HYDROGEOLOGY AND GROUND-WATER-QUALITY CONDITIONS AT THE SUMNER COUNTY LANDFILL, SOUTH-CENTRAL KANSAS, 1989-90

By Nathan C. Myers, Brian A. Heck, and Dirk A. Hargadine

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	*By*	*To obtain*
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	4,047	square kilometer
gallon	3.785	liter
cubic foot	0.02832	cubic meter
foot per mile	0.1894	meter per kilometer
gallon per minute	0.06309	liter per second
foot squared per day[1]	0.09290	meter squared per day
degree Fahrenheit (°F)	°C = 5/9 x (°F-32)	degree Celsius (°C)

[1] The standard unit for transmissivity (T) is cubic foot per day per square foot times foot of aquifer thickness. This mathematical expression reduces to foot squared per day.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

DEFINITION OF TERMS

Aerobic - Living, active, or occurring only in the presence of free oxygen.

Anaerobic - Living, active, or occurring in the absence of free oxygen.

Arkosic - Indicates that a sediment or rock contains at least 25-percent feldspar.

Equipotential line - A line in a two-dimensional ground-water flow field such that the total hydraulic head is the same for all points along the line.

Facultative bacteria - Bacteria that can live either in aerobic or anaerobic conditions.

Hydraulic conductivity - The volume of water at the existing kinematic viscosity that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. Units of hydraulic conductivity are:

$$\frac{\text{length}^3/\text{time}}{\text{length}^2\text{length}/\text{length}} \left(\text{for example, } \frac{\text{feet}^3/\text{day}}{(\text{feet}^2)\ (\text{feet}/\text{feet})} \right)$$

but, as in this report, are commonly reported as length/time (for example, feet/day).

Hydraulic gradient - Rate of change in total hydraulic head per unit of distance of flow in a given direction.

Hydrolysis - A chemical decomposition process involving splitting of a bond and addition of the elements of water (hydrogen and oxygen).

Obligate methanogenic - Bacteria that live only in anaerobic conditions and produce methane as a byproduct of their metabolic processes.

Porosity - Ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.

Potentiometric surface - A surface that represents the levels to which water will rise in tightly cased wells. If the hydraulic head varies considerably with depth in an aquifer, then there may be more than one potentiometric surface for that aquifer.

Redox - Short-hand term for reduction-oxidation chemical reactions in which electrons are transferred from one element to another. An element that loses electrons and thus increases its charge is said to be oxidized, whereas an element that gains electrons and thus decreases its charge is said to be reduced. In the reaction Fe (metal) + Cu^{2+} --> Fe^{2+} + Cu (metal), the iron is oxidized, and the copper is reduced.

Symbiotic - The intimate association of two dissimilar organisms in a mutually beneficial relationship.

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ABSTRACT

An investigation of hydrogeology and ground-water-quality conditions at the Sumner County Landfill, south-central Kansas, was conducted from November 1989 to April 1990. Potentiometric-surface maps constructed from water levels in temporary, monitoring, unused supply, and private-supply wells, and from Beaver Creek indicated that ground-water movement west of Beaver Creek is south and southeast, except near the west end of the cover-material pit, where ground-water movement is southwest. East of Beaver Creek, ground-water movement is southwest.

The Wellington Formation of Permian age crops out along Beaver Creek in the northern part of the landfill and underlies Pleistocene terrace deposits elsewhere on the landfill. A thin layer of Holocene alluvium is present along Beaver Creek downstream from the Wellington outcrop.

Analyses of water samples from 10 monitoring wells, Beaver Creek, and a private-supply well indicate that the primary factor affecting water quality is the source of the water. Water from the Wellington Formation is more mineralized than is water from Pleistocene terrace deposits because of the occurrence of halite and gypsum in the Wellington Formation. Large concentrations of manganese and organic compounds in water from some wells downgradient from the landfill might be the result of landfill leachate mixing with ground water. Concentrations of organic compounds decrease in the downgradient direction due to dispersion, dilution, volatilization, and degradation. Leachate-containing ground water probably discharges to Beaver Creek where it is diluted by creek water.

Periodic water-level measurements and quarterly analyses of water samples for selected compounds would improve understanding of seasonal and long-term changes in hydrologic and water-quality conditions.

INTRODUCTION

Shallow aquifers in central and eastern Kansas provide water for public and private drinking-water supplies, for irrigation and livestock watering, and for industrial uses. Information describing the geologic characteristics of the aquifers, the sources and directions of ground-water flow, and the chemical nature of ground and surface water is an important contribution to informed public-decision making in which water resources are concerned. To determine the effects of landfills on water quality, the Kansas Department of Health and Environment is requiring that ground-water monitoring systems be installed in all public landfills in Kansas (Charles Linn, Kansas Department of Health and Environment, oral commun., 1988). This report presents the results of an investigation conducted by the U.S. Geological Survey (USGS) in cooperation with Sumner County, Kansas, from November 1989 to April 1990. This investigation is one of several being conducted in Kansas by the USGS that describe the effects of landfills on the quality of water in shallow aquifers.

Purpose and Scope

The purpose of this study was to determine the geology, hydrology, and water-quality conditions in the vicinity of the Sumner County Landfill, and the effects of the landfill on shallow ground-water quality. This report describes, in general, the fate of waste materials in landfills, methods used in the investigation, the landfill setting and operation, regional geology and hydrology, landfill geology and hydrology, and regional and landfill-area water quality. The results of test-hole drilling and water-level measurements are used to discuss geology and hydrology in the vicinity of the landfill. Results of ground- and surface-water sampling show water-quality conditions near the landfill and the effects of the landfill on ground-water quality.

General Description of Study Area

The Sumner County Landfill is located about 1 mile southeast of Wellington, in south-central Kansas, in the northwest 1/4 of sec. 25, township 32 south, range 1 west (figs. 1 and 2). This area is in the Arkansas River Lowlands section of the Central Lowland physiographic province (Schoewe, 1949) and is characterized by rolling hills of low relief and flat flood plains along creeks (fig. 2). Surface runoff in the active part of the landfill is east and south towards Beaver Creek. Beaver Creek joins Slate Creek, a major southeast-flowing stream in the area, about one-third of a mile south of the landfill.

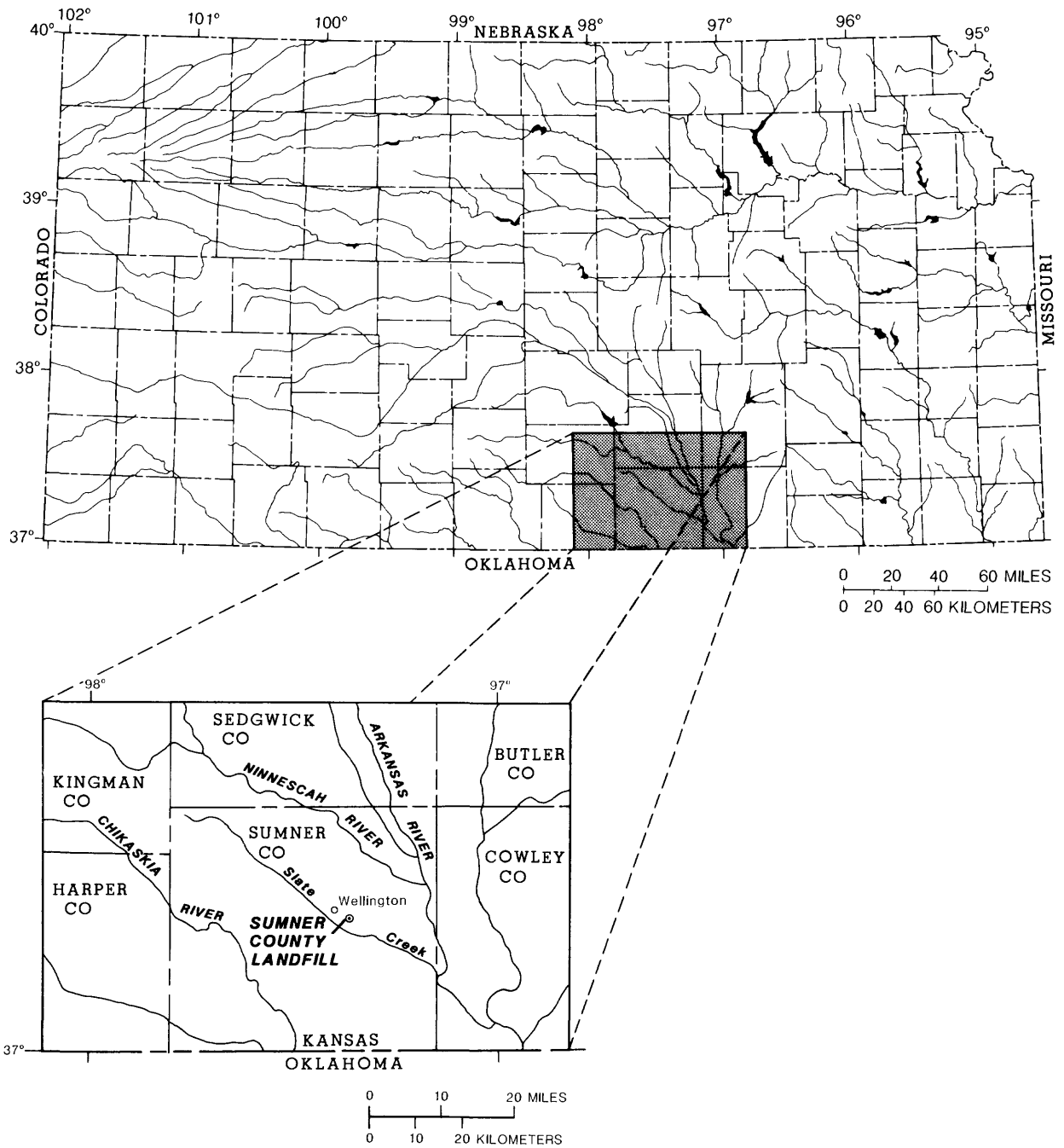


Figure 1. Location of Sumner County Landfill.

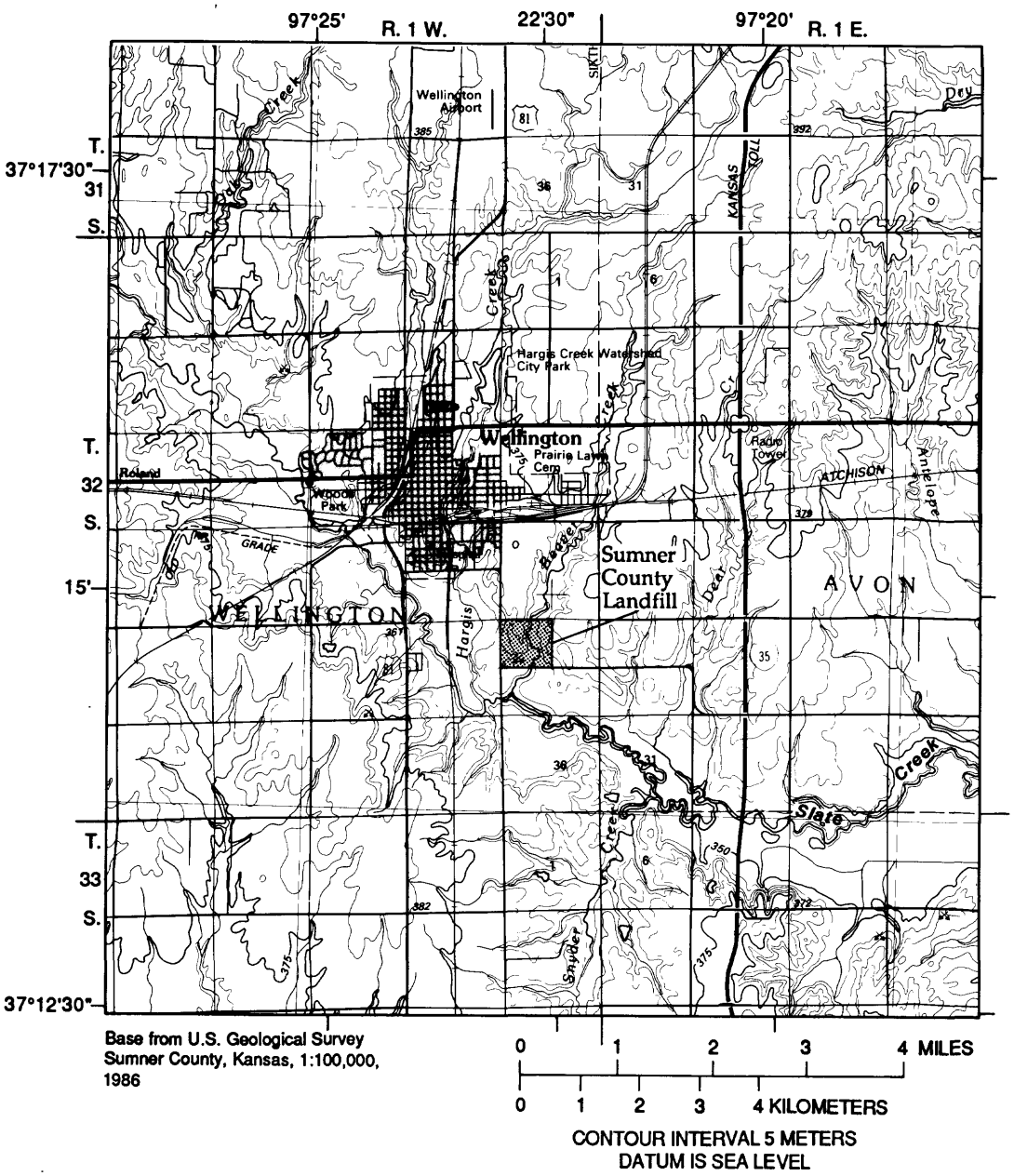


Figure 2. Topography in vicinity of Sumner County Landfill.

Climatic conditions vary considerably from season to season and year to year. Seasonal temperatures generally range from highs in the upper 90 °F range to lows in the subzero range and can reach 120 °F in the summer and -19 °F in the winter (Walters, 1961). For 1951-80, the mean annual precipitation at Wellington was 32.98 inches (National Oceanic and Atmospheric Administration, 1989), of which more than 80 percent fell in the 8-month period from March 1 through October 31.

Acknowledgments

The authors would like to thank several people for their assistance during the study: John Gough, Sumner County Engineer, assisted by coordinating the study through his office; Lloyd Whitney, Motor Pool Foreman, loaned us storage space; James Wimberly, Landfill Operator, provided valuable information about the landfill's history; and heavy-equipment operators provided access to well sites on the landfill.

SOLID WASTES IN PUBLIC LANDFILLS

Although the exact solid-waste composition and chemical processes in the Sumner County Landfill are not known, they can be inferred to be similar to the general compositions and chemical processes discussed in the following paragraphs. The following section is modified from Myers and Bigsby (1989).

Solid-Waste Composition

Solid wastes are discarded, unwanted materials. In the past, landfill sites generally were merely convenient depressions, and solid wastes were considered as serviceable fill to level low-lying areas. Few if any sites were planned as engineering projects. Solid wastes commonly were left uncovered in open dumps. As an alternative, the sanitary-landfill method was developed, incorporating engineering principles for maximum containment of solid wastes. Basic design features of a sanitary landfill are an impermeable bottom and sides, exclusion of drainage, compaction and daily covering of the solid waste, and final impermeable capping (Salvato and others, 1971; Degner, 1974).

The composition of Sumner County Landfill solid wastes is not known explicitly, but typical nationwide composition, by weight, is 45-percent paper, 15-percent food waste, 11-percent yard and garden trimmings, 9-percent metal, 8-percent glass, 4-percent dirt, ashes, and concrete, 3-percent textiles, 3-percent plastics, and 2-percent wood (Tchobanoglous and others, 1977). About 80 percent of the solid waste is combustible, of which aggregate volumes of fixed carbon, moisture, and volatile organic matter represent 7, 20, and 53 percent of the solid waste, respectively. Solid-waste composition varies due to climate, season, recycling, demography, packaging, and marketing (Tchobanoglous and others, 1977).

Solid-Waste Degradation

About 80 percent of typical solid waste, including paper, food waste, yard and garden trimmings, and ferrous metal, degrades quickly. The other 20 percent, mostly glass, wood, rubber, plastics, and synthetic textiles, degrades more slowly (Tchobanoglous and others, 1977). Initially, while solid wastes are exposed to the air, the landfill environment is oxidizing. After trapped or incoming oxygen is depleted by aerobic bacteria, the chemical environment becomes reducing. Degradation processes in the landfill include biologic decomposition, solution, precipitation, sorption, ion exchange, and diffusion of gases (Baedecker and Back, 1979). Sufficient moisture, 40 to 60 percent, is essential, however, for significant degradation rates.

While oxygen is available, biologic decomposition is accomplished by aerobic bacteria and then, in the absence of oxygen, by anaerobic bacteria. Aerobic decomposition proceeds rapidly and probably begins in easily degradable garbage soon after deposition of the waste. Decomposition by hydrolysis allows bacteria to convert complex insoluble organic molecules to simple, soluble ones that the bacteria can use for growth. Net products are primarily carbon dioxide and water, plus sulfate and ammonia (Baedecker and Back, 1979).

When oxygen is depleted by aerobic decomposition, anaerobic decomposition of the organic wastes begins. The organic wastes contain a large microbial population that recycles organic carbon back to the atmosphere (Gaudy and Gaudy, 1980). The recycling of organic wastes by anaerobic decomposition requires a symbiotic relationship between faculative bacteria and obligate methanogenic bacteria. This recycling process is thought to occur in two steps. The first includes the fermentation of large organic particles by faculative bacteria to small soluble molecules and then to fatty acids and alcohols (Gaudy and Gaudy, 1980). These molecules can either remain in the anaerobic zone or diffuse upwards to an aerobic zone. If they diffuse upward, they are converted by microorganisms to carbon dioxide. In step two, many of the acids and alcohols in the anaerobic zone produced by the primary fermentation are converted to methane by obligate methanogenic bacteria (Gaudy and Gaudy, 1980). Depending upon their type, methanogenic bacteria can metabolize hydrogen and carbon dioxide, formic acid, methanol, or acetic acid (Gaudy and Gaudy, 1980). The overall process requires a working relation

between the two bacteria. The methanogenic bacteria utilizes the acids, alcohols, and hydrogen from the fermentative bacteria to produce methane. The use of hydrogen allows the fermentative bacteria to ferment more compounds. End products of the fully completed anaerobic decomposition are methane, water, and carbon dioxide. The end products probably first appear on the periphery of the landfill (Gaudy and Gaudy, 1980) where the higher pH of the leachate is more favorable to methanogenic bacteria.

At any specific time, wastes in different parts of the same landfill can be in different stages of decomposition. Stage and rate of decomposition also will vary from one landfill to another, depending primarily on moisture content, but also on temperature and on local procedures for shredding, mixing, and compacting the wastes. In many landfills, the aerobic stage is completed within a few weeks, and anaerobiosis is quick enough to allow substantial methane production to peak within 2 years and then decrease for 25 years or longer (Tchobanoglous and others, 1977). The progress of anaerobic decomposition at any given time can be estimated from the attendant conditions. In step one, leachate pH is 4.0 to 5.0; specific conductance is large due to acidic solution of metals; and chemical oxygen demand also is large (O'Leary and Tansel, 1986). In step two, methane-gas concentrations in the landfill are large; leachate pH is 7.0 to 8.0; and specific conductance and chemical oxygen demand are small (O'Leary and Tansel, 1986).

Leachate Production and Composition

Leachate is generated by the percolation of water through the waste and the extraction of dissolved and suspended materials, both biological and chemical (Tchobanoglous and others, 1977). Paper, which comprises about 45 percent of all waste, absorbs most of the water originally available in the trash. Therefore, the production and discharge of leachate from a landfill above the water table require the infiltration of precipitation downward from the land surface. Solids, gases, and liquids from the waste are incorporated in water as dissolved, suspended, or sorbed, and miscible or immiscible components. Metabolic carbon dioxide, produced by bacterial action, dissolves easily, decreasing leachate pH. The resulting dissolution of calcium carbonate, if present, increases hardness and dissolved solids. Solvent capability of the leachate also is increased by the bacterially generated organic acids, which allow some metals in the landfill to be dissolved.

Chemical processes in leachate production are oxidation, reduction, dissolution, precipitation, ion exchange, and sorption. In the landfill, these processes are controlled to a large extent by the types of organic compounds present (Baedecker and Back, 1979). Physical processes include settlement, movement of evolved and ejected water by differential hydraulic heads, entrainment of colloidal and particulate material in flushing water, filtration, change of solute concentration by osmosis and concentration gradients, density separation of immiscible phases, and vertical and horizontal migration of gases.

Leachate composition is variable. Some typical concentrations and composition ranges of the most abundant constituents are listed in table 1. Where ranges are given, the larger values are expected only in newer landfills because these are undergoing rapid early-stage biodegradation, which involves acid production. Sodium and potassium tend to remain in solution, unsorbed by clay when calcium is present. Alkalinity normally is significant in leachate because bicarbonate is produced in anaerobic reactions by bacterial reduction of nitrate and nitrite (Apgar and Langmuir, 1971) directly and indirectly when carbon dioxide dissolves. Bicarbonate also is dissolved from landfill ash, soil, and rock. Sulfate, derived from ash and treatment wastes, can be reduced within the landfill anaerobic environment and precipitated as ferrous sulfide, but otherwise tends to remain in solution. Chloride is nonreactive, and its variation in leachate is due mostly to dilution. Nitrogen is present mostly as ammonia because of pH and redox conditions stemming from anaerobic decomposition and the presence of dissolved iron (Apgar and Langmuir, 1971). Iron and manganese commonly are present in leachate in large concentrations. These constituents can be derived from wastes and from oxide coatings and cements in soil and rock.

Table 1. *Typical properties and concentrations of constituents in landfill leachate*

[Concentrations in milligrams per liter (mg/L) except for pH; --, no data]

Property or constituent	Concentrations		
	Salvato and others, 1971	Tchobanoglous and others, 1977	Cameron, 1978
pH (standard units)	5.6-8.3	6.0	7.5
Chemical oxygen demand	7,130	18,000	800
Biochemical oxygen demand	7,050-32,400	10,000	120
Hardness, total	537-8,120	3,500	--
Sodium	350-1,805	500	800
Potassium	655-1,860	300	490
Alkalinity, total as $CaCO_3$	1,290-8,100	3,000	3,400
Sulfate	99-1,220	300	5.3
Chloride	220-2,240	500	2,300
Dissolved solids	2,000-11,254	--	4,270
Nitrate, as N	1.1-4.1	5.6	--
Ammonia, as N	109-656	155	331
Nitrogen, organic, as N	152-550	200	--
Iron	219	60	24

Leachate can contain trace metals such as cadmium, chromium, cobalt, copper, lead, mercury, nickel, strontium, and zinc in detectable concentrations. Other environmentally significant elements detected in landfill leachate include arsenic, boron, and selenium. These elements can occur naturally in the environment or can be derived from the landfill wastes. Elements present at concentrations above natural background are likely derived from municipal and industrial wastes or dissolution of natural compounds by leachate.

METHODS OF INVESTIGATION

The study of the Sumner County Landfill was conducted in four phases. During the first phase, data on the history, geology, hydrology, and land ownership of the landfill was collected. On the basis of this information, temporary-well sites were selected. The second phase included the augering of test holes, the installation of temporary wells to determine the hydrology and geology of the area, and the installation of permanent monitoring wells. In the third phase, water samples were collected from all monitoring wells and from selected surface-water locations. These samples were analyzed by the U.S. Geological Survey's water-quality laboratory in Arvada, Colorado. This report concludes the fourth phase of data interpretation and reporting. The following sections relate details of the investigation methods.

Information Search

Prior to any field work, a search of published literature, of the Kansas Department of Health and Environment (Topeka) files, and of Sumner County (Wellington, Kansas) files was completed. Geologic and hydrologic information enabled estimation of the directions of ground-water flow, depth to bedrock, and geology in the vicinity of the landfill. This information was useful for planning well locations, field activities, and material needed.

Installation of Temporary Wells

Fourteen temporary wells (TW-1 through TW-14) were installed (fig. 3) using 3 1/4-inch inside diameter (6 5/8-inch outside diameter) hollow-stem augers. A knock-out plate inserted in the bit was used to keep the inside of the auger flights free of sand and mud while drilling. In unconsolidated sediments below the water table, it was necessary to "load" the augers with potable water. This prevented sediment surging into the augers when the knock-out plate was dislodged by the action of setting the well. Temporary wells consisted of 2-inch, schedule-80, flush-joint PVC (polyvinyl chloride) casing and a 2-foot, 0.010-inch slot screen with a flush-thread cap on the bottom of the screen. At some locations, two temporary wells were set at different depths (nested) to evaluate vertical ground-water movement.

After installation of all temporary wells, the top-of-casing altitude for each well was determined by a level survey (table 2). Water levels in the temporary wells were measured to the nearest 0.01 foot with a steel tape. Water-level altitudes were used to construct a potentiometric-surface map to indicate approximate directions of ground-water flow. Temporary wells were removed after completion of the field work.

Geologic information was collected while augering; cuttings were collected and described, and bit pressure was noted. Sediment cores were collected with a split-spoon sampler at one location (temporary well TW-10) for a continuous detailed sediment log. Borehole logs of natural gamma activity were recorded with a Mt. Sopris[1] logger to aid in lithologic determinations.

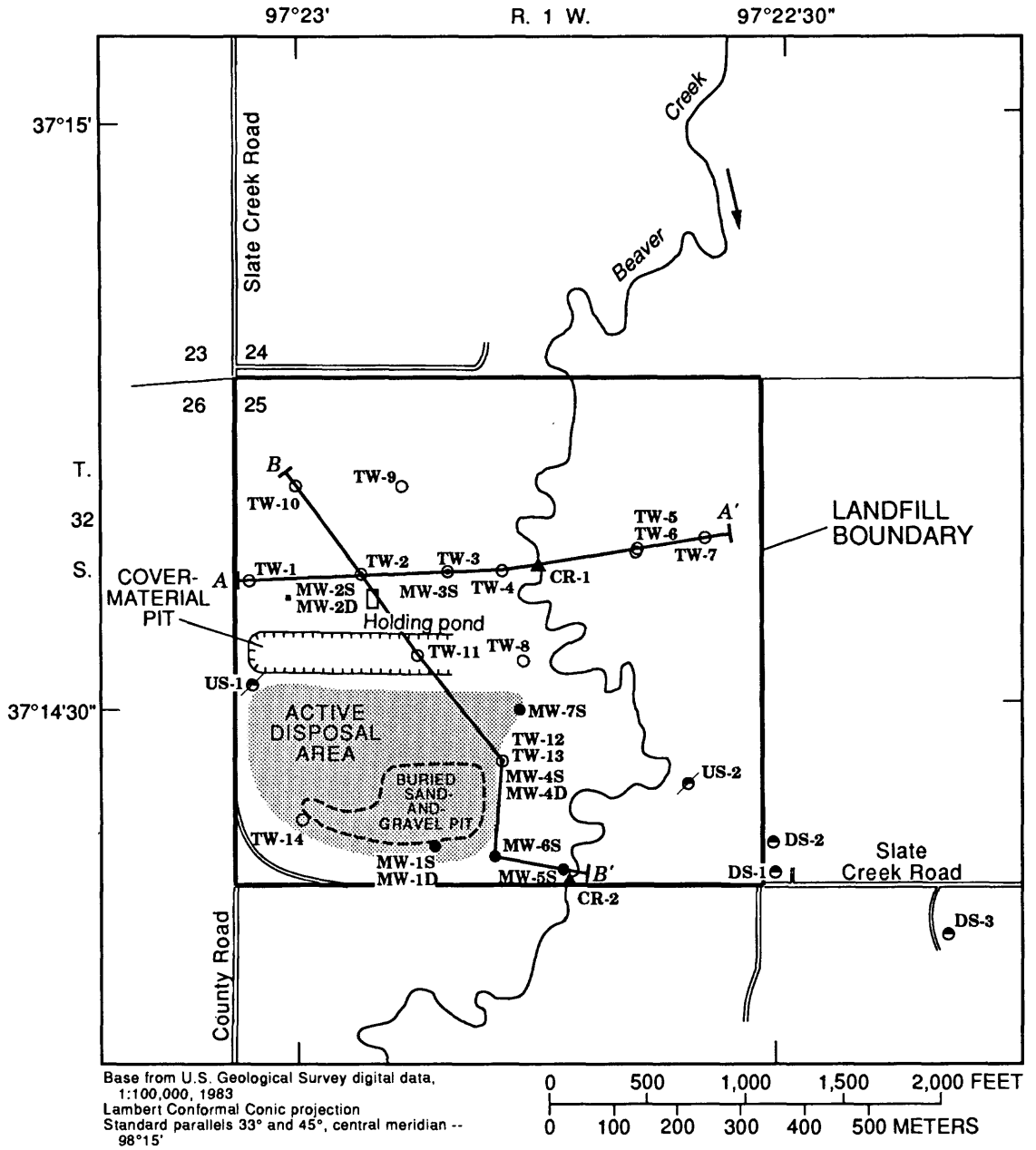
Installation of Monitoring Wells

There were nine monitoring wells installed for this study, in addition to the one existing monitoring well (monitoring well MW-1S) (fig. 3). Each of the nine wells was installed using 6 1/4-inch inside diameter (9 7/8-inch outside diameter) hollow-stem augers with a steel knock-out plate inserted in the bottom of the bit, as described for temporary-well installation. To avoid contamination from non-formation water, the augers were not "loaded" with potable water as in temporary-well installation. Rather, a "Perry-Hart" swab (Perry and Hart, 1985) was used to dislodge the steel knock-out plate and allow the water level inside the flights to equalize with the formation water level. The swab then was removed, and the well casing was lowered down inside the flights. Filter-pack sand and bentonite chips were poured in the annular space of each well as the augers were being withdrawn from the borehole.

To avoid potential cross contamination between wells or from other sources, all equipment was cleaned prior to installation of each monitoring well. Loose cuttings were removed from augers and other tools with a high pressure jet of a potable water. Augers and tools then were scrubbed with a water and alconox mixture and rinsed with potable water. Potable water was obtained from a hydrant at the Sumner County motor-pool shop in Wellington and hauled to the landfill in a stainless-steel tank.

Each monitoring well consisted of a 2-inch diameter, 5-foot, 0.010-inch slotted PVC screen and a 2-inch diameter, threaded, flush-coupled, schedule-40 PVC riser with a buna-n rubber o-ring to create a leakproof seal. No glue or joint solvent was used in well construction. Each of the screens and risers were factory washed and sealed in plastic bags. Filter-sand-pack thicknesess were 6 to 7 feet, extending from the bottom of the well screen to 1 or 2 feet above the screen. Bentonite chips were added through the flights to create a 1- to 2-foot thick seal on top of the filter pack. The flights then were removed, and natural-formation sediments were allowed to collapse on the well casing. A bentonite grout then was pumped into the open hole to seal the borehole from 10 feet to 2 feet below land surface. Bentonite chips then were added to bring the level of grout up to 1 foot below land surface. After grouting, concrete was poured into the remaining 1 foot of borehole to make a plug and a 2-foot-diameter concrete pad. A protective casing, with locking cap, was set in the wet concrete. The typical monitoring-well design is shown in figure 4.

[1] The use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.



EXPLANATION

- A — A' TRACE OF SECTION--Shown in figures 10 and 14
- OUTLINE OF BURIED SAND-AND-GRAVEL PIT
- DIRECTION OF FLOW IN BEAVER CREEK
- TW-10 TEMPORARY WELL AND NUMBER
- MW-4S / MW-4D MONITORING WELL AND NUMBER--S, indicates shallow well; D, indicates deep well
- TEMPORARY WELL AND MONITORING WELL AT SAME SITE
- DS-2 PRIVATE-SUPPLY WELL AND NUMBER
- US-2 UNUSED SUPPLY WELL AND NUMBER
- CR-2 CREEK SAMPLING SITE AND NUMBER

Figure 3. Location of temporary, monitoring, private-supply, and unused supply wells, and Beaver Creek sampling sites.

Table 2. *Top-of-casing altitude and total depth of temporary (TW), monitoring (MW), private-supply (DS), and unused supply (US) wells, altitude of creek bed (CR-1) and chiseled square on north headwall of bridge over Beaver Creek (CR-2), and geologic unit to which well is open*

[Top-of-casing altitude for wells generally is 1 to 3 feet above land surface]

Well or creek (fig.3)	Altitude (feet)	Total depth below land surface (feet)	Geologic unit to which well is open
TW-1	1,208.32	53.0	Terrace deposits
TW-2	1,194.71	38.0	Terrace deposits and Wellington Formation
TW-3	1,204.80	48.0	Terrace deposits and Wellington Formation
TW-4	1,189.91	30.0	Wellington Formation
TW-5	1,179.38	23.0	Wellington Formation
TW-6	1,180.55	14.0	Terrace deposits
TW-7	1,199.34	36.0	Wellington Formation
TW-8	1,180.17	25.0	Terrace deposits
TW-9	1,206.88	43.5	Terrace deposits
TW-10	1,200.95	41.0	Terrace deposits and Wellington Formation
TW-11	1,180.37	22.0	Terrace deposits
TW-12	1,178.23	22.5	Terrace deposits and Wellington Formation
TW-13	1,178.70	15.0	Terrace deposits
TW-14	1,181.53	27.0	Terrace deposits
MW-1S	1,175.57	23.5	Terrace deposits
MW-1D	1,177.19	33.0	Wellington Formation
MW-2S	1,194.78	35.0	Terrace deposits
MW-2D	1,194.99	48.0	Wellington Formation
MW-3S	1,203.67	45.0	Terrace deposits
MW-4S	1,179.38	22.0	Terrace deposits
MW-4D	1,179.50	30.0	Wellington Formation
MW-5S	1,174.85	20.0	Terrace deposits
MW-6S	1,174.66	20.0	Terrace deposits
MW-7S	1,178.43	18.0	Terrace deposits
DS-1	1,181.64	57.5	Terrace deposits (?)
DS-2	Unknown	Unknown	Terrace deposits (?)
DS-3	Unknown	Unknown	Terrace deposits (?)
US-1	1,200.08	46.0	Terrace deposits
US-2	1,180.51	25.0	Terrace deposits
CR-1	1,170.19	Not applicable	Not applicable
CR-2	1,175.14	Not applicable	Not applicable

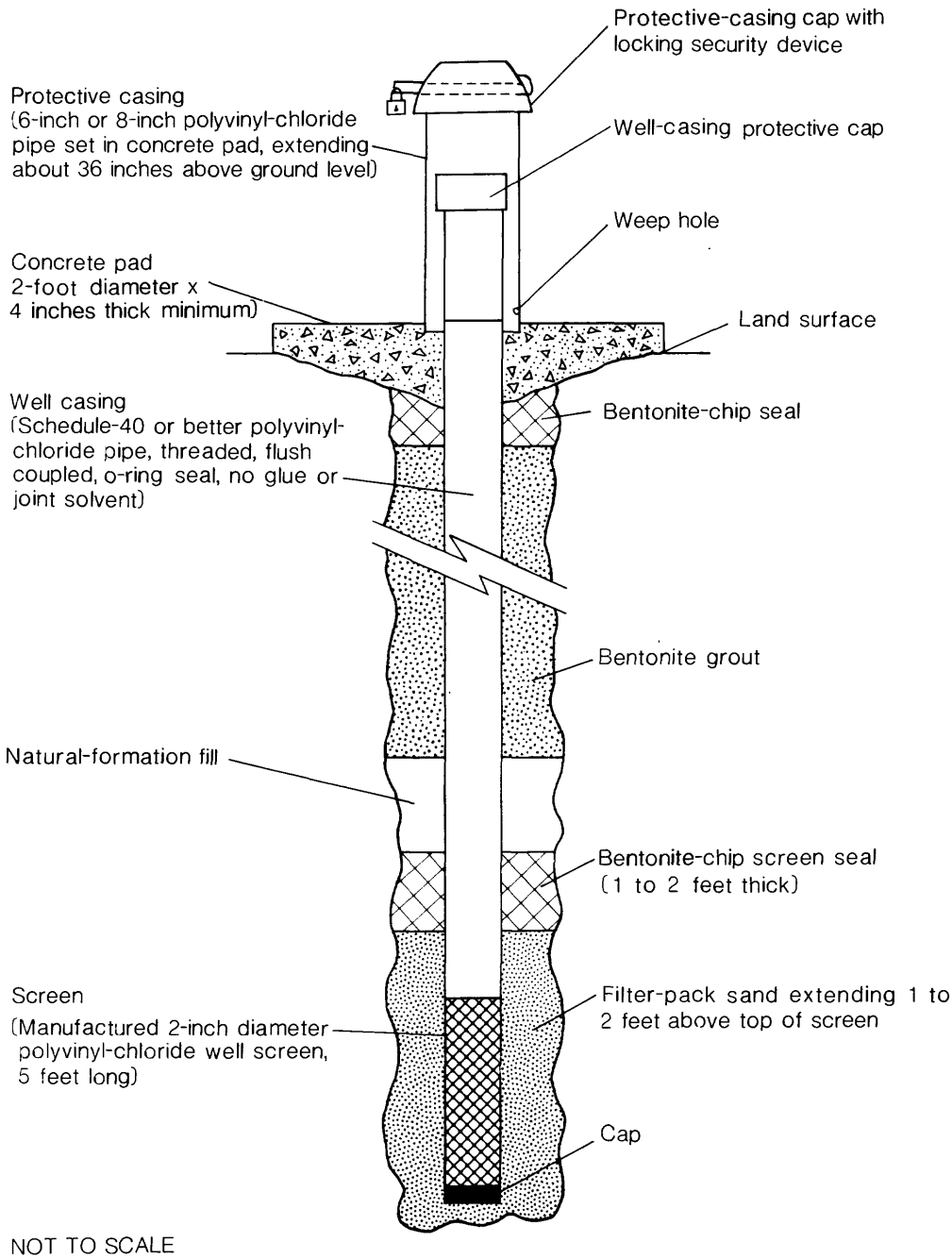


Figure 4. Monitoring-well design.

Monitoring wells were developed using a positive-displacement hand pump or a centrifugal pump. Water was pumped from the wells until the turbidity cleared. Then, the water level in the wells was allowed to recover, and water was pumped again until the turbidity cleared.

Water Sampling

The nine monitoring wells installed by the U.S. Geological Survey (monitoring wells MW-1D, MW-2S, MW-2D, MW-3S, MW-4S, MW-4D, MW-5S, MW-6S, MW-7S) plus one existing monitoring well (monitoring well

MW-1S) at the Sumner County Landfill were sampled on April 4-6, 1990. To minimize contamination, the wells upgradient from the landfill (monitoring wells MW-2S, MW-2D, and MW-3S) were sampled first, and followed by downgradient wells (monitoring wells MW-1S, MW-1D, MW-4S, MW-4D, MW-5S, MW-6S, and MW-7S). In addition, water samples were collected from Beaver Creek (sampling site CR-2) and from private-supply well DS-1. A duplicate sample (MW-6S dup) was collected from monitoring well MW-6S.

Water levels and total depths in all monitoring wells were measured to the nearest 0.01 foot with a steel tape. The tape was cleaned with distilled water before each use. To assure that the water samples collected were representative of aquifer conditions, each well was purged of about five water-column volumes, except monitoring well MW-1S, was pumped dry after removal of 40 gallons, and 50 gallons was pumped from private-supply well DS-1. The volume of water (table 3) to be purged from each well was determined from water-level and total-depth measurements. Each well was purged with a dedicated positive-displacement hand pump that had been cleaned before being transported to the landfill. Water samples were collected from the spigot of the dedicated hand pumps.

Ground-water samples for various analyses were collected in the following order: (1) volatile organic compounds, (2) semivolatile organic compounds, (3) methylene-blue active substances, (4) dissolved organic carbon and common ions, including nutrients and chemical oxygen demand, and (5) trace metals. Care was taken not to aerate the water when collecting samples. Samples were immediately packed in ice. Dissolved-organic-carbon samples were filtered onsite through a 0.2-micrometer silver filter. Trace-metal samples were filtered onsite through a 0.45-micrometer filter. Both types of filters were flushed with about 500 milliliters of sample water before filtration of the sample to be analysed. Specific-conductance, pH, water-temperature, and alkalinity determinations were made at the time of sample collection.

The water samples from private-supply well DS-1 were collected in a similar manner to those from the ground-water monitoring wells, except that samples for analysis of methylene-blue active substances, nutrients, chemical oxygen demand, and trace metals (except iron and manganese) were not collected. Surface-water samples from Beaver Creek were collected by dipping water from near the center of flow in the creek. These samples were collected in the same order and processed in the same way as those for the monitoring wells, except that samples for analysis of volatile organic compounds were not collected.

Water samples were mailed within 5 days of collection to the U.S. Geological Survey water-quality laboratory in Arvada, Colorado. Organic and inorganic constituents were analyzed according to U.S. Geological Survey methods for determining organic substances in water (Wershaw and others, 1987) and inorganic substances in water (Fishman and Friedman, 1989).

LANDFILL SETTING AND OPERATION

The Sumner County Landfill occupies 150 acres along Beaver Creek southeast of Wellington, Kansas (figs. 2 and 5). The active part of the landfill, about 40 acres, is located in the southwestern part of the landfill property near the southern end of a broad ridge west of Beaver Creek. Other parts of the landfill are used for sewage-solids disposal, cropland, and pasture (fig. 5). Sewage solids from a local sewage plant are spread on a field north of the active disposal area. Land surrounding the landfill property is used for agriculture and rural residences.

The original landfill site, operated by the city of Wellington, was located in a sand-and-gravel pit in the southern part of the active disposal area. This sand-and-gravel pit is now solid waste-filled and soil-covered. According to a level survey done in 1976, the altitude of the bottom of this pit ranged from 1,165 to 1,175 feet above sea level, which is similar to the ground-water-level altitudes measured in wells near the pit during this study. In the mid-1970's, landfill operation was taken over by Sumner County. The county operates the landfill as a sanitary landfill. Trash is compacted on the working face of the active disposal area and covered with a layer of soil each day. Soil used for cover material is hauled from a pit immediately north of the active

Table 3. *Water volumes purged from wells before sampling*

Well (fig. 3)	Inside diameter of well (inches)	Height of water column in well casing (feet)	Volume[1] of water in well (gallons)	Volume[2] of water purged (gallons)
MW-1S	5.040	14.11	14.62	40.0 (pumped dry)
MW-1D	2.067	21.17	3.69	18.4
MW-2S	2.067	11.28	1.97	9.8
MW-2D	2.067	25.99	4.53	22.6
MW-3S	2.067	12.68	2.21	11.0
MW-4S	2.067	9.87	1.72	8.6
MW-4D	2.067	20.15	3.51	17.6
MW-5S	2.067	6.96	1.21	6.0
MW-6S	2.067	11.31	1.97	9.8
MW-7S	2.067	10.47	1.82	9.1
DS-1	4.800	47.90	45.02	50.0

[1] The equation used for calculating the volume of water in a well is:

$$V = \left[\pi \left(\frac{ID}{24}\right)^2\right] 7.48H \ ,$$

where V is volume of water in the well, in gallons;
ID is the inside diameter of the well casing, in inches;
H is the height of the water column in the well, in feet; and
7.48 is a conversion factor from cubic feet to gallons.

[2] The volume of water purged from each well was about five times the volume of water in the well, except for monitoring well MW-1S, which was pumped dry after removal of 40 gallons, and private-supply well DS-1 from which 50 gallons were pumped.

disposal area (fig. 5). The Sumner County Landfill's special-waste log indicates that small quantities of grease, paint, oil sludge, drilling mud, school laboratory chemicals, asbestos, chlorodane-contaminated soil, and pesticide containers have been disposed at the landfill. These wastes are mixed and disposed with ordinary solid waste on the working face.

REGIONAL HYDROGEOLOGY

The descriptions of geology and hydrology for Sumner County that follow provide the reader with a framework for the more detailed discussion of landfill hydrogeology later in this report.

Geology

Rocks in Sumner County are primarily shale and limestone of Permian age, which are overlain in parts of the county by unconsolidated sediments of Pleistocene and Holocene age (Walters, 1961). The Permian Wellington Formation crops out or subcrops below Pleistocene sediments throughout the eastern two-thirds of the county, including the area where the landfill is located, whereas the younger Permian Ninnescah Shale crops out or subcrops

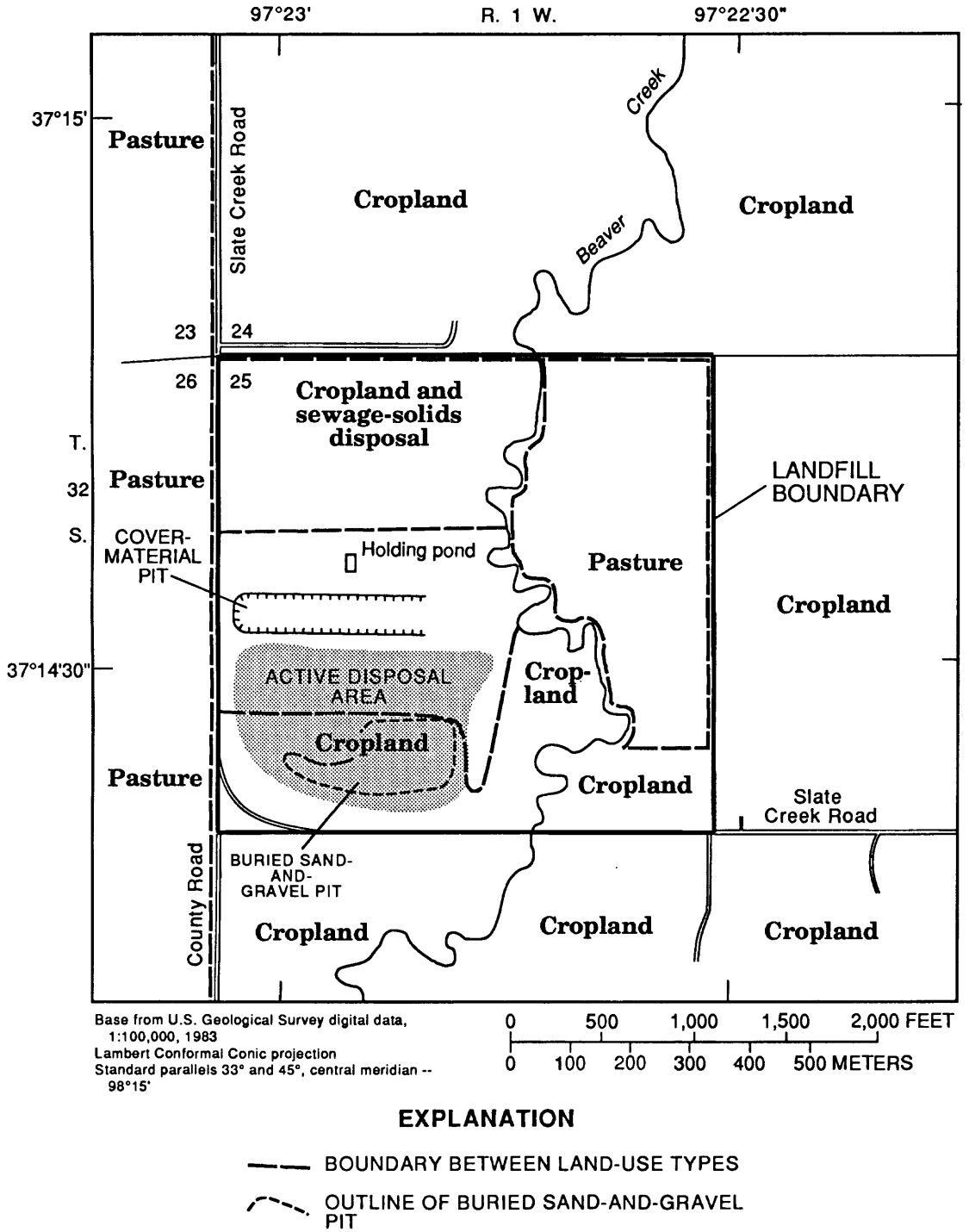


Figure 5. Land use in the Sumner County Landfill and surrounding area.

below Pleistocene sediments in the western one-third of the county.

The Wellington Formation can be divided into lower, middle, and upper parts. In Sumner County, the lower part consists primarily of 250 feet of gray shale and silty shale interbedded with some carbonate-rock lenses and thin anhydrite beds (Walters, 1961; Gogel, 1981). The middle part, the Hutchinson Salt

Member, consists of salt beds that are about 300 feet thick in western Sumner County; these beds thin to less than 50 feet thick near the city of Wellington (Gogel, 1981). The upper part of the Wellington Formation consists of blue, green, and red shale, and numerous thin beds of carbonate rocks (Walters, 1961; Berendsen and Lambert, 1981). Small quantities of gypsum and anhydrite are present throughout the formation. Walters (1961, p. 59) notes that dolomitic limestone near the top of the Wellington Formation contains "***flakes of bright green copper carbonate ***." Berendsen and Lambert (1981) investigated the occurrence of copper sulfides in the Wellington Formation and determined that copper mineralization occurs in the nonoxidized parts of the upper Wellington Formation.

Sediments of Pleistocene age consist of terrace deposits on uplands and along streams, and colluvium on uplands. Early Pleistocene terrace deposits, formed along Pleistocene stream channels, generally consist of arkosic sand and gravel and might be as much as 90 feet thick (Walters, 1961). Late Pleistocene terrace deposits along Slate Creek primarily consist of silt and clay with minor sand and gravel (Walters, 1961). Colluvial deposits result from the weathering and erosion of Permian rocks and Pleistocene terrace deposits. Holocene sediments consist of alluvium and sand dunes in river and creek valleys.

Major structural elements that affect the dip of Permian rocks in Sumner County are the Prairie Plains Homocline, the Nemaha Anticline, the Sedgwick Basin, and the Cherokee Basin (fig. 6) (Merriam, 1963). The Prairie Plains Homocline occupies a large area of eastern Kansas (fig. 6) and adjacent States and dips gently westward (Jewett, 1951; Winchell, 1957). The axis of the Nemaha Anticline extends northeasterly across Kansas and is present in southeast Sumner County (fig. 6). The Nemaha Anticline separates the Sedgwick Basin to the west from the Cherokee Basin to the east. The regional dip of Permian rocks in Sumner County is about 25 feet per mile (0.27 degree) to the west (Winchell, 1957). Dips steeper than 40 feet per mile are associated with the flanks and noses of structures of small areal extent (Winchell, 1957). No major faults are present in Sumner County.

Hydrology

The major streams in Sumner County are the Arkansas, Ninnescah, and Chikaskia Rivers, and Slate Creek, all of which flow in a southeasterly direction through the county (fig. 1). Tributaries to the major streams flow northeasterly or southwesterly.

Water-table contours in Walters (1961, plate 2) indicate that the general direction of ground-water movement in Pleistocene sediments and near-surface Permian rocks is toward the major streams. Local ground-water flow, however, probably is in the direction of the slope of the land surface or toward local discharge points, such as creeks, springs, or pumped wells. There might be some westward movement of ground water in westward-dipping Permian rocks in areas where they crop out (Walters, 1961). Local deviations from the regional direction of ground-water flow might result because of local variations in dip of rocks or because of local recharge and discharge to or from the ground-water system. Recharge of water to shallow aquifers is mainly by precipitation and seepage from ponds and streams during periods of high water levels or floods. Some recharge also might result from water seeping upward from deeper Permian rocks. Discharge of water from shallow aquifers is by evapotranspiration and seepage to streams where the water level in the aquifer is higher than that in the stream.

Ground-water supplies in Sumner County are obtained from alluvial and terrace deposits, from the Ninnescah Shale (which occurs stratigraphically above the Wellington Formation and crops out west of the study area), and from the Wellington Formation. Alluvial and terrace deposits yield large quantities of water to wells (100 to 2,500 gallons per minute), whereas the Ninnescah Shale and the Wellington Formation yield smaller quantities (15 gallons per minute) (Walters, 1961).

LANDFILL HYDROGEOLOGY

Soils

Soils in the vicinity of the landfill have been described and mapped by Fenwick and Ratcliff (1979) and are shown in figure 7. Upland soils

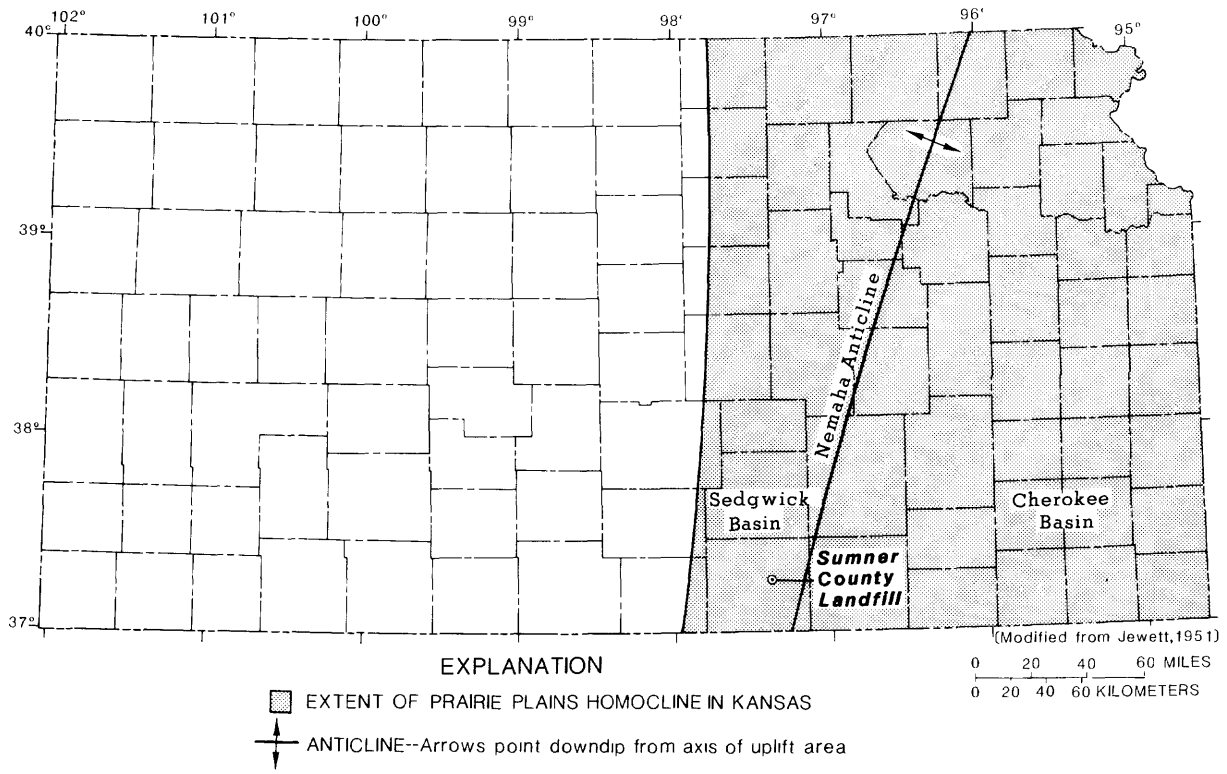


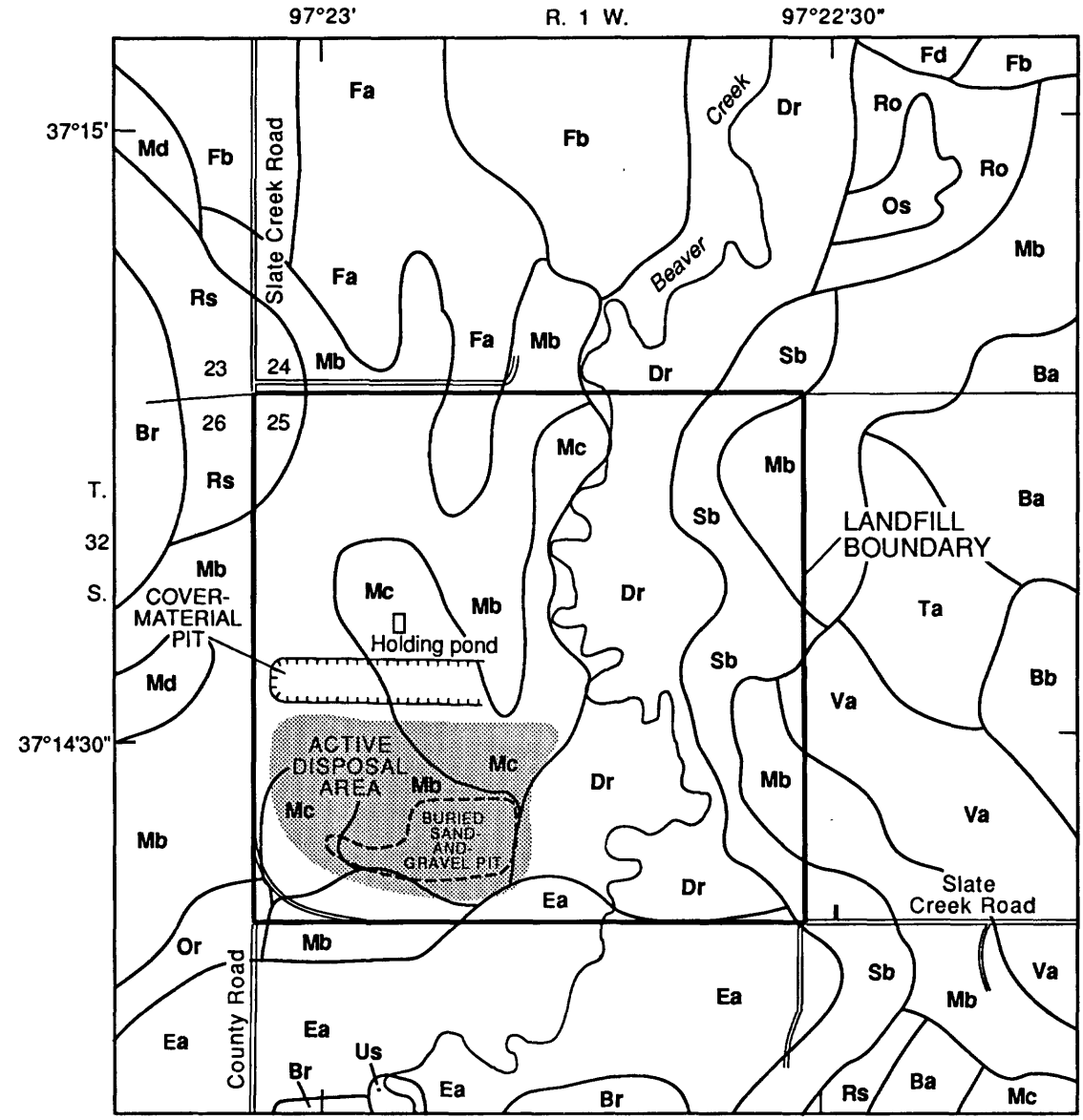
Figure 6. Regional geologic structure in south-central and eastern Kansas.

within the landfill dominantly are Milan loams, with some Shellabarger sandy loam, Farnum loam, Rosehill clay loam, and Vanoss silt loam. Lowland soils along Beaver Creek are Dale and Reinach silt loams and Elandco silty clay loam.

Young and others (1978) developed a map showing the suitability of Kansas soils and geology for solid-waste disposal. Olson (1974) classified Kansas soils according to their suitability for waste disposal on the basis of depth to water table, land slope, soil characteristics to a depth of 5 feet, flooding probability, and mechanical workability of the soil. The suitability of soils within the Sumner County Landfill for waste disposal in trench-type sanitary landfills (fig. 8) and area-type sanitary landfills (fig. 9) is based on the work of Olson (1974). However, Olson's (1974) soil-classification system was developed for statewide use and does not take into account local sediment and rock characteristics, or sediment and rock characteristics below the soil horizons at any particular site.

Geology

Lithologic and natural gamma-ray logs of boreholes and observations of the exposed geologic section on the landfill indicate that both the Wellington Formation and Pleistocene terrace deposits are present at the land surface and in the subsurface. Figures 10A and 10B show the stratigraphic succession along east-trending and southeast-trending geologic sections, respectively. The Wellington Formation crops out along Beaver Creek upstream from sampling site CR-1 (fig. 3) and was penetrated at all well locations. At the outcrop along Beaver Creek, the Wellington Formation consists of alternating layers of gray shale and limestone. Gypsum is present in voids and in partings in shale and limestone. Samples of the Wellington Formation recovered on the drill bit consisted of soft to hard, blue shale with some limestone fragments. The rate at which the bit penetrated the Wellington Formation and the sound and feel of the bit indicated that limestone layers, 1 to several inches thick, are interbedded with the softer shale. The section of Wellington Formation penetrated in boreholes



EXPLANATION

APPROXIMATE BOUNDARY OF SOIL TYPES

OUTLINE OF BURIED SAND-AND-GRAVEL PIT

SOIL TYPES

Ba Bethany silt loam, 0- to 1-percent slopes
Bb Bethany silt loam, 1- to 3-percent slopes
Br Brewer silty clay loam
Dr Dale and Reinach silt loams
Ea Elandco silty clay loam
Fa Farnum loam, 0- to 1-percent slopes
Fb Farnum loam, 1- to 3-percent slopes
Fd Farnum loam, 2- to 6-percent slopes, eroded
Mb Milan loam, 1- to 3-percent slopes
Mc Milan loam, 3- to 6-percent slopes
Md Milan loam, 3- to 6-percent slopes, eroded
Or Owens-Renfrow complex, 2- to 6-percent slopes, eroded
Os Owens-Shale outcrop complex, 8- to 25-percent slopes
Ro Rosehill loam, 1- to 3- percent slopes
Rs Rosehill clay loam, 3- to 6-percent slopes
Sb Shellabarger sandy loam, 3- to 6-percent slopes
Ta Tabler silty clay loam
Us Ustifluvents, channeled
Va Vanoss silt loam, 0- to 1-percent slopes

Figure 7. Soils in the vicinity of the Sumner County Landfill (modified from Fenwick and Ratcliff, 1979).

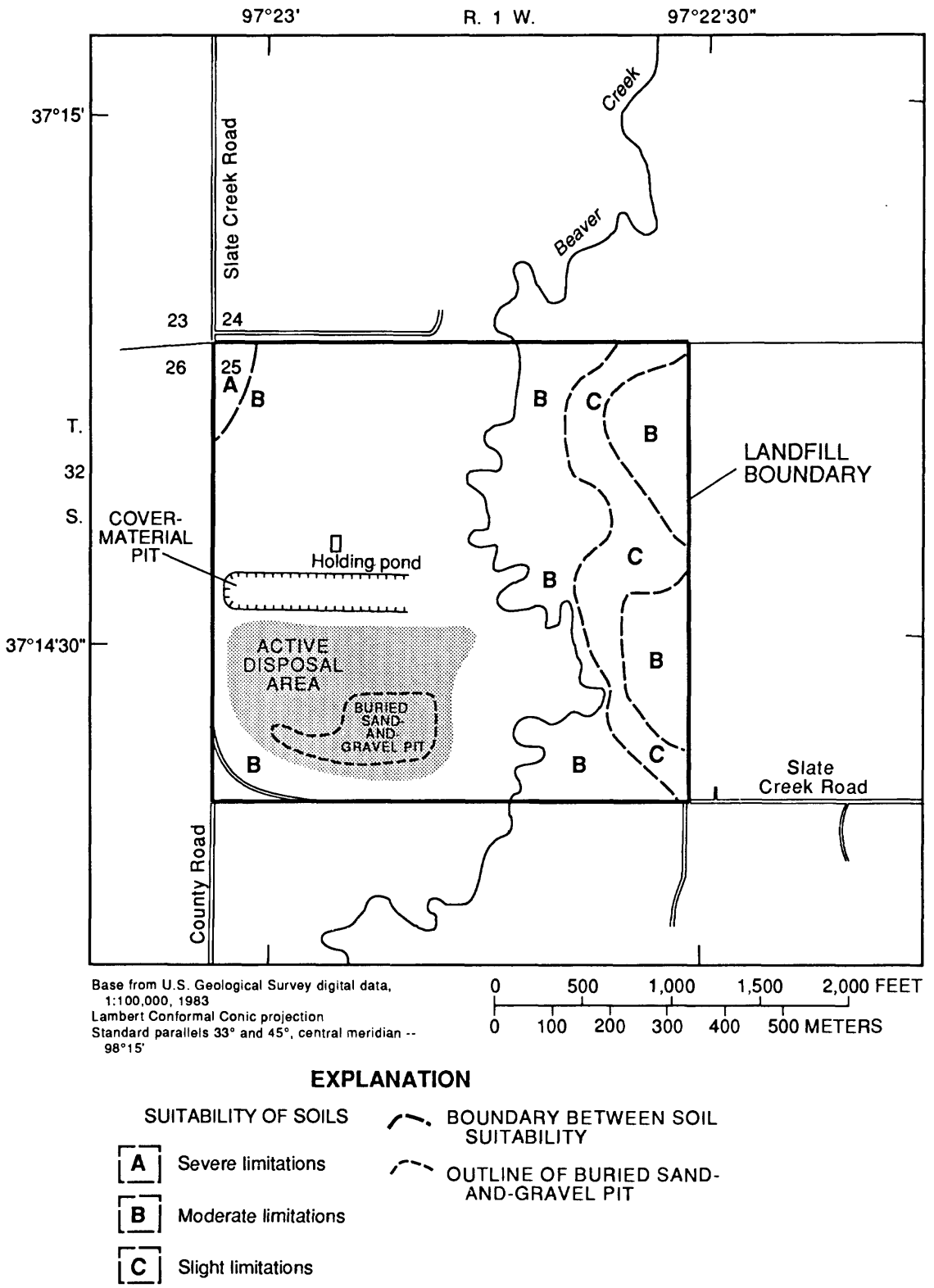


Figure 8. Suitability of soils within the landfill for trench-type, sanitary-landfill operations, ranked from severe to slight limitations (Based on rankings assigned to soil types by Olson, 1974).

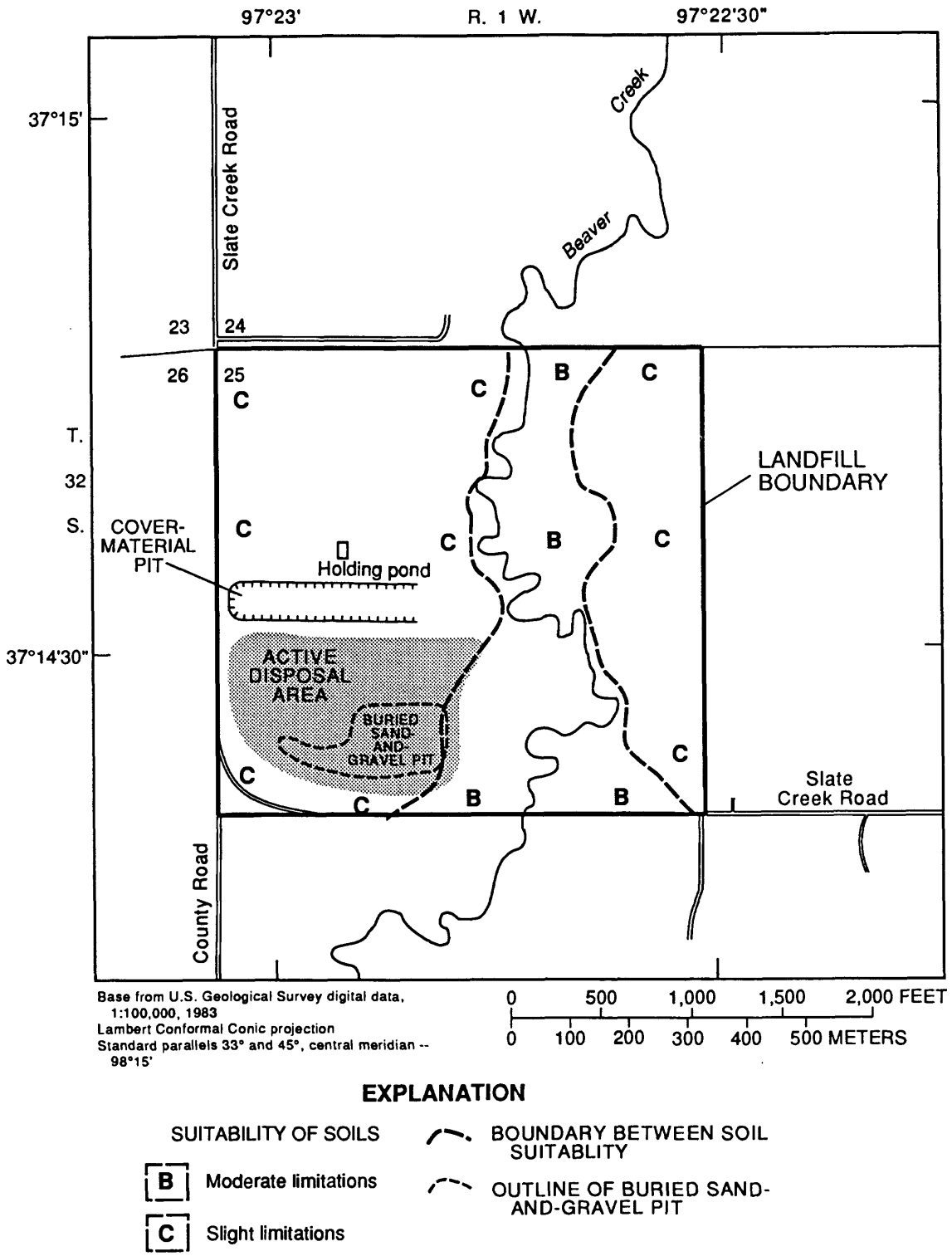


Figure 9. Suitability of soils within the landfill for area-type, sanitary-landfill operations, ranked from moderate to slight limitations (Based on rankings assigned to soil types by Olson, 1974).

probably is similar in lithology to the Wellington Formation observed in the outcrop along Beaver Creek, although stratigraphically lower.

Except for the area where the Wellington Formation crops out along Beaver Creek, the landfill is overlain by Pleistocene terrace and alluvial deposits of varying thickness and lithology (figs. 10A and 10B). Terrace deposits that were visible in the wall of the cover-material pit (fig. 10B) consist of layers of sand and gravel with interbedded layers of clayey sand and shell fragments, overlain by a layer of red sandy silt and clay with interbedded layers of sand and gravel. The contact between the sand-and-gravel layer and the overlying red sandy silt and clay layer is distinct and can be traced around the entire pit. Logs from temporary wells TW-1, TW-2, TW-3, TW-4, and TW-10 indicate a stratigraphic succession similar to that observed in the wall of the cover-material pit. Terrace deposits penetrated by temporary wells TW-5, TW-6, TW-7, and TW-9 had a larger clay content than those in the pit area. Southeast of the active disposal area, terrace deposits consist mostly of sand and gravel. On the east side of Beaver Creek, sediments penetrated consist of blue-gray clay with interbedded silt, sand, and gravel overlain by red sandy silt and clay with minor amounts of sand and gravel. The blue-gray clay probably

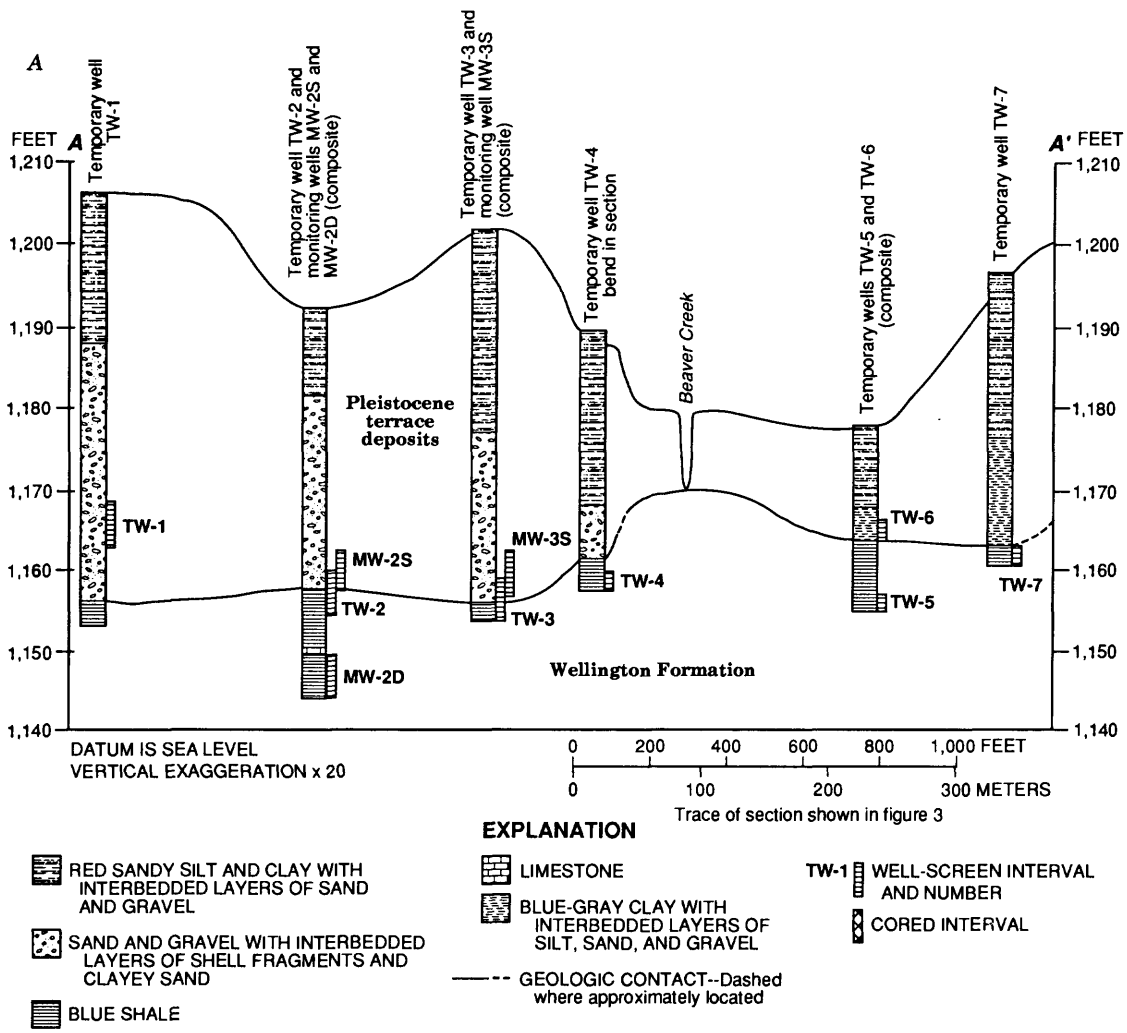


Figure 10. Geologic sections showing lithology of geologic units based on auger cuttings, natural gamma-ray logs, and split-spoon cores: (A) section A-A'; and (B) section B-B'.

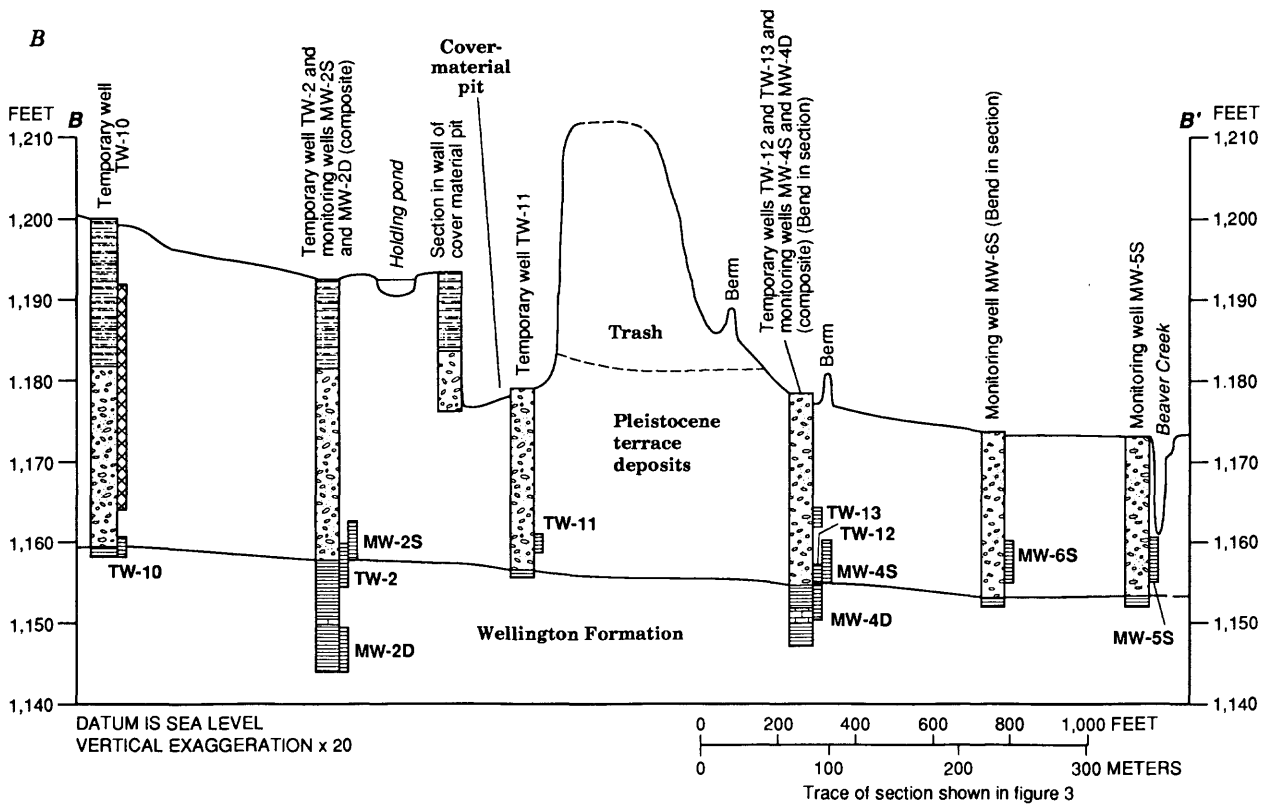


Figure 10. Geologic sections showing lithology of geologic units based on auger cuttings, natural gamma-ray logs, and split-spoon cores: (A) section A-A'; and (B) section B-B'--Continued

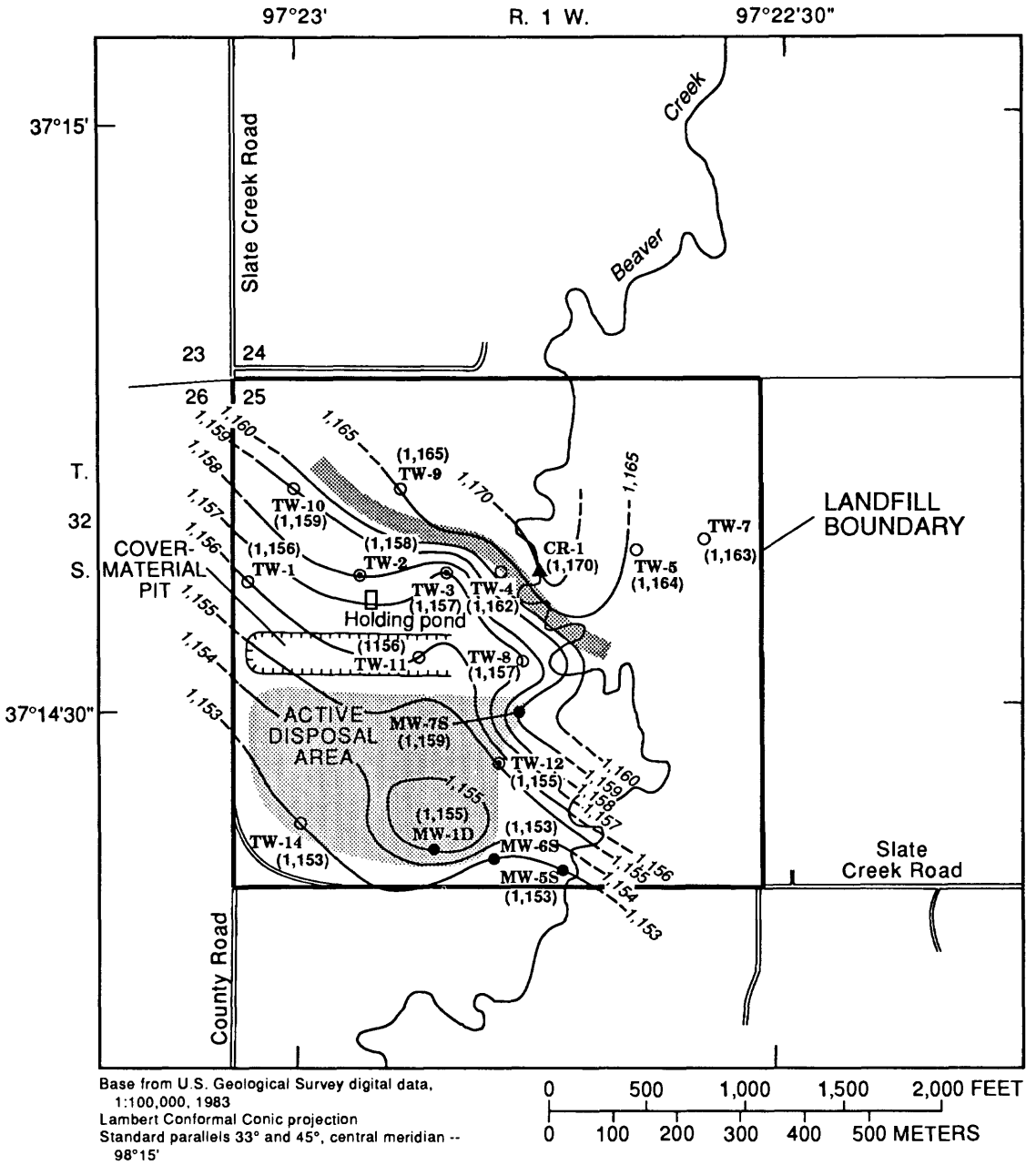
originated from weathering and reworking of the Wellington Formation, whereas the red sandy silt and clay probably represents terrace deposits. A thin layer of Holocene alluvium is present along Beaver Creek and consists of reworked sand and gravel from terrace deposits and shale and limestone fragments from the Wellington Formation.

The altitude and configuration of the top of the bedrock surface is shown in figure 11. The contours show that the bedrock surface slopes southwesterly with a steep scarp trending southeast from the vicinity of temporary well TW-10 (fig. 11). This scarp probably is the northeast edge of a southeast-trending buried stream channel. Coarser sediments would be expected to prevail in this former drainageway, whereas finer sediments would be expected outside of (northeast of) the channel; this concept is supported by the lithology penetrated in boreholes at the landfill.

Hydrology

North of the active disposal area, surface runoff drains southward to a holding pond near the cover-material pit (fig. 5). Surface runoff in the vicinity of the pit flows to the lowest (west) end of the pit where it ponds. Water in the holding pond and pit slowly evaporates or seeps into the ground. Elsewhere on the landfill, surface runoff drains south and east towards Beaver Creek. Berms have been constructed around the south and east sides of the landfill to help control surface runoff.

Water-level measurements in wells and in Beaver Creek (table 4) were used to construct potentiometric-surface maps (figs. 12A, 12B, and 13) and a hydrogeologic section (fig. 14). The direction of ground-water flow shown by the potentiometric contours and lines of equipotential is perpendicular to the contours or lines at any given point. Ground-water flow direction in terrace deposits west of Beaver Creek generally



EXPLANATION

BURIED CHANNEL EDGE

—1,153— TOP OF BEDROCK CONTOUR-- Shows altitude and configuration of the top of the bedrock surface. Dashed where approximately located. Contour intervals 1 and 5 feet. Datum is sea level

TW-10 ○ TEMPORARY WELL AND NUMBER

MW-4S / MW-4D ● MONITORING WELL AND NUMBER-- S, indicates shallow well; D, indicates deep well

◉ TEMPORARY WELL AND MONITORING WELL AT SAME SITE

CR-1 ▲ CREEK SAMPLING SITE AND NUMBER

(1,154) ALTITUDE OF BEDROCK SURFACE IN FEET ABOVE SEA LEVEL

Figure 11. Altitude and configuration of the top of the bedrock surface.

Table 4. *Water-level altitudes in temporary wells (TW), monitoring wells (MW), private-supply wells (DS), unused supply wells (US), and Beaver Creek (CR)*

[Datum is sea level; -- indicates no data avaliable]

Well or creek (fig. 3)	Water-level altitude (feet) Date (month/day/year) 12/14/89	01/04/90	01/25/90	04/04/90
TW-1	1,167.22	1,167.24	1,167.69	--
TW-2	1,167.81	1,167.66	1,170.07	--
TW-3	1,167.85	1,167.62	1,168.42	--
TW-4	1,168.31	1,168.21	1,168.78	--
TW-5	1,168.76	1,168.72	1,170.29	--
TW-6	1,168.47	1,168.46	1,169.75	--
TW-7	1,172.32	1,172.05	1,172.12	--
TW-8	1,166.87	1,166.76	1,167.50	--
TW-9	--	1,168.10	1,168.29	1,170.36
TW-10	--	1,168.06	1,168.27	1,170.45
TW-11	1,167.18	1,167.27	1,168.36	1,169.91
TW-12	1,164.99	1,164.99	1,165.44	1,166.40
TW-13	1,165.27	1,164.91	1,165.45	1,166.40
TW-14	1,166.06	1,166.18	1,167.40	1,167.77
MW-1S	1,165.10	1,164.96	1,165.20	1,166.08
MW-1D	--	--	--	1,165.86
MW-2S	--	--	--	1,170.76
MW-2D	--	--	--	1,170.58
MW-3S	--	--	--	1,170.35
MW-4S	--	--	--	1,166.45
MW-4D	--	--	--	1,166.85
MW-5S	--	--	--	1,162.01
MW-6S	--	--	--	1,165.67
MW-7S	--	--	--	1,168.60
DS-1	--	--	--	1,170.04
DS-2	--	--	--	--
DS-3	--	--	--	--
US-1	1,166.88	1,166.80	1,166.88	1,168.54
US-2	1,166.93	1,166.86	--	1,168.39
CR-1[1]	--	1,170.19	1,170.19	1,170.19
CR-2	--	1,161.35	1,162.03	1,161.50

[1] Water in creek at site CR-1 flows over bedrock and might not be hydraulically connected to ground water in terrace deposits.

is south and southeast, except near the west end of the cover-material pit where ground-water flows southwest. On the east side of Beaver Creek, ground water flows southwest towards Beaver Creek (figs. 12A and 12B). Water-level data indicate that Beaver Creek is gaining ground water from the terrace deposits in the southern part of the landfill property. A hydrogeologic section shows that ground-water flow in the terrace deposits primarily is lateral except near monitoring well MW-5S where there is flow upward toward Beaver Creek (fig. 14). Ground-water flow in the Wellington Formation primarily is southeastward (fig. 13) and lateral

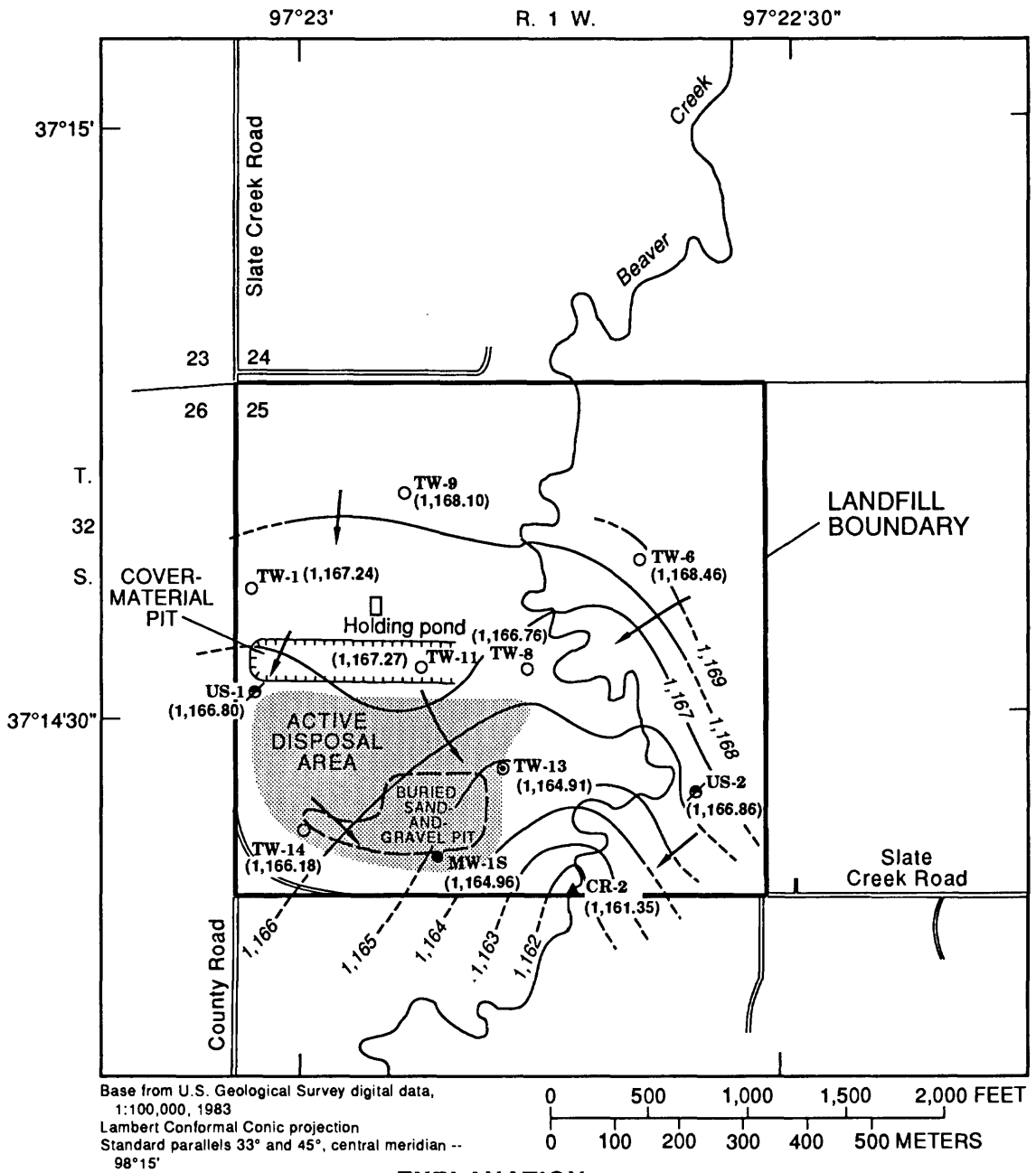


Figure 12. Potentiometric surface in Pleistocene terrace deposits for (A) January 4 and (B) April 4, 1990.

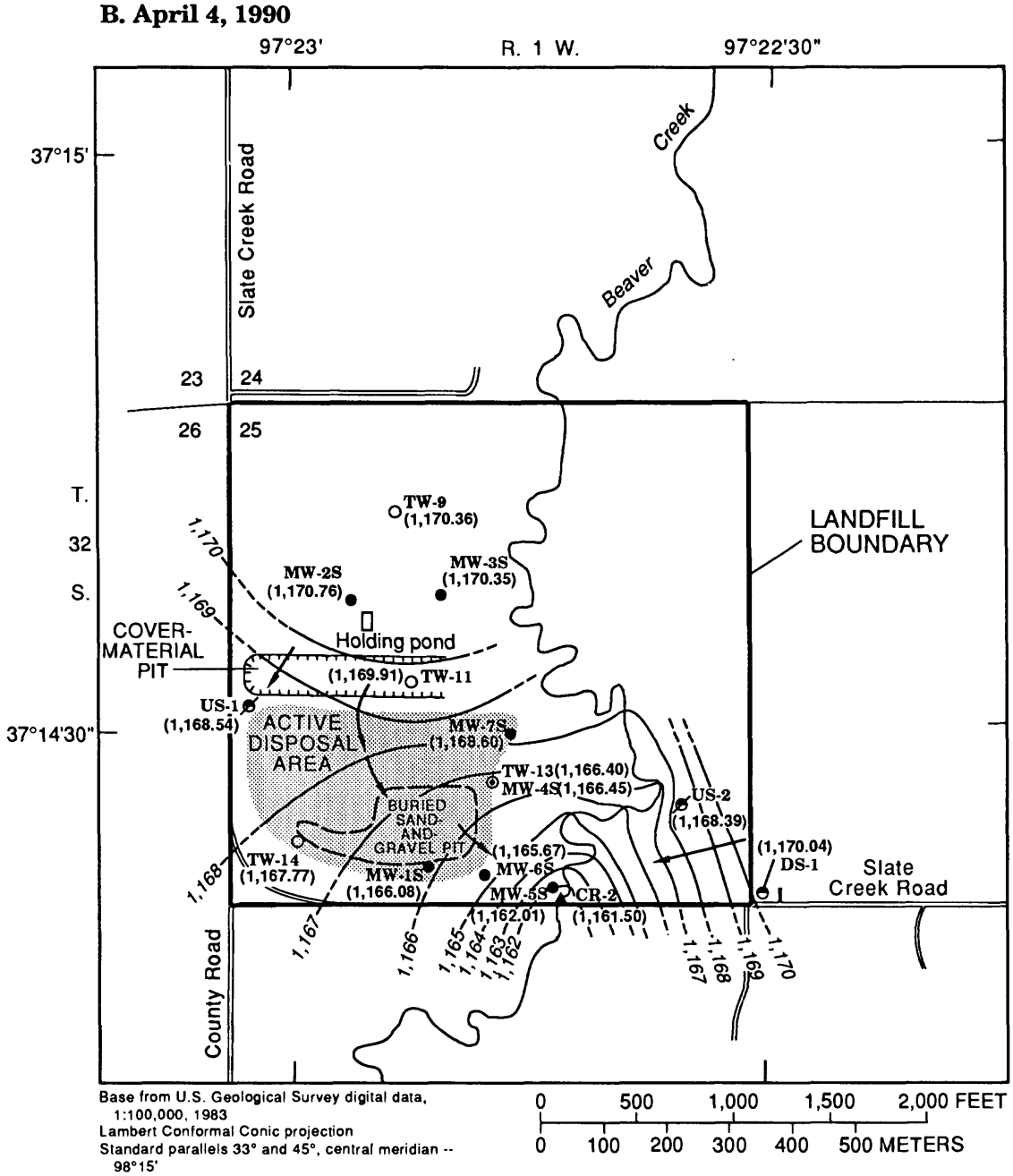


Figure 12. Potentiometric surface in Pleistocene terrace deposits for (A) January 4 and (B) April 4, 1990--Continued

with minor upward and downward components (fig. 14).

REGIONAL GROUND-WATER QUALITY

A summary of ground-water-quality data compiled by Walters (1961) for Sumner County is shown in table 5. Water from alluvial and terrace deposits generally is of suitable quality for most uses, except where contaminated by brine from oil-field activities or by naturally occurring saline water, and can contain large concentrations of iron (table 5) (Walters, 1961). The median concentrations of most constituents are similar in water from the Ninnescah Shale

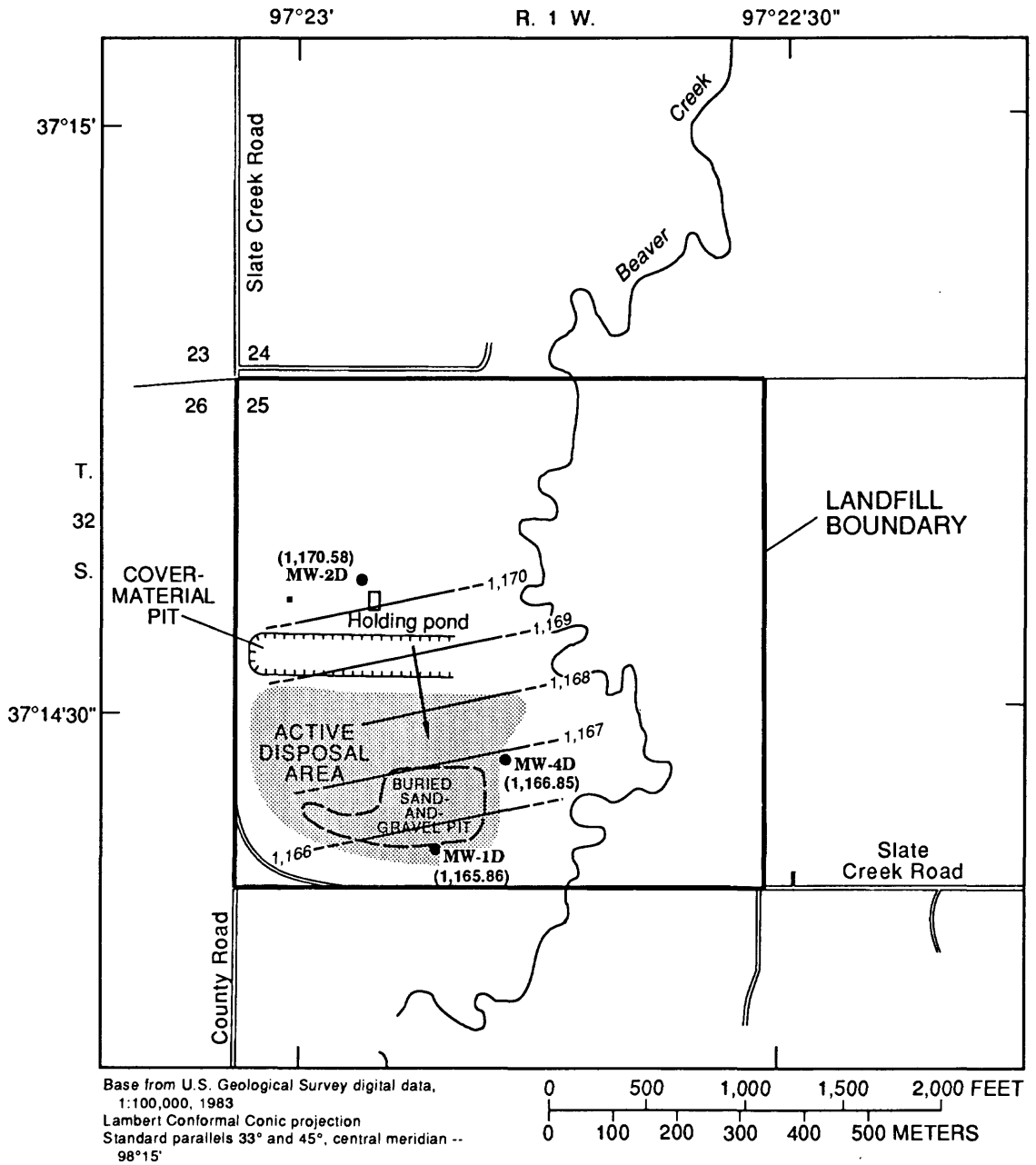


Figure 13. Potentiometric surface in the Wellington Formation for April 4, 1990.

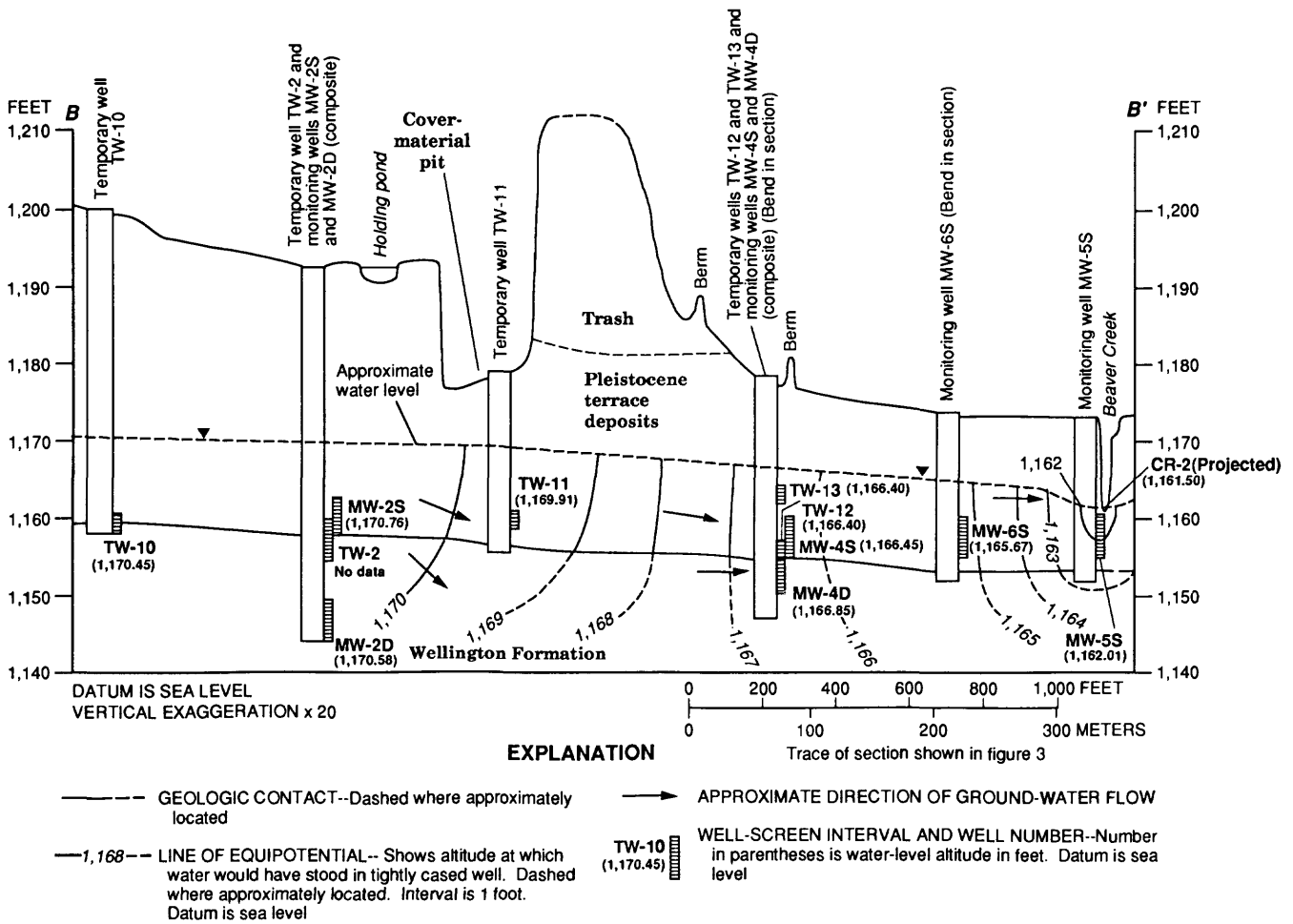


Figure 14. Hydrogeologic section through Sumner County Landfill showing lines of equipotential on April 4, 1990.

and from the alluvial and terrace deposits, but water from the Wellington Formation generally is more mineralized (table 5) due to the presence of salt and gypsum deposits in the formation. The information in table 5 is useful for comparison to water quality at the Sumner County Landfill.

LANDFILL-AREA WATER QUALITY

Tables 6, 7, and 8 list physical properties and inorganic constituents, organic compounds, and tentatively identified organic compounds detected in water samples from monitoring and supply wells and from Beaver Creek, and give applicable drinking-water regulations for these constituents.

The Federal and State drinking-water regulations reported herein have been established for some chemical constituents in public-supply water that can produce adverse health effects or that affect the aesthetic qualities of water such as taste, smell, and appearance. The Maximum Contaminant Level Goal (MCLG) is the concentration of a constituent in drinking water that would have no adverse health effects for lifetime consumption of the water (U.S. Environmental Protection Agency, 1989a). MCLG's are not enforceable. Maximum Contaminant Levels (MCL) are based on the capacity of the best available technology to minimize contaminant concentrations in drinking water (U.S. Environmental Protection Agency, 1989a). MCL's are established to protect public health and are enforceable. Secondary Maximum Contaminant Levels (SMCL) have been established for constituents of water that affect the aesthetic qualities of the water (U.S. Environmental

Table 5. *Summary of ground-water-quality data for Sumner County*

[Data summarized from Walters (1961, table 6, p. 40-42). Concentrations are in milligrams per liter, except for iron, which is in micrograms per liter]

Constituent	SOURCE OF WATER											
	Alluvium and terrace deposits				Ninnescah Shale				Wellington Formation			
	Number of samples	Concentration			Number of samples	Concentration			Number of samples	Concentration		
		Median	Minimum	Maximum		Median	Minimum	Maximum		Median	Minimum	Maximum
Hardness (total at $CaCO_3$)	54	305	54	8,832	8	267	182	1,770	9	1,230	304	1,870
Calcium	54	90	16	1,606	8	59	43	570	9	297	74	546
Magnesium	54	20	2.8	1,174	8	27.5	18	85	9	69	29	182
Sodium plus potassium	50	42	1.0	57,930	8	85.5	23	162	9	158	50	456
Bicarbonate (as HCO_3)	50	302.5	49	432	8	300	193	370	9	356	190	510
Sulfate	54	56	3.7	7,828	8	58	13	1,710	9	828	93	1,740
Chloride	54	33	6.5	89,800	8	53	16	156	9	88	34	700
Fluoride	53	.3	.1	.7	8	.25	.2	.7	9	.5	.2	.7
Silica	32	19	9.0	30	8	19.5	14	25	8	13	6.5	19
Dissolved solids	50	431	146	158,375	8	539	295	2,670	9	2,270	573	3,360
Nitrate (as N)	53	2.5	.16	25	8	3.2	.63	5.9	9	8.0	.45	52
Iron	50	145	10	18,000	7	200	20	670	9	320	50	1,200

Table 6. *Physical properties and inorganic constituents detected in water from monitoring (MW) and private-supply (DS) wells and Beaver Creek (CR), April 1990*

[Units of measurement: mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; <, constituent not detected at the indicated detection level; --, not determined; __, no standard established]

Well or creek (fig. 3)	Date of collection (month-day-year)	Specific conductance, field (µS/cm)	Specific conductance, laboratory (µS/cm)	pH, field (standard units)	pH, laboratory (standard units)	Water temperature (degrees Celsius)	Chemical oxygen demand (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
MW-1S	04-06-90	1,710	1,430	8.1	7.0	15.0	15	680	140	79
MW-1D	04-06-90	1,290	960	7.6	7.6	15.0	17	560	120	62
MW-2S	04-04-90	733	863	7.9	7.6	15.5	21	300	65	33
MW-2D	04-04-90	3,000	3,520	7.8	7.4	15.0	74	1,100	270	100
MW-3S	04-05-90	1,760	1,680	8.0	7.4	15.5	13	540	120	59
MW-4S	04-05-90	1,100	1,040	7.4	6.7	14.0	17	490	110	52
MW-4D	04-05-90	1,970	1,830	7.1	7.1	15.0	19	650	150	68
MW-5S	04-05-90	1,290	1,210	7.6	7.2	13.0	15	580	130	61
MW-6S	04-05-90	1,770	1,650	8.3	7.0	15.0	32	680	150	75
MW-6S dup[8]	04-05-90	1,800	1,640	8.1	7.0	16.0	30	720	160	78
MW-7S	04-05-90	1,630	1,620	7.3	7.2	13.5	15	620	120	78
DS-1	04-05-90	1,540	1,550	7.6	7.3	14.0	--	570	110	72
CR-2	04-05-90	2,370	2,390	8.0	7.8	12.0	29	1,000	200	130
Kansas and Federal Maximum Contaminant Level[1]		—	—	—	—	—	—	—	—	—
Kansas and Federal Secondary Maximum Contaminant Level[2]		—	—	—	—	—	—	400[3]	—	—

Table 6. *Physical properties and inorganic constituents detected in water from monitoring (MW) and private-supply (DS) wells and Beaver Creek (CR), April 1990*--Continued

Well or creek (fig. 3)	Date of collection (month-day-year)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate, field[4] (mg/L as HCO_3)	Alkalinity, field (mg/L as $CaCO_3$)	Alkalinity, laboratory (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)
MW-1S	04-06-90	54	1.6	680	560	500	210	55	0.2	17
MW-1D	04-06-90	76	2.6	590	480	330	180	56	.1	18
MW-2S	04-04-90	59	1.4	180	150	150	230	33	.4	14
MW-2D	04-04-90	370	5.0	220	180	180	760	620	.1	14
MW-3S	04-05-90	170	2.2	540	440	430	340	90	.3	15
MW-4S	04-05-90	34	3.4	510	420	430	54	60	< .1	24
MW-4D	04-05-90	140	2.5	380	310	320	370	210	.2	16
MW-5S	04-05-90	46	1.5	650	530	500	78	78	.1	18
MW-6S	04-05-90	85	2.2	600	490	500	260	98	.1	18
MW-6S dup[8]	04-05-90	85	2.4	660	540	500	260	99	.1	19
MW-7S	04-05-90	95	2.2	520	430	440	260	110	.4	14
DS-1	04-05-90	130	1.2	650	530	530	200	83	.3	16
CR-2	04-05-90	180	4.0	450	370	360	700	180	.2	4.6
Federal and Kansas Maximum Contaminant Level[1]		—	—	—	—	—	—	—	1.8[5]	—
Federal and Kansas Secondary Maximum Contaminant Level[2]		—	—	—	—	—	250	250	2.0	—

Table 6. *Physical properties and inorganic constituents detected in water from monitoring (MW) and private-supply (DS) wells and Beaver Creek (CR), April 1990*--Continued

Well or creek (fig. 3)	Date of collection (month-day-year)	Dissolved solids, residue at 180 degrees Celsius (mg/L)	Dissolved solids, residue at 105 degrees Celsius (mg/L)	Nitrite, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Ammonia, dissolved (mg/L as N)	Phosphorus, ortho-phosphate, dissolved (mg/L as P)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Cadmium, dissolved (µg/L as Cd)
MW-1S	04-06-90	932	940	0.01	<0.10	<0.01	0.02	1	31	<1
MW-1D	04-06-90	816	821	.01	< .10	.02	< .01	1	39	1
MW-2S	04-04-90	579	597	.01	5.7	< .01	.02	1	67	<1
MW-2D	04-04-90	2,490	2,470	.01	.10	.17	< .01	<1	<100[6]	<1
MW-3S	04-05-90	1,140	1,160	< .01	6.2	< .01	.05	2	41	<1
MW-4S	04-05-90	631	627	.01	2.0	.02	.07	1	220	1
MW-4D	04-05-90	1,280	1,300	< .01	.10	.04	< .01	<1	27	<1
MW-5S	04-05-90	758	767	.01	1.9	< .01	.05	1	84	<1
MW-6S	04-05-90	1,110	1,120	.02	8.8	.02	.05	1	55	<1
MW-6S dup[8]	04-05-90	1,100	1,120	.01	8.8	.02	.04	1	58	<1
MW-7S	04-05-90	1,030	1,050	.01	4.6	< .01	.05	1	140	<1
DS-1	04-05-90	975	1,000	--	--	--	--	--	--	--
CR-2	04-05-90	1,880	1,900	.03	1.0	< .01	< .01	1	100	<1
Federal and Kansas Maximum Contaminant Level[1]		—	—	—	10[7]	—	—	50	1,000	10
Federal and Kansas Secondary Maximum Contaminant Level[2]		500	500	—	—	—	—	—	—	—

Table 6. *Physical properties and inorganic constituents detected in water from monitoring (MW) and private-supply (DS) wells and Beaver Creek (CR), April 1990*--Continued

Well or creek (fig. 3)	Date of collection (month-day-year)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Zinc, dissolved (µg/L as Zn)
MW-1S	04-06-90	<5	<10	5	<10	450	<0.1	<1	<1	20
MW-1D	04-06-90	<5	<10	10	<10	57	<.1	<1	1	10
MW-2S	04-04-90	<5	<10	12	<10	2	<.1	2	<1	20
MW-2D	04-04-90	2	16	20	<1	50	.2	<1	2	10
MW-3S	04-05-90	<5	<10	5	<10	4	<.1	10	<1	20
MW-4S	04-05-90	<5	<10	74	10	110	<.1	<1	<1	20
MW-4D	04-05-90	<5	<10	120	<10	61	<.1	<1	2	20
MW-5S	04-05-90	<5	<10	30	10	22	<.1	<1	<1	10
MW-6S	04-05-90	<5	<10	9	<10	8	<.1	<1	<1	20
MW-6S dup[8]	04-05-90	<5	10	17	<10	12	<.1	<1	<1	20
MW-7S	04-05-90	<5	<10	<3	<10	810	<.1	6	<1	20
DS-1	04-05-90	--	--	7	--	1	--	--	--	--
CR-2	04-05-90	1	4	30	<1	150	<.1	3	<1	<10
Federal and Kansas Maximum Contaminant Level[1]		50	—	—	50	—	2.0	10	50	—
Federal and Kansas Secondary Maximum Contaminant Level[2]		—	1,000	300	—	50	—	—	—	5,000

[1] Maximum Contaminant Level for drinking water (Kansas Department of Health and Environment, 1986; U.S. Environmental Protection Agency, 1989a).

[2] Secondary Maximum Contaminant Level for drinking water (Kansas Department of Health and Environment, 1986; U.S. Environmental Protection Agency, 1989b).

[3] Kansas Secondary Maximum Contaminant Level (Kansas Department of Health and Environment, 1986).

Table 6. *Physical properties and inorganic constituents detected in water from monitoring (MW) and private-supply (DS) wells and Beaver Creek (CR), April 1990*--Continued

[4] Bicarbonate concentration is calculated by dividing field alkalinity concentration by 0.8202 (Hem, 1985) and rounding to the nearest tens place.

[5] Kansas Maximum Contaminant Level for fluoride is 1.8 mg/L, the Federal Maximum Contaminant Level for fluoride is 4.0 mg/L, and the Federal Secondary Maximum Contaminant Level for fluoride is 2.0 mg/L (Kansas Department of Health and Environment, 1986; U.S. Environmental Protection Agency, 1989b).

[6] The detection level for a method of analysis may vary depending on factors such as specific conductance and dissolved-solids concentration.

[7] The Kansas and Federal Maximum Contaminant Level is 10 mg/L for nitrate only (Kansas Department of Health and Environment, 1986; U.S. Environmental Protection Agency, 1989a).

[8] MW-6S dup is a duplicate sample.

Table 7. *Organic compounds detected in water samples, April 1990*

[Units of measurement: mg/L, milligrams per liter; µg/L, micrograms per liter; <, compound was not detected at the indicated detection level; +, any positive detection; id, insufficient data to determine standard; --, not determined; __, no standard established]

Well or creek (fig. 3)	Date of collection (month-day-year)	Benzene, total (µg/L)	Chloro-benzene, total (µg/L)	Chloro-ethane, total (µg/L)	Dichloro-difluoro-methane, total (µg/L)	1,1-dichloro-ethane, total (µg/L)	1,2-trans-dichloro-ethene, total (µg/L)	1,2-di-chloro-ethane, total (µg/L)
MW-1S	04-06-90	0.30	<0.2	<0.3	<0.2	0.2	56	<0.2
MW-1D	04-06-90	<.20	<.2	<.2	<.2	<.2	9.6	<.2
MW-2S	04-04-90	<.20	<.2	<.2	<.2	<.2	<.2	<.2
MW-2D	04-04-90	<.20	<.2	<.2	<.2	<.2	<.2	<.2
MW-3S	04-05-90	<.20	<.2	<.2	<.2	<.2	<.2	<.2
MW-4S	04-05-90	<.20	<.2	<.2	<.2	.4	1.4	<.2
MW-4D	04-05-90	<.20	<.2	<.2	<.2	<.2	.4	<.2
MW-5S	04-05-90	<.20	<.2	<.2	<.2	.6	10	<.2
MW-6S	04-05-90	<.20	.3	<.5	.9	.9	22	.2
MW-6S dup[1]	04-05-90	<.20	.2	.3	.7	.7	21	<.2
MW-7S	04-05-90	<.20	<.2	<.2	<.2	<.2	<.2	<.2
DS-1	04-05-90	<.20	<.2	<.2	<.2	<.2	<.2	<.2
CR-2	04-05-90	--	--	--	--	--	--	0
Federal Maximum Contaminant Level Goal[2]		0	—	—	—	—	—	—
Federal Maximum Contaminant Level[3]		5.0	—	—	—	—	—	5.0
Kansas Notification Level[4]		.67	—	+	—	+	+	.7
Kansas Action Level[5]		6.7	—	id	—	id	270	7.0

Table 7. *Organic compounds detected in water samples, April 1990*--Continued

Well or creek (fig. 3)	Date of collection (month-day-year)	1,2-dichloro-propane total (µg/L)	Methylene chloride, total (µg/L)	Tetrachloro-ethylene, total (µg/L)	Trichloro-ethylene, total (µg/L)	Vinyl chloride, total (µg/L)	Sum of volatile organic compounds (µg/L)	Carbon, organic, dissolved (mg/L as C)	Methylene-blue active substance (mg/L)
MW-1S	04-06-90	<0.2	<0.2	0.9	0.9	15	73.3	1.2	0.04
MW-1D	04-06-90	<.2	<.2	<.2	<.2	1.7	11.3	.9	.09
MW-2S	04-04-90	<.2	<.2	<.2	<.2	<.2	<.2	1.3	1.7
MW-2D	04-04-90	<.2	<.2	<.2	<.2	<.2	<.2	2.1	.04
MW-3S	04-05-90	<.2	<.2	<.2	.2	<.2	.2	1.6	1.9
MW-4S	04-05-90	<.2	<.2	<.2	<.2	<.2	1.8	2.4	.02
MW-4D	04-05-90	<.2	<.2	<.2	<.2	<.2	.4	1.1	.04
MW-5S	04-05-90	<.2	<.2	.7	.5	.9	12.7	2.5	.06
MW-6S	04-05-90	.2	.2	1.9	1.3	2.5	30.4	2.6	.02
MW-6S dup[1]	04-05-90	.2	<.2	1.2	.9	1.9	27.1	2.3	.02
MW-7S	04-05-90	<.2	<.2	<.2	<.2	<.2	<.2	1.5	2.0
DS-1	04-05-90	<.2	<.2	<.2	<.2	<.2	<.2	1.7	--
CR-2	04-05-90	--	--	--	--	--	--	4.8	.10
Federal Maximum Contaminant Level Goal[2]		—	—	—	0	0	—	—	—
Federal Maximum Contaminant Level[3]		—	—	—	5.0	2.0	—	—	—
Kansas Notification Level[4]		+	+	—	1.8	1.0	—	—	—
Kansas Action Level[5]		id	150	—	18	10	—	—	—

[1] MW-6S dup is a duplicate sample.
[2] Federal Maximum Contaminant Level Goal for drinking water (U.S. Environmental Protection Agency, 1989a).
[3] Maximum Contaminant Level for drinking water (U.S. Environmental Protection Agency, 1989a).
[4] Kansas Notification Level for drinking water (Kansas Department of Health and Environment, 1986).
[5] Kansas Action Level for drinking water (Kansas Department of Health and Environment, 1986).

Table 8. *Tentatively identified volatile and semivolatile organic compounds detected in water from monitoring wells, April 1990*

Well (fig. 3)	
	Volatile Compounds
MW-1S	chlorofluoromethane
MW-1S	ethyl ether
MW-4S	ethyl ether
MW-6S	dichlorofluoromethane
MW-6S dup[1]	dichlorofluoromethane
	Semivolatile Compounds
MW-2D	alkane
MW-4S	ethylene glycol monobutyl ether

[1] Duplicate sample.

Protection Agency, 1989b). SMCL's are not enforceable. The Kansas Notification Level (KNL) is the concentration of a constituent in water that would have no adverse health effects for lifetime consumption, or, for carcinogens, that would increase the risk of cancer by no more than 1 in 1,000,000 (Kansas Department of Health and Environment, 1986). The Kansas Action Level (KAL) is the concentration of a constituent that could produce adverse health effects after long-term consumption of water (Kansas Department of Health and Environment, 1986).

Water samples were collected from 10 monitoring wells, 1 private-supply well, and from 1 location on Beaver Creek, and were used for an analysis of water quality. A duplicate sample (MW-6S dup) was collected from a well chosen at random for quality control. Seven of the water samples collected were from wells screened in Pleistocene terrace deposits (monitoring wells MW-1S, MW-2S, MW-3S, MW-4S, MW-5S, MW-6S, and MW-7S), hereafter called shallow wells, and three were from wells screened in the Wellington Formation (monitoring wells MW-1D, MW-2D, and MW-4D), hereafter called deep wells (table 2). Private-supply well DS-1 probably is screened in terrace deposits.

Water types in the vicinity of the landfill can be distinguished most easily by their chloride, bicarbonate, and sulfate concentrations. In figure 15, modified Stiff diagrams show the concentrations of common ions expressed as milliequivalents per liter (Stiff, 1951). The alkalinity shown by the modified Stiff diagrams is due primarily to bicarbonate. The bicarbonate ion generally is dominant in water from the terrace deposits and in one water sample from the Wellington Formation (monitoring well MW-1D) (fig. 15). Chloride and sulfate ions are dominant in two samples from the Wellington Formation. Sulfate is dominant in one water sample from the terrace deposits (monitoring well MW-2S) (fig. 15) and in water from Beaver Creek. These relative anion concentrations reflect the chemical conditions present in the sediment or rock from which the water was obtained. Relatively large bicarbonate concentrations reflect the presence of atmospheric carbon dioxide (Hem, 1985) in the terrace deposits, and relatively large chloride and sulfate concentrations reflect the presence of sodium chloride (halite) and calcium sulfate (gypsum or anhydrite) in the Wellington Formation.

Water Properties

Water properties measured were specific conductance, pH, temperature, chemical oxygen demand, total hardness (as $CaCO_3$), and alkalinity. Specific conductance is an indirect measure of the amount of dissolved solids in

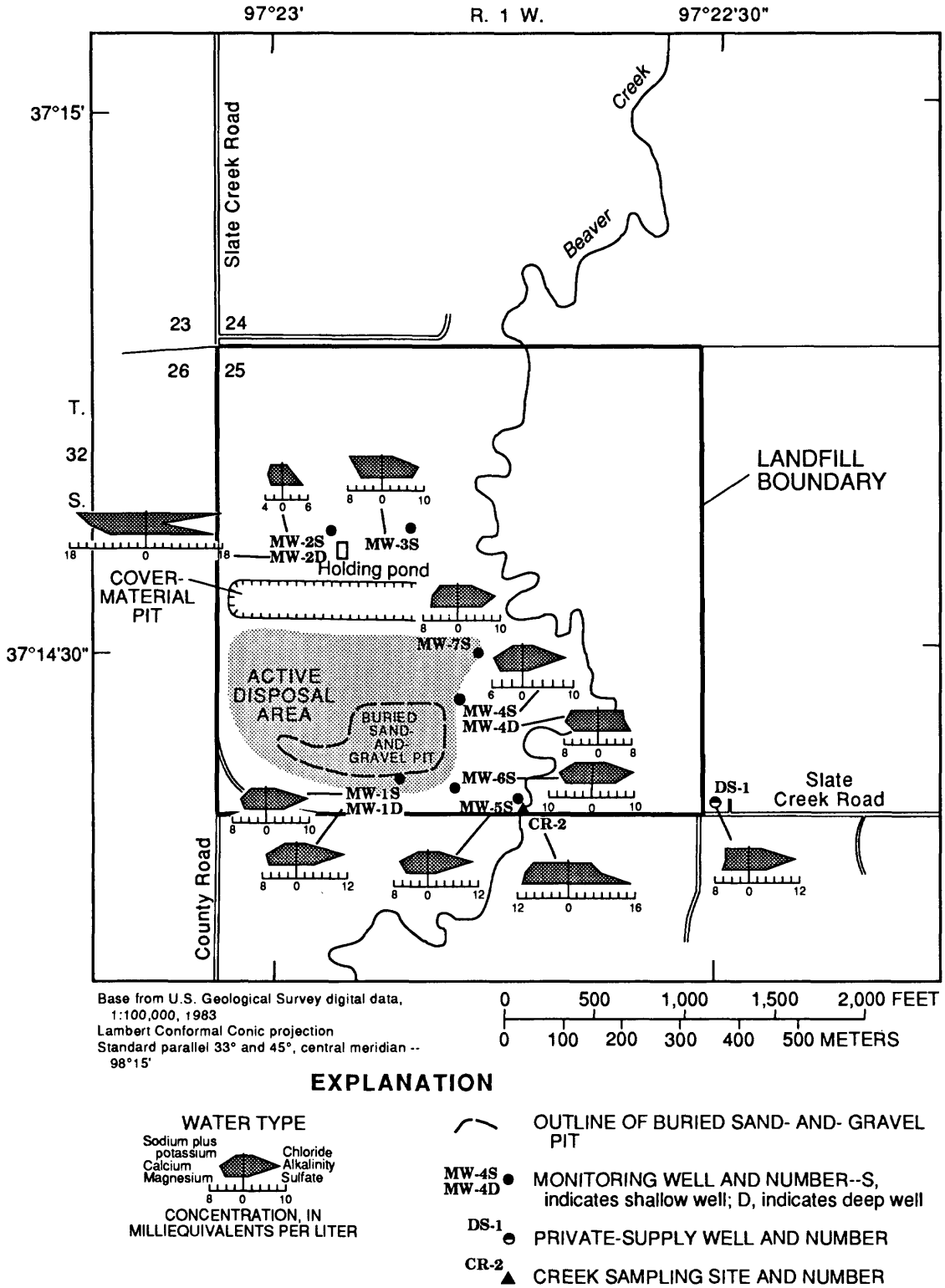


Figure 15. Modified stiff diagrams for ground- and surface-water samples collected in vicinity of Sumner County Landfill.

water. An increase in dissolved-solids concentration gives an increase in specific conductance. Organic compounds in water also may increase specific conductance. Specific conductance, measured at the time of sample collection (table 6), ranged from 733 (monitoring well MW-2S) to 3,000 µS/cm (microsiemens per centimeter at 25 °C) (monitoring well MW-2D). Specific conductance was larger in water from the wells screened in the Wellington Formation (monitoring wells MW-2D and MW-4D) than in water from adjacent wells screened in terrace deposits, except for well MW-1D. The pH, a measure of the acidity of water, ranged from 7.1 (monitoring well MW-4D) to 8.3 (monitoring well MW-6S) as measured onsite (table 6). Water temperature ranged from 12.0 (Beaver Creek sampling site CR-2) to 16.0 °C (monitoring well MW-6S dup). Chemical oxygen demand (COD), is a measure of the oxidizable material in water and generally indicates the minimum amount of organic and reducing material present. COD ranged from 13 (monitoring well MW-3S) to 74 mg/L (milligrams per liter) (monitoring well MW-2D). Hardness generally is an indication of the amount of calcium and magnesium in water. Water with a hardness of more than 180 mg/L (as $CaCO_3$) is classified as "very hard" (Hem, 1985). Total hardness (expressed as $CaCO_3$) ranged from 300 (monitoring well MW-2S) to 1,100 mg/L (monitoring well MW-2D). The total hardness in all samples except that from monitoring well MW-2S exceeded the Kansas SMCL of 400 mg/L (as $CaCO_3$). Alkalinity is defined as the capacity of solutes in water to neutralize acid. Alkalinity concentrations, expressed as $CaCO_3$, were measured onsite and ranged from 150 (monitoring well MW-2S) to 560 mg/L (monitoring well MW-1S).

Dissolved Solids and Major Ions

Dissolved-solids residue on evaporation at 180 °C ranged from 579 (monitoring well MW-2S) to 2,490 mg/L (monitoring well MW-2D). Dissolved-solids concentrations were larger in water from the Wellington Formation and Beaver Creek (monitoring wells MW-2D and MW-4D and sampling site CR-2) than water from terrace deposits but were smaller in water from the Wellington Formation for the sample from monitoring well MW-1D. Dissolved-solids concentrations exceeded the Federal and Kansas SMCL of 500 mg/L in all water samples.

Water samples were analyzed for major cations, including calcium, magnesium, sodium, and potassium, and for major anions, including bicarbonate (computed from alkalinity), sulfate, and chloride. At nested monitoring-well sites MW-2 and MW-4, major ion concentrations were larger in water samples from the Wellington Formation than in samples from terrace deposits. However, water from monitoring well MW-1S had larger ion concentrations (except sodium, potassium, and chloride) than water from monitoring well MW-1D, possibly due to the effects of the landfill on water chemistry. Water from Beaver Creek also had large ion concentrations, probably because Beaver Creek is incised into the Wellington Formation. Because dry conditions prevailed before sampling, the water in Beaver Creek was derived mainly from seepage from terrace deposits and probably from the Wellington Formation.

Calcium concentrations in water samples ranged from 65 (monitoring well MW-2S) to 270 mg/L (monitoring well MW-2D). Magnesium concentrations ranged from 33 (monitoring well MW-2S) to 130 mg/L (sampling site CR-2). Sodium concentrations ranged from 34 (monitoring well MW-4S) to 370 mg/L (monitoring well MW-2D). Larger concentrations of sodium in water from deep wells at nested monitoring-well sites reflect the presence of salt (NaCl) deposits in the Wellington Formation. Potassium concentrations ranged from 1.2 (private-supply well DS-1) to 5.0 mg/L (monitoring well MW-2D). Bicarbonate concentrations, expressed as HCO_3, ranged from 180 (monitoring well MW-2S) to 680 mg/L (monitoring well MW-1S). Sulfate concentrations ranged from 54 (monitoring well MW-4S) to 760 mg/L (monitoring well MW-2D). With the exception of water from monitoring well MW-1D, sulfate concentrations at nested-monitoring-well sites were larger in water from the deep wells. This reflects the presence of gypsum ($CaSO_4 \cdot 2H_2O$) and anhydrite ($CaSO_4$) deposits in the Wellington Formation. Concentrations of sulfate in water from monitoring wells MW-2D, MW-3S, MW-4D, MW-6S, and MW-7S and sampling site CR-2 exceeded the Federal and Kansas SMCL of 250 mg/L. Chloride concentrations ranged from

33 (monitoring well MW-2S) to 620 mg/L (monitoring well MW-2D). At nested monitoring-well sites, larger concentrations of chloride in water from deep wells also reflect the presence of salt deposits in the Wellington Formation. The concentration of chloride in water from monitoring well MW-2D exceeded the Federal and Kansas SMCL of 250 mg/L.

Nutrients

Water samples were analyzed for the nutrients nitrite, nitrite plus nitrate, ammonia, and phosphorus. Nitrite concentrations, expressed as nitrogen (N), ranged from <0.01 (monitoring wells MW-3S and MW-4D) to 0.02 mg/L (monitoring well MW-6S) in ground-water samples. Nitrite-plus-nitrate concentrations, expressed as N, ranged from <0.10 (monitoring wells MW-1S and MW-1D) to 8.8 mg/L (monitoring well MW-6S). Because the nitrite concentrations in ground-water samples were all 0.02 mg/L or less, the nitrite-plus-nitrate concentrations essentially reflect just the concentrations of nitrate. None of the nitrate concentrations exceeded the Federal and Kansas MCL of 10 mg/L as N. Ammonia concentrations, expressed as N, ranged from <0.01 (monitoring wells MW-1S, MW-2S, MW-3S, MW-5S, and MW-7S, and sampling site CR-2) to 0.17 mg/L (monitoring well MW-2D). Phosphorus concentrations ranged from <0.01 (monitoring wells MW-1D, MW-2D, and MW-4D, and sampling site CR-2) to 0.07 mg/L (monitoring well MW-4S).

The presence of nitrate or ammonia in water can be used as an indicator of whether oxidizing or reducing conditions prevail. In the presence of reducing conditions, typical of landfill leachate, nitrate may be reduced to ammonia. This effect was observed at the Geary County, Kansas, landfill (Myers and Bigsby, 1989). At the Sumner County Landfill, nitrate occurs in water from upgradient wells and downgradient wells, except that nitrate concentrations were less than the detection level in water from monitoring wells MW-1S and MW-1D. Ammonia is absent in water from terrace deposits upgradient of the landfill but is present in some water from terrace deposits downgradient of the landfill. Ammonia is present in all water samples from the Wellington Formation and may indicate that reducing conditions are present in the Wellington Formation.

Trace Elements

Water samples were analyzed for trace elements including arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, selenium, silver, and zinc. With few exceptions, concentrations of arsenic, cadmium, chromium, lead, mercury, selenium, and silver were near or less than the analytical detection levels for these elements (table 6). Barium concentrations ranged from 27 (monitoring well MW-4D) to 220 µg/L (micrograms per liter) (monitoring well MW-4S). The detection level for barium in the samples from monitoring well MW-2D and sampling site CR-2 was 100 µg/L, due to the large specific conductance (greater than 2,000 µS/cm) of these water samples. The concentration of copper in the sample from monitoring well MW-2D (16 µg/L) is notable because disseminated copper deposits are present elsewhere in the Wellington Formation (Berendsen and Lambert, 1981). Iron concentrations ranged from <3 (monitoring well MW-7S) to 120 µg/L (monitoring well MW-4D). At nested monitoring-well sites, iron concentrations in samples from deep wells were larger than concentrations in samples from shallow wells, but no relations to ground-water flow direction were apparent. Manganese concentrations ranged from 1 (monitoring well DS-1) to 810 µg/L (monitoring well MW-7S) and generally were larger in samples from downgradient shallow wells than in samples from upgradient shallow wells (fig. 16). Zinc concentrations ranged from <10 (sampling site CR-1) to 20 µg/L (monitoring wells MW-1S, MW-2S, MW-3S, MW-4S, MW-4D, MW-6S, and MW-7S).

Other Inorganic Constituents

Fluoride concentrations ranged from <0.1 (monitoring well MW-4S) to 0.4 mg/L (monitoring wells MW-2S and MW-7S). Silica concentrations ranged from 4.6 (sampling site CR-2) to 24 mg/L (monitoring well MW-4S). All fluoride concentrations measured were less than the Kansas MCL of 1.8 mg/L.

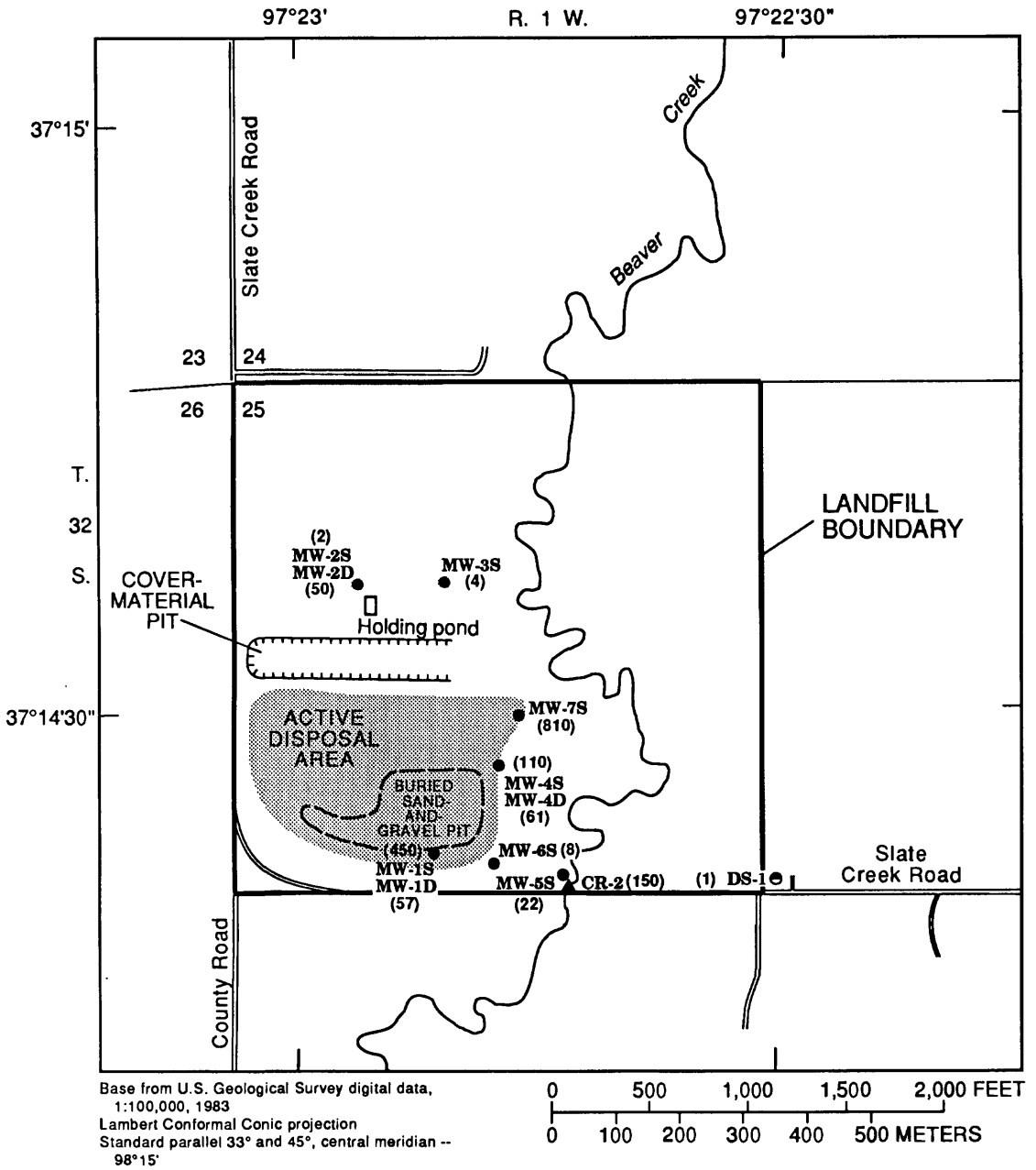


Figure 16. Dissolved-manganese concentrations in water from monitoring wells, a private-supply well, and Beaver Creek.

Volatile Organic Compounds

Water samples were analyzed for 35 volatile organic compounds (table 9). Of the volatile organic compounds listed in table 9, 12 compounds were identified in water samples (table 7). Three volatile organic compounds were tentatively identified in water samples (table 8). Each compound detected is discussed in the following paragraphs.

Benzene was detected in the water sample from monitoring well MW-1S at a concentration of 0.3 µg/L, which exceeded the Federal MCLG of 0 µg/L but was less than the Federal MCL, the KNL, and the KAL (table 7). Benzene is used as a chemical intermediate in the manufacture of chemical compounds, including pesticides and detergents, and is reported in gasoline at concentrations of less than 5 percent by volume (National Research Council, 1977, p. 688). Benzene is listed as a carcinogen by the U.S. Environmental Protection Agency (1989a).

Chlorobenzene concentrations were 0.3 and 0.2 µg/L in the primary and duplicate samples from monitoring well MW-6S, respectively. Chlorobenzene is used as a solvent, in the manufacture of other compounds, including pesticides, and for heat transfer (Sax and Lewis, 1987). Chlorobenzene may be formed by the chlorination of drinking water (National Research Council, 1977). No drinking-water regulations have been established for chlorobenzene.

Chloroethane (ethyl chloride) was detected in the duplicate water sample from monitoring well MW-6S at a concentration of 0.3 µg/L but was not detected in the primary water sample from monitoring well MW-6S. Note, however, that the detection level for the primary sample from monitoring well MW-6S was 0.5 µg/L. Chloroethane is used in the manufacture of chemical compounds, for refrigeration, and as a solvent (Sax and Lewis, 1987). The KNL for chloroethane is "any positive detection" (table 7).

Dichlorodifluoromethane was detected in both the primary and duplicate water sample from monitoring well MW-6S at concentrations of 0.9 and 0.7 µg/L, respectively. This compound is used as a refrigerant in air conditioners, used in the manufacture of plastics, is a low-temperature solvent, and is used for the freezing of food by direct contact (Sax and Lewis, 1987).

1,1-dichloroethane (ethylidene chloride) was detected in water from monitoring wells MW-1S, MW-4S, MW-5S, and MW-6S and ranged from 0.2 to 0.9 µg/L in water from these wells. These concentrations all exceeded the KNL of "any positive detection." 1,1-dichloroethane is used as an extraction solvent and as a fumigant (Sax and Lewis, 1987).

1,2-trans-dichloroethene (1,2-trans-dichloroethylene) was detected in water from monitoring wells MW-1S, MW-1D, MW-4S, MW-4D, MW-5S, and MW-6S and ranged from 0.4 to 56 µg/L in water from these wells. These concentrations exceeded the KNL of "any positive detection" but were less than the KAL of 270 µg/L. This compound is used as a general solvent for organic materials and in perfumes, lacquers, and thermoplastics (Sax and Lewis, 1987). 1,2-trans-dichloroethene also is an intermediate degradation product of trichloroethylene (U.S. Environmental Protection Agency, 1987).

1,2-dichloroethane (ethylene dichloride) was detected in the water sample from monitoring well MW-6S at 0.2 µg/L but was not detected in the duplicate water sample at a detection level of 0.2 µg/L. 1,2-dichloroethane is used extensively in chemical manufacture, as a lead scavenger in gasoline, in paints and varnishes, as a metal degreaser, in soaps and wetting agents, in ore flotation, as a solvent, and as a fumigant (Sax and Lewis, 1987). The concentration of this compound in water from monitoring well MW-6S exceeded the Federal MCLG of 0 µg/L but was less than the Federal MCL, the KNL, and the KAL. This compound is listed as a carcinogen by the U.S. Environmental Protection Agency (1989a).

1,2-dichloropropane (propylene dichloride) was detected in water from monitoring well MW-6S at 0.2 µg/L for both the primary and duplicate samples. This compound is used in chemical manufacture, as a solvent, in scouring compounds, as a metal degreaser, and as a soil fumigant for nematodes (Sax and Lewis, 1987). The KNL for 1,2-dichloropropane is "any positive detection."

Table 9. *Organic compounds for which analyses were made*

Volatile Organic Compounds

benzene
carbon tetrachloride
chloroethane
chloroform
dibromochloromethane
1,2-dichlorobenzene
1,4-dichlorobenzene
1,2-dibromoethylene
1,2-dichloroethane
1,2-trans-dichloroethene
cis-1,3-dichloropropene
1,3-dichloropropene
methyl bromide
methylene chloride
tetrachloroethylene
1,1,1-trichloroethane
trichloroethylene
xylene
bromoform
chlorobenzene
2-chloroethyl vinyl ether
chloromethane
dichlorobromomethane
1,3-dichlorobenzene
dichlorodifluoromethane
1,1-dichloroethane
1,1-dichloroethylene
1,2-dichloropropane
1,3-trans-dichloropropene
ethylbenzene
styrene
1,1,2,2-tetrachloroethane
toluene
1,1,2-trichloroethane
vinyl chloride

Acid-Extractable Semivolatile Organic Compounds

4-chloro-3-methylphenol
2,4-dichlorophenol
2,4-dinitrophenol
2-nitrophenol
pentachlorophenol
2,4,6-trichlorophenol
2-chlorophenol
2,4-dimethylphenol
4,6-dinitro-2-methylphenol
4-nitrophenol
phenol

Base-Neutral-Extractable Semivolatile Organic Compounds

acenaphthene
anthracene
benzo (b) fluoranthene
benzo (g, h, i,) perylene
4-bromophenyl phenyl ether
bis (2-chloroethoxy) methane
bis (2-chloroisopropyl) ether
4-chlorophenyl phenyl ether
dibenzo (a,h) anthracene
1,3-dichlorobenzene
di-n-butyl phthalate
acenaphthylene
benzo (a) anthracene
benzo (k) fluoranthene
benzo (a) pyrene
butyl benzyl phthalate
bis (2-chloroethyl) ether
2-chloronaphthalene
chrysene
1,2-dichlorobenzene
1,4-dichlorobenzene
2,4-dinitrotoluene

Table 9. *Organic compounds for which analyses were made*--Continued

Base-Neutral-Extractable Semivolatile Organic Compounds--Continued	
diethyl phthalate	dimethyl phthalate
2,6-dinitrotoluene	di-n-octylpthalate
bis (2-ethylhexyl) phthalate	fluoranthene
fluorene	hexachlorobenzene
hexachlorobutadiene	hexachlorocyclopentadiene
hexachloroethane	indeno (1,2,3-cd) pyrene
isophorone	naphthalene
nitrobenzene	n-nitrosodimethylamine
n-nitrosodi-n-propylamine	
phenanthrene	pyrene
1,2,4-trichlorobenzene	

Methylene chloride was detected in the primary water sample from monitoring well MW-6S at 0.2 µg/L but not in the duplicate sample. This compound is used as a solvent, a degreaser, and as an aerosol propellant (Sax and Lewis, 1987). The KNL for methylene chloride is "any positive detection."

Tetrachloroethylene (perchloroethylene) was detected in water from monitoring wells MW-1S, MW-5S, and MW-6S and ranged from 0.7 to 1.9 µg/L in water from these wells. This compound is used as a dry-cleaning solvent, a vapor-degreasing solvent, a drying agent for metal, for heat transfer, and in the manufacture of fluorocarbons (Sax and Lewis, 1987).

Trichloroethylene was detected in water from monitoring wells MW-1S, MW-3S, MW-5S, and MW-6S and ranged from 0.2 to 1.3 µg/L in water from these wells. These concentrations exceeded the Federal MCLG of 0 µg/L but were less than the Federal MCL, the KNL, and the KAL. This compound is listed as a carcinogen by the U.S. Environmental Protection Agency (1989a). Trichloroethylene is used for metal degreasing, as a solvent, for dry cleaning, as a refrigerant, as a fumigant, to clean and dry electronic parts, to dilute paints and adhesives, in textile processing, in chemical manufacture, and to flush liquid oxygen from tanks (Sax and Lewis, 1987). Trichloroethylene can be biologically degraded to 1,2-dichloroethylene and vinyl chloride under anaerobic conditions (Rowland and Eisenberg, 1989).

Vinyl chloride was detected in water from monitoring wells MW-1S, MW-1D, MW-5S, and MW-6S and ranged from 0.9 to 15 µg/L in water from these wells. These concentrations all exceeded the Federal MCLG of 0 µg/L. Concentrations in water from monitoring wells MW-1S, MW-1D, and MW-6S exceeded the KNL of 1.0 µg/L. Concentrations in water from monitoring wells MW-1S and MW-6S (primary sample) exceeded the Federal MCL of 2.0 µg/L, and concentrations in water from monitoring well MW-1S exceeded the KAL of 10 µg/L. This compound is listed as a carcinogen by the U.S. Environmental Protection Agency (1989a). Vinyl chloride is a degradation end product of trichloroethylene (Rowland and Eisenberg, 1989). Vinyl chloride is not known to occur in nature and is used primarily in the production of polyvinyl chloride resins (National Research Council, 1977). The use of vinyl chloride as a propellant in aerosols was banned in 1974 (National Research Council, 1977).

Tentatively identified volatile organic compounds (table 8) were chlorofluoromethane, dichlorofluoromethane, and ethyl ether. Chlorofluoromethane and dichlorofluoromethane are used as refrigerants, and ethyl ether is used as an anesthetic, in analytical chemistry, and in explosives manufacture.

Semivolatile Organic Compounds

Tentatively identified semivolatile organic compounds were alkane and ethylene glycol monobutyl ether (table 8). Alkane (paraffin) is a class of hydrocarbons whose physical characteristics depend on molecular weight and range from methane gas to waxy solids (Sax and Lewis, 1987). Ethylene glycol monobutyl ether generally is used as a solvent (Sax and Lewis, 1987).

Dissolved Organic Carbon

Dissolved-organic-carbon (DOC) concentrations detected in water samples ranged from 0.9 (monitoring well MW-1D) to 4.8 mg/L (sampling site CR-2) (table 7). Thurman (1985) reports that DOC concentrations in ground water usually range from 0.2 to 15 mg/L, with a median concentration of 0.7 mg/L, and rarely exceed 2 mg/L. DOC concentrations in surface water usually are larger than in ground water (Thurman, 1985). Large concentrations of DOC may be indicative of contamination of water by organic substances. The concentration of organic chemicals would have to be relatively large to be detected by the DOC analysis because DOC is reported in milligrams per liter and organic compounds are reported in micrograms per liter. The concentrations of DOC in all ground-water samples from the Sumner County Landfill were within the normal range, and no upgradient-to-downgradient trend was apparent.

Methylene-Blue Active Substances

The analysis for methylene-blue active substances (MBAS) tests for the presence of surfactants, including alkyl benzene sulfonate and linear alkyl sulfonate (Wershaw and others, 1987). These surfactants are common components of detergents. Organic and inorganic compounds may interfere with the MBAS analysis giving false readings that are unusually large. For small concentrations of MBAS (less than 0.5 mg/L), the interferences render the results unreliable (American Public Health Association, 1976).

MBAS concentrations detected in water samples from wells at the landfill ranged from 0.02 (monitoring wells MW-4S and MW-6S) to 2.0 mg/L (monitoring well MW-7S).

Due to possible interferences with the analysis, MBAS concentrations smaller than 0.5 mg/L may reflect the interferences rather than actual MBAS. However, MBAS concentrations in water from monitoring wells MW-2S, MW-3S, and MW-7S probably are reliable values.

EFFECTS OF LANDFILL ON WATER QUALITY

This discussion of the effect of the Sumner County Landfill on water quality is based on the water samples collected in April 1990. The analytical results from these samples give a general "snapshot" in time of landfill-induced water quality affects. However, concentrations of inorganic ions and organic compounds may vary due to factors such as the amount of precipitation prior to sampling and the composition and the degradation stage of trash in the landfill.

Typically, landfill leachate contains large concentrations of sodium, potassium, sulfate, chloride, iron (table 1), manganese, and other ions and trace metals, as well as organic chemicals. The leachate may percolate downward and mix with ground water to dilute these constituents. Despite dilutional affects, concentrations of ions, trace metals, and organic compounds in ground water downgradient of landfills commonly are larger than upgradient of landfills. However, studies of three landfills in Kansas (Myers and Bigsby, 1989, 1990; Falwell and others, 1990) have found that the effects of these landfills on major-ion concentrations are inconclusive. On the basis of those studies, the most reliable indicators of landfill leachate in ground water appear to be increased concentrations of iron, manganese, ammonia, and organic compounds, and decreased concentrations of nitrate.

At the Sumner County Landfill, inorganic water quality is most obviously related to the geologic source of the water, but there are indications that the landfill is affecting water quality. The chemical character of water from Pleistocene terrace deposits and the Wellington Formation (table 10) is similar to that observed

Table 10. *Summary of water-quality data for water from Pleistocene terrace deposits and the Wellington Formation at the Sumner County Landfill, April 1990*

[Units of measurement: mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; <, constituent not detected at the detection level]

Physical property or constituent	Pleistocene terrace deposits (seven samples: monitoring wells MW-1S, MW-2S, MW-3S, MW-4S, MW-5S, MW-6S, and MW-7S)[1]			Wellington Formation (three samples: monitoring wells MW-1D, MW-2D, and MW-4D)		
	Concentration			Concentration		
	Median	Minimum	Maximum	Median	Minimum	Maximum
Specific conductance, field (µS/cm)	1,630	733	1,785	1,970	1,290	3,000
Specific conductance, laboratory (µS/cm)	1,430	863	1,680	1,830	960	3,520
pH, field (standard units)	7.9	7.3	8.2	7.6	7.1	7.8
pH, laboratory (standard units)	7.2	6.7	7.6	7.4	7.1	7.6
Water temperature (degrees Celsius)	15.0	13.0	15.5	15.0	15.0	15.0
Chemical oxygen demand (mg/L)	15	13	31	19	17	74
Hardness, total (mg/L as $CaCO_3$)	580	300	700	650	560	1,100
Calcium, dissolved (mg/L as Ca)	120	65	155	150	120	270
Magnesium, dissolved (mg/L as Mg)	61	33	79	68	62	100
Sodium, dissolved (mg/L as Na)	59	34	170	140	76	370
Potassium, dissolved (mg/L as K)	2.2	1.4	3.4	2.6	2.5	5.0
Bicarbonate, field (mg/L as HCO_3)	540	180	680	380	220	590
Alkalinity, field (mg/L as $CaCO_3$)	440	150	560	310	180	480
Alkalinity, laboratory (mg/L as $CaCO_3$)	440	150	500	320	180	330
Sulfate, dissolved (mg/L as SO_4)	230	54	340	370	180	760
Chloride, dissolved (mg/L as Cl)	78	33	110	210	56	620
Fluoride, dissolved (mg/L as F)	.2	<.1	.4	.1	.1	.2
Silica, dissolved (mg/L as SiO_2)	17	14	24	16	14	18
Dissolved solids, residue at 180 degrees Celsius (mg/L)	932	579	1,140	1,280	816	2,490

Table 10. *Summary of water-quality data for water from Pleistocene terrace deposits and the Wellington Formation at the Sumner County Landfill, April 1990*--Continued

Physical property or constituent	Pleistocene terrace deposits (seven samples: monitoring wells MW-1S, MW-2S, MW-3S, MW-4S, MW-5S, MW-6S, and MW-7S)[1]			Wellington Formation (three samples: monitoring wells MW-1D, MW-2D, and MW-4D)		
	Concentration			Concentration		
	Median	Minimum	Maximum	Median	Minimum	Maximum
Dissolved solids, residue at 105 degrees Celsius (mg/L)	940	597	1,160	1,300	821	2,470
Nitrite, dissolved (mg/L as N)	0.01	<0.01	0.015	<0.01	<0.01	0.01
Nitrite plus nitrate, dissolved (mg/L as N)	4.6	<.1	8.8	.10	<.10	.10
Ammonia, dissolved (mg/L as N)	<.01	<.01	.02	.04	.02	.17
Phosphorus, orthophosphate, dissolved (mg/L as P)	.05	.02	.07	<.01	<.01	<.01
Arsenic, dissolved (µg/L as As)	1	1	2	<1	<1	1
Barium, dissolved (µg/L as Ba)	67	31	220	<100	<100	<100
Cadmium, dissolved (µg/L as Cd)	<1	<1	1	<1	<1	1
Chromium, dissolved (µg/L as Cr)	<5	<5	<5	<5	<5	<5
Copper, dissolved (µg/L as Cu)	<10	<10	<10	<10	<10	16
Iron, dissolved (µg/L as Fe)	12	<3	74	20	10	120
Lead, dissolved (µg/L as Pb)	<10	<10	10	<10	<1	<10
Manganese, dissolved (µg/L as Mn)	22	2	810	57	50	61
Mercury, dissolved (µg/L as Hg)	<.1	<.1	<.1	<.1	<.1	.2
Selenium, dissolved (µg/L as Se)	<1	<1	10	<1	<1	<1
Silver, dissolved (µg/L as Ag)	<1	<1	<1	2	1	2
Zinc, dissolved (mg/L as Zn)	20	10	20	10	10	20

[1] The values given for monitoring well MW-6S are an average of values from the primary (MW-6S) and duplicate (MW-6S dup) samples.

for Sumner County (table 5) in that water from the Wellington Formation generally is more mineralized than water from terrace deposits. A comparison of tables 5 and 10 also shows larger median concentrations of hardness, calcium, magnesium, sodium plus potassium, bicarbonate, sulfate, chloride, and dissolved solids in water from terrace deposits at the landfill than for the county as a whole. These larger concentrations may be due to the effects of the landfill on water chemistry or, with the exception of bicarbonate, could result from the mixing of Wellington Formation and terrace-deposit water at the landfill. A comparison of terrace-deposit water quality upgradient and downgradient from the landfill (table 11) shows that the landfill does not have a definitive effect on water properties or common ions. However, larger concentrations of manganese are present in water from some downgradient wells (monitoring wells MW-1S, MW-4S, and MW-7S) and the creek (sampling site CR-2) than in upgradient wells (fig. 16). Although some of the variability in manganese concentrations is natural, it is likely that the larger concentrations downgradient of the landfill are due, at least in part, to the effects of the landfill.

Another indication that the landfill is affecting water quality is the presence of organic compounds in water from wells downgradient from the landfill. Although small concentrations of organic compounds were detected in upgradient well MW-3S (table 7), the relatively larger concentrations of organic compounds in water from some wells downgradient of the landfill indicate that leachate from the landfill is mixing with ground water. The largest concentrations of the sum of volatile organic compounds were detected in water from downgradient monitoring wells MW-1S (73.3 µg/L) and MW-6S (30.4 and 27.1 µg/L in the primary and duplicate samples, respectively) (fig. 17). Smaller concentrations were present in water from downgradient monitoring wells MW-4S, MW-4D, and MW-5S. Concentrations decreased in the downgradient direction, presumably due to mechanical dispersion, dilution by recharge from precipitation, volatilization and degradation of the organic compounds, and mixing with unaffected ground water. No organic compounds were detected in water from private-supply well DS-1. The source of MBAS, detected in water from upgradient monitoring wells MW-2S and MW-3S may be the sewage solids spread on the field north of the active disposal area (fig. 5). MBAS in water from monitoring well MW-7S may be from landfill wastes. On the basis of water-level contours (figs. 12A and 12B), leachate-containing ground water probably discharges to Beaver Creek southeast of the landfill where it is diluted further by water in the creek. The direction of ground-water flow could vary seasonally and could change the reach of Beaver Creek that receives leachate-containing ground water.

Periodic or continuous water-level measurements and quarterly analyses of selected inorganic and organic compounds would improve understanding of seasonal fluctuations in ground-water levels, vertical flow of ground water, and variations in water quality. In addition, yearly analyses of selected inorganic and organic compounds would provide statistically valid long-term information on the effects of the landfill on water quality.

SUMMARY AND CONCLUSIONS

A study of the hydrogeology and ground-water quality in the vicinity of the Sumner County Landfill near Wellington, Kansas, was conducted from November 1989 to April 1990. An information survey was completed prior to starting field work. Temporary wells were installed to determine the geology and the direction of ground-water flow. Monitoring wells were installed in positions upgradient and downgradient of the landfill. Water samples were collected from monitoring wells, from a private-supply well, and from Beaver Creek.

The landfill, originally operated by the city of Wellington, is now operated by Sumner County as a sanitary landfill. The initial landfill operation began in a sand-and-gravel pit in the southern part of the active disposal area. A 1976 level survey showed that the floor of this pit was near the same altitude as water levels measured during this study.

Regional geology and hydrology provide a framework for the more detailed landfill hydrogeology discussion. Rocks that crop out in Sumner County include the Wellington Formation and Ninnescah Shale of Permian age. Pleistocene terrace and colluvial deposits,

Table 11. *Summary of water-quality data collected from wells upgradient and downgradient of the Sumner County Landfill that are screened in Pleistocene terrace deposits, April 1990*

[Units of measurement: mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; <, constituent not detected at the detection level]

Physical property, inorganic constituent, or sum of volatile organic compounds	Upgradient (two samples: monitoring wells MW-2S and MW-3S)			Downgradient (five samples: monitoring wells MW-1S, MW-4S, MW-5S, MW-6S and MW-7S)[1]		
	Concentration			Concentration		
	Median	Minimum	Maximum	Median	Minimum	Maximum
Specific conductance, field (µs/cm)	1,250	733	1,760	1,630	1,100	1,785
pH, field (standard units)	8.0	7.9	8.0	7.6	7.3	8.2
Water temperature (degrees Celsius)	15.5	15.5	15.5	14.0	13.0	15.5
Chemical oxygen demand (mg/L)	17	13	21	15	15	31
Hardness, total (mg/L as $CaCO_3$)	420	300	540	620	490	700
Calcium, dissolved (mg/L as Ca)	92	65	120	130	110	160
Magnesium, dissolved (mg/L as Mg)	46	33	59	76	52	79
Sodium, dissolved (mg/L as Na)	110	59	170	54	34	95
Potassium, dissolved (mg/L as K)	1.8	1.4	2.2	2.2	1.5	3.4
Bicarbonate, field (mg/L as HCO_3)	360	180	530	620	520	680
Alkalinity, field (mg/L as $CaCO_3$)	300	150	440	520	420	560
Sulfate, dissolved (mg/L as SO_4)	280	230	340	210	54	260
Chloride, dissolved (mg/L as Cl)	62	33	90	78	55	110
Dissolved solids, residue at 180 degrees Celsius (mg/L)	860	579	1,140	932	631	1,100
Nitrite, dissolved (mg/L as N)	<.01	<.01	.01	.01	.01	.02
Nitrite plus nitrate, dissolved (mg/L as N)	6.0	5.7	6.2	2.0	<.10	8.8
Ammonia, dissolved (mg/L as N)	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Phosphorus, orthophosphate, dissolved (mg/L as P)	.04	.02	.05	.05	.02	.07

Table 11. *Summary of water-quality data collected from wells upgradient and downgradient of the Sumner County Landfill that are screened in Pleistocene terrace deposits, April 1990*

Physical property, inorganic constituent, or sum of volatile organic compounds	Upgradient (two samples: monitoring wells MW-2S and MW-3S)			Downgradient (five samples: monitoring wells MW-1S, MW-4S, MW-5S, MW-6S and MW-7S)[1]		
	Concentration			Concentration		
	Median	Minimum	Maximum	Median	Minimum	Maximum
Iron, dissolved (µg/L as Fe)	8	5	12	13	<3	74
Manganese, dissolved (µg/L as Mn)	3	2	4	110	10	810
Sum of volatile organic compounds (µg/L)	<.2	<.2	.2	12.7	<.2	73.3

[1] The values given for monitoring well MW-6S are an average of values from the primary (MW-6S) and duplicate (MW-6S dup) samples.

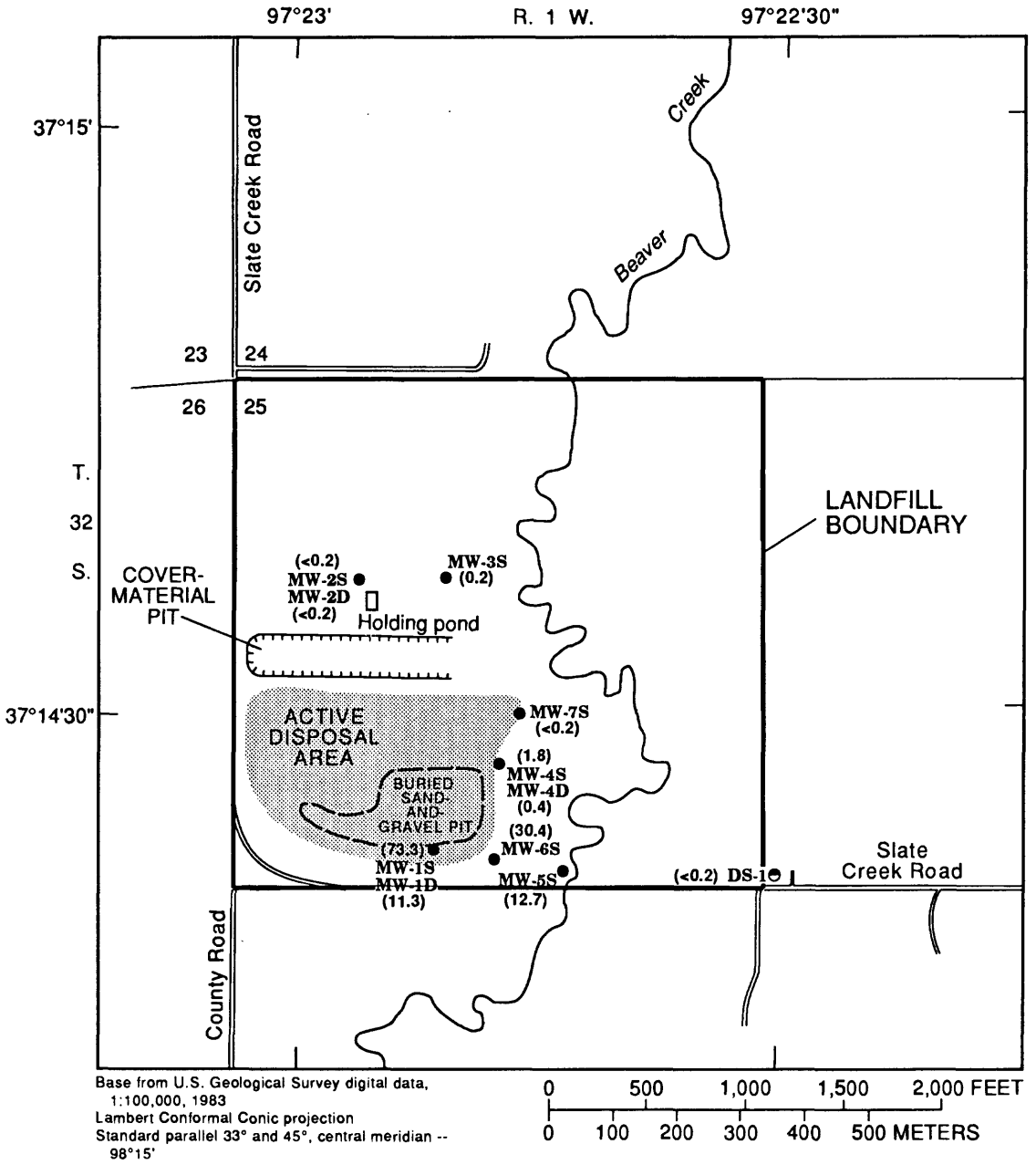


Figure 17. Sum of volatile-organic-compound concentrations in water from monitoring and private-supply wells.

and Holocene alluvium and sand dunes occur on uplands and along streams. Major streams in Sumner County flow southeastward. They are the Arkansas, Ninnescah, and Chikaskia Rivers and Slate Creek. Tributaries to the major streams flow northeasterly or southwesterly. Although the direction of ground-water flow may vary locally, the general direction of ground-water flow in near-surface rocks and sediments is toward the major streams.

Sumner County Landfill hydrogeology includes a discussion of soil, geology, surface water flow and ground water flow. Soil types include Milan loams, Shellabarger sandy loam, Farnum loam, Rosehill clay loam, Vanoss silt loam, Dale and Reinach silt loams, and Elandco silty clay loam. Geologic information gathered during the study shows that the Wellington Formation is present in the subsurface and in outcrops along Beaver Creek. The Wellington Formation is overlain on most of the landfill by Pleistocene terrace deposits of varying thickness and lithology. A thin layer of Holocene alluvium is present along Beaver Creek. North of the active landfill disposal area, surface runoff drains southward to a holding pond. Surface runoff also may pond in the west end of the cover-material pit. Elsewhere on the landfill, surface runoff drains towards Beaver Creek. The direction of ground-water flow in terrace deposits west of Beaver Creek is generally south and southeast, except near the west end of the cover-material pit where ground water flows southwest. On the east side of Beaver Creek, ground water flows southwest towards the creek.

Water obtained from alluvial and terrace deposits in Sumner County generally is of suitable quality for most uses except where contaminated by oil-field activities or naturally occurring saline water. Water obtained from the Ninnescah Shale is similar in quality to water from alluvial and terrace deposits, but water from the Wellington Formation may be more mineralized due to the presence of salt and gypsum deposits in the formation.

Chemical analyses of water from monitoring wells, a private-supply well, and Beaver Creek indicate that water from the Wellington Formation has relatively large sodium, sulfate, and chloride concentrations. Hardness values and concentrations of sulfate, chloride, dissolved solids, and manganese in some water samples exceeded Federal or Kansas drinking-water regulations. Several volatile organic compounds were identified in water samples. In addition, several volatile and semivolatile organic compounds were tentatively identified in water samples.

Analytical results from water samples give a "snapshot" in time of water quality. Although landfill leachate typically contains large concentrations of inorganic ions and organic compounds, water quality at the Sumner County Landfill is related to its source, Pleistocene terrace deposits or the Wellington Formation. However, manganese occurs in larger concentrations in water from some downgradient wells. This may be due to natural variations in concentrations but likely is due, at least in part, to the effects of the landfill. The presence of organic compounds in water from wells downgradient of the landfill indicates that landfill leachate is mixing with ground water. This leachate-containing ground water flows southeasterly and probably discharges into Beaver Creek. Concentrations of organic compounds in ground water decrease in the direction of ground-water flow, probably as a result of dispersion, dilution, volatilization, and degradation.

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