench lined with a low permeability barrier. Membrane caps may be made of polyethylene-type material because meteoric waters that may percolate below a vegetative cover are free of harmful pollutants capable of dissolving organic polymer material. However, synthetic membrane caps must retard the vertical migration of gasses such as ammonia, methane, and carbon dioxide. A layer of activated charcoal near the bottom of each trench should immobilize many percolating organics before leachate enters the collection network. All earth-fill material may either be excavated Pierre Shale or other low permeability material. Geotechnical design must account for the expansion of potentially saturated clay minerals, both in the trenches as fill material and in the Pierre that surrounds the facility.

POTENTIAL WASTE-EARTH AND WASTE-WASTE INTERACTIONS

As there are hundreds of known hazardous compounds, there must be thousands of different possible reactions in industrial landfill leachate. The effects of heavy metals, organics, and other wastes on earth materials has long been of interest to soil scientists and civil engineers. Much of this work is performed in the laboratory and results seem to vary depending on the nature of the earth material studied, the concentrations and molecular characteristics of migrating pollutants, and experimental technique. Although a detailed discussion of the many different experimental findings is beyond the scope of this text, several results and conclusions regarding potential waste-earth and waste-waste interactions warrant review here.

Anderson and others (1982) demonstrated increases in the permeability of compacted calcareous and non-calcareous smectites, mixed cation kaolinite, and mixed cation illite soils when percolated with pure xylene, pure acetone, pure acetic acid, and methanol in 20% water. In the case of non-calcareous smectite treated with pure acetone, a 1000 fold (100,000%) increase in permeability from baseline 10^{-9} cm/sec, established with pure water, was reported. This substantial increase was probably due to the shrinking of the clays when dehydrated by acetone; cracks and fractures in the clay were observed at the conclusion of the experiment. These and other results suggest that certain pure organic solutions may significantly increase some compacted clay permeabilities by a number of different mechanisms, but the authors offer no data using dilute organic solutions that may expand clay structure and offset increases in permeabilities by other mechanisms. However, similar <u>in situ</u> findings of increased permeability at the proposed site should not be disallowed for, and organics should be segregated, perhaps diluted, and buried in trenches or large containers completely lined with inert synthetic material. A slight increase in the permeability of non-calcareous smectite and mixed cation illite followed an initial permeability decrease when treated with pure acetic acid, and was likely caused by dissolution of soil components by acid attack. These findings imply that neutralization of acids and bases prior to burial should be required; many hazardous wastes must initially be neutralized at the site of generation to eliminate corrosion through containing materials.

The adsorption of contaminants onto clay structure will promote the toxic attenuation of percolating leachate. Jeene (1967) suggested that the fixation of heavy metals onto clay surfaces is not related to cation-exchange capacity. He suggested that manganese and iron hydrous oxides, which often form a coating on clay particles, act as sinks for many heavy metals. However, Griffin and others (1977) reported that Cu, Zn, and Cd adsorbed onto kaolinite and montmorillonite in cation-exchange proportions. Adsorption of Zn, Ni, Co, Cr, and Cd on illite, smectite, and kaolinite appear to reach saturation in a slightly alkaline (pH 7.25) environment, whereas the adsorption of Pb onto these pure clays is negliglible at any pH (Krivanek, 1976). Tsunashima and others (1981) reported that uranium adsorption on montmorillonite is strongly preferred when the clay is saturated with Na^+ or K^+ relative to Mg^{2+}, Ca^{2+}, or Ba^{2+}.

Organic-clay mineral complexes form by electrical attraction of polar or ionic organic molecules to clay surfaces, analogous to cation-exchange. Coulombic bonding is enhanced by van der Waals forces and organic molecules may adsorb in excess; 1-(n-alkyl)-pyridium bromide adsorption on montmorillonite is approximately equal to cation-exchange capacity with alkyl chains up to 8 carbons long, whereas larger chains adsorb at double or triple the cation-exchange capacity (Grim, 1968). Homogeneous organic molecules typically adsorb in highly-ordered arrangements. Ion exchange is a diffusion process, and replacement of interlayer cations in smectites and other expanding lattices with aliphatic or aromatic compounds should cause swelling and decrease the permeability while these clays are in equilibrium with dilute organic fluids. Griffin and Chian (1979) reported that total organic carbon was the dominant property by a factor of 3 in adsorbing PCBs from solutions migrating through soil columns; their work implies that an economical layer of activated charcoal near the porous drain of each trench would be money well spent. Although the Sharon Springs shale is likely to have greater hydraulic conductivity than Weskan shale due to the kaolinite-rich character, the Sharon Springs is organic-rich and should provide greater attenuation of organics if any leachate migrates below the Weskan.

Segregation of incompatible wastes prior to burial should be required. Heavy metals and organics react differently with different earth materials and solutions, and more control for analyzing potential interactions may be achieved if different types of wastes are isolated and distantly buried from one another. PCBs, for example, remain immobile in soil columns leached with water or municipal landfill leachate, but become intensely mobile when leached with organic solvents, particularilly carbon tetrachloride (Griffin and Chian, 1979). Hexachlorobenzene is 2.5 times more soluble in municipal landfill leachate than in distilled water (Griffin and Chou, 1980). Much more research is needed in this area to determine a burial scheme based on the compatibility of the particular wastes to be disposed of.

MONITORING SYSTEMS AND REMEDIAL ACTIONS

Permanent monitoring systems should be designed to effectively evaluate vertical and horizontal migration of toxic compounds. Walker (1974) identified six possible avenues in which toxic land disposal pollutants may enter the environment: 1) atmosphere 2) overland runoff 3) soil retention 4) ground water recharge 5) plant residue retention and 6) removal in crops. The geology at the proposed site and the design of the trenches eliminates overland runoff and recharge, but for each remaining consideration, baseline values must be determined prior to the construction of the facility and the implementation of permanent monitoring checks.

Volatilized compounds, such as ammonia, hydrogen sulfide, methane, and carbon dioxide may be released from buried wastes and eventually migrate vertically to the surface. A synthetic membrane cap over each trench should prolong containment and immobilization of these gasses, but should not be expected to last forever. Shallow soil cores and chemical analysis of the vegetative cover should be routinely checked for vertical migration and plant uptake of toxic compounds. Vegetative cover material should not be permitted to enter the food chain. The low concentrations of gasses that will reach the atmosphere are not apt to cause a major hazard to public health or the environment (Walker, 1974), however air quality around the site should be routinely checked, particularily during the active life of the facility to protect workers on site.

Core and well samples taken twice yearly or so from at least 8 stations located equidistant from each other and the center of the facility are suggested to monitor natural hydrogeologic processes in the area and detect migrating contaminants. Cores should contain the entire earth profile to well below trench bottom depth and be analyzed at 5 to 10 feet intervals (Walker, 1974). Samples from wells perforated where discontinuous water bearing Cenozoic deposits are present should be monitored at least monthly because of the high mobility that pollutants will have in these saturated media. Surface water, when available, should be routinely sampled and analyzed.

Immediate remedial actions at a failed facility may necessitate the construction of vertical interceptor drains or impermeable barriers around the facility perpendicular to the direction of flow to intercept contaminants migrating through different horizons. Collected fluids must be pumped out and properly disposed of. Intermittent water zones may need to be artificially lowered by pumping to reduce the driving head on migrating pollution.

The proposed site was selected because of the minimal damage that might result from a failed facility, but a costly cleanup of the site could sometime be necessary if stringent geological, constructional, and operational guidelines are not followed.

HARMONY WITH LOCAL LAND USE

The economy of Wallace County is centered in agriculture and local land use includes hog, sheep, and cattle ranching as well as milo, wheat, and other crop farming. An operating facility should be coordinated with community officials to assure harmony with public concerns.

Long term considerations must include a perennial vegetative cover to stabilize slopes and surface material, irrigated, if necessary, from Lower Cretaceous ground waters. Buffalo grass is indigenous to the High Plains and should be considered for use to maintain harmony with the terrain. The vegetative cover must be routinely analyzed for plant uptake and should not be allowed to enter the food chain by grazing or harvesting. Only the sampling wells and monitoring checks should be permanently foreign to the landscape.

DISCUSSION

Effective July 1, 1985, additional hazardous waste legislation calls for closure and post-closure plans to be made for underground burial sites at hazardous waste management facilities operating in Kansas, and continues to permit the secretary of KDHE to authorize underground burial only when no economically reasonable or technologically feasible methodology exists for the disposal of a particular hazardous waste. Underground injection, mound landfill, land treatment facilities, and above-ground storage remain viable options in the minds of our legislators when in-state recycling or shipment to another state for treatment and/or disposal is not possible.

The underground injection of any hazardous waste at surface temperature may fracture the zone of emplacement, increase pore pressures, promote earth movement, and allow pressured contaminants to migrate in all directions with few monitoring and remedial actions available. This potential for uncontrolled and widespread contamination from injection disposal techniques seems to present a higher, long-term risk factor than does shallow disposal by containment, isolation, and monitoring.

Mound landfills and land treatment facilities present a continuous direct risk to the surface of the earth and the environment, even when properly managed, and seem less suitable for permanent disposal and environmental safety than depositing these wastes in the shallow subsurface where they are out of sight, protected from the elements, and back into the earth from which they originally came.

Permanent above-ground storage is not a disposal technique, but is a suitable short-term remedy if properly managed.

Burial in abandoned salt caverns is not ideal due to the high solubility these deposits may have when in contact with liquid or semi-solid wastes. However, the U.S. EPA will soon award a contract for the selection of three candidate room-and-pillar salt mines for a possible pilot demonstration of waste segregation and safe disposal in salt (Funderburk, 1984).

I believe that if certain toxic wastes must be disposed of within the state, then shallow burial at a compatible site should provide future generations of Kansans with the most protection possible.

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APPENDIX

Well logs from the locations plotted in Figure 11.

* a) 13-38-8 SESESE; June, 1958 augered test hole log:

	Depth, feet
Quaternary.	
Peoria and Loveland Formations	
silt, sandy, brown	03
silt, eolian, light tan	09
silt, eolian, tan	20
silt, eolian, tough, tan	30
Tertiary	
Ogallala Formation	
clay, silty, tough, tan; contains embedded gravel	35
silt, and fine to coarse sand, tan	40
clay, silty, tough	42
Cretaceous	
Pierre Shale	
shale	46

* b) 13-39-5 NWNWNW; June, 1958 augered test hole log:

	Depth, feet
Quaternary	
Peoria and Loveland Formations	
silt, brown	10
silt, eolian, light tan	14
silt, sandy, tough	18
Cretaceous	
Pierre Shale	
shale, grey brown	24

* c) 13-39-10 SWSWSW; June, 1958 augered test hole log:

	Depth, feet
Quaternary	
Peoria and Loveland Formations	
silt, brown	04
silt, light tan	09
silt, tan	12
Tertiary	
Ogallala Formation	
silt, clayey	16
gravel, medium	19
silt, brown	21
clay, tough	24
Cretaceous	
Pierre Shale	
shale, brown, grey	29

** d) 13-39-17 SENWNE; 1/23/78 Driller's log:

	Depth, feet
clay	05
sand and gravel	35
shale	40

** e) 13-39-20 SWSWSW; 9/1/75 Driller's log:

	Depth, feet
clay	09
gravel	11
clay-gravel	22
clay	23
gravel	24
clay	26
shale	31
gravel	40
shale	41

* (From Hodson, 1961)

** (From KDHE, 1985)