United States

Department of the Interior

Geological Survey

EFFECTS OF SELECTED SOURCES OF CONTAMINATION ON GROUND-WATER QUALITY AT SEVEN SITES IN CONNECTICUT

by Elinor H. Handman and James W. Bingham

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations

Open-File Report 79-1596

Prepared in cooperation with

the Connecticut Department of

Environmental Protection

Hartford, Connecticut
1980

UNITED STATES DEPARTMENT OF THE INTERIOR

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GLOSSARY

Adsorption: The adhesion of an extremely thin layer of molecules (as of gases, solutes, or liquids), to surfaces of solids or liquids.

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

Anaerobic: Living or active in the absence of free oxygen.

Aquifer: A geologic formation or unit that can yield usable quantities of water. In this report, the term refers to stratified-drift deposits known or inferred to be capable of yielding moderate to very large amounts of water to individual wells.

Bedrock: Solid rock, commonly called "ledge", that forms the Earth's crust. It is locally exposed at the land surface in Connecticut but is more commonly buried beneath a few inches to more than 300 feet of unconsolidated materials.

Coliform bacteria, total: A particular group of bacteria that are used as indicators of possible sewage pollution. They are characterized as aerobic or facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at $35^{\circ}C$. In the laboratory, these bacteria are defined as the organisms which produce colonies within 24 hours when incubated at $35^{\circ}C \pm 1.0^{\circ}C$ on M-Endo medium (nutrient medium for bacterial growth). Their concentrations are expressed as numbers of colonies per 100 mL of sample.

Cyanide: In waters, refers to all of the CN groups in the cyanide compounds present that can be determined as the cyanide ion, CN-, by the methods used. A toxic compound present in industrial wastes from metal plating operations and chemical industries.

Degradation of water quality: Adverse change in the quality of water.

Dissolved solids: The residue from a clear sample of water after evaporation and drying for one hour at $180^{\circ}C$; consist primarily of dissolved mineral constituents, but may also contain organic matter and water of crystallization.

Evapotranspiration: Loss of water to the atmosphere by direct evaporation from water surfaces and moist soil combined with transpiration from living plants.

Fly ash: Fine particles of noncombustible ash carried out of a bed of solid fuel by the draft; an unburned byproduct of burning coal.

Ground water: Water in the saturated zone.

Ground-water discharge: The discharge of water from the saturated zone by (1) natural processes such as ground-water runoff and ground-water evapotranspiration and (2) artificial discharge through wells and other manmade structures.

Ground-water recharge: The addition of water to the saturated zone by (1) natural processes, such as infiltration of precipitation and (2) artificial recharge through basins, sumps, and other manmade structures.

Hardness, of water: The physical-chemical characteristic of water that is commonly recognized by the increase of quantity of soap required to produce lather. It is attributable to the presence of alkaline earths (principally calcium and magnesium) and is expressed as equivalent calcium carbonate ($CaCO_3$).

Head, static: The height of the surface of a water column above a standard datum that can be supported by the static pressure at a given point.

Hydraulic conductivity (K): A measure of the ability of a porous medium to transmit a fluid. The material has a hydraulic conductivity of unit length per unit time if it will transmit in unit time a unit volume of water at the prevailing kinematic viscosity through a cross section of unit area, measured at right angles to the direction of flow, under a hydraulic gradient of unit change in head over unit length of flow path.

Hydraulic gradient: The change in static head per unit of distance in a given direction. If not specified, the direction is generally understood to be that of the maximum rate of decrease in head.

Inches of water: Water volume expressed as the depth, in inches, to which it would accumulate if spread evenly over a particular area.

Infiltration: Passage of a gas or liquid into or through soil or rock by penetrating pores or small openings.

Leachate: Liquid produced by water percolating through porous or soluble material, such as refuse in a landfill; can contain dissolved and suspended solids.

Methylene blue active substance (MBAS): A measure of apparent detergents, as indicated by the formation of a blue color when methylene blue dye reacts with synthetic detergent compounds.

Micrograms per liter (ug/L): A unit for expressing the concentration of chemical constituents in solution by weight per unit volume of water. One thousand micrograms is equivalent to 1 milligram.

Milligrams per liter (mg/L): A unit for expressing the concentration of chemical constituents in solution by weight per unit volume of water.

Nonpoint source: A source of contamination that does not emanate from a discernible, confined and discrete conveyance, such as a pipe, ditch, or channel.

Nutrients: Compounds of nitrogen, phosphorous, and other elements essential for plant growth.

Organochlorine insecticides: Widely used synthetic organic compounds; toxic; persistent in the environment. Include aldrin, chlordane, DDT, lindane, toxaphene, and others.

pH: The negative logarithm of the hydrogen-ion concentration. A pH of 7.0 indicates neutrality; vlaues below 7.0 denote acidity, those above 7.0 denote alkalinity.

Phenols: A class of aromatic organic compounds in which one or more hydroxyl groups are attached directly to the benzene ring. Commonly a toxic organic compound obtained from coal tar or derivative of benzene.

Point source: Any discernible, confined and discrete conveyance, such as a pipe, ditch, or channel, from which pollutants are or may be discharged (Public Law 92-500, Section 502).

Polychlorinated biphenyls (PCB): Industrial chemicals that are mixtures of chlorinated biphenyl compounds having various percentages of chlorine. They are similar in structure to organochlorine insecticides.

Precipitation: The discharge of water from the atmosphere, in either a liquid or solid state.

Salt water: Water containing about 35,000 mg/L of dissolved solids, including about 19,000 mg/L of chloride (Cl).

Salt-water intrusion: The movement of salt water or brackish water into a nearby aquifer, resulting from the pumping of fresh water near the sea.

Sanitary landfill: Method of solid-waste disposal in which refuse is deposited, compacted, and covered with at least 6 inches of soil daily.

Saturated zone: The subsurface zone in which all open spaces are filled with water under pressure greater than atmospheric.

Septage: Liquid and solid material (sludge) pumped from a septic tank or cesspool during cleaning (New England Interstate Water Pollution Control Commission, 1976, p. 2).

Septic tank: A water-tight receptacle used for the treatment of sewage and is designed and constructed so as to permit the settling of solids, the digestion of organic matter by detention, and the discharge of the liquid part to a leaching system.

Sewage: Human excretions, all liquid domestic wastes, and such liquid agricultural, commercial or manufacturing wastes as may tend to the detriment of the public health.

Solid waste; refuse: Garbage, rubbish, trash and other solid materials from domestic, commercial, and other sources. Commonly requires transport to a disposal site.

Specific conductance, of water: A measure of the ability of water to conduct an electric current, expressed in micromhos per centimeter at 25°C. It is related to the dissolved-solids content and serves as an approximate measure thereof.

Stratified drift: A sorted sediment laid down by or in meltwater from a glacier; includes sand, gravel, silt, and clay deposited in layers.

Till: A nonsorted, nonstratified sediment deposited directly by a glacier and composed of boulders, gravel, sand, silt, and clay mixed in various proportions.

Transpiration: The process whereby plants release water vapor to the atmosphere.

Unconsolidated: Loose, not firmly cemented or interlocked; for example, sand in contrast to sandstone.

Unsaturated zone: The subsurface zone above the water table.

Vulnerable coastal zone: The area along the coast and along estuaries that is susceptible to salt-water intrusion.

Water table: The surface in an unconfined water body at which the pressure is atmospheric. It is defined by the levels at which water stands in wells that penetrate the water body just far enough to hold standing water. In wells penetrating to greater depths, the water level will stand above or below the water table if an upward or downward component of ground-water flow exists.

Water year: A continuous 12-month period, October 1 through September 30, during which a complete streamflow cycle takes place from low to high flow and back to low flow. It is designated by the calendar year in which it ends, and that includes 9 of its 12 months.

FACTORS FOR CONVERTING U.S. CUSTOMARY UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

U.S. customary units	Multiplied by	Are converted to SI units
Length		
inch (in)	25.4	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi^2)	2.590	square kilometer (km^2)
Flow		
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
gallon per minute (gal/min)	.06309	liter per second (L/s)
million gallons per day (Mgal/d)	43.81	liter per second (L/s)
gallon per day per foot (gal/d/ft)	.00014	liter per second per meter (L/s/m)
Hydraulic Units		
transmissivity, foot squared per day (ft^2/d)	.0929	meter squared per day (m^2/d)
hydraulic conductivity, foot per day (ft/d)	.3048	meter per day (m/d)
foot per mile (ft/mi)	.1894	meter per kilometer (m/km)

EFFECTS OF SELECTED SOURCES OF CONTAMINATION ON GROUND-WATER QUALITY AT SEVEN SITES IN CONNECTICUT

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ABSTRACT

The introduction of contaminants has altered the quality of ground water at several places in Connecticut. This investigation of the hydrogeologic environment and the quality of water in stratified-drift aquifers underlying seven probable contaminant sources in Connecticut shows some effects at each site.

Water from test wells downgradient from septage-disposal facilities in Old Saybrook and Clinton contains elevated concentrations of sodium, chloride, manganese, iron, detergent (as MBAS), dissolved organic carbon, and some trace metals. The effects are most pronounced at shallow depths close to the septage lagoons, where concentrations of some constituents exceed Connecticut Department of Health drinking water standards.

Fly-ash disposal at Wallingford has contributed chromium, manganese, and dissolved organic carbon to water in the underlying aquifer, but the low hydraulic conductivity of the fine-grained surficial materials have kept effects to a minimum.

Road salt leached from a storage area in the Tylerville section of Haddam has increased the sodium and chloride concentrations in ground water to the extent that it is unsuitable for drinking water. The effect diminishes in wells 1000 feet downgradient from the storage site.

Water from some wells adjacent to landfills in Bristol and Southington has elevated sodium, chloride, manganese, and dissolved organic carbon concentrations, and samples from two wells near industrial-sludge disposal pits in the Bristol landfill contain cyanide and phenols.

Gasoline odor is present in water samples from a test well 175 feet from a ruptured buried tank in Fairfield. The gasoline odor from this well was also detectable during well construction and sampling.

Table 1.--Maps produced by the U.S. Geological Survey as part of the Connecticut 208 study

(Published separately in the Miscellaneous Field Studies Map Series

of Geological Survey publications and available from:

Distribution Section
U.S. Geological Survey
1200 South Eads Street
Arlington, VA 22202)

MF 981 A - Road salt-storage and road network in Connecticut

(Includes favorable aquifers and salt use by town).

MF 981 B - Disposal of solid wastes in Connecticut

(Includes favorable aquifers).

MF 981 C - Surface-water quality and built-up areas in Connecticut

(Includes favorable aquifers, sampling sites, sewage treatment facilities and industrial discharge sites).

MF 981 D - Industrial areas and ground disposal of industrial wastes in Connecticut

(Includes favorable aquifers and generalized geologic map).

MF 981 E - Nonsewered built-up areas and septage disposal sites in Connecticut

(Includes favorable aquifers and distribution of wells and septic tanks).

MF 981 F - Proximity of agricultural areas to major aquifers in Connecticut

(Includes manure-storage areas, milk-waste lagoons, and livestock, crop, fertilizer, and pesticide distribution, by County).

MF 981 G - Places in Connecticut where ground water is known to have deteriorated in quality

(Includes major aquifers, wells that yield impaired or contaminated water, and areas susceptible to salt-water intrusion).

MF 981 H - Proximity of pipelines and storage facilities for gas and oil to major aquifers in Connecticut

(Includes distribution of gasoline and diesel-fuel dealers, by town.)

PURPOSE AND SCOPE

This study is the second phase of a program designed to assess the effect of nonpoint sources on the degradation of ground-water quality in Connecticut. It is part of the State's 208 program under Public Law 92-500, administered by the U.S. Environmental Protection Agency through the Connecticut Areawide Waste Treatment Management Planning Board. The technical information provided by this investigation is to be used by State and local agencies in preparing "208" programs for water-resources management in Connecticut.

The first phase consists of (1) identification and classification of subsurface contaminants and their sources (see Handman and others, 1979), and (2) determination of the sites of present and potential ground-water degradation. (See table 1.)

This report covers phase 2, an evaluation of the impact of selected nonpoint sources on water quality in stratified-drift aquifers through test drilling and water-quality sampling. It includes the inferred source of degradation; the volume of contaminants, where known, that has been introduced into the hydrologic system; the history of the problem; the areal extent, thickness, and other significant characteristics of the underlying or adjacent aquifer; the probable direction of ground-water movement, and the inferred sites of ground-water discharge.

The study does not completely define contaminant distribution and movement because of the small number of wells installed and sampled and the restricted time framework of the study.

METHODS

From one to nine test holes were augered at each site to determine the composition and thickness of the aquifer materials. Test wells of 2-inch diameter polyvinyl chloride (PVC) casing were installed in most of the test holes for water-level measurements and sample collection. The wells were developed by pumping, and their altitudes, relative to one another, were determined by differential (spirit) leveling from a datum (estimated mean sea level). The general hydraulic gradient in the area of each site was determined from water-level altitudes. In some places, the vertical direction of flow was ascertained from water levels in wells screened at different depths at the same location.

Water samples were collected and analyzed for physical properties, major chemical constituents and trace metals, and selected additional characteristics, depending on the contaminant source. The study used standard U.S. Geological Survey methods for collection and analysis of samples, as described in Brown and others (1970), Goerlitz and Brown

(1972), Wood (1976), and Slack and others (1973). Samples from some upgradient wells established background quality, and samples from downgradient wells were used to determine the effects of the nonpoint sources on ground-water quality.

ACKNOWLEDGMENTS

The U.S. Geological Survey, in fiscal cooperation with the Connecticut Department of Environmental Protection, collected and analyzed the data on which this report is based. Considerable information and assistance was obtained from State agencies, including the Departments of Environmental Protection and Transportation, and from town agencies.

Individuals and towns provided access to their property and permitted the drilling of test holes and installation of observation wells on their land. The cooperation of Paul Zurles of Haddam, Angelo Tomasso, Inc., the towns of Bristol, Clinton, Old Saybrook, and Wallingford, and the Connecticut Department of Transportation, is sincerely appreciated.

HYDROGEOLOGIC SETTING

Connecticut is a 5009-square-mile area drained primarily by the Connecticut River and its tributaries and by several smaller rivers; most of the drainage ultimately discharges into Long Island Sound. Drainage generally follows a north-south trend of highlands. Topography, stream pattern, and ground-water flow are controlled by the major stratigraphic and structural features of the bedrock, modified by glaciation and man.

Precipitation is the major source of ground-water recharge in Connecticut. Annual precipitation averages from 44 to 48 inches over most of the State, or almost 4 inches per month, distributed almost evenly throughout the year (Brumbach, 1965). This is equivalent to about 70 million gallons of water falling on every square mile each month. Nearly half of the precipitation evaporates or transpires, mainly during the growing season. The rest infiltrates and moves downward to the water table or flows overland directly into streams.

The water that infiltrates moves downward to the water table and becomes ground water. Ground water moves downgradient through the saturated zone toward low points in the flow system: streams, ponds, springs and centers of pumping. These low points are the sites of ground-water discharge.

Streams and reservoirs supply most of the State's water needs, but ground-water use in Connecticut has been increasing, and in rural areas it is the source of almost all domestic supply. Land available for additional surface-water impoundments is scarce, the cost of transporting water to new or expanding urban and industrial areas is high, and State policy favors development of future supplies from aquifers. Therefore, local ground-water sources will be an important part of the future water supply.

To insure that ground-water quality will be acceptable for its intended use, protection and management plans are being reviewed, and new or modified plans will be proposed as part of the State's "208" program. These plans will be more effective if they are based on the availability, quantity, and quality of potential supplies, information on probable sources of contamination, and an understanding of the hydrogeologic system.

Aquifers

Water in Connecticut is extracted from aquifers composed of unconsolidated sediments and bedrock (ledge). Unconsolidated sediments overlie bedrock and store and transmit water through interconnected pore spaces between the sediment particles. Water in bedrock is stored in and flows primarily through fracture networks.

The two major types of unconsolidated sediments are stratified drift and till. Both are of glacial origin and are commonly similar in mineral composition to the underlying or adjacent bedrock from which they are dominantly derived. Stratified-drift aquifers that meet certain criteria are the most productive sources of ground water in the State. The largest well yields are generally obtained from coarse-grained deposits near major streams. Other important criteria for developing large supplies are thickness of the water-saturated section and areal extent. Coarse-grained stratified-drift deposits that have a saturated thickness of 10 feet or more are delineated by Meade (1978) and on the maps listed in table 1.

Stratified-drift aquifers are susceptible to contamination as they can receive recharge in three ways: (1) from precipitation directly on the land overlying the aquifer, (2) from ground water that flows downgradient into the aquifer from adjacent upland areas, and (3) from induced infiltration of water from adjacent streams or lakes.

Till, popularly called "hardpan", provides small supplies of water for domestic use. It forms a widespread, discontinuous cover over bedrock throughout most upland areas and extends beneath stratified drift in valleys and lowlands. Till has been largely supplanted by bedrock as a domestic-supply source because of inadequate well yields and susceptibility to pollution.

Bedrock is subdivided into three general types: (1) crystalline rocks (noncarbonate), (2) sedimentary and associated igneous rocks, and (3) carbonate rocks. Yields from these rock types differ depending on the number and size of fractures or other openings intercepted by a well. Bedrock aquifers are the principal source of water for those domestic and commercial users not served by public water supplies.

The distribution of bedrock aquifers is shown as an inset on the map by Meade (1978). The crystalline bedrock aquifer includes rocks of diverse origins but with similar water-yielding properties. It is the most extensive aquifer in the State and underlies the eastern and western highlands. Sedimentary and associated igneous rocks underlie a northeast-southwest band through the center of the State (Connecticut lowland). The sedimentary and igneous rocks are layered; wells may have different yields and water-quality characteristics, depending on the composition

Table 2.--Principal hydrogeologic units: properties, water quality, and susceptibility to contamination
(From Handman and others, 1979, p. 12)

Hydrogeologic unit		Physical characteristics and distribution	Water-bearing properties	Background quality of ground water	Susceptibility to contamination
Unconsolidated sediments	Stratified drift (coarse)	Fine to coarse sand with some silt and gravel; deposits well sorted and stratified. Occur in stream valleys and lowlands. Commonly interbedded with finer layers. Overlie till and bedrock.	Most productive aquifers in State; especially where thick, coarse grained, and hydraulically connected to large streams or lakes. Provide large yields for public-supply and industrial uses.	Low dissolved-solids concentration. Generally moderately hard, especially where constituent fragments or underlying bedrock consist of carbonate rocks. Local high concentrations of iron and manganese.	Highly susceptible because of high hydraulic conductivity, proximity of water table to land surface, extensive cones of depression in heavily pumped areas, use of abandoned sand and gravel pits as dumps, and because of location in larger valleys, many of which are urbanized and industrialized.
	Stratified drift (fine)	Predominantly clay, silt, and very fine to fine sand; deposits well sorted and stratified. Occur in stream valleys and lowlands. Commonly interbedded with coarser layers. Overlie till and bedrock.	Poor aquifers, particularly where very fine grained and not interbedded with coarse layers.	Same as coarse-grained stratified drift.	Less susceptible than coarse-grained stratified drift becuase of its lower hydraulic conductivity.
	Till	Heterogeneous mixture of unstratified materials ranging in size from clay to boulders; generally compact; commonly called "hardpan". Overlies bedrock in most of the State.	Poor aquifers, especially where hydraulic conductivity is low and saturated section is thin. Can provide small supplies to dug wells of large diameter.	Low dissolved-solids concentration. Generally soft to moderately hard. Local high concentration of iron and manganese.	Less susceptible than stratified drift because of its low hydraulic conductivity, but dug wells are subject to contamination from local sources.
Bedrock	Sedimentary (and associated igneous) rocks	Sedimentary aquifers are fine-to-coarse-grained bedded rocks (shale, sandstone, siltstone, and conglomerate); joints well defined. Underlie most of central Connecticut. Associated igneous rocks are basalt and diabase (trap rock) flows separated by sedimentary rocks; joints well defined. Form ridges in central Connecticut.	Yields adequate supplies for domestic and small-scale municipal and industrial purposes from openings along bedding planes and joints.	Moderate dissolved-solids concentration, generally moderately hard to hard. High dissolved sulfate, chloride, and sodium concentrations locally. Significant chemical quality differences, both areally and with depth.	Contaminants can enter along joints and bedding surfaces, especially where covering of till or other unconsolidated deposits is thin. Sedimentary rocks in lowlands susceptible because of urban and industrial land use.
	Carbonate rocks	Calcium and magnesium carbonate (limestone, dolostone and marble). Underlie a few valleys in western part of State.	Provide adequate supplies for domestic and small-scale municipal and industrial purposes.	Moderate dissolved-solids concentration, generally hard; most supplies require softening. Commonly alkaline and low in iron and manganese.	Susceptible where intensively and deeply weathered, as in parts of southwestern Connecticut and where covering of till or other unconsolidated materials is thin. Solution channels facilitating movement of contaminants are rare.
	Crystalline (noncarbonate) rocks	Predominantly metamorphic rocks (schist and gneiss), highly folded, numerous joints. Underlie most of eastern and western Connecticut; overlain by thin till in most places.	Yield adequate supplies for domestic use to drilled wells, from openings along joints.	Low dissolved-solids concentration, soft to moderately hard, locally hard, local high concentrations of iron and manganese.	Contaminants can enter along joints and other fractures, especially where covering of till or other unconsolidated deposits are thin.

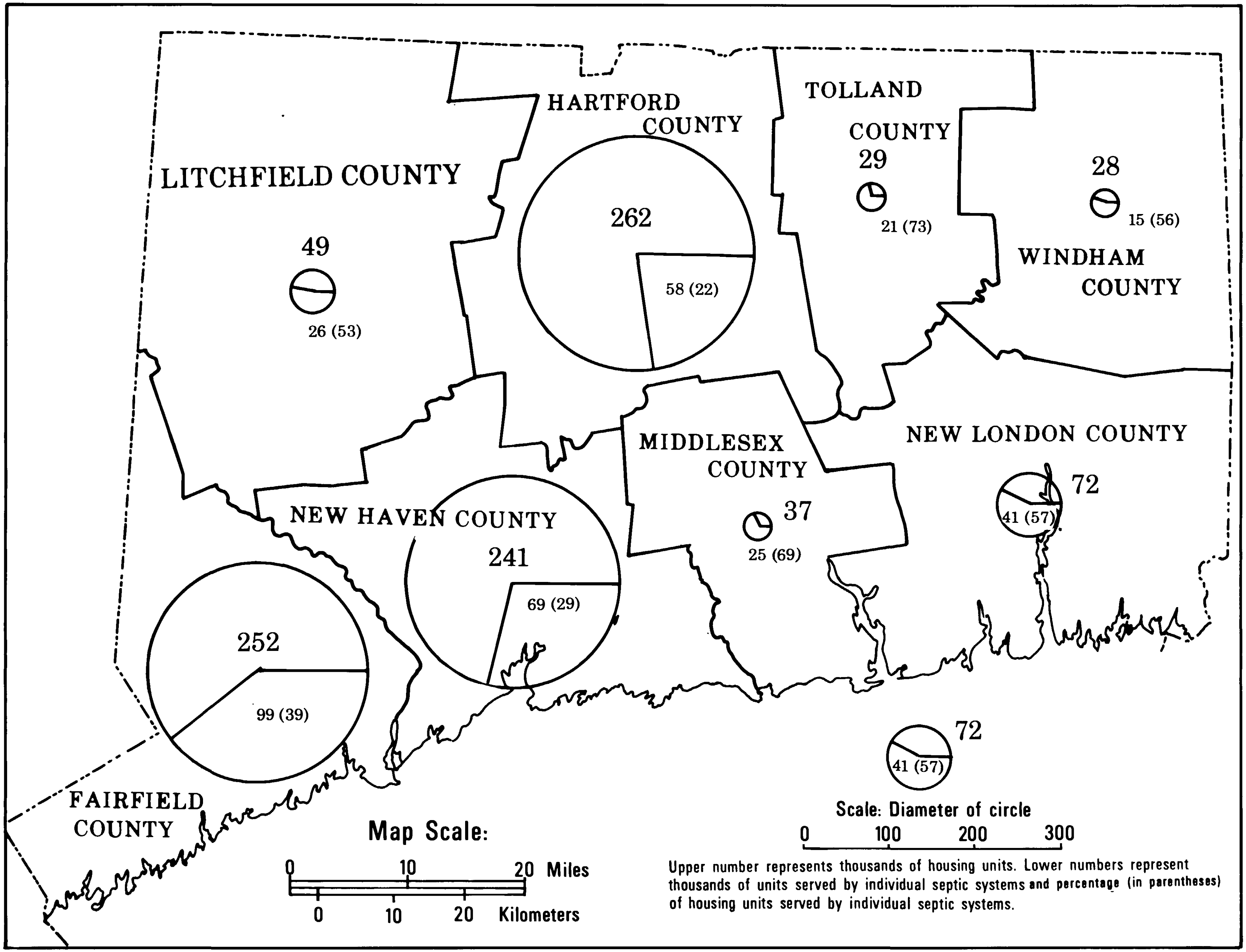


FIGURE 1.--DISTRIBUTION OF HOUSING UNITS AND SEPTIC SYSTEMS, BY COUNTY
(Based on data from U. S. Department of Commerce, 1972. Detailed housing characteristics: 1970 U. S. Census)

and physical properties of the layers tapped. The carbonate bedrock aquifer is principally restricted to valleys in the western highlands. Table 2 summarizes the hydrogeologic characteristics of principal aquifers. More detailed information on specific parts of the State is contained in the series of Connecticut Water Resources Bulletins referenced in this report.

Although most domestic wells are drilled in bedrock, coarse-grained stratified-drift aquifers are the most capable of yielding the large amounts of water needed for public supply and industrial use. Consequently, State and local aquifer protection and management programs generally focus on stratified-drift areas. For this reason, nonpoint sources of contamination located over stratified-drift deposits were selected for this study. The following sections of this report describe the hydrogeologic environment and the quality of ground water at these sites.

SEPTAGE DISPOSAL

In Connecticut, 37 percent of all housing units are served by on-site septic systems (U.S. Bureau of the Census, 1972). For distribution by county, see figure 1 and table 3. Proper maintenance of these systems requires periodic removal of accumulated solids (termed septage or sludge) from their septic tanks. These wastes are disposed of either at sewage-treatment plants or in 39 municipal and private septage-disposal facilities authorized by the Water Compliance Unit of the Connecticut Department of Environmental Protection. Locations of these facilities are shown on a map by Rolston and Bingham (1978), and their distribution by county is listed in table 3.

Septage-disposal facilities consist of two or more sludge digestion cells designed to hold one-tenth of the estimated yearly volume of sludge received from the areas served by the facility. Connecticut Department of Environmental Protection guidelines (1976) require that

Table 3.--Distribution of septic systems and septage-disposal areas by county

(Data from U.S. Bureau of the Census (1972, p. 162-163) and Connecticut Department of Environmental Protection)

	Fairfield	Hartford	Litchfield	Middlesex	New Haven	New London	Tolland	Windham	State total
Land area, in square miles	626	739	925	372	604	667	416	514	4,863
Population	792,814	816,737	144,091	115,018	744,948	230,654	103,440	84,515	3,032,217
Housing units (HUs)	252,334	262,133	48,947	36,591	240,628	71,639	28,951	27,592	968,815
Persons per HU	3.1	3.1	2.9	3.1	3.1	3.2	3.6	3.1	3.1
HUs on septic tanks	99,114	58,141	25,987	25,138	68,692	41,001	21,040	15,472	354,585
Percentage of HUs on septic tanks	39	22	53	69	29	57	73	56	37
Density (HUs per square mile)	158	79	28	68	114	61	51	30	73
Disposal areas, number	2	1	7	8	2	10	4	5	39

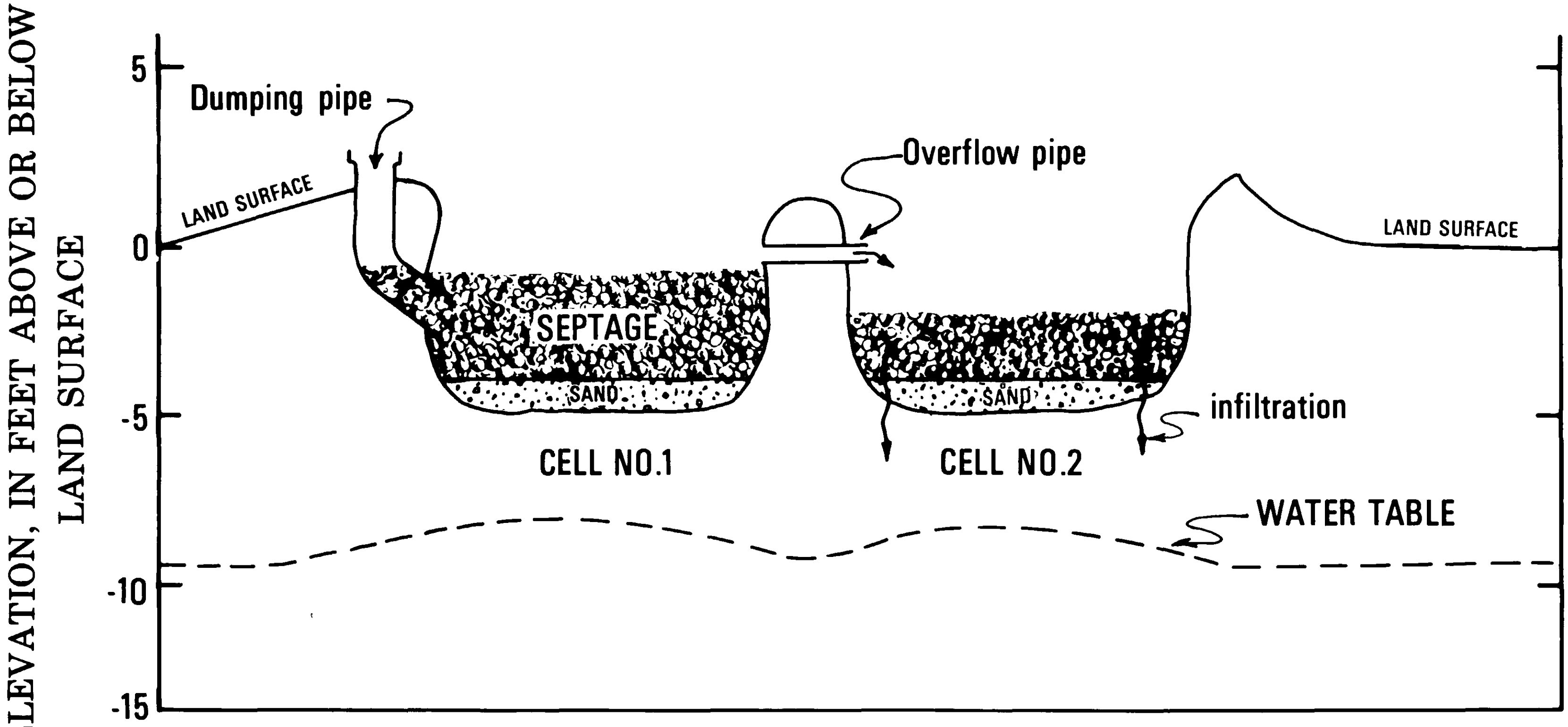


FIGURE 2.--CROSS SECTION THROUGH A GENERALIZED SEPTAGE-DISPOSAL SYSTEM

(VERTICAL EXAGGERATION X 10)

 page 11 follows

cells be at least 4 feet above the estimated maximum position of the water table, lined with at least 1 foot of sand, and have a minimum operating depth of 3 feet. Figure 2 is a cross section of a generalized septage-disposal system.

Sludge is deposited in the first cell, where solids settle out and some bacteria are digested. A neutral pH (range from 6.8 to 7.2) is maintained by adding hydrated lime. Although some liquid evaporates from the surface, precipitation more than compensates for it. Initially, liquid seeps through the bottom and sides of the first cell, but, eventually, settled solids tend to seal the bottom of this pit. When the cell fills, the overflow fluid flows through a pipe to the second cell, from which it seeps into the ground. The environmental consequences of this system are not well known. Patterson and others (1971), in their comprehensive review and evaluation of septic systems, point out that little information on septage disposal is available in the literature, and that research is needed.

Two septage-disposal facilities were chosen for this study, one at Old Saybrook and one in Clinton. (See fig. 3.) Both were constructed and are operated in compliance with State regulations, as outlined above, and both are located in areas of stratified drift. These particular stratified-drift deposits, however, are not suitable for large-scale ground-water development because their location near the coast makes them vulnerable to salt-water intrusion.

Old Saybrook Site

Description and history

This septage-disposal facility, just south of U.S. Route 1, north of the Penn Central railroad tracks and west of the Connecticut River estuary, consists of three lagoons, as shown in figure 4. The land surface slopes to the south, as does the bedrock surface. The area is underlain by fine to medium sand, with some coarser and finer sediment layers, as indicated by the well logs in table 4.

The facility was constructed in 1974 and by March 1978 had received 1.8 million gallons of sludge from septic tanks. The first and second cells have a 195,000-gallon capacity, and the third can hold 167,000 gallons. At the time of sampling (April 1978), the first lagoon was full, and sludge was being deposited into the second cell; the third was nearly empty and showed little sign of previous use.

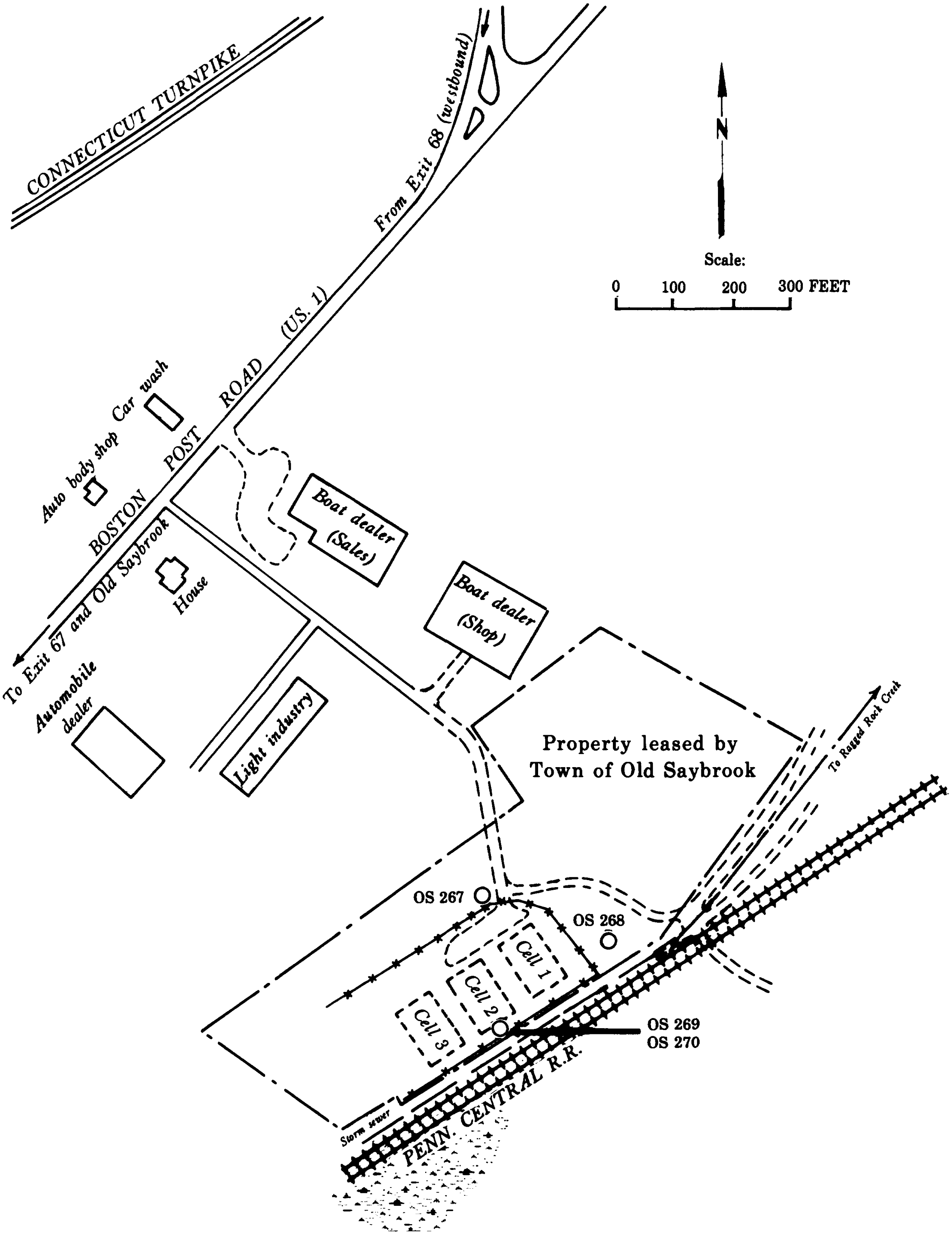


FIGURE 4--MAP OF OLD SAYBROOK SITE SHOWING LOCATION OF WELLS OS 267 - 270

Table 4.--Logs of test holes at Old Saybrook septage-disposal facility[1/]

Well OS 267. Site ID 411821072220301.
Lat 41°18'21", long 72°22'03".

Owner: Town of Old Saybrook. Drilled water-table well in stratified drift, diam 2 in, depth 14 ft, cased with plastic PVC to 9 ft, with 5 ft PVC slotted pipe 9-14 ft. LSD 26 ft above msl. MP is top of plastic casing 1 ft above LSD. Drilled April 6, 1978, by USGS.
Location: 10 ft north and 5 ft west of westerly gate post into septage lagoons and about 950 ft southeast of Boston Post Road.

Materials	Depth below LSD, in feet	
	From	To
Sand, silty, with few pebbles up to 2 in diam	0	2
Sand, coarse, brown; some very coarse sand, some medium sand, and few pebbles	2	7
Sand, medium to coarse, brown; some fine sand, some fine gravel, little clay	7	13
Sand, coarse, brown; some very coarse, little clay and silt	13	14

Refusal at 14 ft on rock

Well OS 268. Site ID 411820072220201.
Lat 41°18'20", long 72°22'02".

Owner: Town of Old Saybrook. Drilled water-table well in stratified drift, diam 2 in, depth 25 ft, cased with plastic PVC to 20 ft, and screened 20-25 ft with slotted PVC pipe. LSD 18 ft above msl. MP is top of plastic casing 1.5 ft above LSD. Drilled April 6, 1978, by USGS.
Location: 30 ft east of fence around septage lagoons and 50 ft north of Penn Central Railroad tracks.

Materials	Depth below LSD, in feet	
	From	To
Sand, fine, yellow-brown; some silt and clay, little gravel up to 2-in. diam	0	7
Sand, fine to very fine, brown; some silt and clay	7	13
Silt and clay, brown; some very fine sand	13	32
Silt and clay, brown and gray	32	42
Clay, brown and gray, trace silt	42	54
Sand, medium to very coarse, hard packed, gray; little fine gravel (till?)	54	62

Bottom of hole at 62 ft in till

Well OS 269. Site ID 411819072220301.
Lat 41°18'19", long 72°22'03".

Owner: Town of Old Saybrook. Drilled water-table well in stratified drift, diam 2 in, depth 26.4 ft, cased with plastic PVC to 21.4 ft, with 5 ft PVC slotted pipe 21.4-26.4 ft. LSD 18 ft above msl. MP is top of 3-in steel casing protector 1.9 ft above LSD. Drilled April 17, 1978, by USGS.
Location: 2 ft north of fence around septage lagoons, 30 ft north of Penn Central Railroad tracks, and 15 ft south of south-center edge of middle lagoon.

Materials	Depth below LSD, in feet,	
	From	To
Soil, black muck	0	2
Gravel and cobbles	2	4
Sand, fine to medium, silty, gray and brown, layered	4	11
Clay, red	11	12
Sand, very fine to medium, silty, brown	12	20
Silt, red and brown, with thin sand layers	20	29
Till, sandy, gray, compact	29	37

Bottom of hole at 37 ft in till

Well OS 270. Site ID 411819072220302.
Lat 41°18'19", long 72°22'03"

Owner: Town of Old Saybrook. Drilled water-table well in stratified drift, diam 2 in, depth 12.3 ft, cased with plastic PVC to 7.3 ft, with 5 ft PVC slotted pipe 7.3-12.3 ft. LSD 18 ft above msl. MP is top of steel casing protector 1.0 ft above LSD. Drilled April 17, 1978, by USGS.
Location: Same as for OS 269.

Material description same as OS 269.
Casing installed in same 6-in auger hole.

1/ Abbreviations used in table

ID Identification no.
PVC Polyvinyl chloride
LSD Land surface datum
msl Mean sea level
MP Measuring point

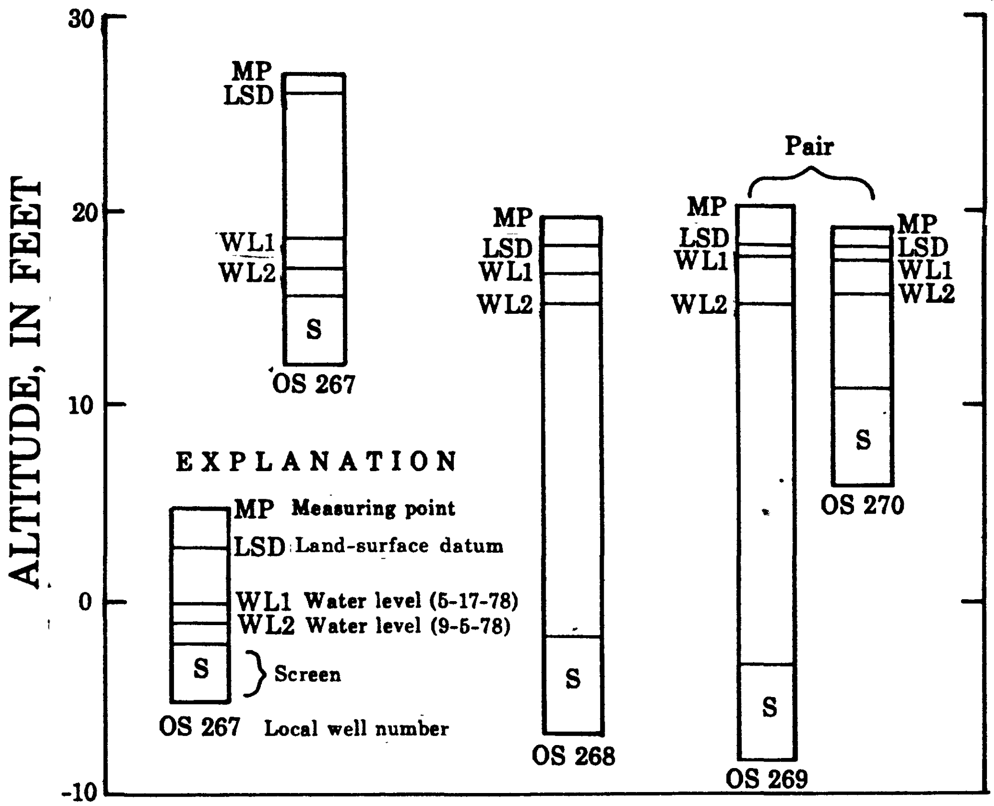


FIGURE 5.--WATER LEVELS IN OLD SAYBROOK WELLS

(FOR WELL LOCATIONS SEE FIGURE 4)

Geologic and hydrologic data

Four test holes were augered and observation wells installed to determine the geologic framework, direction of water movement, and quality of ground water (fig. 4). Well OS 267 is upgradient from the disposal area, and the others are downgradient. Depth to bedrock ranges from 14 feet at OS 267 to more than 62 feet at OS 268.

Materials consist primarily of coarse sand at OS 267, fine sand at OS 269 and OS 270, and silt and clay at OS 268 (table 4). The lagoons are constructed in fine to medium sand (Warren Herzig, Connecticut Department of Environmental Protection, 1978, written communication). Materials differ considerably over short distances and with depth, but at this disposal site, are primarily fine-grained. The probable areal extent of the coarse-grained part of the aquifer is shown in figure 3.

The altitude of the water table, measured on May 17, 1978, ranged from 18.5 feet above estimated mean sea level (msl) at OS 267 to 16.7 feet at OS 268, as shown in figure 5. The water level in the lagoons was higher: 25.5 feet in cell 1, 23.5 feet in cell 2, and 20.3 feet in cell 3, indicating possible mounding of the water table directly beneath

Table 5.--Water-level altitudes in Old Saybrook test wells[1/]

Date	Local well number and relative altitude of land surface[2/]			
	OS 267 26.0	OS 268 18.1	OS 269 18.5	OS 270 18.5
5/17/78	18.5	16.7	17.3	17.2
8/31/78	15.8	--	--	--
9/05/78	15.8	15.1	15.1	15.5
9/06/78	--	--	15.1	15.4

1/ Water-level altitudes based on depths to water in wells, measured to nearest hundredth foot.

2/ Relative altitude of land surface determined to nearest hundredth foot by differential (spirit) leveling from a datum (estimated mean sea level).

Table 6.--Analyses of ground water at septage-disposal facilities

(Chemical constituents dissolved unless otherwise indicated; concentrations in milligrams per liter)

Constituent or property	Well number, depth, and date sampled: OS 269 (26.4 ft) 4-29-78	OS 269 (26.4 ft) 9-6-78	OS 270 (12.3 ft) 4-27-78	Cl 219 (17.9 ft) 4-27-78	Cl 221 (18.5 ft) 4-27-78	Cl 222 (22.0 ft) 4-26-78	Limiting Value	Basis (A)
Aluminum (Al)	--	C	0.1 B	0.07 B	0.05 B	C	--	--
Antimony (Sb)	--	C	.03 B	C	.03 B	C	0.050	3
Bacteria, fecal coliform, in col/100 ml	0	--	0	0	0	0	--	--
Bicarbonate (HCO_3)	60	--	580	16	15	170	--	--
Barium (Ba)	--	.01 B	.1 B	.1 B	.1 B	.03 B	1	1,2
Beryllium (Be)	--	C	C	.0	C	C	.011	2,3
Bismuth (Bi)	--	C	C	C	C	C	--	--
Boron (B)	--	.03 B	.1 B	.07 B	.3 B	.03 B	.75	2
Cadmium (Cd)	--	.002	.01 B	.001 B	.03 B	.005	.010	1,3
Calcium (Ca)	22	10 B	130	23	15	13	--	--
Carbon, organic	4.6	--	22	6.7	36	3.0	--	--
Carbon, organic, suspended	.6	--	.9	.1	.1	.1	--	--
Chloride (Cl)	10	--	66	38	67	27	250 D	1
Chromium (Cr)	--	C	C	C	C	C	.050	1,3
Cobalt (Co)	--	C	.7 B	C	.1 B	C	--	--
Copper (Cu)	--	.01 B	C	C	C	.01 B	1.0	1,3
Detergents (MBAS)	.1	--	.9	.2	.9	.0	.5	1
Gallium (Ga)	--	C	C	C	.03 B	.03 B	--	--
Germanium (Ge)	--	C	.3 B	.03 B	.3 B	.03 B	--	--
Hardness, noncarbonate as $CaCO_3$	27	--	--	69	70	0	--	--
Hardness, as $CaCO_3$	76	--	450	82	83	45	--	--
Iron (Fe)	.02	.01 B	51	.02	66	.05	.3	2
Lead (Pb)	--	.016	.03 B	.002	.05 B	C	.050	1,3
Lithium (Li)	--	C	C	C	C	C	--	--
Magnesium (Mg)	5.2	3 B	30	5.9	11	3.0	--	--
Manganese (Mn)	1.3	1 B	33	1.6	58	.23	.05	2
Molybdenum (Mo)	--	C	.03 B	.01 B	.03 B	C	--	--
Nickel (Ni)	--	C	C	.05 B	C	C	.10	2,3
Nitrite + nitrate as N	.11	--	.03	.62	.00	1.0	10	1,2
Nitrite + nitrate, total, as N	.11	.06	.03	.60	.00	.98	10	1,2
pH, units	6.6	6.4	6.5	5.4	6.3	6.1	--	--
Phosphorus, as P	.00	--	.00	.00	.00	.00	--	--
Phosphorus, total, as P	.30	.12	.13	.00	.02	.06	--	--
Potassium (K)	--	1. B	3. B	3. B	10. B	1. B	--	--
Silica (SiO_2)	--	30. B	30. B	30. B	10. B	10. B	--	--
Silver (Ag)	--	C	C	C	C	C	.050	1,3
Sodium (Na)	13	10. B	41.	22.	60.	8.8	20	1
Specific conductance, in umhos/cm	150	178	820	176	610	114	--	--
Strontium (Sr)	--	.07 B	1 B	.5 B	.3 B	.1 B	-- -	--
Sulfate (SO_4)	41	--	40.	43.	83.	13.	--	--
Tin (Sn)	--	C	.3 B	C	.3 B	.05 B	--	--
Titanium (Ti)	--	C	C	C	C	C	--	--
Vanadium (V)	--	C	.01 B	C	.03 B	C	--	--
Zinc (Zn)	--	.3 B	.3 B	.03 B	.07 B	.07 B	5	2,3
Zirconium (Zr)	--	C	C	C	.005 B	C	--	--

A 1 Maximum permissible level for drinking water, Connecticut Public Health Code Regulation 19-13-B102 (Connecticut General Assembly, 1975).

2 Most stringent criterion recommended by U.S. Environmental Protection Agency (1976).

3 Constituent is on list of toxic substances established by the U.S. Environmental Protection Agency (1978) pursuant to section 307 of Public Law 92-500.

B Semiquantitative analysis. Results are rounded to nearest reporting level. Reporting levels range from the detection limit upward in steps of 1, 3, 5, 7, and 10. Results are reported to one significant figure only.

C Not detected; semiquantitative analysis.

D Background level for most waters in State is less than 20 mg/L.

the disposal area. The general horizontal direction of ground-water flow is to the southeast. At the pair of wells, OS 269 and OS 270, the water-level altitude was slightly lower in the shallower well (OS 270) on May 17, and higher on September 5, 1978. This indicates that the vertical component of flow was downward at this site on the latter date. On September 5, the water levels were about 2 feet lower in all the wells (fig. 5). For altitude of the water table on different dates, see table 5. Shallow ground water and surface runoff probably discharges to a storm sewer which discharges into a drainage ditch that flows beside the railroad tracks northeastward into Ragged Rock Creek. Most ground water probably discharges to a swamp to the south-southwest and eventually into North Cove.

Ground-water quality

Samples were collected from observation wells OS 269 and OS 270 to determine the effect of septage on ground-water quality. The wells are adjacent and about 50 feet south of cell 2 (fig. 4). An odor of septage was detected in both wells during sample collection, although there was no odor in the general area. Analyses are shown in table 6. The water quality can be evaluated by comparing concentrations in the samples with each other and with limiting values in the table. Water from the shallower well, OS 270, is more mineralized and shows more evidence of waste-water contamination than that from the deeper well, although both wells are affected. The water from OS 270 contains higher concentrations of sodium, chloride, detergents (MBAS), and dissolved organic carbon. The extremely high iron and manganese concentrations may come from the septage or be dissolved from underlying unconsolidated materials. The anaerobic conditions maintained in the septage lagoon favor solution of these metals, decomposition of bacteria, and chemical reduction of nitrogen species.

To further evaluate nutrients (nitrogen and phosphorus compounds), additional samples were collected from both wells in September, 1978. The chemical analyses shown in table 7 indicate that higher concentrations of nitrogen and phosphorus constituents are reaching the shallower well, OS 270, than the deeper well, OS 269.

Minor metals, including boron, cadmium, cobalt, lead, and tin detected in water from well OS 270, may be dissolved from the sediments or may have come from the septage itself. Lower concentrations of boron, cadmium, and lead were also detected in OS 269. The New England Interstate Water Pollution Control Commission (1976) reports that domestic sewage contains minor metals and these may accumulate in residential septic tanks during the long intervals (generally greater than 3 years) between cleaning. Industrial septage, which commonly has a higher metal content than domestic septage, is restricted from Connecticut septage disposal facilities.

Table 7.--Analyses of nitrogen and phosphorus in water from wells OS 269 and OS 270

(Sample date Sept. 6, 1978; concentrations in milligrams per liter)

Constituent or property	Well number and depth: OS 269 (26.4 ft)	OS 270 (12.3 ft)
Ammonia (NH_4), total, as N	.18	.68
Nitrogen, total, as N	.64	1.8
Nitrogen, total, as NO_3	2.8	8.1
Nitrogen (N), total organic	.40	1.1
Nitrogen (N), total Kjeldahl	.58	1.8
Nitrite + nitrate, total, as N	.06	.04
pH, units	6.4	6.2
Phosphorus, total, as P	.12	.21
Specific conductance, in umhos/cm	178	790

Clinton Site

Description and history

The Clinton septage-disposal facility, north of U.S. Route 1, just south of the railroad tracks and east of the Hamonassett River, consists of two primary and two secondary lagoons, as shown in figure 6. The land surface slopes to the east. The area is underlain by about 50 feet of stratified sand, as indicated by the well logs in table 8.

The facility, constructed in 1974, receives about 300,000 gallons of domestic septage each year for a total of about 1.3 million gallons through 1978. At the time of well sampling (April 1978), cell 2 was receiving the septage and overflow was into cell 4. The septage level in cell 1 was 1 foot below the overflow pipe, and cell 3 was dry.

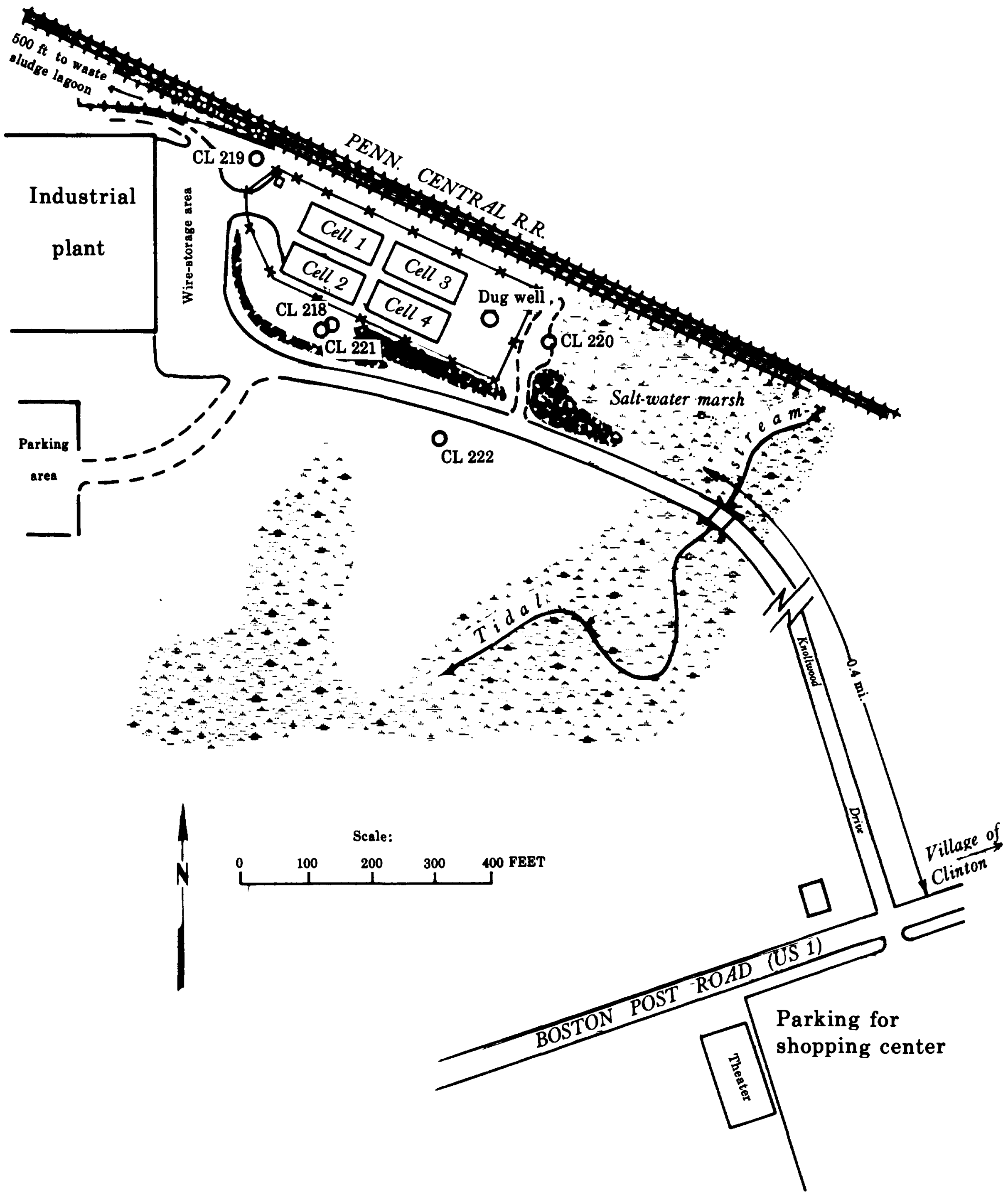


FIGURE 6.--MAP OF CLINTON SITE SHOWING LOCATION OF WELLS CL 218 - 222

Table 8.--Logs of test holes at Clinton septage-disposal facility[1/]

Well CL 218. Site ID 411653072323001.
Lat 41°16'53", long 72°32'30".

Owner: Town of Clinton. Drilled water-table well in stratified drift, diam 2 in, depth 27.4 ft, cased with plastic PVC to 22.5 ft, with 5 ft PVC slotted pipe 22.5-27.4 ft. LSD 20 ft above msl. MP top of plastic coupling 1.5 ft above LSD. Drilled April 17, 1978, by USGS.
Location: 45 ft southwest of cell 2 and 40 ft northeast of Southern New England Telephone Co. pole no. 172.

Materials	Depth below LSD, in feet From	To
Sand, medium to very coarse, brown	0	10
Sand, very fine to medium, silty, gray-brown	10	15
Sand, very fine to medium, and silt, gray	15	25
Silt, gray, soft	25	31
Sand, very fine to very coarse, with few pebbles, gray (till?)	31	34

Bottom of hole at 34 ft

Well CL 219. Site ID 411654072323101.
Lat 41°16'54", long 72°32'31".

Owner: Town of Clinton. Drilled water-table well in stratified drift, diam 2 in depth 17.9 ft cased with plastic PVC to 13 ft, with 5 ft PVC slotted pipe 13.0-17.9 ft. LSD 15.5 ft above msl. MP top of plastic coupling 1.1 ft above LSD and 3.45 ft below CL 218 MP. Drilled April 17, 1978, by USGS.
Location: 30 ft northwest of northwest corner of fence around septage lagoons, 75 ft east of Bostich gate, and 30 ft south of railroad track.

Materials	Depth below LSD, in feet From	To
Sand, very fine to medium, brown, some silt	0	4
Sand, very fine to coarse, brown, some silt	4	5
Sand, fine to coarse, black	5	6
Sand, very fine to very coarse, clean	6	22

Bottom of hole at 22 ft

Well CL 220. Site ID 411653072322801.
Lat 41°16'53", long 72°32'28".

Owner: Town of Clinton. Drilled water-table well in stratified drift, diam 2 in, depth 14.85 ft, cased with plastic PVC to 9.8 ft, with 5 ft PVC slotted pipe 9.8-14.8 ft. LSD 11 ft above msl. MP top of steel casing protector 0.5 ft LSD and 8.23 ft below CL 218 MP. Drilled April 18, 1978, by USGS.
Location: 15 ft east of east gate into septage lagoons, 50 ft south of railroad embankment, and 70 ft north of Knollwood Drive.

Materials	Depth below LSD, in feet From	To
Sand, very fine to medium, silty, brown	0	11
Silt, sandy, gray-brown	11	36
Sand, silty	36	40
Sand and gravel or till	40	41

Refusal at 41 ft

Well CL 221. Site ID 411653072323002.
Lat 41°16'53", long 72°32'30".

Owner: Town of Clinton. Drilled water-table well in stratified drift, diam 2 in, depth 18.5 ft, cased with plastic PVC to 13.5 ft, with 5 ft PVC slotted pipe 13.5-18.5 ft. LSD 20 ft above msl. MP top of plastic coupling 1.5 ft above LSD and 0.01 ft below CL 218 MP. Drilled April 25, 1978, by USGS.
Location: 5 ft south of CL 218

Materials	Depth below LSD in feet From	To
Sand, fine to very coarse, brown	0	11
Sand, very fine to medium, gray	11	17
Sand, very fine to medium, little silt, gray	17	21

Bottom of hole at 21 ft

Well CL 222. Site ID 411652072323001.
Lat 41°16'52", long 72°32'30".

Owner: Town of Clinton. Drilled water-table well in stratified drift, diam 2 in, depth 22.0 ft, cased with plastic PVC to 17 ft, with 5 ft PVC slotted pipe 17.0-22.0 ft. LSD 18 ft above msl. MP top of plastic coupling 1 ft above LSD and 2.37 ft below CL 218 MP. Drilled April 25, 1978, by USGS.
Location: 15 ft south of Knollwood Drive, 150 ft southeast of Southern New England Telephone Co. pole no. 172, and 130 ft southeast of cell 2.

Materials	Depth below LSD, in feet From	To
Sand, medium to coarse, some fine sand, little fine gravel	0	2
Sand, fine to medium, trace of coarse sand	2	17
Sand, medium to very coarse, yellow to brown, some clay layers	17	28
Till, sandy, gray	28	34

Bottom of hole at 34 ft

1/ Abbreviations used in table

ID Identification no.
PVC Polyvinyl chloride
LSD Land surface datum
msl Mean sea level
MP Measuring point

Geologic and hydrologic data

Five test holes were augered and observation wells installed northwest, south, and east of the facility. Sediments from the test holes consist primarily of fine to medium sand, with some silt and some coarse sand layers (table 8). The lagoons are constructed in stratified sand and gravel and sand and clay (Warren Herzig, Connecticut Department of Environmental Protection, 1978, written communication). The probable areal extent of the aquifer is shown in figure 3.

The natural hydraulic gradient, which probably sloped gradually to the east, has been modified by mounding of the water table beneath the septage cells. As a result, the water levels in all five wells may be affected. On May 17, the altitude of the water table ranged from 11.7 feet above estimated msl (water level in well Cl 219) to 8.8 feet (water level in well Cl 220) as shown in figure 7. The altitude of the septage in cell 2 was 15.9 feet. At the pair of wells, CL 218 and CL 221, the water-level altitude was higher in the shallower well (CL 221), indicating ground-water recharge, probably from the lagoons. Water levels were about 1 foot lower in all wells on August 31, 1978 (fig. 7). For water levels on different dates see table 9. Ground water probably discharges to the east to a tidal tributary of the Hamonassett River estuary.

Table 9.--Water-level altitudes in Clinton test wells[1/]

Date	Local well number and relative altitude of land surface[2/]				
	Cl 218 20.0	Cl 219 17.0	Cl 220 11.0	Cl 221 20.0	Cl 222 18.0
4/20/78	--	11.7	8.1	--	--
4/25/78	11.0	--	--	--	--
5/17/78	10.4	11.7	8.8	11.6	10.2
8/31/78	9.5	10.3	7.3	10.6	9.2

1/ Water-level altitudes based on depths to water in wells, measured to nearest hundredth foot.

2/ Relative altitude of land surface determined to nearest hundredth foot by differential (spirit) leveling from a datum (estimated mean sea level).

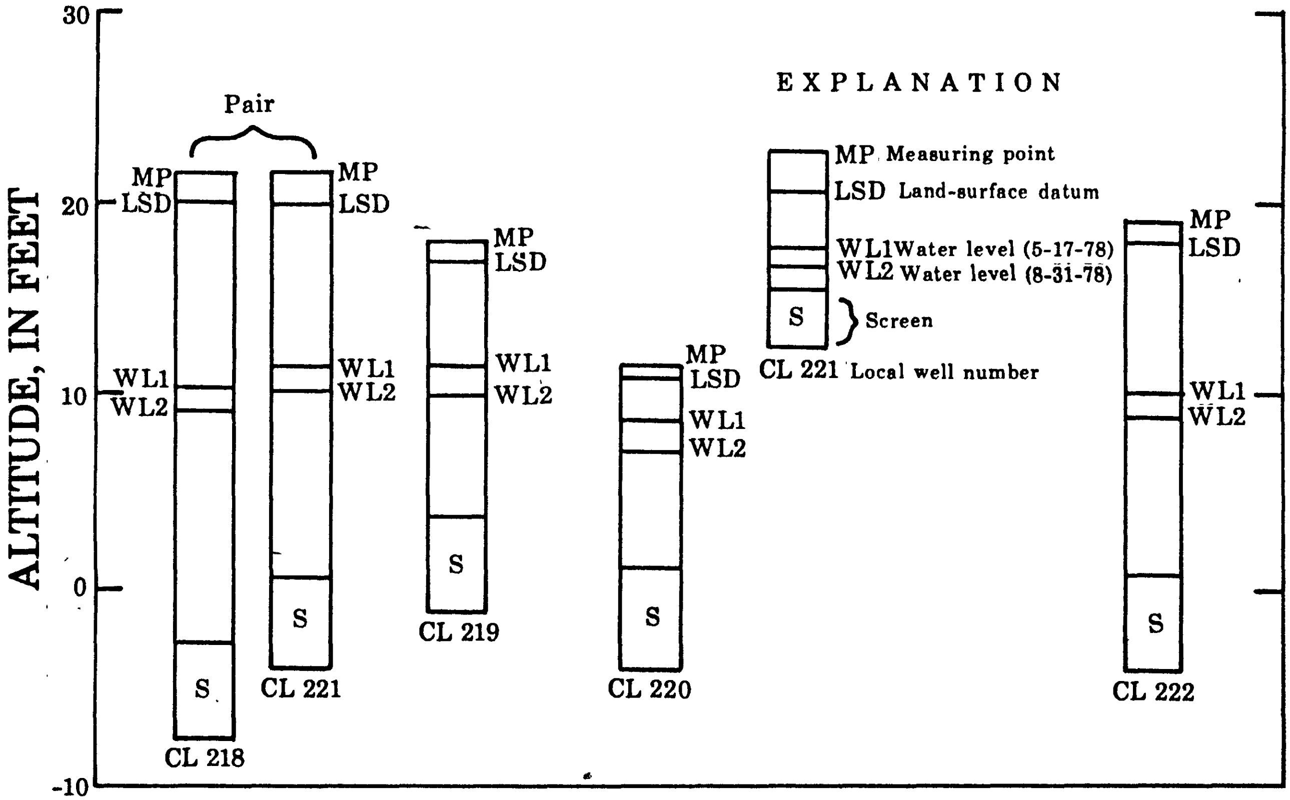


FIGURE 7.--WATER LEVELS IN CLINTON WELLS

(FOR WELL LOCATIONS SEE FIGURE 6)

Ground-water quality

Samples were collected from three observation wells, CL 219, CL 221, and CL 222. Well CL 221 is closest to the septage facility, about 50 feet south of and downgradient from cell 2. The quality of water from this well is similar to that of well OS 270 at the Old Saybrook septage-disposal area. (See table 6 for analyses.) Both have detectable septage odors and elevated concentrations of chloride, sodium, dissolved organic carbon, detergents (MBAS), iron, manganese, and some minor metals, and both exceed the limiting values (table 6) for several constituents (iron, manganese, sodium, detergents, and dissolved organic carbon). Iron and manganese concentrations, in particular, are extremely high compared with concentrations in samples from the other wells. In both wells, OS 270 and CL 221, minor metals may come from solution of sediments or from the septage. At the Clinton facility, an industrial-waste lagoon about 500 feet downgradient is probably not a contributing factor. Water from CL 222, which is farthest from the septage facility, is better in quality and meets Connecticut standards for drinking water for those constituents tested. Water from CL 219 is intermediate in quality. It contains some detergent and elevated concentrations of sodium, chloride, and manganese.

FLY-ASH DISPOSAL

Common sources of ash, the solid residue left when combustible material is thoroughly burned, are incinerators and fossil-fuel generating stations. Bottom ash and fly ash from municipal refuse incinerators are generally disposed of in landfills. Most incinerators in Connecticut have been closed because they contribute to air pollution.

Ash from power generating stations is generally disposed of on-site, at least temporarily. Most coal-fueled plants, which produce great volumes of ash, have been converted to oil, which produces less residue. In 1964, 21 percent of gross energy consumed in the State was from coal. By 1973, coal was down to 1 percent, and the amount consumed had decreased from 4.8 million tons to 0.1 million tons (Connecticut Department of Environmental Protection, 1977, written communication).

Despite a temporary increase in consumption during the oil embargo in 1974, coal has remained only a minor energy source for the State. It may, however, be utilized to a greater extent in the future. Oil-fueled generating plants at Middletown and at Norwalk, for example, have been ordered by the U.S. Department of Energy to convert to coal. Furthermore, abandoned coal-ash disposal areas still affect ground-water quality.

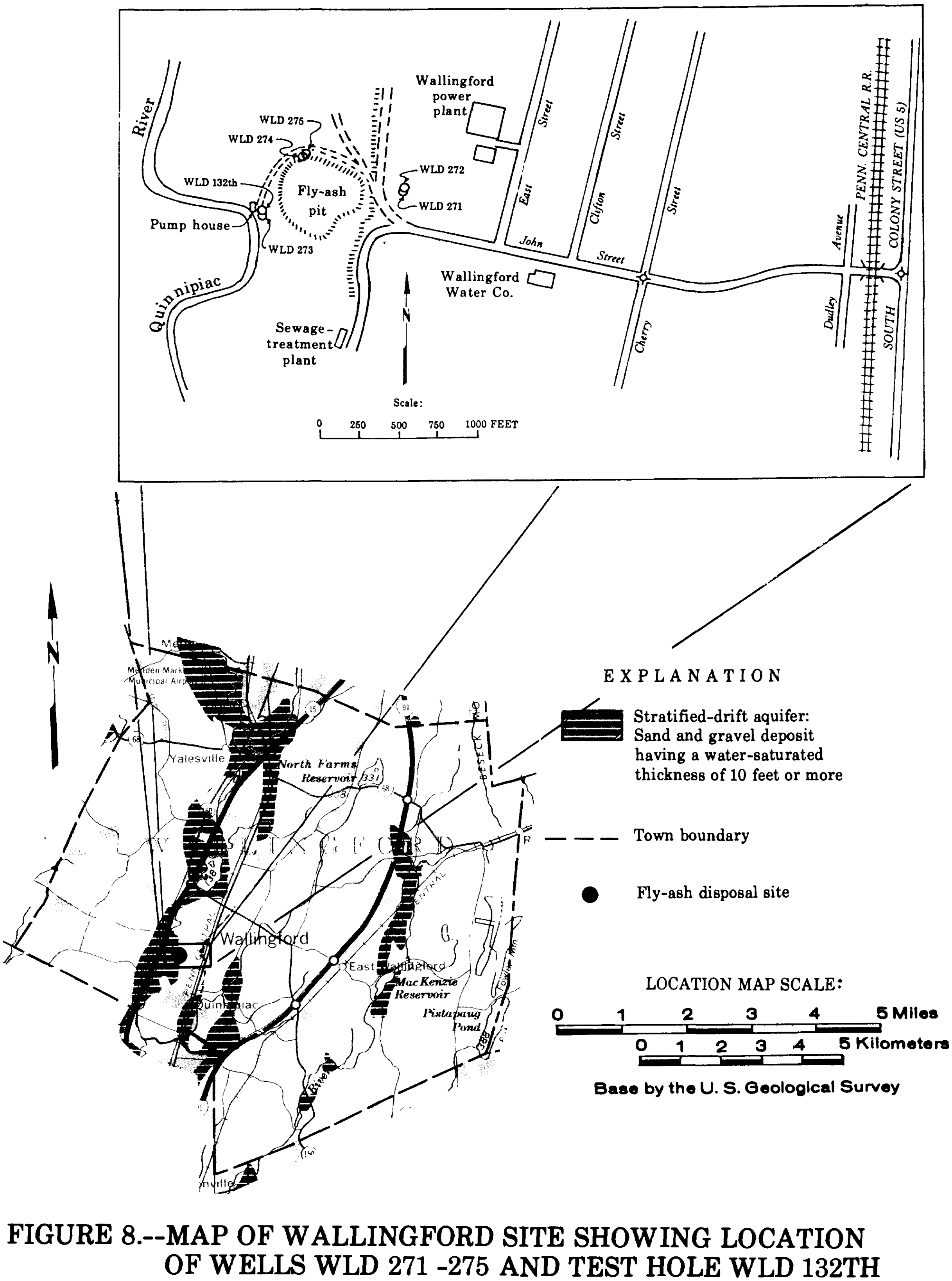


FIGURE 8.--MAP OF WALLINGFORD SITE SHOWING LOCATION OF WELLS WLD 271 -275 AND TEST HOLE WLD 132TH
(INSET-MAP SHOWS LOCATION OF DISPOSAL SITE AND STRATIFIED-DRIFT AQUIFERS IN WALLINGFORD)

Ash composition and solution

Fly ash consists of small glasslike spherical particles coated with metal oxides. Its composition differs, depending on the coal composition and source. Many laboratory and field studies have shown that substances can be leached from fly ash by solution in water. For example, Thomas and others (1968, p. 79-81), report an increase in sulfate, chloride, and dissolved solids in solutions from fly-ash deposits in the Hunts Brook area of Montville, Connecticut. Similar increases were observed in ground water near an ash pit in Wisconsin (Andrews and Anderson, 1978). Theis and Wirth (1977) report solution of metals, such as cadmium, nickel, lead, and arsenic, from the surface of ash particles, and Cox and others (1978) found that 50 percent of the boron in fly ash is leachable.

As leachate from fly-ash deposits percolates through unsaturated sediments, some metals may be adsorbed by oxides of iron, aluminum, and manganese and by organic materials (Theis and Wirth, 1977). Leached materials that reach the water table, however, affect ground-water quality.

Wallingford site

Description and history

The Pierce power station on East Road in Wallingford was chosen for this investigation because coal fly ash has been deposited there since 1953. The disposal area is on a thick stratified-drift deposit adjacent to the Quinnipiac River (fig. 8). Sediments range in particle size from clay and silt to very coarse sand, as indicated in the well logs in table 10. The land surface slopes toward the river, as does the bedrock surface.

The station generates peak power during two shifts daily. At the time of sampling (May 1978), fly ash was sluiced from the stack scrubber twice each shift using a mixture of public-supply and Quinnipiac River water and deposited in the disposal pit shown in figure 8. The ash slurry is temporarily ponded on site, allowed to dewater, and periodically hauled to the town landfill for use as cover material.

Table 10.--Logs of test holes at Wallingford coal-ash site[1/]

Well WLD 271. Site ID 412650072501101. Lat 41°26'50", long 72°50'11".

Owner: Town of Wallingford. Drilled water-table well in stratified drift, diam 2 in, depth 46.0 ft, cased with plastic PVC to 41.0 ft, with 5 ft of slotted plastic pipe 41.0-46.0 ft. LSD 54 ft above msl. MP is top of plastic casing 0.9 ft above LSD. Drilled April 21, 1978, by USGS. Location: 100 ft east of bank top dirt road and 200 ft north of John Street and about 250 ft west of substation, in open field on terrace.

Materials	Depth below LSD, in feet From	To
Sand, fine to very coarse, brown	0	19
Sand, medium to very coarse, red, some granules and pebbles; cobbles at 19, 24, and 25 ft	19	35
Sand, fine to coarse, red, some very fine, clean	35	47

Bottom of hole at 47 ft

Well WLD 272. Site ID 412650072501102. Lat 41°26'50", long 72°50'11".

Owner: Town of Wallingford. Drilled water-table well in stratified drift, diam 2 in, depth 87.1 ft, cased with plastic PVC to 82.1 ft, with 5 ft of slotted plastic pipe 82.1-87.1 ft. LSD 54 ft above msl. MP is top of plastic casing 1.3 ft above LSD. Drilled April 21, 1978, by USGS. Location: 2 ft north of well WLD 271.

Materials	Depth below LSD, in feet From	To
Sand, fine to very coarse, brown	0	19
Sand, medium to very coarse, red, with occasional pebble or cobble	19	35
Sand, very fine to very coarse, red, some granule gravel	35	87
Till(?)	87	88

Bottom of hole at 88 ft in till

Well WLD 273. Site ID 412653072502001. Lat 41°26'53", long 72°50'20".

Owner: Town of Wallingford. Drilled water-table well in stratified drift, diam 2 in, depth 22.6 ft, cased with plastic PVC to 17.6 ft, with 5 ft of slotted plastic pipe 17.6-22.6 ft. LSD 20 ft above msl. MP is top of plastic casing 2.5 ft above LSD. Drilled April 25, 1978, by USGS. Location: 35 ft east and 30 ft south of pump house, 30 ft northeast of Quinnipiac River bank.

Quinnipiac River stage 8.27 ft below MP on June 15, 1978.

Materials	Depth below LSD, in feet From	To
Sand, very fine to very coarse, some silt, red	0	9
Sand, fine to very coarse, and pebble gravel	9	12
Sand, fine to coarse, some granules, clean	12	20
Silt, red	20	33
Sand, gray, very fine to coarse	33	34

Bottom of hole at 35 ft

Well WLD 274. Site ID 412653072501701. Lat 41°26'53", long 72°50'17".

Owner: Town of Wallingford. Drilled water-table well in stratified drift, diam 2 in, depth 93.4 ft, cased with plastic PVC to 88.4 ft, with 5 ft of slotted plastic pipe 88.4-93.4 ft. LSD 20 ft above msl. MP is top of steel casing protector 1.6 ft above LSD and 0.27 ft below WLD 273 MP. Drilled April 27, 1978, by USGS. Location: 275 ft east of WLD 273, 30 ft west of dirt road, and 30 ft northeast of edge of fly-ash pit.

Materials	Depth below LSD, in feet From	To
Fly ash	0	2
Fly ash and swamp muck, brown	2	7
Sand, fine to coarse, some silt and clay	7	17
Sand, very fine and silt, red	17	37
Sand, very fine and silt	37	38
Silt and clay	38	52
Sand, very fine and silt	52	53
Clay, red	53	82
Clay, red, some silt	82	92
Sand, medium, some fine sand	92	93
Sand, very fine to fine	93	98
Till	98	104

Bottom of hole at 104 ft in till

Well WLD 275. Site ID 412653072501702. Lat 41°26'53", long 72°50'17".

Owner: Town of Wallingford. Drilled water-table well in stratified drift, diam 2 in, depth 18.0 ft, cased with plastic PVC to 13.0 ft, with 5 ft of slotted plastic pipe 13.0-18.0 ft. LSD 20 ft above msl. MP is top of steel casing protector at LSD and 1.94 ft below WLD 273 MP. Drilled April 27, 1978, by USGS. Location: 6 in north of WLD 274.

Material description same as WLD 274.

1/ Abbreviations used in table

ID	Identification no.
PVC	Polyvinyl chloride
LSD	Land surface datum
msl	Mean sea level
MP	Measuring point

Test hole WLD 132th. Site ID 412653072502002. Lat 41°26'53", long 72°50'20".

Owner: Town of Wallingford. Drilled with hollow-stem auger in stratified drift, depth 86 ft. LSD 20 ft above msl. Drilled April 26, 1978, by USGS. Location: 5 ft east of well WLD 273. Water level approximately 10 ft below LSD.

Materials	Depth below LSD, in feet From	To
Sand, very fine to very coarse, and gravel to pebble size	0	9
Sand, very fine to very coarse, and silty	9	20
Silt, red	20	28
Silt, red, firm, with layers of very fine sand	28	65
Sand, very fine to very coarse, with layers of silt and compact very fine to fine sand, and granule gravel	65	75
Sand, very fine to coarse, and silt	75	79
Till(?): sand, very fine to very coarse, silty, very compact, dry(?), cobbles at 80 and 82 ft	79	86

Bottom of hole at 86 ft in till

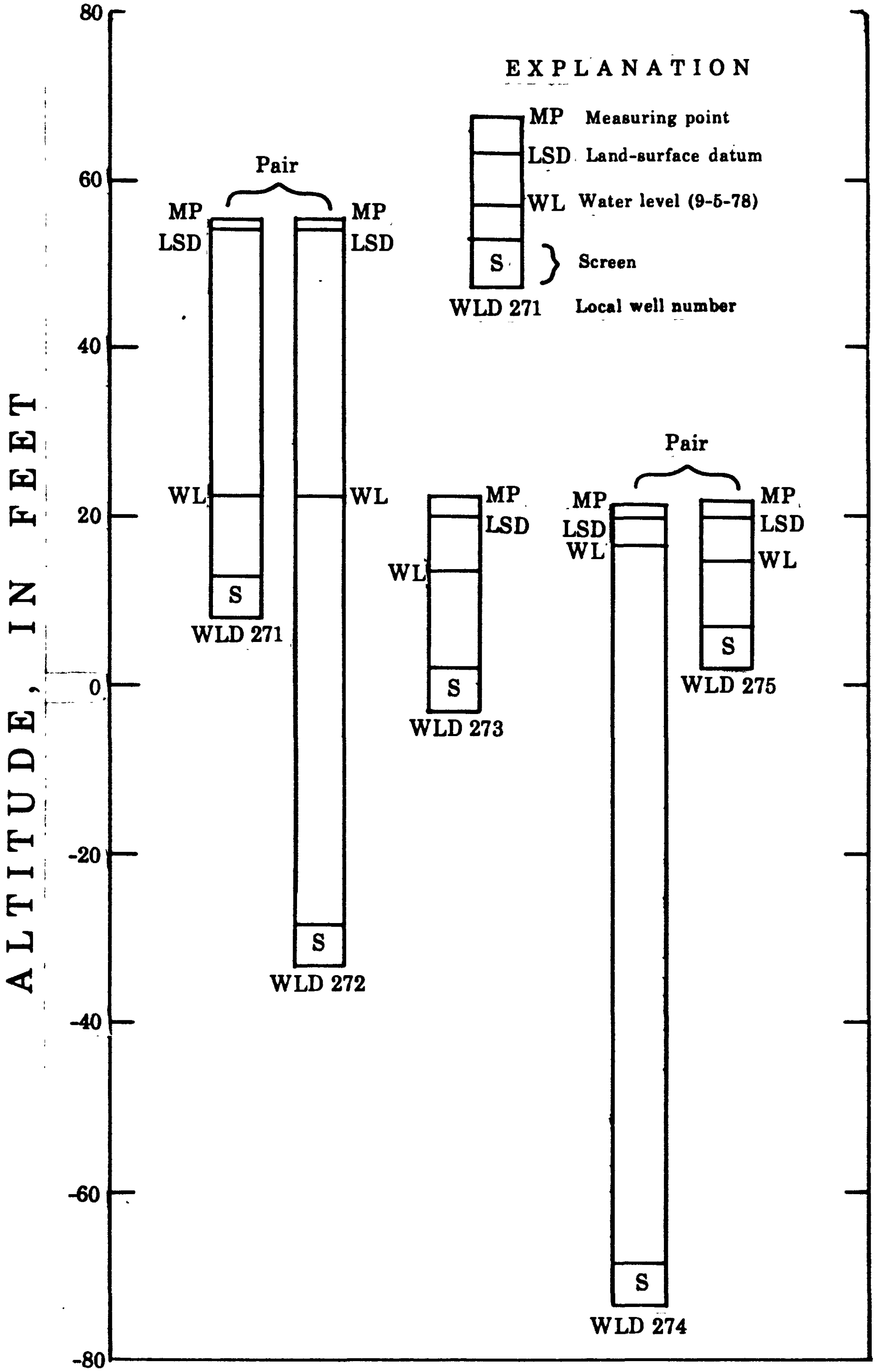


FIGURE 9.--WATER LEVELS IN WALLINGFORD WELLS

(FOR WELL LOCATIONS SEE FIGURE 8)

Six test holes were augered and five observation wells installed. The principal horizontal direction of ground-water flow is from east to west, toward the river. Two of the wells (WLD 271 and WLD 272) were installed upgradient from the current disposal area. Well WLD 274 is closest to the edge of the ponded fly-ash slurry and penetrates 2 to 7 feet of ash. Depth to bedrock is greater than 88 feet at the top of the bank (WLD 271) and greater than 104 feet at WLD 274. Sediments are coarser at WLD 271 and WLD 272 (ranging from fine sand to gravel), than at the other sites, where silt and clay predominate. (See logs in table 10.)

The altitude of the water table ranged from 22.3 feet above estimated msl at WLD 272 to 13.7 feet at WLD 273 on September 5, 1978, as shown in figure 9. For water levels on different dates, see table 11. Vertical flow is slightly upward at the east end of the disposal site and has a larger upward component nearer to the river, as shown by water-level altitudes in the two pairs of wells, WLD 271 and WLD 272, and WLD 274 and WLD 275. Ground water discharges to the Quinnipiac River.

Table 11.--Water-level altitudes in Wallingford test wells[1/]

Date	Local well number and relative altitude of land surface[2/]				
	WLD 271 53.8	WLD 272 53.9	WLD 273 19.6	WLD 274 20.3	WLD 275 20.3
5/18/78	24.8	--	--	--	--
5/23/78	--	--	15.7	--	--
5/25/78	--	--	--	16.8	--
6/2/78	--	--	--	--	15.6
6/5/78	--	24.9	--	--	--
6/6/78	--	--	--	17.2	--
8/31/78	22.3	22.4	13.8	--	--
9/5/78	22.3	22.3	13.7	16.3	14.8

1/ Water-level altitude based on depths to water in wells, measured to nearest hundredth foot.

2/ Relative altitude of land surface determined to nearest hundredth foot by differential (spirit) leveling from a datum (estimated mean sea level).

Table 12.--Analyses of ground water at fly-ash-disposal site

(Chemical constituents dissolved unless otherwise indicated; concentrations in milligrams per liter)

Constituent or property	Well number, depth, and date sampled: WLD 271 (46.0 ft) 5-18-78	WLD 273 (22.6 ft) 5-23-78	WLD 274 (93.4 ft) 7-26-78	Limiting Value	Basis (A)
Alkalinity, as $CaCO_3$	40	140	74	--	--
Aluminum (Al)	C	C	.07 B	--	--
Antimony (Sb)	C	C	C	.050	3
Arsenic (As)	.0	.0	.003	.050	1,3
Barium (Ba)	.1 B	.1 B	.1 B	1	1,2
Beryllium (Be)	C	C	C	.011	2,3
Bismuth (Bi)	C	C	C	--	--
Boron (B)	.07 B	.3 B	.1 B	.75	2
Cadmium (Cd)	.002	.003B	C	.010	1,3
Calcium (Ca)	33	55	34	--	--
Carbon (C), organic	16	4.5	7.9	--	--
Carbon (C), organic, suspended	.1	--	.8	--	--
Chloride (Cl)	50	18	13	250 D	1
Chromium (Cr)	C	C	.080	.050	1,3
Cobalt (Co)	C	C	C	--	--
Copper (Cu)	C	C	.03 B	1.0	1,3
Gallium (Ga)	C	C	C	--	--
Germanium (Ge)	.03 B	.05 B	C	--	--
Hardness, as $CaCO_3$	110	180	110	--	--
Iron (Fe)	.03	.10	.00	.3	2
Lead (Pb)	C	C	C	.050	1,3
Lithium (Li)	C	.01 B	C	--	--
Magnesium (Mg)	6.5	10	5.4	--	--
Manganese (Mn)	.01	.94	.16	.05	2
Mercury (Hg)	.0	.0	.0	.002	1,3
Molybdenum (Mo)	C	C	C	--	--
Nickel (Ni)	C	C	C	.10	2,3
pH, units	7.0	7.2	8.1	--	--
Potassium (K)	1 B	3 B	1 B	--	--
Selenium (Se)	.0	.0	.0	.010	1,3
Silica (SiO_2)	10 B	30 B	10 B	--	--
Silver (Ag)	C	C	C	.050	1,3
Sodium (Na)	14	20	14	20	1
Specific conductance, in umhos/cm	224	465	340	--	--
Strontium (Sr)	.1 B	.3 B	.3 B	--	--
Sulfate (SO_4)	23	88	50	--	--
Tin (Sn)	C	C	C	--	--
Titanium (Ti)	C	C	C	--	--
Vanadium (V)	C	C	C	--	--
Zinc (Zn)	.03 B	.340	.007B	5	2,3
Zirconium (Zr)	C	C	C	--	--

A 1 Maximum permissible level for drinking water, Connecticut Public Health Code Regulation 19-13-B102 (Connecticut General Assembly, 1975)

2 Most stringent criterion recommended by U.S. Environmental Protection Agency (1976)

3 Constituent is on list of toxic substances established by the U.S. Environmental Protection Agency (1978) pursuant to section 307 of Public Law 92-500.

B Semiquantitative analysis. Results are rounded to nearest reporting level. Reporting levels range from the detection limit upward in steps of 1, 3, 5, 7, and 10. Results are reported to one significant figure only.

C Not detected; semiquantitative analysis.

D Background level for most waters in State is less than 20 mg/L.

Ground-water quality

Samples were collected from three wells, one upgradient from the disposal area (WLD 271), one downgradient (WLD 273), and one in an intermediate position (WLD 274). Chemical analyses, shown in table 12, indicate that ground-water quality at all three sites may have been affected by the waste-disposal product. The low hydraulic conductivity of the sediments and the predominantly lateral flow pattern, however, have kept the effects to a minimum.

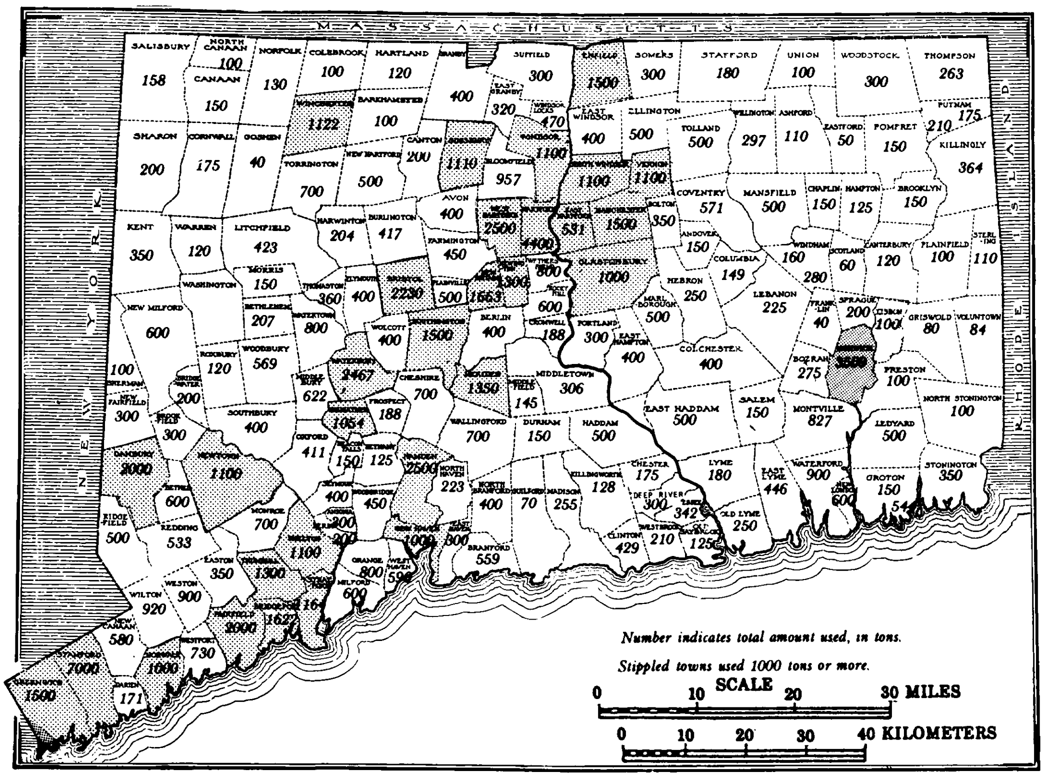
Dissolved organic carbon concentration is elevated in water from the upgradient well (WLD 271), but, based on the location of the well and the overall quality of the water sample, it probably does not represent fly ash contamination. The chromium concentration in the water from the intermediate well (WLD 274) exceeds the limit for public drinking water supplies (Connecticut General Assembly, 1975). Water from the downgradient well (WLD 273) has elevated calcium, sodium, manganese, zinc, and sulfate concentrations. Elevated sulfate concentration has been related to fly-ash contamination in Montville (Thomas and others, p. 80, 1968).

ROAD-SALT STORAGE

Road maintenance in Connecticut uses deicing chemicals, primarily sodium chloride, in winter. The 169 towns use a total of about 100,000 tons on town roads in a typical winter, and the State Department of Transportation (DOT) uses a similar amount on State-maintained roads (Handman and others, 1979). The distribution of salt use by Connecticut towns is shown in figure 10.

Salt is stored at more than 300 sites throughout the State. The locations are shown on a map by Bingham and Rolston (1978). At most of the 100 DOT storage areas, raw salt is kept in sheds or covered bins, and salt mixed with sand is stored on sealed paved areas (Button and Kasinskas, 1975). Town storage practices range from sheds and covered stockpiles on pavement to open piles on unpaved ground. Many stockpiles are located over stratified-drift aquifers considered favorable for large water supplies, and several instances of ground-water quality being affected by road salt have been documented (Handman and others, 1979; Bingham and Rolston, 1978). The DOT reports salt from stockpiles has been detected in ground water as far as 600 feet from the storage area.

Because alternative chemical and physical deicers are costly, and some are more harmful than salt, it is likely that at least some sodium chloride will continue to be utilized for snow and ice control in Connecticut. For a discussion of alternatives to current practices, see Handman and others (1979).



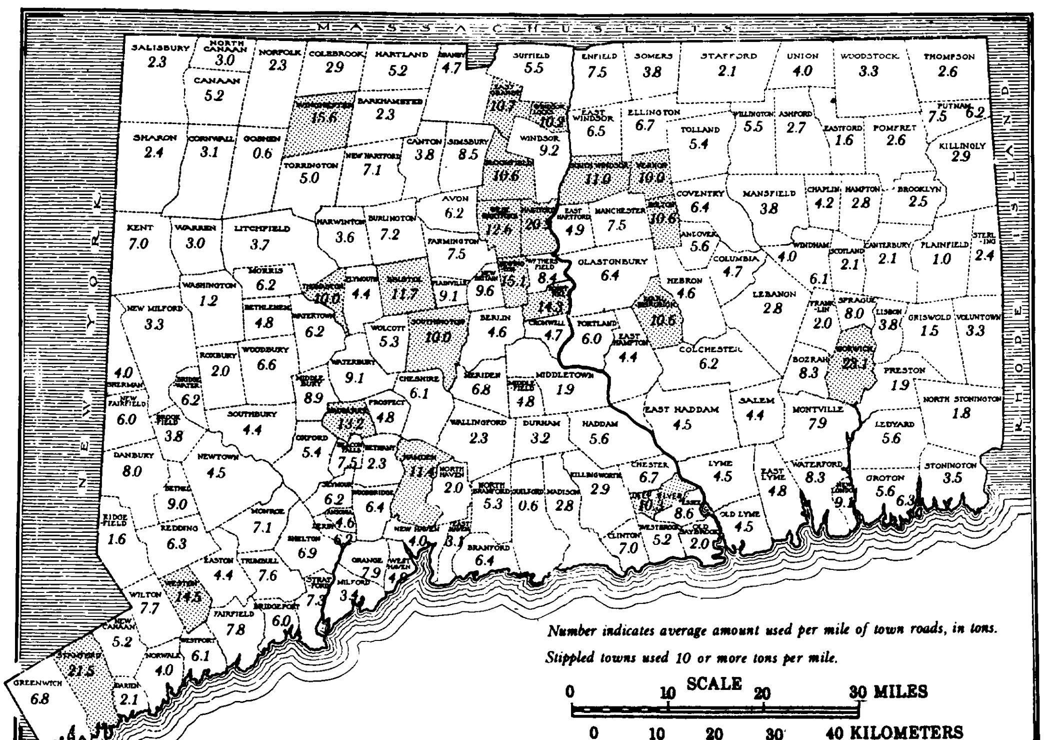


FIGURE 10.--ROAD-SALT USE REPORTED BY TOWNS, WINTER OF 1976-77

(USE IS BASED IN PART ON AMOUNT OF SNOW ACCUMULATION, NUMBER OF SNOW AND ICE STORMS, AND ROAD CHARACTERISTICS SUCH AS HILLS, CURVES, AND INTERSECTIONS, AS WELL AS RATIO OF SALT TO SAND USED AND APPLICATION RATES. FROM BINGHAM AND ROLSTON, 1978.)

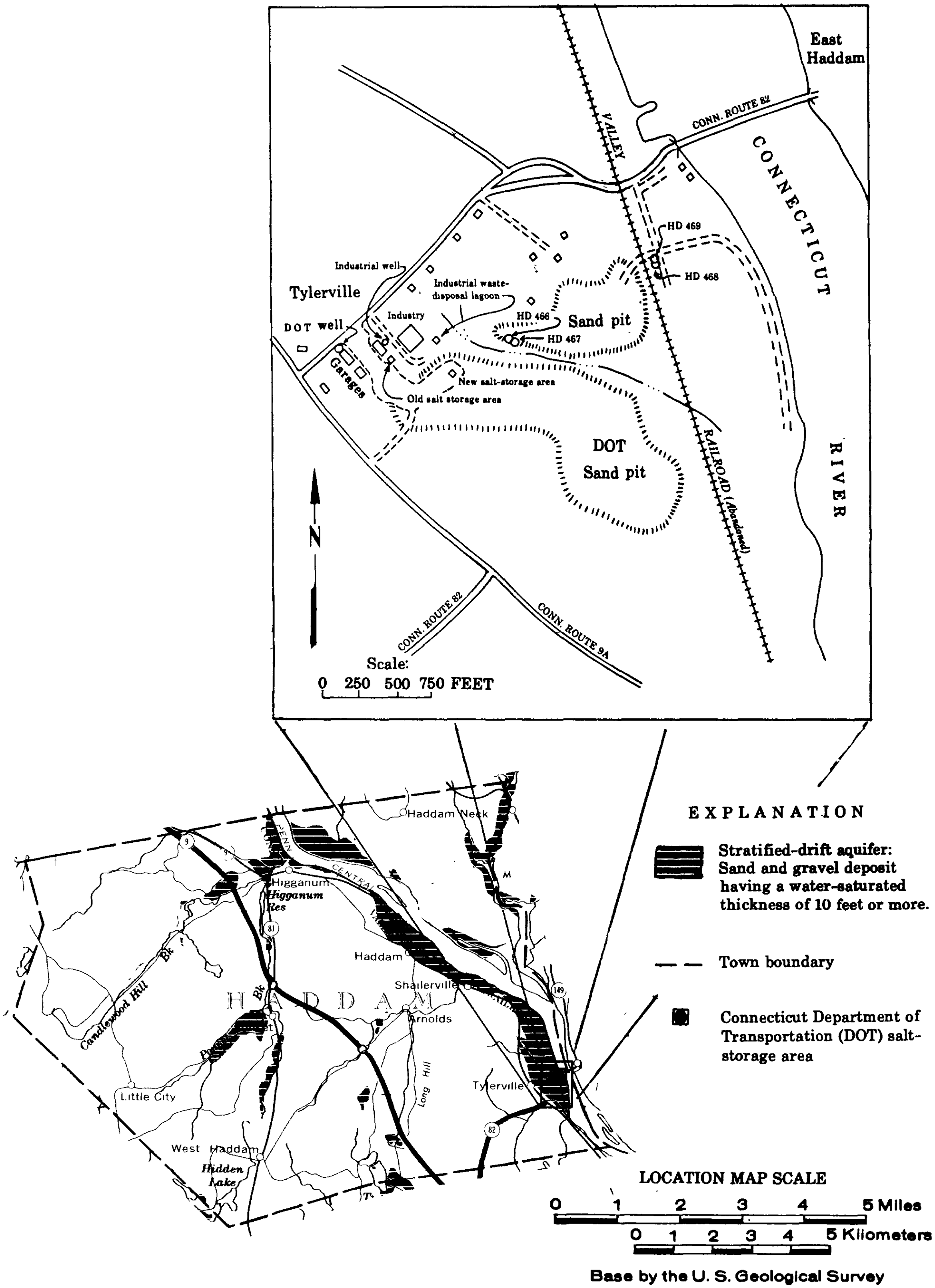


FIGURE 11.--MAP OF HADDAM SITE SHOWING LOCATION OF WELLS HD 466 - 469

(INSET-MAP SHOWS LOCATION OF SALT-STORAGE AREA AND STRATIFIED-DRIFT AQUIFERS IN HADDAM. FROM BINGHAM AND ROLSTON, 1978.)

Table 13.--Logs of test holes at Haddam salt-storage facility 1/

Well HD 466. Site ID 412654072281601.
Lat 41°26'54", long 72°28'16".

Owner: Paul Zurles, Rt. 9A, Haddam. Drilled water-table well in stratified drift, diam 2 in, depth 113.9 ft, cased with plastic PVC to 108.9 ft, with 5 ft of slotted plastic PVC pipe 108.9-113.9 ft. LSD 28 ft above msl and 18.50 ft above HD 469 LSD. MP is top of steel protective casing 1.63 ft above LSD. Drilled May 16, 1978 by USGS.
Location: about 800 ft west of railroad tracks along trail through sand pit and 30 ft north of ravine; 6 in from well HD 467.

Materials	Depth below LSD, in feet From	To
Sand, fine to medium	0	22
Sand, fine; trace of medium to coarse	22	37
Sand, coarse; some medium	37	48
Sand , fine to coarse; trace of silt and clay; little very fine sand	48	52
Sand, fine; some medium; trace of silt and clay	52	80
Sand, medium; trace of silt and clay; thin layers of pebble gravel	80	90
Sand, medium; trace of silt and clay	90	107
Sand, fine; some medium; little very fine sand	107	137
Till(?)	137	138

Bottom of hole at 138 ft

Well HD 467. Site ID 412654072281602.
Lat 41°26'54", long 72°28'16".

Owner: Paul Zurles, Rt. 9A, Haddam. Drilled water-table well in stratified drift, diam 2 in depth 43.45 ft cased with plastic PVC to 38.5 ft, with 5 ft of slotted plastic PVC pipe 38.5-43.45 ft. LSD 28 ft above msl. MP is top of plastic coupling 3.17 ft above LSD. Drilled May 16, 1978, by USGS.
Location: 6 in from HD 466.

Material description same as HD 466
(Well installed in same test hole)

1/ Abbreviations used in table
- ID Identification no.
- PVC Polyvinyl chloride
- LSD Land surface datum
- msl Mean sea level
- MP Measuring point

Well HD 468. Site ID 412656072280201.
Lat 41°26'56", long 72°28'02".

Owner: Paul Zurles, Rt. 9A, Haddam. Drilled water-table well in stratified drift, diam 2 in depth 98.8 ft, cased with plastic PVC to 93.8 ft, with 5 ft of slotted plastic PVC pipe 93.8-98.8 ft. LSD 10 ft above msl. MP is top of plastic coupling 1.17 ft above LSD. Drilled May 17, 1978, by USGS.
Location: 70 ft east of old railroad tracks, 10 ft south of trail across tracks into sand pit, at edge of graded level area, and about 100 ft south of Conn. Rt. 82.

Materials	Depth below LSD, in feet From	To
Sand, fine to medium (fill)	0	8
Silt and clay, gray	8	17
Sand, fine to very fine, gray	17	22
Silt and clay, gray	22	37
Clay, gray	37	45
Sand, medium to coarse, gray; interbedded gray silt and clay	45	49
Sand, fine to very coarse, in brown and gray layers; sime very fine gravel; trace of silt and clay	49	88
Sand, medium to very coarse; trace of silt and clay; and hard-packed gravel layer	88	97
Sand, medium to very coarse, with fine gravel layers	97	108
Sand, fine to very coarse, some fine gravel; trace of silt and clay	108	124
Till(?), silt and clay, with stiff and bumpy drilling	124	129

Bottom of hole at 129 ft

Well HD 469. Site ID 412656072280202.
Lat 41°26'56", long 72°28'02".

Owner: Paul Zurles, Rt. 9A, Haddam. Drilled water-table well in stratified drift, diam 2 in depth 50.2 ft, cased with plastic PVC pipe, open ended - no screen. LSD 10 ft above msl. MP is top of plastic coupling 1.46 ft above LSD. Drilled May 17, 1978, by USGS.
Location: 5 ft northwest of HD 468, 70 ft east of old railroad tracks, about 700 ft south of Conn. Rt. 82, and just south of entrance into sand pit.

Material description same as HD 468.

Haddam Site

Description and history

Road salt has been stored on Connecticut DOT property in the Tylerville section of Haddam since before 1970. The site is on Route 82, east of Route 9A. (See figure 11.) The land surface slopes to the east, toward the Connecticut River. The area is underlain by more than 130 feet of stratified deposits of fine to medium sand with some silt and clay layers, as indicated by the well logs in table 13. The areal extent of the aquifer is shown in figure 11.

The quality of water from an industrial well (fig. 11) downgradient (northeast) from the stockpile was affected by the salt; in 1974, chloride concentrations had risen to 245 mg/L. The salt pile was moved to a new location on the same property during the following year. Since that time, chloride concentrations have continued to fluctuate annually, reaching a high of 359 mg/L in 1975 and diminishing since (Connecticut Department of Transportation, 1978, written communication). Water in the DOT well upgradient from both the former and present (1978) stockpile locations is reported by DOT to be unaffected by salt.

Table 14.--Water-level altitudes in Haddam test wells[1/]

Date	Local well number and relative altitude of land surface[2/]			
	HD 466 28.2	HD 467 28.2	HD 468 10.0	HD 469 10.0
5/25/78	--	--	--	4.6
5/26/78	--	5.4	--	--
5/30/78	--	--	3.7	--
5/31/78	4.5	--	--	--
8/30/78	3.4	5.2	2.6	3.4

[1/] Water-level altitudes based on depths to water in wells, measured to nearest hundredth foot.

[2/] Relative altitude of land surface determined to nearest hundredth foot by differential (spirit) leveling from a datum (estimated mean sea level).

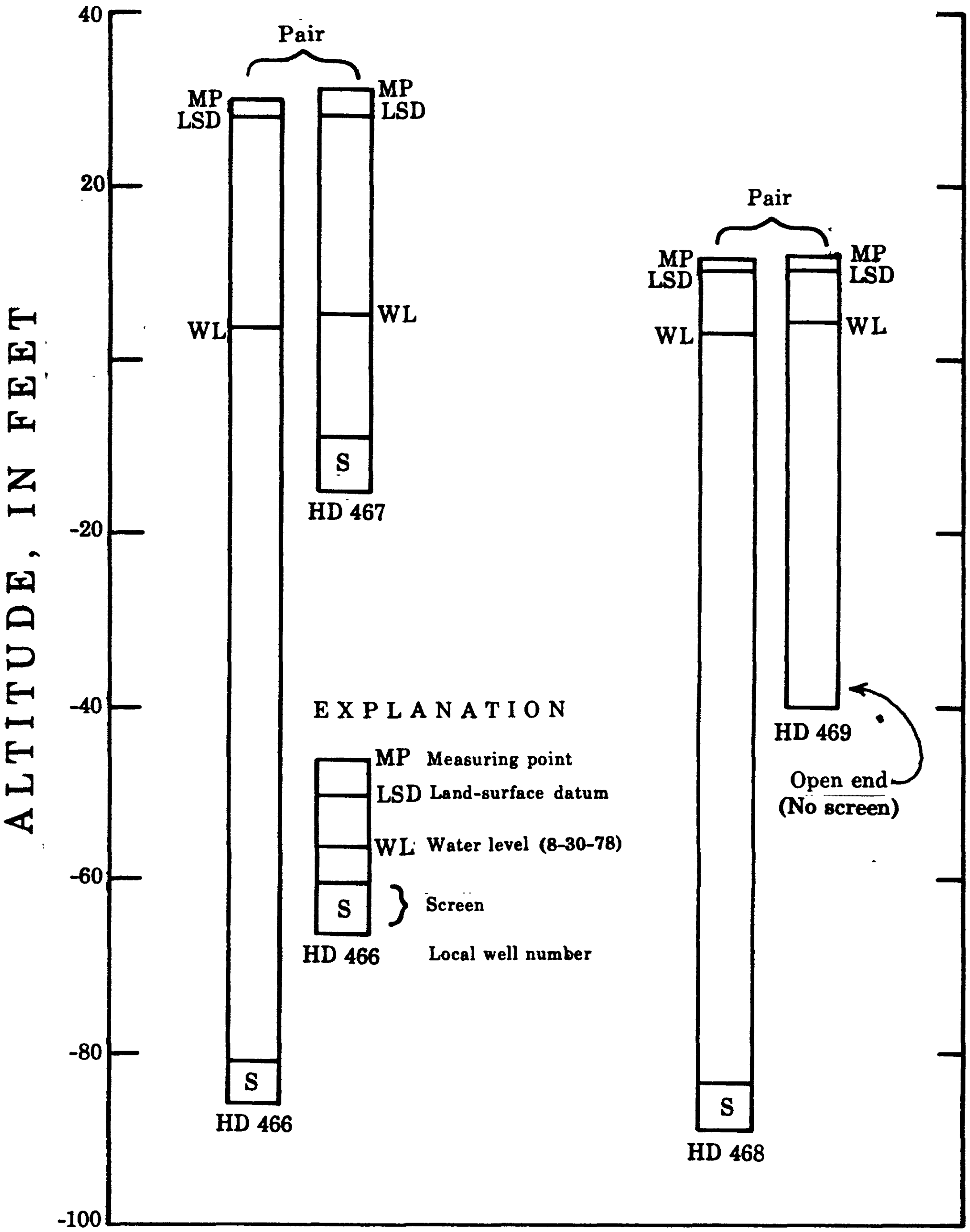


FIGURE 12.--WATER LEVELS IN HADDAM WELLS

(FOR WELL LOCATIONS SEE FIGURE 11)

Geologic and hydrologic data

Two test holes were augered downgradient (east-northeast) from the salt-storage area (fig. 11). A pair of observation wells consisting of one relatively shallow and one deeper well were installed in each hole. (HD 466 and HD 467 at one site, and HD 468 and HD 469 at the other.)

Depth to bedrock is more than 138 feet at HD 466 and HD 467, and more than 129 feet at HD 468 and HD 469. Sediments are coarser in the first set, consisting mainly of fine to coarse sand, than in the second set, where silt and clay layers are common in the upper part of the section. (See logs in table 13.)

The altitude of the water table on August 30, 1978, ranged from 5.2 feet above estimated msl in HD 467 to 2.6 feet in HD 468, as shown in figure 12. In both sets of wells water-level altitudes are higher in the shallower well, indicating that the vertical component of flow is downward. The horizontal flow direction is toward the Connecticut River, the natural point of ground-water discharge. For water-level altitudes on different dates, see table 14.

Ground-water quality

Samples were collected from the two pairs of wells, HD 466 and HD 467 and HD 468 and HD 469, in May 1978 and analyzed for physical properties, major chemical constituents, and trace metals. Water from the deeper well of the first pair, HD 466, has the lowest specific conductance, an indication of its low dissolved-solids content, and has low concentrations of sodium (4.4 mg/L) and chloride (3.7 mg/L), as shown in table 15. No constituents measured in this water exceed the limiting values given in the table. The water represents background quality and meets the standards for public drinking water set by the Connecticut Department of Health (Connectiuct General Assembly, 1975). The vertical component of ground-water flow is downward at this site, but, at the time of sampling, leachate had not reached the well screen.

In contrast, water from HD 467, the shallower well at the same site, is the most mineralized of the four samples, having a high specific conductance (2315 umho/cm) and high concentrations of sodium (450 mg/L) and chloride (750 mg/L). This water does not meet the State standards for public water supplies. The ratio of sodium to chloride in this sample is approximately equal to that of sodium to chloride in road salt, indicating that the salt stockpile is the probable source.

Table 15.--Analyses of ground water from road-salt storage site

(Chemical constituents dissolved unless otherwise indicated; concentrations in milligrams per liter)

Constituent or property	Well number, depth, and date sampled HD 466 (113.9 ft) 5-26-78	HD 467 (43.4 ft) 5-26-78	HD 468 (98.8 ft) 5-30-78	HD 469 (50.2 ft) 5-25-78	Limiting value	Basis (A)
Alkalinity, as $CaCO_3$	27	40	52	44	--	--
Aluminum (Al)	C	C	C	C	--	--
Antimony (Sb)	C	C	C	C	.050	3
Barium (Ba)	.01 B	.70	.1 B	.03 B	1	1,2
Beryllium (Be)	C	C	C	C	.011	2,3
Bismuth (Bi)	C	C	C	C	--	--
Boron (B)	.01 B	.05 B	.1 B	.01 B	.75	2
Cadmium (Cd)	.003B	.047	.001B	.003B	.010	1,3
Calcium (Ca)	10	24	39	15	--	--
Carbon (C), organic	3.8	9.5	7.7	13	--	--
Carbon (C), organic, suspended	.2	.1	.2	.2	--	--
Chloride (Cl)	3.7	730	40	12	250 D	1
Chromium (Cr)	C	C	.36	C	.050	1,3
Cobalt (Co)	.005B	.006	C	C	--	--
Copper (Cu)	C	.073	C	.01 B	1.0	1,3
Gallium (Ga)	C	C	C	C	--	--
Germanium (Ge)	C	C	.03 B	C	--	--
Hardness, as $CaCO_3$	31	76	130	51	--	--
Iron (Fe)	.01	.12	.03	.04	.3	2
Lead (Pb)	C	.03	.015	C	.050	1,3
Lithium (Li)	C	C	.01 B	C	--	--
Magnesium (Mg)	1.5	3.9	8.0	3.4	--	--
Manganese (Mn)	.02	2.3	.38	.03	.05	2
Molybdenum (Mo)	C	C	C	C	--	--
Nickel (Ni)	C	C	C	C	.10	2,3
pH, units	8.0	5.4	7.0	6.1	--	--
Potassium (K)	3 B	10 B	5 B	3 B	--	--
Silica (SiO_2)	10 B	10 B	30 B	10 B	--	--
Silver (Ag)	C	C	C	C	.050	1,3
Sodium (Na)	4.4	450	13	7.4	20	1
Specific conductance, in umhos/cm	103	2600	390	167	--	--
Strontium (Sr)	.03 B	.1 B	.1 B	.05 B	--	--
Sulfate (SO_4)	7.3	15	54	11	--	--
Tin (Sn)	C	C	.1 B	C	--	--
Titanium (Ti)	C	C	C	C	--	--
Vanadium (V)	C	C	C	C	--	--
Zinc (Zn)	.01 B	1.8	.05 B	.17	5	2,3
Zirconium (Zr)	C	C	C	C	--	--

A 1 Maximum permissible level for drinking water, Connecticut Public Health Code Regulation 19-13-B102 (Connecticut General Assembly, 1975)

2 Most stringent criterion recommended by U.S. Environmental Protection Agency (1976)

3 Constituent is on list of toxic substances established by the U.S. Environmental Protection Agency (1978) pursuant to section 307 of Public Law 92-500.

B Semiquantitative analysis. Results are rounded to nearest reporting level. Reporting levels range from the detection limit upward in steps of 1, 3, 5, 7, and 10. Results are reported to one significant figure only.

C Not detected; semiquantitative analysis.

D Background level for most waters in State is less than 20 mg/L.

The sample also contains measurable concentrations of several trace metals, notably barium, cadmium, cobalt, copper, lead, and zinc, which may have been leached from sediments by the relatively acidic (pH 5.4) ground water or migrated from an industrial waste-disposal lagoon. (See fig. 11.) Metal concentrations are lower in water from the adjacent deeper well, HD 466.

The second set of wells, HD 468 and HD 469, show a change in flow pattern in that water from the deeper well of this pair has higher sodium and chloride concentrations than water from the shallower well. These concentrations are above natural levels but within the standards for public drinking water. The water from observation well HD 469 also contains high concentrations of chromium, 360 ug/L, which is more than 7 times the limit for public drinking water. This is above background levels and may have been leached from the industrial waste-disposal lagoon.

SOLID WASTE

Connecticut generates about 8,000 tons of solid waste per day, based on a rate of 5.3 pounds per person per day (estimate from Zanoni, 1972). This waste has been deposited or stored in more than 250 landfills, transfer stations, and incinerators throughout the State; 185 are actively in use (Connecticut Department of Environmental Protection, 1978). The locations of known disposal sites are shown on a map by Rolston, Pregman, and Handman (1978).

When water comes in contact with refuse, leachate is produced. The water comes from precipitation that penetrates the cover material, from the initial moisture of the solid wastes, and from ground water. Refuse decays quickly in humid areas, such as Connecticut, because the soil usually contains a large amount of moisture. The average annual precipitation in Connecticut is 44 to 48 inches distributed evenly throughout the year (Brumbach, 1965), which is equivalent to 800 million gallons for every square mile (or 1.25 million gallons for every acre) each year. About half is evaporated and transpired, mainly during the growing season. The remainder either flows overland directly into streams, or infiltrates the ground (or the solid waste), moves vertically downward to the water table, and eventually discharges to a stream, lake, spring, or well.

Leachate is partly renovated in the unsaturated zone beneath the landfill, but many dissolved constituents pass through unchanged. In Connecticut, at least 24 landfills are known to have affected ground-water quality, and many others are being investigated (Connecticut Department of Environmental Protection, 1977, written communication).

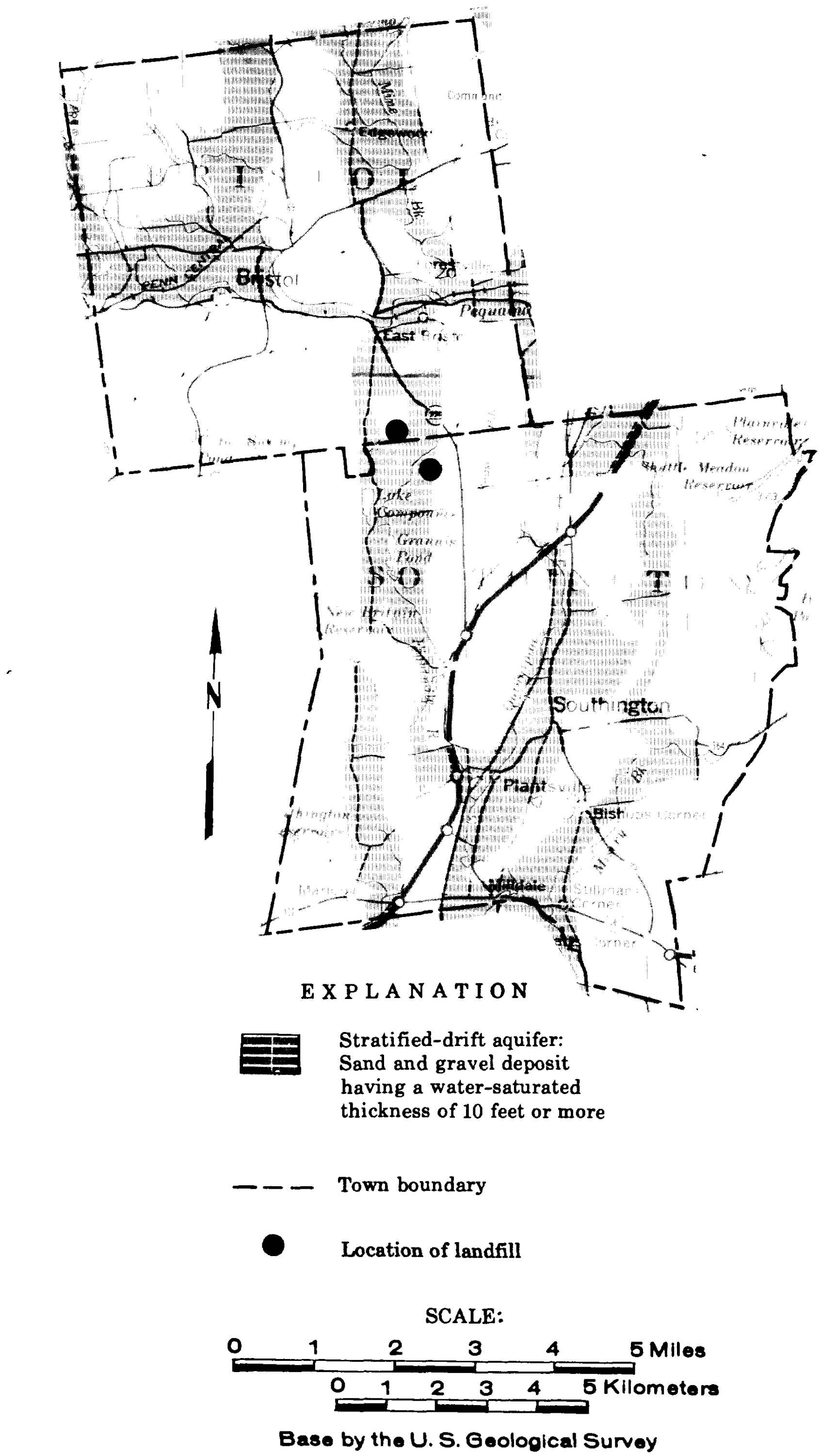


FIGURE 13.--LOCATION OF LANDFILLS IN BRISTOL AND SOUTHINGTON

(FROM ROLSTON, PREGMAN, AND HANDMAN, 1978)

The Bristol and Southington landfills were selected for this study because they have been in operation for several years (Bristol for more than 50 years and Southington since 1967). They are located on an areally extensive, thick coarse-grained stratified-drift deposit (see fig. 13). The Bristol landfill is being considered for expansion.

Bristol Site

Description and history

The 55-acre Bristol landfill, on the Bristol-Southington town line between Lake Avenue and Middle Street, is in the Eightmile River basin. It is classified by the Connecticut Department of Environmental Protection (DEP) as a mixed-waste disposal area and currently (1978) accepts a variety of wastes, including industrial sludges. An average of 180 tons per day is deposited, or approximately 146,000 cubic yards annually. The life of the landfill is projected to 1983 (Maguire, 1977). The landfill is owned by and serves the town of Bristol and is authorized by the DEP. An engineering study is underway for a DEP permit for expansion.

The topography is complex and continually changing because of gravel excavations and landfilling operations. The land surface generally slopes toward the Eightmile River and its tributaries. (See fig. 14). The area is underlain by fine to very coarse sand and gravel, as indicated by the well logs in table 16. The probable areal extent of the aquifer is shown in figure 13.

Geologic and hydrologic data

Eight test holes were augered and observation wells installed at sites in and adjacent to the landfill. (See fig. 14 for well locations.) Depth to bedrock is greater than 85 feet at the deepest well, BS 269. Table 16 shows that sediments consist primarily of fine to very coarse sand interbedded with pebble gravel and a few silty layers. This material is used as cover over solid waste in the landfill.

The altitude of the water table, measured May 18, 1978, ranged from 210.8 feet above estimated msl in well BS 272 to 200.1 feet in well S 382, as shown in figure 15. The water table slopes toward the Eightmile River and its tributaries, which are the local ground-water discharge areas. In wells BS 269 and BS 270 the water level was nearly the same, indicating that the principal flow direction was horizontal. In the other pair of wells, S 380 and S 381, the water level was slightly higher in the shallower well, indicating recharge to the aquifer. The vertical component of ground-water flow is downward at this site. The

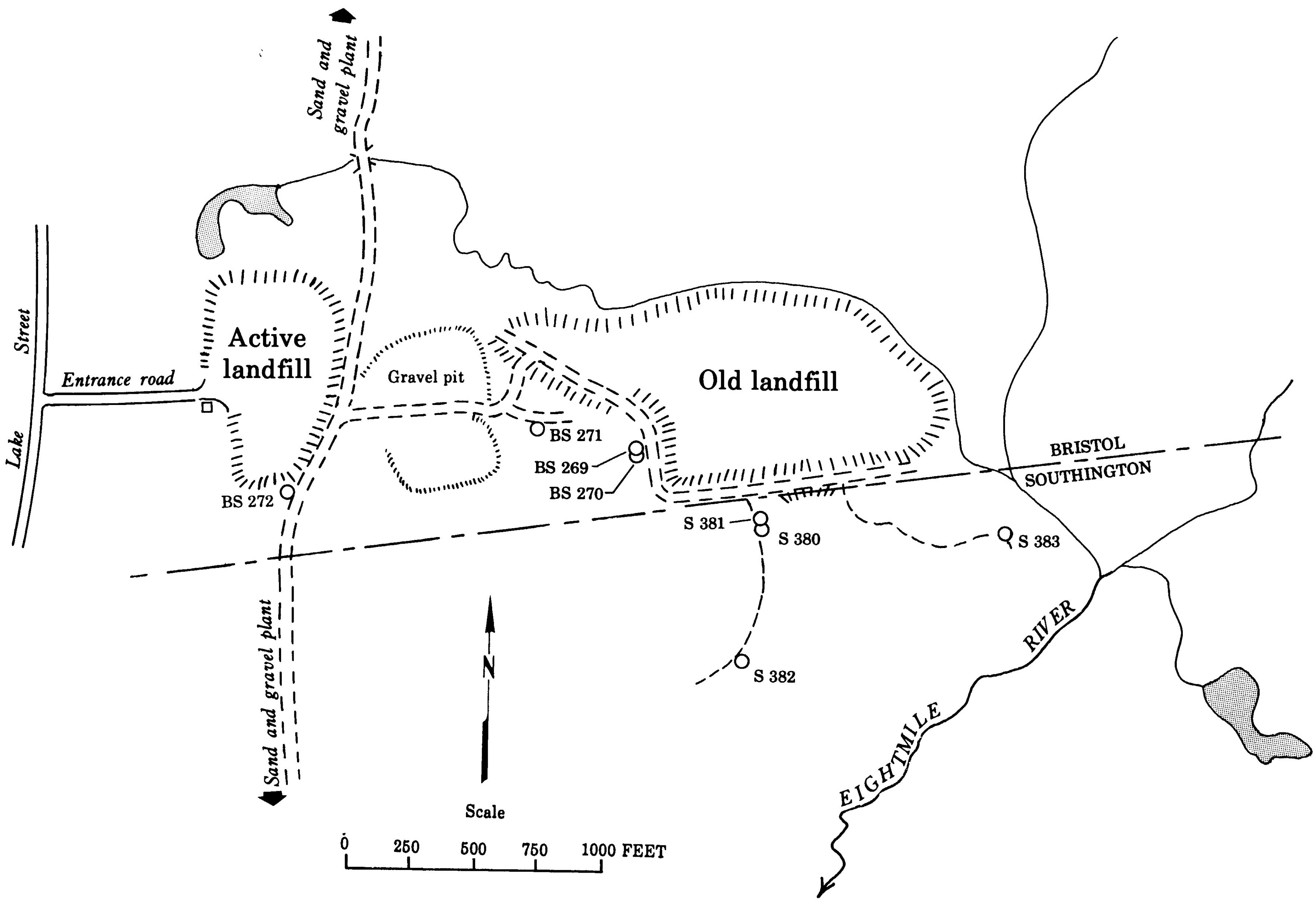


FIGURE 14.--MAP OF BRISTOL SITE SHOWING LOCATION OF S 380 - 383 AND BS 269 - 272

Table 16.--Logs of test holes at Bristol landfill[1/]

Well BS 269. Site ID 413850072545401.
Lat 41°38'50", long 72°54'54".

Owner: Angelo Tomasso Inc. Drilled water-table well in stratified drift, diam 2 in, depth 81.8 ft, cased with plastic PVC to 76.8 ft, with 5 ft of slotted plastic pipe 76.8-81.8 ft. LSD 245 ft above msl. MP is top of plastic casing 1.7 ft above LSD. Drilled May 4, 1978 by USGS.
Location: 45 ft west southwest of corner monument at inside corner of landfill and point of woods; south side of Bristol landfill.

Materials	Depth below LSD, in feet From	To
Sand, medium to very coarse, and gravel, granule to pebble, very clean	0	7
Sand, fine to very coarse, few granules, clean	7	11
Sand, fine to coarse, clean	11	21
Sand, fine to coarse, few pebbles and granules	21	34
Sand, fine to very coarse, some granule to pebble gravel, clean	34	55
Sand, very fine to fine	55	75
Sand, fine to very coarse, silty, and granule to pebble gravel	75	84
Till, red-brown, sandy, pebbly	84	85

Bottom of hole at 85 ft in till

Well BS 270. Site ID 413849072545501.
Lat 41°38'49", long 72°54'55".

Owner: Angelo Tomasso Inc. Drilled water-table well in stratified drift, diam 2 in, depth 48.8 ft, cased with plastic PVC to 43.8 ft, with 5 ft slotted plastic pipe 43.8-48.8 ft. LSD 245 ft above msl. MP is top of plastic casing 0.7 ft above LSD and 0.74 ft below BS 269 MP. Drilled May 8, 1978, by USGS.
Location: 5 ft south of BS 269, about 100 ft south and west of landfill.

Material description same as BS 269

Well BS 271. Site ID 413849072550001.
Lat 41°38'49", long 72°55'00".

Owner: Town of Bristol. Drilled water-table well in stratified drift, diam 2 in, depth 26.6 ft, cased with plastic PVC to 21.6 ft, with 5 ft of slotted plastic PVC pipe from 21.6-26.6 ft. LSD 213 ft above msl. MP is top of plastic casing 0.9 ft above LSD (road fill) and 32.4 ft below BS 269 MP. Drilled May 10, 1978, by USGS.
Location: On south edge of bulldozed road in low area, about 30 ft south of and below sludge pits, 175 ft southeast of eastern concrete-block shed.

Materials	Depth below LSD, in feet From	To
Fill, sandy	0	5
Silt, sandy, black	5	6
Sand, fine to very coarse, and granule gravel	6	21
Sand, fine to very coarse, and gravel, granule to cobble, silty	21	29

Bottom of hole at 29 ft

Well BS 272. Site ID 413844072551201.
Lat 41°38'46", long 72°55'12".

Owner: Angelo Tomasso Inc. Drilled water-table well in stratified drift, diam 2 in, depth 40.6 ft, cased with plastic PVC to 35.6 ft, with 5 ft slotted plastic pipe 35.6-40.6 ft. LSD 231 ft above msl. MP is top of plastic casing 1.4 ft above LSD and 14.0 ft below BS 269 MP. Drilled May 11, 1978, by USGS.
Location: 50 ft west of haul road, 50 ft south of landfill, 15 ft southwest of lone 12-in oak tree, and 6 ft south of property line.

Materials	Depth below LSD, in feet From	To
Sand, medium to very coarse, few granules, clean	0	20
Sand, very fine to medium, clean; pebble layer at 30 ft	20	39
Sand, fine to very coarse, few small cobbles, clean	39	43
Sand, very fine to very coarse, silty, some pebbles, interbedded with layers of very fine to coarse sand with little silt	43	50
Till, clayey and pebbly, very hard	50	52

Bottom of hole at 52 ft in till

Well S 380. Site ID 413846072544801.
Lat $41^{o}38'46''$, long $72^{o}54'48''$.

Owner: Angelo Tomasso Inc. Drilled water-table well in stratified drift, diam 2 in, depth 70.8 ft, cased with plastic PVC to 65.8 ft, with 5 ft of slotted plastic PVC pipe 65.8-70.8 ft. LSD 237 ft above msl. MP is top of steel casing protector 2.3 ft above LSD and 7.4 ft below BS 269 MP. Drilled May 8, 1978, by USGS.
Location: In woods along trail 100 ft south of edge of woods and Bristol landfill border road, 250 ft east of landfill corner.

Materials	Depth below LSD, in feet From	To
Sand, fine to very coarse, and gravel, granule to pebble, clean	0	10
Sand, fine to very coarse, few granules, clean	10	18
Sand, fine to coarse, clean	18	27
Sand, very fine to medium, brown, clean	27	39
Sand, very fine to medium, gray-brown, clean	39	41
Sand, very fine to fine, silty, black, very soft	41	52
Sand and gravel	52	53
Sand, very fine to coarse, with layers of red, silty very fine sand	53	71
Gravel, granule to pebble, and sand, medium to very coarse	71	73
Till, sandy, silty, red	73	74

Bottom of hole at 74 ft in till

Well S 381. Site ID 413847072544901.
Lat $41^{o}38'47''$, long $72^{o}54'49''$.

Owner: Angelo Tomasso Inc. Drilled water-table well in stratified drift, diam 2 in, depth 47.0 ft, cased with plastic PVC to 42.0 ft, with 5 ft of slotted plastic pipe 42.0-47.0 ft. LSD 237 ft above msl. MP is top of steel casing protector 2.0 ft above LSD, 7.0 ft below BS 269 MP, and 0.4 ft above S 380 MP. Drilled May 9, 1978, by USGS.
Location: 8 ft north of S 380 along trail.

Material description same as S 380

1/ Abbreviations used in table

ID	Identification no.
PVC	Polyvinyl chloride
LSD	Land surface datum
msl	Mean sea level
MP	Measuring point

Well S 382. Site ID 413842072544801.
Lat $41^{o}38'42''$, long $72^{o}54'48''$.

Owner: Angelo Tomasso Inc. Drilled water-table well in stratified drift, diam 2 in, depth 40.6 ft, cased with plastic PVC to 35.6 ft, with 5 ft of slotted plastic pipe 35.6-40.6 ft. LSD 212 ft above msl. MP is top of plastic casing 2.1 ft above LSD and 32.3 ft below BS 269 MP. Drilled May 10, 1978, by USGS.
Location: Along trail about 800 ft south of S 380 and S 381, 10 ft east of trail, at bend.

Materials	Depth below LSD, in feet From	To
Sand, fine to coarse, few granules	0	4
Sand, coarse to very coarse, and gravel, granule to pebble	4	7
Sand, fine to coarse, brown	7	16
Sand, fine to medium, brown, few pebbles	16	18
Sand, very fine to medium, cobble at 21 ft	18	23
Sand, fine to very coarse, some granule gravel	23	31
Sand, very fine to very coarse	31	39
Sand, very fine to very coarse, few cobbles	39	42
Sand, very fine to very coarse, silty, few pebbles, interbedded with layers of silty very fine sand	42	45
Till, very sandy, with granules, pebbles, and cobbles	45	48

Bottom of hole at 48 ft in till

Well S 383. Site ID 413847072543701.
Lat $41^{o}38'47''$, long $72^{o}54'37''$.

Owner: Angelo Tomasso Inc. Drilled water-table well in stratified drift, diam 2 in, depth 31.0 ft, cased with plastic PVC to 26.0 ft, with 5 ft of slotted plastic pipe 26.0-31.0 ft. LSD 217 ft above msl. MP is top of plastic casing 2.2 ft above LSD and 27.4 ft below BS 269 MP. Drilled May 11, 1978, by USGS.
Location: In woods at end of bulldozed trail, about 400 ft south of east end of Bristol landfill cell.

Materials	Depth below LSD, in feet From	To
Soil, silty, sandy	0	1
Sand, fine to very coarse, few pebbles	1	3
Sand, fine to medium	3	18
Sand, fine to coarse, few pebbles	18	21
Sand, fine to coarse	21	33
Sand, very fine to very coarse, silty, some granule gravel, interbedded with thin layers of fine to very coarse clean sand	33	38
Till, sandy, pebbly	38	48

Bottom of hole at 48 ft in till

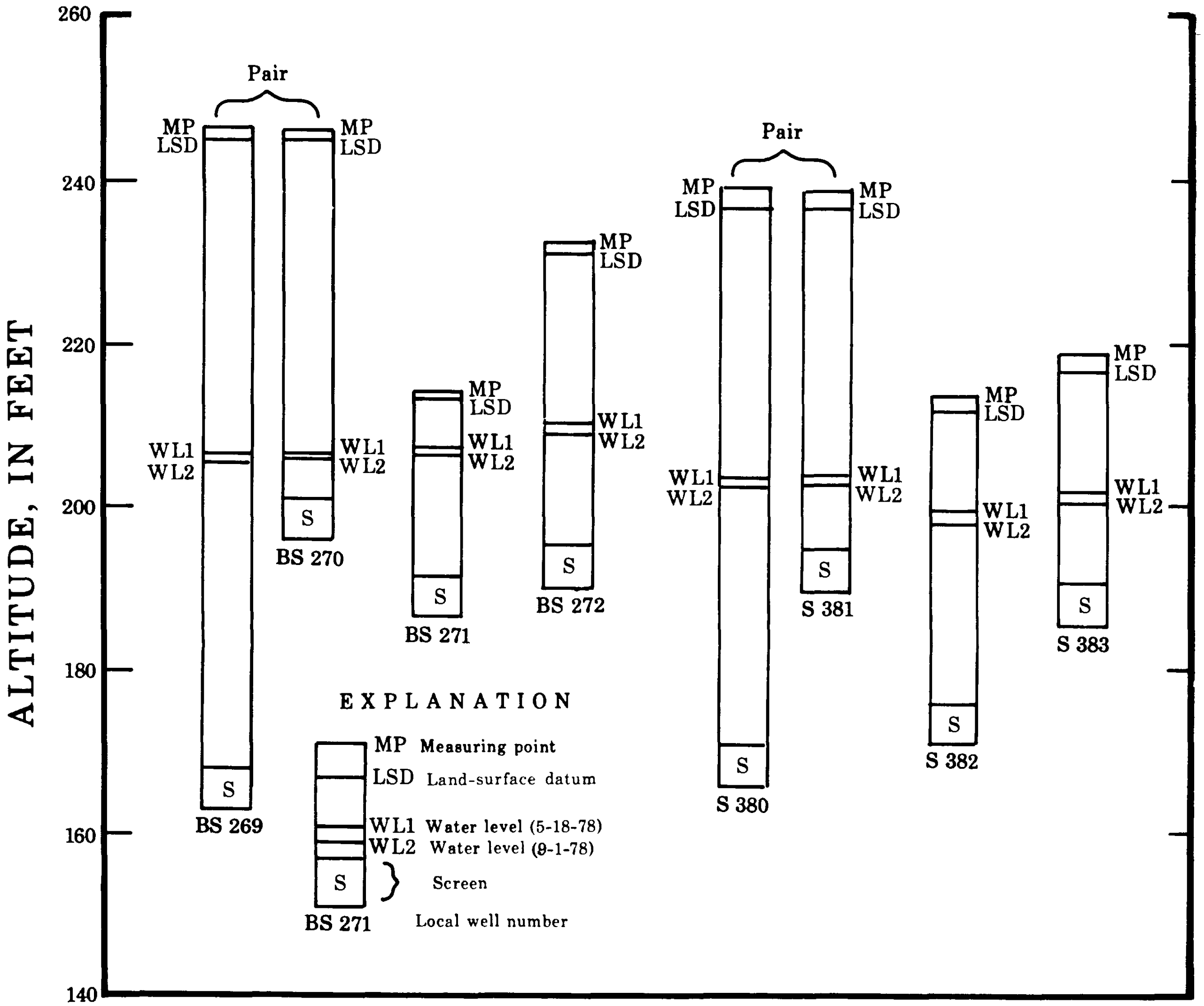


FIGURE 15.--WATER LEVELS IN BRISTOL AND SOUTHINGTON WELLS

(FOR WELL LOCATIONS SEE FIGURE 14)

water level was about 1 foot lower in all the wells on September 1, 1978 (fig. 15). For water-level altitudes on different dates see table 17.

Ground-water quality

Samples were collected from seven wells: BS 269, BS 271, BS 272 and S 380 to S 383. Locations of the wells are given in figure 14. Results of analyses, given in table 18, show that each sample contained concentrations exceeding the State and Federal limiting values for one or more constituent. The samples from wells BS 269, BS 271, S 380, S 382, and S 383, for example, contained high concentrations of sodium and chloride, and the water from BS 269, S 380, and S 382 was extremely hard. High concentrations of dissolved organic carbon, considered a good indication of contamination by organic wastes (Hughes and others, 1974), were detected in water from BS 271, BS 272, and S 383. In addition, samples from all the wells except BS 272 contained high manganese concentrations, and that from S 383 had excessive iron and barium as well.

Table 17.--Water-level altitudes in Bristol and Southington test wells[1/]

Date	Local well number and relative altitude of land surface[2/]								
	BS 269 245.0	BS 270 245.3	BS 271 213.4	BS 272 231.3	S 380 236.9	S 381 237.3	S 382 212.4	S 383 217.0	S 385 205.0
5/18/78	206.6	206.5	207.7	210.8	203.9	204.1	200.1	202.7	--
6/13/78	--	--	--	--	--	--	201.0	--	--
6/14/78	--	--	--	210.4	--	--	--	--	--
6/15/78	--	--	--	--	--	203.5	--	--	--
6/16/78	--	206.3	--	--	--	--	--	--	--
6/29/78	--	--	--	--	203.4	--	--	--	--
7/5/78	--	--	207.1	--	--	--	--	--	--
7/6/78	206.1	--	--	--	--	--	--	--	--
7/10/78	--	--	--	--	--	--	--	202.2	--
7/12/78	--	--	--	--	--	--	--	--	199.8
7/27/78	205.8	--	--	--	--	--	--	--	--
8/30/78	--	--	--	--	--	--	--	--	199.4
9/1/78	205.7	205.8	206.4	208.9	202.7	203.3	198.4	201.2	--

1/ Water-level altitudes based on depths to water in wells, measured to nearest hundredth foot.

2/ Relative altitude of land surface determined to nearest hundredth foot by differential (spirit) leveling from a datum (estimated mean sea level).

Table 18.--Analyses of ground water at solid-waste disposal facilities

(Chemical constituents dissolved unless otherwise indicated; concentrations in milligrams per liter)

Constituent or property	Well number, depth, and date sampled								Limiting Value	Basis (A)
	BS 269 (81.8 ft) 7-27-78	BS 271 (26.6 ft) 7-5-78	BS 272 (40.6 ft) 6-14-78	S 380 (70.8 ft) 6-29-78	S 381 (47.0 ft) 6-15-78	S 382 (40.6 ft) 6-13-78	S 383 (31.0 ft) 7-10-78	S 385 (34.2 ft) 7-12-78		
Alkalinity, as $CaCO_3$	130	110	56	100	23	150	360	520	--	--
Aluminum (Al)	.3 B	C	C	.1 B	C	C	.07 B	.1 B	--	--
Antimony (Sb)	C	C	C	C	C	C	C	C	.050	3
Barium (Ba)	.50	.07 B	.05 B	.3 B	.05 B	.1 B	1.5	.60	1	1,2
Beryllium (Be)	C	C	C	C	C	C	C	C	.011	2,3
Bismuth (Bi)	C	C	C	C	C	C	C	C	--	--
Boron (B)	.1 B	.1 B	.01 B	.1 B	.03 B	.1 B	.7 B	1. B	.75	2
Cadmium (Cd)	.003 B	.001 B	.003 B	.003 B	.007	.003 B	.003 B	.01 B	.010	1,3
Calcium (Ca)	510	12	22	150	25	76	20	87	--	--
Carbon (C), organic	6.9	14	13	3.9	5.1	10	22	40	--	--
Carbon (C), organic, suspended	.4	.2	.3	.1	--	.3	.3	.4	--	--
Chloride (Cl)	1400	83	15	340	57	79	170	120	250 D	1
Chromium (Cr)	C	C	C	C	C	C	C	C	.050	1,3
Cobalt (Co)	C	C	C	C	C	C	.07 B	1. B	--	--
Copper (Cu)	.03 B	C	C	C	.03 B	.01 B	C	C	1.0	1,3
Dissolved solids	--	299 E	120 E	1290 E	227 E	413 E	615 E	798 E	--	--
Gallium (Ga)	.03 B	C	C	C	C	C	C	C	--	--
Germanium (Ge)	.3 B	C	C	.1 B	.05 B	.05 B	.07 B	.1 B	--	--
Hardness, as $CaCO_3$	1500	41	69	460	92	220	100	330	--	--
Iron (Fe)	.00	.11	.00	.03	.23	.03	6.9	81	.3	2
Lead (Pb)	C	C	C	C	C	C	C	C	.050	1,3
Lithium (Li)	.01 B	C	C	C	C	.005 B	.01 B	C	--	--
Magnesium (Mg)	55	2.6	3.4	21	7.2	7.1	13	28	--	--
Manganese (Mn)	.43	5.4	.06	1.0	.57	.28	5.7	1.8	.05	2
Molybdenum (Mo)	C	C	C	C	C	C	C	.03 B	--	--
Nickel (Ni)	C	C	C	C	C	C	C	C	.100	2,3
Nitrite + nitrate, as N	1.2	.15	.65	1.3	.13	1.2	.01	.01	10	1,2
Nitrite + nitrate, total, as N	1.2	.19	.61	1.3	.14	1.2	.01	.00	10	1,2
pH, units	7.1	6.6	7.2	6.6	5.8	7.6	6.8	6.6	--	--
Phosphorus, as P	.01	.00	.02	.00	.00	.01	.00	.00	--	--
Phosphorus, total, as P	.06	.02	.06	.01	.02	.06	.03	.32	--	--
Potassium (K)	5. B	3. B	1. B	1. B	1. B	3. B	70. B	50. B	--	--
Silica (SiO_2)	10. B	7.0 B	10. B	10. B	10. B	10. B	30. B	30. B	--	--
Silver (Ag)	C	C	C	C	C	C	C	C	.050	1,3
Sodium (Na)	290	90	7.6	75	10	32	120	85	20	1
Specific conductance, in umhos/cm	4250	492	198	1425	272	620	1375	1675	--	--
Strontium (Sr)	1 B	.05 B	.05 B	.3 B	.1 B	.1 B	.1 B	.5 B	--	--
Sulfate (SO_4)	16	24	16	29	10	41	10	3.1	--	--
Tin (Sn)	.3 B	C	C	.05 B	C	C	C	.1 B	--	--
Titanium (Ti)	C	C	C	C	C	C	C	C	--	--
Vanadium (V)	C	C	C	C	C	C	C	.01 B	--	--
Zinc (Zn)	1.1	.01 B	.19	.1 B	.43	.48	.07 B	.03 B	5	2,3
Zirconium (Zr)	C	C	C	C	C	C	C	C	--	--

A 1 Maximum permissible level for drinking water, Connecticut Public Health Code Regulation 19-13-B102 (Connecticut General Assembly, 1975)

2 Most stringent criterion recommended by U.S. Environmental Protection Agency (1976)

3 Constituent is on list of toxic substances established by the U.S. Environmental Protection Agency (1978) pursuant to section 307 of Public Law 92-500.

B Semiquantitative analysis. Results are rounded to nearest reporting level. Reporting levels range from the detection limit upward in steps of 1, 3, 5, 7, and 10. Results are reported to one significant figure only.

C Not detected; semiquantitative analysis.

D Background level for most waters in State is less than 20 mg/L.

E Residue on evaporation at 180°C.

Table 19.--Analyses of toxic chemicals in water from wells BS 269 and BS 271

(Concentrations in micrograms per liter)

Constituent	Well number BS 269	Well number BS 271	Limiting Value	Basis (A)	Constituent	Well number BS 269	Well number BS 271	Limiting Value	Basis (A)
Aldrin, dissolved	.00	.00	.003	2,3	Heptachlor, total	.00	.00	.001	2,3
Aldrin, total	.00	.00	.003	2,3	Heptachlor epoxide, dissolved	.00	.00	.001	2,3
Chlordane, dissolved	.0	.0	.01	2,3	Heptachlor epoxide, total	.00	.00	.001	2,3
Chlordane, total	.0	.0	.01	2,3	Lindane, dissolved	.00	.00	4	1,3
Cyanide, total	10	10	20	1,3	Lindane, total	.00	.00	4	1,3
DDD, dissolved	.00	.00	--	--	Mirex, dissolved	.00	.00	.001	2,3
DDD, total	.00	.00	--	--	Mirex, total	.00	.00	.001	2,3
DDE, dissolved	.00	.00	--	--	PCB, dissolved	.0	.0	.001	2,3
DDE, total	.00	.00	--	--	PCB, total	.0	.0	.001	2,3
DDT, dissolved	.00	.00	.001	2,3	PCN, dissolved	--	.0	--	--
DDT, total	.00	.00	.001	2,3	PCN, total	.00	.0	--	--
Dieldrin, dissolved	.00	.00	.003	2,3	Perthane, dissolved	--	.00	--	--
Dieldrin, total	.00	.00	.003	2,3	Perthane, total	--	.00	--	--
Endosulfan I, dissolved	--	.00	.003	2,3	Phenols, total	3	160	1	2,3
Endosulfan I, total	.00	.00	.003	2,3	Toxaphene, dissolved	0	0	5	1,3
Endrin, dissolved	.00	.00	.2	1,3	Toxaphene, total	0	0	5	1,3
Endrin, total	.00	.00	.2	1,3					
Heptachlor, dissolved	.00	.00	.001	2,3					

A 1 Maximum permissible level for drinking water, Connecticut Public Health Code Regulation 19-13-B102 (Connecticut General Assembly, 1975)

2 Most stringent criterion recommended by U.S. Environmental Protection Agency (1976)

3 Constituent is on list of toxic substances established by the U.S. Environmental Protection Agency (1978) pursuant to section 307 of Public Law 92-500.

To further define ground-water quality near industrial waste-disposal areas within the Bristol landfill, the water from BS 269 and BS 271 was analyzed for selected toxic chemicals. These include cyanide, phenols, polychlorinated biphenyl (PCB), and 14 organochlorine insecticides. The results, given in table 19, show that only cyanide and phenols were detected. The phenol concentration in water from BS 271 was extremely high. Phenolic compounds include a wide variety of organic chemicals derived from degradation of wood, coal, petroleum products, human and animal wastes, pesticides, and other organic chemicals. They can be transported long distances in water (U.S. Environmental Protection Agency, 1976).

Southington Site

Description and history

The Southington landfill is in the Eightmile River basin northwest of West Street and Welch Road and south of the Bristol town line, as shown in figure 16. The landfill is owned by and serves the town of Southington and is permitted by DEP. It is classified as a mixed-waste

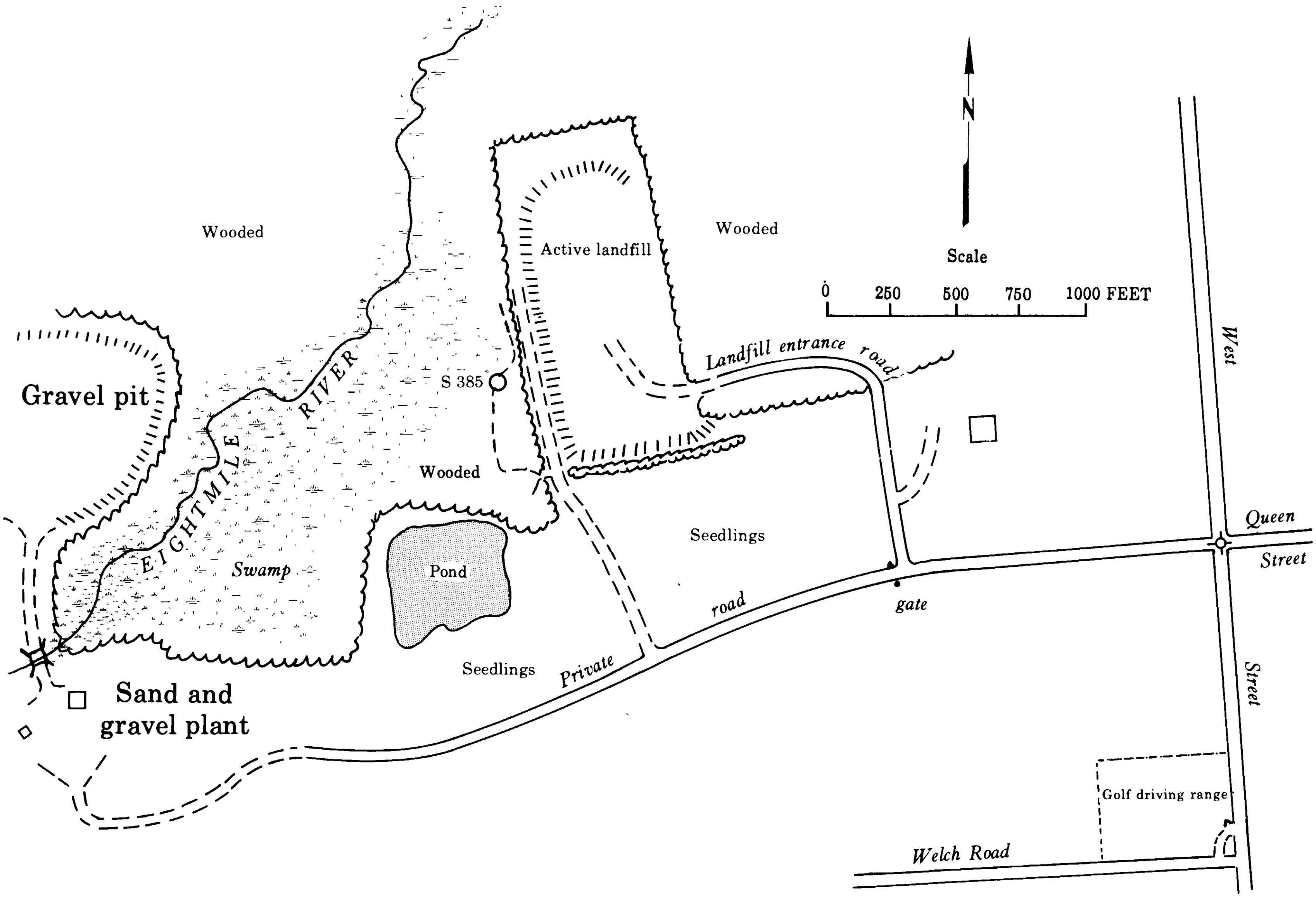


FIGURE 16.--MAP OF SOUTHINGTON SITE SHOWING LOCATION OF WELL S 385

disposal area by DEP, and is expected to reach capacity by 1980. The land surface slopes westward toward the Eightmile River, and the area is underlain by stratified sand. The probable areal extent of the aquifer is shown in figure 13.

Geologic and hydrologic data

A 43-foot-deep test hole was augered at the west edge of the fill area, and a 35-foot observation well, S 385, was installed. (See fig. 16 for well location.)

Table 20.--Log of well at Southington landfill[1/]

Well S 385. Site ID 413823072544001. Lat 41°38'23", long 72°54'40".

Owner: Angelo Tomasso, Inc. Drilled water-table well in stratified drift, diam 2 in, depth 34.2 ft, cased with plastic PVC to 29.2 ft with 5 ft slotted plastic PVC pipe 29.2-34.2 ft. LSD 205 ft above msl. MP is top of plastic casing 2.0 ft above LSD. Drilled May 12, 1978, by USGS.
Location: About 300 ft west of Southington landfill, 40 ft south of edge of swamp, along old road in woods, and about 300 ft north of south boundary of landfill.

Materials	Depth below LSD, in feet From	To
Sand, very fine to medium, little silt	0	4
Sand, fine to very coarse, occasional pebble	4	16
Sand, very fine to very coarse, clean	16	25
Sand, medium to very coarse	25	35
Sand, fine to very coarse, little silt, few granules, interbedded with layers of silty sand and pebbles	35	42
Till, sandy, firm	42	43

Bottom of hole at 43 ft in till

1/ Abbreviations used in table

ID Identification no.
PVC Polyvinyl chloride
LSD Land surface datum
msl Mean sea level
MP Measuring point

The depth to bedrock is more than 43 feet at the well site, and materials range from very fine to very coarse sand interbedded with silty sand and pebbles, as shown in table 20.

The altitude of the water table measured in the well was 199.8 feet above msl on July 12, 1978, and 199.4 feet above msl on August 30, 1978 (table 17). The slope of the water table and direction of ground-water movement probably is west, toward the Eightmile River, which is the inferred site of ground-water discharge.

Ground-water quality

A sample was collected from well S 385 on July 12, 1978, for water-quality analysis. Results can be compared with analyses of water from wells near Bristol landfill, given in table 18.

The sample contained extremely high iron and dissolved organic carbon concentrations, higher than any other sample tested in the course of this study. Sodium, chloride, manganese, boron, cadmium, and cobalt concentrations were also high, reaching or exceeding the State and Federal limiting values (table 18). Leachate from the landfill is affecting ground-water quality at well S 385.

SUBSURFACE PETROLEUM LEAK

More than 3,200 gasoline and diesel fuel retailers are registered in Connecticut (Connecticut Department of Motor Vehicles, 1977). For their distribution, see figure 17. Most dealers have one or more buried storage tanks onsite, and many industries, businesses, and homes have buried fuel tanks. The principal causes of tank leaks are corrosion, equipment failure, and line rupture by earth-moving equipment (U.S. Environmental Protection Agency, 1973).

Steel storage tanks of 3,000 to 5,000 gallon capacity generally last about 15 years, and many installed at service stations throughout the State are more than 15 years old (Connecticut Department of Environmental Protection, 1977, oral communication). Leaks from buried tanks constitute a serious source of ground-water contamination because the leaks may be numerous and difficult to detect.

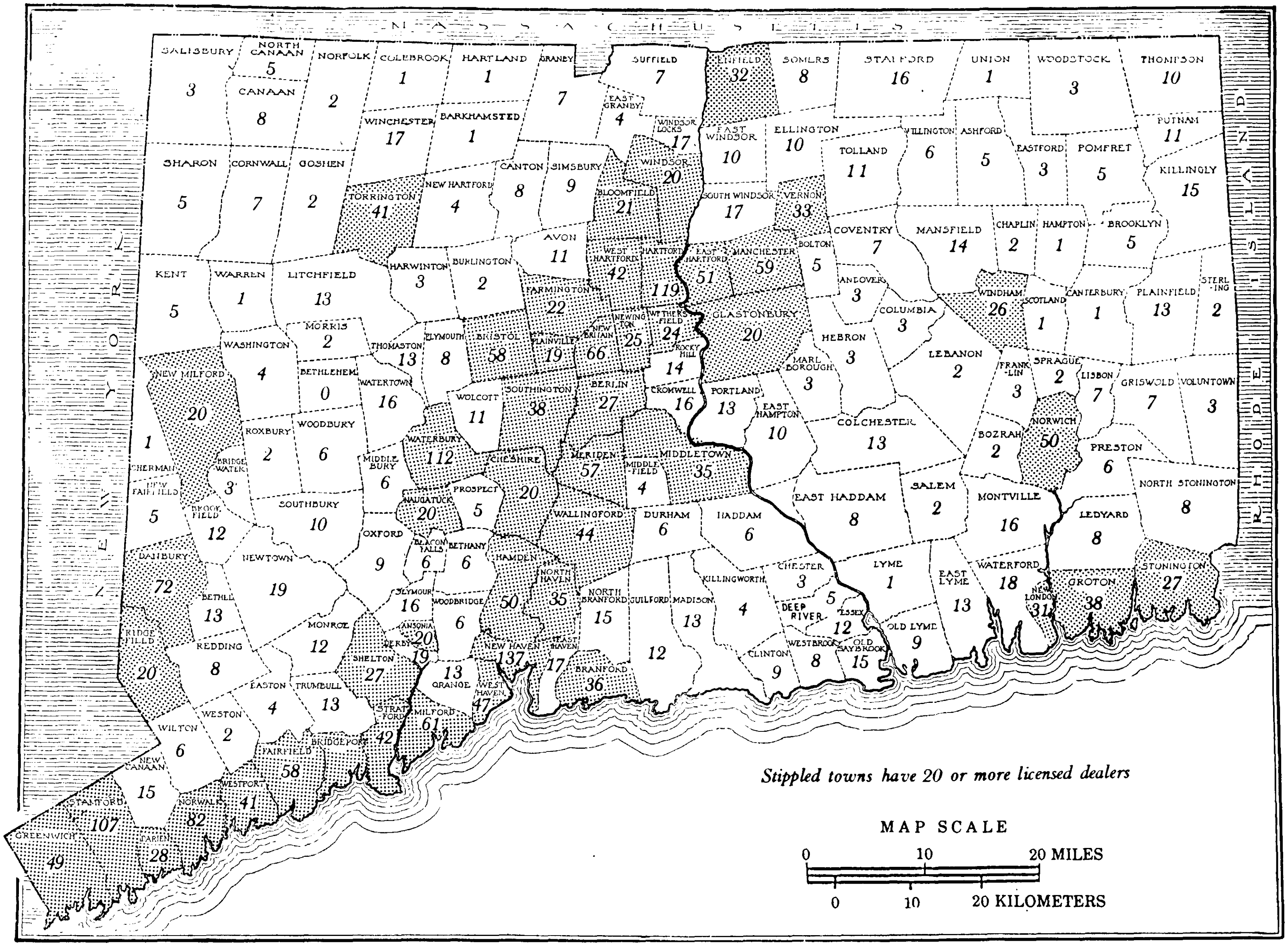


FIGURE 17.--NUMBER OF LICENSED DEALERS OF GASOLINE AND DIESEL FUEL, BY TOWN

(PRIMARILY AUTOMOBILE SERVICE STATIONS. MOST HAVE ONE OR MORE BURIED STORAGE TANKS ON SITE. FROM ROLSTON, BINGHAM, AND HANDMAN, 1979.)

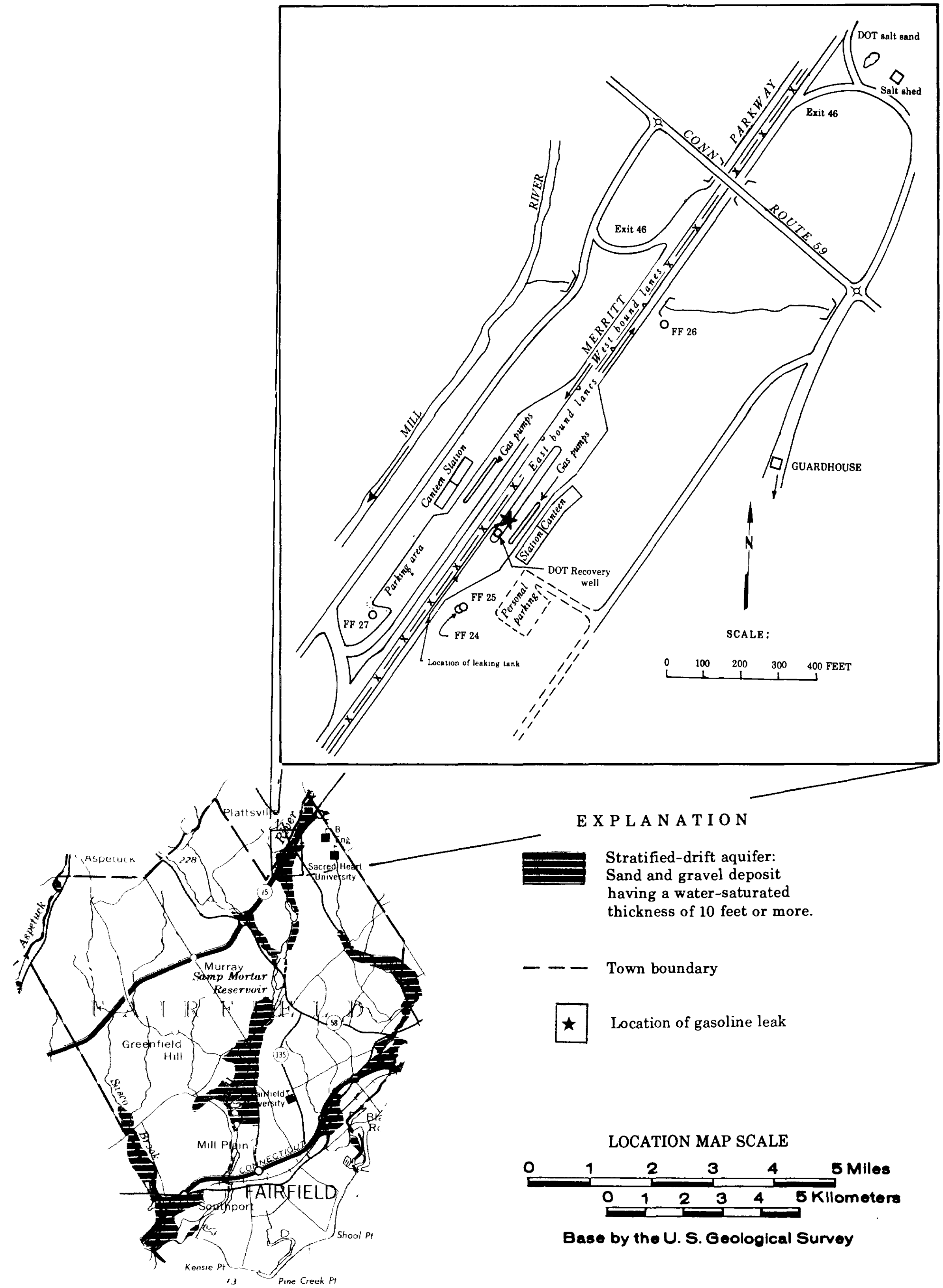


FIGURE 18.--MAP OF FAIRFIELD SITE SHOWING LOCATIONS OF WELLS FF 24 - 27

(INSET MAP SHOWS LOCATION OF GASOLINE LEAK AND STRATIFIED-DRIFT AQUIFERS IN FAIRFIELD)

Fairfield Site

Description and history

The service area on the eastbound side of the Merritt Parkway near exit 46 in Fairfield has 10 gas pumps supplied by underground storage tanks.

One gasoline storage tank, indicated on figure 18, developed a leak from which 7,000 gallons (estimated) of gasoline was lost. As of April 1978, Connecticut DOT had recovered 1,500 gallons of gasoline by periodically pumping water from a well installed for gasoline recovery. For location of the recovery well, see figure 18. At the time of sampling (July 1978), twice-daily pumping of the well was continuing.

The area is underlain by more than 34 feet of stratified sand and gravel, as indicated by the well logs in table 21. The land surface slopes northwest and southwest from the site toward the Mill River; the natural configuration has been modified by construction of the parkway and service area. The areal extent of the aquifer is shown in figure 18.

Geologic and hydrologic data

Four test holes were augered and observation wells were installed in each hole (fig. 18). Wells FF 24 and FF 25 are 5 feet apart and about 175 feet southwest (downgradient) from the ruptured storage tank. Well FF 26 is about 450 feet northeast (upgradient) from the tank. Well FF 27 is southwest of the tank and near the parking area on the westbound side of the parkway.

Depth to bedrock is more than 34 feet at FF 24 and FF 25, more than 20 feet at FF 26, and more than 26 feet at FF 27. Sediments are stratified very fine to very coarse sand and granule to cobble gravel. (See table 21).

The altitude of the water table on August 31, 1978, ranged from 32.4 feet above estimated msl in the upgradient well, FF 26, to 24.7 feet in the downgradient well, FF 27. In the pair of wells FF 24 and FF 25, the water level was higher in the shallower well, FF 25, as shown in table 22 and figure 19. Water-level altitudes indicate that the general horizontal flow direction is to the southwest and that the vertical component of flow at FF 24 and FF 25 is downward. The natural point of ground-water discharge is the Mill River. For water-level altitudes on different dates see table 22.

Table 21.--Logs of test holes at Fairfield site[1/]

Well FF 24. Site ID 411306073152401.
Lat 41°13'06", long 73°15'24".

Owner: Connecitcut Dept. of Transportation. Drilled water-table well in stratified drift, diam 2 in, depth 27.9 ft, cased with plastic PVC to 22.9 ft with 5 ft of slotted PVC pipe 22.9-27.9 ft. LSD 40 ft above msl. MP is top of plastic casing 2.3 ft above LSD. Drilled May 1, 1978, by USGS.
Location: 120 ft west of gas pumps, 25 ft southeast of pavement curb.

Materials	Depth below LSD, in feet From	To
Sand, very fine to very coarse, and pebble to cobble gravel	0	5
Sand, fine to very coarse, and granule to pebble gravel	5	13
Sand, very fine to very coarse, silty	13	15
Sand, very fine to very coarse, and gravel, with layers of coarser gravel; cobble at 31 ft	15	34

Refusal at 34 ft

Well FF 25. Site ID 411306073152402.
Lat 41°13'06", long 73°15'24".

Owner: Connecticut Dept. of Transportation. Drilled water-table well in stratified drift, diam 2 in, depth 15.4 ft cased with plastic PVC to 10.4 ft, with 5 ft of slotted plastic pipe 10.4-15.4 ft. LSD 40 ft above msl. MP is top of plastic casing 0.8 ft above LSD and 1.74 ft below FF 24 MP. Drilled May 1, 1978, by USGS.
Location: 6 ft east of FF 24 and 30 ft southeast of pavement curb.

Material description same as FF 24.

1/ Abbreviations used in table

ID Identification no.
PVC Polyvinyl chloride
LSD Land surface datum
msl Mean sea level
MP Measuring point

Well FF 26. Site ID 411311073151901.
Lat 41°13'11", long 73°15'19".

Owner: Connecticut Dept. of Transportation. Drilled water-table well in stratified drift, diam 2 in, depth 18.0 ft, cased with plastic PVC to 13.0 ft, with 5 ft of slotted plastic pipe 13.0-18.0 ft. LSD 43 ft above msl. MP is top of steel casing protector 1.2 ft above LSD and 3.38 ft above FF 25 MP. Drilled May 2, 1978, by USGS.
Location: 30 ft south of culvert abutment, 60 ft north of large single maple tree, and about 450 ft northeast of service area gas pumps.

Materials	Depth below LSD, in feet From	To
Gravel, pebble to cobble, and sand, very fine to very coarse	0	14
Sand, very fine to very coarse, and some gravel; cobbles at 17 ft and 19 ft	14	20

Refusal at 20 ft

Well FF 27. Site ID 411305073152601.
Lat 41°13'05", long 73°15'26".

Owner: Connecticut Dept. of Transportation. Drilled water-table well in stratified drift, diam 2 in, depth 26.2 ft, cased with plastic PVC to 21.2 ft, with 5 ft of slotted plastic pipe 21.2-26.2 ft. LSD 40 ft above msl. MP is top of plastic casing 1.2 ft above LSD and 0.96 ft below FF 25 MP. Drilled May 2, 1978, by USGS.
Location: 35 ft southeast of curb along west-bound entrance ramp, and 10 ft southwest of curb at west end of parking area of west-bound service area.

Materials	Depth below LSD, in feet From	To
Fill, sand and gravel	0	2
Sand, medium to very coarse, and granule to cobble gravel, little very fine sand and silt	2	11
Sand, very fine to very coarse, and granule to pebble gravel, little silt	11	26

Bottom of hole at 26 ft

Table 22.--Water-level altitudes in Fairfield test wells[1/]

Date	Local well number and relative altitude of land surface[2/]			
	FF 24 40.0	FF 25 39.8	FF 26 42.7	FF 27 38.4
5/1/78	29.0	--	--	--
6/13/78	29.1	29.2	33.5	--
6/14/78	--	--	--	25.3
7/17/78	--	--	--	25.1
7/18/78	--	28.8	--	--
7/19/78	--	--	33.1	--
7/20/78	28.5	--	--	--
8/31/78	28.2	28.5	32.4	24.7

1/ Water-levels altitudes based on depths to water in wells, measured to nearest hundredth foot.

2/ Relative altitude of land surface determined to nearest hundredth foot by differential (spirit) leveling from a datum (estimated mean sea level).

Ground-water quality

Water samples were collected from the four wells in July 1978. Results of the analyses are shown in table 23. During pumping and sampling a slight odor of gasoline was detected from well FF 24, little or no odor from well FF 25, and a fluctuating slight to strong odor from FF 27. No gasoline odor was detected in the upgradient well, FF 26. The samples from all downgradient wells, FF 24, FF 25, and FF 27, had a strong gasoline odor after standing. Only minute quantities of gasoline are needed to produce odors in water (McKee and Wolf, 1963, p. 230).

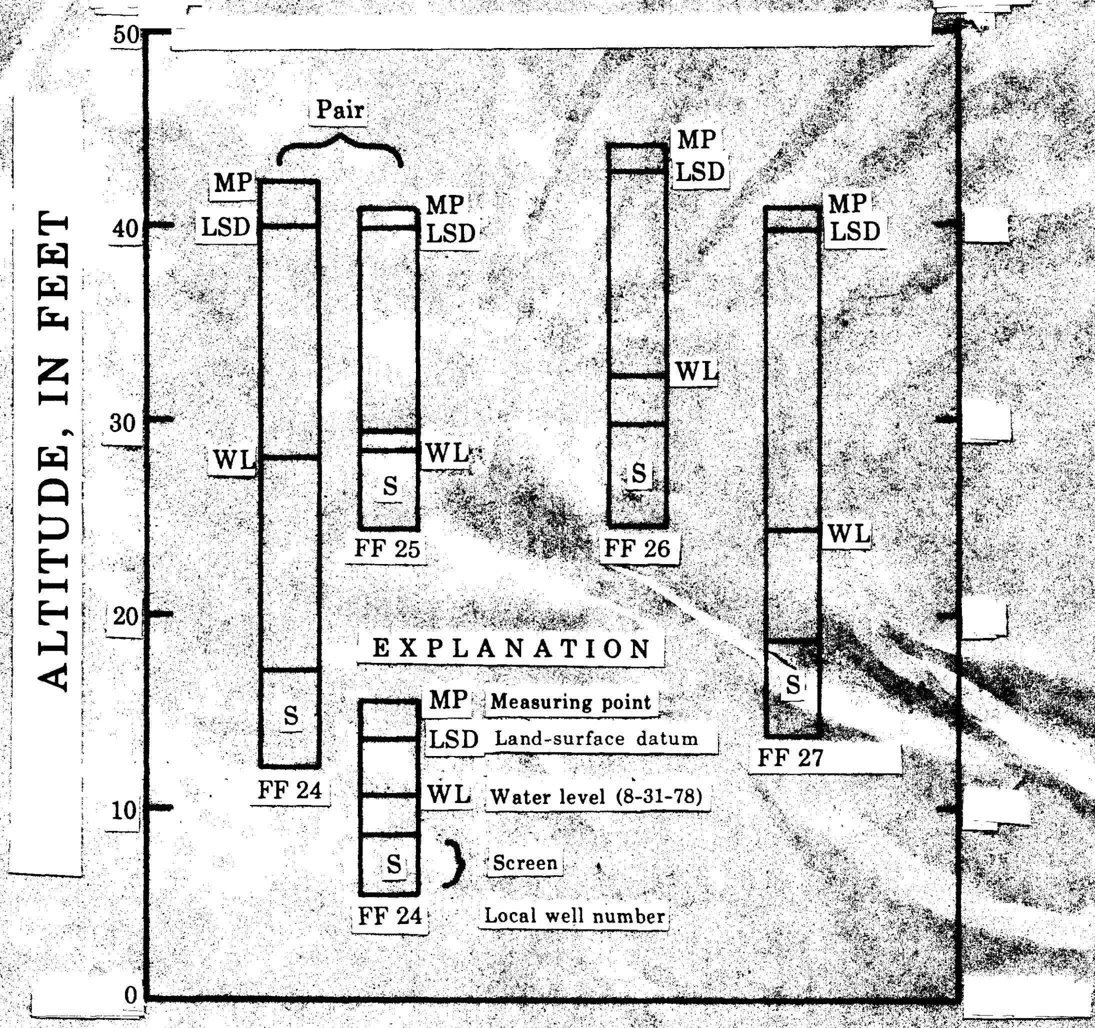


FIGURE 19.--WATER LEVELS IN FAIRFIELD WELLS

(FOR WELL LOCATIONS SEE FIGURE 18)

No Ro

Table 23.--Analyses of ground water near subsurface gasoline leak

(Chemical constituents dissolved unless otherwise indicated; concentrations in milligrams per liter)

Constituent or property	Well number, depth and date sampled: FF 24 (27.9 ft) 7-20-78		FF 25 (15.4 ft) 7-18-78		FF 26 (18.0 ft) 7-19-78		FF 27 (26.2 ft) 7-17-78		Limiting Value	Basis (A)
Alkalinity, total, as $CaCO_3$	82		0		24		43		--	--
Aluminum (Al)	.1	B	.1	B	.05	B	.3	B	--	--
Antimony (Sb)	C		C		C		C		.050	3
Barium (Ba)	.07	B	.05	B	.03	B	.03	B	1.	1,2
Beryllium (Be)	C		C		C		C		.011	2,3
Bismuth (Bi)	C		C		C		C		--	--
Boron (B)	.05	B	.05	B	.05	B	.03	B	.75	2
Cadmium (Cd)	.006		.04		.003	B	.003	B	.010	1,3
Calcium (Ca)	70		6.6		26		80		--	--
Carbon (C), organic	4.1		12		4.6		8.7		10	5
Carbon (C), organic, suspended	.3		.4		.2		.1		--	--
Chloride (Cl)	93		31		36		130		250(D)	1
Chromium (Cr)	C		C		C		C		.050	1,3
Cobalt (Co)	.03	B	.03	B	C		.01	B	--	--
Copper (Cu)	C		.045		C		C		1.0	1,3
Dissolved solids	544	E	143	E	191	E	613	E	--	--
Gallium (Ga)	C		C		C		C		--	--
Germanium (Ge)	.1	B	C		C		.07	B	--	--
Hardness, noncarbonate, as $CaCO_3$	150		22		63		230		--	--
Hardness, as $CaCO_3$	240		22		87		270		--	--
Iron (Fe)	1.6		.89		.09		.09		.3	2
Lead (Pb)	C		C		C		C		.050	1,3
Lithium (Li)	C		C		C		C		--	--
Magnesium (Mg)	15		1.3		5.4		17		--	--
Manganese (Mn)	13		.48		1.5		5.4		.05	2
Molybdenum (Mo)	C		C		C		C		--	--
Nickel (Ni)	C		C		C		C		.10	2,3
pH, units	6.1		5.2		6.5		5.6		--	--
Potassium (K)	10	B	5	B	5	B	10	B	--	--
Silica (SiO_2)	10	B	10	B	10	B	10	B	--	--
Silver (Ag)	C		C		C		C		.050	1,3
Sodium (Na)	55		27		21		75		20	1
Specific conductance, in umhos/cm	850		245		320		955		--	--
Strontium (Sr)	.3	B	.03	B	.1	B	.3	B	--	--
Sulfate (SO_4)	170		43		48		210		--	--
Tin (Sn)	C		C		C		C		--	--
Titanium (Ti)	C		C		C		C		--	--
Vanadium (V)	C		C		C		C		--	--
Zinc (Zn)	.440		1.9		.1		.03	B	5.	2,3
Zirconium (Zr)	C		C		C		C		--	--

A 1 Maximum permissible level for drinking water, Connecticut Public Health Code Regulation 19-13-B102 (Connecticut General Assembly, 1975)

2 Most stringent criterion recommended by U.S. Environmental Protection Agency (1976)

3 Constituent is on list of toxic substances established by the U.S. Environmental Protection Agency (1978) pursuant to section 307 of Public Law 92-500.

B Semiquantitative analysis. Results are rounded to nearest reporting level. Reporting levels range from the detection limit upward in steps of 1, 3, 5, 7, and 10. Results are reported to one significant figure only.

C Not detected; semiquantitative analysis.

D Background level for most waters in State is less than 20 mg/L.

E Residue on evaporation at 180°C.

As shown in the table, sodium, and chloride concentrations were high in all samples, particularly those from the deeper wells, FF 24 and FF 27. This may be a result of leaching of road salts applied to road and parking-lot surfaces the previous winter. A nearby road-salt stockpile (to the northeast, fig. 18) probably does not directly affect water quality at these wells because leachate from it would flow primarily toward the Mill River.

Dissolved organic carbon concentrations were highest in wells FF 25 and FF 27, two of the wells from which gasoline odor was detected, and may be related to the gasoline leak. Manganese concentrations were high in all samples and very high in those from FF 24 and FF 27. Water from well FF 24 also had a high iron concentration, and water from FF 25 contained excessive dissolved cadmium, four times higher than the limit for public drinking water (table 23). The source of these metals is not evident, but solution of aquifer materials may be a contributing factor.

CONCLUSIONS

This study provides a preliminary assessment of the effects of selected nonpoint sources of contamination on ground-water quality in Connecticut. All seven sites are located over stratified-drift aquifers. At five of the sites, the Old Saybrook and Clinton septage lagoons, the Haddam salt storage area, the Bristol landfill, and the Fairfield subsurface gasoline leak, the movement of ground water was from the surface downward. At the Wallingford fly-ash disposal site ground-water flow had an upward component. The predominent direction of flow at all the sites is probably lateral. For more complete definition of the flow regime, periodic water-level measurements in additional wells are needed at all sites.

Water quality showed some effects from the seven probable nonpoint sources studied. At least one sample from each site contained concentrations of some constituents in excess of Connecticut State drinking-water standards. These are summarized in table 24. In addition, concentrations of some constituents for which Connecticut has not set drinking-water limits indicate degradation of ground-water quality. For example, iron, manganese, phenols, and dissolved organic carbon concentrations were very high in some samples.

The analyses in this investigation represent water quality only at the time of sampling and in the vicinity of the sampling points. For a complete evaluation of the water-quality changes with time and of the direction, rate, and extent of leachate movement, periodic samples from additional wells at different locations and depths will be required.

Table 24.--Summary of chemical constituents exceeding drinking-water standards and background levels in ground-water samples from selected sites

Town	Probable source	Constituents exceeding: Drinking-water standards 1/	Constituents exceeding: Probable background levels
Old Saybrook	Septage lagoon	Detergents (MBAS) Sodium	Cadmium Chloride Cobalt Dissolved organic carbon Iron Manganese
Clinton	Septage lagoon	Cadmium Detergents (MBAS) Sodium	Chloride Cobalt Dissolved organic carbon Iron Lead Manganese
Wallingford	Fly-ash disposal	Chromium	Chloride Dissolved organic carbon Manganese Sodium Sulfate
Haddam	Road-salt storage and industrial waste	Cadmium Chloride Chromium Sodium	Barium Copper Dissolved organic carbon Manganese Zinc
Bristol	Landfill and industrial-sludge lagoon	Barium Chloride Sodium	Boron Cyanide Dissolved organic carbon Hardness Iron Manganese Phenols Zinc
Southington	Landfill	Sodium	Boron Cadmium Chloride Dissolved organic carbon Hardness Iron Manganese
Fairfield	Subsurface gasoline leak	Cadmium Sodium	Chloride Dissolved organic carbon Hardness Iron Manganese Zinc

1/ Limits set by Connecticut General Assembly (1975)

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