

THE PROTECTION OF GROUNDWATER - SPECIFICALLY
OIL AND GAS CONTAMINATION

by

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TABLE OF CONTENTS

INTRODUCTION

BACKGROUND ON GROUNDWATER

LEGAL STRUCTURE FOR GROUNDWATER PROTECTION

Federal Strategy

State Strategy

GROUNDWATER QUALITY

Threats to Groundwater Resources

The First Step - Learning About Groundwater

Geology and Hydrology

The Physics of Groundwater

Groundwater Quality Problems Associated With Underground Storage
Tanks

Attenuation

Transport

Floater, Sinkers, and Solutes

Transport of Sinkers

Transport of Floaters

Transport of Solutes

Assessing the Risk of Groundwater Contamination

Management of Groundwater

Remedial Actions

INTERNSHIP - IN DETAIL

Duties Performed for Every Audit

History of Site and Surrounding Properties

Tank Tests

Drilling

Well Installation and Construction

Analysis

Write-up

CONCLUSION

APPENDICES

BIBLIOGRAPHY

LIST OF TABLES

1.	Carcinogenicity of Some Synthetic Organic Chemicals Detected in Drinking Water Wells.....	21
2.	Massachusetts Recommended Maximum Contaminant Levels for Groundwater.....	23
3.	EPA Recommended Maximum Contaminant Levels for Groundwater...	24
4.	Typical Permeability Values.....	30
5.	Range of Values of Hydraulic Conductivity and Permeability...	45
6.	Typical Values for Retention Capacities of Porous Soils.....	62
7.	Analytical Method, Costs, and Detection Abilities for Measuring Groundwater Contamination.....	96

LIST OF FIGURES

1.	Types of Aquifers.....	9
2.	Relationship Between Confined and Unconfined Aquifers.....	10
3.	Cone of Depression of a Pumping Well.....	26
4.	Photographic History of a Groundwater Flow Model.....	27
5.	Porous Media Cross Section.....	29
6.	The Effect of Permeability Variations on the Migration of Oil.....	31
7.	Effect of Variations in Aquifer Composition on the Advance of Contaminants.....	32
8.	Effect of Hydrology on Monitoring Well Effectiveness.....	33
9.	Photographic History of the Horizontal Lens Model.....	34
10.	Contaminant Migration Through a Porous Limestone.....	36
11.	Effect of Aquifer Interconnection on Plume Formation in Groundwater.....	37
12.	Importance of Monitoring Well Depth and Location in Detecting Pollution.....	38
13.	Discharge Versus Drop in Head.....	41
14.	Fluid Potential in a Static Fluid.....	43
15.	Variations in Contaminant Plumes and Factors Causing Them.....	53
16.	Effect of Contaminant Density on Plume Formation in Groundwater.....	54
17.	Effect of Density on Migration of Contaminant Solution in a Uniform Flow Field.....	55
18.	Movement of a Sinker.....	58
19.	Movement of a Floater.....	60
20.	Species Transport.....	65
21.	The Movement of Contaminated Water Through Various Sorptive Soils.....	70

22.	Double Walled Storage Tank Installation.....	75
23.	Cross Section of a Monitoring Well.....	88
24.	Tapping a Water Bearing Formation.....	90
25.	Chromatogram of Regular Unleaded Gasoline.....	93
26.	Chromatogram of Regular Leaded Gasoline.....	94
27.	Groundwater Withdrawals in the United States.....	98

ABSTRACT

Groundwater is a vital resource and efforts must be made to protect its quality. In certain areas, its quality has been threatened by the introduction of oil and gasoline, many times originating from underground storage tanks. Massachusetts has directly reacted to this concern about groundwater quality by promulgating a Massachusetts Superfund Law (Chapter 21E), a more strict version of the federal Superfund.

This report is based on an internship with Bewick Associates, Inc., a firm that performs audits pursuant to Chapter 21E. A detailed description of the internship is given, and a supplemental literature review is included to explain the background and importance of the duties performed at Bewick. The information from the review includes general characteristics of groundwater flow, the pertinent legal aspects related to groundwater protection, and factors affecting groundwater quality. Oil and gas contamination from underground storage tanks and its relation to the Chapter 21E law and other federal and state laws are specifically addressed.

GROUNDWATER PROTECTION - SPECIFICALLY

OIL AND GAS CONTAMINATION

INTRODUCTION

This report on groundwater protection from oil and gas contamination arose from my Summer 1988 internship with Bewick Associates, Inc., a small environmental consulting firm in Watertown, Massachusetts. Bewick specializes in the environmental and groundwater assessment of commercial properties that are being sold, bought, or refinanced. Its principal clients are banks, insurance firms, law firms, and commercial real estate owners. The property investigations or audits conducted by Bewick are in accordance with the provisions of the Massachusetts Superfund Act (Chapter 21E), which requires contamination free groundwater and soil prior to any commercial real estate transaction. If the property under investigation is uncontaminated, the transaction may proceed; if not, remedial work must be undertaken to clean up the site. The audits may be monitored by the Massachusetts Department of Environmental Quality Engineering (DEQE), and include investigation of a property's past and present uses, groundwater and soil quality, and potential neighboring sources of pollution. As an intern, I conducted these environmental audits on sites ranging from small residential properties to large industrial plants. This report describes the legal and technical background associated with these investigations of groundwater and soil quality, as well as the internship itself.

The first section addresses general groundwater flow, defining groundwater and related terms. The second section then explains the legal theory behind groundwater protection, including an introduction to the major laws and agencies involved. The third section discusses the groundwater quality issues that are most important with respect to the legal framework outlined in the second section, with an emphasis on underground storage tanks. This section gives background information about underground storage tanks and their prevalence in the United States, the effects of geology and hydrology on groundwater flow, threats to the groundwater supply, the physics of groundwater movement, and the attenuation of compounds. This description of groundwater movement is necessary to understand the groundwater problems addressed in the prior sections.

The fourth section ties all the aforementioned issues together by describing my internship at Bewick Associates, Inc. It describes the importance and interrelationships among underground tanks, groundwater quality, the federal and state laws, and the physical aspects of groundwater flow. When I worked for Bewick Associates, I had to understand the basic characteristics of groundwater flow, its presence, and quality. I had to become acquainted with the federal and state laws that address groundwater protection, with an emphasis on the Massachusetts Chapter 21E Law. Moreover, I had to know about the threats to groundwater quality, which includes knowledge about the geology and hydrology of the area, the attenuation of compounds, and the transport of them. Because of the multitude of compounds and factors involved with groundwater flow, I found the topic of

groundwater quality both difficult and interesting.

The last section summarizes and draws conclusions about the main issues introduced in this paper, with an emphasis on the effectiveness of the Chapter 21E Massachusetts Superfund Law.

BACKGROUND ON GROUNDWATER

Groundwater supplies about twenty-five percent of the fresh water used for all purposes in the United States. Nationwide, groundwater provides about seventeen percent of all drinking water, but in rural areas, about ninety-six percent. Agriculture is, by far, the greatest user of groundwater in the country, consuming sixty-eight percent of the total (Jordan, 1983).

The amount of groundwater in storage presently dwarfs the surface water supply, being 2,000 to 3,000 times larger than the amount in all the lakes, streams, and rivers combined (Lehr, 1979). Moreover, groundwater provides most of the flow of streams, while lakes and swamps are reflections of the water table (Lehr, 1979). Groundwater also has high quality, has a nearly constant temperature, and is free of sediment.¹

Groundwater refers to the water lying beneath the land surface in faults, fissures, joints, cracks, or other openings in consolidated bedrock or in the small, intergranular spaces between particles of unconsolidated and consolidated soil deposits. Consolidated material includes bedrock, often limestone or sandstone; while unconsolidated material contains deposits of sand, silt, and gravel. The majority of groundwater occurs in unconsolidated deposits, with groundwater flowing through rock formations that have a sufficient number of interconnected openings (permeable material) for the water to pass.

¹. Water retrieved from deep locations has poorer quality because the water has had more time to acquire dissolved minerals, and hence, has greater "hardness".

These water-bearing rocks often connect for hundreds of square miles. Groundwater, therefore, does not flow in huge rivers, veins, or underground oceans, but collects in what are known as aquifers (Lehr, 1979).

Aquifers within sand and gravel deposits (unconsolidated aquifers) are very common, and the water quality of these aquifers is generally very good because they are highly permeable. The water moves easily and rapidly through them and has less opportunity to accumulate dissolved minerals. However, their high permeability also makes these aquifers susceptible to contamination because pollutants can travel quickly, with little attenuation along the way (Freeze and Cherry, 1979). Hence, the type of aquifer is crucial in determining the fate of the pollutant in the subsurface.

Groundwater may occur at any depth beneath the land surface, but the term groundwater most correctly refers to water in the saturated zone. This area has water in all of the openings in the soil and rock; there are no voids containing air. The flow of groundwater and contaminants greatly depends on the type of material; if there are many void spaces within the rock or soil, in other words, the porosity is high, the groundwater will tend to flow more readily. Permeability (or hydraulic conductivity, K) refers to the size and interconnectedness of these voids and describes how readily water will pass through the material. These two topics will be addressed later in the paper.

Aquifers are formations that yield usable amounts of water to a well. Unconfined or surficial aquifers occur only where unsaturated

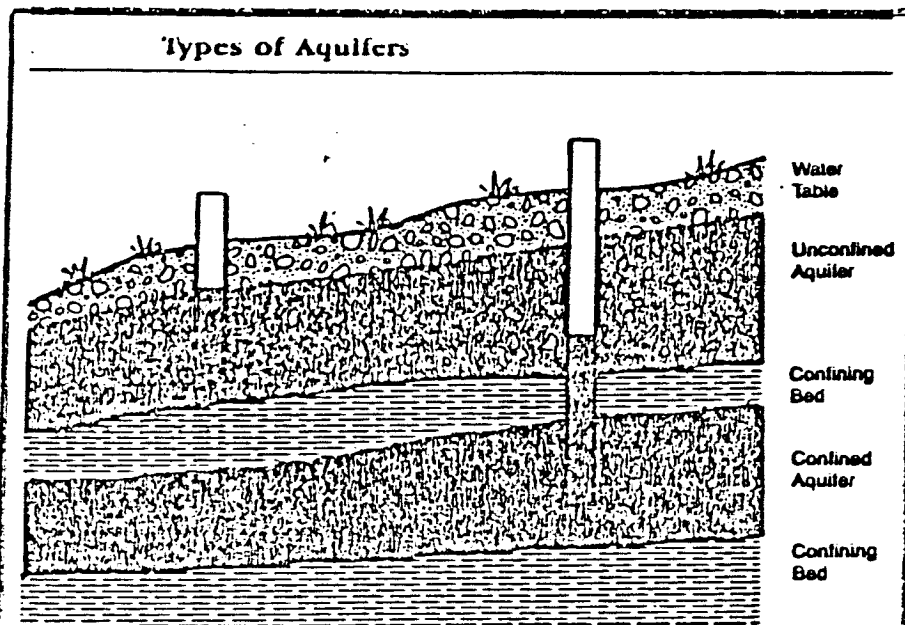
porous material overlies the saturated formation. In such cases, the upper surface of the saturated zone is called the water table. The water table generally follows the contours of the overlying terrain and can be ascertained by mapping the water levels in wells tapping the surficial aquifers.² It is important to understand these surficial aquifers since most contamination of the groundwater occurs in them after it has traveled downward through the unsaturated zone under the influence of gravitational forces (Nielsen, 1986).

Aquifers that are bound at the top and bottom by relatively impermeable formations are called confining beds or aquitards. Because these areas of water are surrounded by impermeable material, little contamination occurs from a spill or a leak since a pollutant can not travel through the impermeable material. However, these confining beds are important because they may be under pressure that is greater than atmospheric, and hence can raise water in wells above the top of the aquifer. Wells in these areas may flow without pumping, and one needs to be aware of them because the groundwater head can be higher than it would be if the water was only in a surficial aquifer. The level that the water would be if it were not being confined by an overlaying layer of rock is called the potentiometric or piezometric surface. It is important to understand both the water table and potentiometric surface gradients because they both define the characteristics of the hydrologic system and the rate and direction of groundwater flow (Jordan, 1983). For example, if the

². The water table is technically defined as the surface in which the fluid pressure in the pores of a porous medium is exactly atmospheric.

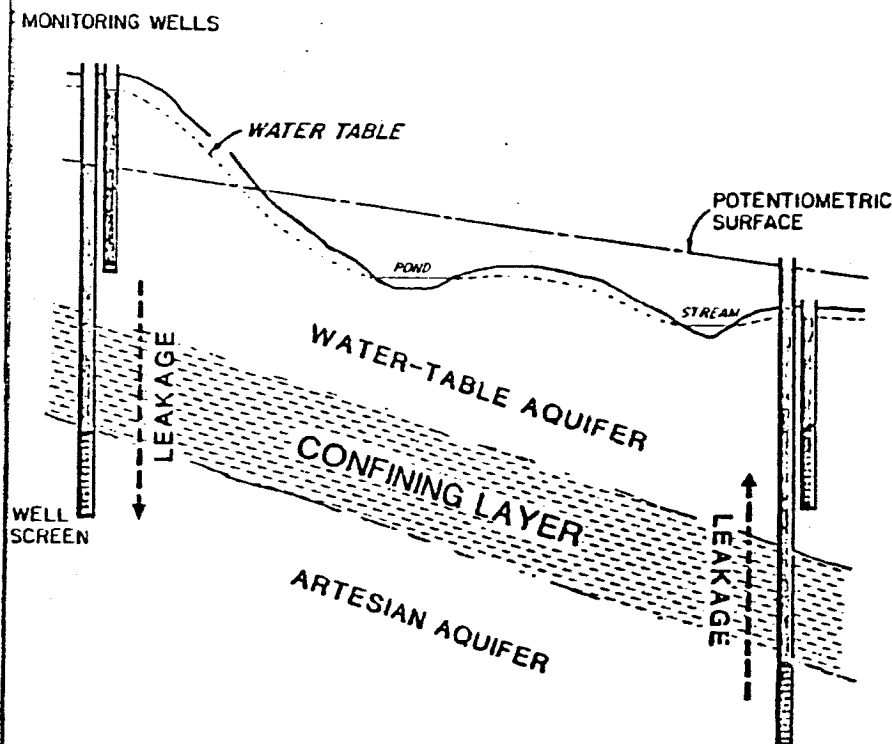
water table is higher than the potentiometric surface, there is relatively high pore pressure that is pushing up the water table level. Figures 1 and 2 illustrate the difference between a water table and potentiometric surface and a confined and unconfined aquifer. Note the difference in water levels due to the confined aquifer.

Because the regional flow of water in aquifers generally reflects the surface topography, it is obvious that groundwater is usually recharged in upland areas and flows toward low points in a drainage basin (Osgood, 1974). Sometimes water drains into springs, streams, and other areas of seepage. These areas of drainage or discharge are often the means by which contamination is detected. For example, unknown contamination may exist in the groundwater for years before it is discharged into a stream or sewer and subsequently detected.

**FIGURE 1**

Jordan, 1983

Relationship Between Confined and Unconfined Aquifers

**FIGURE 2**

Jordan, 1983

Source: Goraghty et al., *Groundwater Fundamentals for Lawyers: Seminar, Washington, D.C., June 21-22, 1984* (©1984, Goraghty and Miller, Inc., Syosset, N.Y.) Reprinted by permission.

LEGAL STRUCTURE FOR GROUNDWATER PROTECTION

Groundwater protection from pollution is an objective of a number of state and federal statutes and programs. The U.S. Environmental Protection Agency (EPA) issued its groundwater protection strategy in 1984, emphasizing the need to protect the public health and "critical environmental systems" with "available fiscal and human resources" (Jordan, 1983). It stresses the need for prevention of future contamination of groundwater sources. However, Massachusetts has taken an additional step and created a more strict provision to protect groundwater. The following is a closer look at both the state and federal standards.

The Federal Strategy

The federal strategy has several components. The first calls for the EPA to assist in building and enhancing groundwater protection institutions at the state level. It explains that the EPA should permit the states to divert funds from existing water quality programs for the development of groundwater protection programs. The EPA is also granted the power to direct funds to state agencies with the best chance of successfully undertaking statewide programs. The second component of this strategy calls for control of the major unregulated sources of groundwater pollution. For example, it states that the EPA should start considering the regulation of underground storage tanks and surface impoundments, and should begin utilizing legislation such as the Resource Conservation and Recovery Act (RCRA) and the Toxic Substances Control Act (TSCA) to regulate underground storage tanks.

The third component of this strategy involves more commitment by the EPA's federal and local offices for groundwater regulation by establishing guidelines for decisions affecting groundwater quality (Jordan, 1983).

The major federal laws affecting groundwater protection are the 1972 and 1977 amendments to the Federal Water Pollution Control Act (also known as the Clean Water Act), the Safe Drinking Water Act of 1974 (the SDWA) and its amendments of 1986, and the federal Solid Waste Management Act (the SWMA), as amended by the Resource Conservation and Recovery Act of 1976. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or the Superfund) also addresses the issue of groundwater protection.

One of the most important pieces of federal legislation for Bewick is the RCRA because it places restrictions on underground storage tanks. For example, a tank is subject to regulation if ten percent of its volume (including the volume of the piping connected to the tank) is beneath the surface of the ground, and if the tank contains materials regulated under CERCLA or RCRA. The law requires states to identify underground storage tanks (including tanks that were removed from service after 1973) and requires information on the tank age, size, type, location, and use. Moreover, both new and used tanks are regulated under RCRA. RCRA states that no new tank may be installed unless it meets certain design specifications that help prevent leaks and corrosion, or unless the soil resistivity measured adjacent to the tank is 12,000 ohm/cm or greater (to minimize

corrosion potential).

In addition to RCRA's regulations on businesses that create more than 1000 kilograms of wastes per month, RCRA also regulates any business that generates more than one hundred kilograms of wastes per month, but less than one thousand kilograms per month. Prior to the RCRA, these businesses were exempt as "small quantity generators". This aspect of RCRA is significant for Bewick because the environmental audits must mention these small businesses in the area of an investigated site as potential sources of contamination.

The transportation of hazardous materials is regulated under both the RCRA and the Hazardous Materials Transportation Act. Although Bewick Associates never transports hazardous materials, the supervisors on a site where hazardous materials are being removed have to sign a release form stating the quantity and type of hazardous material to be transported. Moreover, the main highway leading into Boston is closed to vehicles containing hazardous materials, forcing transporters to seek alternative routes.

CERCLA, the Superfund Law, focuses on past disposal practices at existing or closed facilities. CERCLA authorizes the federal government to respond directly to environmental threats caused by chemical spills or releases of hazardous materials. This aspect of CERCLA is important for Bewick because every audit requires a referral to the national priority list of problem sites that CERCLA's National Oil and Hazardous Substances Pollution Contingency Plan has compiled. It is a list of locations that are chosen by the utilization of a hazard ranking system that considers the magnitude of potential harm

and its probability of occurring. Bewick mentions in any report if such a location is in the vicinity of the site and explains that if contamination exists, it could be from that location, and if no contamination exists now, there may be a future problem.

The Clean Water Act, specifically the 1972 and 1977 amendments, gives the EPA broad authority to protect water resources. It consists of two major goals: to reach a level of water quality that protects fish, wildlife, and recreation in and on the water, and to eliminate the discharge of pollutants into United States waters. The principle means of achieving this goal is through effluent limitations. Note, however, that in the Act's definition of "waters of the United States", underground aquifers are not included; but the Act does have indirect effects on groundwater. For example, a federal permit is required for dredge and fill activities (which affect groundwater) in navigable waterways and wetlands (Jordan, 1983).

The Safe Drinking Water Act of 1974 and its amendments of 1986 address groundwater quality directly. It ensures that public water supply systems meet minimum national standards. In addition, the statute gives the EPA authority to delegate responsibility to the states. This act has several major sections. First, it establishes maximum contamination levels (MCLs) for turbidity, inorganic chemicals, coliform bacteria, and some organic compounds. It also defines two types of aquifer systems: community and non-community. Community systems serve year-round residents, while non-community systems serve transient populations (e.g. hotels, schools, and factories). Usually more strict standards are set for community water

supplies, and all systems must be monitored and tested. Second, the SDWA set up state well head protection programs. Under this provision, states must protect the well head areas of public water supply wells from contaminants posing health risks. In order for states to qualify for funding, they must submit these protection programs to the EPA by 1989. Third, this Act regulates underground injections and sole source aquifers. It requires permits for both and can even stop the flow of federal funds that are going to a federal project that the EPA Administrator finds would contaminate a sole source aquifer. Finally, the SDWA also establishes administrative issues. For example, states may establish their own standards as long as they are at least as strict as the EPA's standards.

The State Strategy

In Bewick's work, the most important law is the Massachusetts General Law, Chapter 21E, commonly known as the Massachusetts Superfund. This law outlines a process for investigation of commercial properties that are being bought, sold, or refinanced. The commercial property is examined for potential releases or threats of release of oil and hazardous materials. If hazardous material is found, it is identified, assessed, and remediated. This process is broken down into five steps:

- 1) Preliminary Assessment - an initial investigation that rapidly evaluates the site, with a conclusion that requires a call for either emergency action, further study, or "no action".
- 2) Phase I - Site Investigation - a preliminary assessment that determines whether an area is a confirmed disposal site (i.e. a hazardous material has already been released) and whether this property should be classified as a priority disposal site (indicating that the site is seriously

contaminated and should be considered as soon as possible).

- 3) Site Classification System - a system that is utilized in conjunction with Phase I to decide those locations that have a "priority status".
- 4) Phase II - Full Evaluation - a thorough study of the types and amounts of contamination. This step must include risks, with an emphasis on problem resolution.
- 5) Short-term Measures - actions taken that prevent or eliminate imminent hazards. These can occur at any time.

Bewick has the capacity to perform all of these steps, but the majority of its investigations do not require all five. These stages are specifically listed in the law; for example, in Step I (the Preliminary Assessment), Chapter 21E describes the purpose, scope, activities, decision criteria, and possible outcomes. Moreover, Chapter 21E subdivides these five steps; for example, it states seven different activities that can be part of a preliminary assessment. Bewick must perform several, if not all of these activities for an audit to be considered a preliminary assessment. Some of these activities involve obtaining specific physical and historical details about the location, identifying the site on topographic maps, searching files to review existing documentation (permits, past environmental violations, and complaints), identifying potential human and environmental receptors, field screening, and/or surveying the site. Recall that these specifications are different activities under one subsection of one step of Chapter 21E. Every step and subsection has many details describing what is accepted by the state of Massachusetts. The complete text of Chapter 21E is given in Appendix 1.

It is extremely important that Bewick follow the Chapter 21E guidelines because the Department of Environmental Quality Engineering (DEQE), an oversight agency, may request a more detailed investigation if it believes the audit is insufficient. The purpose of this legal framework, as stated in the law, is to "provide the basis for an organized and consistent treatment of releases of oil and hazardous materials in Massachusetts", with policies designed "to identify imminent hazards as quickly as possible and to use short-term measures immediately to reduce, eliminate or avoid imminent hazards" (M.G.L. c. 21).

More specifically related to Bewick's work are the state requirements for underground storage tanks. These regulations are administered by the heads of local fire departments under the supervision of the State Fire Marshal in the Massachusetts Department of Public Safety (the DPS). In Massachusetts, owners of existing tanks had to file for a permit with the head of the local fire department (usually the Fire Prevention Office) as of May 1986, even if the permit is in addition to any existing license or permit.³ Moreover, the regulation requires that the owner of a new tank (no exemption) must file the form within thirty days after the tank is brought into use.⁴ A fine of up to \$10,000 per tank can be issued for

3. This requirement includes buried tanks that have been taken out of service since January 1, 1974.

4. Two major categories of tanks are exempt from the notification requirement: farm and residential tanks storing less than 1100 gallons of motor fuel for noncommercial purposes and tanks storing heating oil for burning on the premises.

owners knowingly failing to file a required notification form.

Not only are tank owners required to file for a permit, but they are also regulated on the design and installation of the tank. For example, all new storage facilities (no exemptions) must comply with the new design and installation requirements, with a written certification of qualification from the manufacturer or a petroleum equipment association stating that the tank is properly designed and installed. In addition to prior notification to the head of the local fire department, the Fire Marshal must also inspect, test, and approve the tank. Appendix 2 lists in detail the state underground storage tank regulations.

Secondary containment is also specifically regulated by Massachusetts and it is required for all new or replacement installations above EPA-designated sole source aquifers⁵ (i.e. Cape Cod and Nantucket). The local chief may require secondary containment for new installations within a "cone of influence" of a municipal well or within three hundred feet of a private well.

The state regulations under the Department of Public Safety also have leak detection standards. For example, all new and existing tanks must comply with one of the following: 1) inventory record keeping plus periodic tightness testing; 2) installation and maintenance of an approved monitoring system; or 3) installation of an approved double-walled tank with provisions for continuous monitoring. Time limitations are set for those owners opting for testing

⁵. A sole-source aquifer is an aquifer that is used only for drinking water purposes.

requirements, with the tests occurring more frequently as the tank ages.

In the event of a leak, the owner must immediately notify the head of the local fire department and Office of Incident Response (OIR) of the DEQE. In the course of its work, Bewick also must report any detection of a leak to the OIR of the DEQE within twenty-four hours of detection. The Office of Incident Response is extremely important to Bewick because it is an excellent source of information with respect to leaks that have occurred in the vicinity of a site.

Once the legal aspects with respect to groundwater contamination are familiar to the consultant, he/she can act in accordance with the regulations outlined in the law. However, the proper legal actions can not be effected until some knowledge of the groundwater quality is obtained. The following section outlines some of the main groundwater quality concerns that should be addressed before deciding about the environmental conditions on a site.

GROUNDWATER QUALITY

Threats to Groundwater Resources

Massachusetts developed their own Superfund law because the state was faced with serious threats to groundwater quality. Because the State has many industries that have been operating for decades without any regulations on waste dumping, or tank installation or design, a number of serious contamination problems have resulted. In addition, some industries disposed of their waste merely by dumping it in a field or pit. For example, many paint factories or galvanizing plants dumped waste down the sewer or onto vacant lots. These obvious threats to water quality, along with other subtler dangers, have over the years resulted in a present high level of concern.

Several of the common chemicals found in groundwater are human carcinogens, including benzene, toluene, and xylene - three constituents of gasoline (table 1). Carcinogenic compounds can cause a multitude of human health problems. For example, citizens from the city of Woburn, Massachusetts suffered chronic health ailments when several of the town's wells were contaminated by chlorinated organic compounds which originated from W.R. Grace and Company. Leukemia was detected in seven children within the same neighborhood and other reproductive disorders, birth defects, neurological and sensory disorders were discovered.

Because of the groundwater contamination and serious health threats posed by this and other incidents, Massachusetts passed legislation that set standards for groundwater quality. These

**Carcinogenicity of Some
Synthetic Organic Chemicals
Detected in Drinking Water Wells**

→ Benzene	H
alpha-BHC	CA
beta-BHC	NTA
gamma-BHC (lindane)	CA
Bis (2-ethylhexy) phthalate	NTA
Bromoform	NTA
Butyl benzyl phthalate	NTA
Carbon tetrachloride	CA
Chloroform	CA
Chloromethane	NTA
Cyclohexane	NTA
Dibromochloropropane (DBCP)	CA
Dibromochloromethane	NTA
1, 1-Dichloroethane	SA
1, 1-Dichloroethylene	NTA
1, 2-Dichloroethane	CA
1, 2-Dichloroethylene	NTA
Di-n-butyl phthalate	NTA
Dioxane	CA
Ethylene dibromide (EDB)	CA
Isopropyl benzene	NTA
Methylene chloride	NTA
Parathion	SA
Tetrachloroethylene	CA
→ Toluene	NTA
1, 1, 1-Trichloroethane	NA
1, 1, 2-Trichloroethane	CA
Trichloroethylene (TCE)	CA
Trifluorotrichloroethane	NTA
Vinyl chloride	H, CA
→ Xylene	NTA

H — Confirmed human carcinogen

CA — Confirmed animal carcinogen

SA — Suggested animal carcinogen

NA — Negative evidence of carcinogenicity
from animal bioassay

NTA — Not tested in animal bioassay

The evidence for benzene and vinyl chloride
was derived from epidemiological studies.

Source: Council on Environmental Quality, Contamination
of Groundwater By Toxic Organic Chemicals (1981).

TABLE 1

Jordan, 1983

This table show
three constituents
of gasoline -
benzene, toluene,
and xylene. They
are indicated by
the arrows.

standards are more stringent than some of the federal standards. Along with the five step process explained in Chapter 21E, these standards help keep groundwater clean and serve as a model for companies to follow. Table 2 shows the groundwater quality standards set by Massachusetts, while Table 3 gives the federal standards set by the EPA. In both tables, the constituents of gasoline are indicated by arrows..

The First Step - Learning About Groundwater Flow

Before the quality of groundwater can be protected, much needs to be understood about its presence and flow. The quantity of groundwater available for use within a local area, which depends upon the relationship between the flow of water in and out of aquifers, must also be known. Under natural conditions, aquifers exist in a state of dynamic equilibrium between recharge, evapotranspiration, leakage to and from other aquifers, and discharge to surface waters. Areas of recharge and discharge are especially important because they are sensitive areas. One must also understand the balance between groundwater levels and flow patterns. Moreover, information about the groundwater characteristics on and adjacent to a specific site and the surrounding areas is also necessary for environmental audits when estimating the groundwater flow in an area.

In most situations, the groundwater is assumed to follow the topography. However, there are unusual situations where the opposite happens. For example, if property adjacent to a site is known to overpump the groundwater, it is reasonable to assume that the groundwater will flow towards this property, even if it is upgradient

TABLE 2

SUBSTANCE	CHRONIC D.W. NUMBER (mg/l)	"NUMBER" TYPE
1,1,1-TRICHLOROETHANE	0.14	ORSGL
1,1-DICHLOROETHYLENE	0.007	PMCL
1,2-DICHLOROETHANE	0.005	PMCL
1,2-DICHLOROPROPANE	0.01	ORSGL
1,3-DICHLOROPROPENE	0.01	ORSGL
2,4,5-TP(SILVEX)	0.01	MMCL
2,4-D	0.1	MMCL
ACETONE	0.25	ORSGL
ALACHLOR	0.002	ORSGL
ALDICARB	0.01	HA
ARSENIC	0.05	MMCL
BARIUM	1	MMCL
→ BENZENE	0.005	PMCL
CADMIUM	0.01	MMCL
CARBOFURAN	0.01	ORSGL
CARBON TETRACHLORIDE	0.005	PMCL
CHROMIUM(Cr VI)	0.05	MMCL
DICHLOROMETHANE	0.15	HA
DINOSEB	0.005	ORSGL
ENDRIN	0.0002	MMCL
ETHYLENE DIBROMIDE	0.00004	HA
ETHYLENE GLYCOL	5.5	HA
FLUORIDE	.4 TEMP	MMCL
LEAD	0.05	MMCL
LINDANE	0.004	MMCL
MERCURY	0.002	MMCL
METHOXYCHLOR	0.1	MMCL
METHYL ETHYL KETONE	0.06	ORSGL
METHYL ISOBUTYL KETONE	0.04	ORSGL
NITRATE(AS N)	10	MMCL
OXAMYL	0.05	ORSGL
SELENIUM	0.01	MMCL
SILVER	0.05	MMCL
SODIUM	20	MMCL
TETRACHLOROETHYLENE	0.02	HA
→ TOLUENE	0.34	HA
TOTAL TRIHALOMETHANES	0.1	MMCL
TOXAPHENE	0.005	MMCL
TRICHLOROETHYLENE	0.005	PMCL
TURBIDITY	1 TURBIDITY	MMCL
URANIUM	10 pci/LITER	HA
VINYL CHLORIDE	0.001	PMCL
→ XYLENE	0.62	HA

* MMCL=MASSACHUSETTS MAXIMUM CONTAMINANT LEVEL PER 310.CMR 22.0

* PMCL=U.S. EPA PROPOSED MAXIMUM CONTAMINANT LEVEL

* HA=U.S. EPA DRINKING WATER HEALTH ADVISORIES RECOMMENDED BY DEQE/OR
AS OF 1/27/87

* ORSGL=ORS DRINKING WATER GUIDELINE

To Be Used in Conjunction with all Other DEOE Regulation

COMPOUND	PROPOSED RMCL MG/L
ARSENIC	0.05
ASBESTOS	7.1×10^6 FIBERS/LITER FIBERS > 10 μ m
BARIUM	1.5
CADMIUM	0.005
CHROMIUM(TOTAL III + VI)	0.12
COPPER	1.3
LEAD	0.02
MERCURY(INORGANIC)	0.003
NITRATE NITROGEN	10.0
NITRITE NITROGEN	1.0
SELENIUM	0.045
ACRYLAMIDE	ZERO
ALACHLOR	ZERO
ALDICARB, ALDICARB SULFOXIDE, ALDICARB SULFONE	0.009
CARBOFURAN	0.036
CHLORDANE	ZERO
O-DICHLOROBENZENE	0.62
CIS-, TRANS- 1,2 DICHLOROETHYLENE	0.07
1,2 DICHLOROPROPANE	0.006
2,4-D	0.07
EPICHLOROHYDRIN	ZERO

TABLE 3

Continued →

COMPOUND	PROPOSED RMCL MG/L
→ ETHYLBENZENE	0.68
ETHYLENE DIBROMIDE(EDB)	ZERO
HEPTACHLOR, HEPTACHLOR EPOXIDE	ZERO
LINDANE	0.0002
METHOXYCHLOR	0.34
MONOCHLOROBENZENE	0.06
PCBs (13 A CLASS)	ZERO
PENTACHLOROPHENOL	0.2
STYRENE	0.14
→ TOLUENE	2.0
TOXAPHENE	ZERO
2,4,5 TP(SILVEI)	0.052
→ XYLENE(MIXTURE O,M,P)	0.44
TOTAL COLIFORMS	ZERO
TURBIDITY	0.1 NTU
GIARDIA	ZERO VIABLE CYSTS
PATHOGENIC VIRUSES	ZERO

Continued →

EPA PROPOSED MCLs 11/13/85

COMPOUND	PROPOSED MCL MG/L
TRICHLOROETHYLENE	0.005
CARBON TETRACHLORIDE	0.005
VINYL CHLORIDE	0.001
1,2 DICHLOROETHANE	0.005
→ BENZENE	0.005
1,1-DICHLOROETHYLENE	0.007
1,1,1-TRICHLOROETHANE	0.200
p-DICHLOROBENZENE	0.750

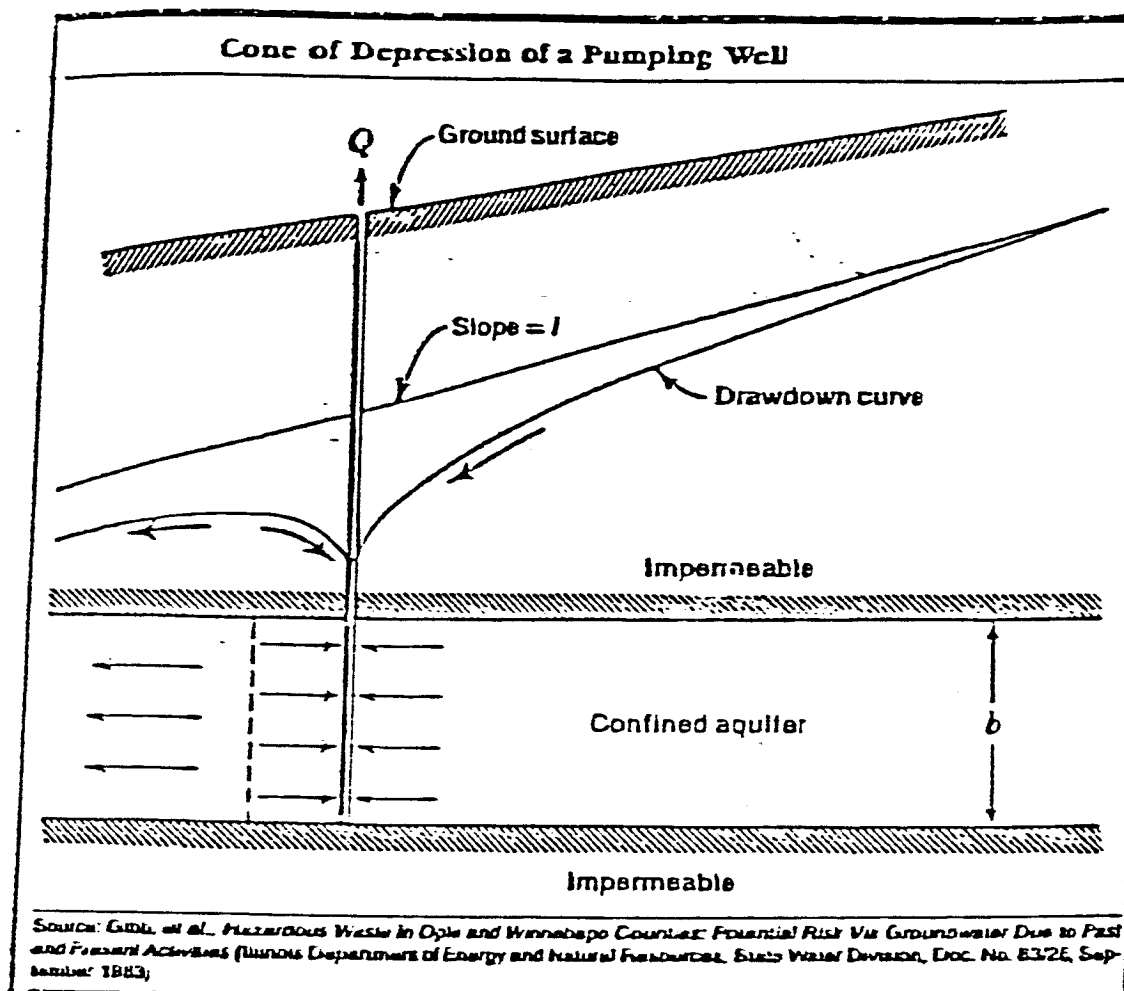
24c

with respect to the topography. Because overpumping causes a drawdown and hence creates an area of low hydraulic head, the water will tend to flow from higher head to lower head. Therefore, the surface topography may indicate a flow pattern in one direction, but the groundwater may be flowing in another direction, towards the cone of depression of a pumping well (figure 3). Moreover, a well that is pumping creates a different flow pattern than a well that is not removing water from the ground. Figure 4 shows how different flow patterns arise at various stages of pumping. In addition, some areas of Massachusetts have overpumped to an extreme, causing saline water from the Atlantic Ocean to flow into the groundwater system and impair the quality of the water (Jordan, 1983). Furthermore, if any stream or lake is nearby, it is considered a discharge area and the groundwater is assumed to flow in its direction (Freeze and Cherry, 1979).

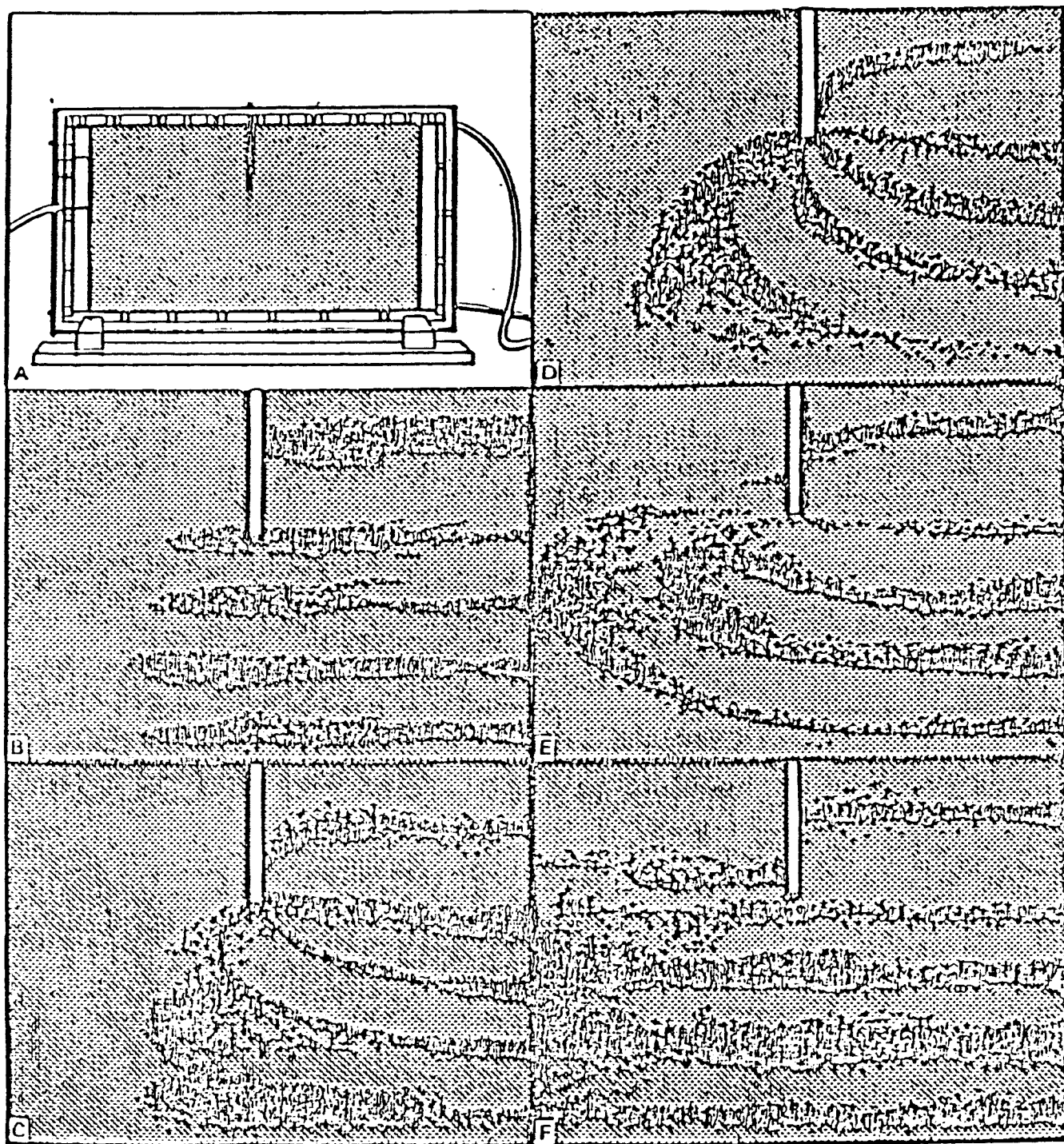
Although, topography and the amount and rate of pumping are important factors in groundwater flow, other parameters in the groundwater flow equation are significant. Geology and hydrology also are important factors in the determination of groundwater flow rate and direction.

Geology And Hydrology

Geology plays a vital role in determining the direction and speed of groundwater flow. First, porosity, which reflects the spaces between soil particles, is extremely important because it determines the location and speed of groundwater flow. Groundwater will travel faster through gravel and sand (which have high porosities) as

**FIGURE 3**

Jordan, 1985



Photographic history of a groundwater flow model. The pictures were taken at the following times: A at 0 min.; B at 23 min. after the entrance of ink; C at 2 min. after pumping began (24 min. after entrance of ink); D at 10 min. after pumping began; E at 6 min. after pumping stopped (pumping had continued for 11 min.); F at 25 min. after pumping stopped. Photographs B through F are enlargements of the porous consolidated medium shown in A.

Lehr, 1979

FIGURE 4

compared to silt and clay (figure 5). In many situations, clay is essentially impermeable since groundwater may take tens to hundreds of years to migrate through it.

Second, permeability is also important in groundwater movement. Permeability reflects the size and interconnectedness of the voids, and subsequently helps determine the rate at which groundwater moves. Table 4 gives various permeability values, showing the huge differences among various geologic mediums. Note, however, that although permeability refers to the capacity of a material to transmit water, it does not show the actual rate the water moves horizontally through the material (Jordan, 1983). This rate is addressed later in the paper. In addition, figure 6 illustrates different migration pathways due to varying permeabilities.

Third, other various geological characteristics can alter the direction and speed of the pollutant. For example, sand or clay lenses can enhance or divert the flow of groundwater, as shown in Figure 7. In this figure, the down-gradient wells tapping the coarse sand lenses will detect contamination before the closer up-gradient wells tapping the finer sand deposits. Figure 8 also shows how an undetected clay lens can greatly alter the assumed direction of groundwater flow. Moreover, figure 9 demonstrates how a clay lens can divert the flow around it, and subsequently sustain the movement of the groundwater.

Groundwater can also flow along cracks or fissures within the subsurface rocks. These cracks can occur along bedding planes or fractures in the rock and can increase the speed of groundwater flow

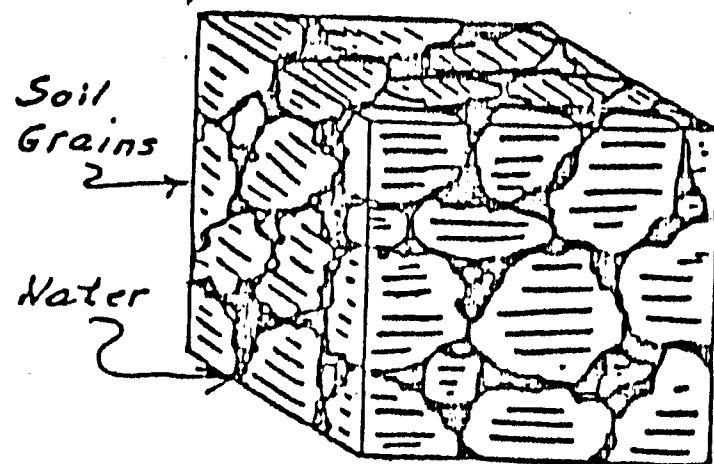


FIGURE 5

Brownlee, 1984

Diagram illustrating that water flows through the openings between soil grains in porous media.

Table 4

Typical Permeability Values

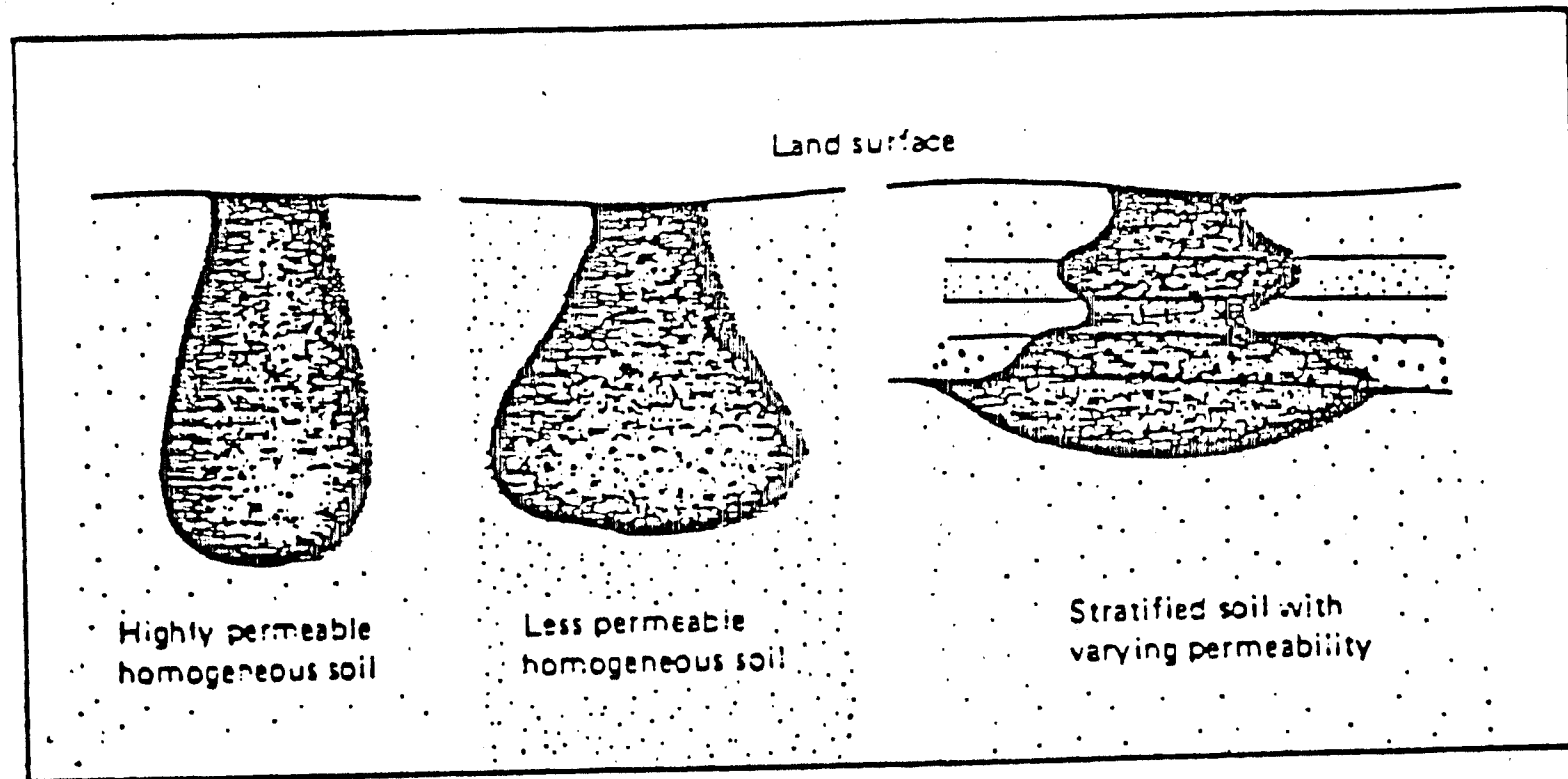
Material	Permeability (feet/day)
Gravels280 to 2,800
Sands60 to 450
Silts05 to 0.8
Silty Sand03 to 280
Glacial Till	3×10^{-7} (.0000003)* to 0.3
Clays	4×10^{-5} (0.00004)*
Sandstone01 to 11
Shale002 to 0.009

* less than an inch per year

Source: VanderMeulen and Reinke, *Groundwater and Transition Landfills* (Kalamazoo: Western Michigan University, Science for Citizens Center, 1982).

Jordan, 1983

FIGURE 6

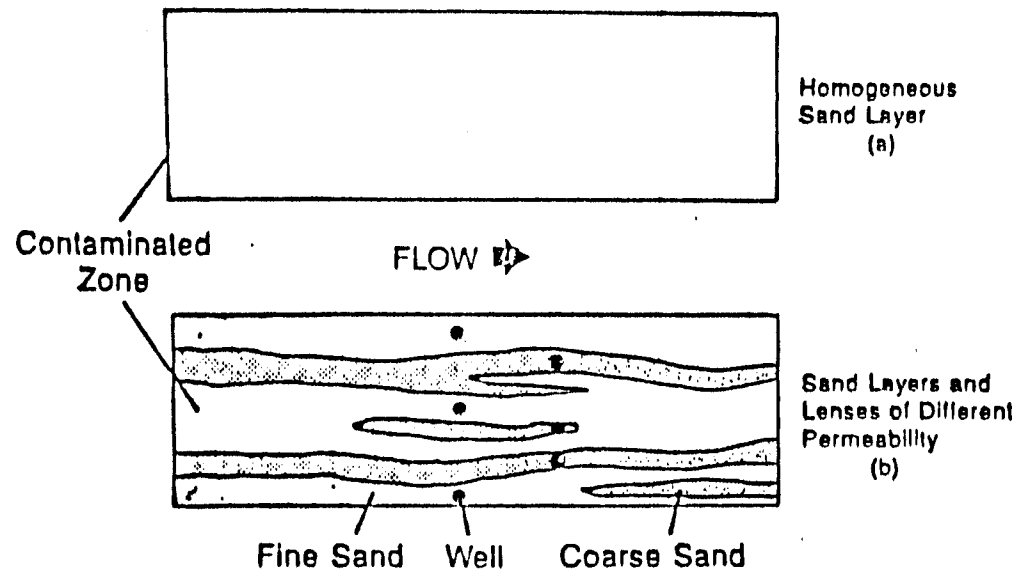


Brownlee, 1984

Vertical section showing generalized shapes of oil volumes migrating through the unsaturated zone and the effect of permeability (from CONCAWE, p. 12).

FIGURE 7

Figure 18. Effect of Variations in Aquifer Composition on the Advance of Contaminants

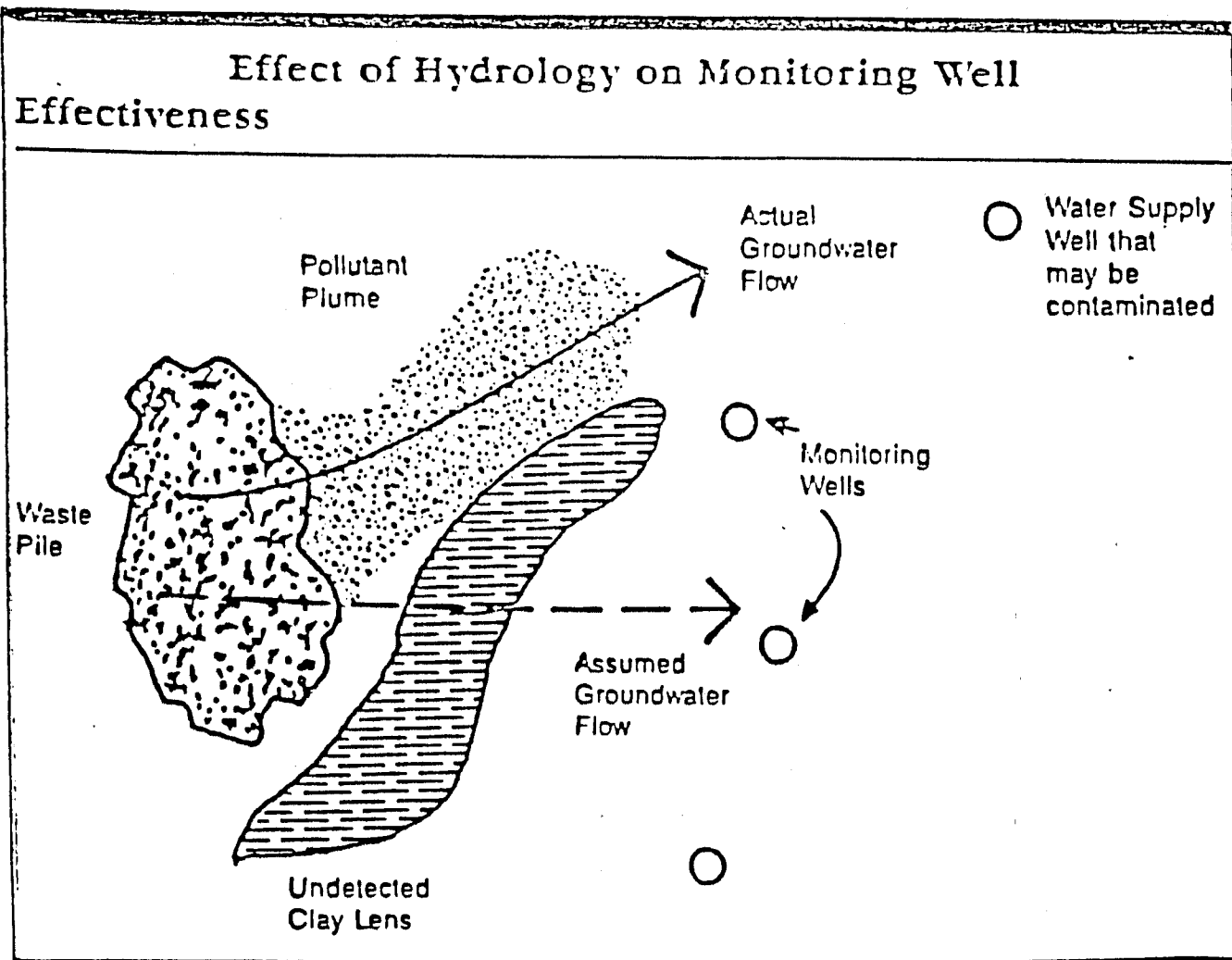


Source: Freeze and Cherry, *Groundwater* (©1979, Prentice-Hall, Inc., Englewood Cliffs, N.J.), as reproduced in Ger-
et al., *Groundwater Fundamentals for Lawyers*. Reprinted by permission.

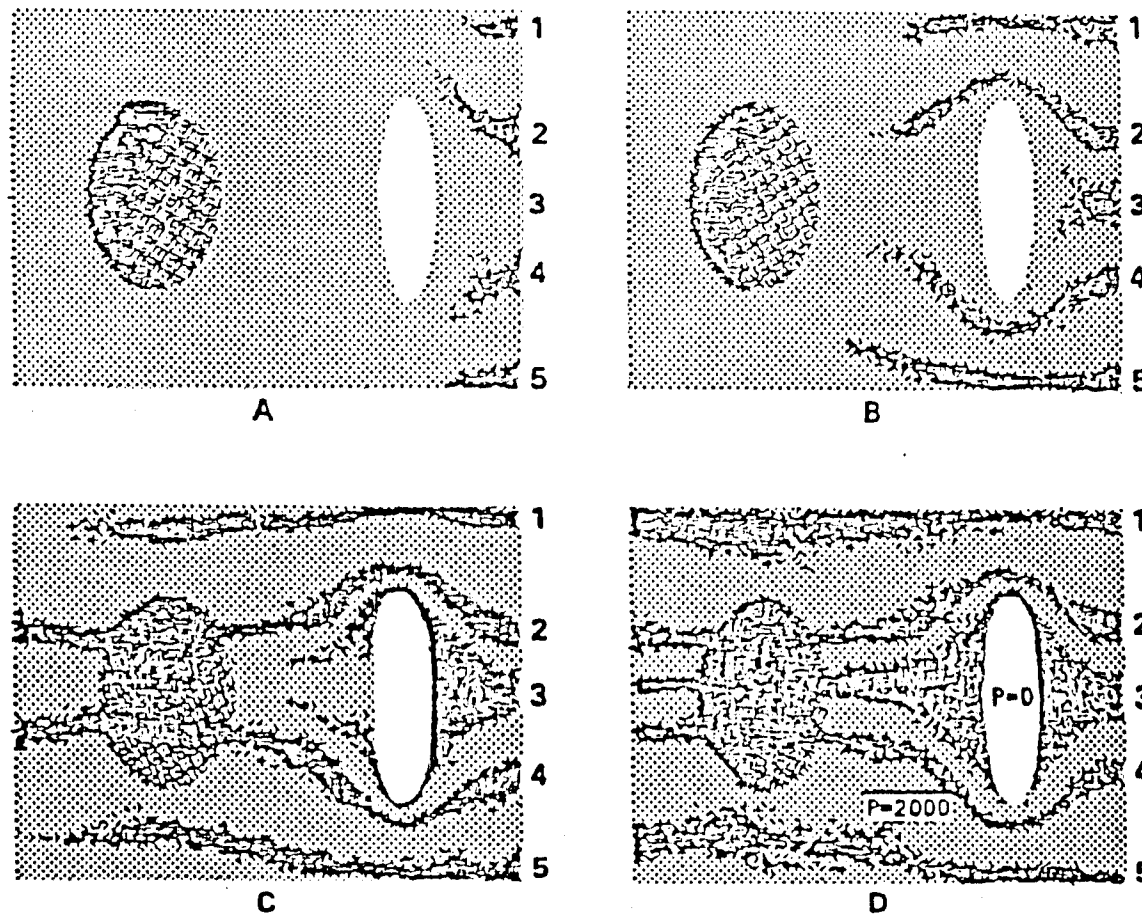
Note that the down gradient wells
will detect contamination first
because they are located in more
permeable soil.

Jordan, 1983

FIGURE 8



Photographic History of the Horizontal Lens Model



— Photographic history of the horizontal lens model. The pictures were taken at the following times after the entrance of the ink: A at 6 min., B at 16 min., C at 34 min., and D at 44 min.

FIGURE 9

Lehr, 1979

(Freeze and Cherry, 1979). Moreover, diffusion into porous rock and fissures can increase the migration of contamination (figure 10).

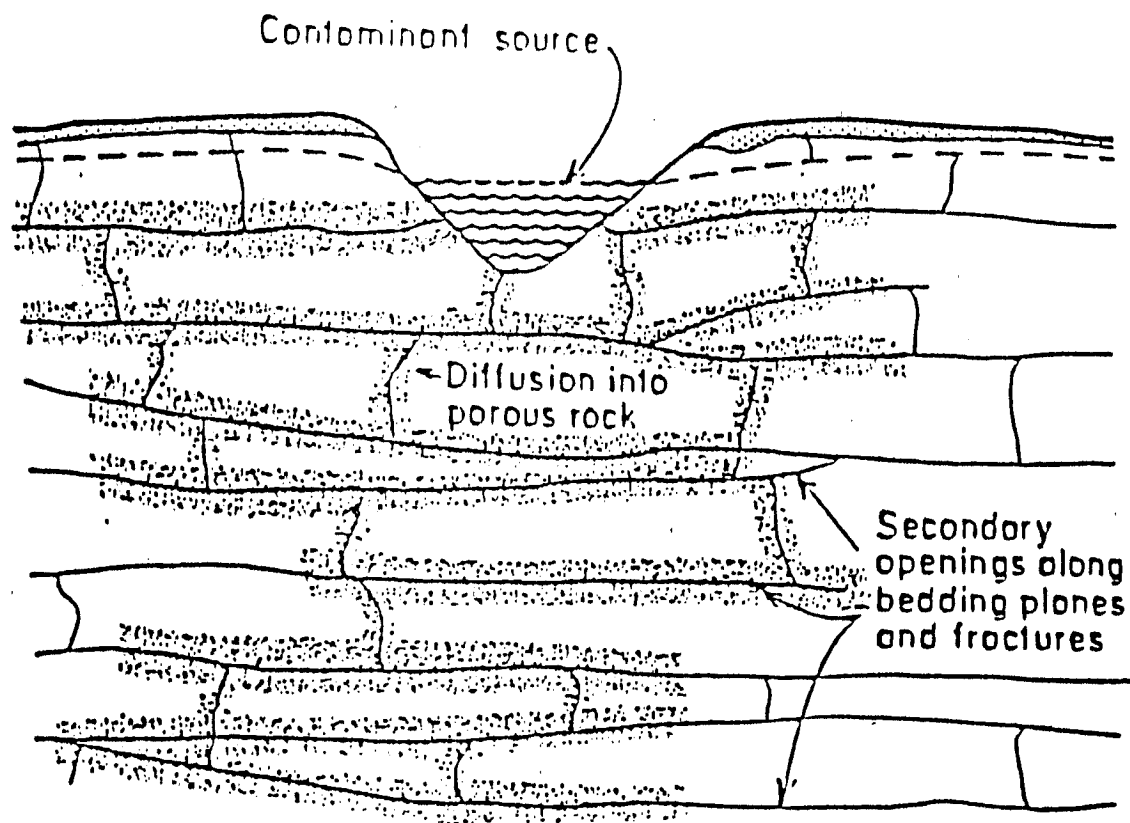
In some situations where extensive layers of clay or sand exist or where leaky confining beds are found, contaminants can move into a separate, lower aquifer and flow within it. Figure 11 illustrates how contaminated water can move into the lower aquifer and can only be detected by wells that penetrate this confined aquifer. This figure demonstrates how the location and depth of wells is crucial in the detection of contamination. For example, in figure 11 the shallowest well near the landfill will detect contamination, but the shallowest well far from the landfill will not detect any contamination. Because the contaminants have migrated down through what was assumed to be impermeable (the clay layer), a well that penetrates this lower aquifer is needed to detect contamination.

Geology and hydrology are thus significant factors in the flow of groundwater. Hence, some information of the geology and hydrology of the area should be known before Bewick performs an audit. This information is necessary to predict groundwater flow and provide an accurate picture of the extent and direction of the groundwater contamination (Jordan, 1983).

Predicting the direction and speed of contaminated groundwater is a formidable task, and results often have significant uncertainty. Figure 12 illustrates how difficult it is to make an accurate representation of the subsurface. Even though there are three monitoring wells down-gradient from the landfill, only well B would detect any pollution. This diagram demonstrates the low probability

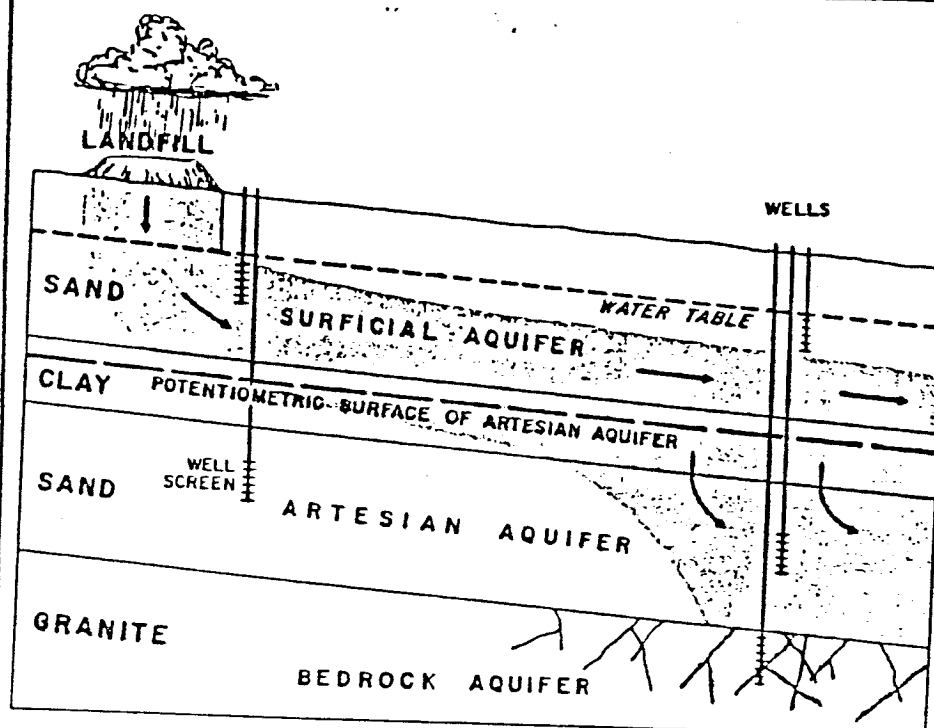
FIGURE 10

Contaminant Migration Through a Porous Limestone



Schematic representation of contaminant migration from a surface source through fractured porous limestone.

Effect of Aquifer Interconnection on Plume Formation in Groundwater

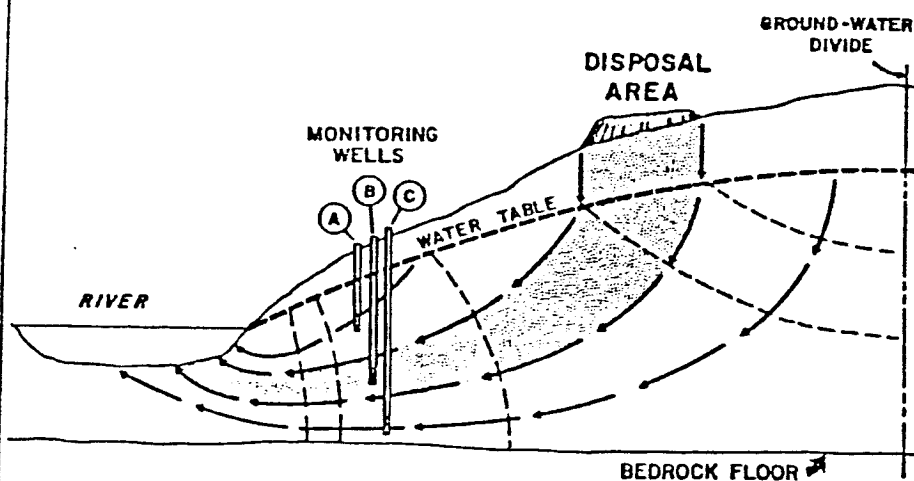


Source: Geraghty, et al., *Groundwater Fundamentals for Lawyers: Seminar, Washington, D.C., June 21-22, 1984*, (©1984, Geraghty and Miller Inc., Syosset, N.Y.) Reprinted by permission.

FIGURE 11

Jordan, 1983

Importance of Monitoring Well Depth and Location in Detecting Pollution



Source: Geraghty et al., *Groundwater Fundamentals for Lawyers: Seminar, Washington, D.C., June 21-22, 1984* (©1984, Geraghty and Miller, Inc., Syosset, N.Y.) Reprinted by permission.

FIGURE 12

Jordan, 1983

of detecting specific source pollution in a hydrologically complex aquifer; and in reality, there exists many more complexities than illustrated here.

In determining the location, depth, number, and type of monitoring wells necessary for an accurate description of the subsurface, many factors need to be understood. Some information should be obtained about the geology of the region and the site, and about the depth, quantity, direction, and speed of groundwater flow. Moreover, one should estimate the amount and use of groundwater and seasonal variations to obtain a reasonable groundwater flow estimate.

Once the geologic and hydrologic conditions are considered, one should know about the general physics of groundwater movement. The factors that lead to increased or decreased discharge, variations in hydraulic head, and changing water levels should all be considered. A brief summary of the physics of groundwater is necessary for a better understanding of the prediction of groundwater flow.

The Physics of Groundwater

Darcy's Law

Henry Darcy, a French hydraulic engineer, first observed and reported the relationships between groundwater flow and filter sands. His apparatus consisted of a vertical iron pipe, 3.50 meters long, flanged at both ends. At a height of 0.2 meters above the base of the column, there was a horizontal screen supported by an iron grillwork with a meter of loose sand above it. Water was added from the top of the apparatus and was discharged through the bottom. The flow rate was adjusted by both the inlet pipe and the outlet pipe. The

pressures were measured by mercury manometers above and below the sand column.

Experiments with different types of sands yielded the same observation. Darcy concluded that the total rate of discharge increases linearly with the drop in head across the sand of two equivalent water manometers (figure 13). Darcy found that when water flows vertically downward through a sand, the volume of water Q passing through the system in unit time is given by:

$$Q = -K * A (h_2 - h_1 / l)$$

where

K = a factor of proportionality, dependent upon the permeability of the sand,

A = the cross-sectional area of the sand through which Q flows,

l = the thickness of the sand, and

h_1, h_2 = the heights above a standard reference elevation of water in equivalent water manometers terminated above and below the sand, respectively.

Since $q = Q/A$, the specific discharge q can be written as:

$$q = -K (h_1 - h_2 / l).$$

In differential form, this equation yields

$$q = -K (dh/dl).$$

These equations state that the specific discharge q is directly proportional to K and to the head loss dh , but inversely proportional to the thickness of the sand dl . Although this relationship correctly describes the conduction of fluids through porous solids, it does not give any insight into the physics of the phenomenon.

M.K. Hubbert was the first person to correctly describe the generality and physical content of these relationships. He explained

Discharge Versus Drop in Head

The two relationships shown here are for two different soil mediums.

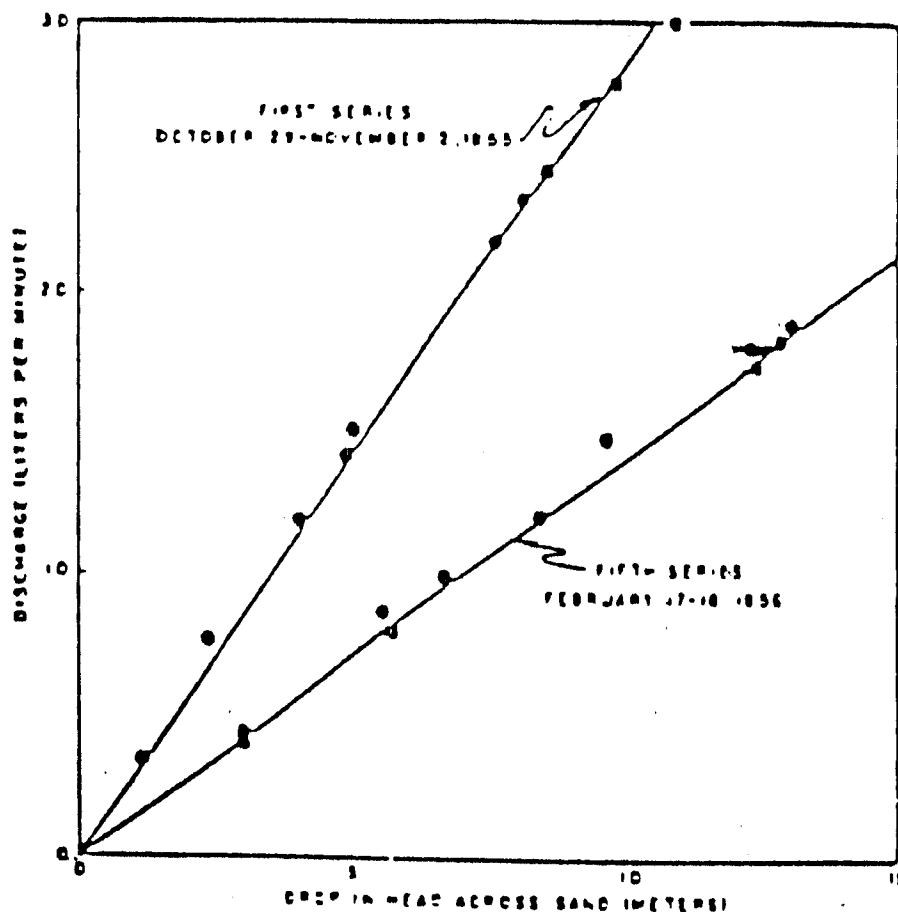


FIGURE 13

Graphs compiled from Darcy's tabular data on his experiments of October 29th to November 2, 1855, and of February 17-18, 1856, showing linear relationship between flow rate and differences in heights of equivalent water manometers (from Hubbert, 1969, p. 268).

the parameters h and K and explained how Darcy's theory fits into general field theory of the flow of fluids.

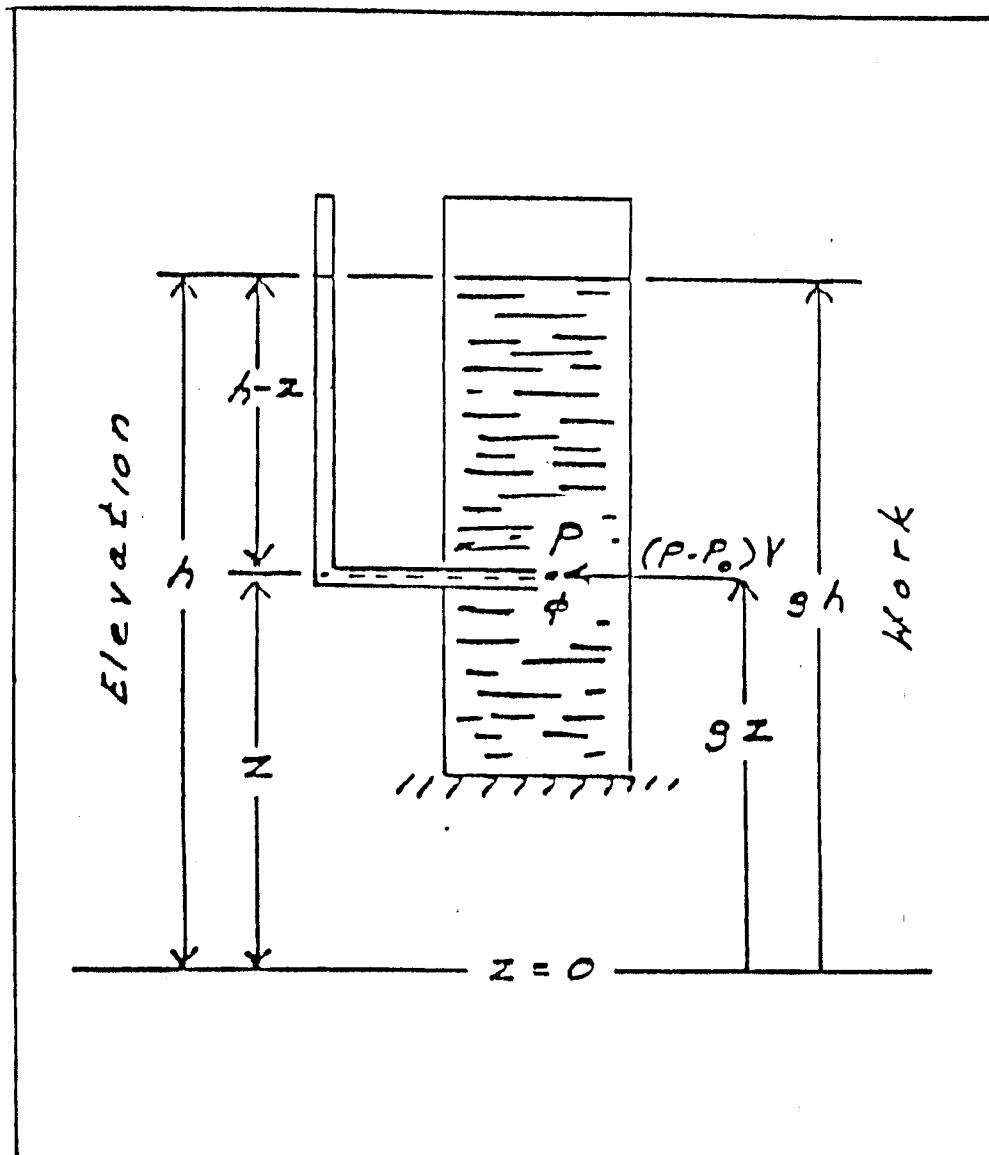
Hubbert's Definition of Head

Hubbert paralleled the laws that govern the flow of electricity from a high potential to a low potential and the flow of heat from a higher temperature to a lower temperature with Darcy's law. He noted that the rates of flow can be explained as a potential gradient, always flowing from higher potential to lower potential.

One of Hubbert's most important conclusions is that the hydraulic head, h , is the sum of two components: the elevation of the point of measurement (or elevation head), z , and the pressure head, $h-z$ (figure 14). He defined potential as a "physical quantity, capable of measurement at every point in a flow system, whose properties are such that flow always occurs from regions in which the quantity has higher values to those in which it has lower values, regardless of the direction in space" (Hubbert, 1940). Moreover, he concluded that the hydraulic head, h , is almost perfectly coordinated with the fluid potential Ψ , where the fluid potential is equivalent to the mechanical energy per unit mass. It is the sum of the work required to lift the unit mass from elevation $z = 0$ to z , and the work done on the fluid in raising the fluid pressure from $p=0$ to p . Hence, Hubbert explained the parameters to Darcy's empirical relationship and related them to measurements that can be taken in the field.

As mentioned before, Hubbert also defined the parameter K . He demonstrated that the constant of proportionality, K , in Darcy's law is a function not only of the porous medium but also of the fluid. By

FIGURE 14



Fluid potential at any point inside a body of static liquid.
(after Hubbert, 1969, p. 43).

microscopically studying the flow of fluids through a porous medium, he was able to distinguish between the physical properties related to the porous medium alone and those related to the fluid. He then derived the definition of a new parameter k , known as specific or intrinsic permeability, which is a function only of the porous medium by itself:

$$k = C d^2$$

where C = a new constant of proportionality including soil properties such as the distribution of grain sizes, sphericity and roundness of the grains, and the nature of their packing, and

d = mean grain diameter.

He then restated Darcy's Law in a form that isolates the properties of the porous medium from those of the fluid. This restatement is as follows:

$$q = (-C * d^2) (p * g / u) (dh/dl)$$

where p = the density of the fluid

u = the dynamic viscosity of the fluid

g = acceleration due to gravity

and the remaining variables as defined previously.

By substitution, Darcy's K can be rewritten as

$$K = k (p * g / u).$$

Table 5 indicates the wide range of values of hydraulic conductivity and permeability for different types of rocks and unconsolidated materials.

Now that different relationships have been given for q , it must be explained that although q has units of velocity, it does not represent the velocity of the groundwater movement even though the value of q is derived from Q/A , which gives a length/time dimension.

Range of Values of Hydraulic Conductivity and Permeability

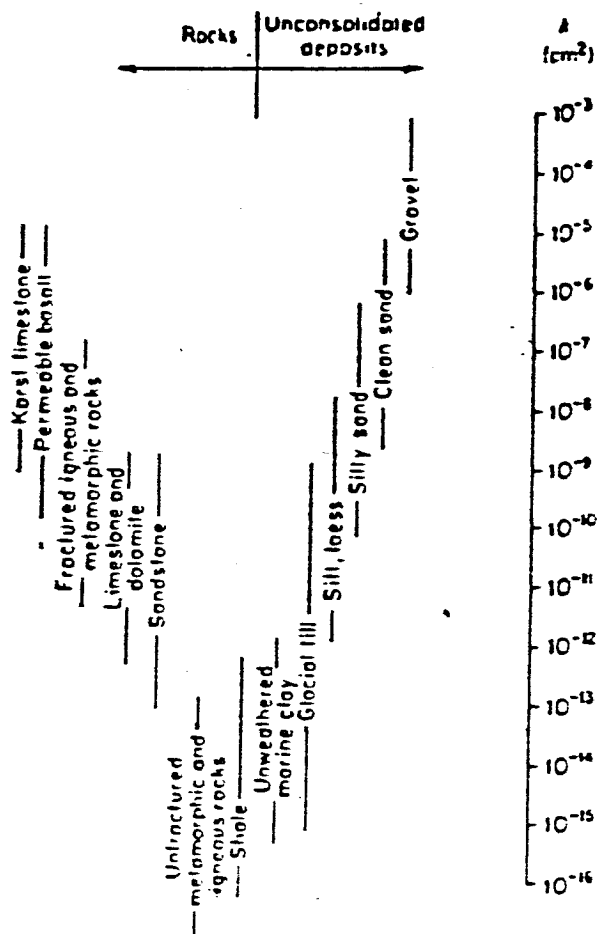


Table 5

Freeze and Cherry, 1979

This table illustrates the wide range of values for the hydraulic conductivity for various mediums.

Recall that the cross sectional area consists of both voids and solids. In actuality, the flow passes only through that portion of the cross sectional area occupied by the voids. The porosity of a soil is the volume of the voids V_v divided by the total volume V_t . This is expressed as

$$n = V_v / V_t$$

which is a dimensionless value. For our purposes, the main interest lies in the water that is drained from the voids in the soil or rock by the force of gravity alone. This is known as the effective porosity or specific yield (n_e). It is defined as

$$n_e = W_y / V$$

where W_y = the volume of water drained by gravity and
 V = the total volume of the sample of the formation.

(Refer back to table 4 for effective porosity values.) Now it is possible to determine the average linear velocity:

$$v = q / n_e.$$

The velocity of groundwater flow can never be exactly known due to the many unknown parameters involved, but an estimate can indicate the seriousness of a spill or leak. If the velocity is high, quick remedial action is necessary.

With a background in relevant federal and state laws, and the characteristics of groundwater now understood, a more specific problem can be confronted: leakage from underground storage tanks. These tanks pose their own type of groundwater contamination problem, and hence, need to be considered separately from other sources of contamination.

Groundwater Quality Problems Associated
with Underground Tanks

Groundwater contamination, which often originates from underground storage tanks, can render water supplies unusable for many years. Because of the slow movement of groundwater and minimal attenuation of contaminants, the only solution to groundwater contamination is prevention. Once contamination already exists, the costs of treatment are high and in some cases are not even feasible.

Underground tanks were originally mandated for the storage of hazardous materials because they reduce the danger of fire and explosion; however, other risks are involved when hazardous materials are stored in underground tanks. These tanks can be dangerous if they leak because potential contaminants are closer to the underlying groundwater, and below the biologically active soil layer where attenuation of the contaminants is most likely to occur. Furthermore, leakage from such tanks may go unnoticed for long periods because it cannot be visibly detected.

It is estimated that in the United States there are 1.2 million steel underground storage tanks at service stations alone, and that another 100,000 fiberglass tanks are used for the storage of petroleum and other products. However, these estimates are thought to represent only a small percentage of the total number of tanks in the United States because many tanks are unregistered or out of use (Jordan, 1983).

The total number of tanks is one concern; another is the total capacity. The EPA estimates that 13.8 billion gallons of hazardous

materials are stored in underground tanks throughout the nation. Moreover, the average service station that typically held 4,000-6,000 gallons in the 1950's, now is designed to store approximately 10,000 gallons. If this estimate is correct, then an average capacity of 10,000 gallons in 2.5 million tanks leads to a different, and perhaps more accurate, total estimate of twenty-five billion gallons of hazardous materials stored underground, as opposed to 13.8 billion gallons (Jordan, 1983).

The typical design life of steel tanks is between fifteen and twenty years and is highly dependent on environmental conditions. For example, leaks may develop within seven years or less if unprotected steel tanks are installed in humid areas or are in contact with saltwater, both of which are possibilities in the Boston area. For example, the Cape Cod area has had serious corrosion problems with tanks that have been exposed to saline water. In fact, the risk of older steel tanks is so great that the Pollution Liability Insurance Association no longer insures them if they are older than twenty years, unless they meet stringent testing requirements (Jordan, 1983). However, if the area is relatively dry, the same tank may last as long as thirty years. Protected steel tanks are estimated to have a design life of more than twenty years and fiberglass tanks between forty and fifty years, if they are installed properly (Jordan, 1983).

The potential contamination from underground storage tanks is primarily from hydrocarbon pollution, more specifically, oil and gas. If tanks consist of single-walled construction (as most of the older tanks do), they may corrode and leak over time. Fittings or pipes may

also fracture in areas of unstable soil. Furthermore, potential contamination is increased in areas of high groundwater or highly permeable soil, where moist conditions can lead to increased corrosion rates and high groundwater in porous soils can transport the contamination. Inadequate monitoring or lack of monitoring of the liquid levels, as previously mentioned, can also allow leakage to continue for years without detection (Jordan, 1983).

Attenuation of Contaminants in the Groundwater System

With underground storage tanks and most other sources of groundwater contamination, the source of the contamination is at the ground level or in the subsurface. The potential for this contamination to reach the aquifer depends upon the amount of attenuation that occurs between the introduction at the surface and the water table. Attenuation, which includes any mechanism that tends to remove or hinder the movement of the pollutant, varies with different geological materials, environmental conditions, and different distances the pollutant must travel through unsaturated materials to reach the groundwater (Osgood, 1974). Those contaminants that do not reach the groundwater initially contaminate only the soil, but will eventually contaminate the groundwater as rain water constantly percolates down through the soils, bringing some contamination with it. The infiltration time depends on the depth to groundwater and the permeability of the soils above the aquifer. Generally, the longer the contaminant remains in the biologically active unsaturated zone, the greater the degree of attenuation (Nielsen, 1986).

Some of the processes that affect contamination concentration are filtration, sorption, oxidation and reduction, and biological decay. Filtration is the process by which the porous soil medium acts as a physical filter to trap suspended particles. The type of soil is a function of the amount of particles that get trapped. Certain soils (clay, for example) tend to act as a large trap for particulate matter because they are fine grained and offer more surface area for contaminants to become trapped. Sorption is the physical (absorption) or chemical (adsorption) capture of individual molecules by soil particles. The rate at which particles are sorbed depends on the soil's density, clay content, and ionic exchange capacity (the readiness with which the soil material will exchange charged fragments of molecules with the material in solution in the infiltrating water) (Jordan, 1983). Oxidation and reduction are chemical processes which can make some materials chemically inert⁶. Biological decay involves plant uptake and microbial decomposition, which also can make some contaminants inert. Some aerobic and anaerobic bacteria can degrade hazardous compounds by oxidation, using the energy obtained by the oxidation to survive. They can create carbon dioxide and water as by-products.

There is little or no attenuation if a pollutant is introduced directly into the water table. For example, if a tank is leaking from a point on the tank that is already below the water table, there is no chance for attenuation in the unsaturated zone. Hence, the

⁶. Those compounds that become inert can be considered attenuated.

contaminant has already polluted the saturated zone and the only hope is for attenuation to occur there. However, there are fewer mechanisms of attenuation in the saturated zone, the principle means of attenuation being dilution by the surrounding groundwater (Holzer, 1976). Because turbulence is rare in groundwater flow, relatively little mixing occurs and primarily diffusion takes place. Hence, the process is very slow and the contaminant plume can stay as a pulse for years until it is discharged (Abriola and Pinder, 1986). Whatever contamination is not attenuated and in the groundwater will now be transported with it.

Transport of Contaminants in the Subsurface Environment

Contaminant plumes move primarily along hydraulic flow lines within the aquifer, from areas of recharge to areas of discharge. The size of the plume varies with the nature of the contaminant, the rate of groundwater flow, the rate of contaminant discharge, and the characteristics of the aquifer (Jordan, 1983).

There are three major ways contamination can travel, depending on how the pollutant enters the subsurface. First, discrete pollution sources create single plumes that gradually disperse and move down-gradient until they reach points of natural or manmade groundwater discharge. Sewers act as manmade discharge points, while streams and lakes can be natural detection points for contamination. Second, continuous pollutant sources, such as incessant leaks, generate uninterrupted down-gradient plumes. Third, intermittent sources create many discrete plumes also moving down-gradient. An example of an intermittent source of contamination is a tank that has a bad

connection in the fill pipe and only leaks when being filled or a tank that has a hole at the top that only leaks when it is full or when it rains enough to top the tank with rain water and cause an overflow. Figure 15 shows different methods of introduction of contamination in the subsurface.

Besides the method of introduction of a pollutant, the type of pollutant is also important in determining its rate of flow. Many oil compounds are mostly immiscible in water and tend to travel in discrete nonaqueous phases (Abriola and Pinder, 1985). The migration of an immiscible organic liquid in the subsurface is governed largely by its density and its viscosity. For example, density differences of only one percent are known to influence fluid movement significantly (Mackay, et. al., 1985). In most cases, the densities of organic compounds differ from that of water by more than one percent, and in many cases, the density differences are ten percent or more. The specific gravities of hydrocarbons (gasoline and other petroleum by-products) are as low as 0.7, while halogenated hydrocarbons are mostly more dense than water (Mackay, et. al., 1985)⁷. Figures 16 and 17 show how different densities can result in different directions of movement.

The viscosity of organic liquids compared to that of water also influences the movement of the contaminant. It has been shown that

⁷. The density and specific gravity of water is 1.0.

FIGURE 15

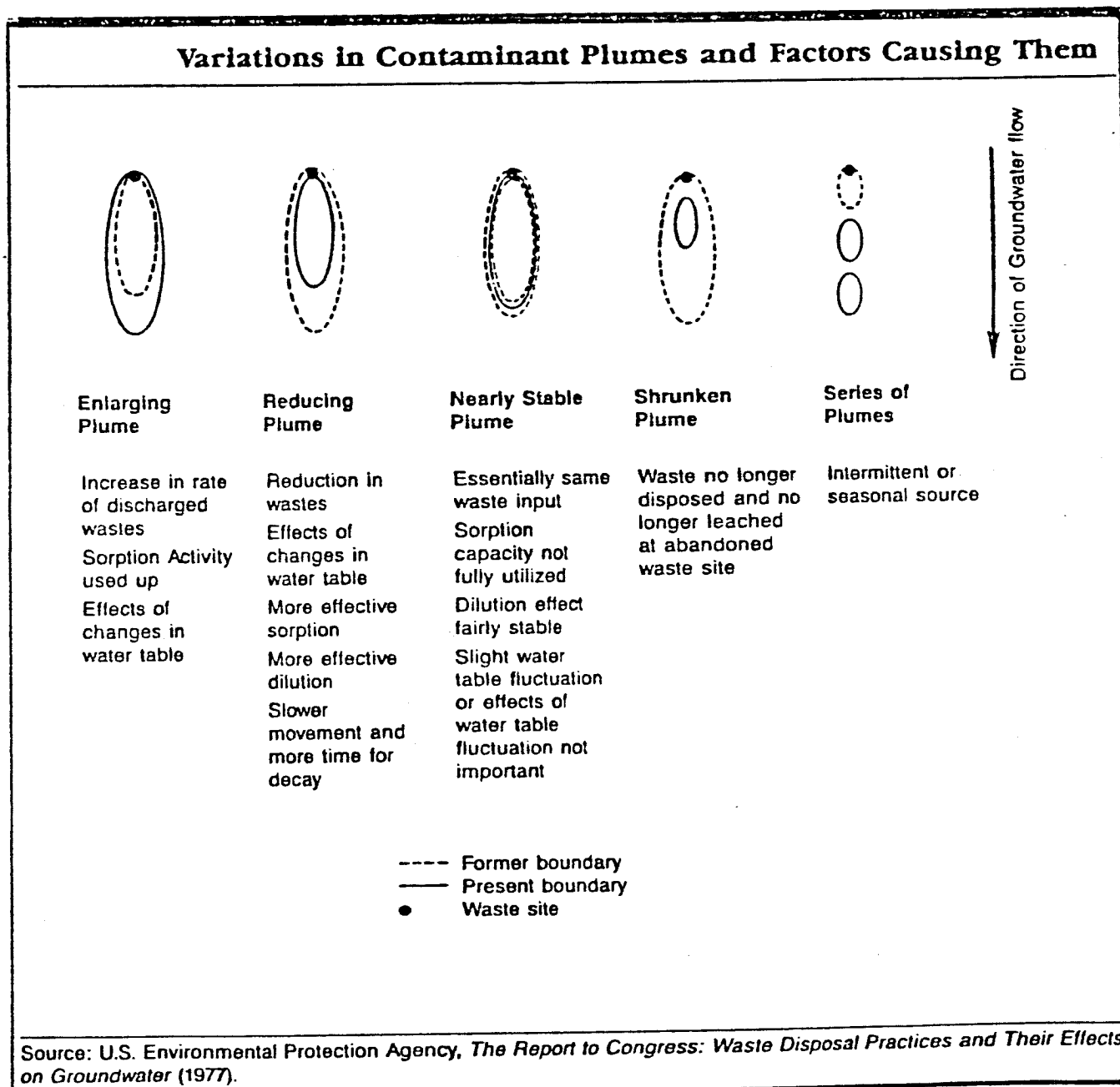
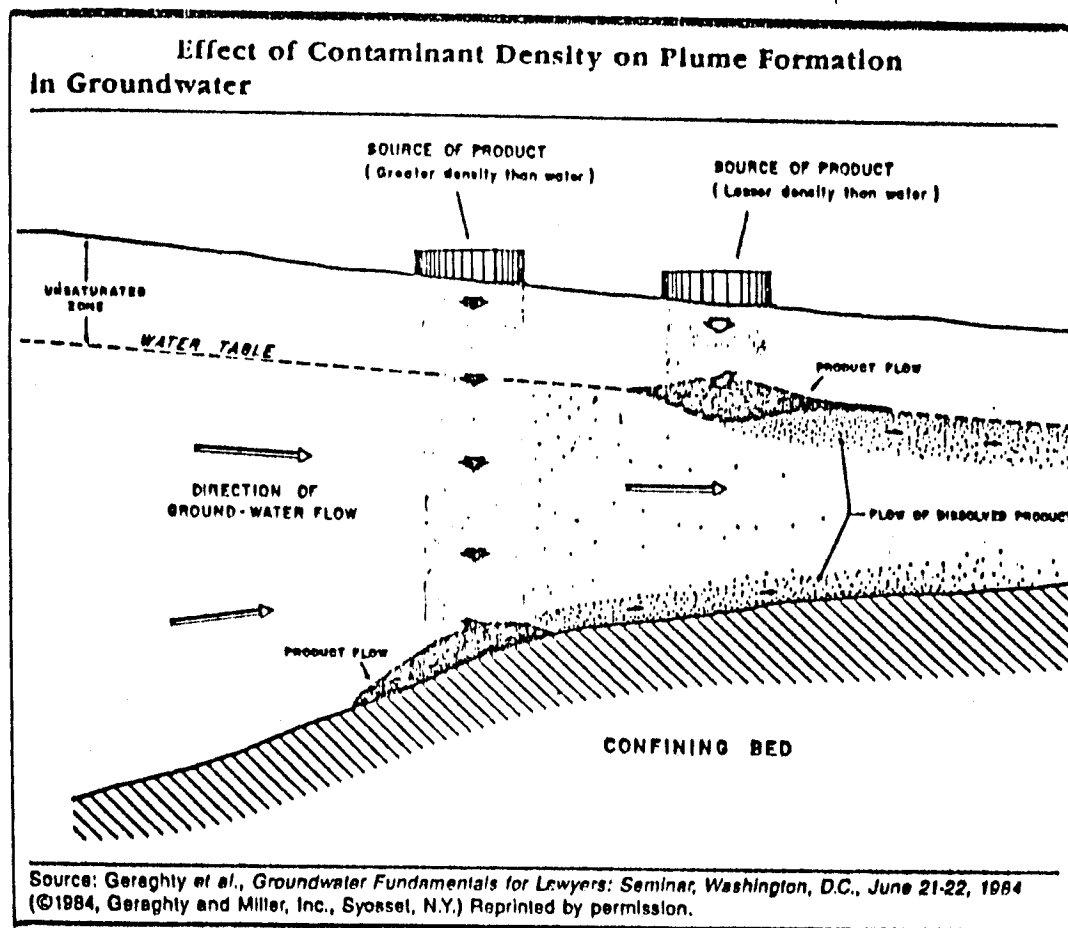


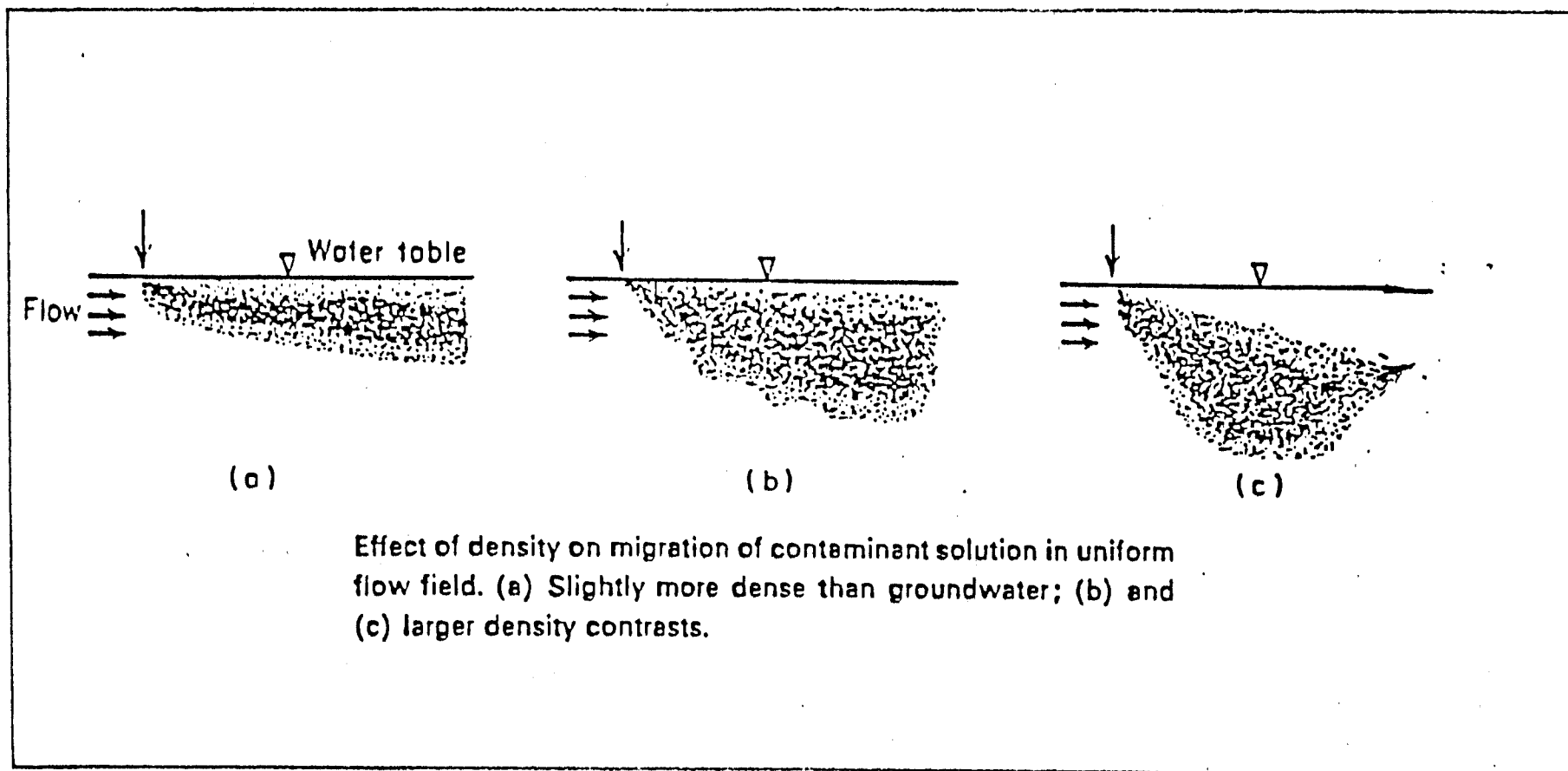
FIGURE 16



Jordan, 1983

A contaminant with a greater density than water will sink and travel along the impermeable surface as shown. A contaminant with a density less than water will travel along top of the water table.

FIGURE 17



Freeze and Cherry, 1979

some immiscible compounds may store as droplets dispersed within the pores of aquifer media, even if the bulk of the migrating mass of liquid is removed. This may result in slow dissolution of this compound as future groundwater flows past it, but doesn't dissolve it immediately (Mackay, et. al., 1985).

Floaters, Sinkers, and Solutes

Besides viscosity and density, solubility also plays a major role in how an organic compound is inclined to travel. The more water soluble a compound, the more it will travel as the groundwater does. With respect to solubility, organic compounds fall into three divisions: floaters, sinkers, and solutes. The classification of a compound determines the rate it will flow. It is therefore important to understand how the oil and/or gasoline pollutant in question is classified.

Many pollutants travel at the same rate as the groundwater, generally between a few inches and a few feet per day. However, organic contaminants (such as oil and gas constituents) can reach the groundwater zone in one of two general categories: either dissolved in water or as an organic liquid phase that is mostly immiscible in water (Abriola and Pinder, 1985). The subsurface transport of immiscible organic liquids (sinkers and floaters) is governed by a set of factors different from those for dissolved contaminants (solutes) (Mackay, et. al., 1985). If the pollutant's specific gravity is comparable to that of water, the pollutant will travel as a solute with the groundwater flow. If, however, the pollutant has a specific gravity that is less than water's (e.g. benzene), it will be classified a "floater" and

will tend to remain on top of the groundwater, forming a lens of contamination. Heavy organics or "sinkers" (e.g. number six oil) will tend to sink through the groundwater and flow along the contact plane between the aquifer and the underlying impervious material (Refer back to figure 15). A closer examination of these three classifications is useful.

Transport of Sinkers

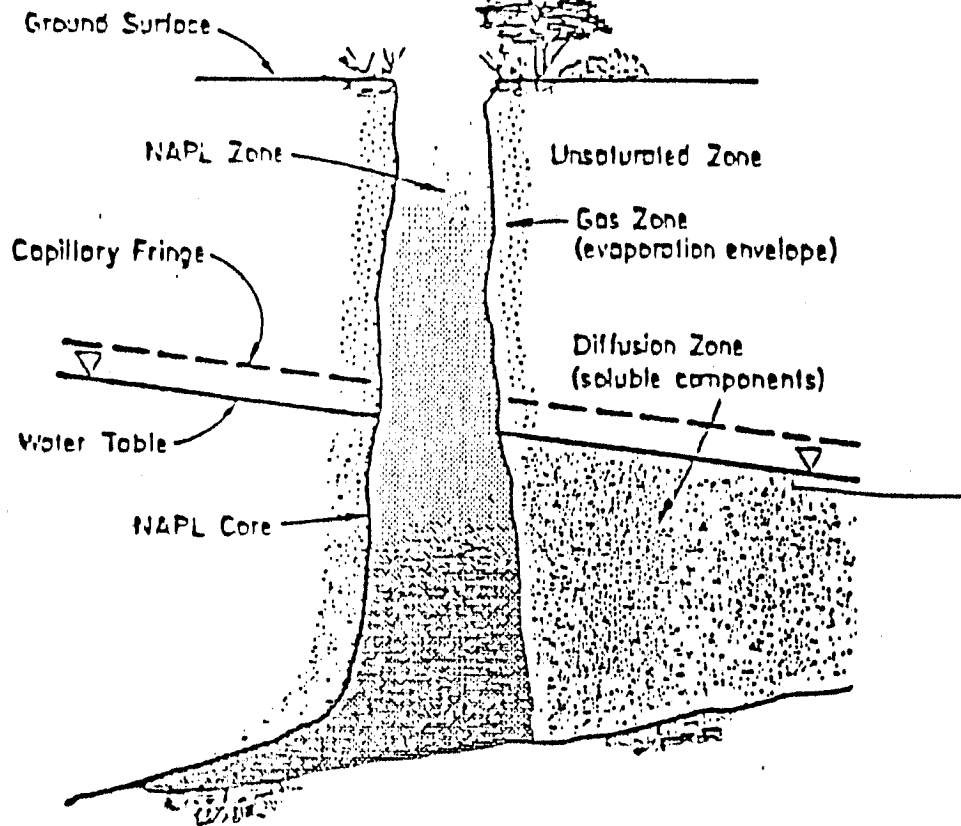
Sinkers are those contaminants that have a specific gravity greater than 1.0 (hence, their densities are greater than the density of water) and are immiscible in water. Number six oil, for example, is very viscous and has a consistency similar to molasses. Other chemicals may also be in this category if the concentration of its species in the groundwater exceeds the upper limit of the compound's solubility, making the solution saturated (Abriola and Pinder, 1985).

The transport of such compounds depends on the nature of the impermeable material at the bottom of the aquifer. Such a substance will migrate through the saturated zone until it comes to rest on the impermeable surface at the bottom of the aquifer (Faust, 1985). Its flow is controlled by the slope of the impermeable boundary, which in some cases is opposite the direction of the groundwater flow (Pinder and Abriola, 1986). The compound will continue to migrate until it reaches equilibrium, often coming to rest on the impermeable surface. Figure 18 illustrates this movement.

Transport of Floaters

Floaters are those contaminants that have a specific gravity less than 1.0 (hence, their densities are less than the density of water)

FIGURE 18



Schematic representation of heavier than water NAPL movement through the saturated and unsaturated zones.

Pinder and Abriola, 1985

NAPL stands for "non aqueous phase liquid", such as many oils..

and are immiscible in water, for example, gasoline and other lighter petroleum products. Although all oils are slightly soluble in water, floaters tend to be mostly immiscible so they remain segregated as a separate liquid phase that remains on top of the groundwater once it reaches the capillary fringe or water table (Abriola and Pinder, 1985). Figure 19 illustrates the general path of an immiscible floater in a groundwater system.

After introduction into the subsurface, the contaminant moves primarily under the influence of gravity. Depending upon the viscosity and volume of oil or gas moving through the unsaturated zone, it may become immobilized by filling the voids in the unsaturated zone or by adsorption on soil particles, especially if they are fine-grained. It may also spread out laterally within the unsaturated zone if it encounters a layer of lower hydraulic conductivity (Brownlee, 1984). The volume of porous geologic materials that is required to immobilize a known volume of oil coming from a spill or a leak can be estimated by the following formula:

$$D = (1000 * V) / A * R * K$$

where D = Maximum depth of penetration

V = Volume of infiltrating oil

A = Area of infiltration at the surface

R = Retention capacity of the soil, and

K = a correction factor for various oil viscosities,

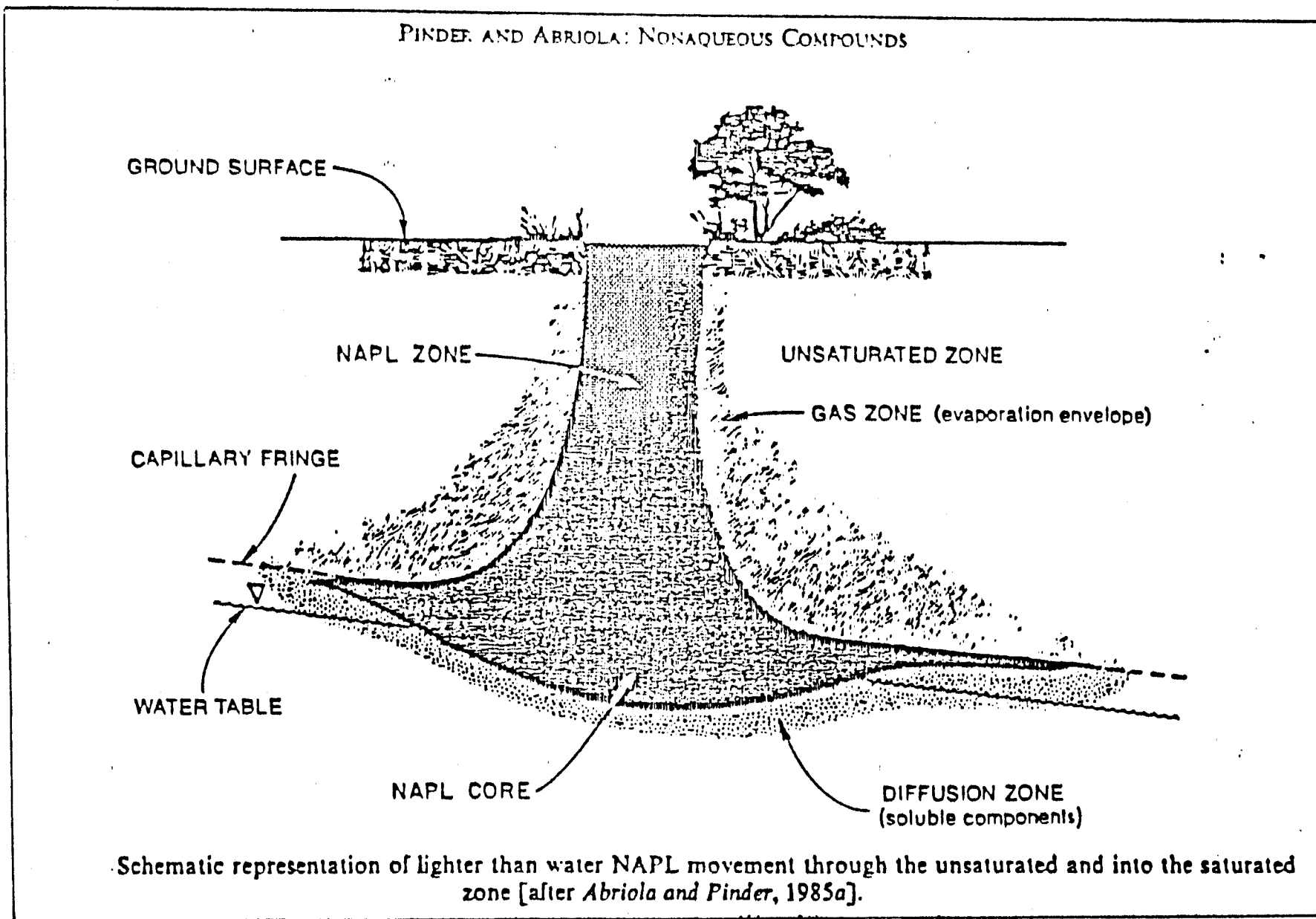
where

K = 0.5 for low viscosity petroleum products
(i.e. gasoline)

K = 1.0 for kerosene, gasoil and products with
similar viscosity

K = 2.0 for more viscous oils such as light
fuel oil.

FIGURE 19



NAPL stands for "non aqueous phase liquid".

Pinder and Abriola, 1985

Typical values for retention capacities of porous soils are given in table 6. In more practical terms, retention capacities can be explained as follows. Assume one cubic meter of kerosene is spilled over a ten square meter area. It will have a final depth of penetration of twenty meters for soil composed of stones and coarse gravel, 6.7 meters for coarse to medium sand, and only 2.5 meters for fine sand to silt type soils (Brownlee, 1984). Hence, knowledge of the type of retention capabilities a medium has is crucial when estimating the depth of infiltration.

If the soil has very high retention capabilities and immobilization occurs above the saturated zone, groundwater contamination is not an immediate problem. Rather there is a soil contamination problem that will eventually lead to groundwater contamination. Bewick has had many situations where soil excavation was necessary to alleviate heavy contamination, while the groundwater was only slightly contaminated. In many instances, this situation is easiest to remedy since little movement of the contamination has occurred and most of the oil and/or gas can be removed from the site and properly disposed in a landfill⁸.

If, however, this oil or gas with a specific gravity less than 1.0 has migrated to the water table, it will form a mound on the groundwater, slightly depressing the water table at the point of

⁸. Although soil removal is technically easy to accomplish, it is expensive for Massachusetts residents because the nearest landfill that accepts contaminated soil is in Maine.

Table 6

Typical values for retention capacities of porous soils are given.

<u>Typical values For Retention Capacities of Porous Soils</u>	
R	
<u>Soil</u>	<u>Oil Retention Capacity (litres/cubic meter)</u>
Stone, coarse gravel	5
Gravel, coarse sand	8
Coarse sand, medium sand	15
Medium sand, fine sand	25
Fine sand, silt	40

Brownlee, 1984

greatest oil thickness. As it accumulates on the water table, the oil zone begins to thin, spreading out laterally in the direction of the water table gradient. Eventually it will reach a state of equilibrium within the capillary fringe and the saturated zone, most of the time progressing with the movement of the groundwater (Holzer, 1976).

Even if equilibrium has been achieved and the migration of oil has ceased, two major environmental problems exist. First, since the oil is at the top of the water table, it is at a water-air interface and gases can easily migrate through the unsaturated zone to cause fire or health hazards (Osgood, 1974). This situation is especially severe when large quantities of gasoline, which is more volatile than most oils, are floating on top of the water table. Second, the solubility of lighter hydrocarbons greatly exceeds the concentration levels at which water is considered to be seriously polluted. Commercial gasoline, for example, has a solubility of 20-80 mg/l in water. It can be detected by taste and odor at concentrations of less than 0.005 mg/l (Brownlee, 1984). Benzene alone has reported solubility values of 1750 mg/l at 10 C (Mackay and Leinonen, 1975); 820 mg/l at 22 C (Chiou et al., 1977); 1780 mg/l at 25 C (Mackay and Wolkoff, 1973); and 1800 mg/l at 25 C (Howard and Durkin, 1977). Ethylbenzene has a solubility of 152 mg/l (Verschueren, 1977), while toluene has a reported solubility of 534.8 mg/l (Sutton and Calder, 1975). Because the solubility of these lighter hydrocarbons greatly exceeds the concentration levels at which water is considered to be seriously polluted, one has to be concerned about not only the localized zone of immiscible hydrocarbons above the water table, but

also the small percentage of dissolved contaminants that might enter a public drinking well. Hence, even though these compounds are mostly immiscible, enough of them do dissolve to contaminate the groundwater. The information concerning these floaters and the proximity of drinking wells is used in this situation to make a decision about the potential for contaminated drinking water.

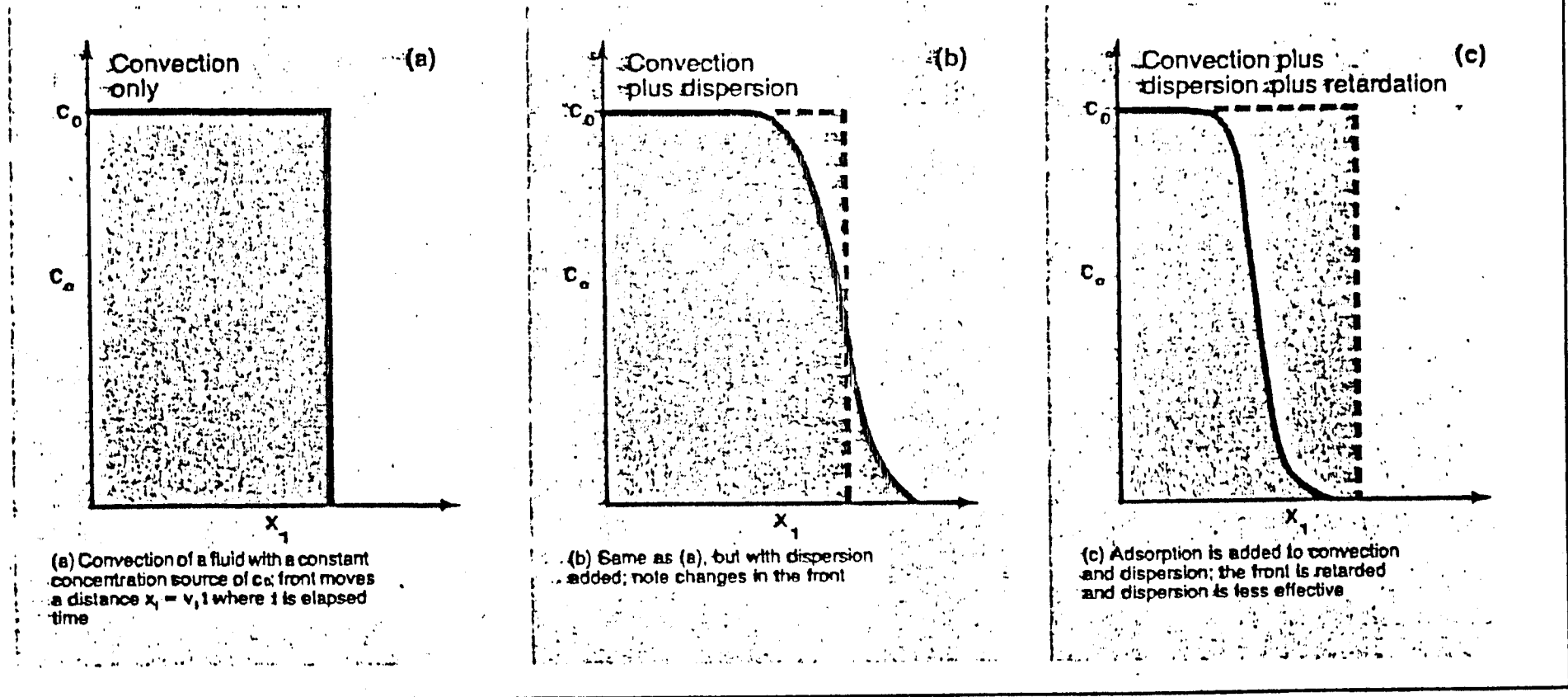
If the source of a floater is continuous and the volume is large, then steady state conditions will not be reached. The compound will continue to spread out over the surface of the water table. If there are underground utility lines that have penetrated the saturated zone and are backfilled with permeable sand or gravel, then the trenches excavated for these utilities may present a route of high permeability that will preferentially be selected as the migration pathway for the contaminant. Trenches for sewer lines are particularly suspect in this regard because they are generally laid at the lowest elevation (Brownlee, 1984). For this reason, it is important to note the number and locations of underground utilities.

Transport of Solutes

All compounds dissolve to some degree, and this dissolved state has many factors that affect its complicated movement. Solutes are those compounds that tend to mostly dissolve in water. Although it is important to know the average velocity of fluids through the pore spaces, this knowledge alone is not adequate in understanding solute transport. With this transport, other factors are involved, such as convection (or advection), dispersion, chemical and biological transformation, sorption, and retardation. Figure 20 shows the stages

FIGURE 20

Species transport



Pinder and Abriola, 1985

of solute transport with just convection, convection with dispersion, and convection, dispersion, and retardation. Convection is just the movement of the contaminant with the water, assuming none of the contaminant is sorbed onto any soil particles or decayed. Dispersion is the spreading out of the compound due to a concentration gradient, occurs with every compound, and can be a significant factor in the movement of the compound. Retardation, as shown in the third graph, inhibits the movement of the solute since the contaminant sorbs to soil particles. This, in turn, slows down the migration of the contaminant. For a more complete understanding, these factors must be addressed individually.

Convection

The dominant factor in the migration of a dissolved contaminant through aquifers is convection. This is the process by which solutes are transported by the bulk motion of the flowing groundwater, and is most profound when the aquifer consists of sand and/or gravel. Since groundwater generally flows from areas where the water level is high to areas where the groundwater level is low, the contaminant dissolved in the groundwater travels the same path. As previously mentioned, this driving force, the hydraulic gradient, is based upon the principle that water will flow from a high potential to a low potential.

For uniform sand and gravel aquifers in gentle topography, the gradient normally follows the topography, and the flow water rate can usually be approximated within a factor of ten (depending on the geology of the area). Groundwater in sand and gravel aquifers

generally have velocities which range from one meter per year to one thousand meters per year; however, in most situations, the typical flow rate is between ten and one hundred meters per year (Mackay, et. al., 1985). Therefore, when considering a contaminated subsurface consisting of sand and gravel in relation to a drinking well located thousands of meters downgradient of the contamination, the average travel time for the contaminant to flow to the well will be on the order of decades.⁹

Dispersion

Dispersion, the process by which dissolved contaminants spread out as they move with the water, results from two basic processes: mechanical mixing and molecular diffusion (Mackay, et. al., 1985). The former results from variations in groundwater velocity within the porous aquifer caused by frictional forces, varying flow directions with respect to the mean flow, and changing pore geometry. The latter is caused by the kinetic activity of the dissolved solutes (Mackay, et. al., 1985). This causes a net flux, or diffusion, of the solutes from a zone of higher concentration to an area of lower concentration.

These two processes act together by diluting the contaminant pulses and attenuating the concentration peaks. The further from the source, the less distinct the peak of contamination; hence, the more uniform the contamination. In addition, dispersive spreading may result in the arrival of detectable contaminant concentrations at a given location significantly before the arrival time that is expected

⁹. The geology of a specific area may allow for much faster transport of the contaminant, and this general estimate should not be used for every case.

solely based on average groundwater flow. (Mackay, et. al., 1985)

Dispersion, however, can not be predicted for a previously unstudied area because dispersion relies heavily on the geologic structure through which the medium is flowing. For simple hydrogeological systems, the spreading is believed to be proportional to the flow rate; however, most systems are not this simple (Mackay, et. al., 1985). Moreover, dispersion in the direction of flow often is observed to be much greater than dispersion in the directions transverse to the flow. Since most soil mediums are unstudied, this obviously leads to a considerable degree of uncertainty.

Sorption and Retardation

Some compounds tend to interact with the aquifer solids as they are transported through the subsurface, causing a distribution between the aqueous phase and the aquifer solid phase. These compounds sorb onto soil particles and subsequently slow the movement of the contaminant relative to the groundwater flow. The higher the fraction of the contaminant sorbed, the more retarded is its transport (Abriola and Pinder, 1985).

The amount of sorption that a compound exhibits depends on a number of factors, which include the concentration of the contaminant, its characteristics, the pH of the groundwater, the presence of other dissolved solutes, and the characteristics of the aquifer solids (Mackay, et. al., 1985). These characteristics can cause a varying flow rate in both space and time, and hence complicate the prediction of contaminant flow. Generally, a contaminant front will not appear until all adsorption sites are filled. In a medium of small clay

mineral particles, there are many sites that can be filled so the amount of sorption is significant. This varying degree of adsorption-desorption onto different mediums explains why the three-dimensional shape of a concentration plume differs for various contaminants (Brownlee, 1984). Figure 21 illustrates this phenomena by showing the different passage speeds of a plume of contaminated water through both non-sorptive and sorptive soil.

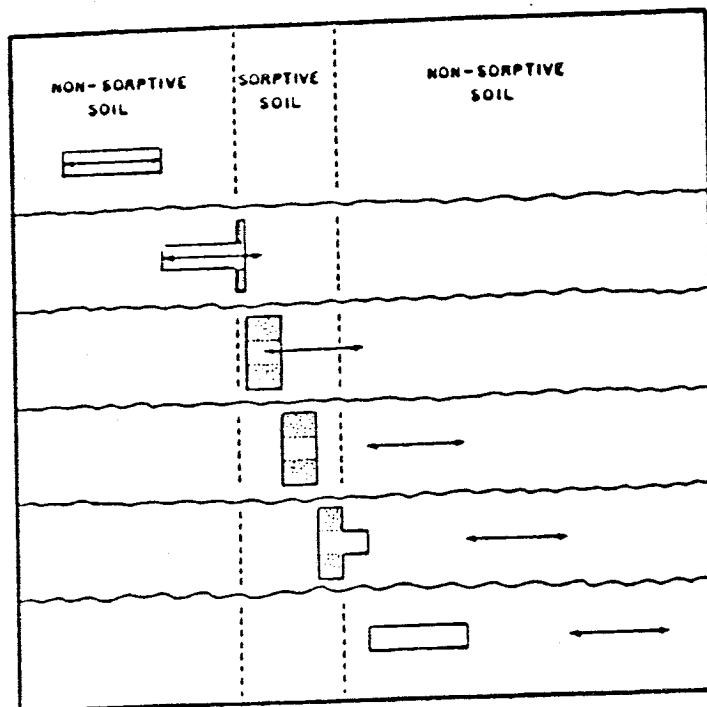
In the case of some organic solvents, sorption is affected primarily by two factors: the fraction of solid organic matter in the aquifer solids (organic carbon content) and the contaminant's hydrophobicity (its tendency not to dissolve in water) (Mackay, et. al., 1985). In a homogeneous aquifer, the sorption of a hydrophobic organic solute should theoretically be constant in space and time. Therefore, it can be predicted because the solute is assumed to move at constant velocity, which is found by dividing the "retardation factor" into the groundwater's average velocity. Such a contaminant is said to be linearly retarded (Mackay, et. al., 1985). However, such simple cases rarely occur. The general observed trends that one should be cognizant of are as follows: the more hydrophobic a compound or the more organic carbon in the aquifer medium, the more highly retarded is its flow rate.

Chemical and Biological Transformation

Organic compounds can be transformed by complex biological and chemical means, the most common chemical reactions being hydrolysis and oxidation. Although some constants have been developed for the

FIGURE 21

The Movement of Contaminated Water Through Various Sorptive Soils



Simplified schematic illustration of the passage of a slug of polluted water through a body of sorptive soil. The horizontal coordinate is distance traveled, and each successive sketch, starting at the top, represents the situation after a certain time has elapsed, the time interval between successive sketches being the same in each case. The double arrow shows the position of the water originally associated with the impurity. The vertical dimension of the slug of impurity represents the impurity concentration in the soil: the stippled segment represents the sorbed portion, while the clear segment represents the dissolved portion. The model assumes that the three bodies of soil have identical porosity and permeability, and that the impurity spends two thirds of its time in the sorbed condition in the sorptive soil (from Moon, p. 15).

rate at which certain organics are degraded, no one knows the actual rates that occur in the subsurface (Mackay, et. al., 1985). It is deemed that the actual rates are slower than the laboratory rates achieved through experimentation, but no proven reason for this discrepancy has been discovered. One hypothesis does exist, however. It states that because laboratory experiments are performed with distilled water (water containing no dissolved constituents), the contaminant can move through the distilled water more rapidly than actual groundwater. Groundwater has inorganic and organic matter that tends to sorb to the contaminant, slowing its movement (Brownlee, 1984).

Certain organic groundwater contaminants can be biologically transformed by microorganisms attached to solid surfaces within the aquifer. The attached bacteria obtain nutrients and energy from the oxidation of contaminants in the groundwater. Both aerobic and anaerobic oxidation may occur depending on the organism.

A number of factors can affect the rate of biotransformation. For example, the water's pH and temperature, the concentration of the substrate, the presence of nutrients, and the number and species of the microorganisms present (Mackay, et. al., 1985). Although it is not presently known if bacteria exist in deep aquifers, it is proven that substantial amounts of bacteria exist in shallow, unconfined aquifers at depths of six meters and less. This results in degradation and a reduction of the number of organic compounds (Mackay, et. al., 1985).

Assessing the Risk of Groundwater Contamination

Once that an understanding of the transport of contaminated groundwater has been achieved, Bewick must decide how to assess the risk or potential risk caused by this contamination. Bewick must consider this contaminated or potentially contaminated site and in turn decide the actions that must be taken to avoid the probability of serious harm. For example, if a drinking water well is located immediately (less than a quarter of a mile) down-gradient, immediate action must be taken to stop the flow of contamination. Moreover, the standards for drinking water are much more strict than the standards for irrigation or transportation water uses, so the method used to eliminate or lessen the flow of contamination must be sophisticated enough to meet drinking water standards. It is up to Bewick to decide how serious the threat of contamination is and what actions to suggest.

One problem with assessing the risks from contaminated groundwater is the determination of the maximum levels of contaminants that are allowable without significant harm to human life. A study done in northeast Michigan concluded that one gallon of gasoline can render a million gallons of water unpalatable (Jordan, 1983). Since underground tanks store hazardous materials and fuels that can leak gallons per day, this source of pollution can make hundreds of thousands of gallons of groundwater unusable for drinking purposes. Furthermore, it can taint drinking water for years, even if the water is technically declared "safe" to drink. Moreover, it is extremely difficult to determine what level is "harmless" to humans since the

laboratory tests can only be performed on animals. Extra precautions have to be taken to ensure human safety. Many times scientists first determine the lowest concentration of a hazardous compound that is harmful to an animal. Then they reduce this amount by a factor of ten and set this value as a maximum concentration limit for human consumption. Although this method is not guaranteed, it is one way human maximum concentration levels can be established without actually testing the harmful effects of a substance on humans.

Management of Groundwater Contamination

After assessing the risk of contaminated groundwater, management of the problem is the next step. Because leakage from underground tanks as a result of corrosion is a complex factor, the management of underground storage tanks is also difficult. Jordan (1983) estimates that as many as seventy-seven percent of underground steel tanks may be affected by point corrosion as a result of faulty installation or certain soil or citing conditions. Even fiberglass tanks can cause leaking problems if they are installed improperly and subsequently crack. Because of the abundance of underground tank problems and the lack of information about specific tanks, management of underground storage tanks is very difficult.

General trends, however, on the tank age, type, and size can help determine a management strategy. A study in New York found that sixty percent of leaks are in tanks older than sixteen years and eighty-six percent in tanks over ten years old. Moreover, in most cases of leakage, the majority of the contaminant stays on the site. In those situations where contamination occurs off the site, the damage is

often extensive, with typical remedial costs of \$2.5-\$5 million and as high as \$11 million (Jordan, 1983). Trends such as these can help in deciding the management aspect of groundwater contamination which is both difficult and costly.

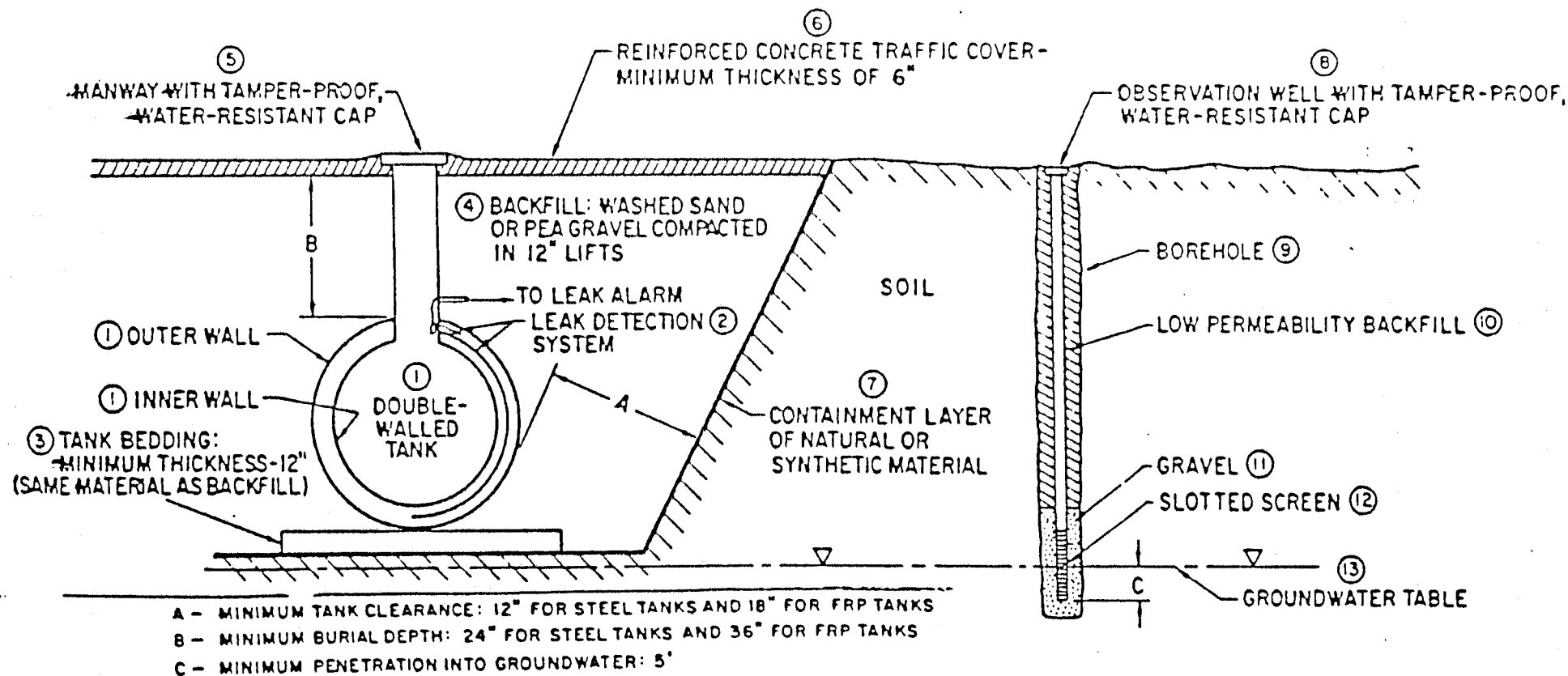
Prevention of leaks, starting with proper installation of the tank, is the most effective method of management. Proper construction includes using double-walled or fiberglass tanks, or tanks within concrete vaults. The latter are essentially a double-walled systems and are more expensive than the former. Figure 22 shows a double-walled tank with an observation well that detects any leakage. Since the installation of tanks is generally not regulated by state building codes or fire codes, some communities have set their own management standards. Acton, Massachusetts, for example, has adopted regulations that ban fuel storage in sensitive areas (Jordan, 1983).

Continuous monitoring and leak detection are also important to ensure any leakage will be detected immediately. Some leak detection and monitoring methods include tank tightness testing (twice yearly) and inventory control (daily), automatic monitoring done by a device in the tank, monitoring vapors in the soil, monitoring liquids in the groundwater, and interstitial monitoring within secondary containment. Proper methods, such as these, along with corrosion protection and spill and overfill prevention should reduce the amount of serious leaks from underground tanks.

Even though management practices are aimed at prevention of underground storage tank leaks, seepage from tanks does occur. In this case, the next step is to cleanup the contaminated groundwater.

FIGURE 22

Double-Walled Storage Tank Installation to Prevent Hazardous Material Leaks



Source: New York Department of Environmental Conservation, *Siting Manual for Storing Hazardous Substances: A Practical Guide for Local Officials*, (October 1982).

Remedial Actions

Five remedial actions are possible once groundwater contamination is detected: 1) containment of the contaminants to prevent migration from their source; 2) withdrawal of the pollutants from the aquifer; 3) treatment of the groundwater at its point of use or withdrawal; 4) aquifer rehabilitation by immobilizing or detoxifying the contaminants while they are still in the aquifer; and 5) management options, such as abandoning the use of the aquifer and using alternative water supplies (Jordan, 1983). All of these remedial options are expensive.

The first two strategies are possible where contamination is highly localized and from a specific known source. Sometimes both techniques are used simultaneously: first the pollution is contained and then groundwater is removed and treated through pumping, gravity drainage, or excavation (Jordan, 1983). Groundwater can be contained by installing grouting curtains or slurry walls that can either stop the migration of the contaminant or direct its flow to a treatment area. The third method involves treating the contaminated water at its point of use or withdrawal. However, such treatment may be impractical, especially if the water is contaminated with viruses. The fourth approach is to treat the water while it is still in the aquifer by removing it, treating it, and then replacing it. This method works best when the source is a spill that is highly localized, but aquifer rehabilitation is extremely expensive and is never completely effective. The fifth technique involves abandonment of the contaminated area, a method used in severe groundwater contamination. In this case, the town must find an alternative source of water or

redrill deeper wells in the same area.¹⁰

Although these methods of remedial work can help, it must be realized that the best way of having high quality groundwater is to prevent the pollution. Generally, cleanup of groundwater pollution by remedial actions is only partly effective. Once an area is contaminated, it will often remain so to some degree for decades, despite efforts to cleanup the area.

¹⁰. Acton, Massachusetts has used the fifth remedial approach by taking two of their four town wells out of use.

INTERNSHIP ACTIVITIES AND RESPONSIBILITIES - IN DETAIL

Duties Performed For Every Audit

When Bewick first receives a call requesting an environmental audit, one of the consultants obtains the necessary data concerning the site (the property under investigation). This information, which includes the use of the property, owner, and address, is necessary prior to scheduling an appointment for a site inspection. Before the inspection, the consultant refers to a topographic map and town map to get acquainted with the area around the site, noticing any water supplies, sensitive receptors, and the general topography in the vicinity of the site. A topographic map is an essential tool in any hydrogeologic investigation, especially for making a preliminary determination of the direction of the groundwater flow. The general direction of groundwater can be ascertained by studying the topography, noting the streams, lakes, reservoirs, and high elevation areas. By starting at a point on the nearest stream and drawing lines perpendicular to the topographic contours, the general direction of groundwater can be mapped. These lines, which represent the flow direction, must be continued up to the nearest hilltops and all the way to the source of the stream. In this manner, general flow direction can be estimated (assuming no major impediment is in the vicinity).

Next is an extremely important part of the audit - the site inspection. This includes an investigation of the property in question to determine if any underground tanks, above ground chemical

storage facilities, or any other source of contamination is in use or was previously used. Evidence of underground storage facilities include vent and fill pipes or manhole covers. Moreover, Bewick inspectors look for any indication of previous storage or spillage, such as stains, odor, or empty barrels. At this time, the inspector also interviews the owner of the property and inquires about the previous history, the current use, the age, former owners, and present and past neighbors. A map is drawn of the area noting the utilities, the potential neighborhood sources of pollution, groundwater gradient, sensitive receptors down-gradient of the site (such as town water wells), overall appearance, and any other pertinent information.

History of Site and Surrounding Properties

The next steps in the audit process are visits and interviews with town and local officials. Much effort is spent on investigating the present and past uses of the site and the surrounding properties. In most instances when contamination is detected, the cause stems from past uses of the site or one of the adjacent lots. This part of the environmental audit involves a trip to the town/city hall to inspect records in the building department, the fire prevention office, the city clerk, the assessor's office, and health department.

The building department is crucial in determining the former uses of the site and surrounding properties. Past permits explain the original date of building construction, any additions, and any problems with building codes. The fire prevention office and city clerk's office have permits of underground storage facilities, and in many situations the fire chief has personal knowledge of any

compliance problems or fires. The assessor's office lists the legal owner and address of the site; and the health department has information about any past health violations on the site.

The amount of information that is obtainable from city and/or town halls differs from town to town. Within the city of Boston, records are fairly accessible and accurate, while in some smaller townships (e.g. Leominster) entire departments and records do not even exist. In the latter situation, much information can be obtained on the day of drilling when neighbors inquire as to why drilling is occurring. Neighbors usually have information for the inspector regarding the history of the property and/or problems associated with the site.

Besides town officials, state administrators are an excellent source of information. The DEQE's Division of Water Supply publishes a "Water Supply Protection Atlas", a series of four overlays based on the United States Geological Survey's topographical maps at a scale of 1:25,000. The first overlay identifies groundwater and surface sources of public water supplies. The second overlay provides information on the potential well yield of known aquifers; while the third shows major river basins. The fourth overlay indicates and classifies the waste sources in the area. These sources include landfills, open dumps, auto junk yards, hazardous waste sites, and road salt storage areas. Every audit must include these waste sources and address their potential threat to the site in question.

Some environmental audits end at this point, drawing conclusions based only on the above ground evidence and the study of the past

history of the site and the surrounding area. Such audits are called "walkarounds" and are based on the findings that no underground storage facility exists and previously never existed at the site. Furthermore, the adjacent properties must have been shown to be contamination-free. The walkaround audits clearly explain that the judgement made about the property is based only on visual inspection and historical review of state and local records. Appendix 3 consists of an example of a walkaround audit.

Tank Tests

Further investigation is required if there is suspected contamination, i.e. if the site or surrounding properties have a history of underground chemical storage. In such a case, the next step involves a decision about the most cost-effective, yet accurate, procedure to test if the subsurface environment is free of contamination. The simplest situation is if the suspicion of contamination stems from a present underground storage facility that is five years old or less, and if the site has not had a tank before the present one. Moreover, the site and the immediate area must not have been used for industrial purposes. If a site fits these requirements, a tank test is usually opted for because it is the least expensive method of determination.

A tank test is a hydrostatic pressure and temperature test that regulates the fluid within the tank and is subsequently able to detect leaks. It first involves connecting a large graduated cylinder (called a standpipe) to a full tank and then topping off the tank through the graduated cylinder so that the level of the tank can be

monitored by observing the height of fluid in the cylinder. The fluid in the tank is then circulated and brought to constant temperature and pressure. For a few hours the level of the tank is observed and recorded to determine if any leaks lower the level of the fluid in the cylinder.

Although this procedure is the least expensive method of determining a leak, it should only be used on tanks that are known to be five years old or less. If there are any reasonable doubts about the adequacy of the test at a given site, the groundwater and soil should also be tested, since a tank test tells nothing about the quality of the subsurface soils and water.

Drilling

The most common method of determining the quality of the soil and groundwater is by drilling and obtaining soil and water samples from the borings. It represents the only opportunity to inspect the nature of the subsurface materials, collect and preserve soil samples for laboratory analysis and tests, observe zones of contaminated soil, analyze the relative contamination of soil samples collected at different depths, determine in-situ permeability, determine the thickness of different geologic layers, and observe the condition of the bedrock surface.

A number of events lead up to a day of drilling. First, anytime drilling is involved in the Boston area, a company called Digsafe is contacted. Digsafe has maps of the water, sewer, gas, electric, and phone lines, and will mark their locations if Bewick notifies them within seventy-two hours of drilling. More importantly, Digsafe

assumes legal responsibility if a line is cut. In some circumstances when Digsafe does not have maps of a certain area, the water and sewer department, local phone, gas, and electrical companies must be visited to obtain maps of the underground cables. These maps are necessary to reduce the risk of the drillers severing lines. In a few instances, the drilling company itself will assume responsibility (by obtaining the proper maps) and will assume liability for any lines that may subsequently be damaged.

The second task is to contact and subcontract a drilling rig and two workers for the day to perform the operation. Usually three bore holes are drilled in a day. Sometimes, two are used only for the procurement of soil samples, taken every five feet, while the third is drilled to obtain soil samples every five feet and water samples that are collected at a later date. This third boring requires more time and materials for the well installation; and the water sampling must be done by a Bewick employee after the well has had adequate time to recharge. Many times all three borings are used for both soil and water samples. When this occurs, the groundwater flow direction can be obtained by measuring the height of the water in the wells and calculating the hydraulic gradient.

The two techniques most commonly used for the installation of monitoring wells in Massachusetts are 1) rotary drilling with a hollow-stem auger and 2) driving casing by alternately dropping and lifting a heavy weight and then washing out the unconsolidated deposits from the interior of the drive casing (a technique known as drive-and-wash). Augering is the faster technique and preferable for

shallow unconsolidated deposits, which includes most of Bewick's work. Augering, however, becomes less satisfactory when drilling is required below forty-five feet because there is a tendency of the head of water in the aquifer to cause the unconsolidated deposits to flow upward through the hollow stem. This condition, called "heaving" or "running sand", makes it extremely difficult for the drillers to continue to collect samples in advance of the auger through the hollow stem. Even in holes less than forty-five feet, the drillers can encounter pressure in the hole which makes the acquisition of samples very demanding. In this situation, the alternative drive-and-wash technique is used.

Another situation when the drive and wash technique is chosen is in those circumstances where the soil is very compact. Augers usually can not adequately drill in dense soil (i.e. clay) because there is too much friction and heat generated. It is then necessary to drill using casing with water to wash away the soil and keep the bits cool. However, when this is done, the soil samples get washed and can not be utilized for analysis. Therefore, this type of drilling is usually not opted for unless there is no other solution. In this situation, Bewick must base its assessment completely on the water samples taken from the well in the following days.

A day of drilling yields three holes, assuming no problems have arisen. Two borings are usually drilled down-gradient from the potential source of pollution and one is drilled up gradient to determine if the contamination is from a neighboring source (assuming contamination has been detected). A surface soil sample is first

obtained by hammering a split spoon sampler into the soil surface. The soil is then inspected to see if there is any obvious contamination and then placed in a sampling jar. Subsequent samples are acquired by augering and then hammering the sampler into the soil a few feet below the augers. After the split spoon sampler is brought up, the soil is again inspected for any obvious contamination and then placed in the jars. As the drilling proceeds, the type of soil is noted and the depth to the water table is recorded. This process continues until the depth of the hole is at least five feet below the water table or five feet into impermeable clay or bedrock, depending on the geology of the region¹¹. Usually Bewick inspectors insist on drilling into the impermeable clay for at least five feet, on the assumption that no contamination can permeate beyond this point.

If bedrock is reached, the drillers have hit what is known as "refusal". This means that the drill cannot physically drill any farther. This causes many problems. First, this indicates that the entire site may have bedrock underlying it, meaning that no adequate samples can be obtained. Secondly, even if refusal is not hit until eight feet down (inferring that some samples have been obtained), it is not deep enough to make an accurate conclusion about the quality of the subsurface soil and water below eight feet. Thirdly, if refusal occurs at all drill locations on a large piece of property, the drillers may have to be hired for one more day, which means more expense for the client. In this situation, it is up to the judgement

¹¹. In downtown Boston, clay is usually reached within ten feet of the surface of the ground, indicating that contamination rarely seeps below the start of the clay surface.

of the inspector where to drill next since the hole where refusal was hit yields little or no subsurface quality information.

Bewick Associates relies on both the soil and water samples to give an indication of the quality of the subsurface. The soil samples are taken by the drillers, observed by a Bewick inspector to see if any visible or odoriferous contamination is present, and subsequently sent to the laboratory for analysis. Before they reach the laboratory, they are preserved in a cooler in air tight jars. If they may contain volatiles, aluminum foil is placed over the jar to catch the volatiles. Then a photoionization detector (an HNu device) is used to measure the level of volatile organics. This ionization detector is a method of checking in the field the levels of volatiles, and helps the consultant decide which tests should be performed at the laboratory.

Well Installation/Construction and Sampling

The well installation and construction program has rigid specifications. The inside diameter of a monitoring well should be large enough to easily accommodate the sampling device that will be used for the collection of samples, but small enough so that large quantities of water need not be removed before a representative sample can be collected. Bewick's sampling devices, called bailers, are two inches in diameter and approximately three feet long. The drill hole is made about nine inches in diameter, with the well being about three or two and a half inches in diameter. The area between the well and hole is packed with inert materials with high permeability so that the well can recharge at a natural rate. Generally, the smaller the hole

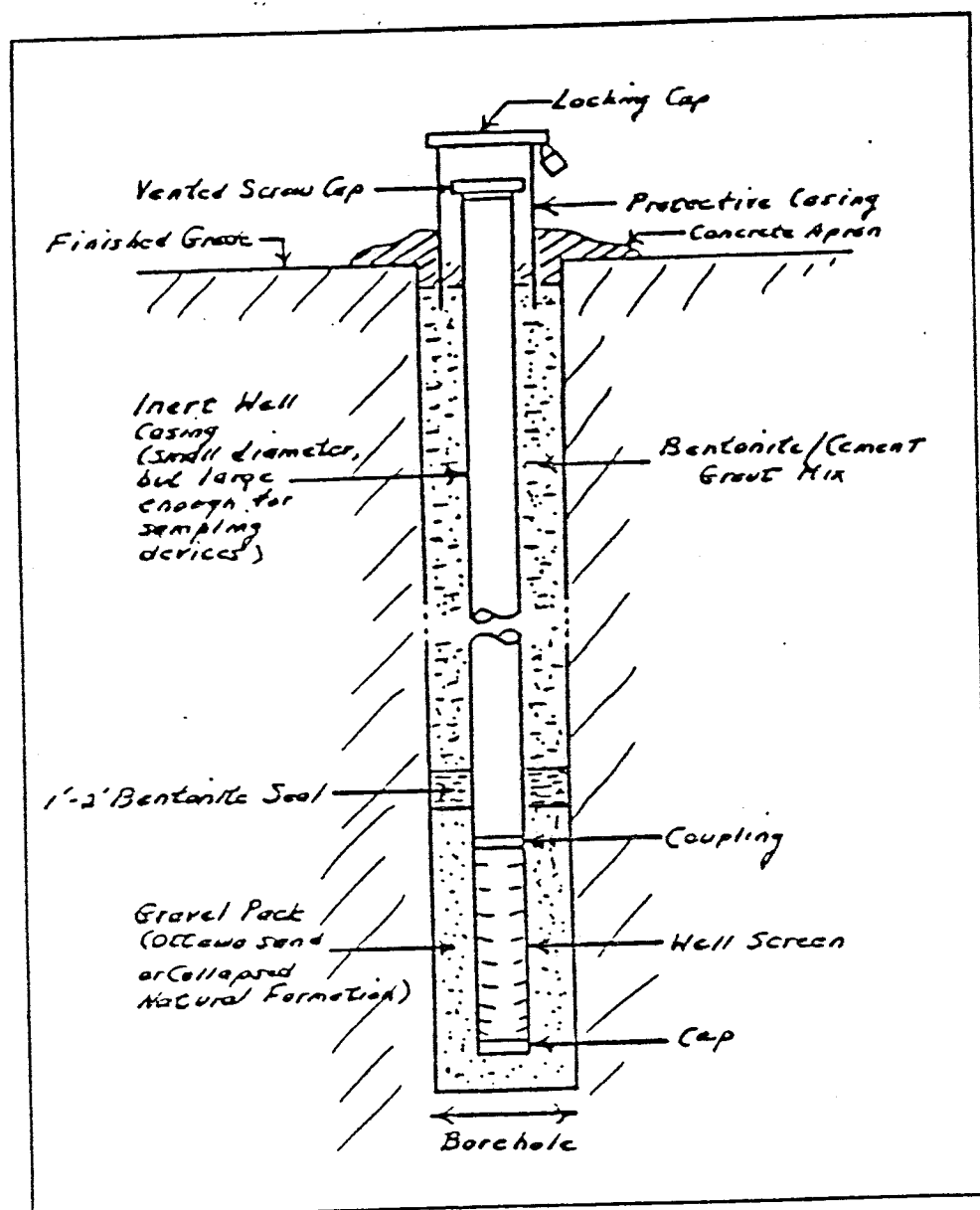
diameter, the less it will cost for drilling and construction.

The well usually consists of five to ten feet of screen (slotted pipe) and the remainder of solid pipe. The material used for the well screen and well casing must be inert to the type of contamination expected at the site (most of the drilling companies Bewick hires use standard PVC pipe.) The openings in a well screen should be large enough to permit easy flow of water into the well, but small enough to prevent the passage of fine-grained material. With monitoring wells, sediment-laden water can greatly lengthen filtering times and create chemical interferences with the collected samples. To reduce the number of poor quality samples that occur from groundwater that has a high sediment load, pipes with slots of 0.01 inches or 0.02 inches are generally used.

After the casing and slotted pipes are installed, the space between the screen and the side of the bore-hole is filled with clean washed sand ("Ottawa sand") for a vertical distance of at least one foot on either side of the well screen. Then a "road box", a metal, hollow, circular cover is placed over the well and placed flush with the ground. The road box is cemented into the ground, extending two feet into the ground around the well, and is designed so that at any time, access to the well is possible. It is designed to be a permanent well for sampling purposes, yet a well which can be driven over by traffic. Figure 23 shows the cross section of a well.

Inspectors must be aware of the problems that stem from the well installation and soil sampling. First, since most drilling companies

FIGURE 23



Schematic drawing showing monitoring well construction details for a single-level well.

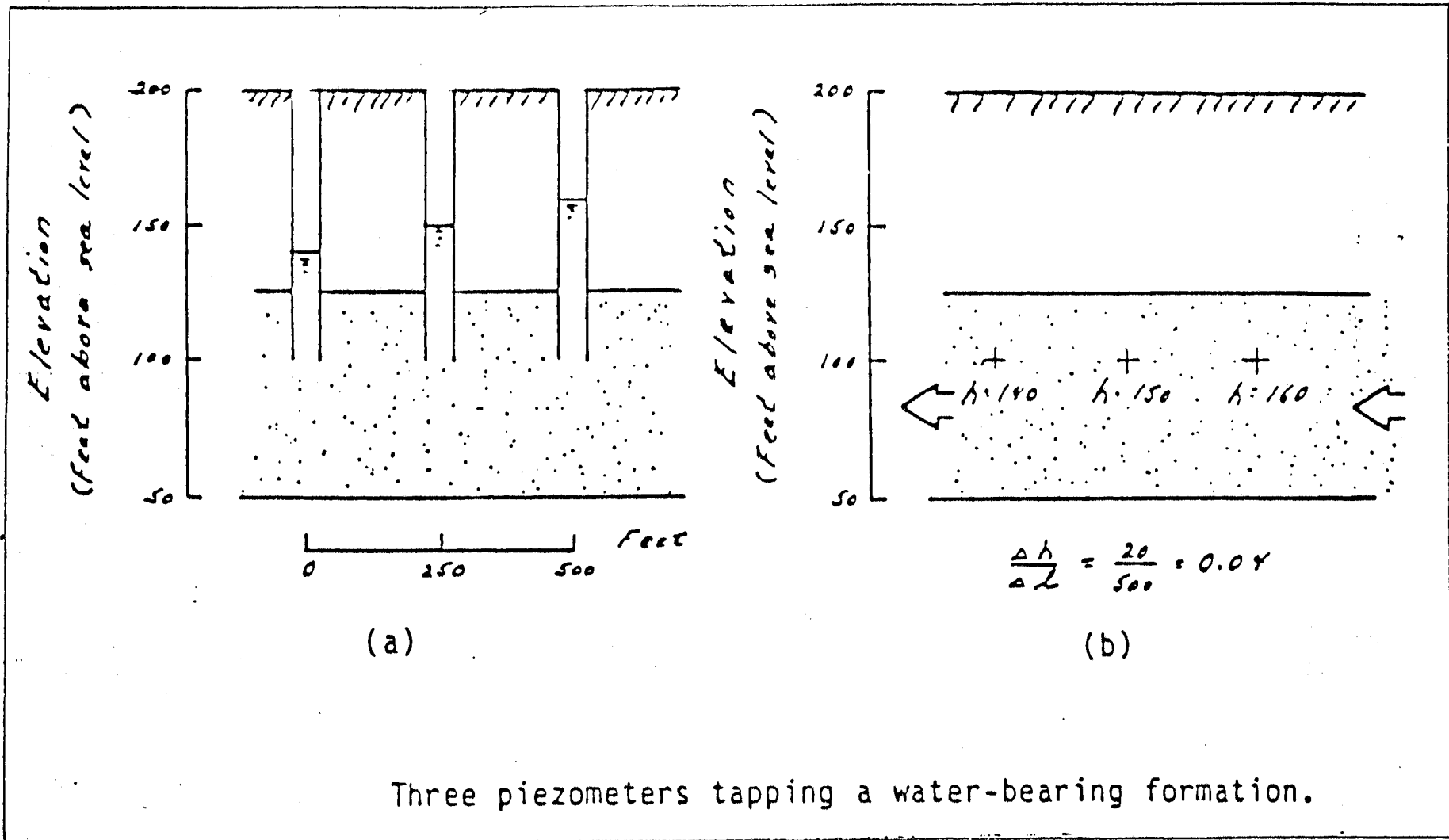
Brownlee, 1984

are familiar only with engineering studies or water well drilling, they are not aware of the needs of an environmental water quality monitoring well. For example, since the water sampling bailer is straight and unbendable, the wells have to be installed perfectly straight so that the consultant can obtain a sample. Second, if the well is not packed correctly or the well caves in, the pipe will be bent and will be useless for sampling. Third, most drillers are unaware of cross-contamination, and do not clean their equipment and tools from boring to boring and sample to sample. The consultant must inform the drillers exactly what has to be done and how, and then observe the majority of the drilling and sampling, being particularly careful about reducing the chances of cross contamination.

As mentioned earlier, the water sampling requires a Bewick employee (many times the same person who supervised the drilling) to return to the site within a few days to obtain the samples. The water level in each well is first determined by lowering a water sensitive device into the well. When the instrument reaches water, it will record the depth of water in the hole. Because the distance between the piezometers (wells) is known, the hydraulic gradient (dh/dl) can be calculated. In other words, by determining the water level, the direction of groundwater flow can be estimated. Figure 24 illustrates how easily this is accomplished.

Next the total volume of the wells is calculated (since the total depth of the wells is known). The proper amount of water to be purged is then determined by multiplying the volume of the well by three, and removing that quantity. It is then allowed to recharge at its usual

FIGURE 24



groundwater flow rate, after which the samples are taken. The wells are always purged to ensure that the samples taken are representative of the water flowing through the ground at that instant in time. If the water left in the well from the previous day of drilling is sampled, unusually high amounts of contamination can be discovered because many pollutants are less dense than water and would tend to collect on the surface of the water. The grease the drilling companies use on their drilling bits can get deposited in the well and cause this high reading. After the well has been purged, however, if any free product or visible contamination on top of the water is evident, it is noted. This free product represents a serious contamination problem.

Bewick owns its own bailers, which are constructed from a wide variety of inert materials. They are simple to use, portable, easy to clean, economical, and require no power source. However, they are also time consuming if multiple wells must be sampled or if the wells have a high volume of water to be removed. They also may allow the water samples to lose some volatiles in the process of transferring the water from the bailer to the sampling jars. If large volumes of water need to be removed, other techniques, such as pumps, are used.

The size and number of samples required depends on the necessary analytical work. If only oil, grease, and pH analyses are being performed on the groundwater, large jars of water must be obtained. However, if any volatile aromatic tests are going to be done, small vials are also necessary. These vials are specially designed so that water can be obtained and placed in the jar without any air bubbles

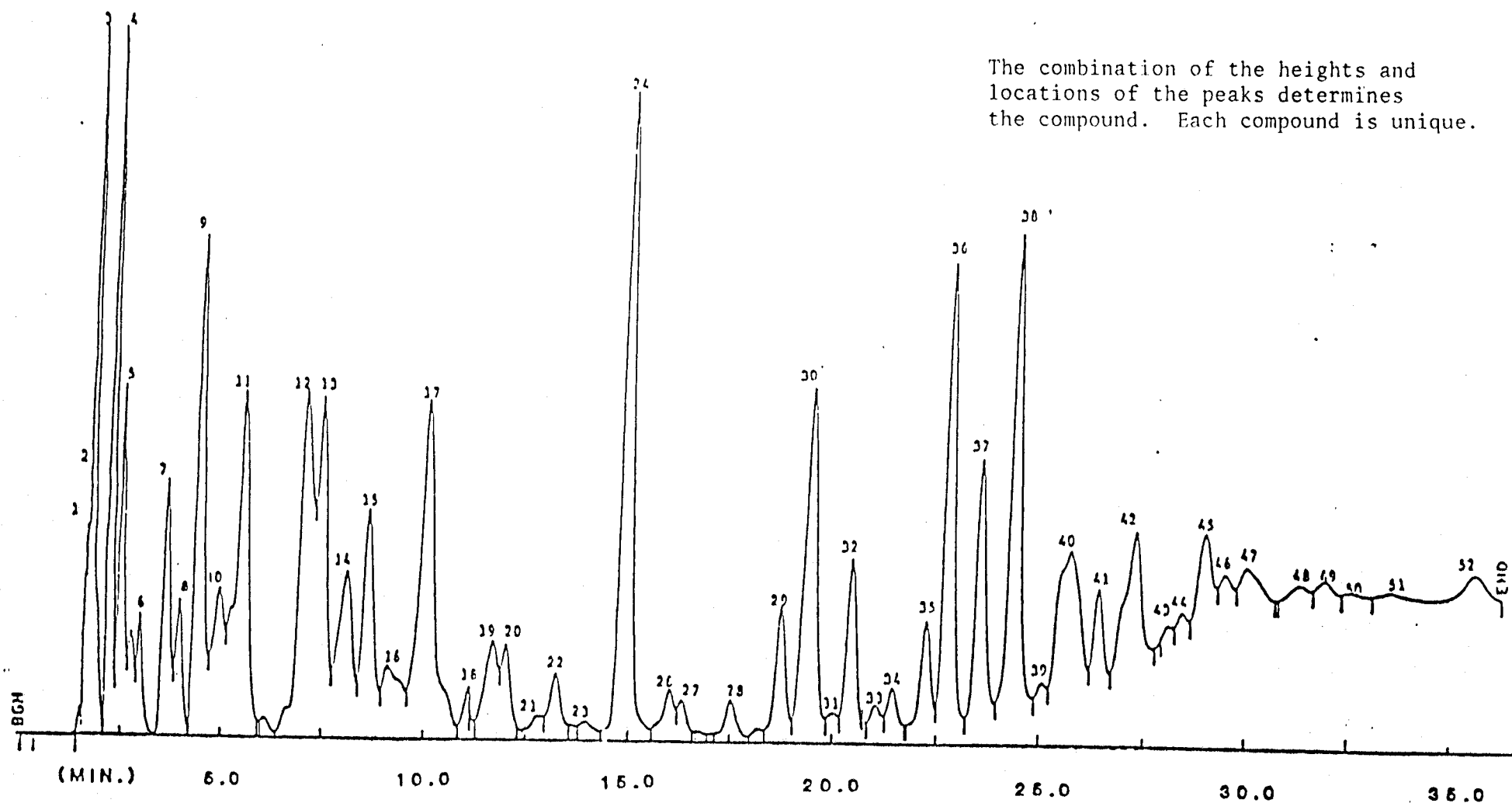
forming inside the vial. If any air does get inside, it can allow the organics to volatilize and escape when the vial is opened. Once the samples are collected, they are brought to a lab for analysis.

Analysis

The analysis of the soil and water samples varies depending upon the history of the site. For example, if the site is a gas station, was a gasoline station, or is adjacent to a past or present station, the analysis will include tests that determine levels of benzene, ethyl benzene, toluene, and xylene. Many analyses consist of a gas chromatography test that will identify the levels and type of pollutant. Figures 25 and 26 show how unleaded and leaded gasoline are identified by this analytical test. Moreover, in every lab analysis a pH test is performed to see if any unusual pH levels exist, and a few blanks are analyzed with the samples as a quality control check. If the site is a paint factory, the analysis includes tests for solvents and heavy metals. If the site has a rich industrial history, a multitude of tests are performed to check for the most common pollutants, and many times additional testing is required after the first results are obtained. If the site is surrounded by potential contaminating sources, an expensive "fingerprint" test can be performed to identify the exact source of the pollution. In this way, Bewick can determine if the contamination has its source on the site or on one of the neighboring properties.

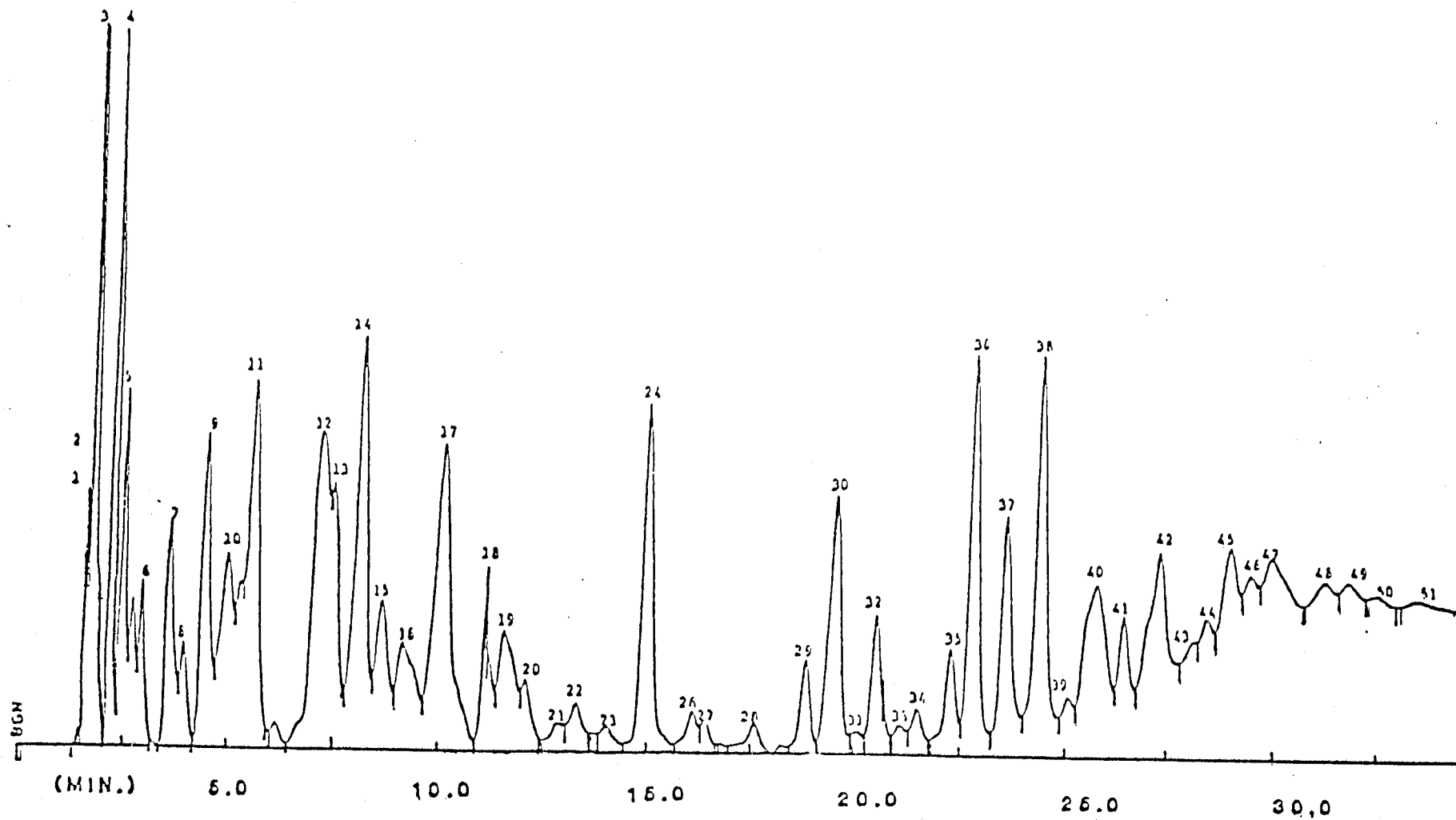
The analytical tests done at the laboratory are executed under strict specifications set by the EPA. The laboratory must be certified by the EPA in its methods and instrumentation; and the lab

FIGURE 25



GC/FID CHROMATOGRAM OF REGULAR UNLEADED GASOLINE

FIGURE 26



GC/FID CHROMATOGRAM OF REGULAR LEADED GASOLINE

is always credited in the audit reports.

Although analytical tests can be quite expensive (table 7), they are necessary for every audit that has soil and water samples. The analytical aspect of a 21E environmental audit is crucial because it tells exactly the quantities and type of contamination present; and it serves as a basis for determining the appropriate remedy.

Write-Up

Once the laboratory results are received, Bewick now has scientific data to use in determining if the site in question is environmentally clean. The Chapter 21E law sets groundwater standards for known chemicals, indicating a natural background level and a threshold level where any amount above that level is considered contamination. Based on the samples and research into the history of the site, a conclusion is reached. If no contamination is found, the audit states that as of that date and based on the information obtained through the local and state offices, Bewick has found no contamination. If the site is determined to be contaminated, the owner is given a suggestion as to how to remedy the situation. Appendix 4 gives an example of an audit that concluded that the site was contaminated. If the site is proven to be extremely contaminated, the DEQE will set the guidelines for the remedial action and they will supervise the cleanup. It is at this point that Bewick Associates finishes most environmental audits, although efforts are presently being made to involve Bewick in the supervision of the remedial work.

Table 7

Analytical Methods, Costs, and Detection Abilities for Measuring Groundwater Contamination*

Methods	Contaminants Measured	Cost Per Sample	Detection Ability (parts per million)
Organics			
General methods			
Total organic carbon	Carbon containing	\$ 15-30	1
UV spectroscopy	Aromatic hydrocarbons	30-60	(0.1, e.g.)
Fluorescence	Polynuclear hydrocarbons	20-40	(1, e.g.)
Refractive index	Soluble organics	10-30	—
4-aminioantipyrine	Phenols	30-60	0.002
Total Kjeldahl nitrogen	Nitrogen-containing	20-30	0.002
Methylene blue active substance	Sulfonate detergents	20-40	0.025
Total organic halogen	Halogenated organics	60-100	0.01
→ Oil and grease	Oil/grease in solution	20-30	0.2
Total phosphorus	Phosphorus-containing (both organics and inorganics)	30-70	0.01
Contaminant-specific methods			
Gas chromatography/conventional detection	Organics	30-500	<0.001-0.1
→ Gas chromatography/mass spectroscopy	Organics	100-1,500	<0.001-0.01
High-performance liquid chromatography	Polynuclear aromatics	40-500	0.000001
Inorganics			
General methods			
Oxidation potential	Oxidizing metals	10-15	N/A
Specific conductance	Ionized species	3-5	N/A
→ pH	Mineral acids	3-5	± 0.1 pH unit
Acidity	Mineral acids	10-15	± 0.1 mg CaCO ₃ /l
Contaminant-specific methods			
Atomic absorption spectrometry	Metals/cations	150	<0.001-0.2
Induction-coupled argon plasma	Metals	125-200	<0.001-0.2
Wet chemistry (colorimetry, gravimetry, titrimetry)	Acids	10-35	0.1-1
Microorganisms			
General methods			
Plate count, filtration, and fermentation	Bacteria, pathogens, parasites	75/group	N/A
Contaminant-specific methods			
Culturing, morphology, and concentration/identification	Pathogens, parasites, fungi	1,000/strain	N/A

Source: U.S. Congress, Office of Technology Assessment, *Protecting the Nation's Groundwater from Contamination* (Report OTA-0-23; Washington, D.C., October 1984).

The most common analytical tests performed by Bewick Associates are indicated by arrows.

Jordan, 1983

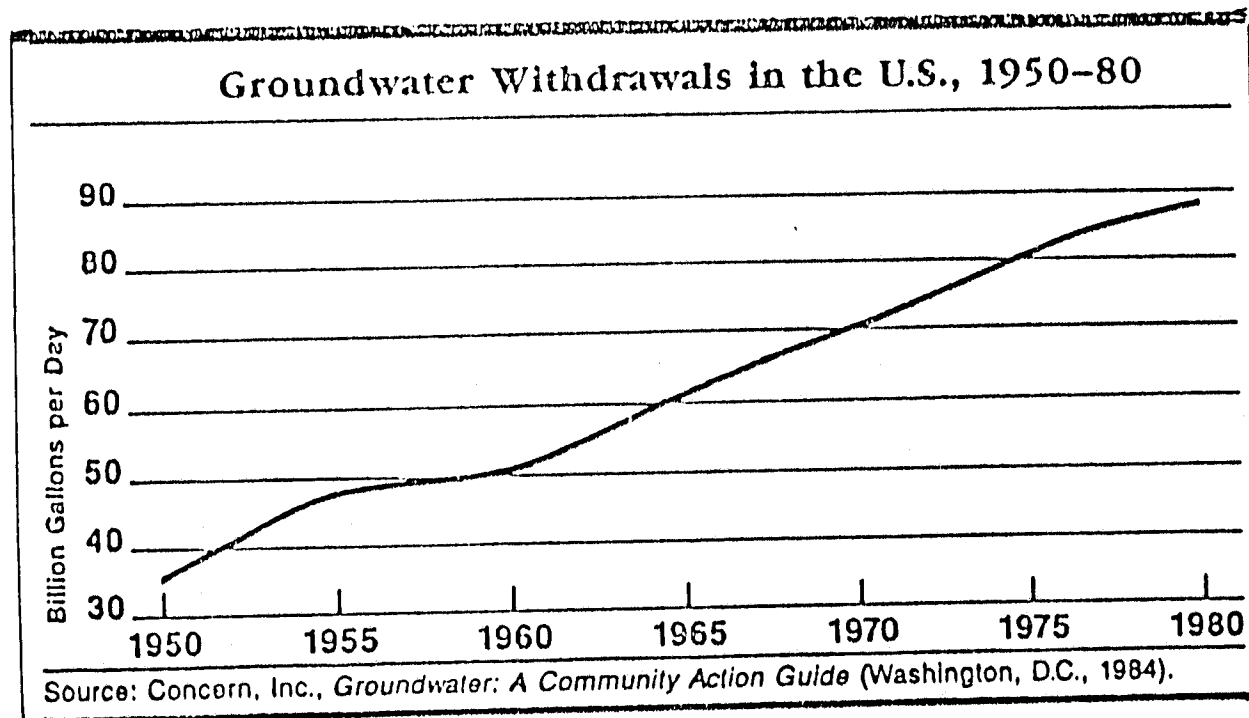
CONCLUSION

Groundwater is a vital resource that is increasingly being used in the United States (figure 27). In certain areas, its quality has been lowered by the introduction of contaminants such as oil and gasoline. Contaminants such as these have caused health problems in humans and have led to concerns about the quality of groundwater. Such concern has caused legislators to pass laws that address groundwater quality protection. One such law is the Chapter 21E Massachusetts Superfund Law.

Chapter 21E requires the identification, assessment, and remediation of locations that have had releases or have threats of releases of hazardous materials. It specifically outlines a procedure that I believe is relatively effective in identifying and assessing those properties that are to be bought, sold, or refinanced. However, I feel that Chapter 21E is lacking in two areas. First, it does not explain in enough detail the remediation process. Second, its overall effectiveness is not complete because it addresses only those properties that are undergoing a financial transaction. Hence, it omits many properties that may be presently contaminated or have a threat of contamination.

By legislating Chapter 21E, Massachusetts has taken a vital first step in the protection of groundwater. This has resulted in a greater awareness of groundwater problems and solutions and has emphasized the importance of prevention of groundwater contamination in the future.

FIGURE 27



Jordan, 1983

The amounts of groundwater usage are expected to continue to increase in the future.

For example, business people are forced into proper installation of underground storage tanks because it is more cost effective to spend money on prevention rather than remediation. This leads to a trend of better prevention and subsequently less groundwater contamination.

Although Chapter 21E does not address all issues of groundwater protection, it is a good beginning of the protection of groundwater. The majority of states in the US do not have legislation similar to this, but probably will create some soon because the costs of cleanup are skyrocketing and banks and insurance companies do not want to be financially responsible for the cleanups. Furthermore, groundwater is a valuable resource used for drinking in many parts of the US and its quality needs to be protected.

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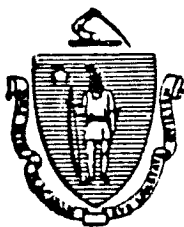
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APPENDIX 1




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Division of Hazardous Waste
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MEMORANDUM

TO: DHW Deputy Directors, DHW Program Managers, REEs, DREEs, Superfund Advisory Committee

FROM: William F. Cass, Director, DHW 

DATE: June 22, 1987

SUBJECT: Revised Policy 7 - Guidance Policy for Preliminary Assessments, Phase I - Site Investigations, Phase II Full Evaluations, Site Classification, and Short-Term Measures for releases and threats of releases of oil and/or hazardous materials.

I. Introduction

Recent amendments to M.G.L. c. 21E describe in general terms a process by which locations potentially having releases or threats of release of oil and hazardous material will be identified, assessed and remediated. However, in fulfilling this aspect of the statute, it is important for the Department to provide guidance that will lead to consistent evaluations and responses.

A location is initially listed on the "To Be Investigated" and is investigated in the Preliminary Assessment, Site Investigation (Phase I) and Phase II evaluations. In Phase III, remedial action alternatives are developed and a permanent or interim remedial action identified. In Phase IV, the remedial actions are implemented. To a large extent, these evaluations will be similar to those conducted in the past, however, the requirements and timing are more explicit in order to achieve a greater degree of consistency. This policy provides interim guidance for investigating and evaluating locations where oil or hazardous materials have been released or threaten to release. Specifically, it addresses Preliminary Assessment, Phase I - Site Investigation, Phase II - Full Evaluation, Site Classification, as well as Short-Term Measures. Briefly these steps of the process can be described as follows:

Preliminary Assessment - an initial assessment to rapidly evaluate the need for emergency action (Short-Term Measures), further study, or "no action". A Preliminary Assessment must be completed within one year of listing on the "To Be Investigated" list.

Phase I - Site Investigation - a preliminary investigation to determine whether a location is a confirmed Disposal Site (i.e., a release has occurred) and whether a location should be classified as a Priority Disposal Site. This investigation must be completed within two years of listing.

Site Classification System - a system that will be used in Phase I to determine which sites should have a "priority status" within the meaning of Question 4.

Phase II - Full Evaluation - a complete evaluation of the extent and levels of contamination and risk, tailored toward problem resolutions.

Short-Term Measures - actions that may be taken at any time to prevent or eliminate imminent hazards.

The Massachusetts Contingency Plan (which must be promulgated by January 1, 1988) will establish a framework for investigating, evaluating, and remediating releases of oil and/or hazardous materials. Until the plan is promulgated, this policy will provide interim guidance for those areas listed above.

II. Purpose

The proposed framework for site evaluation, investigation, and remediation is intended to provide the basis for an organized and consistent treatment of releases of oil and hazardous materials in Massachusetts. The process described, in part, in this policy is designed to identify imminent hazards as quickly as possible and to use Short-Term Measures immediately to reduce, eliminate or avoid imminent hazards. In addition, Disposal Sites will be classified in order to identify Priority Disposal Sites and consideration of alternatives is required before the most appropriate alternative can be chosen.

III. Applicability

This policy guides Preliminary Assessments, Phase I - Site Investigations, Phase II - Full Evaluations, Site Classification, and Short-Term Measures for releases of oil and/or hazardous materials. Either DEQE or potentially responsible parties may undertake site assessment, classification, and investigation activities as well as Short Term Measures. If potentially responsible parties assume any of these activities, DEQE will provide oversight to ensure adherence to this policy. At any Federal Superfund site, Federal National Contingency Plan requirements for the activities described in this policy are considered to be the minimum requirement. However, DEQE shall not be precluded from conducting or requesting additional evaluations or investigations. In addition, DEQE may request that Short-Term Measures be taken at a Disposal Site if deemed necessary pursuant to this policy.

IV. Preliminary Assessment

A. Purpose

1. A Preliminary Assessment is a study used to make an initial determination as to whether a Short-Term Measure, further study, or "no action" is needed to assess or control a release or threat of release of oil and/or hazardous materials.
2. Primary Goal: A Preliminary Assessment is intended to rapidly evaluate the likelihood and/or the extent of an existing or future threat to the public health, safety and welfare or to the environment posed by a release or threat of release of oil and/or hazardous materials.

B. Scope

A Preliminary Assessment of a location is performed whenever the Department is notified of a release or threat of release of oil and/or hazardous materials pursuant to M.G.L. c.21E Section 7 or whenever a property is listed as a location to be investigated pursuant to M.G.L. c.21E Section 3A(b). Preliminary Assessments are predominantly fact-finding investigations and include reviewing existing documentation and making a location inspection. Based on the information obtained, a determination is made by the Department as to what type of response, such as Short Term Measure, further assessment, or "no action", is needed.

This information is compiled on Preliminary Assessment Forms, to be completed by a qualified representative of a potentially responsible party as defined in M.G.L. 21E §5a. and submitted to DEQE by the Department's agents and employees.

C. Activities

Preliminary Assessment fact-finding activities include, but are not limited to, any or all of the following:

1. Obtaining specific physical and historical details about the location.
2. Identifying the location on maps. The UTM coordinates and latitude and longitude should be included.
3. Performing a file search to review existing local, state, and federal documentation, e.g., permits, past environmental violations and complaints types of materials used at the location, etc.
4. Consulting with community officials and/or residents.
5. Identifying potential human and environmental receptors, e.g., proximity to water supplies, residential areas.
6. Performing initial analyses of field data and/or performing field screening.
7. Conducting a perimeter survey and/or visiting the location.

D. Decision Criteria

After reviewing the Preliminary Assessment, the Department will determine what type of response, if any, is needed at a location based on the following considerations:

1. Nature, characteristics, and quantity of oil and/or hazardous materials released or posing a threat of release from the location.
2. Department's prior knowledge of location and/or evidence found in file search.
3. Proximity of the location to environmentally-sensitive receptors and to population.
4. Imminent or substantial hazard to public health, safety, welfare and to the environment as well as possibility of irreparable harm posed by the oil and/or hazardous materials at the location.
5. Regulatory status of the owners and/or operators of the location.
6. Source and reliability of information obtained about the location.

E. Possible Outcomes

A Preliminary Assessment can result in one of three determinations:

1. Confirmation that there has been no release and that there is no threat of release of oil and/or hazardous materials from the location.
2. Confirmation that there has been a release from the location or there is a threat of release of oil and/or hazardous materials and that it is a "Disposal Site" as defined this policy.
3. Determination that it is unclear whether there has been a release or threat of release of oil and/or hazardous materials from the location.

Based on the results of the Preliminary Assessment, one or more of the following actions may be taken:

1. If it is determined that there has been no release, or threat of release, documentation will be prepared stating that no further action is warranted at the location.
2. If it is determined that the situation is not subject to M.G.L. c. 21E, the case will be referred to the appropriate Departmental division or to another state, local, or federal agency.
3. If a release or threat of release is confirmed, Phase I - Site Investigation activities will begin at the location. These activities will also be initiated if it is unclear whether a release has occurred or a threat of release exists.
4. Short-Term Measures will be performed at locations when it is determined that an imminent hazard exists.

F. Public Involvement

Guidance is provided in the Public Involvement Policy.

V. Phase I - Site Investigation

A. Purpose

1. A Phase I Study - Site Investigation should confirm whether there has been a release or there is a threat of release of oil and/or hazardous materials at a location if this could not be determined in the Preliminary Assessment. In addition, the Site Investigation will allow the Department to determine whether the confirmed Disposal Site should be classified as a Priority Disposal Site.
2. Primary Goal: A Site Investigation is intended to preliminarily describe conditions at a location in order to establish the existence and the extent of a release or threat of release of oil and/or hazardous materials.

B. Scope

A Phase I Study - Site Investigation is not intended to provide a comprehensive assessment of the conditions at a location. A Site Investigation should, however, develop the following information:

1. A property history which details past and present uses of the location, including a description of property management practices.
2. An initial characterization of oil and/or hazardous material present at the location.
3. Identification of pathways by which oil and/or hazardous materials may migrate to or from the location and initial identification of human and environmental receptors which may be affected by the release or threat of release.
4. Identification of parties potentially liable for the release or threat of release of oil and/or hazardous materials at or from the location.
5. Determination if additional preliminary data collection and evaluation is necessary to: confirm whether a release or threat of release of oil and/or hazardous materials is occurring or has occurred at the location and therefore whether the location is a confirmed Disposal Site; evaluate whether the confirmed Disposal Site is a Priority Disposal Site; and determine what action to undertake next.

A Site Investigation is performed after a Preliminary Assessment or after a Short-Term Measure. A Site Investigation confirms the existence of a release or threat of release at a location and thus establishes if the location is a confirmed Disposal Site. It also allows the Department to determine if the Confirmed Disposal Site is a Priority Disposal Site. Guidance for classifying a Disposal Site is described in Section VII of this policy.

C. Activities

A Phase I Study shall include a location history, a location description, and initial screening/sampling results. This information will be described in a report to be submitted to DEQE. The purpose of the following activities is to obtain enough data to allow the Department to determine whether the location is a confirmed Disposal Site and whether the confirmed Disposal Site is a Priority Disposal Site.

1. Location History

The location history shall include:

- a) A list of past and present owners/operators of the location and of other potentially liable parties as described in Section 5(a) of M.G.L. c.21E.
- b) A description of past and present uses of the location, including commercial activities and industrial or manufacturing processes. Local sources of information should be utilized.
- c) A description of types (including generic names, chemical names, and trade names) and quantities of oil and/or hazardous materials used, treated, stored, disposed, or generated through past and present uses of the location.
- d) For all specific areas within the location where oil and/or hazardous materials were used, stored, treated or disposed, a separate description of the conditions of containment and the types and amounts of materials used, stored, treated, or disposed.
- e) A history of all waste disposal practices at the property, including disposal locations, types and quantities of material disposed. This should include a description of disposal locations that are not located on the property.
- f) A history of all release incidents, environmental permits and violations; as well as other federal, state, or local occupational health and safety or environmental regulatory history of the location, including information on past/present storage of flammable liquids pursuant to fire regulations.
- g) A brief description of past and present land use on adjacent properties.

2. Location Description

The location description shall include:

- a) Geographical placement of property, including a locus map on a USGS map. The UTM coordinates and latitude and longitude should be included.
- b) Copies of plot-plans, USGS maps, aerial photos, or property photos

- c) Description of the geologic, hydrologic, and hydrogeologic conditions at and surrounding the location.
- d) Description of present property conditions, including but not limited to:
 - Overt evidence of a release or threat of release.
 - Overt evidence of environmental damage.
 - Physical location of and information on facilities, structures, or conduits where oil and/or hazardous materials were used treated, stored, disposed, processed, or generated.
 - Areas of fill and distribution of fill over the property.
 - Evidence of blasting and excavating activities.
- e) Analysis of the presence of municipal water or sewer, private water supplies (including any unused wells), subsurface disposal systems and other subsurface utilities in the vicinity of the property.
- f) Brief description of all proximate environmentally-sensitive areas such as water supplies, wildlife habitats, wetlands, areas prone to flooding, or residential areas.
- g) Characterization of land use in the vicinity of the property.
- h) Description of the potential for direct human contact from all routes of exposure.

3. Initial Location Sampling and Screening

Field testing and observation should be designed to locate and initially characterize the sources of release or threat of release of oil and/or hazardous materials from the location and to identify the types of oil and/or hazardous materials present, including a rough estimate of their quantities. Both on-and off-site sampling may be included. The type of field testing required should be determined by conditions at the location and the Site Classification criteria as discussed in Section VII of this policy. In some situations, portions of a Phase II Study may need to be performed in order to obtain the necessary data. The field testing should be designed to allow the Department to determine whether the location is a Disposal Site and whether it is a Priority Disposal Site.

Several techniques can be used for this activity, the selection of which will depend on the specifics of the location. These techniques include:

- a) Field screening (e.g., using portable instrumentation).

- b) Field sampling (of various media) with subsequent laboratory analysis.
- c) Geophysical investigations.

Although a sampling plan need not be submitted to the Department prior to field screening or sampling, all QA/QC procedures must be documented.

4. Short-Term Measures

As for the Preliminary Assessment, the Site Investigation should include an evaluation of the need for Short-Term Measures as described in Section VIII of this policy.

D. Possible Outcomes

A Phase I Study - Site Investigation can result in two possible determinations:

1. Confirmation that there has been no release or threat of release of oil and/or hazardous materials from the location.
2. Confirmation that there has been a release or a threat of release of oil and/or hazardous materials from the location and therefore it is a Disposal Site as defined in M.G.L. c. 21E. A determination will also be made as to whether or not the Disposal Site is a Priority Disposal Site.

Based on the outcome of a Phase I Study, one or more of the following actions may be taken:

1. If it has been determined that there has been no release or threat of release, documentation will be prepared indicating that no further action is warranted at the location.
2. If it is determined that the situation is not subject to M.G.L. c. 21E, the case will be referred to the appropriate Departmental division or to another state, federal or local agency.
3. If the location is determined to be a confirmed Disposal Site a Phase II - Full Evaluation will commence at the site. Priority Disposal Sites are put on a shorter time schedule than non-priority Disposal Sites.
4. Short-Term Measures will be performed at locations when it is determined that an imminent hazard exists.

E. Site Specific Health and Safety Plan

For on-site personnel or employees of investigating teams, contractors, or subcontractors, a Site Health and Safety Plan must be prepared and implemented.

F. Public Involvement

Guidance is provided in the Public Involvement Policy.

VI. Phase II - Full Evaluation

A. Purpose

1. A Phase II - Full Evaluation is a complete investigation of a Disposal Site, and its scope of work should be based upon the results of a Phase I Study. It is intended to a) accurately characterize the type and quantity of oil and hazardous materials at the Disposal Site; b) determine the nature and extent of the Disposal Site's impacts on the environment; c) determine the degree of risk that the Disposal Site presents to the public and the environment; and d) identify needs, if any, for additional site study. A Phase II Study is tailored towards problem resolution by providing data to define and assess Remedial Action Alternatives. If the Phase I information is inadequate, a systematic search of the entire Disposal Site may be necessary to ensure that sources of oil and/or hazardous material releases do not go undetected.
2. Primary Goal: A Phase II Study must provide a complete description and analysis of the extent to which oil and/or hazardous materials from a Disposal Site have contaminated, or threaten to contaminate, air, water, soil, human or environmental receptors. In addition, the Phase II Study should evaluate the risk of adverse effects on public health or the environment.

B. Scope

A Phase II study must include a sampling plan, describing the media and locations to be sampled and the rationale. It should include a comprehensive hydrogeologic investigation, as well as sampling in other media, as appropriate. Justification must be provided for any media not included in the sampling plan.

The scope of a Phase II Study varies by site. The level of effort and study detail will depend on the following:

1. The nature, physical and chemical characteristics, and quantity of oil and/or hazardous materials released or posing a threat of release at or from the Disposal Site.
2. The Department's prior knowledge of the Disposal Site.
3. The Disposal Site's proximity to human and environmental receptors.
4. The threat to public health, safety and welfare and to the environment posed by the Disposal Site.

All of the activities described in Section D shall be completed in a Phase II Study unless the exclusion of a particular item(s) can be justified in the Phase II Proposal.

The Phase II process is an iterative one; as specific information/data becomes known about a Disposal Site, additional Phase II Study may become necessary.

C. Phase II Proposal

After a Phase I Study and Report has been completed, a Phase II Study Proposal must be submitted to the Department. The Phase II Proposal must include, but shall not be limited to, the following:

1. Scope of work, including justification for proposed exemptions and level of detail. The need for work as related to data gaps identified in Phase I and to remedial alternative development should be specified.
2. Schedule for implementation of Phase II work.
3. Sampling plan and analytical protocols.
4. Quality assurance/quality control plan.
5. Health and Safety plan, including measures to safeguard nearby residents.

The schedule for implementation of the Phase II Study shall be adhered to unless written notice requesting an extension is given to the Department reasonably in advance of established due dates. The Department recognizes that field conditions sometimes necessitate a change in plans and/or schedule. Professional engineering or scientific judgement should be used in such circumstances and the change should be well-documented.

D. Phase II Activities

The following activities must be performed for a Phase II Study:

1. Investigation of Physical Site Characteristics

Data must be collected that describes and defines the Disposal Site's topography, hydrogeology, and surface characteristics for the entire area where oil and/or hazardous materials are located or have the potential to migrate. Specifically, the following site characteristics shall be included in a Phase II Study:

- a. Site and locus maps. Include the scale used, property boundaries, and geographical coordinates (UTM and latitude and longitude).
- b. Topography, surface drainage characteristics, and vegetation characteristics.
- c. Surface water locations.
- d. Flooding potential.
- e. Wetlands and critical habitats.
- f. Types of overburden materials and thickness; soil classification and permeability.
- g. Types of bedrock and depths to bedrock.
- h. Groundwater elevations; groundwater flow direction and flowrate; piezometric surfaces and gradients.
- i. Predominant wind direction.
- j. Other pertinent physical site characteristics.

These characteristics should be mapped, if possible, in order to determine their relationship to the extent of contamination.

2. Definition of Source and Extent of Contamination

At a minimum, each area of release or threat of release on the Disposal site, including underground storage tanks, subsurface drainage and/or disposal systems, and associated piping, identified in either a Phase I Report or by a systematic search of the site must be examined to determine:

- a. Exact location, concentration, volume, and containment (or lack thereof) of the oil and/or hazardous material.
- b. Source(s) of release or threat of release.
- c. Identification of existing or potential migration pathways, include all potential soil, groundwater, surface water, air, vapor, and food chain pathways. (Use Table 1 as guidance).
- d. Identification of plume(s) of oil and/or hazardous materials in groundwater, including data and map.
- e. Define the spatial area and concentrations of oil and/or hazardous material contamination in all other media.

3. Assessment of Impacts on Human and Environmental Receptors.

An assessment of present and potential impacts of oil and/or hazardous material on human and environmental receptors must include an evaluation of: the characteristics, the environmental fate, the migration pathways, and the levels of exposure for oil and hazardous materials. Assessments must include the following items:

a. Characterization of Oil and/or Hazardous Materials:

- describe type, composition, nature, physical, chemical, and toxicological characteristics, and quantity of oil and/or hazardous materials present on the site.
- describe environmental fate characteristics of oil and/or hazardous materials (e.g., mobility, stability, volatility, ability and opportunity for bioaccumulation, persistence).

b. Evaluation of Migration Routes:

- evaluate where oil and/or hazardous materials have been or could be released into the environment and what environmental media will receive or transmit the oil and/or hazardous materials;
- evaluate interaction of oil and/or hazardous materials with media encountered in terms of degradation, partitioning, transformation, etc.;
- include all potential soil, groundwater, surface water, air, vapor, and food chain migration routes in the above evaluations.

		Considerations		
Potential Hazard	Site Characteristics	Ground Water Route	Surface Water Route	Air Route
Contaminant Migration	<ul style="list-style-type: none"> Route Characteristics Oil and/or Hazardous Materials Containment Oil and/or Hazardous Materials Containment Receptors 	<ul style="list-style-type: none"> Depth to aquifer of concern Net precipitation Permeability of unsaturated zone Physical state Containment type Toxicity/persistence/stability Chemical and physical properties Oil and/or hazardous material quantity Ground Water Use Distance to Nearest Well/Population Served 	<ul style="list-style-type: none"> Facility slope and intervening terrain One-Year 24-hour rainfall Distance to nearest surface water Physical state Containment type Toxicity/persistence/stability Chemical and physical properties Oil and/or hazardous material quantity Surface water use Distance to sensitive environment Population served/distance to water intake downstream 	<ul style="list-style-type: none"> Facility slope and intervening terrain Meteorological data Containment type Reactivity/incompatibility/stability Chemical and physical properties Oil and/or hazardous material quantity Land use Population within 4-mile radius Distance to sensitive environment
Fire and Explosion	<ul style="list-style-type: none"> Oil and/or hazardous Materials Containment Oil and/or hazardous Materials Containment Receptors 	<ul style="list-style-type: none"> Containment type Direct evidence of fire or explosion Ignitability Reactivity Incompatibility Oil and/or hazardous material quantity Distance to nearest population Distance to nearest building Distance to nearest sensitive environment Land use Population within 2-mile radius Number of buildings within 2-mile radius 		
Direct Contact	<ul style="list-style-type: none"> Observed Incident Accessibility Waste Containment Toxicity Receptors 	<ul style="list-style-type: none"> Observed incident Accessibility of oil and/or hazardous materials (site security) Containment type Toxicity Population within 1-mile radius Distance to critical habitat 		

c. Identification of populations at risk and potentially at risk:

- identify all human, plant, and animal populations at risk or potentially at risk;
- identify any sensitive subgroups or risk groups that may exist within the human, plant, or animal populations;
- consider all routes of exposure to identified populations and risk groups (i.e., address the potential for inhalation, ingestion or direct contact with oil and/or hazardous materials, and characterize activities or conditions required for exposure);
- describe any affected food chains;
- determine the proximity of the site to public and private drinking water supplies;
- characterize the populations by numbers and geographic location for each exposure route.

d. Evaluation of exposure:

- compare environmental concentrations of oil and/or hazardous materials found at site to existing standards or recognized guidelines to make initial determination of the seriousness of exposure to oil and/or hazardous materials;
- estimate exposure levels and expected duration of exposure or dosages of oil and/or hazardous materials;
- perform a detailed toxicological evaluation for substances found at the site if required by the Department.

e. Assessment of impacts:

- analyze potential impact on populations identified in part "c." above;
- determine impacts of potential degradation products;
- determine actual and potential impacts on environmental receptors and/or environmental quality.

4. Initial Remedial Measures:

Throughout a Phase II Study, the necessity for performing Short-Term Measures, as described in Section VIII should be determined.

E. Phase II Study Report:

A Phase II Study Report must include:

1. Executive Summary
2. Scope of Work

3. Summary of Phase I Study
4. Physical Site Description
5. Source(s) and Extent of Contamination
6. Routes of Migration
7. Actual and Potential Receptors
8. Assessment of Potential Impacts on Human and Environmental Receptors
9. Conclusions
10. Recommendations for Future Actions
11. Appendices:
 - Summary of data and "raw" data;
 - Explanations of deviations from standard operating procedures, sampling plans, QA/QC procedures, schedule, etc.

F. Possible Outcomes

A Phase II Study can result in any of the following actions:

1. Continue additional Phase II work.
2. Start Phase III activities.
3. Perform Short-Term Measures.
4. Document that no further action is necessary at the Disposal Site.
5. Document that no remedial action is anticipated, but confirmatory monitoring is required at this time.
6. Initiate other studies (e.g., Health Studies).

G. Public Involvement

Guidance is provided in the Public Involvement Policy.

VII. Site Classification System

A. Purpose

1. The Site Classification System is a simple system used to segregate confirmed Disposal Sites into two groups based, in general terms, on the degree of risk posed by the sites.
2. Primary Goal: The Site Classification System will function as a screening device to identify those Disposal Sites in the Commonwealth that should have a "priority" status, in other words, sites that represent a substantial hazard to public health, safety, and welfare, or the environment.

B. Scope

All Disposal Sites identified in the Commonwealth will be classified according to this Site Classification System in order to identify Priority Disposal sites pursuant to M.G.L. c. 21E section 3A(d). Priority Disposal sites are then subject to specific timing and procedural requirements. The classification will be made, based on information gathered in the Phase I-Site Investigation. The priority status of a Disposal Site may be reevaluated as additional data becomes available in later phases of the site remediation process. The system is intended to classify sites based on the degree of risk posed by the Disposal Site. Inherent in an evaluation of risk is a consideration of the probability of exposure and the probability and expected severity of the effects. In order to address the probability of exposure, the criteria will be used to evaluate existing conditions as well as conditions that may exist in several years. In the Site Classification System, some of the criteria assume that if exposure occurs, then the severity of effects would be of concern. Other criteria explicitly evaluate the expected severity of effects through the use of drinking water and surface water standards and criteria.

C. Activities

In order to determine whether a Disposal Site poses a substantial hazard and therefore is a priority Disposal Site, a number of criteria have been developed. Meeting any one of the listed criteria will usually result in a Priority Disposal Site classification.

A Disposal Site which currently displays or may display within several years one or more of the following characteristics will be considered a Priority Disposal Site as defined by M.G.L. c. 21E unless evidence is demonstrated to the contrary. Best professional judgement is to be used when applying each criteria to a Disposal Site.

1. There exists or could exist physical access to a Disposal Site that provides the opportunity for direct contact with hazardous materials via surface contamination, open lagoons, drum storage areas and sludges.
2. There exists uncontained, migrating, free-floating oil and/or hazardous materials in groundwater or surface water.

3. There is evidence of groundwater contamination with oil and/or hazardous materials at levels exceeding State and/or Federal drinking water standards/guidelines (or detectable levels of contaminants for which there are no State/Federal standards or guidelines) and the evidence of groundwater contamination is:
 - a. within 2000 feet of municipal water supply well(s), or
 - b. within a mapped cone of influence of a municipal water supply well(s), or
 - c. found in or is likely to be found in private water supply well(s).

A Disposal Site which fulfills the above criterion #3 will be considered a Priority Disposal Site unless one or more of the following justifications is provided to the Department's satisfaction:

- a. proof that a hydrogeologic connection does not exist between the groundwater containing oil and/or hazardous materials and the water supply, or
 - b. proof that the concentrations of oil and/or hazardous materials found, for which there are no drinking water standards or guidelines, will not be harmful to those drinking the water, or
 - c. proof that the oil and/or hazardous materials have not migrated to and will not migrate to the public or private water supply well(s).
4. There is evidence of a release of oil and/or hazardous materials into surface water that is upstream of a potable surface water supply intake structure or of the recharge area a municipal well(s) unless one or more of the following justifications is provided to the Department's satisfaction:
 - a. proof that a hydrogeologic connection between the oil and/or hazardous materials release and the well(s) does not exist, or
 - b. proof for those situations where there is a hydrogeologic connection that concentrations at the well will never exceed State and/or Federal drinking water standard/guidelines, or
 - c. proof that the release of oil and/or hazardous materials has not or will not reach the surface water supply intake at concentrations exceeding State and/or Federal drinking water standards/guidelines, or
 - d. proof that the concentrations of oil and/or hazardous materials found or predicted at either the surface water supply intake or the recharge area of a municipal water supply well(s), and for which there are no drinking water standards or guidelines, will not be harmful to those drinking the water.

5. There is evidence of a release of oil and/or hazardous materials to surface water that has resulted or could result in a concentration which exceeds ambient water quality criteria for the protection of aquatic life or human health. Such surface waters may be public recreational areas and/or sensitive environmental areas (e.g., marine sanctuaries, wild and scenic rivers, tidal areas and freshwater tidelands, farmland, wilderness areas, etc.)
6. There is a threat of fire and/or explosion.
7. There are or could be air emissions from oil and/or hazardous materials, which could adversely impact human or environmental receptors.
8. There are releases of oil and/or hazardous materials that have affected or could adversely affect the human food chain.
9. There is any other information that indicates that the Disposal Site may pose a significant or otherwise unacceptable risk of harm to public health, safety, welfare, and to the environment if left in its present state for several years. This criterion is to be used only if none of the previous eight criteria apply. Documentation of the rationale for site classification based on this criteria must be provided.

D. Possible Outcomes

Site Classification will result in the designation of sites as Priority or Non-Priority Disposal Sites.

VIII. Short-Term Measures

A. Purpose

1. A Short-Term Measure is intended to abate imminent hazards due to the release or threat of release, the continued or future migration, potential for fire and/or explosion, or direct contact with oil and/or hazardous materials.
2. Primary Goal: Short-Term Measures are actions which contain, isolate, remove, or secure an existing release or alleviate a threat of release and thereby eliminate or prevent an imminent hazard to the public health, safety, and welfare and to the environment until such time as any substantial hazard at the site can be addressed through the full site assessment and remediation process. Short-Term Measures may also be implemented for engineering or economic reasons.

B. Scope

The extent, type, timing and frequency of a Short-Term Measure(s) required for a Disposal Site will be determined by the factors listed in "C" below. The need for performing Short-Term Measures must be evaluated constantly throughout the Site Remediation Process and these measures must be implemented whenever mandated by Disposal Site conditions.

C. Factors

The severity of the following factors shall be considered in determining the need for and extent of a Short-Term Measure:

1. Existing or potential exposure of nearby human, plant, and animal populations to oil and/or hazardous materials.
2. Existing or potential contamination of drinking water supplies or environmentally sensitive areas by oil and/or hazardous materials.
3. Oil and/or hazardous materials in drums, barrels, tanks, or other bulk storage containers, which pose a threat of release.
4. Levels of oil and/or hazardous materials in soils largely at or near the surface of the site.
5. Weather conditions that may cause or contribute to the migration or release of oil and/or hazardous materials.
6. Threat of fire or explosion.
7. Any other factors which may constitute imminent hazards to the public health, safety and welfare, or the environment.
8. Public health, safety and welfare, environmental, engineering or economic reasons that make it prudent to undertake a Short Term Measure prior to or during the completion of comprehensive investigations and/or studies.

D. Appropriate Short-Term Measures

Whenever feasible in choosing an appropriate Short-Term Measure, the action chosen should not limit any options for future Remedial Actions. The following options shall be considered in order to evaluate the suitability of each for the specific situation. However, this list will not limit the Department from taking or requiring any other actions deemed necessary in response to any situation.

1. Fences, warning signs (multilingual and symbolic, if necessary), or other security or site control precautions to prevent animal or unauthorized human access to the site;
2. Drainage controls (e.g., run-off or run-on diversions) to prevent or reduce precipitation or run-off (e.g., flooding) from entering or leaving the Disposal Site and causing either continued/future migration of or a release of oil and/or hazardous materials;
3. Stabilization of berms, dikes, or impoundments to maintain their integrity;
4. Temporary covering or capping of contaminated soils or sludges to prevent or reduce any public health or environmental risks associated with direct contact and/or to prevent or reduce the migration of oil and/or hazardous materials into soil, groundwater, surface water, or air;
5. Installation of waste/product recovery and groundwater treatment systems to reduce migration of oil and/or hazardous materials;
6. Removal of contaminated soils to reduce any public health or environmental risks associated with direct contact and/or to reduce the migration of oil and/or hazardous materials;
7. Removal of the contents of and/or removal of drums, barrels, tanks or other bulk containers which contain or may contain oil and/or hazardous materials to reduce the likelihood of spillage, leakage, exposure to humans, wildlife, or elements of the food chain, or fire or explosion;
8. Temporary evacuation of the area or relocation of the residents to control the potential for human exposure, adverse health effects, or safety hazards associated with the release or threat of release of oil and/or hazardous materials.
9. Provision of temporary alternative water supplies to prevent the risk of human health effects.
10. Any other action that is consistent with the Primary Goals of a Short-Term Measure.

E. Public Involvement

Guidance is provided in the Public Involvement Policy.

F. Site Specific Health and Safety Plan

For on-site personnel or employees of investigating teams, contractors, or subcontractors, a Site Health and Safety Plan must be prepared and implemented.

G. Monitoring

Monitoring may be required during a Short-Term Measure in order to:

1. Evaluate the effectiveness of the Short-Term Measure. For example, data collected from product recovery and groundwater treatment systems can indicate the degree of effectiveness of the source control measures.
2. Document if there are any on- and/or off-site impacts on the environmental quality and/or a temporary increased threat to the public health, safety and welfare during the implementation of Short-Term Measure (e.g., potential air emissions during construction). Any such situations which require on-and/or off-site monitoring require Departmental approval of a contingency plan prior to implementation of the Short Term Measure.

H. Possible Outcomes

Short-Term Measures should alleviate an imminent hazard at a Disposal Site, which will then continue through the full site evaluation, classification, and remediation process.

APPENDIX 2

The Conservation Law Foundation has sent to every Massachusetts city and town over the past year: 1. CLF's manual entitled *Underground Petroleum Storage Tanks: Local Regulation of a Groundwater Hazard*; 2. a model bylaw to regulate underground storage of petroleum products and other "hazardous materials."

This brochure brings you up to date on the *new federal and state requirements*; points out the gaps that *local regulation* can fill; and informs you of the **May 8, 1986 deadline** for compliance by all tank owners (*including cities and towns*) with federal and state notification requirements.

Federal Requirements

Notification

1. Owners of *existing* underground storage tanks, containing either petroleum products or other "hazardous materials," must file a notification form with the Massachusetts Department of Public Safety (DPS) by **May 8, 1986**. This requirement includes buried tanks that have been taken out of service since January 1, 1974.
2. The owner of a *new* tank must file the form within 30 days after it is brought into use.
3. Two major categories of *tanks that are exempt* from the notification requirement are:
 - (a) farm and residential tanks storing less than 1,100 gallons of motor fuel, for noncommercial purposes;
 - (b) tanks storing heating oil for burning on the premises.
4. A **fine of up to \$10,000 per tank** is the penalty for knowingly failing to file a required federal notification form.

State Requirements

New DPS regulations for underground storage of *flammable products* (based in large measure on CLF's model bylaw) went into effect on February 1, 1986. *Petroleum products* are the primary focus of these regulations.

Administration

1. The state regulations are to be administered by the heads of local fire departments under the supervision of the State Fire Marshal's office in the DPS.

Permits

1. Owners of *existing* tanks must file for a permit with the head of the local fire department by **May 8, 1986**. The permit is *in addition* to any existing license or permit the owner may have.
2. Two categories of *existing* tanks are *exempt* from the permitting requirement:
 - (a) farm and residential tanks storing 1,100 gallons or less of motor fuel, for non-commercial purposes;
 - (b) tanks storing heating oil for burning on the premises.
3. Owners of *new* tanks (*no exemptions*) must file for a permit prior to installation.

Design and Installation

1. All *new* storage facilities (*no exemptions*) must comply with the new design and installation requirements.
2. The design requirements apply to tanks, piping and pumping systems.
3. Installation contractors must supply a *written certification of qualification* from the manufacturer or a petroleum equipment association.

local fire department of any installation, as well as inspection, testing and approval.

Secondary Containment

1. Secondary containment (e.g. a double-walled tank) is *required* for all new or replacement installations above EPA-designated sole source aquifers (e.g. for Cape Cod and Nantucket).
2. The local fire chief *may* require secondary containment for *new* installations:
 - (a) within the "cone of influence" of a municipal well;
 - (b) within 300 feet of a private well.
3. Tanks storing heating oil or waste oil exclusively for burning on the premises are *exempt* from the secondary containment requirement above EPA-designated sole source aquifers.

Leak Detection

1. Tanks storing heating oil or waste oil exclusively for burning on the premises are *exempt* from these requirements.
2. All other new and existing tanks must comply with *one* of the following:
 - (a) inventory record keeping plus periodic tightness testing;
 - (b) installation and maintenance of an approved monitoring system;
 - (c) installation of an approved double-walled tank with provision for continuous monitoring.
3. Owners selecting the inventory record keeping and testing option must have tanks and piping tested as follows:
 - (a) *New facilities*: during the 15th and 20th years and every 2nd year thereafter;
 - (b) *Existing facilities that meet new design requirements*: same as new facilities;

13th, 15th, 17th, and 19th years and every year thereafter.

Response to Leaks

1. In the case of any *tank storing petroleum products or other flammables*, the operator must immediately notify the owner, and the owner must immediately notify the head of the local fire department and Office of Incident Response (OIR) of DEQE.
2. In the case of any *tank storing a hazardous material* (not including petroleum products), the owner must immediately notify OIR-DEQE and the EPA.

Taking Tanks Out of Service

1. If a tank has been, or is to be, taken out of service *permanently*, the owner must obtain a permit from the local fire chief and (except in specified circumstances) have the tank *removed* from the ground.
2. There are requirements for taking a tank out of service *temporarily* (for less than 6 months).

Local Options

General Principles

1. Under *Home Rule*, a city or town may regulate underground storage of petroleum products and other "hazardous materials" through:
 - (a) a zoning bylaw/ordinance
 - (b) a nonzoning bylaw/ordinance
 - (c) board of health regulations
2. Local regulations must be "*not inconsistent*" with the *general purpose* of the state regulations.

3. Local regulations may:
 - (a) impose *stricter* requirements than the state regulations (but not *less* strict);
 - (b) regulate categories of storage tanks that are *exempt* from state and federal requirements.
4. For further guidance, consult Chapter IV of the CLF manual.

Specific Suggestions

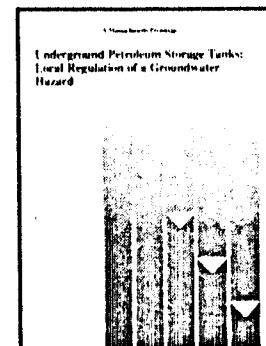
1. Identify on an *overlay map* a protection district that includes the groundwater and surface water sources of your municipal and/or private water supplies. For further guidance, consult Chapter II of the CLF manual.
2. Amend your *zoning bylaws* to provide *special* protection for your water supplies. In particular, we recommend:
 - (a) prohibiting all *new* underground storage facilities in the overlay protection district;
 - (b) requiring double-walled tanks and piping for all *replacements* in existing facilities.

For further guidance, consult Chapter II and Appendix B of the CLF manual.

3. Adopt a *general bylaw* to *supplement* the new state regulations under 527 CMR 9.00. Include provisions in the bylaw:
 - (a) requiring the head of the local fire department to send to the board of health, the water department, and the conservation commission a copy of every permit application for a *new* storage facility, with a request for a recommendation of approval or disapproval within 30 days;
 - (b) requiring a permit from the head of the local fire department for all storage facilities *exempt* from the state permitting requirements of 527 CMR 9.24;

- (c) requiring (unless already provided for in a protection district bylaw) double-walled tanks and piping for all new storage facilities within the "cone of influence" of municipal wells and within 300 feet of private potable water wells; and
- (d) requiring periodic tightness testing, in accordance with the schedules and other provisions of 527 CMR 9.18, for tanks storing heating oil or waste oil exclusively for burning on the premises and exempt from the leak detection provisions of the state regulations (527 CMR 9.16, 9.17 and 9.18).

For further guidance, consult Appendix A of the CLF manual.



Underground Storage Tank Manual

CLF's work on the threat of leaking underground storage tanks to groundwater reached a major milestone with the publication of our definitive legal and technical manual on the subject, *Underground Petroleum Storage Tanks: Local Regulation of a Groundwater Hazard*. The 106-page manual, the first of its kind in the nation, describes the dangers posed by leaking tanks and promotes local action to deal with the problem by including model underground tank and aquifer protection bylaws. Copies of the manual have been distributed to all 351 Massachusetts cities and towns and to various state and federal agencies. Municipal agencies may purchase the manual for \$5.00.

APPENDIX 3

B E W I C K

S I T E A U D I T

- Compliance Management
- Permits
- Site Assessments
- Facility Siting
- Waste Management
- Right-to-Know

ENVIRONMENTAL AUDIT REPORT

for

MGL c.21E

on

341 WEST BROADWAY, SOUTH BOSTON, MASSACHUSETTS

September 1986

September 12, 1986

Leonard DePaola, Esq.
43 Kingston Street
Boston, Massachusetts 02111

Edward Kutchin, Esq.
Lapping and Kutchin
Suite 1215
One Boston Place
Boston, Massachusetts 02108

Dear Sirs:

This is an Environmental Audit Report on a property located at 341 West Broadway in South Boston, Massachusetts (the Site) done for the purposes of MGL Chapter 21E, the Massachusetts Superfund Act (the Act).

The purpose of the Report is to determine whether or not there is evidence of oil or hazardous materials being released or threatened to be released on the Site or in the vicinity of the Site for the purposes of the Act.

Location

The Site is located at 341 West Broadway in South Boston, Massachusetts, on the southwest side of West Broadway, between the intersections of West Broadway with D Street and E Street. The Site is indicated in Figure 1, Locus Map, a portion of the USGS map of the Boston South, MA quadrangle. It is also indicated in Figure 2, Location Map, a portion of the street map of South Boston.

Site Description

The current owner is Lambi Adams. The Site consists of 1,996 square feet. It is recorded as Parcel 489, Lot 343, Ward 6, on the Boston Assessors' Map.

The Site is occupied by a one story cement block building. The building has a basement with a dirt floor. The building is serviced by underground water, sewer, gas, phone, and electric lines. The building is heated with gas. There is an above ground 275 gallon oil storage tank on the dirt floor in the cellar, that is not in use.

The Site is almost entirely built upon. The remainder of the Site consists of grass and weeds in a strip of land only a few inches wide on the south and east sides of the building.



Figure 1
Locus Map

341 W. BROADWAY
S. BOSTON, MA

Bewick Associates
617-924-7455

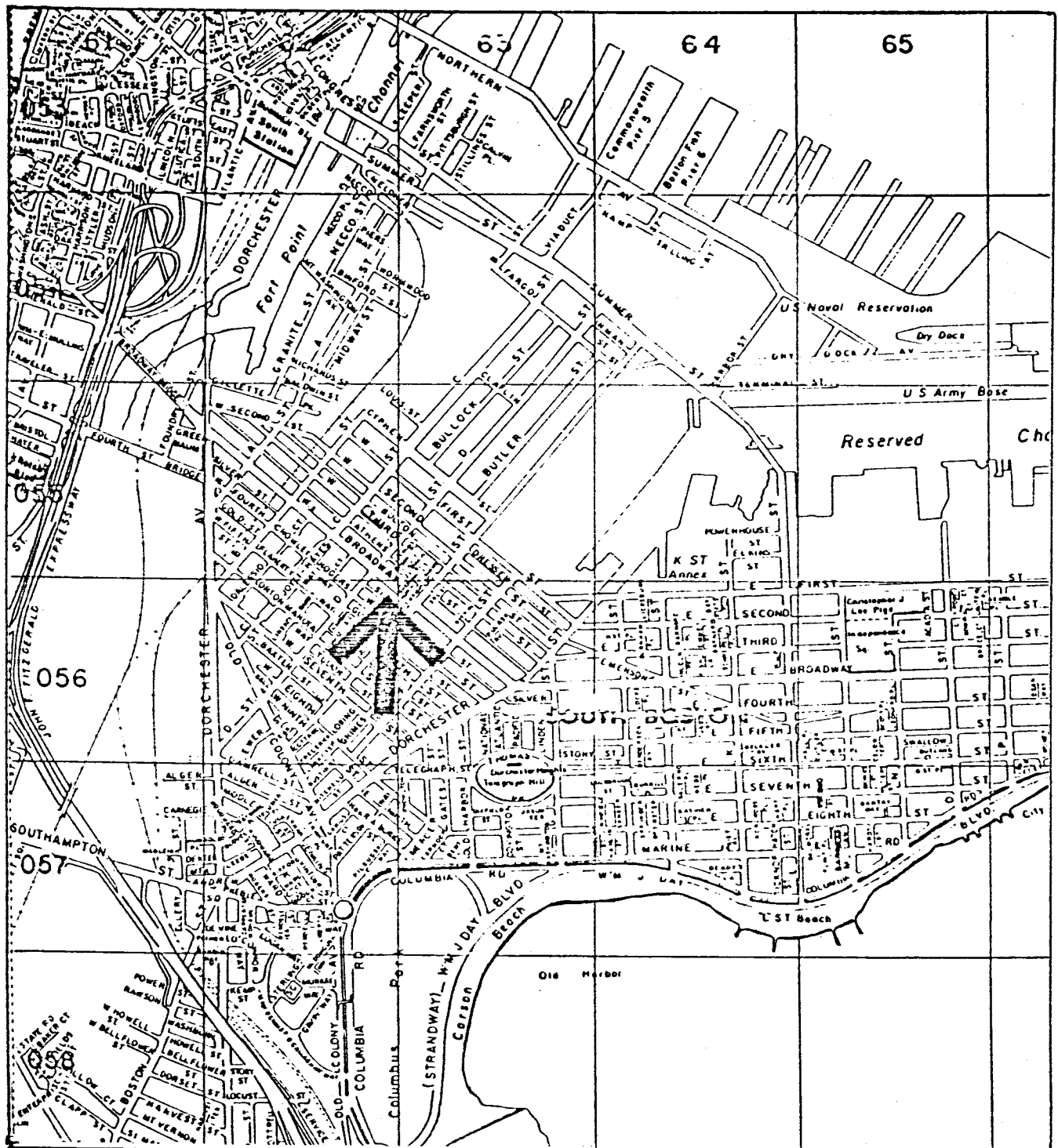


Figure 2
Location Map

341 W. BROADWAY
S. BOSTON, MA

Bewick Associates
617-924-7455

History of Site and Adjacent Properties

The building at the Site is occupied by the Adams Liquor Store. The age of the building is not known, but it was apparently built about 1920. It has been occupied by a liquor store for at least twenty-five years. Prior to that, historical records show that in the 1920's, it was a three story wood building that housed a bakery, the Tea and Butter Corporation on the first floor, and the Progress Clothing Company on the top two floors. From the 1940's to the 1960's, there were small stores on the first floor and apartments above.

The Site is in an area of South Boston zoned for business. The Site fronts on West Broadway to the northeast. Across the street from the Site are a restaurant, apartments, a bar, and a shoe repair shop. The adjoining property to the west is occupied by a building for an American Legion Post and to the east by a vacant lot. Behind the Site to the southwest are apartments. Along West Broadway are small businesses and apartments. There do not appear to be any industrial properties in the vicinity of the Site.

The Health Department of Boston did not have any records of any environmental or health problems at the Site.

Regional Description

The Site is located at an elevation of approximately twenty feet above mean sea level, and is level. The land in the vicinity of the Site slopes down gradually to the northwest. The regional topography is moderately hilly. Telegraph Hill, which reaches an elevation of approximately 135 feet above mean sea level, is located one half of a mile southeast. The remainder of the surrounding land slopes gradually down to the north and northeast.

The Site is in the Boston Harbor drainage basin, with the Boston Inner Harbor located three quarters of a mile north. Water bodies in the vicinity of the Site include the Boston Inner Harbor, the Reserved Channel for the Naval Reserve, and the Fort Point Channel, all located to the north. The Old Harbor is located three quarters of a mile southeast. If unimpeded, surface runoff would be towards the north. The groundwater flow direction was not determined, but is likely to be also towards groundwater discharge areas in the Inner Harbor to the north.

The public drinking water of South Boston is supplied by the MWRA and has sources located outside the vicinity of the Site. The DEQE Water Supply Protection Atlas does not indicate any public drinking water supply sources in the vicinity of the Site that might be affected by the Site, within a one mile radius or downgradient of the Site.

The DEQE and EPA hazardous waste site inventories do not list any hazardous waste sites in the vicinity of the Site. The DEQE Water Supply Protection Atlas indicates one waste source in the vicinity of the Site within a one mile radius of the Site, which is not likely to affect the Site. This source is a confirmed salt storage located three quarters of a mile west. There is one mapped surface liquid waste impoundment in the vicinity of the Site. The EPA inventory of hazardous waste facilities does not list any facilities in South Boston in the vicinity of the Site.

Site Inspection

The Site was inspected on September 11, 1986 by Karen M. Stash.

The Site is occupied by a one story cement block building.

The Site appeared clean, without any unusual debris that might suggest the presence, use, or disposal of hazardous materials.

There did not appear to be any significant current use or storage of chemicals or hazardous materials throughout the building .

There was no apparent visual evidence of asbestos insulation at the Site.

There was very little vegetation at the Site, and no soil visible. There were no pits or undulations in the ground surface that might indicate the presence of subsurface liquid wastes or the settling of solid wastes.

There was no visual evidence, such as vent or fill pipes, of underground fuel storage tanks at the Site. There is an above ground fuel oil storage tank located in the northeast side of the cellar. It has not been in use for at least twelve years, and is located on a dirt floor. There were no obvious signs of leakage, such as dripping or stains.

There did not appear to be any significant sources of pollution in the immediate vicinity of the Site, such as gas stations or industrial properties. The Site is generally surrounded by small businesses, and apartments. Surface runoff past the Site appears to be from the streets, sidewalks, and roof tops.


There was no visual evidence of oil or hazardous materials being released or threatened to be released on the Site or in the vicinity of the Site for the purposes of the Act, based on a visual walk-around Site inspection of the surface conditions on September 11, 1986.

Bewick Associates, Inc.
Project EA0304, Page 4
341 W. Broadway, S. Boston, MA
September 12, 1986

The observations in this Report were made under the conditions noted in the Report. The conclusions were based on discussions with you and others, and on a visual walk-around Site inspection of the surface conditions at the Site. The Report has been prepared in accordance with accepted geotechnical and geohydrological practice. No other warranty, express or implied, is made.

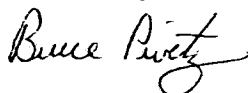
It has been a pleasure to serve you. Please feel free to call if there are any questions or if we may be of further assistance.

Sincerely,



Karen M. Stash
Field Inspector

Reviewed by,



Bruce Pivetz
Project Manager

APPENDIX 4

Bewick Associates, Inc.

Specialists in environmental
engineering and manage

B E W I C K

S I T E A U D I T

- Compliance Management
- Permits
- Site Assessments
- Facility Siting
- Waste Management
- Right-to-Know

ENVIRONMENTAL AUDIT REPORT

for

MGL c.21E

on

1274 DORCHESTER AVENUE

DORCHESTER, MASSACHUSETTS

August, 1986

124 Watertown St., Suite 3A
Watertown, MA 02172
Telephone (617) 924-7455

August 18, 1986

Mr. Kosta Papoulidis
15 Freeport Way
Dorchester, Massachusetts 02122

Dear Mr. Papoulidis:

I am pleased to submit herewith this Environmental Audit Report done for the purposes of MGL c.21E, the Massachusetts Superfund Act (the Act) on a property located at 1274 Dorchester Avenue in Dorchester, Massachusetts (the Site).

The purpose of the Report is to determine whether or not there is evidence of oil or hazardous materials being released or threatened to be released on the Site or in the vicinity of the Site for the purposes of the Act. The findings herein are based on discussions with you and others, subsurface borings, and chemical analysis of soil and groundwater samples.

SUMMARY OF FINDINGS

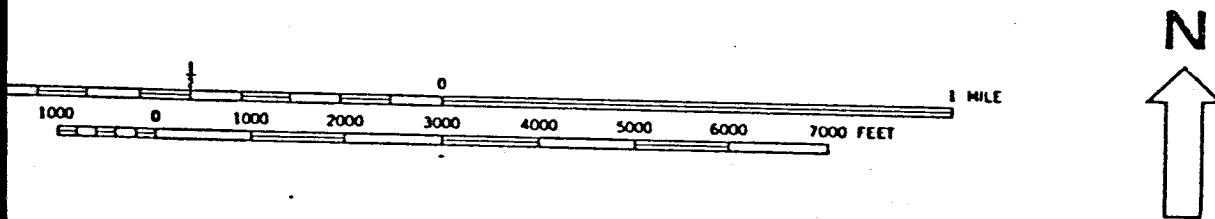
There was significant evidence of oil or hazardous materials being released or threatened to be released on the Site or in the vicinity of the Site for the purposes of the Act.

The results of analytical tests on soil and groundwater samples taken at the Site indicate that there has been a release of gasoline from current or former underground gasoline storage tanks at the Site. The hazardous materials are at a level that should be reported to the DEQE as a release under c.21E. The date and exact source of the release are not known.

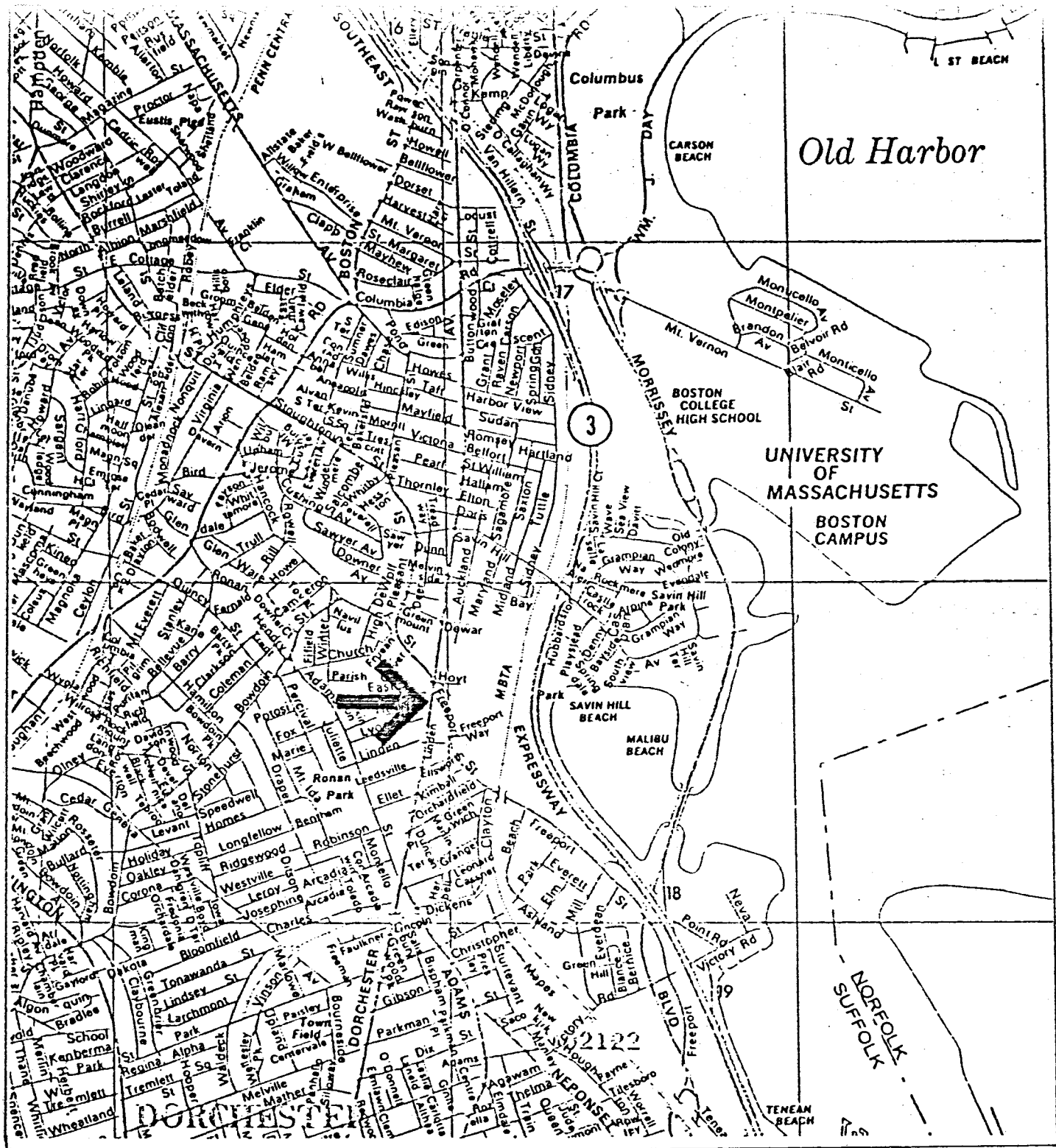
The release of gasoline is not significant as a threat to public or private groundwater or surface water drinking water supplies, as there are no downgradient drinking water uses. The groundwater at the Site is eventually discharged into Dorchester Bay, where the levels of contaminants detected may not exceed the Federal Criteria for the Protection of Saltwater Aquatic Life.

SITE LOCATION

The Site is located at 1274 Dorchester Avenue in Dorchester, Massachusetts, on the eastern side of Dorchester Avenue at the southeast corner of the intersection of Freeport Street with Dorchester Avenue. The Site is indicated in Figure 1, Locus Map, a portion of the USGS map of the Boston South, MA quadrangle. It is also indicated in Figure 2, Location Map, a portion of the street map of the Dorchester section of Boston.



<p>Figure 1 ocus Map</p>	<p>1274 DORCHESTER AVENUE DORCHESTER, MA</p>	<p>Bewick Associates 617-924-7455</p>
------------------------------	--	---



0 .1 .2 .3 .4 .5 mile
0 1000 2000 3000 feet



Figure 2
Location Map

1274 DORCHESTER AVENUE
DORCHESTER, MA

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617-924-7455

Bewick Associates, Inc.
Project EA0270, Page 2
1274 Dorchester Avenue, Dorchester, MA
August 18, 1986

SITE DESCRIPTION

The Site is located at 1274 Dorchester Avenue in Dorchester, Massachusetts, on the eastern side of Dorchester Avenue at the southeast corner of the intersection of Freeport Street with Dorchester Avenue.

The Site is recorded on the Boston Assessor's Map as Parcel 330, Ward 15. The current owners are Kosta Papoulidis and Prenca Juncovic. The Site consists of 12,567 square feet. The Site is indicated in Figure 3, Site Plan.

The Site consists of two portions. The northern is occupied by a Mobil gas station and is located at the intersection of Dorchester Avenue and Freeport Street, consisting of 7,461 square feet. The southern portion, consisting of 5,106 square feet, is an empty paved lot.

The southern portion of the Site is entirely paved with asphalt, and is unused. It is completely surrounded by a chain link fence.

The northern half of the Site is occupied by a one story concrete block and brick building on the central part of this portion of the Site. The building has a slab floor and does not have a basement. The building consists of two service bays, an office, storage space, and restrooms. The building is serviced by underground water, sewer, electric, and telephone lines. The building is heated with oil, contained in a 500 gallon underground tank located along the southwestern side of the building.

This portion of the Site is almost entirely built upon or paved. The remainder of the gas station portion of the Site consists of two gas pump islands, one along each of the intersecting streets, and paved areas for pump access and parking. There is a small area of grass and weeds at the southwest corner of the building.

The underground fuel storage tanks at the Site include 4000 gallon and 6000 gallon fiberglass tanks, apparently installed in 1981, and a 4000 gallon steel tank, apparently installed in 1972. There is a 500 gallon fuel oil tank for on-premises heating, and a 550 gallon waste oil tank. The gasoline tanks are located towards the northern corner of the Site, and are indicated on Figure 3. The heating oil tank is at the southwestern side of the building and the waste oil tank at the northeastern side of the building.

The Site is located at an elevation of between approximately 15 to 20 feet above mean sea level, and has a slight gradient of several feet down towards the northeast and east along Freeport Street. The land in the vicinity of the Site slopes slightly downhill to the north along Dorchester Avenue, and gradually up to the west. Along Freeport Street to the southeast and along Dorchester Avenue to the south the land is generally level in the vicinity of the Site. The regional topography is moderately hilly to the west, with the 130 foot Meeting House Hill

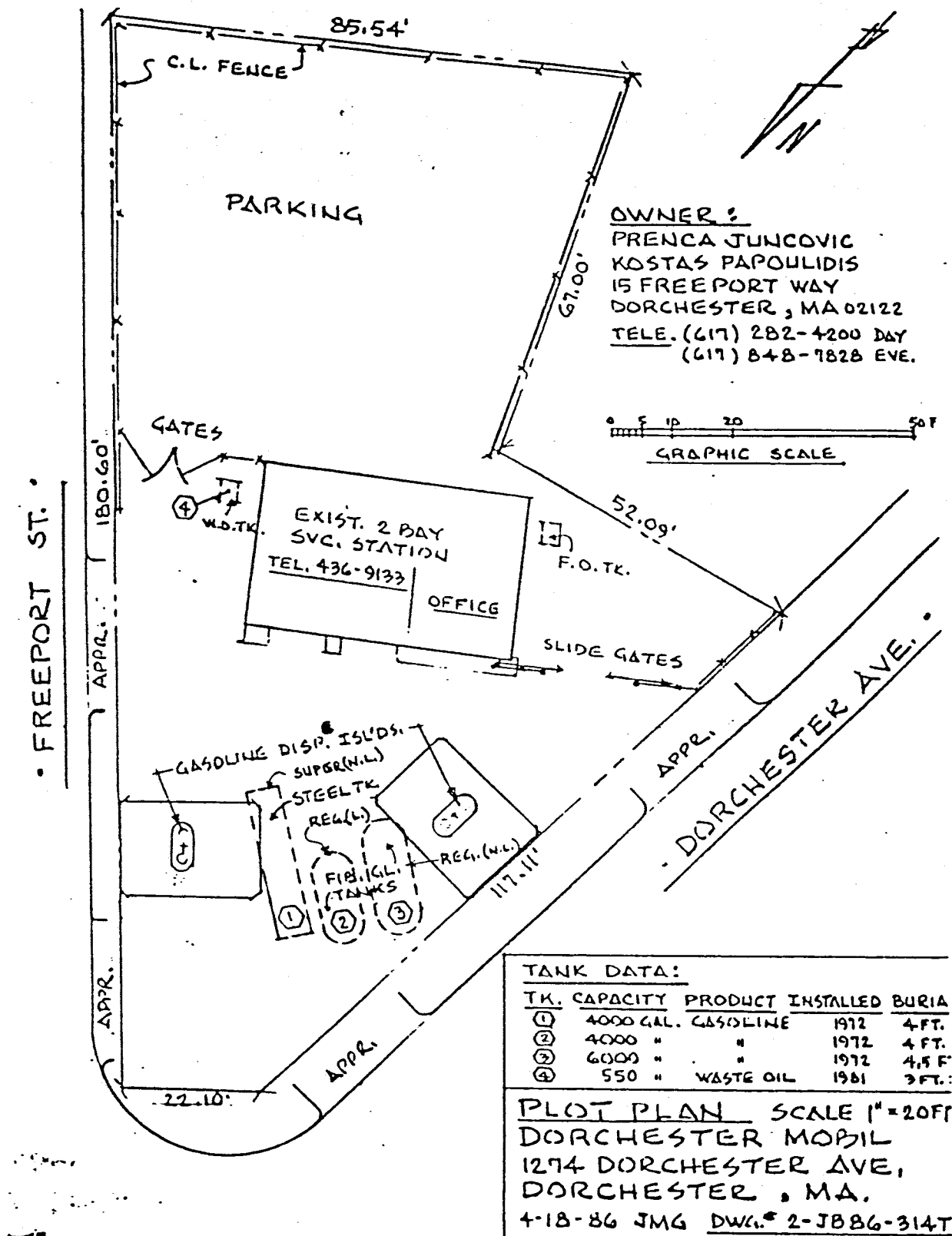


Figure 3
Site Plan

1274 DORCHESTER AVENUE
DORCHESTER, MA

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Project EA0270, Page 3
1274 Dorchester Avenue, Dorchester, MA
August 18, 1986

located about 1/3 mile to the southwest, and with a 120 foot hill approximately 1/2 mile to the northwest. The 110 foot Savin Hill is found about 1/2 mile northeast. The land to the east slopes gradually down to the level of Dorchester Bay, approximately 1/4 to 1/2 mile from the Site.

There are no bedrock outcrops at the Site. The nearest outcrops are located about 500 to 600 feet west and northwest of the Site. Bedrock underlying the Site is likely to be a metamorphosed conglomerate. Refusal was encountered at 17 to 18.5 feet in two test borings at the Site. The test borings revealed several feet of fill underlain by clay, silt, sand, and till. Some weathered rock was encountered at refusal.

The Site is in the Massachusetts Bay drainage basin, with a small bay opening onto Dorchester Bay located about 1/4 mile east of the site. There are no water bodies on or adjoining the Site. Water bodies in the vicinity of the Site include only Dorchester Bay. If unimpeded, surface runoff would be from the west towards the east. The groundwater flow direction was not determined, but is likely to be also towards groundwater discharge areas along Dorchester Bay to the east.

CURRENT AND HISTORIC USES OF SITE AND ADJACENT PROPERTIES

The Site is currently occupied by a Mobil Gas Station.

The building at the Site is occupied by the repair bays, office, and restrooms of the service station. The building was reported to have been built in 1941. It has been occupied by a gas station since that time. Prior to that, historical records show that there was a previous gas station building at the Site from about 1926 to 1941. Prior to 1926 there was a dwelling at the Site, which was demolished to construct the gas station.

Underground fuel storage tanks have existed at the Site since 1926. Fire Department records indicate a permit for the storage of 3000 gallons of gas underground in 1926 under the name of the Socony Vacuum Oil Company, Inc. In 1931 500 gallons of additional storage was permitted. In 1935 the tanks at the Site included two 1500 gallon tanks. An additional 1500 gallons was permitted in 1941 to 1942. The storage at the Site next increased in 1963, when 5000 gallons was added to the amount allowed to be stored. A 500 gallon fuel oil tank and a 500 gallon waste oil tank are also revealed in the records existing at the Site. The records are unclear as to the size of tanks existing at the time. However, a 1500 gallon tank was apparently removed and a new 4000 gallon tank installed. There was also apparently either two 3000 gallon tanks or one 6000 tank installed at that time under the name of the Socony Mobil Oil Company, Inc. In 1972 the total underground storage was 11,680 gallons. An additional 4000 gallons of gas was added in 1972.

Bewick Associates, Inc.
Project EA0270, Page 4
1274 Dorchester Avenue, Dorchester, MA
August 18, 1986

In 1980 a permit was issued to replace a 4000 gallon and a 6000 gallon steel tank with fiberglass tanks. This work was done in 1981, at which time it was evident that one or both tanks were leaking. In 1981, a 4000 gallon and a 6000 gallon fiberglass tank was installed. It appears that the current tanks at the Site include the 4000 and 6000 gallon fiberglass tanks installed in 1981 and the 4000 gallon steel tank installed in 1972. The smaller oil tanks are apparently from at least 1963.

The southern half of the Site has apparently been vacant land. A 1965 Assessor's Map indicating other buildings in the vicinity does not indicate any building on this portion of the Site.

The Site is in a commercial and light industrial area of Dorchester. The uses of the adjacent properties are shown in Figure 4, Adjacent Uses. The Site fronts on Dorchester Avenue to the west. Across Dorchester Avenue from the Site is a Speedy Muffler King. Slightly to the south across Dorchester Avenue is a small grocery and liquor store and G&L Auto Repair. Adjoining to the south is a two story brick building housing the Dineen Automotive Supply Co. The Site also fronts on Freeport Street to the northeast. Across Freeport Street is a two story brick building and a one story warehouse type structure housing Gilman Brothers, Free-Port Ltd. The adjoining property to the southeast along Freeport Street is occupied by Universal Auto Body and a parking lot. Along Dorchester Avenue to the south are empty lots, stores, and small businesses. To the north are similar uses, including a Sunoco Gas Station. Along Freeport Street to the southeast are mostly auto body shops, junkyards, and other small businesses. There do not appear to be any heavy industrial properties in the vicinity of the Site. The junkyards along Freeport Street are located downgradient of the Site. There do not appear to be any immediately upgradient pollution sources. Upgradient of the Site to the west is a generally residential area.

The available DEQE oil spill and hazardous waste incident response files do not appear to list any incidents at the Site.

The DEQE and EPA hazardous waste site inventories list several hazardous waste sites in Dorchester and Boston. The three nearest sites are located 2 miles northwest, about 3/4 mile northeast, and approximately 3/4 mile southeast. None of these sites appear to be able to have any effect on the Site, as there are no upgradient sites.

The DEQE Water Supply Protection Atlas indicates waste sources in the vicinity of the Site within a one mile radius of the Site. These include a surface impoundment approximately 1000 feet northeast and a hazardous waste site about 1000 feet southeast of the Site. These sites are both downgradient. The hazardous waste site to the southeast is located along Freeport Street. It has apparently been cleaned up to the satisfaction of the DEQE, although there is some neighborhood pressure for further work. Neither of the waste sources indicated by the Water Supply Protection Atlas appear to affect the Site.

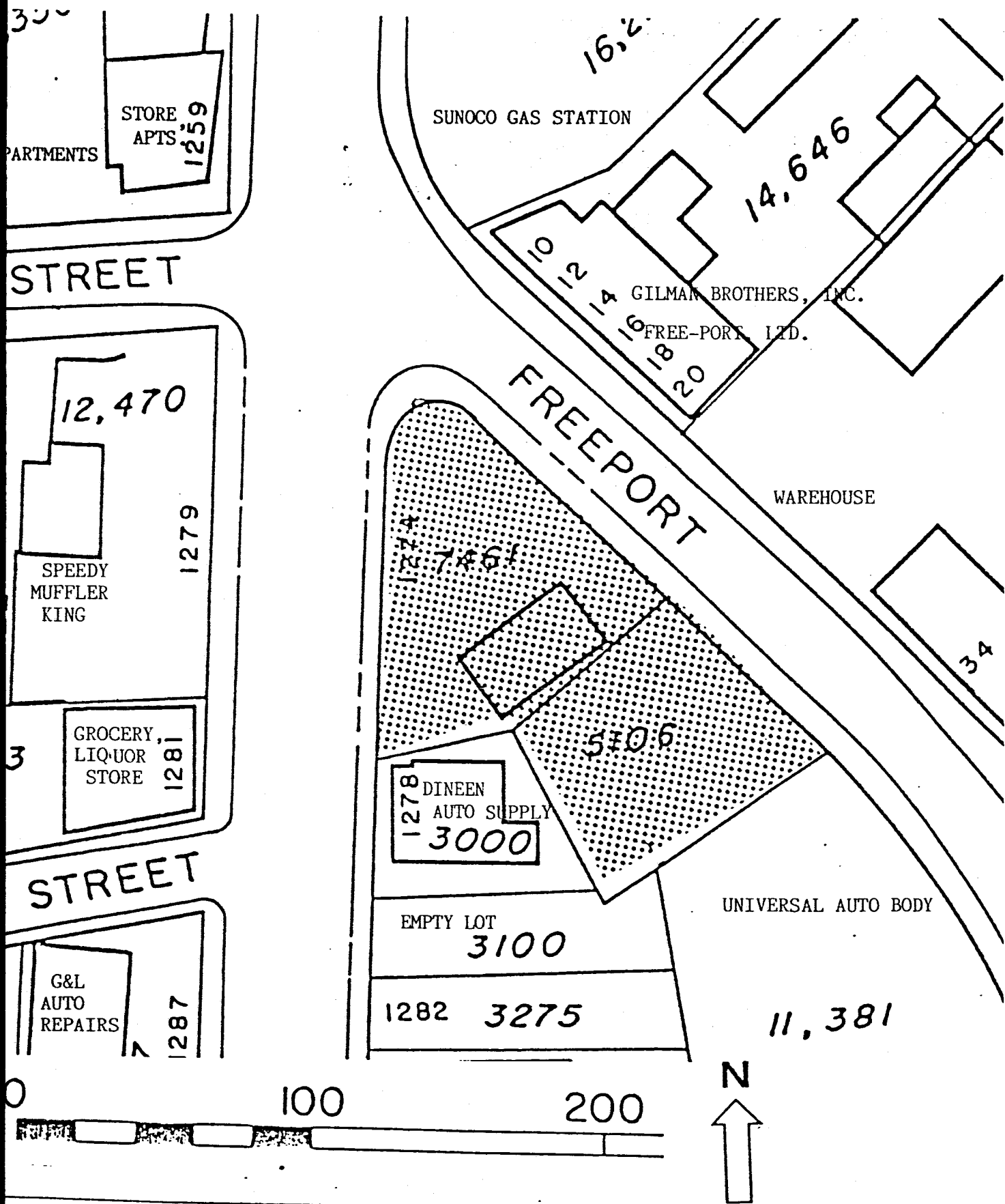


Figure 4
Adjacent Uses

1274 DORCHESTER AVENUE
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Project EA0270, Page 5
1274 Dorchester Avenue, Dorchester, MA
August 18, 1986

There are not any mapped surface liquid waste impoundments in the immediate vicinity of the Site, on a statewide map of impoundments.

Several hazardous waste facilities are listed for the vicinity of the Site on an EPA inventory. These include three downgradient facilities along Freeport Street that are all small quantity generators and Tom's Auto Body, Inc., a small quantity generator located about 200 feet to the southwest. This last facility does not appear to be directly upgradient.

The Health Department of Boston did not have any records pertaining to problems at the Site.

Problems reported by the Site occupant included an incident of leaking underground gasoline tanks, as indicated above.

The public drinking water of Dorchester and Boston is supplied by the MDC system and has sources located outside the drainage area of the Site. The DEQE Water Supply Protection Atlas does not indicate any public drinking water supply sources in the vicinity of the Site that might be affected by the Site, within a one mile radius or downgradient of the Site. The nearest water body to the Site, Dorchester Bay, is classified as having Class SB Water, for Marine Fishery, Shellfishing, and Recreation uses.

Site Inspection

The Site was inspected on several occasions including on July 17, 1986 by Bruce Pivetz.

The Site is occupied by a one story concrete block building housing a Mobil gas station on the central portion of the northern half of the Site, and by an empty paved lot on the southern half of the Site.

The Site is serviced by underground water, sewer, electric, and telephone lines.

The Site appeared relatively messy. with the usual debris and mess associated with a busy gas station. There were oil stains on the pavement, on the garage floor, and in the pit used to service cars. A small dumpster was located at the west corner of the building. Along the southwest side of the building was debris including tires, old pipes, miscellaneous car parts, batteries, two drums of antifreeze, and wheels. There did not appear to be any unusual debris that would indicate the improper storage or disposal of hazardous materials.

There did not appear to be any current use, storage, or disposal of any chemicals or hazardous materials other than what would be expected at a normal gas station, such as antifreeze, brake fluid, transmission fluid, degreasers, fuels, and cleaners.

Bewick Associates, Inc.
Project EA0270, Page 6
1274 Dorchester Avenue, Dorchester, MA
August 18, 1986

There was not any apparent visual evidence of asbestos insulation at the Site.

There was very sparse vegetation at the Site, consisting of a few weeds and very little grass.

There was not any soil visible. There were no pits or undulations in the ground surface that might indicate the presence of subsurface liquid wastes or the settling of solid wastes.

The fill pipes and access manholes to the underground gasoline storage tanks at the Site are located in the paved area near the gas pumps at the northern end of the Site. The vent pipes for these tanks are located at the eastern corner of the building, along the rear wall. The fill pipe and vent pipes for the heating oil tank are located along the southwestern wall of the building. Waste oil is introduced into the waste oil tank by means of a pipe in the service pit of the garage and goes through a pipe to the tank located along the northeastern side of the building. The access to the tank for pumping out the waste oil is by means of a small pipe with a cap flush with the pavement.

The location of the previous tanks was apparently between the current location of the underground tanks and the front of the building.

There was not any visual evidence, such as vent or fill pipes that might indicate the presence of abandoned underground fuel storage tanks, or tanks other than the ones mentioned above.

There did not appear to be any significant sources of pollution in the immediate vicinity of the Site, such as industrial properties. There are numerous auto body shops, junkyards, and a gas station in the vicinity of the Site but the only business that appears to be directly upgradient is the Speedy Muffler King which did not appear to have any underground tanks. Further to the west, the direction from which surface runoff and groundwater flow are likely to come, are mostly apartments and houses.

Due to the presence of underground fuel storage tanks, observation wells were installed at the Site and soil and groundwater samples analyzed to determine if a release had occurred or was occurring at the Site.

TEST RESULTS

The locations of the test borings and observations wells are shown in Figure 5, Sample Locations. The observation well logs are given in Appendix I.

Two observation wells were installed at locations downgradient of the oil and gasoline tanks at the Site. The downgradient locations were determined by examination of the topography in the vicinity of the Site and by the presence of ground water to the east. Well D-

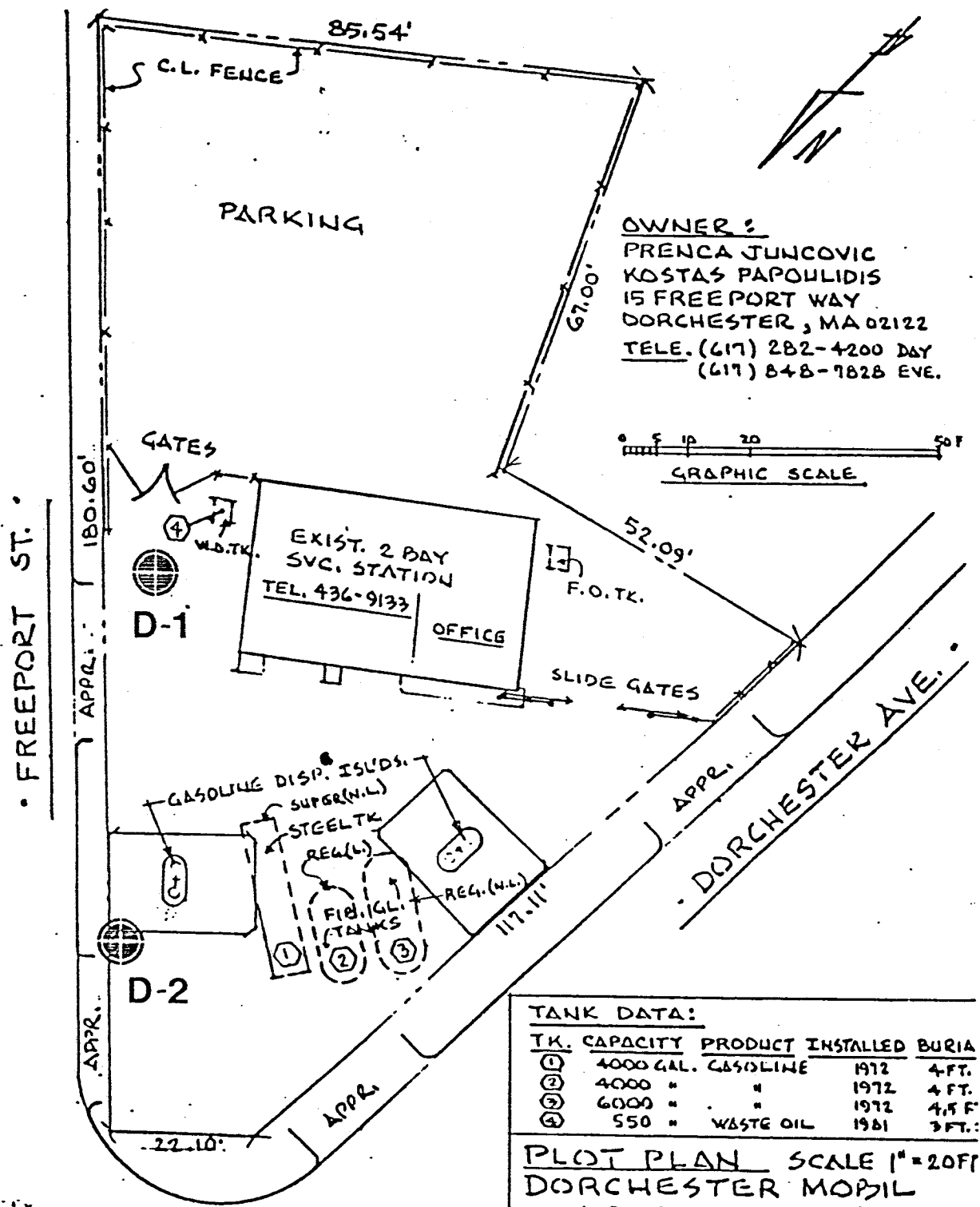


Figure 5
Sample Locations

1274 DORCHESTER AVENUE
DORCHESTER, MA

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Project EA0270, Page 7
1274 Dorchester Avenue, Dorchester, MA
August 18, 1986

1 was located near and downgradient of the waste oil tank. This well was also downgradient of all the other tanks, and of the former location of gasoline tanks. Well D-2 was located near and downgradient of the current underground gasoline tanks. After consultation with the Site owner, it was decided not to attempt an upgradient well, as the locations of the underground utility lines at the upgradient side of the property were not known.

As only two observation wells were installed, it was not possible to determine the exact groundwater flow direction and gradient.

The depth of each well and the depth to groundwater is given below.

<u>Well</u>	<u>Depth (ft)</u>	<u>Water Depth (ft)</u>
D-1	18.5	13
D-2	17	14

Several days after installation of the observation wells groundwater samples were taken from each well using individual bailers that had been cleaned with detergent, water, distilled water, and methanol. The depth to groundwater was determined and several well volumes of water were removed from each well prior to taking a sample. Samples were then taken and placed in 1 liter glass bottles and 40 ml VOA vials with teflon coated septa. The samples were then transported to an approved laboratory for analysis.

The groundwater samples were analyzed for pH, total RCRA metals, oil and grease, volatile halocarbons, and volatile aromatics. Soil samples obtained at the 15 to 16.5 foot depth from each boring were analyzed for oil and grease.

The test results are given below.

<u>Soil samples</u>	<u>D-1</u>	<u>D-2</u>
Oil and grease (mg/Kg)	1,554	30

Bewick Associates, Inc.
 Project EA0270, Page 8
 1274 Dorchester Avenue, Dorchester, MA
 August 18, 1986

<u>Groundwater samples</u>	<u>D-1</u>	<u>D-2</u>
pH	6.64	6.75
Oil and grease	1,970	ND
Total RCRA Metals (mg/L)		
Arsenic	ND	ND
Barium	0.25	0.51
Cadmium	ND	ND
Chromium	ND	ND
Lead	ND	0.08
Mercury	ND	ND
Selenium	ND	ND
Silver	ND	ND
Volatile Halocarbons (ug/L)		
1,2-Dichloroethane	3	
Chlorobenzene		20
1,4-Dichlorobenzene/ 1,3-Dichlorobenzene/ 1,2-Dichlorobenzene		45
Volatile Aromatics (ug/L)		
Benzene	3,615	658
Toluene	160	1,028
Ethylbenzene	36	455
Xylenes	526	3,052

In addition to the analytical results, approximately 1/2 inch of free product appeared in Well D-1.

The levels of oil and grease in the soil samples are below the level of 1% (10,000 mg/KG) that is used by the DEQE to indicate the necessity for removal of soil.

The level of oil and grease in the groundwater sample from well D-1 indicates possible leakage from the waste oil tank.

The pH readings of the groundwater samples are within the normal range.

The levels of the few RCRA metals detected are below the standards set for drinking water, except for lead in well D-2 (a level of 0.08 as compared to a standard of 0.05). However, the groundwater at the Site is not used as drinking water. The level of lead also exceeds the groundwater quality standards for Class I and Class II groundwater. However, it is not clear that the groundwater in the vicinity of the

Bewick Associates, Inc.
Project EA0270, Page 9
1274 Dorchester Avenue, Dorchester, MA
August 18, 1986

Site is or would be classified as Class I or II. It is likely that it would be considered Class III groundwater, in which case the level of lead would not be significant.

The levels of volatile halocarbons are likely due to small quantities of these chemicals used over time at the Site or in the vicinity of the Site. The levels do not exceed the level of 1,000 ug/L (1 ppm) that is used by the DEQE as a level that should be reported.

The levels of several of the volatile aromatics detected exceed the level of 1,000 ug/L (1 ppm) that should be reported to the DEQE. These volatile aromatics are constituents of gasoline and indicate the current or former release of gasoline. It is very likely that these levels are from a source at the Site. The long history of the Site as a gas station and the known incident of gasoline tank leakage indicate that the Site is the most likely source. It is not possible to tell from the available information whether the source of gasoline is current or from the past.

The groundwater at the Site eventually is discharged into Dorchester Bay, where the applicable standard would be the protection of saltwater aquatic life. It is not very likely that human ingestion of water or organisms will occur from Dorchester Bay. The applicable standards are given below, from the Federal Register of November 28, 1980, EPA Water Quality Criteria Documents; Availability.

Saltwater Aquatic Life Standards

	<u>Acute Toxicity (ug/L)</u>	<u>Chronic Toxicity (ug/L)</u>
Benzene	5,100	adverse effects at 700 for 168 days
Ethylbenzene	430	
Toluene	6,300	
		5,000

A comparison of these criteria indicate that the levels of toluene are not significant as a threat to acute or chronic toxicity of saltwater aquatic life. The levels of benzene do not exceed the acute toxicity standard but do exceed the chronic toxicity standard from the water in well D-1. The levels of ethylbenzene in the water from well D-2 exceed the acute toxicity standard. However, the degree of contamination is likely to decrease in the distance between the Site and Dorchester Bay so that there may not be a threat to saltwater aquatic life. The significance of the groundwater contamination can only be assessed through a review of the Site specific conditions by the DEQE.

RECOMMENDATIONS

The DEQE should be notified of the analytical results of the groundwater and soil sampling at the Site, as a release of oil or hazardous materials appears to have occurred at the Site. It would be advisable to send a copy of this Report along with any other information

Bewick Associates, Inc.
Project EA0270, Page 10
1274 Dorchester Avenue, Dorchester, MA
August 18, 1986

pertaining to the Site that the Site owner or occupant has. The DEQE will determine what further action is required at the Site.

It is likely that further action will involve leak tightness testing of all of the underground tanks at the Site. Should any tanks fail the test, they would have to be removed. Remedial cleanup activity may be required to cleanse the groundwater. This would first require an investigation to determine the source and extent of the contamination, including but not limited to installation of an upgradient well, determination of the hydraulic gradient, and further sampling.

However, the extent of work required can only be determined under the directives of the DEQE, and their determination of the significance of the levels of contaminants in the groundwater.

FINDINGS RELATIVE TO THE PRESENCE
OF OIL OR HAZARDOUS MATERIALS

There was significant evidence of oil or hazardous materials being released or threatened to be released on the Site or in the vicinity of the Site for the purposes of the Act.

The levels of volatile aromatics are above the level that should be reported to the DEQE as evidence of a release of oil or hazardous materials.

The observations in this Report were made under the conditions noted in the Report. The conclusions were based on the noted observations of surface and subsurface conditions, discussions with you and others, chemical analysis of soil and groundwater samples, and Site inspections. The Report has been prepared in accordance with accepted geotechnical and geohydrological practice. No other warranty, express or implied, is made.

It has been a pleasure to serve you. Please feel free to call if there are any questions or if we may be of further assistance.

Sincerely,

Bruce Pivetz
Project Manager

Karen M. Stash
Inspector

Bewick Associates, Inc.
Project EA0270

Bewick Associates, Inc.
Project EA0270, Page 11
1274 Dorchester Avenue, Dorchester, MA
August 18, 1986

LIST OF CONTACTS

1. Fire Prevention Bureau, Boston
2. Health Inspector, Boston
3. Assessor's Office, Boston
4. City Clerk, Boston
5. Water and Sewer Department, Boston
6. Building Department, Boston
7. DEQE, NE Regional Office, Woburn

APPENDIX I

Observation Well Logs



GUILD DRILLING CO., INC.

100 WATER STREET

EAST PROVIDENCE, R 1

TO Bewick AssociatesPROJECT NAME 1274 Dorchester AvenueREPORT SENT TO aboveSAMPLES SENT TO Taken at SiteADDRESS Watertown, Mass.LOCATION Boston, Mass.PROJ. NO. 87-126OUR JOB NO. 87-126SHEET 1 OF 1

DATE _____

HOLE NO. D-1

LINE & STA. _____

OFFSET _____

SURF. ELEV. _____

GROUND WATER OBSERVATIONS

At 12'6" after 2½ Hours
(In Well)

At _____ after _____ Hours

Type _____

Size I.D. _____

Hammer Wt. _____

Hammer Fall _____

CASING

H/S

Auger

SAMPLER

S/S

1-3/8"

140#

30"

CORE BAR

BIT

Date _____ Time _____

START 7/17/86 a.m.COMPLETE 7/17/86 p.m.

TOTAL HRS. _____

BORING FOREMAN J. PhillipsINSPECTOR R. P.

SOILS ENGR. _____

LOCATION OF BORING:

DEPTH	Casing Blows per foot	Sample Depths From - To	Type of Sample	Blows per 6" on Sampler			Moisture Density or Consist.	Strata Change Elev.	SOIL IDENTIFICATION Remarks include color, gradation, Type of soil etc. Rock-color, type, condition, hardness, Drilling time, seams and etc.	SAMPLE		
				From 0-6	6-12	To 12-18				No	Pen	Rec.
		6"-2'6"	D	13	7	6			2" Black Top			
						5		3'6"	Dark Gray Sand, Cinders, Brick & Gravel - FILL	1	24"	9"
		5'-6'6"	D	16	39	41		5'6"	Yellow Brown Silty CLAY			
								8'	Light Brown fine to coarse SAND, some fine to coarse gravel, some silt (Till)	2	18"	14"
		10'-11'6"	D	19	39	50			Weathered Purple ARGILLITE	3	18"	13"
		15'-16'6"	D	26	32	48		18'6"	Refusal - Bottom of Boring 18'6"	4	18"	-
									Installed 2" I.D., PVC, Sch. 40, .010" Slotted, Monitor Well at 18'6"			
									10' Slotted - 8'6" Riser 350 lbs. of Ottawa Sand 20 lbs. of Peltonite 1/4 Bag of Cement One small Gate Box			

GROUND SURFACE TO 18'6"USED Auger "CASING: THEN _____

Sample Type

D=Dry C=Cored W=Washed

UP=Undisturbed Piston

TP=Test Pit A=Auger V=Vane Test

UT=Undisturbed Thinwall

Proportions Used

trace 0 to 10%

little 10 to 20%

some 20 to 35%

and 35 to 50%

140 lb Wt. x 30" fall on 2" O.D. Sampler

Cohesionless Density

0-10 Loose

10-30 Med. Dense

30-50 Dense

50+ Very Dense

Cohesive Consistency

0-4 Soft

4-8 M/Stiff

8-15 Stiff

15-30 V-Stiff

30 + Hard

SUMMARY:

Earth Boring 18'6"

Rock Coring _____

Samples 4HOLE NO. D-1

APPENDIX II

Analytical Results

TOXIKON
359 ALLSTON STREET
CAMBRIDGE, MASSACHUSETTS 02139

CLIENT: Bewick Associates

TOXIKON: 86C-0992

ADDRESS: 124 Watertown Street, Suite 3A

P.O.#:

Watertown, MA 02172

DATE RECEIVED: 07/23/86

Attn: Mr. Bruce Pivetz

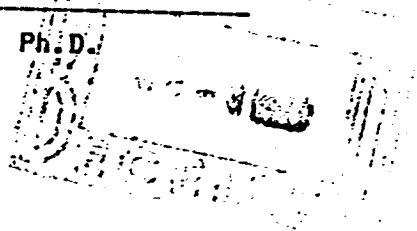
DATE REPORTED: 08/01/86

METHODOLOGIES:

1. Standard Methods for Examination of Water and Wastewater. APHA-AWWA-WACF. 15th Edition. 1980.
2. Test Methods for Evaluating Solid Waste: Physical/Chemical Methods. EPA SW-846. 1982.
3. Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater. EPA 600/4-82-057. 1982.
4. Methods for Chemical Analysis of Water and Wastes. EPA 600/4-82-055. 1982.
5. Analysis of PCB's in Transformer Fluid and Waste Oil. EPA 600/4-81-045. 1981.
6. The United States Pharmacopeia. The National Formulary. USP 21st Edition. Formulary 15th Edition. 1985.
7. Sprayed Asbestos-Containing Materials in Buildings: A Guidance Document. EPA 450/2-78-014. 1978.

Thomas F. Brennan

Thomas F. Brennan, Ph.D.
STUDY DIRECTOR



Laxman S. Desai (R.E.)

Laxman S. Desai, D.Sc.
SCIENTIFIC DIRECTOR

CERTIFICATE OF ANALYSIS

Page 2 of 5

CLIENT: Bewick Associates

ANALYSIS REQUESTED: As listed below

TOXIKON NUMBER: B6C-0992.1

DATE SAMPLED: 07/23/86

DATE REPORTED: 08/01/86

CLIENT IDENT: EA0270-01

SAMPLE LOCATION:

SAMPLE DESCRIPTION: XX water

soil oil sludge

SAMPLE CONTAINER: 2 glass

plastic 2 VOA vial

solid other:

FIELD PREP:

NUMBER OF CONTAINERS: 4

PARAMETER	RESULT	UNITS	MDL*	INST	REF**	EXTRACT	DATE ANALYZE
Oil & Grease	1,970	mg/L	2	Grav.	1		07/24/86
pH	6.64			Meter	1		07/24/86
Total RCRA Metals:							
Arsenic	ND	mg/L	0.01	HGA	4	07/29/86	08/01/86
Barium	0.25	mg/L	0.01	ICP	4	07/29/86	07/29/86
Cadmium	ND	mg/L	0.01	ICP	4	07/29/86	07/29/86
Chromium	ND	mg/L	0.01	ICP	4	07/29/86	07/29/86
Lead	ND	mg/L	0.01	ICP	4	07/29/86	07/29/86
Mercury	ND	mg/L	0.01	FAA	4	07/29/86	07/29/86
Selenium	ND	mg/L	0.01	CV*1	4	07/29/86	07/30/86
Silver	ND	mg/L	0.01	HGA	4	07/29/86	08/01/86
				ICP	4	07/29/86	07/30/86
Volatile Halocarbons*2							
1,2-Dichloro-ethane	3	ug/L	1	GC	3		07/31/86
Volatile Aromatics*3							
Benzene	3,615	ug/L	1	GC	3		07/31/86
Toluene	160	ug/L	1	GC	3		07/31/86
Ethylbenzene	36	ug/L	1	GC	3		07/31/86
Xylenes	526	ug/L	1	GC	3		07/31/86

*1 - Cold Vapor.

*2 - A list of volatile halocarbons analyzed for and their detection limit is attached.

*3 - A list of volatile aromatics analyzed for and their detection limit is attached.

*MDL - Method Detection Limits (same units as the Results)

**REF - Reference as cited on the cover (first) page of this report.

CLIENT: Bewick Associates

ANALYSIS REQUESTED: As listed below

TOXIKON NUMBER: 86C-0992.2

DATE SAMPLED: 07/23/86

DATE REPORTED: 08/01/86

CLIENT IDENT: EA0270-02

SAMPLE LOCATION:

SAMPLE DESCRIPTION: XX water soil oil sludge

solid other:

SAMPLE CONTAINER: 1 glass plastic 2 VOA vial

NUMBER OF CONTAINERS: 3

FIELD PREP:

PARAMETER	RESULT	UNITS	MDL*	INST	REF**	DATE	
						EXTRACT	ANALYZE
Oil & Grease	ND	mg/L	2	Grav.	1		07/24/86
pH	6.75			Meter	1		07/24/86
Total RCRA Metals:							
Arsenic	ND	mg/L	0.01	HGA	4	07/29/86	08/01/86
Barium	0.51	mg/L	0.01	ICP	4	07/29/86	07/29/86
Cadmium	ND	mg/L	0.01	ICP	4	07/29/86	07/29/86
Chromium	ND	mg/L	0.01	ICP	4	07/29/86	07/29/86
Lead	0.08	mg/L	0.01	FAA	4	07/29/86	07/29/86
Mercury	ND	mg/L	0.01	CV*1	4	07/29/86	07/30/86
Selenium	ND	mg/L	0.01	HGA	4	07/29/86	08/01/86
Silver	0.01	mg/L	0.01	ICP	4	07/29/86	07/30/86
Volatile Halocarbons*2							
Chlorobenzene	20	ug/L	1	GC	3		07/31/86
1,4-Dichloro- benzene/1,3-Dichloro- benzene/1,2-Dichloro- benzene	45	ug/L	1	GC	3		07/31/86
Volatile Aromatics*3							
Benzene	658	ug/L	1	GC	3		07/31/86
Toluene	1,028	ug/L	1	GC	3		07/31/86
Ethylbenzene	455	ug/L	1	GC	3		07/31/86
Xylenes	3,052	ug/L	1	GC	3		07/31/86

*1 - Cold Vapor.

*2 - A list of volatile halocarbons analyzed for and their detection limit is attached.

*3 - A list of volatile aromatics analyzed for and their detection limit is attached.

MDL - Method Detection Limits (same units as the Results)

*REF - Reference as cited on the cover (first) page of this report.

CERTIFICATE OF ANALYSIS

Page 4 of 5

CLIENT: Bewick Associates

ANALYSIS REQUESTED: As listed below

TOXIKON NUMBER: 86C-0992.3

DATE SAMPLED: 07/23/86

DATE REPORTED: 08/01/86

CLIENT IDENT: EA0270-01-4

SAMPLE LOCATION:

SAMPLE DESCRIPTION: water XX soil oil sludge

SAMPLE CONTAINER: XX glass plastic VOA vial solid other:

FIELD PREP: NUMBER OF CONTAINERS: 1

PARAMETER	RESULT	UNITS	MDL*	INST	REF**	EXTRACT	DATE ANALYZE
Oil & Grease	1,554	mg/L	2	Grav.	1		07/24/86

MDL - Method Detection Limits (same units as the Results)

*REF - Reference as cited on the cover (first) page of this report.

CERTIFICATE OF ANALYSIS

Page 5 of 5

CLIENT: Bewick Associates

ANALYSIS REQUESTED: As listed below

TOXIKON NUMBER: 86C-0992.4

DATE SAMPLED: 07/23/86

DATE REPORTED: 08/01/86

CLIENT IDENT: EA0270-02-5

SAMPLE LOCATION:

SAMPLE DESCRIPTION: water XX soil oil sludge

SAMPLE CONTAINER: XX glass plastic VOA vial solid other: NUMBER OF CONTAINERS: 1

FIELD PREP:

PARAMETER	RESULT	UNITS	MDL*	INST	REF**	EXTRACT	DATE ANALYZE
Oil & Grease	30	mg/L	2	Grav.	1		07/24/86

*MDL - Method Detection Limits (same units as the Results)

**REF - Reference as cited on the cover (first) page of this report.

VOLATILE HALOCARBONS

Parameter

Chloromethane
Bromomethane
Vinyl Chloride
Dichlorodifluoromethane
Chloroethane
Methylene Chloride
Trichlorofluoromethane
1,1-Dichloroethene
1,1-Dichloroethane
Trans-1,2-Dichloroethene
Chloroform
1,2-Dichloroethane
1,1,1-Trichloroethane
Carbon Tetrachloride
Bromodichloromethane
1,2-Dichloropropane
Trans-1,3-Dichloropropane
Trichloroethene
Cis-1,3-Dichloropropene
1,1,2-Trichloroethane
Dibromochloromethane
2-Chloroethylvinyl ether
Bromoform
1,1,2,2-Tetrachloroethane
Tetrachloroethene
Chlorobenzene
1,4-Dichlorobenzene
1,3-Dichlorobenzene
1,2-Dichlorobenzene

Method: 601

Limit of Detection: 1 ug/L