UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

A PRELIMINARY EVALUATION OF HYDROLOGY AND WATER QUALITY NEAR THE TACOMA LANDFILL, PIERCE COUNTY, WASHINGTON

By W. E. Lum II and G. L. Turney

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WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
1201 Pacific Avenue - Suite 600
Tacoma, Washington 98402-4384

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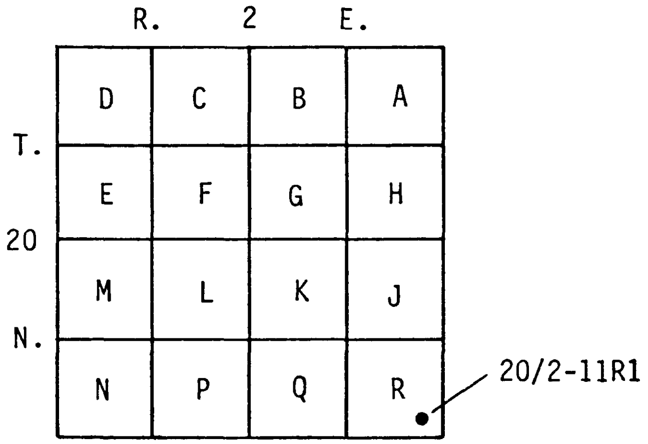
METRIC CONVERSION TABLE

Multiply	By	To obtain
inches (in.)	25.4	millimeters (mm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
feet per day (ft/d)	0.3048	meters per day (m/d)
micromho per centimeter at 25°Celsius (umho/cm at 25°C)	1.000	microsiemens per centimeter at 25° Celsius (uS/cm at 25°C)
degrees Fahrenheit (°F)	0.555, after subtracting 32	degrees Celsius (°C)

WELL-NUMBERING SYSTEM

In this report wells are designated by symbols that indicate their location according to the rectangular-grid system for subdivision of public land. For example, in the symbol 20/2-11R1 the part before the hyphen indicates successively the township and range (T. 20 N., R. 2 E.) north and east of the Willamette base line and Willamette meridian. Because all townships mentioned in this report are north of the Willamette base line and east of the Willamette meridian, the letters "N" and "E" are omitted in the text. The first number after the hyphen indicates the section (11) in which the well is located; the letter denotes the 40-acre subdivision of the section according to the following diagram. The last number is the serial number of the well in the 40-acre subdivision. For example, well 20/2-11R1 is in the SE¼SE¼ sec. 11, T. 20 N., R. 2 E., and is the first well in that tract to be listed.

Springs are numbered in the same manner, except that the lowercase letter "s" is added after the location number. Thus, the first spring recorded in that 40-acre tract would have the number 20/2-11R1s. In figure 3 in this report this spring would be referred to as R1s, in tables it would be referred to as 20/2-11R1s.



Section 11

A PRELIMINARY EVALUATION OF HYDROLOGY AND WATER QUALITY NEAR THE TACOMA LANDFILL, PIERCE COUNTY, WASHINGTON

By W. E. Lum II and G. L. Turney

ABSTRACT

The Tacoma landfill, located in western Pierce County, Washington, has been used for the disposal of waste since about 1960. Disposal operations are planned to continue at this site until at least 1990. This landfill has been designated by the U.S. Environmental Protection Agency as a "Superfund" site. The purpose of this investigation was to gather, describe, and interpret all available data on the hydrology and ground- and surface-water quality and to identify the need for additional data at the landfill site.

Data indicate that hazardous liquid wastes and hazardous wastes dissolved in the ground water probably are present in the landfill. The landfill is underlain by glacially derived deposits that consist of a wide variety of materials ranging in size from clay to boulders in a wide variety of sorted to unsorted mixtures. Within these materials are two distinct layers of permeable sand and gravel that constitute major artesian aquifers which are tapped for both domestic and municipal use. An undetermined number of domestic wells and 18 public supply wells are within 3 miles of the landfill and may be affected by ground-water contamination.

Analysis of water from one well near the landfill indicated dissolved-solids concentrations of up to 644 milligrams per liter, about 2 to 3 times higher than natural concentrations in this area. Organic compounds such as trans-dichloroethene, trichloroethene, and toluene are also present in concentrations of 2 micrograms per liter in the same well. Sediment from nearby Leach Creek was found to contain certain metals in high concentrations. As an example, lead and zinc were both present at concentrations of 508,000 micrograms per kilogram. Water seeping from parts of the landfill also contained high concentrations of metals, such as zinc in concentrations up to 9,810 micrograms per liter.

There is evidence indicating ground- and surface-water contamination, but further investigations of the geology, hydrology, and water quality are needed to characterize the impact the landfill has on ground water and surface water in the surrounding area.

INTRODUCTION

Among the many environmental issues facing the people of the State of Washington, safe disposal of waste materials is one of the more serious. Ten sites in Washington (mostly active or former waste disposal areas) were identified in 1982 by the U.S. Envionmental Protection Agency (EPA) to be included under the "Superfund" program requiring some type of remedial action to deal with their actual (or potential) contamination of the environment. The Tacoma landfill is one of these sites. In addition, the Washington Department of Ecology (WDOE) has identified more than 400 sites in the State where disposal of wastes has caused, or may cause, damage to the environment (Michael Ruef, WDOE, oral commun., May 15, 1984). Other undetected occurrences of surface-water and ground-water contamination probably occur throughout the State.

This study is part of a cooperative program between the WDOE and the U.S. Geological Survey (USGS) to make a preliminary assessment of the hydrologic setting, including surface- and ground-water quality, of several landfill sites within Washington and to identify data deficiencies. This report describes results of such a study conducted for the Tacoma landfill, Pierce County, Washington (fig. 1). Hazardous waste materials may be migrating away from the landfill into the surrounding environment. Ground water is a major source of municipal water in this area and protection of this resource is extremely important.

Purpose and Scope

Using existing data the purpose of this study was to 1) describe the geohydrologic setting in the immediate vicinity of the Tacoma landfill, and 2) determine the presence or absence of ground- and surface-water contamination attributable to the landfill. An evaluation was also to be made to determine what additional data, if any, are necessary to further describe the above items 1 and 2.

Data Sources

In addition to published reports of the USGS (see selected references, end of report), numerous contacts for data were made with other Federal, State, and local governmental agencies. These agencies (listed below) provided both unpublished data and copies of reports (see selected references, end of report) that were written under contract for the agency by private consulting firms. The materials collected are stored in the Tacoma Office of the USGS, Water Resources Division. Sources of data and reports included:

Town of Fircrest
City of Tacoma - Water Division
- Refuse Utility Division

U.S. Environmental Protection Agency (EPA)
Washington State Department of Ecology (WDOE) - Southwest regional office
- Office of Water Programs

Tacoma-Pierce County Health Department (TPCHD)
Washington State Department of Social and Health Services (DSHS)

Ground-water data were available from nearly all sources contacted. Well locations, geology, and ground-water flow system data came primarily from published reports including Walters and Kimmel, 1968; Brown and Caldwell, 1983; Griffin and others, 1962; and Larsen, 1963 and 1971. The primary sources of ground-water quality data included published and unpublished data of the USGS and unpublished (mostly) data from the files of the EPA, WDOE, DSHS, and TPCHD.

Surface-water chemical quality data came primarily from the EPA. Data on streamflow of Leach Creek were obtained from published reports of the USGS. Spring locations and flow rates are taken from Walters and Kimmel (1968).

Those data used in this investigation that were not collected by the USGS were not subjected to verification procedures normally used by the USGS and therefore are not evaluated by the Survey. The results of this investigation suggest that errors may exist in some of these data. In those cases where this was readily identifiable the information was not used. Even so, it is possible that some of the conclusions of this report are in error because of erroneous data or at best cannot be fully substantiated.

Description of the Landfill

The Tacoma landfill (fig. 1) is located in southwest Tacoma and is generally bounded by Orchard Street on the west, South 31st Street on the north (not shown in fig. 1), South Manitou Way and South Tyler Street on the east, and South 48th Street on the south. The undulating land surface of the landfill (ranging from about 270 to 380 feet above sea level) is the result of the latest glaciation that occurred in the area. Elongate ridges (drumlins) trend north-south; within the boundaries of the landfill the intervening valleys are being filled with waste materials. The landfill has been in operation since 1960, with waste materials being compacted and covered daily with native till removed from nearby ridge tops. The dates of waste emplacement in various parts of the landfill are shown in figure 1. It is estimated that the landfill will be full of waste and no longer usable in about 1990. The landfill was originally planned for use as a disposal area for normal household refuse; the emplacement of hazardous materials in the landfill was not anticipated. However, it is now believed that it is probable that there is a variety of unknown waste materials in the landfill, some of which are potentially hazardous if released to the surrounding environment (Dr. R. M. Nicola, TPCHD, oral commun., July 11, 1984).

Climate

Average annual precipitation in Tacoma, Wash., is about 37 inches, with about 75 percent occurring during the 6-month period October-March. Average annual temperature is about 52.1°F and average monthly temperature ranges from 39.9°F in January to about 64.2°F in July and August (U.S. National Oceanic and Atmospheric Administration, 1982).

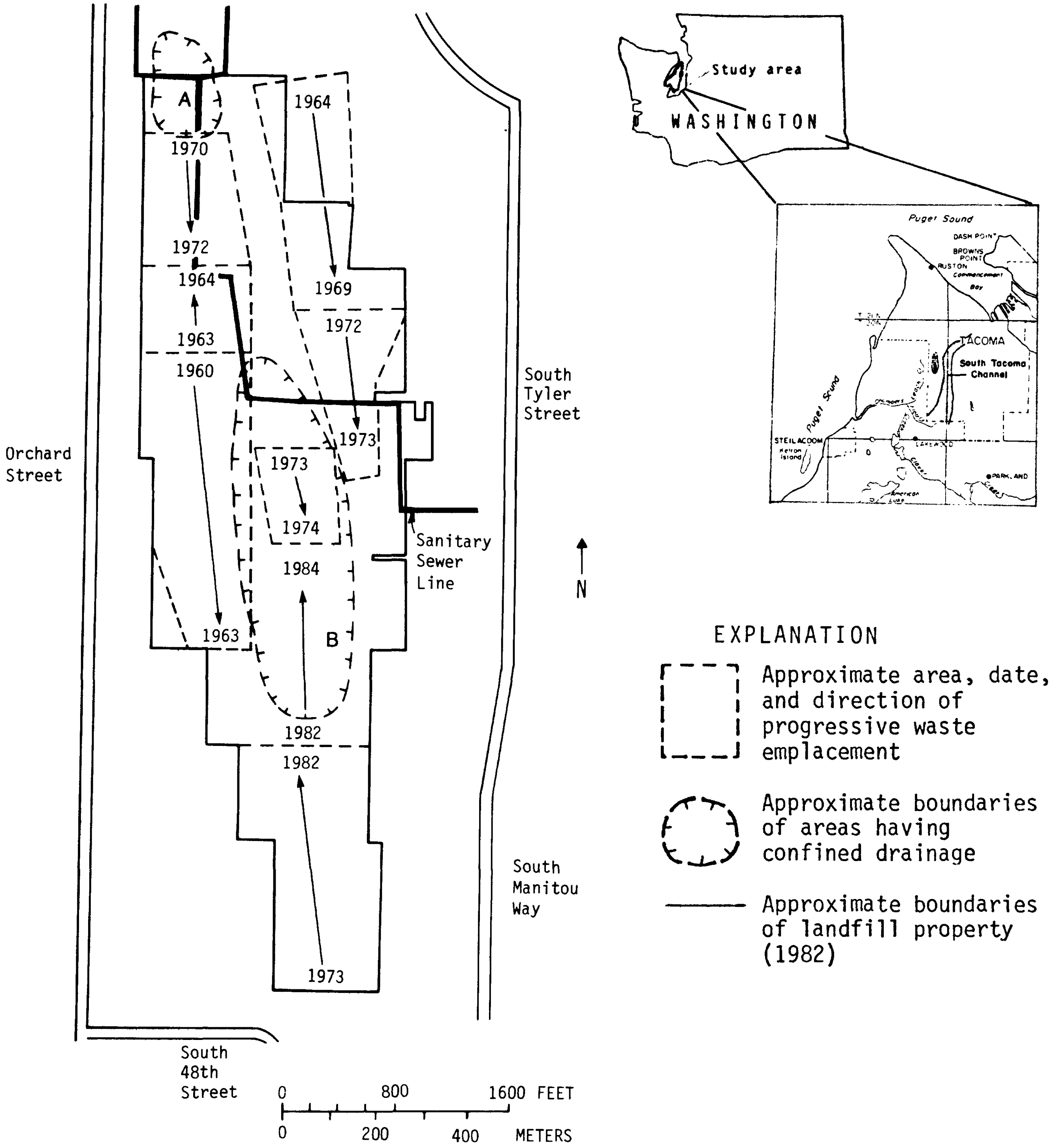


FIGURE 1.--Map of the Tacoma landfill showing location and waste disposal areas 1960-84 and areas of confined drainage.

INFILTRATION OF PRECIPITATION THROUGH THE LANDFILL

The quantity of water that is available to infiltrate into and through the landfill is represented by:

$$I = P - ET - RO$$

Where:

I = Infiltration, the amount of water moving vertically through the landfill; this water is capable of dissolving waste and creating leachate.
P = Precipitation on the landfill.
ET = Evapotranspiration, evaporation of moisture from soil and transpiration of moisture by plants.
RO = Runoff of water (controlled or uncontrolled) to Leach Creek, storm or sanitary sewers, and the south Tacoma Channel area.

Calculations based on daily precipitation and temperature records over a 26-year period (1953 to 1978) indicate actual evapotranspiration averages about 10.2 in./yr (inches per year) for the Tacoma area. Average precipitation for the same period is 37.6 in./yr. The landfill has an area of about 0.31 mi^2 (square mile); thus, an average of about 400,000 gal/d (gallons per day) of precipitation minus evapotranspiration must either go to runoff or infiltration. As the quantity of runoff that occurs either through controlled drainage to sewers or uncontrolled through natural or manmade stream channels has never been measured and cannot be determined from existing data, the distribution of the 400,000 gal/d (runoff plus infiltration) must be estimated.

There are two closed basins within (or at the edge of) the landfill (A and B, fig. 1) where runoff out of the basin does not occur. In those areas then, the amount of infiltration is equal to the difference between precipitation and evapotranspiration. Ponds that occur intermittently in areas A and B after periods of heavy rainfall cover only a small part of the basins and loss of water due to direct evaporation from the surface of the pond is considered insignificant. Based on the land area covered by A and B (0.07 mi^2) the infiltration from those areas would be about 90,000 gal/d. The amount of water infiltrating the landfill thus lies somewhere between the 90,000 gal/d (assuming no infiltration except in areas A and B) and 400,000 gal/d (assuming no runoff for the entire landfill). The water that infiltrates into the landfill may dissolve waste materials, creating leachate. The leachate probably continues moving downward (fig. 2) and may carry those materials to the water table underlying the landfill. Once mixed with the ground water, the leachate would move in the same manner and direction as the ground water (discussed later in "Ground-Water Flow System").

GEOHYDROLOGIC SETTING

Geology

According to Griffin and others (1962) Tacoma "is underlain by a great thickness of semiconsolidated and unconsolidated materials that partly fill the large north-south structural basin known as the Puget Trough. These materials include clay, silt, sand, gravel, glacial till (boulder clay), and thin strata of peat, and they extend in some places to depths exceeding 2,000 feet. They were deposited in lakes, or by streams, during Recent [Holocene], Pleistocene, and late Tertiary time. The Pleistocene deposits consist largely of glacial drift laid down from the Vashon Glacier that occupied the area late in the ice age. Individual strata generally show marked changes in lithology; a clay stratum may grade laterally into a sand stratum, and a sand stratum may grade into gravel. These changes in lithology make stratigraphic correlation difficult and uncertain." The more common types of these deposits that occur near the landfill are described in the explanation on figure 2.

Within the unconsolidated materials underlying the landfill there are two distinct units of more permeable sand and gravel (coarser outwash in fig. 2). These layers constitute major artesian aquifers which are tapped for both domestic and municipal water supplies (fig. 3, table 1 and 2, discussed later).

With respect to contamination of the environment that may occur as a result of disposal of wastes in the landfill, the most significant geologic unit present is the till (see fig. 2) upon which the landfill is being constructed. The thickness of the till is not well known but in places it is probably as much as 50 feet thick. In other places, the till may be absent or it may have been removed. At the landfill, undisturbed till is probably continuous with two possible exceptions. One exception is areas of the landfill where a sanitary sewer line was constructed (in 1968, from one side of the landfill to the other, see fig. 1) after disposal at the site had begun (Larsen, 1971). During trenching operations for construction of the sewer line the till layer was significantly reduced in thickness and it was fully penetrated in places where bucket auger holes were bored to determine its exact thickness (Larsen, 1971). Larsen (1971) also reported "...an average of 5 feet of undisturbed..." till underlies the sewer line within the landfill boundaries. However, he noted that in this area differentiation between till and similar appearing but more permeable types of glacial deposits is difficult at best. The other exception is that some till was reportedly excavated in areas where waste was scheduled to be emplaced. Part (or all?) of the till layer was removed and temporarily stored in other areas of the site so that waste could be emplaced in the resulting trench.

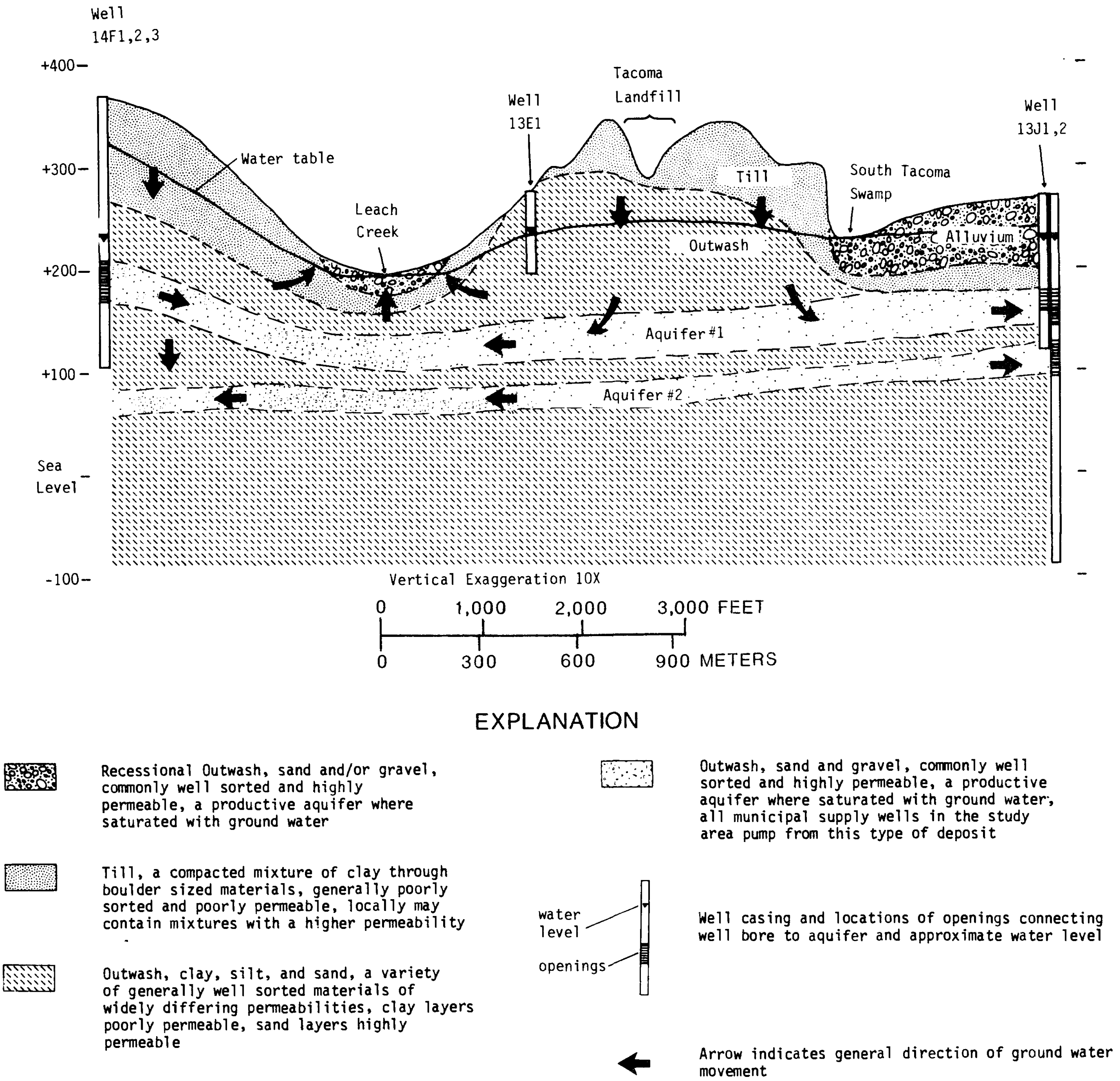


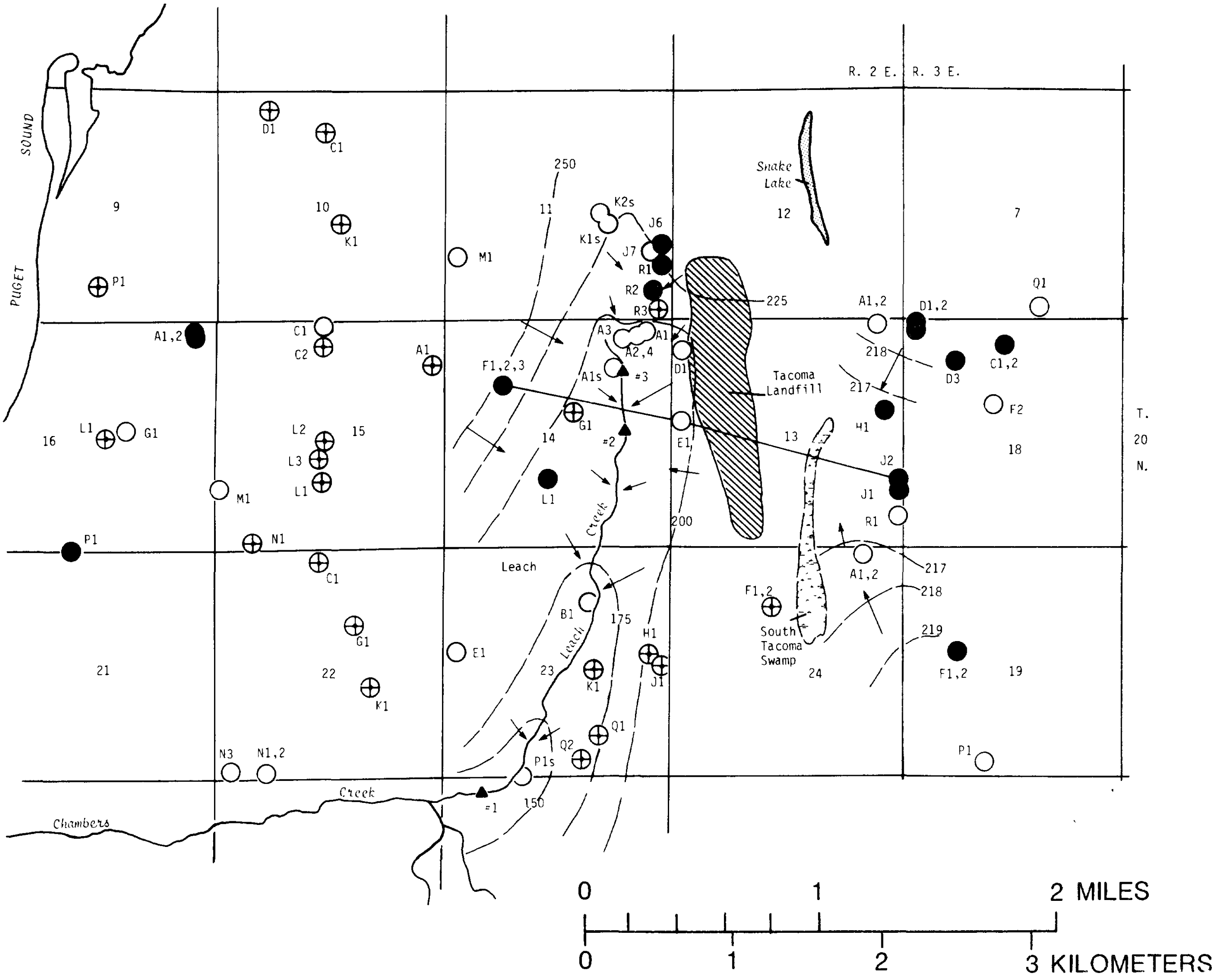
FIGURE 2.--Diagrammatic geohydrologic section in the study area.

Ground-Water Flow System

The estimated configuration of the water table underlying the landfill is shown in figures 2 and 3. As indicated in figure 2, the water table occurs in the outwash deposits and is approximately 50 feet below land surface at the landfill. Any leachate derived from the landfill would therefore have to move this distance prior to reaching the ground-water system. Movement of ground water within the outwash is towards Leach Creek and the South Tacoma swamp. Sufficient data do not exist to determine the configuration of water levels in aquifers 1 and 2, but the data that are available indicate that water moves downward from the outwash to aquifer 1 and from aquifer 1 to aquifer 2.

As will be discussed subsequently, there are at least 18 public supply wells located within 3 miles of the landfill. The nearest of these are three Fircrest wells located within 0.2 mile of the west edge of the landfill. All of the above wells are open to either aquifer 1 or 2 and the rate of pumping from them can be relatively large. Because of the proximity of these and other wells to the landfill, it is probable that the natural ground-water flow system underlying the landfill has been altered, and that ground water could move from the landfill to some or all of the high-yield wells.

An example of such induced movement at the "Tacoma Well Field" located generally on the east edge of the South Tacoma channel 0.5 to 1.0 mile east of the landfill has been recently documented. According to a study prepared for EPA "...the natural flow of ground water is away from the well field and toward the source of contamination..." however, ..."pumping the well field reverses this natural flow and pulls contamination toward the operating wells. After the pumping season, the contamination recedes toward the source area..." (CH_2M Hill and Ecology and Environment, 1984). The "source area", contaminated with a variety of organic compounds, is 0.4 mile from well 18C2 and 0.6 mile from well 18D3; these wells are at the northern end of the "Tacoma Well Field." These considerations make it imperative that the definition of ground-water levels within at least 3 miles of the landfill be established if the present or potential impact of the landfill is to be fully and adequately addressed.



EXPLANATION

D1 ⊕	Domestic supply well
L1 ○	Well location and number
R2 ●	Public supply well and number
————	Geologic section line (see fig. 2)
#2 ▲	U.S.G.S. streamflow gaging stations on Leach Creek and number
— — 225	Approximate altitude of the water table above sea level (after Larsen, 1963 and Black and Veatch, 1983). Contour interval 1 and 25 feet.
——→	Approximate direction of ground water flow as indicated by the water table

FIGURE 3.--Map of the study area showing the location of the Tacoma landfill, data-collection points, well locations and selected physiographic features. (Some well locations have not been verified by USGS personnel.)

Hydraulic Characteristics of Deposits Underlying the Landfill

The hydraulic characteristics of the materials underlying the landfill vary greatly. The sand and gravel aquifers contained within the outwash deposits (see fig. 2) are highly permeable. Well yields of 9,000 gallons per minute (gal/min) have been reported and yields ranging from 1,000 to 5,000 gal/min are not unusual (see table 1). The hydraulic conductivity (a measure of the permeability of a material or its ability to transmit ground water) of the materials in the aquifers probably ranges from 100 to 500 or more feet per day (ft/d). Other materials present in the outwash deposits probably have hydraulic conductivities ranging from less than 1 (clay) to 100 ft/d (medium to coarse sand). The outwash lying between the till and the aquifers that underlie the landfill at depth (fig. 2) is typical of these materials with widely varying, but generally lower permeability than the aquifers.

Till is a compact material due to the pressure of the overlying ice and the wide variety of particle sizes (clay to boulders) present during deposition. Till is also poorly permeable, generally having a hydraulic conductivity of less than 1 ft/d. As mentioned previously, till is used to cover waste materials emplaced in the landfill. However, because this till has been dug up, moved (in some cases temporarily stored and then moved again), spread over waste, and compacted by mechanical means, its permeability would be higher than that of an undisturbed till. Ground water probably moves through disturbed till at a much higher rate than it would through undisturbed till. This is significant, as a more permeable, disturbed till cover might allow increased infiltration to those areas where waste materials were emplaced and covered.

Distribution and Use of Wells

Although no effort was made to inventory all wells near the landfill, it is believed that the number exceeds 100. Wells in the area are probably open to both aquifers 1 and 2 and to the coarser outwash materials. However, there are not sufficient data to determine which aquifer each well pumps water from.

Currently (1984), there are at least 18 wells in use for public water supply located within 3 miles of the Tacoma landfill. Operators of these wells are City of Tacoma-Water Division, University Place (operated by City of Tacoma-Water Division), and Town of Fircrest. About 20 wells were used to supply domestic water in the middle 1960's (Walters and Kimmel, 1968). The number of currently (1984) operating wells supplying domestic water is unknown. Descriptions of selected wells (including domestic and public water supply wells) and locations are shown in table 1 (end of report) and figure 3, respectively.

The City of Tacoma water-supply system depends primarily on water piped into the area from the Green River watershed. The wells operated by the City of Tacoma (the "Tacoma Well Field" with at least nine operating wells within 3 miles of the landfill) are used to supplement imported Green River water during summer peak demand or occassionally during the periods of highly turbid water in the Green River. Water-quality data available for some of the Tacoma wells indicate that there are at least two distinct ground-water contamination problems in the "well field" area. These are discussed under "Ground-Water Chemical Quality." The UP (University Place) system relies primarily on imported water supplied by the City of Tacoma. The three UP wells are used primarily to supply peak summer demands and pumping at other times is limited. The Town of Fircrest operates six wells in the study area. Wells are the only source of water to the Fircrest system and are operated on a daily basis. Three of the Fircrest wells (11J6, R1 and R2) are within 0.2 mile of the west edge of the Tacoma landfill. Waste materials were emplaced near that boundary during 1970-72 (see fig. 3).

GROUND-WATER CHEMICAL QUALITY

Water-quality data for 25 wells are presented in tables 2, 3, and 4 (end of report). They represent all the existing data in the landfill area, with the following exceptions. First, Tacoma and Fircrest have multiple chemical analyses of water from most of their wells. Because many of their data are similar and showed no significant temporal changes (exceptions are discussed later in this section), only the most recent analyses are shown in the tables. Also, analyses of organic compounds in water from some City of Tacoma wells were performed frequently (weekly or more often). These data are summarized by indicating the concentration ranges over a given time period (see table 4). Lastly, a few analyses for organic compounds included more constituents than those presented in table 4. These data were only for a few wells and a few constituents and it was determined that they were not pertinent or significant to this discussion.

Physical Characteristics and Major Dissolved Constituents

The physical characteristics and major dissolved constituents (table 2) are typical of those found in waters in glacial deposits. Specific-conductance values range from approximately 100 to 300 umhos/cm (micromhos per centimeter) and pH values range from 6.0 to 7.5. The waters are soft or moderately hard and dissolved-solids concentrations are generally less than 200 mg/L (milligrams per liter). Calcium and magnesium are the predominant cations and bicarbonate (represented by alkalinity) is the predominant anion.

There are some indications of ground-water contamination near the landfill. Well 20/2-13D1, near the west edge of the landfill, has water with a reported specific conductance of 1,099 umhos/cm and a dissolved-solids concentration of 644 mg/L. These high values may represent ground water from the landfill, or may be due to leakage of surface water down the side of the well casing; the exact cause cannot be determined from existing data. These results may be misleading as it was also reported that the well could not be flushed satisfactorily before sampling (EPA, written commun., May 16, 1983). In any case, this well does not penetrate either of the major artesian aquifers, and is indicative only of conditions in the outwash deposits overlying the aquifers. Water from well 20/3-18D2 (City of Tacoma 2B) has a specific conductance of 825 umhos/cm and a dissolved-solids concentration of 707 mg/L. The predominant anion is chloride. This is thought to be the result of a brine spill in the mid-1950's (?) at a nearby food processing plant (Bob Myrick, oral commun., August 13, 1984). The brine slowly percolated downward through the unsaturated zone and eventually reached the water table. Pumping probably caused the brine/ground-water mix to move toward the well where it was detected during routine chemical analyses of water from the well. This represents a common mechanism of contaminant movement from a source into the surrounding environment.

Temporal increases in major dissolved constituents have been observed in some wells. Well 20/3-18D3 (City of Tacoma 9A) has water indicating threefold increases in dissolved-solids concentrations and specific conductance during the period 1952 to 1982. Chloride concentrations increased an order of magnitude (from 5 to 54 mg/L) over the same period. This, in conjunction with the well's proximity to well 20/2-18D2 suggests the brine spill may have affected it also. Water from two other wells, 20/3-19F1 (City of Tacoma 5A) and 20/3-19P1 (City of Tacoma 1A) have shown a doubling of dissolved-solids concentrations from the 1930's to 1980's. As this is reflected in increased concentrations of most of the major dissolved constituents and these wells are over a mile from 20/3-18D2 and 20/3-18D3, it is probably not a result of the brine spill and may be due to unexplained dissolution of minerals from the surrounding aquifer material.

Nutrients

The nutrient data consist primarily of nitrate analyses (see table 3). The few ammonia and total organic nitrogen analyses available indicate negligible concentrations. Nitrate concentrations exceeding 1 mg/L (as nitrogen) are found in water from several wells and could indicate some type of manmade source because nitrate concentrations in ground water in the Puget Sound area are generally less than 1.0 mg/L (G. L. Turney, 1985). Even so, the highest concentration found is 4.0 mg/L, well below the EPA drinking water standard of 10 mg/L. Septic tanks and drainfields were used at one time in the western part of the study area and are still used in a large area (25 mi^2) south of the study area; therefore a number of potential sources of nitrate other than the landfill exist. Ground-water flow needs to be more fully understood to determine the actual sources.

Metals

Concentrations of most trace metals analyzed for were generally less than 10 ug/L (micrograms per liter; see table 3). Iron and manganese concentrations were generally higher, exceeding EPA drinking water standards of 300 and 50 ug/L, respectively, in some samples. In most instances, this could have been due to natural causes, as iron and manganese are known to occur naturally in Puget Sound glacial deposits (VanDenburg and Santos, 1965; G. L. Turney, 1985).

Four wells had water with unusually high concentrations of metals. Water from well 20/2-24A2 had an iron concentration of 2,000 ug/L in 1946. This occurred before the landfill was used and obviously it could not be implicated as a source. Water in well 20/2-13E1 had an iron concentration of 4,000 ug/L in 1969. This analysis was the first indication that ground water near the landfill may be contaminated (City of Tacoma Department of Public Works, 1969). This well, like 20/2-13D1, does not penetrate either of the two major artesian aquifers and the mechanism of contamination is also not known. Well 20/2-13D1, discussed earlier as being possibly contaminated, had an analysis with an iron concentration of 67,500 ug/L and manganese concentration of 2,700 ug/L in 1983. Well 20/2-11M1 had a concentration of aluminum of 4,600 ug/L and an iron concentration of 3,300 ug/L in 1983. This represents a substantial increase from a previous analysis from this well in 1970. Well 20/2-11M1 is used for irrigation at a golf course and the source of these metals dissolved in the ground water is not known.

Organic Compounds

Analyses of organic compounds are generally limited to volatile organic compounds, specifically common cleaning solvents (table 4, end of report). Most of the wells sampled and analyzed for organic compounds are operated by the City of Tacoma and located east and south of the landfill. These data were collected primarily over concern for the contamination of well 20/2-18C2 (City of Tacoma 12A) with solvents. Wide ranges of concentrations of all the volatile organic compounds analyzed (some up to 9,900 ug/L) were found in water from many City of Tacoma wells. Concentrations of 1,1,2,2-tetrachloroethane as high as 30,000 ug/L were found in well 20/3-7Q1, a test well. These compounds have been attributed to sources in the industrial area surrounding the wells, as opposed to the Tacoma landfill (CH_2M Hill and Ecology and Environment, 1984). Nevertheless, the organic compounds discovered in these wells are, in many instances, the same as those that might be expected from the landfill.

Analyses from the two wells closest to the landfill, 20/2-13D1 and 13H1 (City of Tacoma 4A), indicated comparatively lower concentrations of volatile organic compounds than those in the City of Tacoma wells mentioned above. Water in well 20/2-13H1 had concentrations of 0.5 ug/L or less for all volatile organic compounds analyzed (table 4). Water in well 20/2-13D1 had concentrations of trans-dichloroethene, trichloroethane, and toluene of 2 ug/L. The presence of these contaminants in the water from this well is an indication of ground-water contamination. A trichloromethane (chloroform) concentration of 13 ug/L was observed in water from well 20/2-16P1 (UP10). Because of the distance between the well and the landfill and a lack of any trichloromethane in nearby well 20/2-16A2, the source remains unknown.

Data Limitations

The chemical data in tables 2, 3, and 4 were usually collected for some purpose other than determining ground-water pollution resulting from the Tacoma landfill. They were often collected as part of another study, or as a routine monitoring effort required by DSHS for public drinking water supplies. Therefore, the constituents analyzed vary from one analysis to the next, even from the same well. This makes it difficult to compare results because the same types of analyses are not always available for all wells or one well over a long time period.

Methodology of analysis is of concern in interpretation of these data. It is a reasonable assumption that standard methods, such as those outlined in American Public Health Association and others, 1981, have been followed, but this has not been verified. The phase (dissolved or total concentrations) of some analyses is unknown and this should be considered before interpretations of the data are made. In some cases, order of magnitude differences in concentration are seen, especially in the metals data, and on this scale some conclusions can be drawn.

Examples of inconsistencies in the data include an analysis on April 30, 1980, for well 20/2-13J2 (City of Tacoma 11A) which had a magnesium concentration three times that of any other analysis for this well (see table 2). The reported dissolved-solids concentration (in the same analysis) of 112 mg/L is about half of what a calculated value would be, approximately 200 mg/L, indicating an inconsistency within the analysis itself. An analysis of the same well on July 7, 1981, has a chloride concentration of 100 mg/L, three times that of the second highest concentration. These examples are extremes, but they do illustrate one of the problems of dealing with a large volume of data gathered from numerous sources. Despite these problems the data are generally considered useful for evaluating the overall water chemistry in the area surrounding the landfill.

SURFACE-WATER HYDROLOGY

Overland Runoff From the Tacoma Landfill

For some areas of the landfill the City of Tacoma Refuse Utility Division controls overland runoff of rainfall and seepage by collecting it in holding ponds and then directing it to sanitary sewers. These sewers flow to Tacoma's (primary) sewage-treatment plant. However, not all runoff and seepage is controlled and some collects in ponds where it may infiltrate to become ground water. Also, some overland runoff that occurs during periods of heavy rainfall enters natural tributaries to Leach Creek or storm sewers that discharge into Leach Creek (EPA, written commun., March 4, 1984).

Streamflow Characteristics of Leach Creek

Leach Creek (fig. 3) drains the area west and southwest of the Tacoma landfill. It is a perennial stream whose base flow is maintained by ground-water discharge, including major contributions from numerous springs in the basin (described in the next section). An undetermined part of the flow of Leach Creek is probably derived from ground water flowing from under the landfill.

There are currently (1984) three streamflow gaging stations operated by the USGS on Leach Creek. Mean monthly flow at the upstream station (#3, fig. 3) during the period October 1980-September 1981 ranged from 1.98 cubic feet per second (ft^3/s) in August 1981 to 10.6 ft^3/s in December 1980 (U.S. Geological Survey, 1983). The other two sites (see #2 and #1, fig. 3) had August mean monthly flows of 2.43 and 6.78 ft^3/s, respectively, and December mean monthly flows of 11.9 and 20.0 ft^3/s, respectively. August flows are usually considered to represent essentially the ground-water component of outflow from the stream basin. Overland runoff from heavy winter rains in the basin dominates December streamflow. Winter streamflow in Leach Creek is also supplemented by storm-water runoff from urban areas in Fircrest and Tacoma and runoff from the landfill.

Description of Springs

Several springs (table 5) are known to occur west of the landfill (Walters and Kimmel, 1968). These springs commonly discharge from the coarser outwash deposits where underlain by clay or silt layers or from outwash deposits truncated in stream channels such as Leach Creek valley. Most of the base flow of Leach Creek (mean annual flow 9.9 ft^3/s) is probably derived from these major springs (Walters and Kimmel, 1968). An unknown amount of spring discharge is probably derived from ground water that has traveled under or through the landfill. No water-quality data for springs are available.

SURFACE-WATER CHEMICAL QUALITY

Water-quality analyses of surface waters and sediments are limited. The few analyses that do exist are from seeps, ponds, and sewers directly related to the landfill and from nearby Leach Creek (site description, see table 6). In some cases, samples of both water and sediment were analyzed. Metals and organic compounds data from the sites sampled are shown in tables 7 and 8. No physical characteristics or major dissolved constituent data were available for surface-water sites.

Concentrations of aluminum, iron, manganese, and zinc in the "south seep" exceeded 4,000 ug/L in January 1983. Concentrations of arsenic, chromium, and nickel exceeded 100 ug/L in the same analysis. These concentrations are roughly an order of magnitude higher than concentrations of the same metals in the other surface-water sites. In contrast, the concentration of copper and lead in water from the "south seep" is lower than most other sites. Whereas metals concentrations in the "south seep" are high enough to potentially implicate the landfill as a source, metals concentrations in other sites are low enough that they may be considered natural or from other sources. The sanitary sewer downstream of the landfill has higher concentrations of iron, manganese, and zinc than the sanitary sewer upstream of the landfill, but concentrations of aluminum, copper, and lead are virtually the same. It appears that some metals concentrations in the sanitary sewer have sources other than, or in addition to, the landfill.

It should be noted that the two samples of the "south seep" were taken only 3 months apart, yet some metals concentrations in these analyses differ by an order of magnitude. A possible explanation is a heavy rainfall event which occurred about a week before the first sampling, the one with the higher concentrations. There was a dry period prior to the second sampling (U.S. National Oceanic and Atmospheric Administration, 1983a, 1983b). This suggests possible correlations between the chemistry of the seepage, precipitation, and runoff; however, these correlations are unclear.

Zinc concentrations ranged from 129,000 to 658,000 ug/Kg (micrograms per kilogram) in the sediments from the ponds, the storm sewer, and Leach Creek. Lead concentrations ranged from 20,000 ug/Kg in the drained pond sediment to 508,000 ug/Kg in Leach Creek sediment. Arsenic, chromium, copper, and nickel concentrations were lower, generally ranging between 6,000 and 60,000 ug/Kg. Mercury concentrations of 40 ug/Kg or less were observed in all sediment samples except those of Leach Creek, where concentrations were 2,400 ug/Kg. Even though they vary considerably, these concentrations are several orders of magnitude above the water concentrations of the metals in the storm sewer and Leach Creek. It is obvious, and to be expected, that metals are concentrating in the sediments analyzed. However, as in the water samples, most of the metals have potential sources other than the landfill. (For example, chromium and lead are automotive pollutants, and arsenic and copper have known industrial sources in the area.)

High concentrations of polynuclear aromatic hydrocarbons (or PAHs), specifically fluoranthene, phenanthrene, and pyrene, were detected in the sediments, but not the waters. PAHs are a product of all types of combustion, even natural fires, and cannot be directly attributed to the landfill.

Concentrations of volatile organic compounds were 6.4 ug/L or less at all sites except the "south seep," but this might be expected in flowing, aerated surface waters.

As with the ground-water data, variations in constituents analyzed makes data interpretation difficult. These data appear to implicate the landfill as a source of heavy metals in the seeps and ponds on the landfill. However, the sewer lines and Leach Creek drain substantial areas other than the landfill and more control data are needed to identify the source of contaminants found in those two places.

EVALUATION OF EXISTING DATA AND REPORTS

Existing data and reports concerning the Tacoma landfill provide limited background information on the geology, hydrology, and water chemistry of the area. Specifically, the shortcomings of existing information include:

1) The types of (geologic) materials underlying the landfill and surrounding areas are poorly known.

2) The thickness and lateral extent of the till, upon which wastes are placed, is poorly known, especially in areas where excavations have been made to make room for a sewer line and more wastes.

3) There is not sufficient information to determine accurately the permeability of the till, the disturbed till, and underlying non-aquifer materials (directly related to pollutant movement).

4) There are not sufficient data on water levels in materials under (and surrounding) the landfill to determine the direction and rate of ground-water movement (directly related to pollutant movement).

5) Seasonal water-level fluctuations are not well documented, and both natural and pumpage induced water-level changes may have an effect on pollutant movement.

6) Construction techniques used for wells 20/2-13D1 and 13E1 are not known; therefore, the method of contamination of the ground water (as indicated by analyses of water from these wells) near the landfill cannot be easily proven. Typical construction techniques of water supply wells and current techniques for construction of wells for chemical sampling differ greatly.

7) Previous chemical sampling of ground and surface water usually has been for a variety of purposes. Sites sampled and constituents analyzed are inconsistent, making it difficult to compare data and reach meaningful conclusions.

8) Adequate control samples from points upgradient of the landfill to isolate it as a pollution source are not available. This applies to both ground water and surface water.

DESCRIPTION OF ADDITIONAL DATA NEEDED

To describe accurately the situation regarding ground- and (or) surface-water contamination as a result of the operation of the Tacoma landfill and to determine the type(s) of environmental damage that has occurred or may occur as a result of disposal of wastes at the site will require additional data (and appropriate interpretation of the data). Data collection activities should include:

1) Drill test wells.
Test wells should be drilled to help interpret the ground-water flow system and contaminant distribution. Exact locations of the test wells were not selected as part of this study. However, the following criteria are suggested:

a) As public health is of utmost concern, test wells should be placed to determine ground-water movement and contaminant concentrations near the north end of the landfill. Town of Fircrest wells are located in the southeast corner of section 11, within 0.2 mile of the landfill.

b) Test wells should be placed to determine the direction of ground-water movement on the east side of the landfill. City of Tacoma operates municipal supply wells in secs. 13 and 18, some less than 0.5 mile from the landfill.

c) Pollution of the ground and surface water that is going into Leach Creek (about 0.5 mile west of the landfill) is also of concern. Wells placed in the southwest corner of sec. 13 or southeast corner of sec. 14 would help determine contaminant distribution and the ground-water flow system in that area.

At each well site the makeup, thickness, and permeability of the materials present could be more fully evaluated regarding the transport of contaminants.

2) Measure ground-water levels in wells.
Water-level information for each aquifer is also necessary to understand the ground-water flow system of the area. To allow interpretation of the seasonal and man-induced water-level fluctuations that probably occur in this area, water levels should be measured in selected (existing) wells in the area over a period of about 1 year. Water levels in newly drilled wells should be monitored for at least 18 months after the well is completed.

3) Collect ground- and surface-water quality samples.
Test wells and surface water in the area should be sampled for a specific set of chemical constituents which are considered indicators of pollution in this particular case. The indicators include (but are not limited to):

Temperature
Specific conductance
pH
Calcium
Magnesium
Sodium
Potassium
Alkalinity

Chloride
Sulfate
Fluoride
Silica
Hardness
Dissolved solids
Ammonia
Total Kjeldahl nitrogen
Nitrate

1,1,2,2-Tetrachloroethane
Trans-dichloroethene
Tetrachloroethene
Trichloroethene
Fluoranthene
Dichloromethane (methylene chloride)
Tetrachloromethane
(carbon tetrachloride)
Trichloromethane (chloroform)
Phenanthrene
Phenol
Toluene (methyl benzene)

Aluminum
Arsenic
Cadmium
Chromium
Copper
Iron
Lead

Manganese
Mercury
Nickel
Silver
Zinc

Samples of ground and surface water should be taken at the same time and the samples should be analyzed for the same constituents. As the presence or absence of these (or other constituents) is determined, the list may be altered appropriately.

Control sites upgradient of the landfill must be established for both ground-water and surface-water quality. These sites would be sampled, at least initially, in the same manner as other sites.

SUMMARY

The Tacoma landfill has been used for the disposal of waste since about 1960. Disposal operations (fill, compact, and cover on a daily basis) are planned to continue at this site until at least 1990. The purpose of this investigation was to describe the hydrology and ground- and surface-water quality for the area surrounding the landfill based on existing data and to evaluate what additional data were necessary to further describe those subjects.

Data were collected from a variety of Federal, State, and local governmental agencies and consulting firms contracted by these agencies. The resulting accumulation of reports, maps, and letters is currently (1984) stored in the Tacoma offices of the U.S. Geological Survey, Water Resources Division. The data presented in this report which were obtained from a number of sources are believed to be generally reliable and the following conclusions may be drawn concerning hydrology of the landfill and surrounding areas:

1. Hazardous wastes are probably present in the landfill. These wastes may contaminate water infiltrating through the landfill (estimated to be 90,000 to 400,000 gallons per day).

2. Water infiltrating through the landfill probably moves downward through the underlying till and into the ground water. Leakage of wastes or leachate through manmade breaches in the till may also occur.

3. Surface water in the area may be contaminated by seepage through the disturbed till cover to nearby streams and flow into sanitary and storm sewers.

4. The Town of Fircrest operates six wells on a daily basis to supply domestic water for more than 5,000 people. Three of the Fircrest wells are only 0.2 mile from the west edge of the landfill and produce water from aquifers subject to possible contamination.

5. The City of Tacoma operates numerous public supply wells that provide as much as 40 percent of the water used during summer peak demand periods by more than 158,000 people. Some of these wells are only 0.5 mile from the east edge of the landfill and also produce water from aquifers subject to contamination.

6. An undetermined number of domestic water-supply wells are within 3 miles of the landfill and might be affected by ground-water contamination from the landfill.

7. Contamination of the surrounding environment as a result of wastes moving away from the landfill is possible but cannot be conclusively proven with available data. There is evidence of ground-water contamination in two unused wells on the west edge of the landfill. Evidence of surface-water contamination in ponds and seeps directly on the landfill also exists.

Thus, there is a limited amount of evidence indicating ground- and surface-water contamination, possibly as a result of the landfill, but the limited evidence may be the result of a scarcity of data as opposed to a lack of contamination. Further investigations are needed to characterize the contamination problem surrounding the Tacoma landfill.

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TABLE 1.--Records of selected wells

EXPLANATION

Local number: Numbered by township, range, section, and 40-acre subdivision, as described on page v.

Owner: Name of owner or tenant at time of inventory.

Date completed: Reported date.

Use of water: H, domestic supply; I, irrigation; P, public supply, U, unused; Z, other; as reported at time of inventory.

Altitude of land surface: Altitude of the land surface at the well, in feet, with reference to sea level.

Depth of well: As measured, in feet below land surface, by Geological Survey personnel or other agencies or as reported by well drillers or owners at time of inventory.

Finish: P, perforated; S, screened.

Water level: Measured water level of well, in feet below land surface.

Date water level measured: Month and (or) years of measurement, usually during well inventory.

Discharge: Pumping discharge of well, in gallons per minute, as generally reported by drillers; values are not necessarily the maximum obtainable from well.

Drawdown: Distance, in feet, that water level was lowered by pumping at stated discharge rate.

Specific capacity: Discharge divided by drawdown if both are reported.

Pumping period: Length of time the stated discharge was maintained, as reported by well driller or owners.

TABLE 1.--Records of selected wells--Continued

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	ALTITUDE OF LAND SURFACE (FEET)	DEPTH OF WELL (FEET)	CASING DIAM- ETER (INCHES)	FINISH	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED	DISCHARGE (GAL/MIN)	DRAW- DOWN (FEET)	SPECIFIC CAPACITY (GAL/MIN/ FT)	PUMPING PERIOD (HOURS)
20N/02E-09P01	WAER	--	H	260	40	4	--	23	02/25/1960	--	--	--	--
20N/02E-10C01	PENDER	--	H	330	175	4	--	87	12/03/1940	--	--	--	--
20N/02E-10D01	CRAFT	--	H	250	28	24	--	27.9	03/01/1960	--	--	--	--
20N/02E-10K01	HOLMAN	--	H	313	62	48	--	DRY	02/26/1960	--	--	--	--
20N/02E-11J06	FIRCREST #2	07/ /1941	P	290	169	10	P	63.00	07/ /1941	600	--	--	--
20N/02E-11J07	FIRCREST #3	1950	U	285	312	12	--	51.00	07/ /1950	150	--	--	--
20N/02E-11M01	FIRCREST GOLF C	1952	I	318	257	10	P	--	--	600	80	7.5	4.0
20N/02E-11R01	FIRCREST #4	07/ /1950	P	295	152	12	P	6.65	02/29/1960	500	--	--	--
20N/02E-11R02	FIRCREST #5	1958	P	285	136	10	P	55.00	05/07/1958	1250	--	--	--
20N/02E-11R03	HOLLY	--	H	275	87	6	P	48.28	05/16/1960	25	5	5.0	--
20N/02E-13A01	TACOMA LIGHT	06/18/1953	Z	246	211	24	S	38.60	06/18/1953	620	--	--	--
20N/02E-13A02	TACOMA LIGHT	06/ /1953	Z	244	85	24	S	--	--	2500	--	--	--
20N/02E-13D01	TACOMA	1963	U	315	153	6	P	84.00	05/08/1963	--	--	--	--
20N/02E-13E01	HOME BLDR ASSN	--	--	275	--	--	--	--	--	--	--	--	--
20N/02E-13H01	TACOMA #4A	1930	P	245	184	38	P	36.40	01/01/1972	1450	92	15.8	--
20N/02E-13J01	TACOMA #6A	1939	P	267	175	26	P	28.68	11/10/1960	3210	60	53.5	4.0
20N/02E-13J02	TACOMA #11A	1950	P	269	112	36	S	58.00	11/ /1960	9130	24	380.4	24.0
20N/02E-13R01	S TACOMA ICE CO	1929	Z	275	140	6	D	30.00	--	75	--	--	--
20N/02E-14A01	UNIV PLACE	1945	--	220	70	10	P	9.00	06/ /1945	--	--	--	--
20N/02E-14A02	UNIV PLACE	1945	--	220	75	10	P	17.20	02/25/1960	300	--	--	--
20N/02E-14A03	UNIV PLACE	1935	--	220	31	10	--	--	--	--	--	--	--
20N/02E-14A04	UNIV PLACE #11	10/05/1970	--	220	213	12	P	51.00	--	800	--	--	--
20N/02E-14F01	FIRCREST	07/ /1962	--	370	264	6	P	154.00	--	--	--	--	--
20N/02E-14F02	FIRCREST #6	07/ /1962	P	350	203	16	--	150.00	--	--	--	--	--
20N/02E-14F03	FIRCREST #7	05/14/1965	P	350	204	16	P	154.00	05/05/1965	825	--	--	--
20N/02E-14G01	CHRISTENSON	--	H	280	80	6	--	54.38	03/01/1960	--	--	--	--
20N/02E-14L01	FIRCREST #8	1969	P	295	141	20	S	81.00	02/ /1969	855	113	7.6	--
20N/02E-15A01	FICHTNER	--	H	365	78	48	--	72.47	05/22/1940	--	--	--	--
20N/02E-15C01	UNIV PLACE	1956	--	400	285	10	--	188.00	11/ /1956	900	38	23.7	--
20N/02E-15C02	LARSON	--	Z	400	252	6	--	190.59	04/12/1960	--	--	--	--
20N/02E-15L01	NELSON	1938	U	410	251	8	--	200.00	--	--	--	--	--
20N/02E-15L02	ERICKSON	1940	H	405	122	36	--	117.32	05/23/1940	--	--	--	--
20N/02E-15L03	LUNDELL	1958	H	405	245	8	--	204.00	02/25/1960	--	--	--	--
20N/02E-15M01	FORSYTHE	05/ /1935	H	410	435	36	--	299.50	05/29/1940	20	--	--	--
20N/02E-15N01	BOEDECKER	1935	--	415	145	--	--	--	--	--	--	--	--
20N/02E-16A01	UNIV PLACE #6	04/ /1951	P	171	171	8	P	96.50	02/26/1960	440	--	--	--
20N/02E-16A02	UNIV PLACE #7	05/ /1948	P	310	176	8	--	94.00	--	385	28	14.0	--
20N/02E-16G01	UNIV PL SCHOOL	1955	--	250	138	10	P	45.00	12/ /1955	200	75	2.7	--
20N/02E-16L01	CURRAN	1954	H	230	62	8	--	32.00	06/ /1954	12	14	0.9	--
20N/02E-16P01	UNIV PLACE #10	02/10/1967	P	300	342	16	P	234.00	--	1319	--	--	--

TABLE 1.--Records of selected wells--Continued

LOCAL NUMBER	OWNER	DATE COMPLETED	USE OF WATER	ALTITUDE OF LAND SURFACE (FEET)	DEPTH OF WELL (FEET)	CASING DIAM-ETER (INCHES)	FINISH	WATER LEVEL (FEET)	DATE WATER LEVEL MEASURED	DISCHARGE (GAL/MIN)	DRAW-DOWN (FEET)	SPECIFIC CAPACITY (GAL/MIN/FT)	PUMPING PERIOD (HOURS)
20N/02E-22C01	DRUM	--	H	395	260	6	--	193	06/10/1947	--	--	--	--
20N/02E-22G01	MILLER	--	H	356	177	6	--	165	--	--	--	--	--
20N/02E-22K01	THOMPSON	--	H	385	177	6	--	163.4	02/24/1960	--	--	--	--
20N/02E-22N01	WRIGHT ACADEMY	1957	--	230	174	--	--	132.40	02/29/1960	15	--	--	--
20N/02E-22N02	WRIGHT ACADEMY	1960	--	230	379	10	S	155.50	05/31/1961	--	--	--	--
20N/02E-22N03	WRIGHT ACADEMY	--	--	230	150	--	--	--	--	--	--	--	--
20N/02E-23B01	LEVESQUE	02/16/1976	H	--	97	6	S	4.62+	02/16/1976	20	20	1.0	1.0
20N/02E-23E01	UNIV PLACE #12	04/21/1973	--	305	296	--	P	173.00	04/21/1973	1000	--	--	--
20N/02E-23H01	CUTT	--	H	275	51	6	--	49.37	03/03/1960	--	--	--	--
20N/02E-23J01	COREY	--	H	310	138	--	--	103.6	03/10/1960	30	1	30.0	--
20N/02E-23K01	HARTTS	--	H	195	54	8	--	5	10/13/1954	--	--	--	--
20N/02E-23Q01	WALDER	--	H	255	70	48	--	67.44	05/17/1940	--	--	--	--
20N/02E-23Q02	KONSCHUH	--	H	290	101	6	--	86.73	03/01/1960	--	--	--	--
20N/02E-24A01	N PACIFIC RR	--	--	252	41	360	--	20.70	--	--	--	--	--
20N/02E-24A02	N PACIFIC RR	1928	--	252	196	18	P	32.00	--	1200	--	--	--
20N/02E-24F01	SIMS	--	H	295	67	48	--	62.59	05/17/1940	--	--	--	--
20N/02E-24F02	SIMS	--	H	295	124	6	--	7.2	03/02/1960	--	--	--	--
20N/03E-07Q01	TACOMA CBW-10	1983	--	320	--	--	--	--	--	--	--	--	--
20N/03E-18C01	TACOMA	1952	U	310	185	12	P	94.00	05/ /1953	--	--	--	--
20N/03E-18C02	TACOMA #12A	03/ /1957	P	309	167	30	P	88.20	11/10/1960	4920	--	--	--
20N/03E-18D01	TACOMA #2A	1930	P	243	172	38	--	39.20	11/10/1960	--	--	--	--
20N/03E-18D02	TACOMA #2B	1948	P	245	78	30	S	10.65	04/ /1949	3600	--	--	--
20N/03E-18D03	TACOMA #9A	1949	P	294	113	30	S	60.59	11/10/1960	5500	--	--	--
20N/03E-18F02	38T ST GOLF	12/30/1959	H	300	117	8	--	77.00	01/05/1960	50	--	--	--
20N/03E-19F01	TACOMA #5A	--	P	266	378	--	--	--	--	--	--	--	--
20N/03E-19F02	TACOMA #5	--	--	--	310	--	--	--	--	--	--	--	--
20N/03E-19P01	TACOMA #1A	1929	P	260	305	24	P	27.00	06/16/1930	3075	--	--	--

TABLE 2.--Ground-water quality at selected sites - physical characteristics and major dissolved constituents

Local identifier	Owner	Date	Specific conductance (umhos)	pH (units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Calcium (mg/L as Ca)	Magnesium (mg/L as Mg)	Sodium (mg/L as Na)	Potassium (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate (mg/L as SO_4)	Chloride (mg/L as Cl)	Fluoride (mg/L as F)	Silica (mg/L as SiO_2)	Dissolved solids (mg/L)
20/2-11J6	Fircrest #2	79-06	253	--	--	81	--	--	--	--	--	--	--	--	--	--
		80-12-08	--	--	--	--	--	--	--	--	--	--	5	--	--	--
		81-01-05	--	--	--	--	--	--	--	--	--	--	< 10	--	--	--
		81-07-21	--	--	--	--	--	--	--	--	--	--	8	--	--	--
		81-09[1]	210	--	--	115	--	--	9	--	--	--	--	0.8	--	--
		84-01-19	221	6.65	--	92	--	--	8.65	--	78	--	--	--	--	--
20/2-11M1	Fircrest Golf Course	70-12-14	159	7.2	6.7	59	12	7.1	7.4	2.2	59	10	3.0	.9	34	112
		71-06-25	147	7.1	--	55	12	6.0	--	--	59	--	4.0	--	--	--
20/2-11R1	Fircrest #4	79-06	301	--	--	71	--	--	--	--	--	--	--	--	--	--
		81-09[1]	210	--	--	115	--	--	9	--	--	--	--	.8	--	--
		84-01-19	218	6.50	--	89	--	--	8.78	--	81	--	--	--	--	--
20/2-11R2	Fircrest #5	79-06	223	--	--	67	--	--	--	--	--	--	--	--	--	--
		81-09[1]	210	--	--	115	--	--	9	--	--	--	--	.8	--	--
		84-01-19	201	6.40	--	100	--	--	8.71	--	70	--	--	--	--	--
20/02-13D1		83-02-02	1,099	6.4	--	431	--	--	--	--	--	4.7	--	--	--	644
20/2-13H1	Tacoma #4A	83-12-01	281.0	--	--	118.0	18.2	14.1	11.0	--	71.5	24.0	14.0	.1	35.6	250
20/2-13J1	Tacoma #6A	52-11-04	--	7.50	--	63	9.9	16	9.4	--	46	0	6	.2	22	105
		81-10-13	199	6.95	--	98	23	14	11	--	55	20	--	.2	23	158
20/2-13J2	Tacoma #11A	60-03-22	212	7.2	13.5	82	16	10	8	1.7	66	18	7	.1	28	147
		60-10-25	212	7.1	12.0	86	16	11	7.1	1.7	64	17	9	.1	28	138
		74-08-23	297	7.0	11.2	110	22	14	12	2.3	78	20	25	< .1	--	172
		74-11-21	285	6.9	10.2	110	22	14	12	2.5	78	19	20	< .1	--	173
		75-02-13	288	7.0	11.0	110	20	14	12	2.4	78	20	23	< .1	--	179
		75-05-29	305	6.8	10.8	120	22	15	13	2.4	80	23	28	.1		187
		80-04-30	200	--	--	128	11.5	45.8	.01	--	85	16.5	33	.18	35	112
		80-12-29	--	--	--	--	--	--	--	--	--	--	10	--	--	--
		81-01-26	--	--	--	--	--	--	--	--	--	--	20	--	--	--
		81-02-04	240	--	--	100	--	--	--	--	--	--	15	--	--	--
		81-07-07	--	--	--	--	--	--	--	--	--	--	100	--	--	--
		83-01-12	224.0	--	--	96.2	14.7	10.85	8.0	--	70.0	23	5.1	< .1	28.7	138
20/2-14F3	Fircrest #7	79-06	201	--	--	68	--	--	--	--	--	--	--	--	--	--
		81-01-05	--	--	--	--	--	--	--	--	--	--	<10	--	--	--
		81-09[1]	191	--	--	98	--	--	8	--	--	--	--	.1	--	--
		84-01-19	212	6.7	--	108	--	--	15.5	--	73	--	--	--	--	--
		84-02-09	220	6.3	12.2	--	--	--	--	--	--	--	7.0	--	--	152
20/2-14L1	Fircrest #8	79-06	329	--	--	94	--	--	--	--	--	--	--	--	--	--
		80-12-08	--	--	--	--	--	--	--	--	--	--	5	--	--	--
		81-01-05	--	--	--	--	--	--	--	--	--	--	<10	--	--	--
		81-09	260	--	--	133	--	--	10		--	--	--	--	--	--
		84-01-19	261	6.75	--	88	--	--	10.0	--	96	--	--	--	--	--

TABLE 2.--Ground-water quality at selected sites - physical characteristics and major dissolved constituents--Continued

Local identifier	Owner	Date	Specific conductance (umhos)	pH (units)	Temperature (°C)	Hardness (mg/L as $CaCO_3$)	Calcium (mg/L as Ca)	Magnesium (mg/L as Mg)	Sodium (mg/L as Na)	Potassium (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate (mg/L as SO_4)	Chloride (mg/L as Cl)	Fluoride (mg/L as F)	Silica (mg/L as SiO_2)	Dissolved solids (mg/L)
20/2-15C1	U.P.	60-06-21	122	7.00	13.5	49	8.0	7.1	5.0	1.2	45	8.0	3.0	.1	32	90
20/2-16P1	U.P. #10	83-12-01	44.2	--	--	17.8	6.3	1.1	2.0	--	15.7	9.0	1.7	<.1	13.9	40
		84-02-07	55	6.0	8.9	--	--	--	--	--	--	--	3.0	--	--	45
20/2-22N3	Charles Wright Academy	74-08-29	144	7.4	10.4	56	7.3	9.1	5.6	2.2	52	12	3.0	.1	--	98
		74-11-22	141	7.4	10.8	54	7.7	8.4	6.8	2.0	52	12	3.0	.1	--	102
		75-02-14	140	7.1	11.5	61	10	8.8	5.4	1.9	53	12	3.0	.1	--	101
		75-05-28	135	7.1	10.9	53	7.6	8.2	6.5	2.0	53	13	3.0	.1	--	105
		80-12-22	--	--	--	--	--	--	--	--	--	--	5.0	--	--	--
		81-01-20	--	--	--	--	--	--	--	--	--	--	10.0	--	--	--
20/2-23B1	Levesque	80-12-16	140	--	--	50	--	--	--	--	--	--	< 5.0	--	--	--
		81-07-21	--	--	--	--	--	--	--	--	--	--	5.0	--	--	--
20/2-24A2	N.Pac. R.R.	46-00-00	--	7.2	--	43	9.0	4.0	--	--	52	0	10	--	22	70
20/3-18C2	Tacoma #12A	80-12-15	--	--	--	--	--	--	--	--	--	--	30	--	--	--
		81-01-12	--	--	--	--	--	--	--	--	--	--	30	--	--	--
		81-02-04	320	--	--	140	--	--	--	--	--	--	20	--	--	--
		81-07-07	--	--	--	--	--	--	--	--	--	--	17	--	--	--
20/3-18D1	Tacoma #2A	81-09-15	225	7.1	--	93	16.9	11.7	23.2	--	38	38	12.4	.1	35	191
20/3-18D2	Tacoma #2B	82-07-02	825	7.0	--	204	33.1	31.2	82.8	--	85	24	204	<.09	28.4	707
20/3-18D3	Tacoma #9A	52-04-21	131	7.3	10.0	55	8.8	8.0	5.5	1.2	44	11	5	.1	31	100
		61-12-06	223	6.9	11.0	76	12.0	11.0	--	--	61	--	--	--	--	--
		80-12-15	--	--	--	--	--	--	--	--	--	--	90	--	--	--
		81-01-12	--	--	--	--	--	--	--	--	--	--	75	--	--	--
		81-02-04	380	--	--	150	--	--	--	--	--	--	40	--	--	--
		82-07-02	350	7.0	--	132	11.6	25.5	26.3	--	96	25	54	< .09	28.4	321
		84-02-07	310	6.3	11.7	--	--	--	--	--	--	--	21	--	--	190
20/3-19F1	Tacoma #5A	39-01-04	--	7.1	--	55	11.0	6.7	4.9	1.4	48	7	4	.3	28	94
		80-12-15	--	--	--	--	--	--	--	--	--	--	10	--	--	--
		81-01-12	--	--	--	--	--	--	--	--	--	--	<10	--	--	--
		83-12-01	206.0	--	--	93.0	15.7	9.8	9.0	--	71.4	22.0	4.8	<.1	29.6	166
		84-02-07	220	6.3	11.7	--	--	--	--	--	--	--	8	--	--	160
20/3-19P1	Tacoma #1A	31-10-27	--	--	--	38	7.9	4.4	4.1	1.4	31	5	4	--	25.0	76
		39-01-04	--	--	9.0	34	7.2	4.0	3.4	1.2	29	4	3	.00	24.0	70
		80-12-15	--	--	--	--	--	--	--	--	--	--	10	--	--	--
		81-01-12	--	--	--	--	--	--	--	--	--	--	< 10	--	--	--
		81-07-07	--	--	--	--	--	--	--	--	--	--	8	--	--	--
		81-09-15	176	7.2	--	90	15	10.8	10	--	51	23	7.2	.2	30	169

[1] Analysis represents composite sample from one or more wells

TABLE 3.--Ground-water quality at selected sites - nutrients and metals

Local identifier	Date 12/12/12	Nitrate (mg/L as N)	Ammonia (mg/L as N)	T-KjN (mg/L as N)	Aluminum (ug/L as Al)	Arsenic (ug/L as As)	Cadmium (ug/L as Cd)	Chromium (ug/L as Cr)	Copper (ug/L as Cu)	Iron (ug/L as Fe)	Lead (ug/L as Pb)	Manganese (ug/L as Mn)	Mercury (ug/L as Hg)	Nickel (ug/L as Ni)	Zinc (ug/L as Zn)
20/2-11J6	79-06	--	--	--	--	--	--	--	--	50	--	--	--	--	--
	80-12-08	2.2	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-01-05	2.2	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-07-21	1.6	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-09[1]	.8	--	--	--	0.4	1	7	--	10	0.2	0.8	0.2	--	--
	83-01-13	--	--	--	--	--	--	--	--	--	--	--	--	--	72
	84-01-19	--	--	--	--	--	--	--	90	50	--	--	--	--	--
20/2-11M1	70-12-14	.47	--	--	910	--	--	<30	<50	930	<100	100	--	--	<10
	83-01-13	--	--	--	4,600	--	--	11	--	3,330	--	263	--	--	14
20/2-11R1	79-06	--	--	--	--	--	--	--	--	10	--	--	--	--	--
	81-09[1]	.8	--	--	--	.4	1	7	--	10	.2	.8	.2	--	--
	84-01-19	--	--	--	--	--	--	--	30	10	--	--	--	--	--
20/2-11R2	79-06	--	--	--	--	--	--	--	--	10	--	--	--	--	--
	81-09[1]	.8	--	--	--	.4	1	7	--	10	.2	.8	.2	--	--
	84-01-19	--	--	--	--	--	--	--	20	20	--	--	--	--	--
20/2-11R3	83-01-13	--	--	--	--	--	--	--	--	118	--	--	--	--	155
20/2-13D1	83-02-02	--	--	--	--	--	--	.7	1.3	67,500	.9	2,700	.18	37	8
20/2-13E1	69-00	--	--	--	--	--	--	--	--	4,000	--	--	--	--	--
20/2-13H1	83-12-01	1.2	< 0.1	--	--	<10	<2	<10	--	440	<10	121	<1	--	--
20/2-13J1	52-11-04	1.0	--	--	--	--	--	--	--	50	--	--	--	--	--
	81-10-13	3.0	< .002	--	--	10	2	10	--	30	10	13	.8	--	--
	83-06-07	--	--	--	--	< 5	< 2	<1	8	--	< 5	--	< .1	< 2	42
20/2-13J2	60-03-22	2.3	--	--	--	--	--	--	--	<10	--	--	--	--	--
	60-10-25	2.1	--	--	--	--	--	--	--	40	--	--	--	--	--
	74-08-23	2.4	.01	--	--	<1	< 2	ND	< 2	50	13	<10	<.5	--	20
	74-11-21	2.5	.02	0.12	--	4	< 2	< 20	2	<10	2	<10	<.1	--	< 20
	75-02-13	2.3	.04	.15	--	1	ND	ND	ND	<10	2	<10	<.5	--	30
	75-05-29	2.0	.03	.08	--	1	< 2	< 20	2	<10	ND	<10	< .5	--	ND
	80-04-30	1.9	<.01	--	--	23	2	3	--	10	11	<10	.9	--	--
	80-12-29	4.0	--	--	--	--	--	--	--	--	--	--	--	--	--
	80-01-26	2.4	--	--	--	--	--	--	--	--	--	--	--	--	--
	80-02-04	2.4	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-07-07	1.8	--	--	--	--	--	--	--	--	--	--	--	--	--
	83-01-12	2.8	<.1	--	--	<10	<2	<10	--	<10	<10	<8	<1	--	--
20/2-14F3	79-06	--	--	--	--	--	--	--	--	10	--	--	--	--	--
	81-01-05	2.9	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-09[1]	.9	--	--	--	.7	1	.3	--	50	1	8	.2	--	--
	84-01-19	--	--	--	--	--	--	--	20	20	--	--	--	--	--
	84-02-09	3.1	--	--	--	--	--	--	--	--	--	--	--	--	--
20/2-14L1	79-06	--	--	--	--	--	--	--	--	30	--	--	--	--	--
	80-12-08	1.9	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-01-05	1.8	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-09	1.0	--	--	--	1	1	1	--	10	5	3	.2	--	--
	83-01-13	--	--	--	--	--	--	--	--	51	--	--	--	--	22
	84-01-19	--	--	--	--	--	--	--	20	10	--	--	--	--	--
20/2-15C1	60-06-21	2.1	--	--	--	--	--	--	--	100	--	--	--	--	--
20/2-16P1	83-12-01	<.1	<.1	--	--	<10	< 2	<10	--	30	<10	< 8	<1	--	--
	84-02-07	.42	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 3.--Ground-water quality at selected sites - nutrients and metals--Continued

Local identifier	Date 12/12/12	Nitrate (mg/L as N)	Ammonia (mg/L as N)	T-KjN (mg/L as N)	Alum-inum (ug/L as Al)	Arsen-ic (ug/L as As)	Cad-mium (ug/L as Cd)	Chro-mium (ug/L as Cr)	Cop-per (ug/L as Cu)	Iron (ug/L as Fe)	Lead (ug/L as Pb)	Man-ganese (ug/L as Mn)	Mer-cury (ug/L as Hg)	Nickel (ug/L as Ni)	Zinc (ug/L as Zn)
20/2-22N3	74-08-29	0.14	0.02	--	--	1	< 2	ND	4	40	2	90	<0.5	--	80
	74-11-22	.00	.03	0.04	--	6	< 2	<20	2	70	3	60	< .1	--	60
	75-02-14	.04	.05	.29	--	2	ND	ND	ND	40	ND	70	< .5	--	120
	75-05-28	.03	.02	.06	--	3	< 2	ND	ND	60	ND	80	< .5	--	100
	80-12-22	.30	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-01-20	.20	--	--	--	--	--	--	--	--	--	--	--	--	--
20/2-23B1	80-12-16	< .20	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-07-21	< .20	--	--	--	--	--	--	--	--	--	--	--	--	--
	83-01-13	--	--	--	--	14	--	--	--	415	--	242	--	--	285
20/2-24A2	46-00	--	--	--	--	--	--	--	--	2,000	--	--	--	--	--
20/3-18C2	80-12-15	1.5	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-01-12	1.8	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-02-04	1.6	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-07-07	1.7	--	--	--	--	--	--	--	--	--	--	--	--	--
20/3-18D1	81-09-15	3.25	<.002	--	--	3	.4	1	--	--	1	17	.6	--	--
20/3-18D2	82-07-02	2.9	.0012	--	--	1	0	1	--	43	5	2	1.2	--	--
20/3-18D3	52-04-21	1.0	--	--	--	--	--	--	--	--	--	--	--	--	--
	80-12-15	1.5	--	--	--	--	--	--	--	110	--	--	--	--	--
	81-01-12	2.6	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-02-04	2.5	--	--	--	--	--	--	--	--	--	--	--	--	--
	82-07-02	3.7	.001	--	--	3	.1	2	--	33	5	0	1.2	--	--
	84-02-07	2.5	--	--	--	--	--	--	--	--	--	--	--	--	--
20/3-19F1	39-01-04	1.1	--	--	--	--	--	--	--	40	--	--	--	--	--
	80-12-15	2.1	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-01-12	3.0	--	--	--	--	--	--	--	--	--	--	--	--	--
	83-12-01	2.4	<.1	--	--	<10	< 2	<10	--	<10	<10	<8	<1	--	--
	84-02-07	3.3	--	--	--	--	--	--	--	--	--	--	--	--	--
20/3-19P1	31-10-27	1.2	--	--	--	--	--	--	--	290	--	--	--	--	--
	39-01-04	1.3	--	--	--	--	--	--	--	40	--	--	--	--	--
	80-12-15	3.3	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-01-12	3.8	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-07-07	3.8	--	--	--	--	--	--	--	--	--	--	--	--	--
	81-09-15	2.7	<.002	--	--	10	2	10	--	30	10	10	1.7	--	--

[1] Analysis represents composite sample from one or more wells

TABLE 4.--Ground-water quality at selected sites - organic compounds

Local identifier	Date	1,1,2,2 tetra-chloro-ethane (ug/L)	Trans-dichloro-ethene (ug/L)	Tetra-chloro-ethene (ug/L)	Tri-chloro-ethene (ug/L)	Fluor-anthene (ug/L)	Dichloro-methane (ug/L)	Tetra-chloro-methane (ug/L)	Tri-chloro-methane (ug/L)	Phenan-threne (ug/L)	Phen-ols (ug/L)	Tolu-ene (ug/L)
20/2-13D1	83-02-02	--	2	--	2	--	--	--	--	--	--	2
20/2-13H1	83-05-23-	0.5-	<.1-	<0.1-	0.5-	--	--	--	trace	--	--	--
	83-06-15	<1	<1	<1	<1	--	--	--	0.5	--	--	--
20/2-13J1	83-05-12-	.5-	.1-	<.1-	1.7-	--	--	--	.2-	--	--	--
	83-06-15	<1	<.8	<1	4.8	--	--	--	.68	--	--	--
	83-06-07	[1]ND	ND	ND	trace	ND	14	ND	ND	ND	14	ND
20/2-13J2	74-08-23	--	--	--	--	--	--	--	--	--	1	--
	74-11-21	--	--	--	--	--	--	--	--	--	0	--
	75-02-13	--	--	--	--	--	--	--	--	--	0	--
	75-05-29	--	--	--	--	--	--	--	--	--	0	--
	83-03-14-	.5-	<.1-	<.1-	.6-	--	--	--	none-	--	--	--
	83-06-15	<1	<1	<1	3.6	--	--	--	.78	--	--	--
20/2-16A2	83-07-26	< 1	< 1	< 1	< 1	--	--	--	< 1	--	--	--
20/2-16P1	84-02-07	--	--	--	--	--	--	--	13	--	--	--
22/2-22N3	74-08-29	--	--	--	--	--	--	--	--	--	0	--
	74-11-22	--	--	--	--	--	--	--	--	--	0	--
	75-02-14	--	--	--	--	--	--	--	--	--	1	--
	75-05-28	--	--	--	--	--	--	--	--	--	4	--
20/3-7Q	83-05-12-	266.30-	160-	<1-	362.68-	--	--	--	ND-	--	--	--
	84-03-19	30,000	8,700	225.63	15,000	--	--	--	<50	--	--	--
20/3-18C2	81-07-24-	17 -	30 -	1.6-	54 -	--	--	--	--	--	--	--
	81-09-15	300	100	5.4	130	--	--	--	--	--	--	--
	82-08-06	ND-	ND-	--	ND-	--	4.9-	--	ND-	--	ND-	ND-
	82-11-30	9,900	1,000	--	2,500	--	1,400	--	<10	--	2.7	1.3
	83-04-25-	.4-	.63-	<.1-	.33-	--	--	--	ND-	--	--	--
	84-03-19	61.0	30	1.6	79.0	--	--	--	<1	--	--	--
20/3-18D1	83-04-25-	<.1	<.1-	<.1-	.3-	--	--	--	.1-	--	--	--
	83-10-24	13	4.1	13	2.6	--	--	--	.82	--	--	--
20/3-18D2	83-05-09-	.3-	<.1-	<.1-	.4-	--	--	--	.24-	--	--	--
	83-10-24	18	3.9	5.2	23	--	--	--	2.5	--	--	--
20/3-18D3	83-05-17-	.88-	ND-	<.1-	1.6-	--	--	--	<.1-	--	--	--
	84-03-19	28	25	25	19	--	--	--	<1.0	--	--	--
	84-02-07	--	--	--	4.0	--	--	--	--	--	--	--
20/3-19F1	83-04-11-	.5-	<.1-	.2-	<.1-	--	--	--	.2-	--	--	--
	83-06-14	<1	<1	<1	<1	--	--	--	1.1	--	--	--
20/3-19P1	83-03-29-	.5-	<.1-	<.1-	<.1-	--	--	--	.3-	--	--	--
	83-06-14	<1	< 1	< 1	23	--	--	--	1.1	--	--	--

[1] None detected

TABLE 5.--Records of selected springs in the study area

Local number	Owner	Altitude (feet)	Estimated yield (gal/min)
20N/2E-11K1s	Town of Fircrest	226	450
-11K2s	---do-----------	222	900
-14A1s	University Place	197	2,000
-23P1s	Unknown (Keystone Spring)	165	3,500

TABLE 6.--Description of surface-water data collection sites (from EPA, written commun., May 6, 1983, and September 2, 1983)

Sanitary sewer (upstream and downstream). "Sewage from the sanitary trunk sewer which crosses the landfill was sampled both upstream of the landfill and downstream."

West seep. "A leachate collection system is buried at the toe of the refuse fill just west of the recycle building. It discharges into a nearby sanitary sewer manhole."

South seep. "A heavy flow of leachate or runoff discharged into the same sanitary sewer manhole as for..." the south seep. "The source is a catch basin south of the manhole. This stream is probably overflow from a perennial pond near the site of current refuse fill operations."

Pond sediment. "A sediment sample from a ponded area in the landfill which reportedly is the source of the leachate sampled as..." the south seep.

Drained pond sediment. "A sediment sample from a large pond in the landfill that had been recently drained. This is a perennial pond that overflows into a basin sampled as..." pond sediment.

Storm sewer. "A water sample taken at the storm sewer outlet to the west of the landfill. This storm sewer drains much of the landfill and discharges into Leach Creek" through two 48-inch culverts."

Storm sewer sediment. "A sediment sample taken at the same location as..." the storm sewer sample.

Leach Creek. "A water sample collected from Leach Creek approximately 1/2 mile downstream from the point where surface water drains from the landfill into the creek..." (the storm sewer). "This is also the point at which Leach Creek begins to flow through a residential area."

Leach Creek sediment. "A sediment sample taken at the same location as..." the Leach Creek water sample.

TABLE 7.--Surface-water (including sediments) quality at selected sites--metals

Site[1]	Date	Aluminum (ug/L as Al)	Arsenic (ug/L as As)	Cadmium (ug/L as Cd)	Chromium (ug/L as Cr)	Copper (ug/L as Cu)	Iron (ug/L as Fe)	Lead (ug/L as Pb)	Manganese (ug/L as Mn)	Mercury (ug/L as Hg)	Nickel (ug/L as Ni)	Zinc (ug/L as Zn)
Sanitary sewer(upstream)	83-01-12	523	--	--	--	79	913	10	83	--	--	150
Sanitary sewer (downstream)	83-01-12	684	10	--	15	70	2,630	9	351	0.5	--	415
West seep	83-01-12	973	--	--	19	--	10,600	24	793	--	--	145
South seep	83-01-13	4,680	220	--	111	--	66,300	19	9,210	.2	194	9,810
	83-04-26	--	4.7	0.4	--	14	2,300	2.2	--	--	34	16
Pond sediment[2]	83-04-26	--	10,900	1,500	37,000	38,000	--	22,000	--	40	50,000	658,000
Drained pond sediment[2]	83-04-26	--	6,000	500	45,000	43,000	--	20,000	--	30	60,000	214,000
Storm sewer	83-04-26	--	3.6	.4	--	19	64	1.5	--	--	27	27
Storm sewer sediment[2]	83-04-26	--	7,000	500	22,000	51,000	--	240,000	--	30	39,000	129,000
Leach Creek	83-04-26	--	3.5	.2	--	8	146	--	--	--	35	5
Leach Creek sediment[2]	83-04-26	--	32,000	3,100	47,000	140,000	--	508,000	--	2,400	26,000	508,000

[1]For site description, see table 7.
[2]Sediment concentrations are in ug/Kg (micrograms per kilogram)

TABLE 8.--Surface-water (including sediments) quality at selected sites--organic compounds

Site[1]	Date	Trans-dichloroethene (ug/L)	Tetrachloroethene (ug/L)	Trichloroethene (ug/L)	Fluoranthene (ug/L)	Dichloromethane (ug/L)	Trichloromethane (ug/L)	Phenanthrene (ug/L)	Phenols (ug/L)	Pyrene (ug/L)	TCDD dioxin (ug/L)	Toluene (ug/L)
Sanitary sewer(upstream)	83-01-12	--	5	--	--	--	5	--	--	--	--	--
Sanitary sewer (downstream)	83-01-12	5	--	--	--	6	--	--	--	--	--	12
South seep	83-01-13	10	--	5	--	140	--	--	2,200	--	--	62
	83-04-26	--	--	--	0.03	--	2.7	--	--	0.03	[2]ND	--
Pond sediment[3]	83-04-26	--	--		45	--	--	120	--	75	ND	21
Drained pond sediment[3]	83-04-26	--	--	--	6.2	6.4	--	30	74	14	ND	130
Storm sewer	83-04-26	--	--	--	--	--	--	--	--	--	ND	--
Storm sewer sediment[3]	83-04-26	--	2	--	120	--	2	150	--	94	ND	2
Leach Creek	83-04-26	2	--	--	.03	--	--	--	--	.03	ND	--
Leach Creek sediment[3]	83-04-26	--	4	--	2,500	--	4	1800	--	3100	ND	4

[1]For site description, see table 7.
[2]None detected.
[3]Sediment concentrations are in ug/Kg (micrograms per kilogram).