STATE OF CALIFORNIA
GEORGE DEUKMEJIAN, *Governor*

STATE WATER RESOURCES CONTROL BOARD
DIVISION OF LOANS AND GRANTS
2014 T STREET
P.O. BOX 944212
SACRAMENTO, CA 94244-2120

OCT 18 1989

Interested Parties

LUFT FIELD MANUAL REVISION

Enclosed is the October 1989 version of the LUFT Field Manual. In April 1989, Section II, the procedures portion, of the LUFT Field Manual, was extensively revised and published as a separate document. This version, October 1989, incorporates the April 1989 revision and includes additional minor changes.

These changes are as follows:

1. Page 8 - Table 1-1 - Basic Properties of BTX&E.

   Action Levels (ALs) and Maximum Contaminant Levels (MCLs) regulatory thresholds were updated.

2. Page 29 - Table 2-1 - Leaching Potential Analysis.

   Explanation was provided on why maximum allowable levels for BTX&E, at the most sensitive sites, are not applicable.

3. Page A12 - Appendix C - Sample Collection and Transport.

   Appendix C was divided into two separate appendices to separate information on sample collection and transport from analytical procedures (See Appendix D). Also, soil sampling procedures were changed to require that soil samples be kept cold (4°C) instead of frozen, and clarification on sample homogenization was provided.

4. Page A21 - Summary of Method.

   Limitations of the Headspace Method was discussed.

5. Pages A47-A56 - Appendix H - LUFT Worksheets.

   The worksheets were revised to match the April 1989 changes previously made in Section II (the field procedures) and to facilitate their use. Also, worksheet 5 was eliminated because laboratory analysis of soil samples is required, and the laboratories will provide these results.

6. Page A63 - Appendix J, the chemical composition of diesel fuels, was added.

General inquiries regarding the LUFT Field Manual should be directed to the State Board's Division of Loans and Grants. For copies of the LUFT Field Manual, please contact Joel Smith at (916) 739-4267. For questions about the general risk appraisal modeling or analytical procedures, please contact Kim Ward at (916) 739-4317. Please direct other questions about the document to Diane Edwards at (916) 739-4263.

Sincerely,

Terry Brazell

Terry Brazell
Underground Storage Tank Section
Division of Loans and Grants

Enclosure

LEAKING UNDERGROUND FUEL TANK FIELD MANUAL:

GUIDELINES FOR SITE ASSESSMENT, CLEANUP, AND UNDERGROUND STORAGE TANK CLOSURE

OCTOBER 1989

STATE OF CALIFORNIA
LEAKING UNDERGROUND FUEL TANK TASK FORCE

ACKNOWLEDGMENTS

This field manual is the product of the Leaking Underground Fuel Tank (LUFT) Task Force. The LUFT Task Force is a multiagency working group designed to develop practical guidance that field personnel can use when dealing with leaking fuel tank situations. LUFT Task Force members contributing in development of this document are:

LUFT Task Force Co-Chairmen:

David J. Leu, Ph.D.
California Department of Health Services

Michael Falkenstein
California State Water Resources Control Board

Preliminary Site Assessment Committee

Chairwoman: Cheri Eir, R.S., M.P.H.
San Diego County Health Department

Members:

Mark S. Cousineau
Orange County Health Department

Dan Tempelis
California Regional Water Quality Control Board
San Francisco Bay Region

Site Characterization Committee

Chairman: Seth J. Daugherty, R.S.
Orange County Health Care Agency

Members:

Kurt V. Berchtold, P.E.
California Regional Water Quality Control Board
Santa Ana Region

Paul W. Hadley, P.E.
California Department of Health Services

Ashok Jain
California Department of Health Services

Stephen D. Reynolds, C.E.G.
California Department of Health Services

Chuck Stultz
California Regional Water Quality Control Board
Los Angeles Region

QA/QC Laboratory Committee

Chairman: Bart Simmons
California Department of Health Services

Members:

Tom Leibold
County of Fresno

Fred Seto
California Department of Health Services

William Quan
California Department of Health Services

Dan Tempelis
California Regional Water Quality Control Board
San Francisco Bay Region

Environmental Fate Committee

Chairman: Gordon Lee Boggs
California Regional Water Quality Control Board
Central Valley Region

Members:

Wayne Hubbard
State Water Resources Control Board

Judy Tracy
California Department of Health Services

Dick Jones
California Department of Health Services

Toxicology Committee

Chairman: Jeff Wong, Ph.D.
California Department of Health Services

Members:

Judy Heath
California State Water Resources Control Board

Jon Marshack
California Regional Water Quality Control Board
Central Valley Region

Denise Kato
California Department of Health Services

Remedial Action Committee

Chairman: Robert Holub, P.E.
California Regional Water Quality Control Board
Santa Ana Region

Members:

Nestor Acedera
California Department of Health Services

Gordon Lee Boggs
California Regional Water Quality Control Board
Central Valley Region

Sylvia Marson
Orange County Health Care Agency

Lewis Pozzebon
City of Vernon

Maxine Richey
California Department of Health Services

Mike Sorensen
California Department of Health Services

Rick Walls
Los Angeles County Department of Public Works

Josh Workman
Regional Water Quality Control Board, Los Angeles Region

Final Document Committee

Chairman: Brian Zamora
Solano County Department of Environmental Health

Members:

Gordon Lee Boggs
California Regional Water Quality Control Board
Central Valley Region

Terry Brazell
California State Water Resources Control Board

Seth J. Daugherty
Orange County Health Care Agency

Diane Edwards
California State Water Resources Control Board

Cheri Eir
San Diego County Health Department

Mike Falkenstein
California State Water Resources Control Board

Charles Fischer
California State Water Resources Control Board

Paul Hadley
California Department of Health Services

Wayne Hubbard
California State Water Resources
Control Board

Peter Johnson
California Regional Water Quality
Control Board
San Francisco Bay Region

Jack S. McGurk, R.S., M.P.A.
California Department of Health
Services

George Rose
California Department of Health
Services

Ashok Jain
California Department of Health
Services

David J. Leu, Ph.D.
California Department of Health
Services

Stephen Reynolds
California Department of Health
Services

Jeff Wong
California Department of Health
Services

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SECTION 1 -- INTRODUCTION TO THE DOCUMENT

A. Aim of the Leaking Underground Fuel Tank (LUFT) Task Force

In mid-1985, the Department of Health Services (DHS) and State Water Resources Control Board (SWRCB) (State Board) formed a task force to establish procedures for determining whether an underground storage fuel tank site is clean and safe so as to protect public health and the environment. These procedures are contained in this LUFT Field Manual. The field manual was written to be consistent with all applicable provisions of statutes and regulations. The procedures it presents attempt to provide a systematic means of determining if an unauthorized release has occurred, has contaminated soil so as to pose a threat to ground water, or has directly affected ground water.

The task force decided to focus on fuel tanks because the majority of underground storage tanks in the state contain fuel. The statutory authority in California for cleanup of contaminated soil and water to protect water quality is the Porter Cologne Water Quality Control Act (Water Code). The State Board's "Statement of Policy with Respect to Maintaining High Quality of Waters in California", adopted in 1968 and reaffirmed in 1987, calls for protection of existing, and restoration of previous, high quality of the state's water. (See Appendix A, Figures III-I and III-2). This policy to protect the high quality of water, sets the goal of the removal of all contamination from the soil, surface water, and ground water affiliated with the site (e.g., to return the site to its former uncontaminated condition) where feasible. However, the LUFT Task Force recognizes that this goal is unattainable at many sites. Typically, due to the lack of established scientific and technical knowledge, along with limited resources available to the property owner and local, state, and federal governmental agencies, most cleanup actions cannot achieve a "zero" contamination level.

Since the result of most cleanup actions will yield some level of residual contamination, the following assumptions apply:

1. Cleanup of all contaminated soil and dissolved product in ground water is not always necessary to protect public health and the environment. However, it is desirable to clean up soils and ground water to the maximum extent practical to reduce any future risk.

2. All free product floating on ground water should be removed, unless neither threat to beneficial uses of

water nor danger to residents/workers from fire or explosion exists.

3. Statewide cleanup levels for contaminated soil and dissolved product are undesirable. Because conditions vary from region to region, the task force decided to develop a general approach that can be used to quickly establish site-specific levels instead of setting statewide cleanup levels.

Problems at a suspected or actual fuel leak site include: ground water and surface water pollution, soil contamination, air pollution, and fire and explosion hazards. This guidance focuses on soil contamination and ground water pollution for several reasons.

First, the effect of a fuel leak on surface water is relatively easy to assess, compared with a leak threatening ground water. Second, local air quality management districts have jurisdiction for toxic air pollution control in their regions, so statewide guidance cannot be presented. Third, other state and local agencies (i.e., Office of the State Fire Marshall, Office of Emergency Services, city and county fire departments, and hazardous materials management offices) have the expertise necessary to develop detailed guidance and procedures for dealing with fire and explosion hazards at tank closures and fuel leak sites.

B. Purpose of the LUFT Field Manual

The Leaking Underground Fuel Tank field manual is intended to provide practical guidance to regulatory agencies responsible for dealing with leaking fuel tank problems. Specifically, its purpose is to provide assistance in:

1. Investigating suspected or known leaks from underground fuel storage sites.
2. Assessing risk to human health and the environment when leaks have occurred.
3. Determining cleanup levels in soil, ground water, and air for contaminated sites.
4. Screening out sites which represent an acceptable degree of risk from further study; and
5. Taking remedial actions.

The procedures are intended to avoid unwarranted analysis while ensuring that adequate analysis is done to identify the extent of contamination problems. For example, sometimes soil contamination may be higher at greater depths than at shallower depths. If inadequate soil analysis is performed, a site may be prematurely declared clean. Later the regulatory agency may find, based on follow-up monitoring, contamination threatens water quality or public safety and that additional cleanup is required.

This field manual is the result of the best collective efforts put forth by local, regional, and state representatives. However, this field manual is a guidance document. It is offered as one approach to deal with a growing problem. The LUFT Task Force followed the approach of the California Site Mitigation Decision Tree Document (DHS, 1986) in development of this field manual. Thus, it views this manual as a practical extension of the processes contained in the Decision Tree Document.

C. Status of the LUFT Field Manual

On February 18, 1988, the State Board adopted a water quality policy for underground storage tank leak cleanup using ear-marked State and Federal funds (Pilot Program). The draft pilot program policy proposed including the LUFT field manual as part of the policy, to provide uniform procedures statewide. The consensus among public agency regulators, tank owners and private industry was that the LUFT field manual should remain a technical staff report. This consensus was based mainly on the fact that the vadose zone and ground water modeling which form the backbone of the contaminated soil analysis has not been verified for underground storage tank leak cleanups. A few regulatory agencies thought that the ground water contamination risk appraisal might be too lenient; industry representatives thought that the same cumulative concentrations might be too stringent.

A LUFT field manual evaluation team, consisting of State Board, Regional Board, and local agency representatives was formed in May, 1988, after the initial pilot program contracts were executed. The local agency members of the evaluation team were selected from among the agencies which negotiated pilot program contracts to oversee underground storage tank leak investigation and cleanup. The Regional Board members represented the same geographic area as the local agency members. The evaluation team met several times in the spring and summer of 1988 and discussed the use of the LUFT field manual in a report to the State Board on the progress of the pilot program in September, 1988. Appropriate changes were made to the LUFT field manual as a result of these meetings.

The LUFT Task Force recognizes that there are other approaches aimed at dealing with leaking fuel tanks. Therefore, if the reader is aware of and prefers the use of another approach, this document does not preclude its use. Furthermore, the LUFT Task Force is aware of the ever-changing laws and regulations which have direct impact on dealing with leaking tanks. Therefore, this field manual is viewed as a technical staff document which presents recommended but not mandatory measures and is not meant to supersede any statute or regulation.

Several Regional Water Quality Control Boards (Regional Boards) have developed procedures for fuel leak investigation cleanup. For example, the Regional Boards covering the North Coast, San Francisco Bay and the Central Valley have collaborated on a set of guidelines to ensure consistent site investigation and monitoring in their regions. These guidelines, which also have not been verified, differ from the LUFT field manual primarily because they were intended for shallow ground water areas. The LUFT field manual was designed to be broader in its application to site investigation and monitoring because of its statewide scope. The responsible Regional Board is to be consulted on all cases where ground water is directly affected, and any soil contamination cases that will require Regional Board sign-off.

D. Agency Jurisdiction

Staff working on closures or leak cleanups should be aware that other agencies may have overlapping jurisdiction for aspects of tank inspection, closure, and cleanup. Some of the agencies which may become involved include: the city, the local fire department, the county, the Air Quality Management District (AQMD), the Regional Board, the State Board, and DHS.

Responsibilities for water quality control and hazardous materials management related to the underground storage tank program include the following. The State Board and Regional Boards are responsible for protecting beneficial uses of water. Beneficial uses, which can be actual or potential, include municipal water supply, recreation, industrial water supply, and agricultural water supply. The Department of Health Services is responsible for setting standards for drinking water supplies and regulating hazardous waste management.

Local health departments often include an environmental health, occupational health, or hazardous materials management office which regulates underground tanks, and may supervise soil and sometimes ground water cleanup. City and county fire departments and hazardous materials management offices also regulate underground tanks, supervise some cleanup, and have responsibility for fire and explosion prevention/control at leaking fuel tank sites. All 58 California counties (by law) and 42 cities (by choice) are responsible for implementing the underground tank law.

Thus, local agencies usually have primary responsibility for inspection, leak detection, closure, and fire/public safety.

In many instances, they also supervise soil and, to a more limited extent, ground water pollution cleanup at fuel tank sites. The regional boards have the authority to supervise fuel tank cleanup at sites referred by local agencies and to signoff on cleanup cases where water quality is affected or threatened. DHS administers the state and federal superfunds for cleanup of major hazardous waste sites, some of which may include leaking fuel tank cases. Thus, the Regional Board or DHS may be responsible for approving cleanup plans for significant spills affecting water quality. The local AQMDs may require an air discharge permit or variance for volatile emissions, and DHS may require a permit to use on-site treatment technology.

E. Organization of the LUFT Field Manual

For clarity and ease of use, this document has been divided into three color-coded sections. The blue section is an introduction which presents some basic information that influenced the development of the procedures cited in the field manual. The white section is the working field manual. This is the section that should be used on a day-to-day basis by field personnel when dealing with leaking fuel tank situations. The yellow section contains technical appendices which offer information that the user may need while in the field.

F. Fuel Products Covered by LUFT Field Manual

This field manual deals with gasoline and diesel fuel products only. These products account for the vast majority of all reported underground storage tank leaks in California, and therefore are of major importance. Other hydrocarbon-based materials, such as waste oil or solvents, may be dealt with in future supplements to these guidelines.

1. Gasoline

Gasoline is a mixture of over 200 petroleum-derived chemicals plus a few synthetic products that are added to improve fuel performance (see Appendix I). The majority of gasoline components range from C4 to C12 hydrocarbons. Analysis of gasoline components is usually limited to detection of benzene, toluene, xylene, and ethylbenzene (BTX&E) because: (1) they are readily adaptable to gas chromatographic detection, (2) they pose a serious threat to human health (benzene is a carcinogen), (3) they have the potential to move through soil and contaminate ground water, and (4) their vapors are highly flammable and explosive.

Some basic information on these four compounds is presented in Table 1-1 (page 8).

In addition to BTX&E, analysis for total petroleum hydrocarbons (TPH) is commonly conducted. This analysis detects aliphatic (straight-chain hydrocarbons) and aromatic constituents (hydrocarbons made up of one or more benzene rings) contained in fuel. Detection is reported as the sum total of all hydrocarbons in the sample, rather than as individual chemicals. Because the lighter fractions (such as BTX&E) are more mobile, they can migrate or dissipate away from the main body of contamination. Initial analysis may show low detectable concentrations, even though significant concentrations exist at lower depths. Less mobile hydrocarbons, such as those detected in TPH analysis, may give a more accurate indication of the actual contamination. For these reasons, soils are analyzed for both BTX&E and TPH as indicators of contamination.

The underground storage tank regulations for tank closure [23 California Code of Regulations (CCR), Section 2672(d)(3)] call for an analysis of constituents of previously stored hazardous substances and their breakdown and transformation products. The LUFT Task Force believes that fuels have been adequately studied to justify limiting the analysis to BTX&E and TPH, except where site-specific conditions warrant analysis of additional constituents, such as ethylene dibromide (EDB) and organic lead.

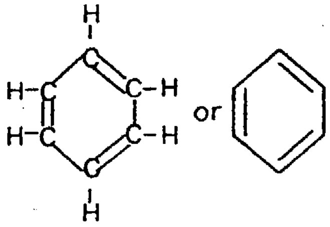
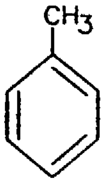
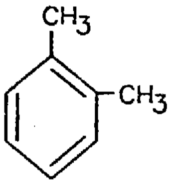
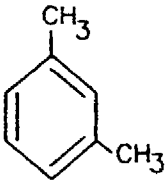
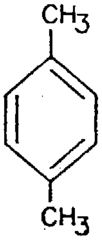
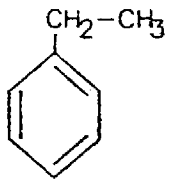
It is recognized that other groups or individuals have also used EDB and/or organic lead as indicators of leaded gasoline leaks. The LUFT Task Force recommends caution in the use of such indicators. EDB has been so widely used in rural areas that its detection may not be due to a gasoline leak. When it has been found affiliated with a gasoline leak, its levels often have been so low as to be of questionable validity. Analysis for EDB is only recommended where site-specific conditions warrant this additional step.

In the case of organic lead, one must recognize that many laboratories only analyze for total lead and cannot readily distinguish between organic and inorganic lead. It has been the experience of many LUFT Task Force members that when they request organic lead analysis, the results received are expressed in terms of total lead content (including inorganic lead). Because inorganic lead is native to many California soils, this use of total lead analysis has led to false readings of organic lead being reported. Reliable measures of organic lead pollution can only be obtained where background total lead concentrations are known or can be analyzed from a clean area of the site or immediately off-site. However, organic lead is extremely toxic and should be surveyed where significant leaded gasoline leaks have occurred or where the investigator feels that there may be potential danger of exposure (e.g., site next to a school yard).

2. Diesel Fuel Products

Diesel fuel consists primarily of straight-chain hydrocarbons (alkenes and alkanes) ranging in length from C10 to C23 (see Appendix J). Carbon chain lengths of C16 and C17 predominate in the mixture, whose composition approximates a bell-shaped curve with C16 and C17 as the mean. Diesel fuel may also contain some aromatic constituents (depending on the source and refining process), including benzene. But these are minor components usually accounting for less than 0.1 percent of the total product.

Table 1-1
Basic Properties of BTX&E

Compound	Chemical Structure	Water Solubility mg/l	Weight Percent In Gasoline	Toxic Effects	ppb
Benzene		1780	0.12-3.50	carcinogen (leukemogen)	0.7 *
Toluene		535	2.73-21.80	neurotoxicity	100*
Xylene	 ortho  meta  para	175	0.68-2.86 (ortho) 1.77-3.87 (meta) 0.77-1.58 (para).	neurotoxicity	1,750**
Ethylbenzene		152	0.36-2.86	neurotoxity	680**

* Department of Health Services Action Level (AL).

** Maximum Contaminant Level (MCL) Regulatory Thresholds. (Section 6444.5, Article 5.5, Division 4, Title 22 CCR.)

SECTION II -- THE LUFT FIELD MANUAL

A. Introduction

This section contains the day-to-day working portion of the field manual. The reader is referred to Section I (the blue pages) for a brief description of the limits and precepts behind the field manual. Section III (the yellow pages) contains appendices which may be useful when in the field.

This document presents a phased approach to leaking underground fuel tank site investigation and cleanup that is tailored to the severity of each specific site. To facilitate a phased approach, the field manual includes a categorization of tank sites. (In this document the word "cleanup" includes various mitigation efforts, such as on-site treatment, containment, and off-site disposal of contaminants.) The categorization will also guide regulatory agencies in deciding how much evaluation of a site is necessary to determine if the site requires cleanup and to derive an appropriate cleanup level. The regulatory agency makes the final decision on how the site investigation will proceed and how the results of any analysis will be interpreted.

The field manual consists of four decision tree flow charts (Figures II-1, II-2, II-3, and II-4), explanatory material related to each figure, and instructions for using each decision tree flow chart. Every step in each flowchart is numbered for easy cross-referencing. To facilitate following the instructions, a series of worksheets was developed. These worksheets are contained in Appendix G.

B. Selection of Site Category

Introduction

Figure II-1 (page 11) presents a decision tree flow chart of the site designation process.

For the purpose of this field manual, tank sites are classified into one of three categories:

Category 1:	No evidence of significant soil contamination or any ground water pollution.
Category 2:	Known soil contamination.
Category 3:	Known or suspected ground water pollution, or areas with shallow ground water (less than 5 feet below the tank).

The site selection process consists of a series of information gathering steps that will yield an initial designation for a site. Sites where tanks are being closed for reasons other than evidence of a significant leak may fall into the first category. Sites where tanks or product lines have failed to pass a precision test, show discrepancies in monitoring records, or show visual evidence of leakage may fall into the second category. Sites where tanks or piping have shown a significant loss of product, especially in areas of high ground water, may fall directly into the third category. Depending on the course of the investigation, a site may be reclassified from one category to another. The process always moves from less complex to more complex analysis if the field investigation shows, or field personnel suspect, that more serious contamination has occurred than was originally anticipated.

1. Establish the Basis for LUFT Investigation

Explanation

Reasons for initiating an investigation for a leaking underground fuel tank usually fall into one of two general categories:

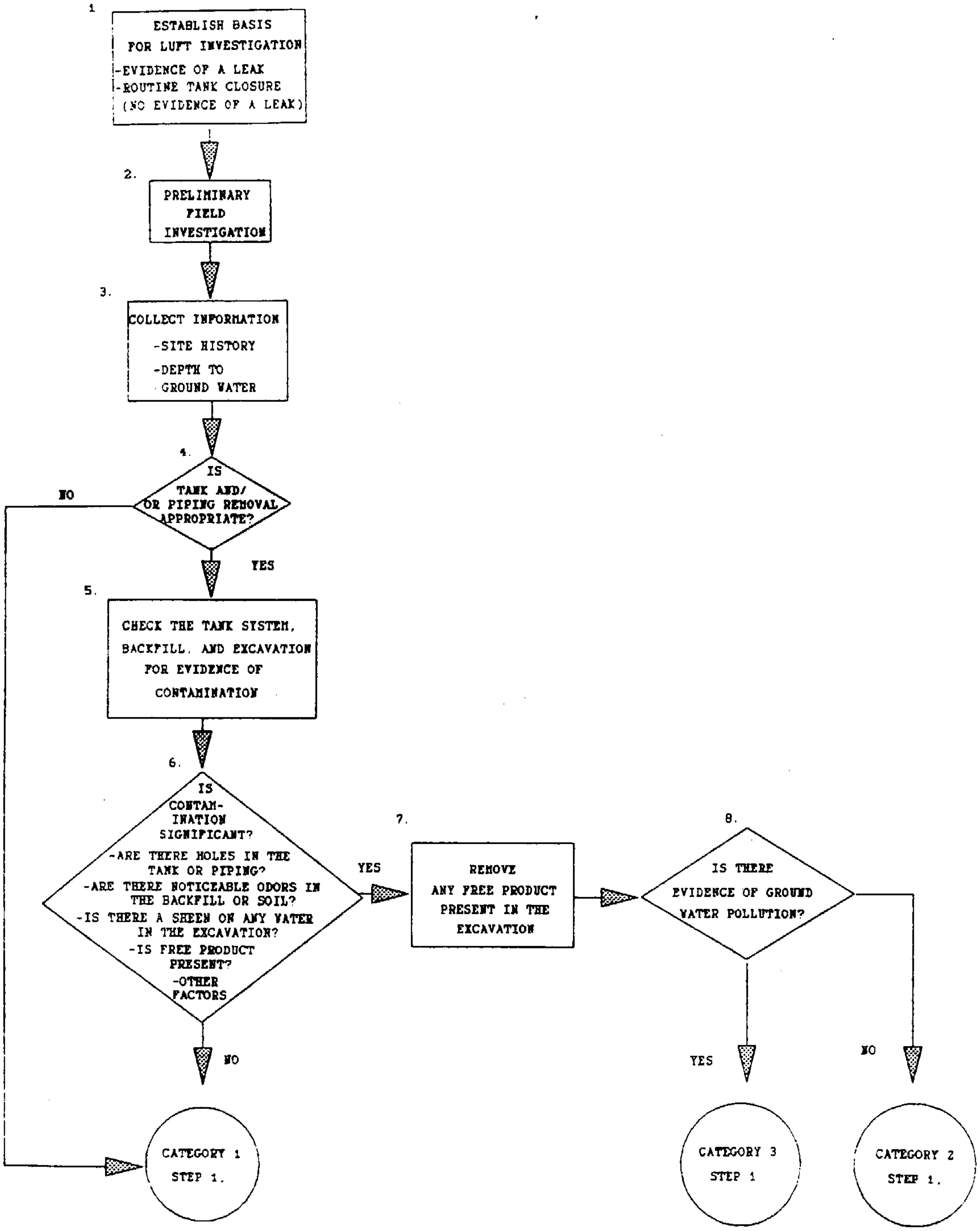
(a) Evidence of a leak

Leaking underground fuel tanks are discovered in a variety of ways. Some of the most common are:

(i) Contamination observed or detected during routine field inspection of tank.

FIGURE II - 1

SELECTION OF SITE CATEGORY



(ii) Contamination observed or detected during routine tank closure or replacement.

(iii) Confirmed failed precision test and/or inventory discrepancies reported by tank owner/operator.

(iv) Flammable liquid and/or vapors detected on-site or off-site (e.g., migrating from suspected source into sanitary sewer, utility vault, or open excavation).

(v) Reports of an odor problem or other nuisance conditions from unknown or suspected sources.

(b) Routine tank closures where no evidence of a leak exists

Instructions

The extent of site history and preliminary field investigations should vary depending upon the reason for initiating the LUFT investigation. For example, where there is no evidence of a leak, some elements may not need to be addressed.

2. Preliminary Field Investigation

Once the investigation has been initiated for any of the reasons listed in the previous step, the following assessment should be performed by the tank owner, his/her contractor, or by the regulatory agency during the first field visit. Worksheets for Site History, Site Drawing and Vapor Migration are provided in Appendix H to assist in making the assessment. Some of the questions that should be asked are:

(a) If there is evidence of a leak, has the fire department been consulted to determine whether or not a fire hazard or explosive situation exists?

(b) Safety: An immediate concern at any leaking underground fuel tank site is an evaluation of any present or potential threat to public safety. Are vapor exposures significant to workers in neighboring buildings through windows, ventilation systems, or subsurface electrical vaults? Is ponded product finding its way into sewer lines and posing a potential explosion hazard? These are a few of the questions regarding site health and safety hazards which should be asked and answered in the earliest stages of problem identification. If they exist, sources of possible hazardous vapors should be identified and eliminated.

(c) If a leak has occurred, has it been abated?

(d) Is this site near sensitive land uses (i.e., next to homes or a school)?

(e) Are records and/or informal sources of information available at the site?

(f) Are existing pathways of concern apparent (i.e., sewer laterals, utility conduits, nearby wells, surface runoff)?

(g) Are temporary on-site waste storage procedures being conducted in a safe and secure manner?

(h) Make any other observations which seem pertinent during the initial site survey.

3. Collect Information on Site History and Depth to Ground Water

Explanation

Once any immediate health or safety issues have been assessed and abated, the field personnel should begin collecting information for site categorization. This phase of the investigation focuses on site history and depth to ground water information. The site history includes fact-finding, research, and background review which field personnel will want to do, in addition to the field work.

Common elements of site history are the review of the permit application and any information obtained pertaining to the site. Specifically, information regarding the following areas may be helpful:

(a) Inventory records.

(b) Precision testing records.

(c) Repair records.

(d) Records of any water pump-outs from the tank(s).

(e) Available environmental monitoring information.

(f) Neighborhood complaints.

(g) Fire department observations (also RWQCB, AQMD, Environmental Health Department, etc.).

(h) Previous ownership and description of businesses/uses at the site.

(i) Current operator/owner data including type of business and associated activities that take place at the site.

(j) Current equipment installation and maintenance data including number and capacity of operating tanks.

(k) Current leak detection system(s) functioning.

(l) Interviews with employees.

Information from well records or boring logs approved by the regulatory agency can be helpful in determining the depth to ground water. Information on ground water can also be found at the State Department of Water Resources and irrigation district agencies.

Instructions

See Appendix H for the site history worksheets.

4. Is Tank and/or Piping Removal Appropriate?

Explanation

Tank and/or piping removal may be appropriate depending on evidence of leakage and site features. If there is evidence of contamination, it is generally advisable to remove the tank when feasible. The underground storage tank regulations (23 CCR, Subchapter 16, Article 7) allow closure of tanks in place. The regulations apply to tank closures in areas where the local underground storage tank permitting agency is subject to all provisions of state law and regulations. These regulations, which are available from the State Board, are optional in other localities, although many of these exempt local agencies have adopted the State Board regulations in part under local ordinances.

Many local ordinances prohibit closure in place because of the possibility of overlooking contamination or complicating future development at the site. These local ordinances generally allow in-place closure only when the tank is inaccessible (e.g., underneath a structure) or when tank removal would damage or weaken nearby structures. For tank closure, the state regulations [23 CCR, Sec 2672(c)(2)] requires removal of piping unless this would damage structures or pipes in a common trench.

Instructions

If tank and/or piping removal is appropriate, proceed to Step 5. If tank and/or piping removal is not appropriate, begin the Category 1 investigation (page 19).

5. Check the Tank System, Backfill, and Excavation for Evidence of Contamination

Explanation

To determine if the site is contaminated, a thorough examination of the tank system, backfill and excavation is required, after the tank (and piping, if appropriate) is removed. The following points should be considered when conducting the inspection:

(a) The tank and associated piping are to be removed by certified personnel. Inspection and oversight will be conducted by appropriate Local Implementing Agency (LIA) staff (or their designee).

(b) A field hydrocarbon vapor analyzer may provide qualitative evidence of fuel hydrocarbons in the excavated material. (See page 22 and Appendix B for a discussion of the value and limitation of this type of instrument.)

(c) Water in the excavation may be indicative of either a shallow aquifer, local precipitation that has accumulated, or seepage from local irrigation. It is necessary to determine both the source and degree of contamination of the water. First, collect one grab sample representative of the water found in the excavation. It is necessary to analyze this water to determine if it requires disposal as hazardous waste. This water should be qualitatively analyzed for TPH using the DHS method described in Appendix D.

(d) If possible, pump the excavation dry. Retain the water in appropriate containers for proper disposal later. If the water does not return to the pit within 24 hours, its source may be considered not to be ground water. If the water returns within 24 hours or the tank pit cannot be pumped dry, then the source of the water should be considered ground water.

Instructions

The inspection should include the following:

(a) Check the tank and piping for holes.

(b) Check the tank system for loose or improper connections or other defects.

(c) Check the backfill or native soil for visible stains or residual odors.

(d) Determine if there is any free product floating on top of the water or soil surface. If free product is present, a stop work order should be initiated, and abatement procedures implemented (see step 7, page 17).

(e) Check to see if there is water in the excavation.

(f) Check to see if there is a sheen on any water in the excavation.

The information obtained from the inspection covered under this step should be used in the remaining steps (6,7, and 8). Procedures contained in those steps may be carried out concurrently with the inspection. However, if free product is present in the excavation, it must be removed before any further investigation or analytical work can occur.

6. Is Contamination Significant?

Explanation

Five questions are presented in this step to help determine if contamination is "significant" based on the evidence of contamination collected in the previous inspection (step 5). A single "yes" answer in some cases may justify a determination that contamination is significant. For example, free product in the excavation represents significant contamination and a site with this condition should not be investigated using Category 1 analysis. Similarly, if there is water in the excavation which is determined to come from ground water seepage, this condition will require a Category 3 analysis. In other cases, however, it may not be appropriate to make a determination based solely on a single "yes" answer. For example, although holes in the tank may be indicative of a leak, in some cases holes may have been created during tank removal. The investigator should weigh the relevance of the answers to these questions in determining if contamination is significant.

Instructions

Answer the following questions to determine if contamination is significant:

(a) Are there holes in the tank or piping?

(b) Are there noticeable odors in the backfill or soil? (If the odors are strong enough to be recognized as fuel odors or to register on a field vapor analyzer, the answer should be "yes".)

(c) Is free product present? (See glossary for definition of free product.)

(d) Is there a sheen on any water in the excavation (indicating that some fuel may be present on the water surface)?

(e) Are there any factors which could allow significant contamination to go undetected in excavation samples, e.g., abandoned site, former tank/piping location unknown or geological features which could mask historical leaks (sand layers)?

If contamination is determined to be significant, proceed to Step 7, "Remove Any Free Product in the Excavation". If contamination is determined not to be significant, proceed to Category 1 "No Evidence of Significant Soil Contamination or any Ground Water Pollution".

7. Remove Any Free Product in the Excavation

Free product lying in the excavation will always pose health or safety risks. Therefore, it must be removed as soon as possible. Remedial action usually consists of withdrawing the free product by suction methods. However, if the free product was not the result of spillage and was initially floating on ground water in the excavation, it will usually return when the ground water seeps back in. An engineered interim remedial cleanup plan needs to be developed for situations involving seepage of ground water and free product.

8. Is there Evidence of Ground Water Pollution?

Explanation

At this point, contamination has been determined to be significant. Because of this contamination, ground water will be polluted if it seeps into the excavation. However, the investigator should be able to distinguish ground water from surface runoff or rainwater in the excavation, based on pumping it (See Step 5, page 15).

If information gathered during preliminary field investigation or examination of site history indicates the presence of ground water pollution, it is appropriate to assume that the source of ground water pollution is the site being investigated.

Instructions

If ground water is determined to be polluted, proceed to Category 3 "Known or Suspected Ground Water Pollution or Areas With Shallow Ground Water". If ground water is determined not to be polluted, proceed to Category 2 "Known Soil Contamination".

C. Category 1: No Evidence of Significant Soil Contamination or Any Ground Water Pollution

1. Collect Soil Samples

A decision tree flow chart outlining Category 1 is presented in Figure II-2 (page 20).

Explanation

At this step in the Category 1 site investigation, the tank may or may not have been removed and there is no evidence of significant contamination. If the tank is scheduled for routine closure in place, this evidence may consist only of information on site history and possibly on depth to ground water. Where evidence of a leak exists, a preliminary field investigation has been conducted, in addition to gathering information on site history. If the tank was removed, a visual inspection of the tank has occurred and the excavation has been checked for odors and sheen on any water. There may be water in the excavation from surface runoff or infiltration. This water should have been analyzed for TPH under Step 5 of the Selection of Site Category flow chart, page 15. Based on available information, there is no ground water in the excavation.

At this stage all evidence indicates that no significant spillage or leakage has occurred at the site. To confirm this supposition, the field investigator should take soil samples for laboratory analysis of TPH and BTX&E. The regulatory agency should either supervise or approve sampling locations and collection and preservation techniques. Reliable laboratory results depend on good field sampling and sample handling practices. See Appendix C for guidance on sample collection and preservation. Samples must be delivered to a DHS-certified hazardous materials testing laboratory for analysis. An address for obtaining the name and address of certified labs in different parts of California is listed in Appendix D.

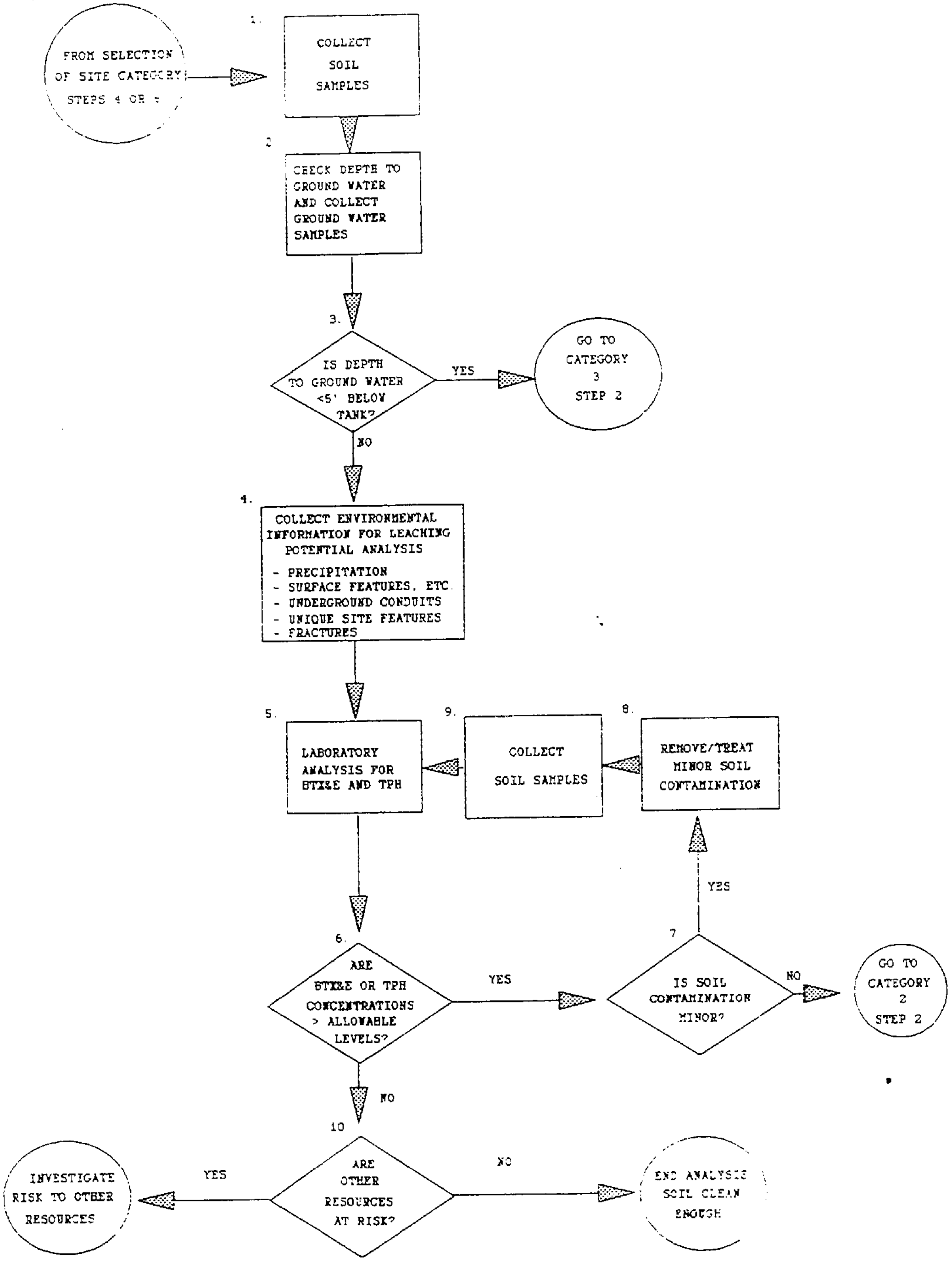
Instructions

(a) Location and Number of Samples

Collecting soil samples from the excavation requires keeping both safety and accuracy in mind. The most accurate samples are those collected by causing the least disturbance of soil and thus avoiding loss of volatile constituents. Appendix C contains information on sample collection.

FIGURE 11-2
CATEGORY I - SITE INVESTIGATION

NO EVIDENCE OF SIGNIFICANT SOIL CONTAMINATION OR ANY GROUND WATER POLLUTION



The best place to take undisturbed samples is from the bottom of the excavation. To ensure the accuracy of the samples, they should be taken <u>from</u> the excavation, as opposed to <u>next to</u> the excavation. At some tank sites, it may be safe to enter the hole. At these sites, samples may be collected with a corer or trowel. However, in most cases, samples can only be safely obtained from a backhoe bucket. Commercial or custom-made hand-corer extensions can be used to take samples from minimally disturbed soil.

Soil samples should be taken one to two feet below the bottom of the excavation at suspected worst-case locations. Worst-case locations include: (1) areas around the tank and piping, or where they used to be, that record the highest readings with vapor monitoring instruments; (2) areas around the tank and piping, or where they used to be, that look stained or discolored; (3) the lowest point of the tank, if this can be readily determined; (4) where the tank meets the piping; and (5) beneath the fill lines. At least two soil samples, one from either end of the tank, should be taken for each tank suspected of leaking at a site. For tank closure, the State regulations [23 CCR, Sec. 2672(d)(1)] require one soil sample for every 20 linear feet of piping trench. Soil samples should be collected as soon as possible after removal of the tank. All preparations for soil sampling should be made before tank removal, where feasible.

When the tank is closed in place and it is feasible to take soil samples, it is preferable to take them from beneath the center or the lowest point of the tank. Samples from beneath the center of the tank can be obtained by using a slant boring rig. If slant boring is infeasible and the top of the tank can be exposed, two samples should be taken -- one where the tank and the piping meet, and the other at the opposite end of the tank -- unless exposing the top of the tank reveals other locations where leakage appears to be likely.

(b) Chain of Custody Procedures

Chain of custody procedures should be followed to ensure the validity of the samples in the event of a legal challenge. Chain of custody can be summarized as knowing who has the sample and where it has been from the time of collection until the laboratory analyzes it. If the chain of custody is broken, i.e., if someone leaves the sample unattended, then tampering or unacceptable handling can be alleged. See Appendix D for an example of a chain of custody form.

(c) Optional Site Screening Using Hydrocarbon Vapor (HV) Analysis.

Field Hydrocarbon Vapor (soil gas) analyzers can be used as screening tools to determine sampling locations. This procedure is not included as a distinct step because it is optional. The types of portable instruments that are most appropriate for field HV detection include: flame ionization detectors (FIDs), photoionization detectors (PIDs), combustible gas meters with a numerical scale only, combustible gas meters with a colorimetric indicator, and gas chromatographs (GCs). The portable GC is the most accurate of these instruments, but it is also the most expensive and requires extensive training to use. These instruments, as well as variables that affect measurements, are discussed in Appendix B.

Field hydrocarbon vapor analyzers should not be used to confirm the absence of soil contamination because the results that they yield have been found to correlate poorly to laboratory-derived results. Available information from field work, where combustible gas meters and laboratory analysis have both been used, shows a poor correlation between field and laboratory measurements. Experience has suggested that it is common to get low field values and high laboratory values in situations where the spill is relatively old and volatile components have had time to degrade or migrate away from the site. It has also been found that soils contaminated predominantly by migrating vapors, rather than liquids, will show higher field values than laboratory values upon analysis.

Another limitation of field hydrocarbon vapor analyzers is that they should not be used at diesel tank closures. While diesel fuel products do contain some volatile organic compounds, their composition percentage as compared to gasoline is rather limited. The Field Hydrocarbon Vapor test is viewed as lacking the needed sensitivity to be used as a screening tool for diesel spills or leaks.

2. Check Depth to Ground Water (and Collect Ground Water Samples)

Explanation

If existing information on depth to ground water cannot confirm that the seasonal high ground water is more than 5 feet below the tank (or bottom of the excavation), it will be necessary to check for shallow ground water. It is important to determine if ground water is shallow, because the risk of ground water pollution is high even if no soil contamination is detected. Also, the leaching potential analysis and the general risk appraisal, presented in Categories 1 and 2 respectively, cannot be used when ground water is less than 5 feet below the tank (or excavation).

Instructions

While collecting soil samples, check for ground water down to 5 feet below the tank (or excavation) using a backhoe, Shelby tube, or drill rig, if feasible. A visual inspection for indicators of the seasonal high ground water table should also be made particularly when the investigation is conducted in the drier months. The inspection should examine the soil strata encountered in the excavation and below the excavation. The presence of soil mottling, reddish iron oxide stains, greying, clay skins and other properties of soil can be used by a professional engineering geologist or a registered geologist to help determine the seasonal high ground water table.

In the course of determining whether the seasonal high ground water is more than 5 feet below the tank (or excavation), ground water may be encountered. If this occurs, collect one or more ground water samples after allowing several hours for equilibration. The samples should be submitted for laboratory analysis (Category 1 Step 5, page 25 or Category 3, Step 2, page 51).

Ground water samples should be quantitatively analyzed using EPA Method 602. Water sample results should be reported in parts per billion, i.e, in micrograms of fuel constituents per liter of water ($\mu g/l$). Appendix D explains these analytical procedures and how to interpret results.

3. Is Depth to Ground Water Less Than 5 Feet Below the Tank?

Explanation

Ground water table elevations usually fluctuate seasonally. This seasonal fluctuation may be more extreme in some years than others. Ground water that lies less than 5 feet below the tank (or bottom of the excavation) may come into direct contact with the contamination. Under these circumstances, Category 1 or Category 2 investigations are not appropriate and Category 3 should be used.

Instructions

If ground water is less than 5 feet below the tank (or excavation), proceed to Category 3, Step 2 for laboratory analysis of soil and/or water samples and consultation with the Regional Board to determine required actions. If ground water is greater than 5 feet below the tank (or excavation), continue the Category 1 site investigation.

4. Collect Environmental Information For Leaching Potential Analysis

Explanation

Existing data on precipitation and site features should also be gathered at this time and evaluated for use. Existing information on the depth to ground water should already have been collected and will be used in the leaching potential analysis. The minimum seasonal depth, i.e., highest ground water, should always be used in calculating distance from surface to ground water.

Instructions

Collect the following information on the site environment:

(a) the topography of the site and surrounding area;

(b) the presence of man-made or natural objects in the subsurface environment;

(c) the presence of highly permeable soil layers in the subsurface environment (e.g., sand and or gravel lens) and

(d) the presence of faults, fractures or joints (common in areas of underlying rock) in the subsurface environment.

Much of this information can be obtained from U.S.G.S. topographical maps and from U.S. Mines and Geology geological maps. The information can also be located in Soil Conservation Survey reports, joint University-County reports, and other sources. A site inspection can also be useful in collecting some of this information.

Determine the average annual precipitation (in inches rounding to the nearest tenth) for the general area in which the site is located. Precipitation rates can usually be obtained from the National Oceanic and Atmospheric Administration (NOAA) or local airports. Other possible sources of precipitation data are the Department of Water Resources, county agricultural commissioner, and county extension service. <u>It is the position of the task force that no allowance be made for the effect of any type of paving or building on infiltration of rainfall.</u> Although paving may result in temporary reduction of rainfall infiltration, breaks, cracks, uneven grades, leaking water pipes, etc., may actually increase infiltration.

5. Laboratory Analyses for BTX&E And TPH

Explanation

The following points about chemical analyses for fuel constituents should be kept in mind. First, benzene is the primary fuel constituent of concern, because it is a known human carcinogen. Second, benzene is very volatile and has a relatively high water solubility. These properties give benzene a strong tendency to either escape the subsurface environment by evaporating from the surface or migrate to greater depths during the leaching process. Therefore, the absence of benzene in soil at an excavation does not rule out the presence of the other less mobile fuel constituents. Furthermore, the absence of benzene in samples collected beneath a tank does not preclude its presence at greater depth.

Benzene, toluene, xylene and ethylbenzene all have established drinking water action levels (see Table 1-1, page 8 of the blue section). In addition, these constituents are all more mobile, to varying degrees, than the remaining constituents in gasoline. It is essential, therefore, to include a specific analysis for all of these constituents.

Because BTX&E are more mobile than the remaining constituents, an analysis of BTX&E alone, without characterizing the entire contaminated soil profile, cannot be used to quantify the amount of fuel contamination in the soil. An analysis of Total Petroleum Hydrocarbons (TPH) should be included to check for other less mobile fuel constituents that could be adsorbed onto the soil in higher concentrations. This additional analysis may serve as a check for the possibility that BTX&E have migrated to deeper depths.

While TPH levels generally indicate fuel contamination, certain sites may have natural or historical use features (e.g., former oil field), that make interpretation difficult. Also, reported soil concentrations of volatile organic chemicals may vary with soil type. Complete recovery of volatiles during sample collection is difficult in sandy soils, due to losses from evaporation. Also, adsorption may limit extraction efficiency in clayey soils.

In the leaching potential analysis that follows, the recommended detection limit for benzene, toluene, xylene, and ethylbenzene is 0.3 ppm for each compound. This 0.3 ppm value for BTX&E was determined to be a detection level that most laboratories can routinely achieve, based on a survey conducted by DHS. Most laboratories today can routinely detect well under this limit and the current trend indicates that detection limits will continue to drop in the future.

Whereas the 0.3 ppm value is a readily obtainable detection limit, Appendix D presents minimum detection limits set by DHS for optimal sample conditions, i.e. minimal organic interference and soil matrix effect. Soils with high organic and/or clay materials are more difficult to analyze than those with minimal amounts of these materials. Further, background interferences that are coextracted from a sample may elevate chromatographic baselines or minimize resolution, significantly reducing detection capability.

Although 0.3 ppm is the recommended detection limit, regulatory agencies may use a lower detection limit based on specific evidence that a particular laboratory can consistently achieve the lower detection limit for field samples.

Instructions

Soil samples should be quantitatively analyzed for BTX&E using EPA Method 8020. Soil samples should also be quantitatively analyzed for TPH using the DHS method described in Appendix C. All results should be reported in parts per million, either milligrams of fuel constituents per kilogram of soil (mg/kg) or in micrograms of fuel constituents per gram of soil (µg/g). Appendix C explains these analytical procedures and how to interpret results.

6. Do BTX&E or TPH Concentrations Exceed Allowable Levels?

Explanation

To estimate the levels of BTX&E and TPH that can be safely left in place or used as cleanup values without threatening water quality, a leaching potential analysis was developed (see Table 2-1, page 29). This leaching potential analysis is based on modeling results and the best professional judgment of experienced field staff.

The leaching potential analysis begins with four characteristics that heavily influence downward migration of fuel constituents: depth to ground water, subsurface fractures, precipitation, and man-made conduits. A fifth characteristic -- unique site features -- was added to account for special local conditions. Next, the analysis requires scoring each characteristic on a scale of low (10 pts.), medium (9 pts.) or high (5 pts.) potential for leaching. Finally, the leaching potential analysis sets allowable levels at three degrees of sensitivity, expressed in terms of ppm of BTX&E and TPH, that can be left in the soil without degrading ground water. If the concentration of benzene, toluene, xylene, ethylbenzene, or TPH is above the allowable level, then the site investigation should proceed to the General Risk Appraisal (page 37).

No BTX&E level is presented for the most sensitive sites (e.g., 40 pts. or less). BTX&E levels should be below detection limits if TPH levels are 10 ppm or lower, therefore no BTX&E levels are presented to avoid the impression that detection limits are recommended as cleanup levels. Thus, the leaching potential analysis for sensitive sites relies exclusively on TPH values. If BTX or E are detectable, even though TPH is below 10 ppm, the site investigation should proceed to the General Risk Appraisal.

These numbers for allowable residual soil contamination represent a conservative approach to setting limits, based on field experience at different leak sites and modeling results. Minimum ground water depths and maximum precipitation amounts, from conditions listed in Table 2-1 (page 29), were used to derive acceptable levels of BTX&E from the General Risk Appraisal tables. The General Risk Appraisal uses DHS Action Levels for water (Table 1-1 page 8) to determine acceptable levels for soil. Corresponding acceptable TPH levels were approximated by using the acceptable BTX&E levels divided by their percent composition in gasoline. The highest calculated TPH level was used and rounded off to intervals of 10, 100 and 1000, gasoline and intervals of 100, 1000, and 10,000 for diesel in Table 2-1.

Table 2-1 provides a simplified way to assess the possible threat to ground water from contaminated soils. Alternate cleanup levels, based on additional site-specific analysis, would supersede the initial allowable levels.

Instructions

To use Table 2-1, find the description of the characteristics that fit the site. If either the depth to ground water or precipitation rate cannot be determined precisely, use a conservative rating, i.e., 26-40 inches precipitation or 0-25 feet to ground water. Score the site using the weighting system shown at the top of each column. Sum the points and match the total number of points to the corresponding allowable levels for BTX&E and TPH concentrations.

Regulatory agencies may want to consider additional factors, such as hydraulic continuity, actual and potential uses of ground water. and present and future land use. They may also decide to increase the allowable soil limits for diesel and other fuels consisting primarily of aliphatics (i.e., isoalkanes and isoalkenes). These aliphatic hydrocarbons have lower leaching potential and are less toxic than aromatic hydrocarbons. An increase by a factor of ten for the acceptable TPH levels is presented in Table 2-1 (page 29) for diesel. The BTX&E levels are the same in Table 2-1 for diesel as for gasoline. The acceptable TPH levels for diesel should only be used if it appears that the tank never contained gasoline.

Soil with TPH and BTX&E concentrations below the allowable level can be left in place. Sites with values above the allowable level for any of these constituents or TPH require either cleanup or additional site analysis.

Table 2-1
Leaching Potential Analysis for Gasoline and Diesel Using Total Petroleum Hydrocarbons(TPH) and Benzene, Toluene, Xylene and Ethylbenzene (BTX&E)

The following table was designed to permit estimating the concentrations of TPH and BTX&E that can be left in place without threatening ground water. Three levels of TPH and BTX&E concentrations were derived (from modeling) for sites which fall into categories of low, medium or high leaching potential. To use the table, find the appropriate description for each of the features. Score each feature using the weighting system shown at the top of each column. Sum the points for each column and total them. Match the total points to the allowable BTX&E and TPH levels.

<table>
<tr><th colspan="2">SITE FEATURE</th><th>SCORE</th><th>SCORE 10 PTS IF CON-DITION IS MET</th><th>SCORE</th><th>SCORE 9 PTS IF CON-DITION IS MET</th><th>SCORE</th><th colspan="2">SCORE 5 PTS IF CON-DITION IS MET</th></tr>
<tr><td colspan="2">Minimum Depth to Ground Water from the Soil Sample (feet)</td><td></td><td>>100</td><td></td><td>51-100</td><td></td><td colspan="2">25-50\1</td></tr>
<tr><td colspan="2">Fractures in subsurface (applies to foothills or mountain areas)</td><td></td><td>None</td><td></td><td>Unknown</td><td></td><td colspan="2">Present</td></tr>
<tr><td colspan="2">Average Annual Precipitation (inches)</td><td></td><td><10</td><td></td><td>10-25</td><td></td><td colspan="2">26-40\2</td></tr>
<tr><td colspan="2">Man-made conduits which increase vertical migration of leachate</td><td></td><td>None</td><td></td><td>Unknown</td><td></td><td colspan="2">Present</td></tr>
<tr><td colspan="2">Unique site features: recharge area, coarse soil, nearby wells, etc</td><td></td><td>None</td><td></td><td>At least one</td><td></td><td colspan="2">More than one</td></tr>
<tr><td colspan="2">COLUMN TOTALS→TOTAL PTS</td><td></td><td>+</td><td></td><td>+</td><td></td><td>=</td><td></td></tr>
<tr><td colspan="2">RANGE OF TOTAL POINTS</td><td colspan="2">49pts or more</td><td colspan="2">41 - 48 pts</td><td colspan="3">40pts or less</td></tr>
<tr><td colspan="2">MAXIMUM ALLOWABLE B/T/X/E LEVELS (PPM)</td><td colspan="2">1/50/50/50</td><td colspan="2">.3/.3/1/1</td><td colspan="3">NA\3</td></tr>
<tr><td rowspan="2">MAXIMUM ALLOWABLE TPH LEVELS (PPM)</td><td>GASOLINE</td><td colspan="2">1000</td><td colspan="2">100</td><td colspan="3">10</td></tr>
<tr><td>DIESEL</td><td colspan="2">10000</td><td colspan="2">1000</td><td colspan="3">100</td></tr>
</table>

\1 If depth is greater than 5 ft. and less than 25 ft., score 0 points.
If depth is 5 ft. or less, this table should not be used.

\2 If precipitation is over 40 inches, score 0 points.

\3 Levels for BTX&E are not applicable at a TPH concentration of 10ppm (gasoline) or 100ppm (diesel) (For explanation see step 6, page 27.)

7. Is Soil Contamination Minor?

In cases involving very low levels or small amounts of contamination, the inspector may defer escalating the site to Category 2 analysis if he/she determines that only minor cleanup is required and expects that soil samples will be clean, based on laboratory analysis, after the minor cleanup has taken place. While professional judgment will determine the definition of "minor" from site to site, generally a small amount of contamination can be (1) removed by a backhoe and treated on-site, consistent with local fire ordinances, air quality regulations or other regulatory requirements (e.g. county underground storage tank ordinance); or (2) hauled away for treatment or disposal in one or two dump truck loads. The "minor contamination" option cannot be applied to sites where the seasonal high ground water table is less than 5 feet below the tank (or excavation).

8. Remove/Treat Minor Soil Contamination

The regulatory agency may defer additional site evaluation if all information collected, including the results of lab analysis for BTX&E and TPH, indicates minor contamination at the site. If the regulatory agency believes that, after minor cleanup, the undisturbed soil will not exceed the allowable BTX&E and TPH levels discussed above, then necessary treatment/removal should occur. This assessment needs to be verified by laboratory analysis for BTX&E and TPH after cleanup has taken place.

9. Collect Soil Samples (After Soil Removal/Treatment)

Explanation

In cases where minor cleanup has occurred (see previous step) the enlarged excavation must be sampled again to demonstrate that all contaminated material has been removed. However, if unique soil site features are present at the site, it is possible that samples will erroneously indicate that all contaminated material has been removed.

Unique site features at underground tank sites can result in the movement of contaminants from the leaking tank in unexpected directions. Examples of unique site features include underground utilities, presence of fill material, sand and gravel lens, and impermeable layers. These unique features can result in a lateral movement of contaminants which may or may not be discovered by site investigation, particularly if the samples are collected below the point of lateral migration.

Instructions

Samples should be taken from the side walls and bottom of the enlarged excavation at worst-case locations (e.g., along migratory pathways or where the soil is stained). The number of samples will vary according to the size of the excavation.

The determination of whether or not a particular site has unique features should be made with the assistance of an qualified professional civil engineer (experienced in the field of geology), engineering geologist or a registered geologist. The determination should be based, at minimum, on a visual inspection of excavation sidewalls. In the event that unique site features are found to be present, additional sampling to assess off-site migration of constituents may be necessary.

10. Are Other Resources at Risk?

At this point, the possibility of risks to other resources may still be present and should be evaluated when considering current and future uses of the site and surrounding area. For example, there may be a possibility of health risks associated with acute and chronic exposure to vapors or with direct contact with contaminated soil. Consideration of risks to other resources may require a detailed investigation, currently beyond the scope of this manual.

If the concentrations detected in soil samples do not exceed the allowable levels in Table 2-1 and there are no anticipated risks to other resources, then the site investigation can end and no remedial action is necessary. However, the regulatory agency may require verification of the leaching potential analysis results.

D. Category 2: Known Soil Contamination

A decision tree flow chart outlining Category 2 is presented in Figure II-3 (page 33).

1. Gather Existing Data on Precipitation and Site Environment

Explanation

Information on the LUFT site environment should be collected in order to determine which, if any, risk appraisal can be used. Existing information on the depth to ground water should already have been collected during the process for selection of site category and may again be used in Category 2. In addition, existing data on precipitation and site environment should also be gathered at this time and evaluated for use with the appropriate risk appraisal methodology.

Instructions

Specific instructions for collecting information on precipitation and site environment are contained in Step 4 "Collect Environmental Information for Leaching Potential Analysis" of Category 1 (page 24). These instructions include collecting information on surface characteristics, sub-surface characteristics and precipitation. If Category 2 was reached by way of Category 1, Step 7, this information may have already been collected and can be used again in the Category 2 analysis.

2. Do Soil Borings and Take Soil Samples

Explanation

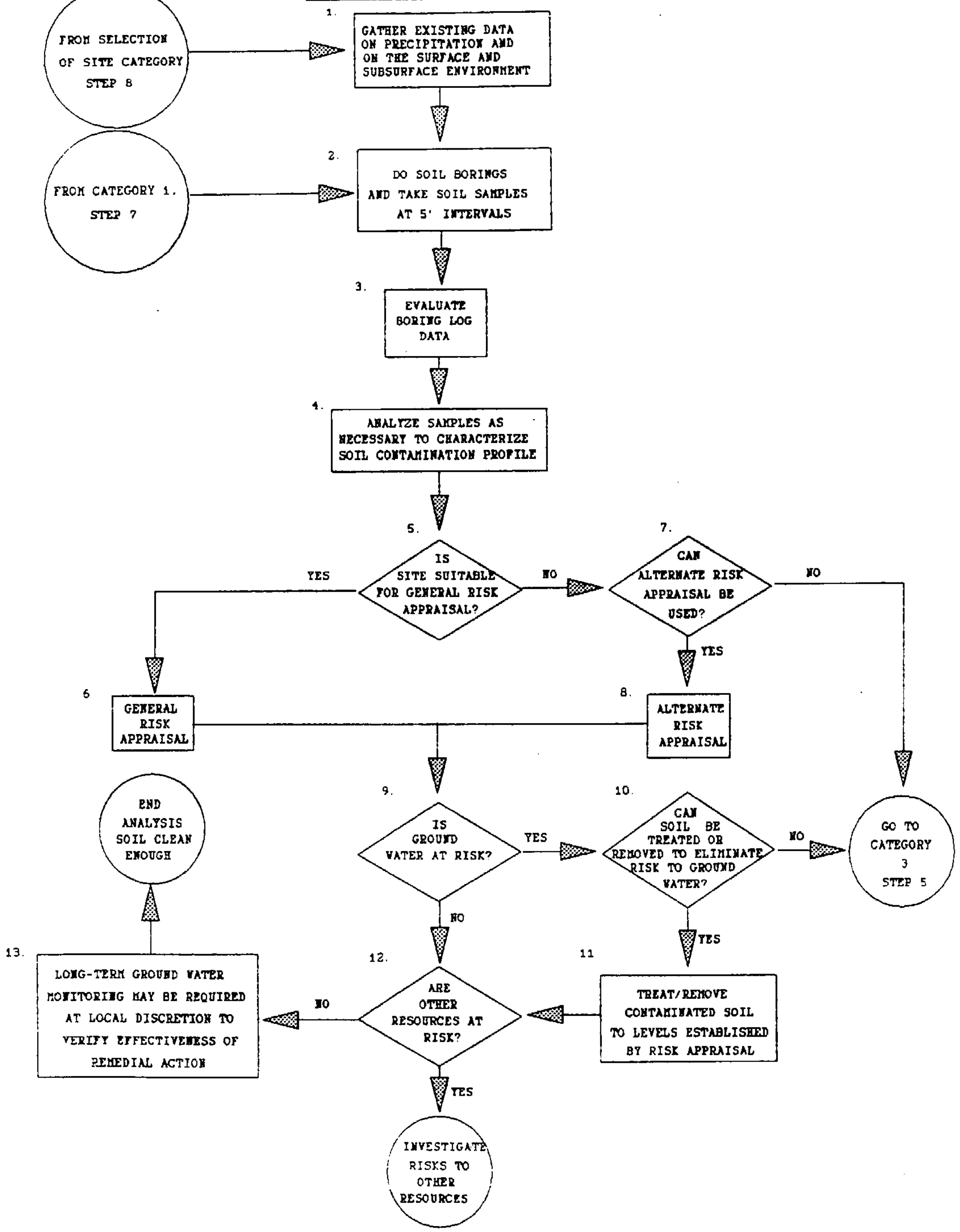
Soil samples should be collected from multiple soil borings to check for lateral as well as vertical movement of contaminants in the soil. The borings should be deep enough to extend through the entire depth of contaminated soil or to reach ground water. When ground water is shallow enough to be reached using available equipment (i.e., less than 50 feet), it may be appropriate to drill the bore holes so as to be suitable for well installations.

Instructions

A minimum of three borings should be taken below or next to the tank or the area previously occupied by

FIGURE 11 - 3
CATEGORY 2 - SITE INVESTIGATION

KNOWN SOIL CONTAMINATION



the tank. Additional borings may be necessary in some cases, particularly at locations where associated piping is suspected of leaking. To avoid bringing drilling equipment on site more than once, the borings should extend to a depth of 50 feet or just past the point where ground water is encountered. The depth of the borings may vary depending on what information is available to help determine the vertical extent of soil contamination. It is important to make the borings deep enough to extend below the area of soil contamination. Sites with soil contamination which extends more than 50 vertical feet should be treated as severe soil contamination cases. These cases may require a more extensive investigation and site specific analysis to define both the lateral and vertical extent of contamination and evaluate the associated risks.

Caution should be taken with regard to drilling through aquatards to avoid unnecessary vertical spreading of contamination. Borings should be made with the supervision of an engineering geologist or a registered geologist.

Soil samples should be taken from the borings at consistent intervals of 5 feet to develop a complete profile of the soil contamination. If a change in lithology, an area of obvious contamination, or ground water is encountered, an additional sample should be taken at that point. If this sample is found to have a higher concentration of fuel constituents than the sample taken from the nearest 5 feet interval, it should be used in place of that 5 feet interval sample in the general risk appraisal. See Appendix C for details on sample collection and handling and quality assurance/quality control.

3. Evaluate Boring Log Data

Explanation

While drilling to collect soil samples, data on the subsurface environment should be collected to later assist in applying appropriate risk appraisal methodology. This information should be organized into logs for each boring performed.

Instructions

Each boring log should contain the following information:

(a) drilling company,

(b) location,

(c) date drilled,

(d) total depth of the hole,

(e) diameter of the hole,

(f) drilling method and

(g) sampling method

Each boring log should graphically present information on:

(a) soil types,

(b) depth from surface,

(c) location of sampling sites,

(d) location of ground water table if encountered and

(e) any unique subsurface features.

Descriptions of the soil classifications and notes of specific observations of subsurface conditions should also be included in the boring log.

4. Analyze Samples as Necessary to Characterize the Soil Contamination Profile.

Explanation

Soil samples must be analyzed for concentrations of BTX&E to provide information for risk appraisal. It is not necessary to analyze the sample for TPH if the analytical results are to be used only for the general risk appraisal. It may not be necessary to analyze all samples taken. However, any sample that might contain concentrations of BTX&E should be analyzed in order to characterize the entire profile of soil contamination.

Instructions

Samples should be sent to a certified laboratory to obtain analytical results for BTX&E concentrations using EPA Method 8020 (Appendix D). Samples may be analyzed all at one time, or they may be sent in smaller groups to avoid analyzing numerous samples that were taken below the area of soil contamination. The concentration of the deepest sample analyzed should have a non-detectable (0.3 ppm or lower) concentration of BTX&E. If multiple borings are used, the boring sample with the highest concentration at a particular depth should be used to represent the concentration at that depth when using the general risk appraisal. Results should be reported in parts per million, either milligrams of fuel constituents per kilogram of soil (mg/kg) or in micrograms of fuel constituents per gram of soil ($\mu g/g$).

5. Is the Site Suitable for the General Risk Appraisal?

Explanation

As presented in this field manual, the general risk appraisal uses a simulated environmental system that adapts two computer models to estimate the concentrations of BTX&E that can be left in place (using remedial action, if needed) without risking ground water pollution. Appendix F describes the elements of these computer models and how they were adapted for this field manual.

This general risk appraisal uses the latest information on observed and calculated properties of chemicals and on environmental fate processes. It also considers a variety of environmental conditions found throughout the State (i.e., climate and depth to ground water). This approach allows for a site-specific and chemical-specific analysis. It is based on a technical foundation which conservatively accounts for influences on pollutant migration.

However, the general risk appraisal uses two models which are subject to the deficiencies of all models. Models are theoretical representations of complex and only partially predictable events. The SESOIL model has been tested and verified by the U.S. Environmental Protection Agency. The extent of the testing and verification includes comparison with other models and field data. However, to the best of the task force's knowledge, it has not been checked using field data from leaking underground fuel tanks. Information regarding testing and verification of the other model (AT123D) and the interfaced combination of the two models could not be found. Data from underground tank site cleanups will be used to assess the validity of this general risk appraisal and make any necessary changes.

The general risk appraisal assumes relatively homogeneous permeable soil and simplified hydrogeological features. The environmental input used with these models is intended to represent sites with a high potential for ground water pollution. However, some site-specific conditions may present a greater risk for ground water pollution than accounted for by the general risk appraisal.

Instructions

The checklist in Table 2-2 (page 38) contains questions which are designed to identify sites with environmental conditions which could produce a greater risk to ground water than was modeled. The questions may be answered from existing data that were collected on the site environment and data that were collected during excavation or drilling. The predictions of the models are most applicable if all of the questions on the checklist can be answered "no" with reasonable certainty. If any of the questions on the checklist cannot be answered "no" then the results of the general risk appraisal may be less valid. If answers to the checklist questions indicate that the general risk appraisal results are not valid enough to be practical, then an alternative risk appraisal should be considered (Step 7, Page 41).

6. The General Risk Appraisal

Explanation

The general risk appraisal was developed using environmental fate and chemistry data for BTX&E to evaluate the risk of ground water pollution from LUFT sites under severe conditions. This risk appraisal requires a limited amount of site-specific information; conservative assumptions have been substituted for other site-specific information. The general risk appraisal is more sophisticated than the leaching potential analysis done as part of the Category 1 investigation.

TABLE 2-2

GENERAL RISK APPRAISAL FOR PROTECTION OF WATER QUALITY: APPLICABILITY CHECKLIST	YES	NO
1. Is the site in a mountainous area? (shaded moist areas &/or areas with rocky subsurface conditions)		
2. Is the site in an area that could collect surface runoff or intercept water from a source other than the natural precipitation?		
3. Does the areal extent of soil contamination exceed 1000 $feet^2$?		
4. Do the concentrations of fuel constituents in any soil samples exceed the following amounts: benzene - 100 ppm, toluene - 80 ppm, xylene - 40 ppm, ethylbenzene - 40 ppm?		
5. Are there any records or evidence of man-made or natural objects which could provide a conduit for vertical migration of leachate?		
6. Do any boring or excavation logs show the presence of fractures, joints or faults that could act as a conduit for vertical migration of leachate?		
7. Do any boring logs show that contaminated soil could be within 5 ft. of highest ground water?		
8. Do any boring logs show the presence of a layer of material, 5 ft. thick or more, which is more than 75% sand and/or gravel?		

Directions:

1. Boring logs taken during the general risk appraisal can be used to answer questions 5-8. In addition, analytical results of the soil samples taken during the general risk appraisal can be used to answer questions 3 and 4.
2. Lateral migration of constituents to problem areas should also be considered in questions 5-8.
3. The above checklist contains questions which are designed to identify sites with environmental conditions which could produce a greater risk to ground water than was modeled. The results of the general risk appraisal are most applicable if all of the questions on the checklist can be answered "no" with reasonable certainty. If any of the questions on the checklist cannot be answered "no", then the results of the general risk appraisal may be less valid.

Instructions

An environmental fate worksheet (Table 2-3, page 42) was designed to help organize and analyze information on rainfall, ground water, and soil contamination used in the general risk appraisal. Step-by-step instructions for filling in the worksheet follow:

(a) Fill in information, previously collected, for precipitation (A) and distance from the natural soil surface (not the subsurface at the bottom of the excavation) to ground water (B). In areas where ground water is deeper than 150 feet, the general risk appraisal can be based on the maximum depth presented in Tables 2-4 through 2-7. The minimum seasonal depth, i.e., highest ground water, should always be used in calculating distance from surface to ground water.

(b) Determine the distance from the natural soil surface to each sampling point (in feet, rounding to the nearest tenth of a foot). Calculate the distance from each sampling point to ground water (D) by subtracting the depth of the soil sample (C) from the depth of the ground water (B).

(c) Although this general risk appraisal is set up to assess the risk associated with soil concentrations on a sample-by-sample basis, the total volume of contaminated soil must also be considered. The computer models have shown that increasing the volume of contaminated soil, independent of the concentration of contaminants, produces an increase in ground water concentrations. As a simplified and conservative method of accounting for this additive effect of soil volume, concentrations for each 5-feet interval must be summed progressively with vertical distance. This sum is referred to as a <u>cumulative contamination level</u> and is no longer expressed as a concentration. To determine what the <u>cumulative</u> contamination level is at a particular depth (E), add the concentration at that depth to the sum of the concentrations for each interval above it. For example: the first sample (at a 15 ft. depth) = <u>4 ppm</u>, the second sample (at a 20 ft. depth) = <u>5 ppm</u>, and the third sample (at a 25 ft. depth) = <u>1 ppm</u>; cumulative contamination levels are <u>4</u> for the first sample, <u>9</u> (4+5) for the second sample, and <u>10</u> (9+1) for the third sample. The last sample to be included in the calculations for cumulative contamination must be at or above the detection limit (0.3 ppm). The calculation of cumulative contamination levels is only done for the zone of contaminated soil; the analysis stops at the lowest extent of contamination.

(d) Use Tables 2-4 through 2-7 (pages 43 to 46) to determine the acceptable cumulative soil contamination levels for each layer of contaminated soil (F). The tables show distance from contamination to ground water on the vertical axis and annual rainfall on the horizontal axis. Note that the tables show distance from the sampling point to ground water (D), <u>not</u> from the surface of the soil (C). For example, the acceptable levels in the top row are acceptable for the layer 5 to 10 feet above ground water, while the values in the bottom row are for the layers which are more than 150 feet above ground water. The models were used to derive acceptable cumulative soil contamination levels, which the tables show as whole numbers ranging from 0 to 1000. The acceptable levels can be found on the table using the average annual precipitation (A) and the distance from the sampling point to ground water (D). The models actually generated precise numbers, but it was decided to round the numbers down to the left-most digit for two reasons. First, the more precise a number is, the more accurate it appears to be. The general risk appraisal estimates, but does not pinpoint, the threat of ground water pollution. Second, the results were rounded down to lower numbers to provide an additional margin of ground water protection in the analysis.

(e) Determine if the soil must be cleaned up or if it can be left in place (G). If a cumulative contamination level at any depth is higher than the corresponding suggested acceptable level, remedial action may be required. If the cumulative contamination levels are not higher than the acceptable levels, the soil may be left in place, provided that fire hazard or pollution of resources other than water is not anticipated.

Also, if the concentration of any single field sample is higher than 100 ppm for benzene, 80 ppm for toluene, or 40 ppm for xylene or ethylbenzene, the general risk appraisal should not be used. These single-sample concentration limits are based on the solubility of the fuel constituents. At these concentrations, the chemicals may not be entirely in solution. The models simulate transport of chemicals in solution and cannot be used for undissolved constituents. The less soluble a chemical is, the smaller the amount of the chemical that the model can handle will be.

(f) Simulate remedial action. Starting with the top layer, change the concentration value to 0 ppm (simulating soil treatment or removal and replacement with clean backfill). Recalculate the cumulative contamination levels. Continue with the next layers until all cumulative contamination levels are no longer above their corresponding acceptable levels. This recalculation will determine how much contaminated soil must be treated or removed. Alternatively, take the lowest acceptable contamination level from the contaminated soil profile (the bottom contaminated layer) and divide it by the number of contaminated layers of soil to find the minimal cleanup level (a soil concentration expressed in ppm) for the entire volume of contaminated soil.

7. Can an Alternate Risk Appraisal be Used?

Explanation

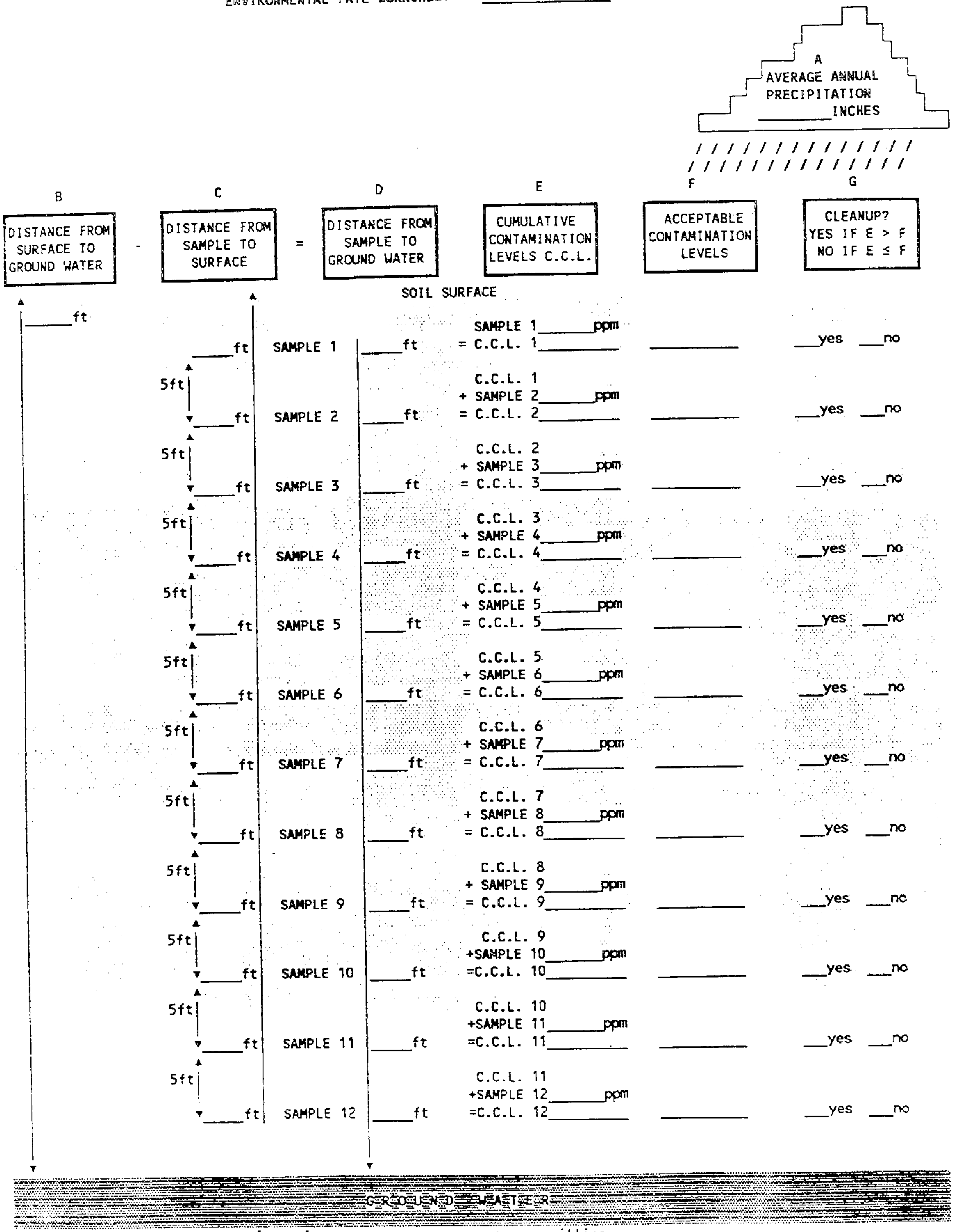
For sites where the general risk appraisal cannot be used, field investigators may consider using other kinds of environmental risk appraisals approved by the regulatory agency. Alternative risk appraisals for the Category 2 investigation should be designed to answer the question: Does soil contamination pose the risk of polluting ground water?

Instructions

If ground water pollution is suspected or known at this point, the investigation should proceed to Category 3. In addition, if site-specific conditions prohibit the practical use of any approved risk appraisal methodologies, the investigation should also proceed to Category 3. If an alternate risk appraisal is found to be appropriate for this site, the investigation should proceed with an alternate risk appraisal (Step 8, page 47).

TABLE 2-3

ENVIRONMENTAL FATE WORKSHEET FOR______________(FUEL CONSTITUENT)



B		C		D	E	F	G
DISTANCE FROM SURFACE TO GROUND WATER	-	DISTANCE FROM SAMPLE TO SURFACE	=	DISTANCE FROM SAMPLE TO GROUND WATER	CUMULATIVE CONTAMINATION LEVELS C.C.L.	ACCEPTABLE CONTAMINATION LEVELS	CLEANUP? YES IF E > F NO IF E ≤ F
______ft		_____ft	SAMPLE 1	_____ft	SAMPLE 1_______ppm = C.C.L. 1__________	__________	___yes ___no
		5ft _____ft	SAMPLE 2	_____ft	C.C.L. 1 + SAMPLE 2_______ppm = C.C.L. 2__________	__________	___yes ___no
		5ft _____ft	SAMPLE 3	_____ft	C.C.L. 2 + SAMPLE 3_______ppm = C.C.L. 3__________	__________	___yes ___no
		5ft _____ft	SAMPLE 4	_____ft	C.C.L. 3 + SAMPLE 4_______ppm = C.C.L. 4__________	__________	___yes ___no
		5ft _____ft	SAMPLE 5	_____ft	C.C.L. 4 + SAMPLE 5_______ppm = C.C.L. 5__________	__________	___yes ___no
		5ft _____ft	SAMPLE 6	_____ft	C.C.L. 5 + SAMPLE 6_______ppm = C.C.L. 6__________	__________	___yes ___no
		5ft _____ft	SAMPLE 7	_____ft	C.C.L. 6 + SAMPLE 7_______ppm = C.C.L. 7__________	__________	___yes ___no
		5ft _____ft	SAMPLE 8	_____ft	C.C.L. 7 + SAMPLE 8_______ppm = C.C.L. 8__________	__________	___yes ___no
		5ft _____ft	SAMPLE 9	_____ft	C.C.L. 8 + SAMPLE 9_______ppm = C.C.L. 9__________	__________	___yes ___no
		5ft _____ft	SAMPLE 10	_____ft	C.C.L. 9 +SAMPLE 10_______ppm =C.C.L. 10__________	__________	___yes ___no
		5ft _____ft	SAMPLE 11	_____ft	C.C.L. 10 +SAMPLE 11_______ppm =C.C.L. 11__________	__________	___yes ___no
		5ft _____ft	SAMPLE 12	_____ft	C.C.L. 11 +SAMPLE 12_______ppm =C.C.L. 12__________	__________	___yes ___no

ft = feet ppm = parts per million

* NOTE: CONCENTRATIONS FOR ANY SINGLE SOIL SAMPLE CANNOT EXCEED 100ppm FOR BENZENE, 80ppm FOR TOLUENE, 40ppm FOR XYLENE AND 40ppm FOR ETHYLBENZENE IN ORDER TO BE USED WITH THE GENERAL RISK APPRAISAL.
THE LAST SAMPLE TO BE INCLUDED IN THE CALCULATIONS FOR CUMULATIVE CONTAMINATION MUST BE AT OR ABOVE THE DETECTION LIMIT; DO NOT INCLUDE BOTTOM SAMPLES WHICH HAVE CONCENTRATIONS LESS THAN THE DETECTION LIMIT.

TABLE 2-4
BENZENE
ACCEPTABLE CUMULATIVE SOIL CONTAMINATION LEVELS FOR PROTECTION OF GROUND WATER AT QUALIFIED SITES

Stop: Do not use this table unless the site in question has been screened using the applicability checklist (Table 2-2) for general risk appraisal to protect ground water

MEAN ANNUAL INCHES PRECIPITATION

		0 to 5	5.1 to 6	6.1 to 7	7.1 to 8	8.1 to 9	9.1 to 10	10.1 to 11	11.1 to 12	12.1 to 14	14.1 to 16	16.1 to 18	18.1 to 20	20.1 to 22	22.1 to 24	24.1 to 26	26.1 to 28	28.1 to 30	30.1 to 32	32.1 to 34	34.1 to 36	36.1 to 38	38.1 to 40
	5-9.9	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10-14.9	5	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	15-19.9	10	10	6	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20-24.9	60	40	20	10	5	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25-29.9	200	100	60	30	10	7	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	30-34.9	800	400	200	100	40	20	10	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0
DISTANCE	35-39.9	1000	1000	700	300	100	60	20	10	3	1	0	0	0	0	0	0	0	0	0	0	0	0
	40-44.9	1000	1000	1000	1000	400	100	80	30	9	2	0	0	0	0	0	0	0	0	0	0	0	0
TO	45-49.9	1000	1000	1000	1000	1000	500	200	100	20	4	1	1	0	0	0	0	0	0	0	0	0	0
	50-54.9	1000	1000	1000	1000	1000	1000	600	200	50	9	2	2	1	1	0	0	0	0	0	0	0	0
HIGHEST	55-59.9	1000	1000	1000	1000	1000	1000	1000	700	100	20	5	3	2	1	1	0	0	0	0	0	0	0
	60-64.9	1000	1000	1000	1000	1000	1000	1000	1000	300	40	9	6	4	3	2	1	1	0	0	0	0	0
GROUND	65-69.9	1000	1000	1000	1000	1000	1000	1000	1000	700	80	10	10	8	5	3	2	1	1	0	0	0	0
	70-74.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	100	30	20	10	9	6	4	2	1	1	0	0	0
WATER	75-79.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	300	60	40	20	10	10	7	4	2	1	1	0	0
	80-84.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	100	70	40	30	10	10	7	4	2	1	1	0
FROM	85-89.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	200	100	80	50	30	10	10	7	4	2	1	0
	90-94.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	400	200	100	90	50	30	10	10	6	3	2	1
SOIL	95-99.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	200	100	90	50	30	10	10	5	3	1
	100-104.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	400	200	100	90	50	20	10	8	4	2
SAMPLE	105-109.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	400	200	100	80	40	20	10	7	3
	110-114.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	400	200	100	70	30	10	10	5
IN	115-119.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	200	100	50	20	10	7
	120-124.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	300	100	90	40	20	10
FEET	125-129.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	500	200	100	60	30	10
	130-134.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900	400	200	100	40	20
	135-139.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	300	100	60	30
	140-144.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	500	200	100	40
	145-149.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	300	100	60
	150+	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	500	200	90

Note: Individual concentrations for any soil sample cannot exceed 100 ppm. The numbers in this table do not represent soil concentrations; they reflect the accumulation of pollutant mass in contaminated soil. These numbers can be derived from the LUFT manual worksheet (Table 2-3).

TABLE 2-5
TOLUENE
ACCEPTABLE CUMULATIVE SOIL CONTAMINATION LEVELS FOR PROTECTION OF GROUND WATER AT QUALIFIED SITES

Stop: Do not use this table unless the site in question has been screened using the applicability checklist (Table 2-2) for general risk appraisal to protect ground water

DISTANCE TO HIGHEST GROUND WATER FROM SOIL SAMPLE IN FEET	MEAN ANNUAL INCHES PRECIPITATION																				
	0 to 5	5.1 to 6	6.1 to 7	7.1 to 8	8.1 to 9	9.1 to 10	10.1 to 11	11.1 to 12	12.1 to 14	14.1 to 16	16.1 to 18	18.1 to 20	20.1 to 22	22.1 to 24	24.1 to 26	26.1 to 28	28.1 to 30	30.1 to 32	32.1 to 34	34.1 to 36	36.1 to 38	38.1 to 40
5-9.9	70	50	30	20	10	8	5	3	2	1	1	1	1	0	0	0	0	0	0	0	0	0
10-14.9	200	100	100	70	40	20	10	8	4	3	2	2	1	1	1	1	1	1	0	0	0	0
15-19.9	1000	600	400	200	100	60	30	10	10	6	4	3	3	2	2	2	1	1	1	1	0	0
20-24.9	1000	1000	1000	700	300	100	90	40	20	10	8	7	6	5	4	3	2	2	2	1	1	1
25-29.9	1000	1000	1000	1000	1000	500	200	100	50	20	10	10	10	9	7	5	4	3	2	2	1	1
30-34.9	1000	1000	1000	1000	1000	1000	600	200	100	50	30	20	20	10	10	9	7	5	4	3	2	1
35-39.9	1000	1000	1000	1000	1000	1000	1000	600	200	100	60	40	30	20	20	10	10	8	6	4	3	2
40-44.9	1000	1000	1000	1000	1000	1000	1000	1000	600	200	100	80	60	40	30	20	10	10	9	6	4	3
45-49.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	400	200	100	100	80	50	40	20	20	10	9	6	4
50-54.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	400	300	200	100	100	60	40	30	20	10	9	5
55-59.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	500	300	200	100	100	70	40	30	10	10	7
60-64.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	400	200	100	100	70	40	20	10	10
65-69.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	300	100	100	60	40	20	10
70-74.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	400	200	100	100	50	30	10
75-79.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	400	200	100	80	40	20
80-84.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	200	100	60	30
85-89.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	300	100	80	40
90-94.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900	400	200	100	50
95-99.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	300	100	70
100-104.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	400	200	90
105-109.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	200	100
110-114.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900	400	100
115-119.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	500	200
120-124.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	200
125-129.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	300
130-134.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	500
135-139.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600
140-144.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900
145-149.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
150+	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Note: Individual concentrations for any soil sample cannot exceed 80 ppm. The numbers in this table do not represent soil concentrations; they reflect the accumulation of pollutant mass in contaminated soil. These numbers can be derived from the LUFT manual worksheet (Table 2-3).

TABLE 2-6
XYLENE
ACCEPTABLE CUMULATIVE SOIL CONTAMINATION LEVELS
FOR PROTECTION OF GROUND WATER AT QUALIFIED SITES

Stop: Do not use this table unless the site in question has been screened using the applicability checklist (Table 2-2) for general risk appraisal to protect ground water

MEAN ANNUAL INCHES PRECIPITATION

		0 to 5	5.1 to 6	6.1 to 7	7.1 to 8	8.1 to 9	9.1 to 10	10.1 to 11	11.1 to 12	12.1 to 14	14.1 to 16	16.1 to 18	18.1 to 20	20.1 to 22	22.1 to 24	24.1 to 26	26.1 to 28	28.1 to 30	30.1 to 32	32.1 to 34	34.1 to 36	36.1 to 38	38.1 to 40
	5-9.9	100	100	90	60	40	30	20	10	10	9	7	7	6	6	5	5	5	4	4	4	3	3
	10-14.9	600	400	300	200	100	80	50	30	20	10	10	10	10	9	8	8	7	6	5	5	4	4
	15-19.9	1000	1000	1000	600	400	200	100	70	40	20	20	10	10	10	10	10	10	9	8	7	6	5
	20-24.9	1000	1000	1000	1000	1000	600	300	100	80	50	30	30	20	20	10	10	10	10	10	9	7	6
	25-29.9	1000	1000	1000	1000	1000	1000	700	300	100	90	50	40	40	30	20	20	20	10	10	10	9	8
	30-34.9	1000	1000	1000	1000	1000	1000	1000	700	300	100	90	70	60	50	40	30	20	20	10	10	10	9
DISTANCE	35-39.9	1000	1000	1000	1000	1000	1000	1000	1000	600	200	100	100	100	80	60	50	40	30	20	20	10	10
	40-44.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	500	200	200	100	100	90	70	50	40	30	20	10	10
TO	45-49.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	400	300	200	100	100	100	80	60	40	30	20	10
	50-54.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	500	300	200	200	100	100	80	60	40	30	20
HIGHEST	55-59.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	600	400	300	200	100	100	80	50	30	20
	60-64.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900	600	400	300	200	100	100	70	40	30
GROUND	65-69.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	300	200	100	90	60	40
	70-74.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	400	200	100	100	70	50
WATER	75-79.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	400	200	100	90	60
	80-84.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900	500	300	200	100	70
FROM	85-89.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	200	100	90
	90-94.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	300	100	100
SOIL	95-99.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	400	200	100
	100-104.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	500	300	100
SAMPLE	105-109.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	200
	110-114.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900	500	200
IN	115-119.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	300
	120-124.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	300
FEET	125-129.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	400
	130-134.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	500
	135-139.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600
	140-144.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800
	145-149.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	150+	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Note: Individual concentrations for any soil sample cannot exceed 40 ppm. The numbers in this table do not represent soil concentrations; they reflect the accumulation of pollutant mass in contaminated soil. These numbers can be derived from the LUFT manual worksheet (Table 2-3).

TABLE 2-7
ETHYLBENZENE
ACCEPTABLE CUMULATIVE SOIL CONTAMINATION LEVELS FOR PROTECTION OF GROUND WATER AT QUALIFIED SITES

Stop: Do not use this table unless the site in question has been screened using the applicability checklist (Table 2-2) for general risk appraisal to protect ground water

MEAN ANNUAL INCHES PRECIPITATION

		0 to 5	5.1 to 6	6.1 to 7	7.1 to 8	8.1 to 9	9.1 to 10	10.1 to 11	11.1 to 12	12.1 to 14	14.1 to 16	16.1 to 18	18.1 to 20	20.1 to 22	22.1 to 24	24.1 to 26	26.1 to 28	28.1 to 30	30.1 to 32	32.1 to 34	34.1 to 36	36.1 to 38	38.1 to 40
	5-9.9	300	200	100	100	70	40	30	20	10	10	10	9	8	8	7	6	6	5	5	5	4	4
	10-14.9	1000	800	500	300	200	100	70	40	30	20	10	10	10	10	10	9	8	8	7	6	5	5
	15-19.9	1000	1000	1000	1000	500	300	100	90	50	30	20	20	20	10	10	10	10	10	9	8	7	6
	20-24.9	1000	1000	1000	1000	1000	800	400	200	100	60	40	30	30	20	20	20	10	10	10	10	8	7
	25-29.9	1000	1000	1000	1000	1000	1000	1000	400	200	100	70	50	40	40	30	20	20	10	10	10	10	9
	30-34.9	1000	1000	1000	1000	1000	1000	1000	900	400	100	100	90	70	60	50	40	30	20	20	10	10	10
DISTANCE	35-39.9	1000	1000	1000	1000	1000	1000	1000	1000	800	300	100	100	100	90	70	50	40	30	20	20	10	10
	40-44.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	300	200	100	100	100	80	60	40	30	20	20	10
TO	45-49.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	400	300	200	200	100	100	80	60	40	30	20	10
	50-54.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	500	400	300	200	100	100	80	60	40	30	20
HIGHEST	55-59.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900	600	400	300	200	100	100	80	50	40	20
	60-64.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	500	300	200	100	100	70	50	30
GROUND	65-69.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	300	200	100	90	60	40
	70-74.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	200	100	100	70	40
WATER	75-79.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	400	200	100	90	50
	80-84.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	500	300	100	100	70
FROM	85-89.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	200	100	80
	90-94.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900	500	300	100	100
SOIL	95-99.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700	400	200	100
	100-104.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900	500	200	100
SAMPLE	105-109.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	300	100
	110-114.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	400	200
IN	115-119.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	500	200
	120-124.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600	300
FEET	125-129.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	800	300
	130-134.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	400
	135-139.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	500
	140-144.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	600
	145-149.9	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	700
	150+	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	900

Note: Individual concentrations for any soil sample cannot exceed 40 ppm. The numbers in this table do not represent soil concentrations; they reflect the accumulation of pollutant mass in contaminated soil. These numbers can be derived from the LUFT manual worksheet (Table 2-3).

8. Alternate Risk Appraisals

In considering alternate risk appraisals, regulatory agencies should be aware of (a) the complexity of the required analysis (i.e., environmental chemistry and hydrogeology), (b) the need for thorough review of findings and recommendations, and (c) the need for follow-up monitoring of contamination left in place.

Site evaluations should include the following considerations at a minimum. First and foremost, the same observation may be interpreted very differently, depending on perspective. For example, high hydrocarbon concentrations in a deep clayey layer could be used as evidence that the layer retarded pollutant migration. Alternatively, they could be regarded as a source of continuing contamination for years to come due to diffusion and lack of effective chemical or biological breakdown.

Second, site evaluation should assess the potential for hydrocarbon vapors to migrate along or within man-made conduits. These vapors may pose a health hazard or threat of explosion or fire if concentrations reach explosive levels and an ignition source is present. The acceptable soil contamination levels listed in Tables 2-4 through 2-7 (pages 43 to 46) were developed only for the protection of ground water. A field level that does not threaten ground water may pose a risk of exposure or explosion from vapor buildup in sewer lines, for instance.

Finally, regulatory agencies should note that general statements about mitigating effects of confining layers or biodegradation may not be valid in specific cases. The ability of clay layers to effectively retard the movement of hydrocarbons and other organic chemicals is highly questionable. Also, although there is evidence that natural microbiological processes can have a substantial effect on degradation of hydrocarbons, the rates of degradation are very site-specific and seasonal. In addition, natural biodegradation rates in the saturated subsurface environment may be insignificant.

As one alternative to the general risk appraisal, a more detailed site-specific analysis, employing the two models (SESOIL and AT123D) used in the general risk appraisal, may be performed. However, the regulatory agency overseeing the cleanup must evaluate and approve of the parameter values used in the model simulation. State Board staff are available to assist in this evaluation. These models are available through the U.S. Environmental Protection Agency's Graphical Exposure Modeling System (GEMS). In order to use the system, it is necessary to obtain an account, which can be requested by calling (202) 382-3929. The system, which is remotely accessed by computer, can be used once an account is established.

9. Is Ground Water at Risk?

Explanation

Concentrations of BTX&E in the soil at the site may exceed the appropriate cumulative contamination levels given in the general risk appraisal. In this event, one can conclude that there is a possibility for BTX&E to eventually reach the ground water in concentrations exceeding the action levels for drinking water. An alternate risk appraisal done for the site must be performed with the same goal in mind: to determine if ground water is at risk.

Instructions

If the risk appraisal clearly indicates that ground water is not at risk from soil contamination, then risks to other resources should be considered before the investigation is concluded (Step 12). If the risk appraisal indicates that ground water may be at risk, the investigation should proceed to evaluate remedial action alternatives (Step 10).

10. Can Soil be Treated or Removed to Eliminate Risk to Ground Water?

Explanation

In many instances, it will be feasible to either treat the contaminated soil in place or remove the contaminated soil to eliminate the risk of polluting ground water. However, the site should first be evaluated to determine if there are any conditions which may prohibit soil treatment or removal.

Instructions

If the analysis shows that the worst contamination is close to the ground surface and no overlying structures are present, it may be easiest to remove the contaminated soil (Step 11). If there are overlying structures, or contamination is deep within the soil profile, the alternative of in-situ treatment of contaminated soil should be considered (Step 11). If in-situ treatment or removal of the contaminated soil is not feasible, it will be necessary to proceed to Category 3 for further investigation.

11. Treat/Remove Contaminated Soil to Levels Established by Risk Appraisal

Explanation

Removal of contaminated soil may involve on-site treatment of the soil or transportation of the soil to an appropriate facility. On-site treatment of the removed soil often involves aeration. It is necessary to check with the local air pollution control district to determine if aeration of the contaminated soil is acceptable.

Instructions

The general risk appraisal can be used to determine how much soil needs to be removed or to what level the soil should be cleaned up. The general risk appraisal does not determine the amount of lateral contamination to be cleaned up; it makes the assumption that the soil contamination is contained within a column 32 feet wide by 32 feet long (or dimensions having an equivalent area). Remedial actions should deal with the entire lateral extent of contamination. Post-remedial action sampling should be used to confirm the absence of lateral contamination. Results from alternative risk appraisals should also provide a means of determining the amount of cleanup that is necessary.

Remedial action alternatives should be approved by the responsible regulatory agency. It may be appropriate at this point to consider risks to other resources before proceeding with soil removal or treatment.

12. Are Other Resources at Risk?

At this point, the possibility of risks to other resources may still be present and should be evaluated when considering current and future uses of the site and surrounding area. Consideration of risks to other resources may require a detailed investigation, currently beyond the scope of this manual.

If the concentrations detected in soil samples do not exceed the values in Tables 2-4 through 2-7 and there are no anticipated risks to other resources, then the site investigation can end and no remedial action is necessary, unless the regulatory agency requires verification of the risk appraisal results. Follow-up ground water monitoring (Step 13) may be required by the regulatory agency, to ensure that ground water continues to not be at risk.

13. Long Term Ground Water Monitoring

Ground water monitoring may be required for sites where contaminated soil is left in place. The frequency and duration of the monitoring will vary depending on the site. If significant ground water pollution is subsequently found, more monitoring, further investigation, and/or remedial action may be required.

E. Category 3: Known or Suspected Ground Water Pollution or Areas With Shallow Ground Water

1. Collect Water and Soil Samples From the Excavation

A decision tree flow chart outlining Category 3 is presented in Figure II-4 (page 52).

At this step in the investigation, the tank (and possibly piping) has been removed, when appropriate, and there is evidence of known or suspected ground water pollution or shallow ground water. If there is ground water or surface water in the excavation, grab samples should be collected following the procedures described in Category 1, Step 2, page 23. Soil samples should be collected by following the instructions presented in Category 1, Step 1, Page 19. At sites where the excavation is in contact with ground water, soil samples should be collected from side walls.

2. Laboratory Analysis of Samples for BTX&E and TPH

Explanation

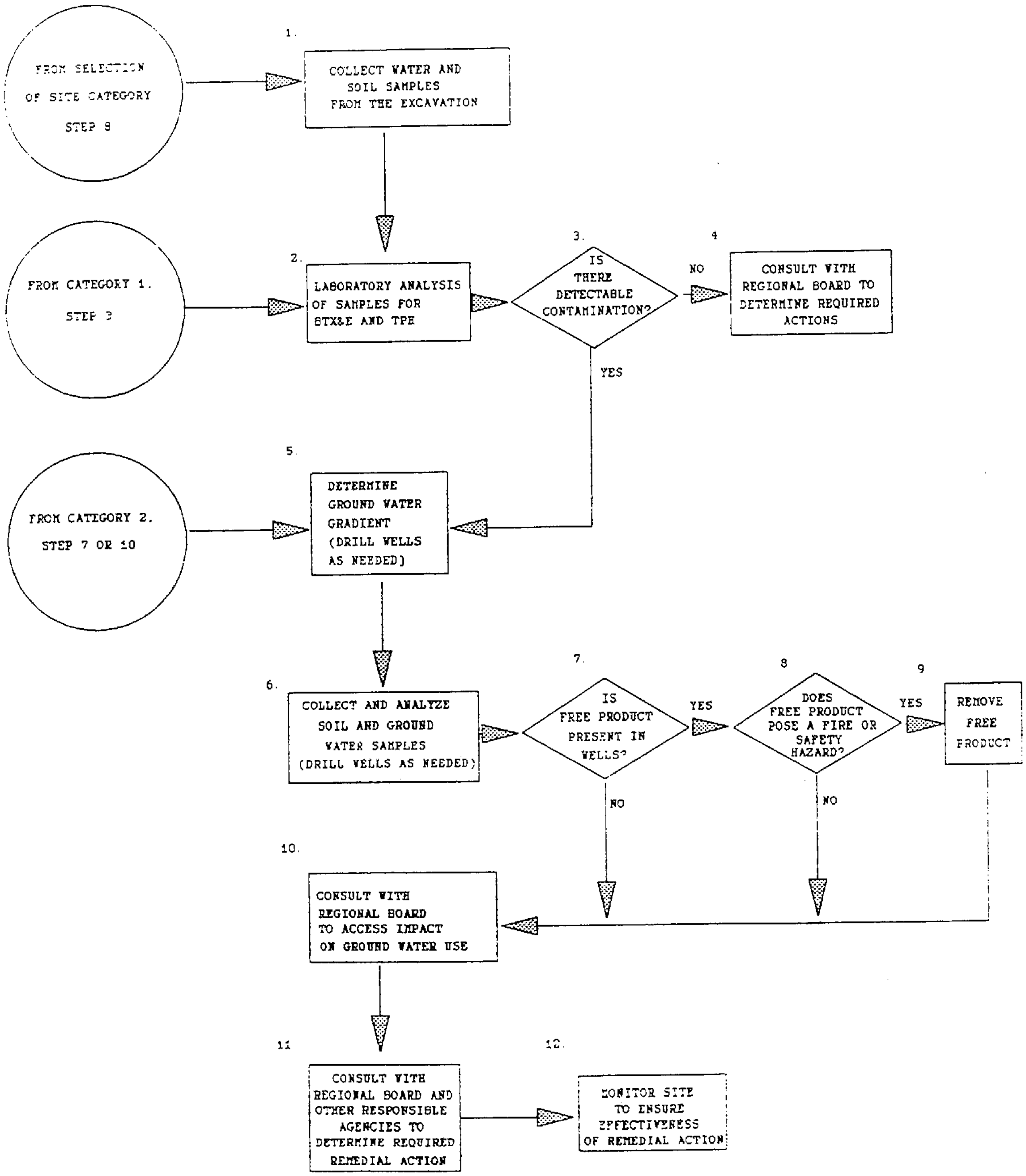
At this step, the investigation may have proceeded from either Category 1, Step 3 or Category 3, Step 1. If the former, there is no evidence of significant soil contamination or ground water pollution. If the latter, such evidence exists. The analytical process is the same for both types of cases, although detectable levels of contamination are not expected for Category 1 sites. Soil samples and any grab samples of surface or ground water present should be quantitatively analyzed for both BTX&E and TPH.

Instructions

Soil samples should be quantitatively analyzed for BTX&E using EPA Method 8020. Ground water samples should be quantitatively analyzed for BTX&E using EPA Method 602. Soil and water samples should also be quantitatively analyzed for TPH using the DHS method described in Appendix D. Soil sample results should be reported in parts per million, either milligrams of fuel constituents per kilogram of soil (mg/kg) or in micrograms of fuel constituents per gram of soil (μg/g). Water sample results should be reported in parts per billion, in micrograms of fuel constituents per liter of water (μg/ml). Appendix D explains these analytical procedures and how to interpret results.

FIGURE 11 - 4
CATEGORY 3 - SITE INVESTIGATION

KNOWN OR SUSPECTED GROUND WATER POLLUTION OR AREAS WITH SHALLOW GROUND WATER



3. Is There Detectable Contamination?

Explanation

A site may have fallen into the Category 3 investigation simply because of its close proximity to ground water. At this point, it is possible that no contamination may exist at the site. The criterion for deciding whether the Category 3 investigation should continue is the detection of contamination. The ability to determine if contamination is detectable in soil or ground water depends on the laboratory detection limits used for BTX&E and TPH. A detection limit of 0.3 ppm for BTX&E in soil is recommended in Category 1. Appendix D also presents minimum detection limits for soil and water set by DHS for optimal sample conditions. Although these detection limits are presented in this manual, regulatory agencies may use a lower detection limit, based on the past performance of the particular laboratory and on the sample conditions.

Instructions

Evaluate the analytical results for soil and water samples to determine if there is any detectable soil contamination or ground water pollution. If analytical results show concentrations above the detection limit, the investigation should proceed to determination of ground water gradient (Step 5). If analytical results do not show concentrations above the detection limit, the investigation should proceed to consultation with the regional board (Step 4).

4. Consult With Regional Board to Determine Required Actions

Explanation

In most cases, the laboratory analysis of soil and water samples will show nondetectable levels of BTX&E or TPH only for sites which proceeded directly from Category 1, Step 3. These sites could not be analyzed using the leaching potential analysis, because ground water is less than 20 feet deep. For cases with suspected or known ground water pollution, detectable concentrations of BTX&E or TPH are expected. For the shallow ground water cases with nondetectable levels, it is advisable for the local agency to consult with the regional board due to the high risk to ground water.

Instructions

If the regulatory agency is a local agency, the regional board should be consulted to confirm or question the determination that there is no detectable contamination in the soil or ground water. If contamination is suspected or anticipated, the regional board may recommend additional sampling and analyses to support the initial analyses. In some cases, the regional board may recommend proceeding directly with the remainder of the Category 3 investigation.

5. Determine Ground Water Gradient

Explanation

At this step the investigation may have proceeded from Category 2, Step 7 or 10, or from Category 3, Step 3.

In order to determine if ground water is contaminated, down gradient ground water samples must be properly collected and analyzed. Ground water gradients are generally obtained by measuring stabilized ground water levels at a number of different points within the site. Although ground water flows in only one direction, gradients may be influenced by flow in a non-horizontal direction, especially in ground water recharge or discharge areas. In addition, ground water may flow in different directions at different places beneath a site, and the direction could vary over time due to seasonal recharge, discharge from wells, and other causes.

Ground water surfaces are best determined by short-screened (one-to five-feet) piezometers. More broadly screened ground water monitoring wells are used to determine gradient, but cannot be used to determine the vertical components of the gradient. The gradient of ground water can be determined by the three-point problem solution, which is adequate to define a plane. If the water table surface is irregular, or if vertical components of flow are significant, three points may not be adequate to determine gradient or direction of flow. Four points, allowing the separate solution of four three-point problems, are necessary to indicate the nonplanar nature of the potentiometric surface. If each of the four solutions is the same, then the gradient and direction of flow are known. If the solutions are different, then further investigation is needed. Further investigation could include the installation of more piezometers, including piezometer clusters, and more monitoring wells. If ground water velocity is important (such as sites where leaks have occurred and the source stopped in the past), or if it is necessary to proceed to a detailed investigation, then slug tests to estimate hydraulic conductivity and physical soil tests to estimate porosity may be needed. In all cases, investigations relating to gradients and direction should be made or supervised by professionals with expertise in hydrogeology and hydrology.

Caution should be exercised in drilling through contaminated zones and confining layers to avoid creating vertical conduits for contaminant spread. It may be prudent not to drill through confining layers in certain areas, or to drill only partly into them to determine their effectiveness in retarding vertical movement of fuel contaminants.

All piezometers and monitoring wells piercing contaminated zones and confining layers should be adequately sealed, as should all abandoned boreholes and ground water monitoring wells. Evaluation of the specific measures needed to determine gradients, seal borings and abandon wells should be made by an accredited professional. A Registered Geologist (R.G.) or Certified Engineering Geologist (C.E.G.) usually performs this evaluation.

Instructions

In general, a minimum of four measurements of the potentiometric surface, allowing the independent solution of four different three-point problems, should be used to determine ground water gradient. In some areas the water table may be known well enough to confidently determine direction of flow of the first ground water without determining the potentiometric surface at four or more points. However, a registered professional (R.G., C.E.G., or equivalent) should sign a statement or obtain a written statement from an appropriate water district or regional board to that effect.

There are several ways to obtain the needed information. For example, four piezometers could be installed around the tank, gradient determined, and samples collected either from the piezometers or from ground water monitoring wells placed up-and down-gradient. As another example, three monitoring wells could be installed, gradient determined, and a fourth well installed in an appropriate location to help verify gradient. Piezometers or wells arranged in the configuration of a rectangle or equilateral triangle would be placed to increase the chance to be correctly positioned to obtain a down-gradient sample. If the site investigation reached Category 3 by means of Category 2 analysis, the borehole(s) used to collect soil samples may be converted to wells to save time and money.

6. Collect and Analyze Ground Water and Soil Samples

Explanation

Remedial action of sites with ground water pollution requires information on both ground water and subsurface soil. Soil analysis is required to determine if and how much soil is contaminated and whether the contamination at the site leached through overlying soil into the ground water. For example, it is common for more than one retail gas station to be located at the same intersection. A leak at one facility may pollute ground water beneath another facility. It is essential to identify the source of the ground water pollution to take appropriate cleanup action.

Ground water samples are collected and analyzed to determine: (1) the presence of free product, (2) concentrations of dissolved product, and (3) the extent of ground water pollution. In all cases, a Registered Geologist or Certified Engineering Geologist should supervise the placement of wells.

The proper placement and design of a ground water monitoring well is based upon the preceding characterization of the site geology and hydrology. The appropriate well is designed based upon the characteristics of the zone or strata to be monitored, keeping in mind the types of contaminants to be expected. A detailed discussion of the thought process applied to design of ground water investigations and ground water monitoring networks may be found in DHS (1986), Driscoll (1986), and U.S. EPA (1986).

The appropriate references are:

California Department of Health Services, May, 1986. The California Site Mitigation Decision Tree Manual.

Driscoll, F.G. (Principal Author and Editor), 1986. Ground Water and Wells. Johnson Division, St. Paul, Minnesota.

U. S. EPA, September, 1986. RCRA Ground Water Monitoring Technical Guidance Document.

Instructions

Ground water samples must be collected properly to determine if ground water is contaminated. A description of ground water sampling procedures and diagrams of piezometers and monitoring wells may be found in Appendices D and E respectively. Information on soil contamination is also required. If the site investigation reached Category 3 by means of Category 2 analysis, then information should already be available on the extent of soil contamination. If a Category 2 analysis was not performed, then the extent of any soil contamination, as well as ground water pollution, must be ascertained. Soil samples should be collected by following the instructions presented in Category 2, Step 2, page 32.

At sites where the excavation is in contact with ground water, samples should be collected from the side walls. At least two samples should be taken, one from each wall next to the tank ends, for tanks up to 10,000 gallons. At least four samples should be taken, two from each end wall, for tanks over 10,000 gallons or for tank clusters.

Soil samples should be quantitatively analyzed for BTX&E using EPA method 8020. Ground water samples should be quantitatively analyzed for BTX&E using EPA method 602. Analytical results should be reported as described in Category 3, Step 2 (page 51).

7. Is Free Product Present?

Ground water sampling will indicate whether or not free product is present. If free product is present, then the immediate risk of fire or explosion must be assessed. See Step 8 below. If free product is not present, then the site analysis proceeds to the assessment of ground water use (See Step 10).

8. Does Free Product Pose a Fire or Safety Hazard?

Free product must be removed from ground water if it poses a fire or safety hazard. This hazard may be immediate or long term. Free product could form a source of flammable vapors and lead to an explosion. Alternatively, it may be necessary to prevent future safety problems that may exist when digging or trenching occurs in the vadose zone above the free product. Finally, conduits (i.e., sewer or underground electrical lines), vaults or other confined space structures may, in the future, be installed in the area and could create an explosive situation. If no fire or safety hazard exists from the presence of free product in ground water, then free product removal depends on the assessment of ground water use. See Step 10 below.

9. Remove Free Product

Free product removal to eliminate fire and explosion risks comes under the jurisdiction of the local fire department. If the local agency overseeing site investigation is the fire department, then no additional coordination is needed. If the local agency overseeing site investigation is not the fire department, then the responsible fire department should be contacted to oversee or provide guidance for free product removal.

10. Consult With Regional Board to Assess Impact on Ground Water Use

Protection of water quality is primarily the responsibility of the nine regional boards and the State Board. The Department of Health Services enforces the federal Safe Drinking Water Act and sets drinking water standards (maximum contaminant levels, action levels, etc.). The State Board and Regional Boards' responsibility for water quality protection is expressed in the opening sections of Division 7 of the Water Code, Sections 13000 and 13001.

Chapter 1. Policy

"13000. The Legislature finds and declares that the people of the state have a primary interest in the conservation, control, and utilization of the water resources of the state, and that the quality of all the waters of the state shall be protected for use and enjoyment by the people of the state."

"The Legislature further finds and declares that activities and factors which may affect the quality of the waters of the state shall be regulated to attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible."

"The Legislature further finds and declares that the health, safety and welfare of the people of the state requires that there be a statewide program for the control of the quality of all the waters of the state; that the state must be prepared to exercise its full power and jurisdiction to protect the quality of waters in the state from degradation originating inside or outside the boundaries of the state; that the waters of the state are increasingly influenced by interbasin water development projects and other statewide considerations; that factors of precipitation, topography, population, recreation, agriculture, industry and economic development vary from region to region within the state; and that the statewide program for water quality control can be most effectively administered regionally, within a framework of statewide coordination and policy."

"13001. It is the intent of the Legislature that the state board and each regional board shall be the principal state agencies with primary responsibility for the coordination and control of water quality. The state board and regional boards in exercising any power granted in this division shall conform to and implement the policies of this chapter and shall, at all times, coordinate their respective activities so as to achieve a unified and effective water quality control program in this state."

Each Regional Board has adopted a Regional Water Quality Control Plan for its hydrogeologic area, pursuant to Section 13240 of the Water Code.

According to Section 13241 of the Water Code, each water quality control plan must consider the following factors:

(a) Past, present, and probable future beneficial uses of water.

(b) Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto.

(c) Water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area.

(d) Economic considerations.

(e) The need for developing housing within the region. (Amended by Stats. 1979, Ch. 947)."

Section 13242 states that:

"The program of implementation for achieving water quality objectives shall include, but not be limited to:

(a) A description of the nature of actions which are necessary to achieve the objectives, including recommendations for appropriate action by any entity, public or private.

(b) A time schedule for the actions to be taken.

(c) A description of surveillance to be undertaken to determine compliance with objectives."

To protect water quality, the State Board has adopted statewide plans such as the Ocean Plan. In addition, Section 13142 of the Water Code directs the Board to adopt water quality policy as needed. The State Board adopted a policy to protect the high quality of waters in 1968, which was reaffirmed in 1987. See Figures III-1 and III-2 (Appendix A). Although this policy was originally adopted to prevent loss of water quality in pristine areas, it has become the cornerstone of all water quality corrective and enforcement actions. The 1987 memo clarifies the broad applicability of the policy.

In assessing ground water use, regional boards review existing and potential beneficial uses of the aquifer, narrative and numerical objectives set to protect these uses and other information and guidance contained in the basin plan for the area, statewide plans for the area, statewide policy, regional board policy and guidance, any existing cleanup activities, and any pending enforcement action. Due to the many factors influencing a particular beneficial use assessment, it is impossible to generalize about the process in a meaningful way.

11. Consult With Regional Board and Responsible Agencies to Determine Required Remedial Action

The reader should refer to the lead agency for ground water cleanup for information pertaining to a specific site. If the lead agency is not the regional board and the ground water is threatened or affected, then the lead agency must consult with the appropriate regional board to ensure that anticipated remedial action is consistent with the applicable water quality control plan(s) and policies. A map showing the regional board boundaries and telephone numbers is included in Figure II-5 (page 62).

In addition, the reader should consult with other responsible agencies to determine what remedial action measures are needed to protect other resources which could be impacted.

12. Monitor Site to Ensure Effectiveness of Remedial Action

Ground water monitoring is required for sites with designated uses where free product or dissolved product is left in place. The frequency and duration of monitoring are determined by the regional board. These determinations are made on a case-by-case basis and depend upon site-specific conditions. Some regional boards require no less than monthly gradients and quarterly samplings. If contamination levels increase significantly during the first year, more frequent and additional monitoring is often required. After a history is established for the site showing that contamination levels have been stable or declining during the first year, then a gradual reduction in monitoring requirements can be allowed. Eventually, if pollution continues to be stable or decline, the monitoring requirements may be discontinued.

POSTSCRIPT

This concludes the field manual portion of this document. If the reader has questions regarding implementing this cleanup approach, he/she should contact Betty Moreno at the Division of Loans and Grants, State Water Resources Control Board, at (916) 739-2421.

FIGURE 11-5

STATE WATER RESOURCES CONTROL BOARD
P. O. Box 100, Sacramento, CA 95801

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARDS

NORTH COAST REGION (1)

1440 Guerneville Road
Santa Rosa, CA 95403
(707) 576-2220

SAN FRANCISCO BAY REGION (2)

1111 Jackson Street, Rm. 6040
Oakland, CA 94607
(415) 464-1255

CENTRAL COAST REGION (3)

1102-A Laurel Lane
San Luis Obispo, CA 93401
(805) 549-3147

LOS ANGELES REGION (4)

107 South Broadway, Rm. 4027
Los Angeles, CA 90012
(213) 620-4460

CENTRAL VALLEY REGION (5)

3443 Routier Road
Sacramento, CA 95827-3098
(916) 361-5600

Fresno Branch Office

3614 East Ashlan Ave.
Fresno, CA 93726
(209) 445-5116

Redding Branch Office

100 East Cypress Avenue
Redding, CA 96002
(916) 225-2045

LAHONTAN REGION (6)

2092 Lake Tahoe Boulevard
P. O. Box 9428
South Lake Tahoe, CA 95731
(916) 544-3481

Victorville Branch Office

15428 CIVIC DRIVE, SUITE 100
VICTORVILLE, CA 92392-2359

(619) 241-6583

COLORADO RIVER BASIN REGION (7)

73-271 Highway 111, Ste. 21
Palm Desert, CA 92260
(619) 346-7491

SANTA ANA REGION (8)

6809 Indiana Avenue, Ste. 200
Riverside, CA 92506
(714) 782-4130

SAN DIEGO REGION (9)

9771 Clairemont Mesa Blvd. Ste. B
San Diego, CA 92124
(619) 265-5114

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SECTION 111 - APPENDICES

TABLE OF CONTENTS

APPENDIX A

STATE BOARD'S STATEMENT OF POLICY WITH RESPECT TO MAINTAINING HIGH QUALITY OF WATERS IN CALIFORNIA

FIGURE 111-1

STATE WATER RESOURCES CONTROL BOARD

RESOLUTION NO. 68-16

STATEMENT OF POLICY WITH RESPECT TO MAINTAINING HIGH QUALITY OF WATERS IN CALIFORNIA

WHEREAS the California Legislature has declared that it is the policy of the State that the granting of permits and licenses for unappropriated water and the disposal of wastes into the waters of the State shall be so regulated as to achieve highest water quality consistent with maximum benefit to the people of the State and shall be controlled so as to promote the peace, health, safety and welfare of the people of the State; and

WHEREAS water quality control policies have been and are being adopted for waters of the State; and

WHEREAS the quality of some waters of the State is higher than that established by the adopted policies and it is the intent and purpose of this Board that such higher quality shall be maintained to the maximum extent possible consistent with the declaration of the Legislature;

NOW, THEREFORE, BE IT RESOLVED:

1. Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies.

2. Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters will be required to meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to assure that (a) a pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained.

3. In implementing this policy, the Secretary of the Interior will be kept advised and will be provided with such information as he will need to discharge his responsibilities under the Federal Water Pollution Control Act.

BE IT FURTHER RESOLVED that a copy of this resolution be forwarded to the Secretary of the Interior as part of California's water quality control policy submission.

CERTIFICATION

The undersigned, Executive Officer of the State Water Resources Control Board, does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Resources Control Board held on October 24, 1968.

Dated: October 28, 1968

Kerry W. Mulligan

Kerry W. Mulligan
Executive Officer
State Water Resources
Control Board

State of California

FIGURE 111-2

Memorandum

To : Jananne Sharpless
Secretary
Environmental Affairs Agency

Date : July 10, 1986

(COPY)

ORIGINAL SIGNED BY

W. DON MAUGHAN
Chairman

From : **STATE WATER RESOURCES CONTROL BOARD**

Subject: RECONFIRMATION OF STATE BOARD RESOLUTION NO. 68-16

State Board Resolution 68-16, the "Statement of Policy with Respect to Maintaining High Quality of Waters in California", was adopted as part of State policy for water quality control. It has also been adopted, as a water quality objective, in all 16 of the State's regional water quality control plans. Recent interest in Resolution 68-16 has caused the State Board to review that policy. It has been the cornerstone of this State's successful water program for almost 20 years. We see no reason to amend that policy and we will continue to follow it and make it part of the regional plans.

If and when the Board decides amendments are ripe, the State Board will follow the procedures set forth in the Porter-Cologne Water Quality Control Act. These procedures establish public review periods and public hearing requirements, and provide for the participation of the regional boards.

cc: Regional Board Chairs
Regional Board Executive Officers

bcc: Board Members
Executive Staff

APPENDIX B

FUEL LEAK DETECTION AND SCREENING METHODS

A. Observation

1. Sight: Staining or discoloration of soil, iridescence on water surface, hole in tank, leaking pipes. Highly qualitative, but useful as preliminary step in on-site evaluation.

2. Smell: Smell of motor fuel on-site or off-site in basements, sewage lines, utility systems, etc. Odor complaints often come from nearby residents or utility workers before leak is suspected or discovered. May include complaints about odor/taste of water supply. Highly qualitative and limited on-site because of background odors from daily operation. Primarily useful as an off-site alert mechanism. (See API reference #4419, Appendix M)

B. Physical Measurement

1. Precision/Pressure Test: Measures the ability of a system to hold pressure. The method has limitations because reproducibility of results from successive tests is often poor. Erratic readings may reflect changing temperature, barometric pressure, etc., and there may be difficulty in interpreting results from large tanks (>20,000 gallons). Failed test results should be followed by additional investigation and/or periodic monitoring.

2. Fuel Inventory: Unaccountable product loss based on volumetric measurements or volumetric meter receipts. The underground tank regulations [23 CAC, Section 2641 (c) (5) (B)] specify allowable daily variations for inventory reconciliation based on tank size. If these allowable daily variations are exceeded, then steps must be taken to identify whether or not a leak has occurred [23 CAC, Section 2644 (f)].

C. Direct-Reading Instruments for Surveying Fuel Vapor

Any reference contained herein to products and manufacturers is intended solely for purposes of illustration and is not meant as an endorsement of the manufacturer or the product by the State of California.

These instruments are portable and, for the most part, battery powered. Vapor is drawn in through a probe, analyzed, and the response read from a scale or digital readout. The instruments can be used to survey vapor in ambient air or by placing the probe close to contaminated soil to detect vapor coming directly from soil.

The field hydrocarbon vapor (HV) test uses the latter principle. Soil suspected of being contaminated is placed in a jar to about one third capacity. The jar is sealed and placed in an area of elevated temperatures (e.g., in the sun, heated room). After 15 minutes, the container is opened and either a PID, FID, or combustible gas indicator probe (see below) is immediately inserted into the headspace and the concentration of organic vapor is measured. The method incorporates several undesirable techniques, and vapor concentration measurements are commonly not in agreement with results from laboratory soil analysis at the site. An example is presented in Figure III-3 (page A7), where results of field detection with an HNU [Trade Name (HNU Systems, Inc.) of instrument used in this study] Portable Photoionization Detector (PID) and laboratory analysis show a good correlation between the presence of positive field vapor readings and purgeable and extractable hydrocarbon concentrations, but no direct relationship between field measurements and total purgeable or extractable hydrocarbons. However, it does offer a qualitative approach that may be used as an indicator of volatiles in soil.

1. Portable Photoionization Detector (PID): This uses an ultraviolet light detector to measure organic vapor and is especially sensitive to aromatics such as benzene, toluene, and xylene and in decreasing sensitivity to nonaromatic hydrocarbons and chlorinated hydrocarbon solvents. Care should be used in interpreting readings where mixed vapor is encountered because sensitivity may vary (see Table 3-1). The user should be familiar with the limitations of the calibration gas in use. This instrument is useful as a general field survey tool. It cannot be adapted for use as a gas chromatograph.

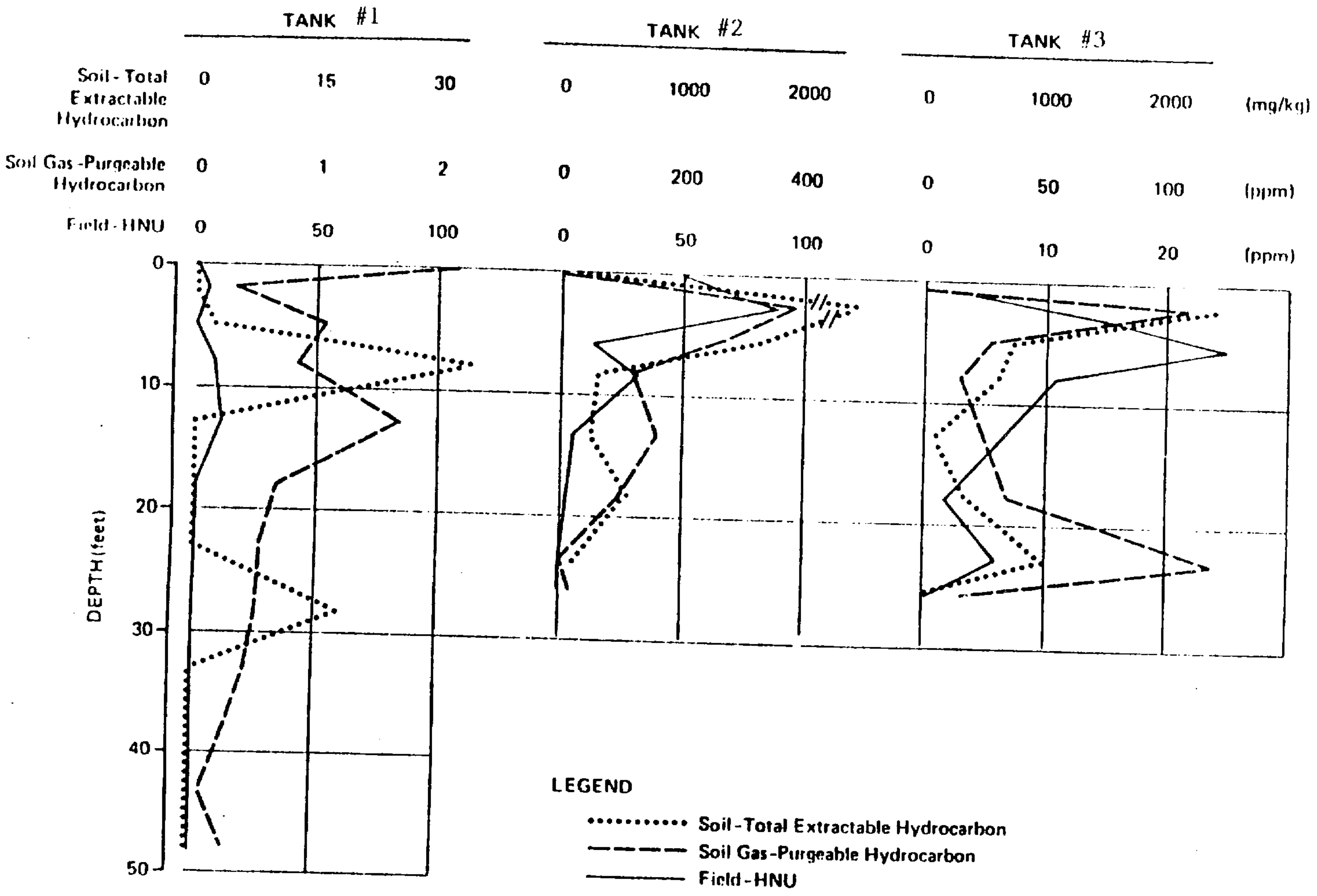


FIGURE 111-3 **VERTICAL HYDROCARBON PROFILES,**
Courtesy of Chevron Research Co.
Richmond, Ca.

TABLE 3-1

THE COMPARATIVE RESPONSE OF HAND-HELD PHOTOIONIZATION DETECTOR TO A SELECTED LIST OF CHEMICALS 1/

Chemical	Photoionization Response 9.5eV 2/ LAMP	 10.2eV LAMP	 11.7eV LAMP
Methane	NR 3/	NR	NR
Methanol	NR	NR	H 4/
Methyl Chloride	NR	NR	H
Ethanol	NR	L 5/	H
Ethylene dibromide (EDB)	NR	H	H
Trichloroethylene (TCE)	H	H	H
Acetylene	NR	NR	H
Hexane	NR	L	H
Benzene	H	H	H
Toluene	H	H	H
Xylene	H	H	H
Chlorobenzene	H	H	H
Ammonia	NR	L	H
Hydrogen Sulfide (H2S)	NR	H	H
Tetraethyl lead	H	H	H

1/ List of chemicals and the relative photoionization response reprinted (with modifications) courtesy of the manufacturer, HNU Systems, Inc.

2/ eV = electron volts (Ionization potential is measured in electron volts).

3/ NR = No Response

4/ H = High Response

5/ L = Low Response

2. Flame Ionization Detector (FID): This is an organic vapor analyzer (OVA) that is similar to a PID unit, but uses a hydrogen flame detector instead of ultraviolet light to measure gas vapor. The unit can operate as a limited field unit or as a gas chromatograph. The commonly used OVA is factory-calibrated to methane. Therefore, readings can only be reported relative to the methane standard used. In the field survey mode, the FID reflects the total concentration of fuel vapors present.

3. Colorimetric Indicator Tube: Glass tubes filled with reagent material that will react quickly with gas vapor. They are precalibrated for easy reading in ppm or in percent concentration. A measured volume of air is drawn into the tube with a small bellows or syringe-type pump. If the vapor reacts with the reagent material, a readily observable color change occurs in the tube. The length of the color change on the precalibrated scale corresponds to the contaminant concentration. This is a semiquantitative measurement. These are simple to operate and moderate in cost. The user should be aware that response may vary among tube suppliers and that tubes must be properly stored to avoid contamination.

4. Combustible Gas Indicator (explosivity meter): Detects gas vapor in air and indicates whether the test atmosphere contains a flammable level of gas vapor. Instrument sensitivity is, in general, limited to a calibrated gas concentration of >100 ppm. The presence of certain chemicals such as tetraethyl/tetramethyllead and chlorinated hydrocarbons can damage the filament on commonly used "hot wire" models. Combustion indicators do not provide accurate measurements under deficient oxygen conditions. This is particularly critical in closed spaces.

5. Oxygen Meter: Measures oxygen concentration in ambient air and supplements the combustible gas indicator, particularly in confined spaces. It does not detect fuel hydrocarbons, but does show if an area contains enough oxygen to allow normal breathing.

6. Infrared Spectrophotometer (IR): Measures concentration of vapor in air. The instrument has limited field application because it was designed primarily for industrial hygiene work in factories or other enclosed work spaces.

D. Gas Chromatography (GC): This procedure provides a method for analyzing fuel hydrocarbons in water and soil. Gas chromatography, while being quantitatively accurate, involves assumptions regarding the identities of compounds detected. A technique used to minimize these assumptions is called Second Column Confirmation. This involves a second analysis primarily using a chromatographic column different from the first column that was used. Second Column Confirmation is used to confirm positive findings. Unlike previous methods cited, gas chromatography usually requires sample preparation prior to analysis. Two GC detectors are used for identification of motor fuel components:

1. PID: Commonly used for detection of BTX&E.
2. FID: This method is used for total petroleum hydrocarbon (TPH) analysis for both gasoline and diesel.

These detection methods are identical to those discussed for direct reading PID and FID units with the exception that operating temperatures are controlled in GC analysis, and mixtures of chemicals can be separated and identified individually. In GC analysis, the precision and accuracy of the analytical method is known; therefore, these procedures are qualitative and quantitative. An analysis by GC usually requires transport of samples to a laboratory. Detection of fuel products is at the low ppb range for water and ppm range for soil. Examples of chromatograms from analysis of gasoline and diesel are presented in Figures III-4 and III-5

An analysis of the additives ethylene dichloride and ethylene dibromide requires use of a GC equipped with an electroconductivity detector (by the DHS-recommended method).

Where verification of GC analysis is required, gas chromatography/mass spectrometry (GC/MS) must be requested. This operation is an additional cost.

E. Atomic Absorption Spectrometry (AA): This is a qualitative and quantitative method for analysis of metals (tetraethyl/tetramethyllead). Detection is at the low ppb range for water and ppm range for soil. The procedure reports both inorganic and organic lead in the sample as total lead. (A method that detects organic lead is presented in Appendix D.)

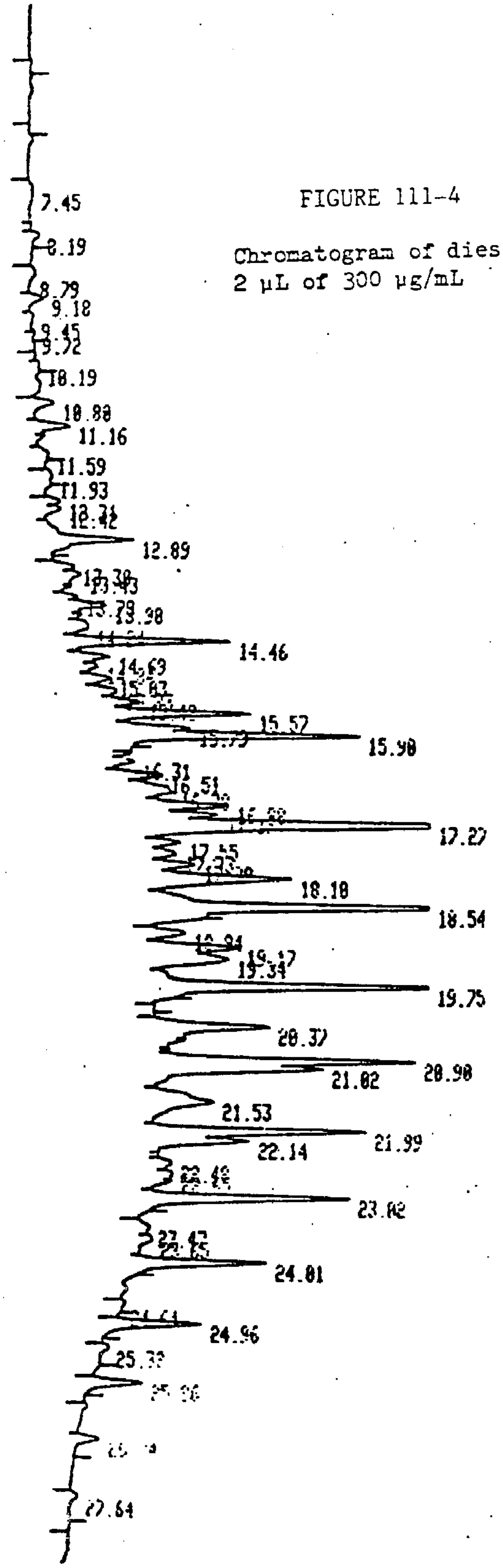


FIGURE 111-4

Chromatogram of diesel.
2 µL of 300 µg/mL

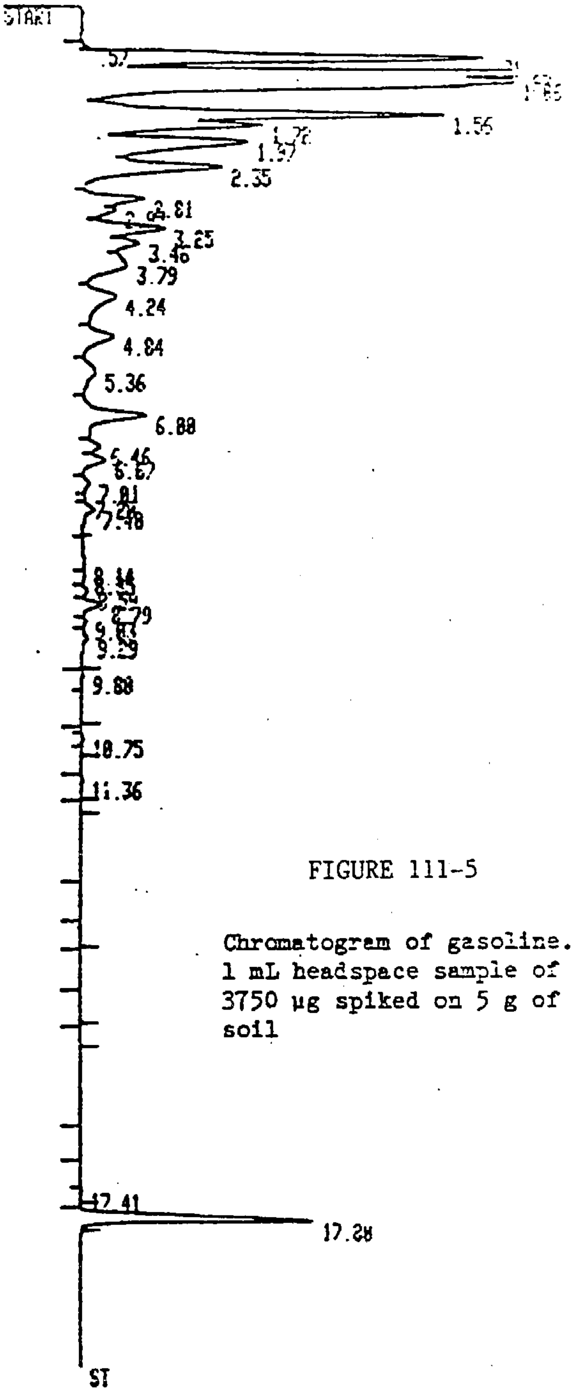


FIGURE 111-5

Chromatogram of gasoline.
1 mL headspace sample of
3750 µg spiked on 5 g of
soil

APPENDIX C

SAMPLE COLLECTION AND TRANSPORT

A. Sample Collection

1. Field Notebook

The field investigator should keep a field notebook (preferably bound with pages numbered) to record sample collection procedures, dates, laboratory identification, sample collection location, and the name of the sampler. This is important for later recall or legal challenge.

2. Soil Samples

a. Hydrocarbons: Soil samples collected from a backhoe, the ground or a soil coring device, should be collected in a thin-walled stainless steel or brass cylinder at least three inches long by one inch in diameter that has been prepared by the laboratory doing the analysis or the project consultant (cylinders can be made to fit inside the preferred split-barrel core sampler). About one inch of soil should be removed from the immediate surface area where the sample is to be taken and the cylinder then pounded into the soil with a wooden mallet. No headspace should be present in the cylinder once the sample is collected. When the sample is collected, each end of the cylinder should be covered with aluminum foil and then capped with a polyethylene lid, taped, and labeled. The sample should then be immediately placed in an ice chest containing dry ice and kept cold (4°C) for delivery to the laboratory. Care should be taken throughout to avoid contamination of both the inside and outside of the cylinder and its contents (1).

Sample homogenization should not be performed on samples intended for volatile and semivolatile organic analysis since the mechanical action of mixing exposes a larger surface area of the contaminated soils and other solids in the samples to the air, thus increasing the total amount of volatilization.

Samples should be kept cold (4°C) at the laboratory until they are analyzed. Holding time should not exceed 14 days from the time of collection. If necessary, cold soil cores should be removed from the cylinders by spot heating the cylinder and immediately extruding the sample (or a portion of it). A portion of the cold sample should be removed and prepared for analysis according to approved EPA methods.

In situations where the above procedure is inappropriate, i.e. semi-solid samples, glass vials (properly prepared by contract laboratory or consultant) with Teflon seal and screw cap should be used, and maintained at 4°C until analysis.

b. Organic lead: Tetraethyl/tetramethyllead are volatile: therefore, soil samples should be collected in cylinders and kept cold as described for volatile hydrocarbons above

c. Shipping Samples: Where commercial shippers are involved, dry ice may present Department of Transportation (DOT) shipping problems and "blue ice" may have to be substituted.

3. Water Samples

a. Free floating product (from a well): Sampling of free floating product on the surface of ground water should not be performed until the well has been allowed to stabilize for at least 24 hours after development or other withdrawal procedure. A sample should be collected that is indicative of the thickness of floating product within the monitoring well. This may be accomplished by the use of a clear, acrylic bailer designed to collect a liquid sample where free product and ground water meet. A graduated scale on the bailer is helpful for determining the thickness of free product. Samples should be field-inspected for the presence of odor and/or sheen in addition to the above evaluation.

Electronic measuring devices also are available for determining the thickness of the hydrocarbon layer floating on ground water.

b. Dissolved product (from a well): If free product is detected, analysis of water for dissolved product should be conducted after the free product has been substantially removed from the well. Before collecting a water sample, a well should be purged until temperature, conductivity and pH stabilize. Often, this will require removal of four or more well volumes by bailing or pumping. Once well volumes are removed and well water is stabilized, a sample can be taken after the water level approaches 80 percent of its initial level. Where water level recovery is slow, the sample can be collected after stabilization is achieved.

Ground water samples should be collected in a manner which reduces or eliminates the possibility of loss of volatile constituents from the sample. For collecting samples, a gas-actuated positive displacement pump or a submersible pump is preferred. A Teflon or stainless steel bailer is acceptable. Peristaltic pumps or airlift pumps should not be used.

Cross-contamination from transferring pumps (or bailers) from well to well can occur and should be avoided by thorough cleaning between sampling episodes. Dedicated (i.e.. permanent installation) well pumps, while expensive, are often cost effective in the long term and ensure data reliability relative to cross-contamination. If transfer of equipment is necessary, sampling should proceed from the least contaminated to the most contaminated well, if the latter information is available before sample collection.

Water samples should be collected in vials or containers specifically designed to prevent loss of volatile constituents from the sample. These vials should be provided by an analytical laboratory, and preferably, the laboratory conducting the analysis. No headspace should be present in the sample container once the container has been capped. This can be checked by inverting the bottle, once the sample is collected, and looking for bubbles. Sometimes it is not possible to collect a sample without air bubbles, particularly if water is aerated. In these cases, the investigator should record the problem and account for probable error. Cooling samples may also produce headspace (bubbles), but these will disappear once the sample is warmed for analysis.

Samples should be placed in an ice chest maintained at 4°C with blue ice (care should be taken to prevent freezing of the water and bursting of the glass vial). A thermometer with a protected bulb should be carried in each ice chest.

c. Surface water: Grab samples should be collected in appropriate glass containers supplied by the laboratory. The sample should be collected in such a manner that air bubbles are not entrapped. Semisolid samples should be collected the same way. The collected samples should be refrigerated (blue ice, 4°C) for transport and analyzed within 7 days of collection (14 days with preservatives).

B. Guidelines for Handling Samples (Presented in Tables 3-2 and 3-3)

TABLE 3-2

REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES FOR WATER SAMPLES 1/

Test	Container 2/	Preservation	Maximum Holding Time 3/
Purgeable aromatic hydrocarbons (BTX&E) Method 8020 or 602	G, Teflon-lined septum	Cool, 4°C, 0.008% $Na_2S_2O_3$ 4/ HCl to pH2 5/	Analyze within 7 days (max. 14 days with preservative)
Total petroleum hydrocarbons as gasoline	G	Cool, 4°C 0.008% $Na_2S_2O_3$ 4/ HCl to pH2 5/	Analyze as soon as possible. (max. 14 days)
Total petroleum hydrocarbons -- diesel fuel oil	G	Cool, 4°C	14 days; analyze extract within 40 days

1/ Modified from 40 Code of Federal Regulations (CFR), Part 136, Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act.

2/ Glass (G).

3/ Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for a longer period only if the collector or laboratory has data on file to show that the specific types of samples under study are stable for the longer time. Some samples may not be stable for the maximum time period given in the table.

4/ Should only be used in the presence of residual chlorine.

5/ Sample receiving no pH adjustment must be analyzed within seven days of sampling. Sample vials containing hydrochloric acid (HCL) as a preservative should be handled with caution to avoid eye and skin contact

TABLE 3-3

HOLDING TIME FOR SOIL SAMPLES 1/

Analyte	Holding Time for Soil
Benzene, toluene, xylenes	Analyze as soon as possible (maximum 14 days)
Total Petroleum Hydrocarbons, as gasoline	Analyze as soon as possible (maximum 14 days)
Total Petroleum Hydrocarbons, as diesel	Extract within 14 days, analyze extract within 40 days

1/ Results from samples not meeting the listed holding times should be considered minimum values. That is, the actual concentration is equal to or greater than the concentration determined after the holding time has expired.

APPENDIX D

ANALYTICAL PROCEDURES

A. Analytical Methods

Table 3-4 (page A19) summarizes common analytical procedures for soil and water analysis of fuel products. The Department of Health Services may approve an alternate analytical method which has at least equivalent detection limits, precision, and accuracy as the referenced methods. For example, a cryogenic gas chromatography/mass spectrometry (GC/MS) system may be used instead of a gas chromatography (GC) system, provided that the GC/MS system can produce data which are equal to or better than data provided by the referenced GC system in terms of detection limits, precision and accuracy for an identical sample matrix.

Total Petroleum Hydrocarbons (TPH) arising from gasoline or diesel and total organic lead can be analyzed by the attached Department of Health Services (DHS) methods. The investigator should alert the laboratories to the procedures given in Table 3-4 and supply the laboratories with copies of the TPH and total organic lead methods, if necessary.

TABLE 3-4 - SUMMARY OF ANALYTICAL PROCEDURES

	Substance to be Analyzed	Analytical Method 3/	Reference
1.	Gasoline:		
	a. Benzene, toluene, xylene, ethylbenzene (aromatic volatile organics)	EPA 8020 (soil)	2
		EPA 602 (water)	3,5
	b. Total Petroleum Hydrocarbons	DHS (recommended procedure)	See text
	c. Halogenated volatile organics, including 1,2-dibromoethane (EDB) 1,2-dichloroethane (EDC)	EPA 8010 (soil)	2
		EPA 601 (water)	3,5
	EDB	DHS extraction method 1/	6
2.	Diesel:		
	a. Total Petroleum Hydrocarbons	DHS (recommended procedure)	See text
	b. Total Recoverable Petroleum Hydrocarbons (TRPH) 2/	EPA 418.1	4
3.	Organic lead:	DHS	See text
4.	Ignitability: Flash Point	EPA 1010, 1020	2

1/ This liquid/liquid extraction procedure for water samples was developed by DHS and provides a means for detecting EDB at a lower concentration (parts per trillion) than does EPA method 8010 (parts per billion). The procedure was developed to detect EDB in ground water as part of the AB 1803 program.

2/ This relatively quick analytical procedure measures recoverable petroleum hydrocarbons, including oil and grease. It is applicable for measuring light fuel fractions, but loses approximately half of any gasoline present (ref.4). The method costs less than the recommended procedure and is useful primarily as a survey tool.

3/ Other analytical methods are available, for example, some laboratories use a modified EPA method 8015 that detects volatile, non-halogenated hydrocarbons for TPH analysis. The investigator should check with the laboratory (or consultant) to ensure that the analytical method used will provide acceptable data.

B. Detection Limits for LUFT Investigations

Minimum detection limits for key analytes are listed in Table 3-5 below. The detection limits for benzene, toluene, and xylene are consistent with the experience of several commercial laboratories under optimal conditions. The detection limits for benzene, toluene, and xylene in soil assume the direct purging of a soil-water mixture and subsequent gas chromatography-photoionization detection (GC-PID). Lower detection limits are achievable with available technology by using modifications of reference methods, taking a larger sample or using additional concentration techniques. Detection limits may be significantly higher in samples with interfering organics or matrix effects. The readily obtainable 0.3 ppm detection limit cited under Category 1, Step 5, takes into account potential sample interferences.

TABLE 3-5

DETECTION LIMITS FOR COMMONLY ANALYZED FUEL PRODUCTS

Analyte	Water µg/l	Soil µg/kg	Method
Benzene	0.3	5	EPA 602, 8020
Toluene	0.3	5	EPA 602, 8020
Xylenes, total	0.6	15	EPA 602, 8020
Total Petroleum Hydrocarbons	500.0	10,000	DHS: GC-FID

C. Recommended DHS Analytical Methods

Total Petroleum Hydrocarbons (TPH) Analysis -- Gasoline and Diesel

1. Scope and Application

   a. This method is for the determination of gasoline and diesel in contaminated ground water, sludges, and soil.

   b. This method is recommended for use by, or under the supervision of, analysts experienced in the operation of GC and in the interpretation of chromatograms.

2. Summary of Method

a. This method involves the determination of volatile hydrocarbons (gasoline) by the headspace method (EPA 5020) or the purge and trap method (EPA 5030) (2) and the determination of semivolatile organics (diesel) by the extraction method. A sample, after headspace, purge and trap, or extraction treatment, is injected into a GC, and compounds in the GC effluent are detected by an FID. Blanks, duplicates and spikes must be analyzed at a minimum of once for every batch of samples (5) or each type of matrix or every 20 samples whichever is more frequent.

Because of the greater imprecision of the headspace sample preparation method, it generally yields lower analytic values than the other two methods. Headspace analysis is probably more useful in the screening phases of a contamination investigation than in those phases which require more reliable preparation methods, such as confirmation sampling.

b. The sensitivity of this method usually depends on the level of interference rather than on instrument limitations. Table 3-6 below lists the limits of detection established by the Department of Health Services in the absence of interferences for water and soil samples.

TABLE 3-6

TPH METHOD DETECTION LIMITS

Parameter	Matrix	Extraction Method	Headspace Method
Gasoline	Aqueous	0.5 mg/l	5.0 mg/l
	Soil	10.0 mg/kg	5.0 mg/kg
Diesel	Aqueous	0.5 mg/l	
	Soil	10.0 mg/kg	

3. Interferences

a. Solvents, reagents, glassware, and other sample-processing hardware must be demonstrated to be free from interferences under the conditions of the analysis by running method blanks.

b. Before processing any samples, the analyst should demonstrate daily, through the analysis of a solvent blank, that the entire system is interference-free.

4. Apparatus and Materials

a. Gas-tight syringe: One cubic centimeter (cc) with chromatographic needles.

b. Vial with cap: 40 milliliter (ml) capacity screw cap (Pierce number 13075 or equivalent). Detergent wash, rinse with tap and distilled deionized water, and dry at 105°C before use.

c. Septum: Teflon-faced silicone (Pierce number 12722 or equivalent). Detergent wash, rinse with tap and distilled deionized water, and dry at 105°C for 30 minutes before use

d. Separatory funnel: 2-liter with Teflon stopcock.

e. Kuderna-Danish (K-D) apparatus.

f. Boiling chips: Solvent extracted approximately 10/40 mesh.

g. Water bath: Heated, with concentric ring cover, capable of temperature control. The bath should be used in a hood.

h. GC: Analytical system complete with programmable GC suitable for on-column injection and all required accessories, including FID, column supplies, recorder, and gases. A data system for measuring peak area is recommended.

i GC column: 6 feet by 1/8 inch ID glass column packed with 5% SP-2100 on Supelcoport 60/80 mesh.

j. Detector: FID.

k. Microsyringes: 10 µl, 100 µl, 200 µl.

l. Erlenmeyer flask: Pyrex, 250 ml capacity with a screw cap.

m. Mechanical shaker.

5. Reagents

   a. Stock diesel standard solutions: Prepare a commercial diesel standard in carbon disulfide. Place 9 ml of CS_2 into a 10 ml glass-stoppered volumetric flask. Allow to stand for a few minutes. Weigh the flask to the nearest 0.1 mg. Using a 100 μl syringe, immediately add an amount of diesel to the flask, then reweigh. Be sure that the liquid falls directly into the CS_2 without contacting the neck of the flask. Dilute to volume, stopper, mix by inverting the flask several times. Calculate the concentration in μg/l from the net gain in weight. Secondary working standards can be prepared from the stock standards.

   b. Stock gasoline standard solutions: Gasoline stock standards can be prepared as above using commercial gasoline as standard in dodecane.

   c. Sodium sulfate, anhydrous, ACS, granular.

   d. Carbon disulfide, glass distilled, high purity. Another solvent such as ethyl acetate or methylene chloride may be used provided that the solvent can extract the petroleum hydrocarbons and does not interfere with the resulting gas chromatogram of the TPH. This must be demonstrated by spike and recovery prior to the analysis of samples.

   e. Dodecane, purified.

6. Procedures

   a. Organic Liquid

      Organic liquid can be analyzed by dissolving a known amount of sample into a certain volume of carbon disulfide in a volumetric flask.

   b. Water

      (1) Transfer one liter of sample to the two liter separatory funnel.

(2) Add 60 ml of solvent to the separatory funnel.

(3) Seal and shake the funnel for 60 seconds with periodic venting to release vapor pressure.

(4) Allow the phases to separate for minimum of 10 minutes. If emulsion occurs, the analyst must employ mechanical techniques to complete the phase separation.

(5) Collect the extract and repeat the extraction two more times using fresh portions of solvent.

(6) Combine three extracts and dry by passing through a column of anhydrous sodium sulfate.

(7) Collect the dried extract in a K.D evaporative concentrator equipped with a 10 ml collection ampule.

(8) Add one or two clean boiling chips to the flask and attach a three-ball Snyder column. Pre-wet the Snyder column by adding 1 ml of solvent to the top. Place the K-D apparatus on a steam or hot-water bath. Adjust the water temperature as required to complete the concentration in 15 to 20 minutes. When the volume of liquid reaches 1 ml, remove the K-D apparatus and allow it to drain for at least 10 minutes while cooling.

(9) Rinse the K-D apparatus with a small volume of solvent. Adjust the sample volume to 5 ml with the solvent to be used in instrument analyses.

c. Soil and Sludges

(1) Weigh 20.0 gram (g) sample into a 250 ml screw cap Erlenmeyer flask. Add 80 ml of solvent.

(2) Cap the flask and shake on a mechanical shaker for at least four hours.

(3) After the extraction is completed, filter the extract and dry it by passing through a column of anhydrous sodium sulfate.

(4) Collect the dried extract in K.D flask, fitted with a 10 ml concentrator tube and a three-ball Snyder column. Wash the extractor flask and the sodium sulfate with a portion of carbon disulfide and collect it into the K.D flask.

(5) Add one or two clean boiling chips and concentrate the extract to 5 ml as discussed in steps (8) and (9) above.

d. GC Conditions

The recommended GC column and operating conditions are:

Column: 6 feet by 1/8 inch ID glass column packed with 5% SP-2100 on Supelcoport, 60/80 mesh with nitrogen carrier gas at 20 ml/minute flow rate. Column temperature is set at 40°C at the time of injection, hold for 4 minutes, and programed at 10°C/minute to a final temperature of 265°C for 10 minutes.

e. Calibration

(1) Establish GC operating parameters as specified in d. above. By injecting secondary standards, adjust the sensitivity of the analytical system for the analysis of gasoline and diesel in environmental samples. Detection limits for the extraction method and the headspace method are listed in Table 3-6 (page A21). Calibrate the chromatographic system with the external standard technique. At least three concentration levels should be used for the preparation of the calibration curve. One of the external standards should be at a concentration near, but above, the method detection limit. The other standard should correspond to the expected range of concentrations found in real samples or should define the working range of the detector.

(2) Using injections of 2 to 5 μl of each calibration standard, tabulate total peak height or area responses against the mass injected. The results can be used to prepare a calibration curve for gasoline and diesel.

(3) The working calibration curve must be verified on each working day by the measurement of one or more calibration standards. If the response varies from the predicted response by more than ten percent, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve must be prepared.

f. Analysis of Samples

(1) Extract

(a) Inject 2 to 5 µl of the sample extract using the solvent flush technique. Record the volume injected to the nearest 0.05 µl, and the resulting total peak areas.

(b) If the total peak areas exceed the linear range of the system, dilute the extract and reanalyze.

(2) Headspace Method [Note: Purge and trap (EPA 5030) may be used instead of headspace.]

(a) Place 20 g (ml) each of the waste sample into three separate 40 ml septum seal vials.

(b) Inject into one sample vial through the septum 200 µl of the gasoline standard in dodecane (concentration 7,500 µg/ml). Label this "spike".

(c) Inject into a separate (empty) 40 ml septum seal vial 200 µl of the same standard. Label this "standard".

(d) Place the sample, spike, and standard vials into a 90°C water bath for one hour. Store the remaining sample vial at 4°C for possible future analysis.

(e) While maintaining the vials at 90°C, withdraw 1 ml of the headspace gas with a gas-tight syringe and analyze by injecting into a GC.

(f) Analyze the standard and adjust instrument sensitivity to give minimum response of at least two times the background. Record and sum up all peak areas of the gasoline standard.

(g) Analyze the spike sample in the same manner. Record all peak areas.

(h) Analyze the undosed sample as in (g) above.

(i) Small sample size should be used if the concentration is found to be outside the concentration range of the instrument.

g. Standard laboratory quality control practices should be used with this method.

Determination of Organic Lead -- DHS Method

1. Discussion

Organic lead compounds constitute the largest single industrial application of organo-metallic chemistry. Estimates indicate that about 1,450 organic lead compounds were known in 1968, and the number has increased with synthesis of about 130 new compounds each year. The widespread presence of toxic, volatile, lipophilic organic lead compounds in the environment can lead to serious public health effects and damage to the aquatic biota. With the phasing out of leaded fuels, substantial amounts of lead compounds from petroleum sludges are being discharged into waste streams. There is also evidence to suggest that the more toxic organic leads such as tetramethyllead can be synthesized from lead salts and simple chemical reagents in aqueous solutions.

Caution: Some organic lead compounds are volatile and toxic. Process the samples in a well-ventilated hood.

2. Scope

The method describes the determination of organic lead compounds in various types of hazardous material samples. In this method, a rapid organic extraction technique is applied to separate the organic lead from a matrix with xylene, followed by reaction with 1% Aliquot 336/MIBK on 1_2 solution. The extract is then analyzed by a flame atomic absorption spectrophotometer. <u>The detection limit for organic lead is: soil 0.5 mg/kg; water 0.1 mg/l</u>

3. Reagents

   a. (MIBK) methyl-isobutyl ketone (4-methyl-2-pentanone).

   b. Iodine solution: Weigh 3.0 g of I_2 and dissolve and dilute to 100 ml with benzene. Store in brown bottle.

   c. Aliquot 336 (tri-capryl methyl ammonium chloride), available from McKesson Company, Minneapolis, Minnesota.

      10% V/V Aliquot 336/MIBK
      1% V/V Aliquot 336/MIBK

   d. Xylene.

   e. $PbCl_2$ -- Lead chloride

      (1) Stock $PbCI_2$ solution. Dissolve 0.3356 g $PbCI_2$ previously dried at 105°C for 3 hours in 10% Aliquot 336 in MIBK solution and dilute to 250 ml. Store in brown bottle. This solution contains 1,000 µg/ml of Pb.

      (2) Preparation of intermediate Pb standard: Pipet 10 ml of the stock solution (1,000 µg/ml Pb) and dilute to 100 ml with xylene/MIBK solution (40% xylene).

   f. Sodium sulfate (Na_2SO_4), anhydrous, crystals.

4. Apparatus

   a. Erlenmeyer flask with ground glass stopper, 250 ml.

   b. Mechanical shaker.

   c. Filter funnel and paper (Whatman No. 40 or equivalent).

   d. Flame atomic absorption spectrophotometer and recorder or integrator.

   e. Lead hollow cathode or electrodeless discharge lamp.

5. Procedure

   a. Sludges, sediments, and soils: Weigh out to the nearest 0.1 g about 50 g of homogenized sample into an Erlenmeyer flask. Add 100 ml xylene. Stopper the flask and shake it for 1/2 hour on a mechanical shaker. Filter the extract through filter paper and anhydrous sodium sulfate

   b. Add 20 ml of MIBK to a 50 ml volumetric flask.

   c. Pipet 20.0 ml of the xylene extract (Step 5a) into the flask and mix.

   d. Pipet 0.1 ml of I_2 solution into the flask and mix for about one minute.

   e. Pipet 5 ml of 1% Aliquot 336 in MIBK and mix.

   f. Dilute to volume with MIBK and mix.

6. Standard and Blank Preparation

   Prepare appropriate working standards and blank from 100 μg/ml Pb standard.

   a. Add approximately 20 ml of xylene to 50 ml volumetric flask. Pipet the correct amount of the 100 μg/ml Pb standard into the flask to prepare the right standard.

   b. Add immediately 0.1 ml of I_2 solution and mix well.

   c. Add 5 ml of 1% Aliquot 336/MIBK and mix well.

   d. Dilute to volume with MIBK and mix well.

   e. Blank xylene/MIBK (40% xylene) should be treated as the working standard solutions.

7. Analysis

   a. Set up the AA according to the manufacturer's instructions. Use background correction to decrease broad band absorption interference.

   b. Aspirate H_2O into the flame and adjust the acetylene flow to 8.5 l/min and the air flow to 25 l/min.

c. Aspirate MIBK containing 40% xylene into the flame.

d. Reduce the acetylene flow to about 4.8 l/min and make fine adjustments in the acetylene flow to produce an even flame with no yellow luminescence to obtain optimum conditions.

e. Aspirate into the flame blank, working standards, and sample to measure the absorbencies. Estimate the concentrations of organic lead in sample.

8. Calculations

Solids:

$$\frac{100\text{ ml}}{50\text{g}} \times \frac{50\text{ ml}}{20\text{ ml}} \times \frac{\mu\text{g/l}}{1000\text{ ml/l}} \times F = \mu\text{g/g organic Pb calculated as Pb.}$$

where F = dilution factor.

E. Quality Assurance (QA) and Quality Control (QC)

1. Definition

Quality Assurance: Systematic procedures that are used to provide assurance to a producer or user of information that defined standards of quality were met. QA covers field and laboratory performance, i.e., the quality control procedures that have been followed.

Quality Control: The activities that are used to implement the quality assurance plan. Quality includes adequacy of the methods employed, reliability of the results, and cost effectiveness.

2. Chain of Custody

A Chain of Custody Record is the disposition of a sample from collection to laboratory delivery. A Chain of Custody Record should be made out after samples are collected and signed by individuals collecting, relinquishing, and receiving samples. See Figure III-6 (page A33) for an example of a U. S. EPA Chain of Custody form.

3. Laboratory Certification

All soil and water samples should be analyzed by a DHS-certified laboratory. Two certification programs exist in California and both are administered by DHS. Additional information can be obtained from the addresses listed:

- Hazardous Materials Laboratory Certification Program

  California Department of Health Services
  Hazardous Materials Laboratory
  2151 Berkeley Way, Room 234
  Berkeley, CA 94704
  (415) 540-3003

- Drinking Water Laboratory Certification

  California Department of Health Services
  Sanitation and Radiation Laboratory
  2151 Berkeley Way, Room 465
  Berkeley, CA 94704
  (415) 540-2201

4. QA Project Plan: This is a plan that outlines objectives, operational procedures, and the means for assuring how data of known and acceptable quality can be obtained. Where major projects are involved in remedial action, a plan for a performance audit (field and laboratory operations) and corrective action may be needed.

5. Number of Samples to Collect: The number of samples required relates directly to project objectives and the level of data reliability desired. The following are minimal recommendations and do not ensure that representative or statistically valid sampling of a site has been achieved.

- Soil -- Tank excavation hole: At least two samples collected immediately after the tank is removed. This number should be increased for more accurate representation in very large excavations.

- Soil background: Average of three samples.

- Soil: where >10 samples are to be collected at the same site, five percent duplicates should be collected and analyzed.
- Water: Volatile organic analysis (VOA): All VOA samples should be collected in duplicate. One

sample should by analyzed. The other acts as a backup in case a vial is broken or re-analysis is necessary.

- Water: Non-VOA analysis (0.5-1-liter volume): One sample.

- QC for remedial action should be designed to meet clean-up/closure objectives for the particular site. The basic principles outlined should be applied.

A general guide for field QC samples is presented in Table 3-7 (page A34).

6. Special Split-Sample Collection Instructions (7)

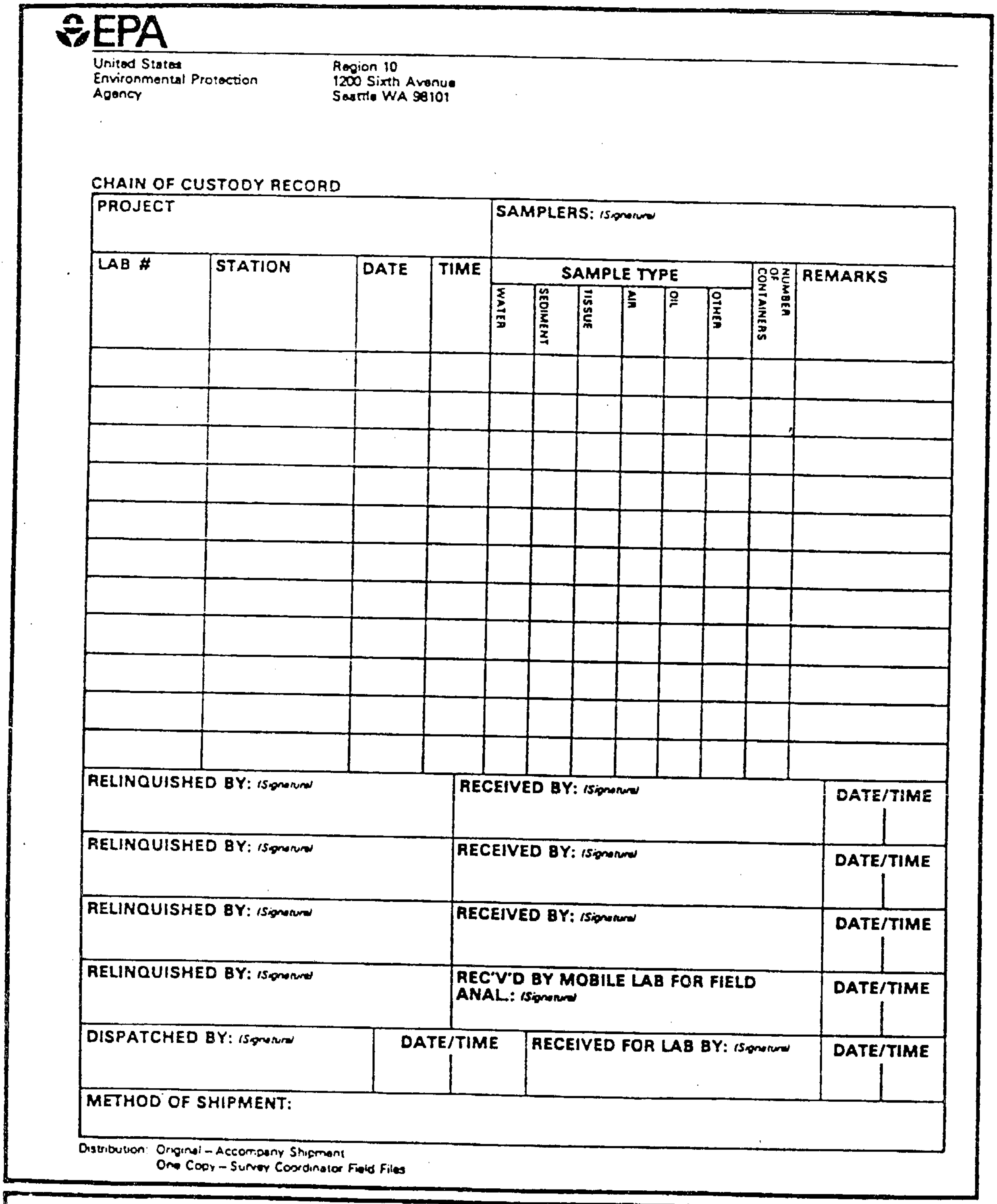
   a. Purgeable organics or VOAs: Individual samples are taken rapidly in succession in the specified containers. The individual samples may then be analyzed in replicate. With the exception of samples collected in a bailer, VOA splits should not be collected by pouring from one container into another.

   b. Nonvolatile hydrophobic organics (e.g., PCBs): Due to the hydrophobic character of these compounds, it is not practical to split an aqueous sample. Consequently, it is recommended that replicates be run on the extract only. That is, when the analytical procedure for a hydrophobic organic is followed, the extract should be carried through in replicate through the column chromatography and analytical determinations.

   c. Other analyses: Samples are split into portions while the original sample container is agitated.

   d. Metals, except chromium VI and dissolved metals: When splitting samples for metal analyses, the sample must be acidified with nitric acid to pH <2 before dividing the sample. Acidification is especially critical if the sample is basic, in order to prevent precipitation of metallic hydroxides.

FIGURE 111-6



EPA

United States
Environmental Protection
Agency

Region 10
1200 Sixth Avenue
Seattle WA 98101

CHAIN OF CUSTODY RECORD

PROJECT

SAMPLERS: (Signature)

LAB #	STATION	DATE	TIME	SAMPLE TYPE						NUMBER OF CONTAINERS	REMARKS
				WATER	SEDIMENT	TISSUE	AIR	OIL	OTHER		

RELINQUISHED BY: (Signature)	RECEIVED BY: (Signature)	DATE/TIME
RELINQUISHED BY: (Signature)	RECEIVED BY: (Signature)	DATE/TIME
RELINQUISHED BY: (Signature)	RECEIVED BY: (Signature)	DATE/TIME
RELINQUISHED BY: (Signature)	REC'V'D BY MOBILE LAB FOR FIELD ANAL.: (Signature)	DATE/TIME

DISPATCHED BY: (Signature)	DATE/TIME	RECEIVED FOR LAB BY: (Signature)	DATE/TIME

METHOD OF SHIPMENT:

Distribution: Original – Accompany Shipment
One Copy – Survey Coordinator Field Files

U.S. EPA Chain of Custody Form

TABLE 3-7

A General Guide for Collection of Field QC Samples (7)

QC Sample	Description and Purpose	Number of QC Samples
Trip or Travel Blank (Mandatory for volatile organics)	A sample container filled in the laboratory with organic-free water and carried unopened during the sampling trip. It must be prepared by the laboratory supplying sample containers. It is used to identify contamination introduced from the originating laboratory. The trip blank remains with the collected samples and is analyzed along with the field samples to check residual contamination. Trip blanks are mandatory for volatile hydrocarbon analysis in water.	1. One per sample set. 2. Greater than 20 samples per set 5 percent trip blank analysis should be done. Statistical need and cost effectiveness should be considered where large numbers of samples are involved.
Field Blank (optional)	A sample container filled with organic-free water that is taken on the field trip. It is opened and exposed at the sampling site to detect contamination from air exposure. The water sample may be poured into appropriate containers to simulate actual sampling conditions. Contamination from air exposure can vary considerably from site to site therefore, the need for this sample should be evaluated relative to the sample situation. Reference material (i.e., chemically defined soil) can be used in lieu of organic-free water as dictated by the sampling needs.	1. One for each team per trip, or 2. One for each relevant sample type, or 3. One per day at a single site 4. The need for field blanks should be made relative to site specific conditions and sampling requirements.
Blind Sample (optional)	A sample whose composition or source is known to the submittee but not known by the person logging in samples or the analyst. It is submitted along with the regular field sample set. When both the anticipated sample composition and the blind status of the sample are not known to the analyst, the sample is called a "double blind" sample. A blind sample is used to check analytical performance and proficiency.	1. One per sample set up to 10 samples. 2. 10-14 samples: 5 percent blind sample analysis. >40 samples: Requirements should be based on the needs of the project.
Field Duplicate (optional except required for volatile analysis (VOA)	A second field sample collected identically to and immediately after the first sample. This provides a measure of analytical precision and second sample confirmation. It provides a means of determining random error when adequate numbers of duplicates are collected. Field duplicates may also be collected as splits. Duplicates can also serve as blind field samples.	1. The need to collect duplicates is determined by project objectives. 2. The number of sample duplicates required is determined by project objectives and QC requirements.
Split Sample 1/ (optional)	The goal in obtaining splits is to obtain subsamples that do not differ significantly from each other or from the original sample. These are used to compare performance between/among laboratories.	1. 10 percent 2. Need for these is determined by project objectives.

1/ Split sample collection has critical limitations. [See special instructions under E-6, Quality Assurance (QA) Quality Control (QC), page 76].

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2. U. S. EPA. 1986. Test Methods for Evaluating Solid Waste; Physical/Chemical Methods. SW-846, Third Edition. Office of Solid Waste and Emergency Response, U. S. EPA, Washington, D.C.

3. U. S. EPA. 1982. Test Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater. EPA 600/4-82-057, U. S. EPA Environmental Monitoring and Support Laboratory, Cincinnati, OH.

4. U. S. EPA. 1983. Methods for Chemical Analysis of Water and Wastes. EPA 600/4-79-020, Revised March 1983. U. S. EPA Environmental Monitoring Laboratory, Cincinnati, OH.

5. U. S. EPA. 1984. Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act. Federal Register: 40 CFR, Part 136, Friday, October 26, 1984. Washington, D.C.

6. Department of Health Services. 1985. Recommended Methods of Analysis for the Organic Components Required for AB 1803, Fourth Edition. California DHS Sanitation and Radiation Laboratory, Berkeley, CA.

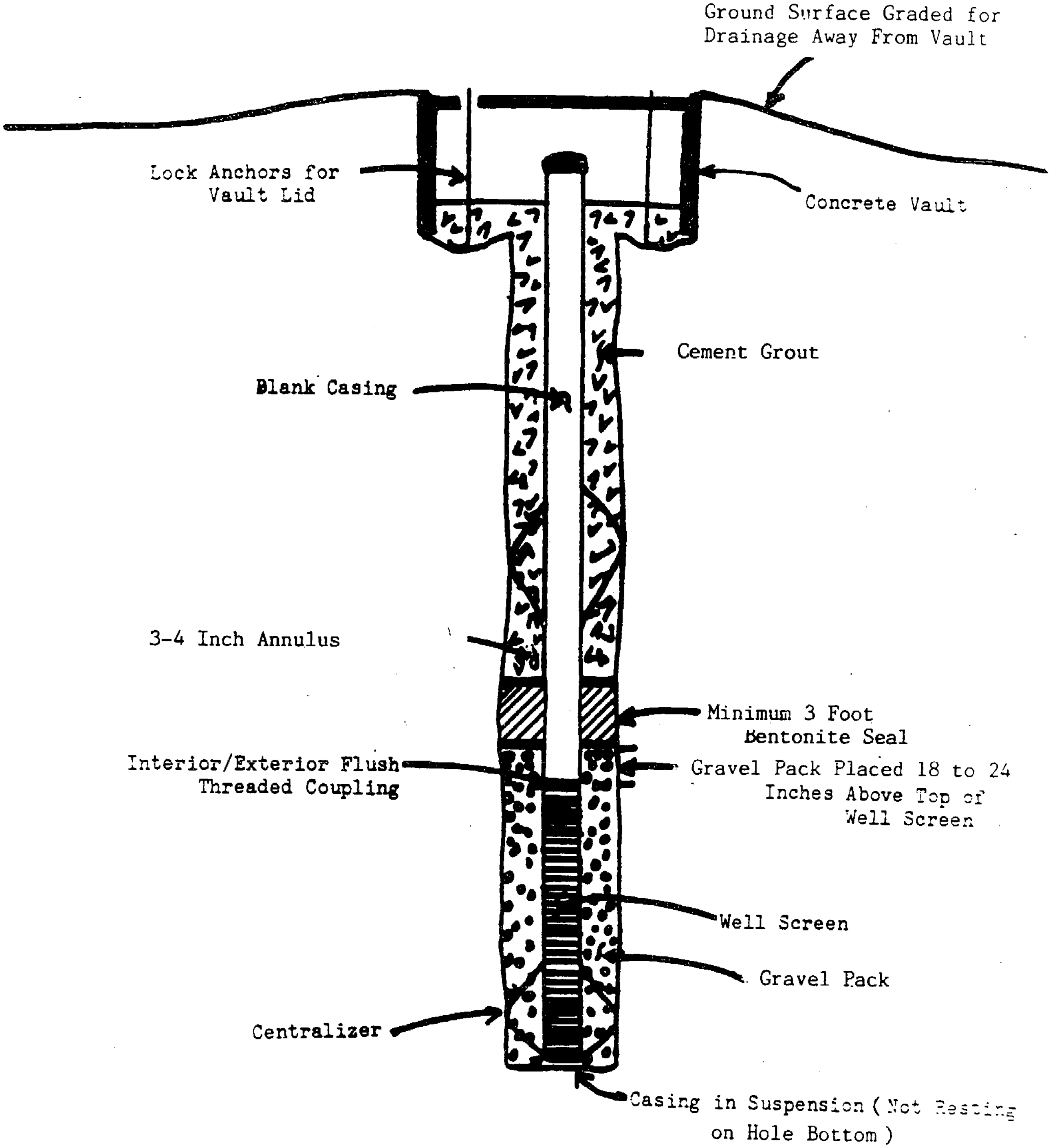
7. Fischer, C. 1986. Quality Assurance Management Guidelines for Environmental Studies. Draft Report. California State Water Resources Control Board, Sacramento, CA.

8. National Research Council. 1981. Prudent Practices for Handling Hazardous Chemicals in Laboratories. National Academy Press, Washington, D.C.

APPENDIX E

MONITORING WELL AND PIEZOMETERS:ILLUSTRATIONS

The following figures were adapted from the California Site Mitigation Decision Tree Document (DHS, 1986). The reader is referred to Chapter 3.4 of that document for a detailed discussion on the proper placement and use of piezometers and monitoring wells.



Not To Scale

FIGURE 111-7

Completion of Piezometer or Shallow Monitor Well in Uncontaminated Vadose Zone

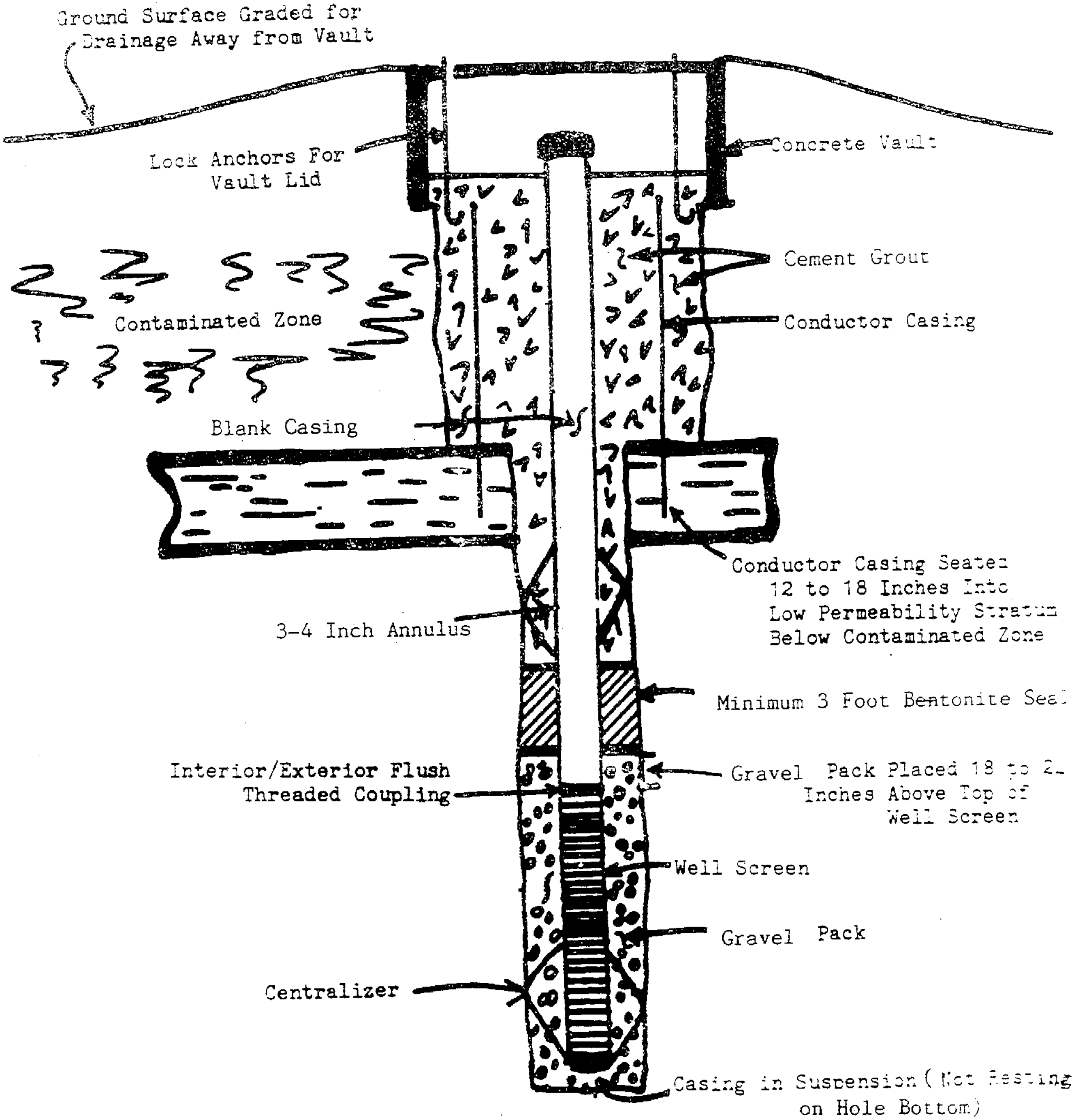


FIGURE 111-8

Completion of Piezometer of Shallow Monitor Well
in Contaminated Vadose Zone

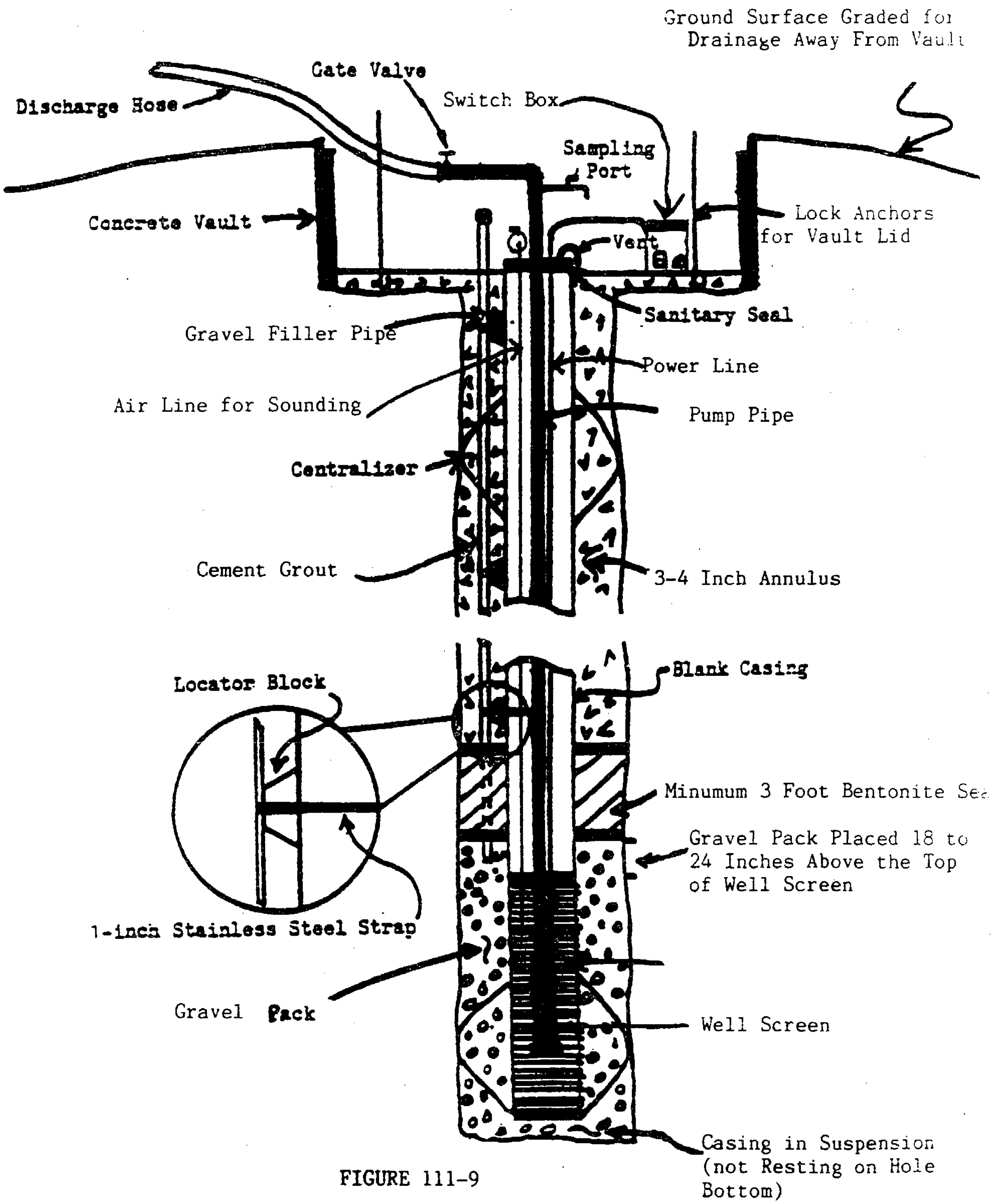


FIGURE 111-9

Completed of Deep Monitor Well (with Dedicated Pump) in Uncontaminated Vadose Zone

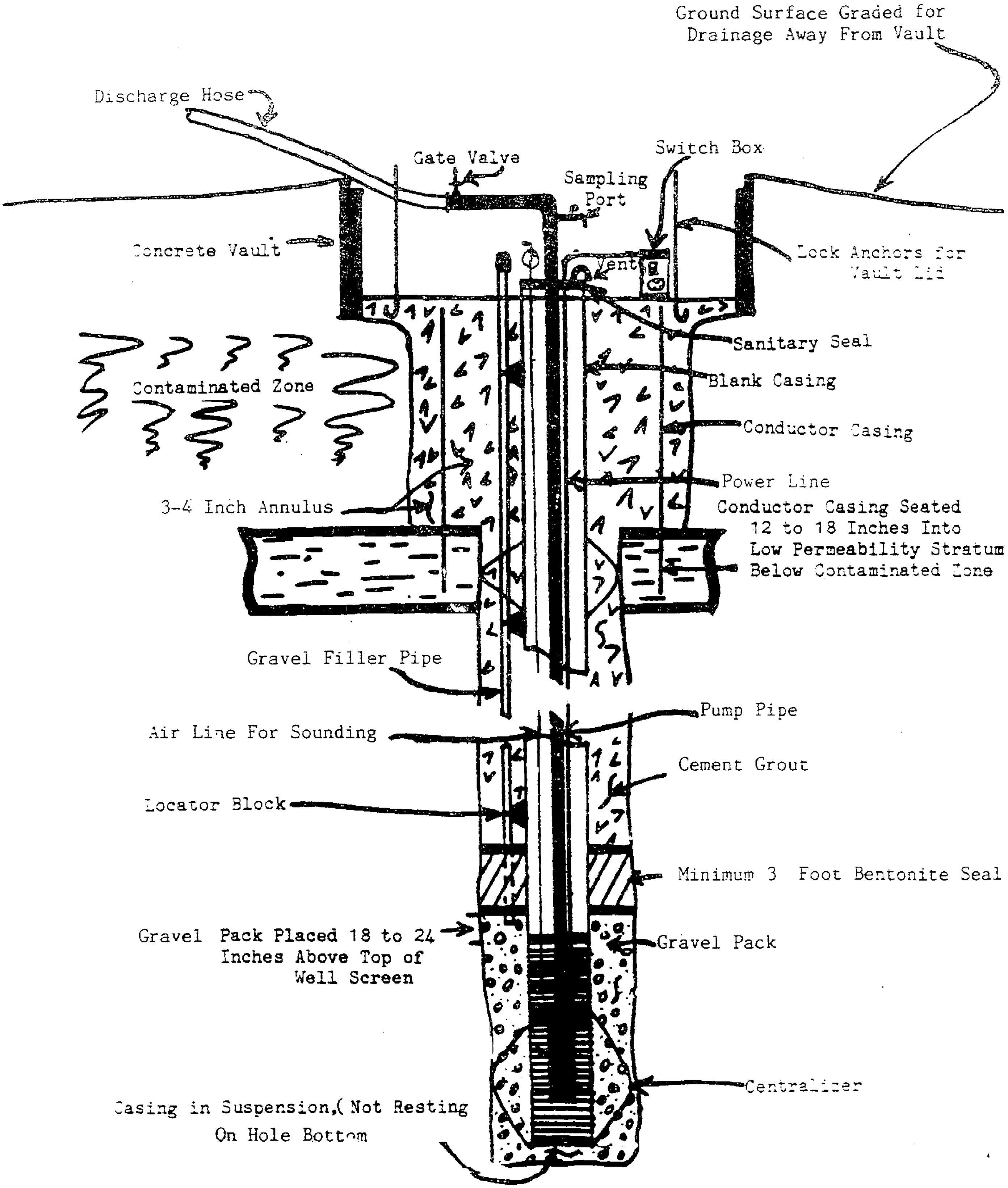


FIGURE 111-10

Completion of Deep Monitor Well (with Dedicated Pump) in Contaminated Vadose Zone

APPENDIX F

MODELING FOR GENERAL RISK APPRAISAL

The general risk appraisal used in this manual to determine acceptable cumulative contamination levels for soil was derived using two models: SESOIL, a vadose zone model, and AT123D, a ground water model. Neither model could be used to produce the acceptable cumulative contamination levels by itself; each model represents an integral subsystem of the entire system being modeled. The results produced by these models were incorporated into a spreadsheet to create usable tables containing a wide range of values.

It is important that regulatory agency personnel understand the basic assumptions and development of the values given in the tables. A conservative approach, allowing for severe case scenarios, was followed.

Three phases were used in the modeling process: (1) SESOIL modeling, (2) AT123D modeling, and (3) spreadsheet manipulation. The following assumptions and input used to produce the acceptable cumulative concentration levels are grouped under these three phases.

A. SESOIL Modeling

SESOIL is a seasonal soil compartment model designed for long-term environmental fate simulations of pollutants in the vadose zone. It can simulate movement of pollutants introduced into the vadose zone and predict the amount of pollutant which will enter ground water.

SESOIL includes assumptions about environmental fate processes, the handling of temporal and spatial variations, and the applicability to different scenarios. User input defined the climate, soil and pollutant characteristics, and the application parameters as follows:

1. The soil column considered was ten meters wide by ten meters long below an underground tank excavation five meters deep. This assumes that the source of the leak will be stopped and that the tank excavation will be filled with natural backfill.

2. Each concentration value calculated from field samples is assumed to represent a layer of soil ten meters long by ten meters wide and may be located anywhere in the soil column. Each layer cannot be evaluated independently, but must be evaluated cumulatively with other layers directly above it. The easiest way to consider the cumulative effect of this contamination thickness is to add the additional concentration value of each layer as depth increases. The samples are taken at five-feet intervals which lessen the number of concentrations which have to be added together and thus decrease the cumulative total. This consideration more accurately reflects the modeled effect of adding layers of contaminated soil and is more compatible with field procedures. The entire volume of contaminated soil must be characterized in this fashion.

3. Simulations were carried out for up to ten years to determine the simulated maximum concentration of pollutant in ground water that would result from the contaminated soil.

4. Detailed climatic data from the following four areas in California were used in the model: Bakersfield (south interior), Los Angeles (south coastal), Sacramento (north interior), and Eureka (north coastal).

5. November was used as the initial month of contamination since the rainy season has usually begun by then.

6. The site was assumed to be exposed to rainfall and not to be covered by an effective barrier to infiltration. Although many sites may be covered with concrete or asphalt, breaks and slopes in such covers may result in a funnel effect unless underlying structures are specifically designed as infiltration barriers.

7. Soil type used is homogeneous sandy loam with a density (specific gravity) of 1.35, an intrinsic permeability of 0.2, a disconnectedness index of 6.3, an effective porosity of 0.25, an organic carbon content of 0.02 percent, and a clay content of 10.0 percent. Note that SESOIL should not be used in areas where there are fissures or solution channels, or in areas where secondary porosity is a significant factor. Because of the scenario used in the SESOIL model, the tables are not intended for use in areas where there exist significant deposits of sand, gravel, or cobbles. However, the tables may generally be used for silty or clayey areas, or where such layers or lenses exist in a sandy loam substrate. Such heterogeneous formations which may retard, increase distance of travel, or

increase dispersion should serve to make the table values more conservative.

8. Pollutants modeled were BTX&E. Chemical and physical properties were obtained from standard chemical references. These properties include molecular weight, solubility, Henry's law constant, and organic carbon/water partitioning coefficient. Biodegradation was given a conservative rate of 0.002 percent per day. Other types of degradation were not considered.

B. AT123D Modeling

AT123D is an analytical transient one-, two-, or three-dimensional computer ground water model. The model is designed to estimate the rate of pollutant transport/transformation in a ground water system. It is used in this modeling application to intercept leachate simulations generated from SESOIL and predict resulting concentrations in ground water. AT123D incorporates assumptions regarding the simulation of hydrogeological processes. Much of the input regarding hydrogeological parameters and pollutant release comes directly from SESOIL via an interactive modeling system. User input defined some of the boundary conditions. Following are some of the more significant input and assumptions that were incorporated:

1. Pollutant input to AT123D is confined to only what is released from the column of soil defined in SESOIL. Pollutants moving outside the column are lost.

2. Maximum ground water concentrations are taken from a point directly ten meters downstream, allowing some mixing to occur, at the top of the aquifer.

3. The modeled aquifer is infinitely deep and infinitely wide.

4. The longitudinal dispersivity is 5 meters; the lateral dispersivity is 0.5 meters; the vertical dispersivity is 0.5 meters; the decay constant is 0.0; and the hydraulic gradient is 0.01.

5. All other parameters are set to match SESOIL output.

C: Spreadsheet Manipulation

A Lotus 123 spreadsheet was used to create tables of acceptable cumulative soil contamination. The spreadsheet used modeling results to calculate which soil concentrations of a pollutant would produce concentrations in the ground water equivalent to its specified water quality limit. Following are some of the pertinent input and assumptions used:

1. The water quality limits used were: DHS, Sanitary Engineering Branch, drinking water supply action levels of 0.7 ppb (parts per billion) of benzene, 100 ppb of toluene, and 620 ppb of xylene; and the federal water criterion of 680 ppb of ethylbenzene. These levels in turn are based on long-term health effects and assume a lifetime exposure based on consuming two quarts of water contaminated with BTX or E at the above levels per day over a 70-year period.

2. Although model output is in precise numbers, the numbers in the tables are shown as whole numbers ranging from 0 to 1,000. It was decided to round the numbers down to the leftmost digit, to diminish the perception of accuracy and to provide an additional margin of ground water protection in the analysis. The first range (0.1 ppm) is assigned an acceptable level of zero ppm (nondetectable level). The second range (1-10) is rounded down to integer values (1, 2, 3...etc.). The third range (10-100) is rounded down to multiples of ten (10, 20, 30...etc.). The last (100-1,000) is rounded down to multiples of 100. The levels did not exceed 1,000 because contamination above this level may indicate a condition where the site should always be either completely cleaned up or more extensively evaluated.

3. Attenuation was assumed to be constant with depth.

4. Annual precipitation and depth to ground water and volume of contaminated soil were the only factors presented in the tables for determining acceptable cumulative contamination levels.

5. The effect of thickness of the contaminated layer was assumed to be additive, when using concentrations taken at five-feet intervals, in all cases.

D: Software Version: Risk-on-a-Disk

A software version of the general risk appraisal is available on a double sided/double density 5 1/4 inch floppy diskette for IBM and IBM-compatible microcomputers with at least 512k RAM. This software version consists of six Lotus 123 files which can only be run using the Lotus 123 program, release 2.0 or later. Lotus 123 is not provided. It is not necessary to know lotus 123 commands, because this software package uses simple instructions instead of Lotus 123 commands.

Risk-on-a-Disk simulates two remedial action alternatives: (1) cleanup of the soil to a specified level of contamination, and (2) removal of a specified amount of the contaminated soil. Intervals of sampling may be varied from one to seven feet. All cumulative contamination levels are calculated by the computer. For requests or additional information. contact Kim Ward in the Division of Loans and Grants of the State Board at (916) 739-4317.

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APPENDIX G

HAZARDOUS WASTE CLASSIFICATION CRITERIA FOR CONTAMINATED SOIL AND USED TANKS

If contaminated soil is to be treated at or removed from a site, a decision needs to be made regarding the waste classification of the soil. If the soil is classified as hazardous, it must be managed accordingly (i.e., manifested, licensed hauler, sent to a licensed facility). If it is treated on-site, the treatment system must have a permit or variance from Department of Health Services (DHS).

In the past, DHS has set a TPH concentration of 1,000 mg/kg (ppm) in soil as a hazardous waste classification criterion. This value was based on ignitability characteristics of gasoline in sandy soil. DHS realizes the complexity of adsorption of various hydrocarbon compounds in different soil types, as well as the different characteristics between old gasoline (i.e., less volatile), new gasoline, and diesel fuels. DHS currently is researching this issue with the objective of reassessing this threshold value. The LUFT Task Force thus recommends that the 1,000 mg/kg TPH value be used by field personnel to classify contaminated soil as a hazardous waste until new criteria are released by DHS.

In regard to excavated fuel tanks, the Department of Health Services views such tanks as hazardous waste. The basis of this classification is contained in CAC Title 22, Article 2, Sections 66300 and 66305. Therefore, the handling and treating of these tanks must be in accordance with all applicable hazardous waste regulations (e.g., storage, transportation, manifest, treatment and other requirements).

The Department has authorized various facilities around the state to receive and treat excavated fuel tanks. The names and addresses of these facilities can be obtained by contacting the Department's Regional Office closest to you. The Regional Offices are located in Burbank [(818) 567-3000], Long Beach [(213) 590-5950], Emeryville [(415) 540-3347], and Sacramento [(916) 324-1807].

The Department and the State Water Resources Control Board are jointly working on the development of procedures for the safe handling and decommissioning of fuel tanks on-site. While these procedures are being developed, the LUFT Task Force recommends that all contacts in regard to this matter be referred to the local agency implementing the Underground Tank Program (e.g., local health department, fire department).

APPENDIX H

LUFT WORKSHEETS

The following worksheets were developed to provide a tool for regulatory officials dealing with LUFT and tank closure sites. The worksheets are designed to facilitate collecting a variety of types of information that will determine whether more detailed site analysis or cleanup is needed

These worksheets are not intended to limit the amount of data collection and analysis for particular fuel tank sites, nor are they intended to substitute for an intensive investigation of contaminated sites. Four general areas are included in the environmental fate worksheets: site history, qualitative analysis, quantitative analysis, and ground water analysis.

WORKSHEET 1. SITE DRAWING

Include a drawing of the site showing distance to nearby structures, subsurface utilities, vaults, switch-boxes, etc. Drawing should be approximately to scale, including distances and directions as measured, notably the north arrow. Relationship of the tank to permanent objects, such as curbs or buildings, should be shown to facilitate finding the tank or excavation at a later date.

WORKSHEET 2. SITE HISTORY

The following information generally applies to most fuel tank sites:

Name of facility ______________________________

Location (may include address and legal description) ______________________________
____
____

Location of tank(s) (attach reference, schematic, etc.) ______________________________
____

Type(s) of fuel ______________________________
____

Tank description ______________________________
(volume, gal.) (material of construction)

Age of tank(s) (if available) ______________________________

History of previous tankage on site (that is, could previous tank have also contributed to the problem?) ______________________________
____
____
____

History of other tanks in area or on-site ______________________________
____
____
____

Basis for investigation. Check applicable reasons for initiating the investigation.

____ Confirming a clean closure for a routine tank removal or closure in place where there was no prior evidence of a leak.

____ Contamination observed or detected during routine tank closure or replacement.

____ Confirmed failed precision test and/or inventory discrepancies reported by tank owner/operator.

Tank test results (recorded/measured leakage rate); may need additional page ______________________________
____
____
____

Worksheet 2 (continued)

Inventory loss: period of record, % loss, amount unaccounted for, if available. ____________________
____
____
____
____

____ Flammable liquid and/or vapors detected on-site or off-site (e.g., migrating from suspected source into sanitary sewer, utility vault, or open excavation).

____ Reports of an odor problem or other nuisance conditions from unknown or suspected sources.

Describe and give detail as to how nuisance odors were investigated and handled, with particular emphasis as to how fire/explosion potential was investigated and/or mitigated:

____
____
____
____
____
____
____
____

Has air monitoring occurred? ____Yes ____No

If yes, present analytical results and procedures, and compare reported values (at existing or potential points of exposure) with available AALs for air. Note that background levels of ambient air at tank sites often contain fuel constituents of concern. It is important to identify the precise source of the air contaminants and not assume that the source is the tank. Fuel may have spilled on paved surfaces.

____ Failure/discharge
____(A) Catastrophic loss
____(B) Long-term leakage
____(C) Overtopping
____(D) Unknown
____(E) Other
describe: ____________________
____

WORKSHEET 3. VAPOR MIGRATION

At present, few, if any, methodologies are available for predicting the migration potential of vapors associated with soils contaminated with gasoline, or any other volatile organic compound. In light of this, a monitoring-oriented approach is recommended. The basic approach includes:

1. Identification of points and structures likely to allow migration and/or exposure.
2. Evaluation of fire and explosion potential from gasoline vapors.
3. Monitoring of ambient and/or subsurface air to evaluate precleanup and postcleanup conditions.

Postcleanup monitoring is important when a capping mechanism, e.g., paving, is used. Such a cap might block upward vertical migration into the air, but increase the potential for lateral migration.

WORKSHEET 4. QUALITATIVE ANALYSIS

In the context of this document, qualitative analysis includes on-site measurement of those constituents that indicate that a discharge or leak may have occurred. The recommended practice includes (1) evaluation of and observations based on sight and smell, (2) calibration of a hydrocarbon-detecting instrument such as an OVA or HNU meter, (3) determination of background response of the instrument and (4) measurement of vapors in the soil in the excavation or near the tanks and piping.

Date of qualitative analysis ______________________________

Conducted by (name, title, agency or company) ______________________________
____

Type of instrument ______________________________

Serial number or manufacturer's identification ______________________________
____

Calibrated to (compound, i.e., benzene, methane. etc.) ______________________________

Date calibrated ______________________________

Number of background samples taken (locations should be illustrated on schematic, if possible, or otherwise documented) ______________________________

Results of background samples

Sample No.	Response

__________ average

Worksheet 4 (Continued)

Qualitative analysis of soil samples from excavation

Sample No.	Description*	Response

_________average

* For example, ". .from near area of suspected leak, randomly located, visually stained or discolored, etc."

Qualitative analysis ________Pass (samples below background) ________Fail (samples above background)

If "Pass", no further qnalysis required.

If "Fail", quantitative analysis required

WORKSHEET 5. GROUNDWATER ANALYSIS

Site Drawing

The site drawing should be to scale and more detailed than the drawing recommended under "Site History". The drawing should identify boring locations, ground water monitoring locations, tank and line locations, nearby structures, proximity of underground utilities and conveyances, suspected location(s) of leakage, etc. This drawing will also be used to illustrate the direction of ground water flow, based on measurements of on-site water levels.

Subsurface Investigation

- Boring and well logs (including description of drilling apparatus) should include all field logs and notes, as well as refined logs.
- Geologic cross-section(s).
- Chemical stratigraphy (i.e., pattern of contamination observed in borings and displayed with cross-section).
- Occurrence of ground water (depth to ground water).

Hydrogeologic Setting

Basin, foothill, or alpine setting (note: analysis developed for constructing Table 2-1 (Section II) assumes a basin setting).

Describe/discuss: ______________________________

Recharge or discharge zone (if known).

Describe/discuss: ______________________________

Conceptual model of regional hydrogeologic system containing site (may be available from previous basin studies).

Describe/discuss: ______________________________

Worksheet 5 (Continued)

Agreement/disagreement of subsurface conditions at site with regional setting (i.e., significant subsurface structures and deposits as expected or as not expected).

Describe/discuss: ______________________________

Evidence of excessive heterogeneity in subsurface deposits (note: the analysis conducted to construct Table 2-1 assumes a relatively permeable but homogeneous soil; excessive heterogeneity introduced by fractured rock, coarse sand, and travel deposits, etc., may necessitate a more conservative approach than set forth in the following worksheets).

Describe/discuss: ______________________________

Beneficial use(s) of ground water, including existing water usage and existing (documented) water quality.

____

Interpretation of Results of Ground Water Analysis

Analytical Results (append, including analytical results for any QA/QC samples collected).

Depth of ground water measured on site? ____Yes ____No

If "No", give basis for determining depth to ground water. Also, describe those conditions (i.e., historically documented excessive depth to ground water) or intervening low-permeability strata that were believed to preclude/inhibit migration to ground water, thus reducing the need for determining the actual depth to ground water.

____

Minimum expected depth to ground water: The minimum expected depth to ground water should be used. This depth may vary from the depth to ground water measured on a given date, due to seasonal and long-term fluctuations of the water table. Adjusting the value of depth to ground water is particularly important for those areas where: (1) annual fluctuations in the water table are significant, (2) existing depth to ground water is slight, and (3) existing water levels are measured during the dry season. Historical records and basin studies can aid in determining an appropriate adjustment to the observed depth of ground water.

Direction of ground water flow: Illustrate on-site drawing, including monitoring locations and relative measured elevations of water surface. Include analysis of three-point problem to determine direction.

Downgradient water sample: Give analytical results showing no impact to ground water quality. This might be included on illustration presenting direction of ground water flow.

ANALYTICAL RESULTS FOR DOWNGRADIENT WATER SAMPLE

Constituent	Concentration (µg/l)	Reported Detection Limit (µg/l)
Benzene		
Xylene		
Toluene		
Ethylbenzene		

APPENDIX I

CHEMICAL COMPOSITION OF GASOLINE

Compound	Number of Carbons	Concentration (Weight Percent) (a)	Reference
Straight Chain Alkanes			
Propane	3	0.01 - 0.14	8,10
n-Butane	4	3.93 - 4.70	8,10,11
n-Pentane	5	5.75 - 10.92	8,10,11
n-Hexane(d)	6	0.24 - 3.50	8,10,11
n-Heptane	7	0.31 - 1.96	10,11
n-Octane	8	0.36 - 1.43	10
n-Nonane	9	0.07 - 0.83	10
n-Decane	10	0.04 - 0.50	10
n-Undecane	11	0.05 - 0.22	10
n-Dodecane	12	0.04 - 0.09	10
Branched Alkanes			
Isobutane	4	0.12 - 0.37	8,10
2,2-Dimethylbutane	6	0.17 - 0.84	10
2,3-Dimethylbutane	6	0.59 - 1.55	8,10,11
2,2,3-Trimethylbutane	7	0.01 - 0.04	10
Neopentane	5	0.02 - 0.05	10
Isopentane	5	6.07 - 10.17	8,10,11
2-Methylpentane	6	2.91 - 3.85	8,10,11
3-Methylpentane	6	2.4 (vol)	8,10,11
2,4-Dimethylpentane	7	0.23 - 1.71	8,10,11
2,3-Dimethylpentane	7	0.32 - 4.17	8,10,11
3,3-Dimethylpentane	7	0.02 - 0.03	10
2,2,3-Trimethylpentane	8	0.09 - 0.23	10,11
2,2,4-Trimethylpentane	8	0.32 - 4.58	8,10
2,3,3-Trimethylpentane	8	0.05 - 2.28	10
2,3,4-Trimethylpentane	8	0.11 - 2.80	10,11
2,4-Dimethyl-3-ethylpentane	9	0.03 - 0.07	10
2-Methylhexane	7	0.36 - 1.48	10
3-Methylhexane	7	0.30 - 1.77	10,11
2,4-Dimethylhexane	8	0.34 - 0.82	10
2,5-Dimethylhexane	8	0.24 - 0.52	10
3,4-Dimethylhexane	8	0.16 - 0.37	10
3-Ethylhexane	8	0.01	10
2-Methyl-3-ethylhexane	9	0.04 - 0.13	10
2,2,4-Trimethylhexane	9	0.11 - 0.18	10

Compound	Number of Carbons	Concentration (Weight Percent) (a)	Reference
2,2,5-Trimethylhexane	9	0.17 - 5.89	10
2,3,3-Trimethylhexane	9	0.05 - 0.12	10
2,3,5-Trimethylhexane	9	0.05 - 1.09	10
2,4,4-Trimethylhexane	9	0.02 - 0.16	10
2-Methylheptane	8	0.48 - 1.05	10
3-Methylheptane	8	0.63 - 1.54	10
4-Methylheptane	8	0.22 - 0.52	10
2,2-Dimethylheptane	9	0.01 - 0.08	10
2,3-Dimethylheptane	9	0.13 - 0.51	10
2,6-Dimethylheptane	9	0.07 - 0.23	10
3,3-Dimethylheptane	9	0.01 - 0.08	10
3,4-Dimethylheptane	9	0.07 - 0.33	10
2,2,4-Trimethylheptane	10	0.12 - 1.70	10
3,3,5-Trimethylheptane	10	0.02 - 0.06	10
3-Ethylheptane	10	0.02 - 0.16	10
2-Methyloctane	9	0.14 - 0.62	10
3-Methyloctane	9	0.34 - 0.85	10
4-Methyloctane	9	0.11 - 0.55	10
2,6-Dimethyloctane	10	0.06 - 0.12	10
2-Methylnonane	10	0.06 - 0.41	10
3-Methylnonane	10	0.06 - 0.32	10
4-Methylnonane	10	0.04 - 0.26	10
Cycloalkanes			
Cyclopentane	5	0.19 - 0.58	8,10
Methylcyclopentane	6	Not quantified	8
1-Methyl-cis-2-ethylcyclopentane	8	0.06 - 0.11	10
1-Methyl-trans-3-ethylcyclopentane	8	0.06 - 0.12	10
1-Cis-2-dimethylcyclopentane	7	0.07 - 0.13	10
1-Trans-2-dimethylcyclopentane	7	0.06 - 0.20	10
1,1,2-trimethylcyclopentane	8	0.06 - 0.11	10
1-Trans-2-cis-3-trimethylcyclopentane	8	0.01 - 0.25	10
1-Trans-2-cis-4-trimethylcyclopentane	8	0.03 - 0.16	10
Ethylcyclopentane	7	0.14 - 0.21	10
n-Propylcyclopentane	8	0.01 - 0.06	10
Isopropylcyclopentane	8	0.01 - 0.02	10
1-Trans-3-dimethylcyclohexane	8	0.05 - 0.12	10
Ethylcyclohexane	8	0.17 - 0.42	10

Compound	Number of Carbons	Concentration (Weight Percent) (a)	Reference
Straight Chain Alkenes			
cis-2-butene	4	0.13 - 0.17	10
trans-2-butene	4	0.16 - 0.20	10
Pentene-1	5	0.33 - 0.45	10
cis-2-pentene	5	0.43 - 0.67	8,10
trans-2-pentene	5	0.52 - 0.90	10,11
cis-2-hexene	6	0.15 - 0.24	10
trans-2-hexene	6	0.18 - 0.36	10
cis-3-hexene	6	0.11 - 0.13	10
trans-3-hexene	6	0.12 - 0.15	10
cis-3-heptene	7	0.14 - 0.17	10,11
trans-2-heptene	7	0.06 - 0.10	10
Branched Alkenes			
2-Methyl-1-butene	5	0.22 - 0.66	8,10,11
3-Methyl-1-butene	5	0.08 - 0.12	10
2-Methyl-2-butene	5	0.96 - 1.28	8,10,11
2,3-Dimethyl-1-butene	6	0.08 - 0.10	10
2-Methyl-1-pentene	6	0.20 - 0.22	10,11
2,3-Dimethyl-1-pentene	7	0.01 - 0.02	10
2,4-Dimethyl-1-pentene	7	0.02 - 0.03	10
4,4-Dimethyl-1-pentene	7	0.6 (vol)	11
2-Methyl-2-pentene	6	0.27 - 0.32	10,11
3-Methyl-cis-2-pentene	6	0.35 - 0.45	10
3-Methyl-trans-2-pentene	6	0.32 - 0.44	10
4-Methyl-cis-2-pentene	6	0.04 - 0.05	10
4-Methyl-trans-2-pentene	6	0.08 - 0.30	10
4,4-Dimethyl-cis-2-pentene	7	0.02	10
4,4-Dimethyl-trans-2-pentene	7	Not quantified	10
3-Ethyl-2-pentene	7	0.03 - 0.04	10
Cycloalkenes			
Cyclopentene	5	0.12 - 0.18	10
3-Methylcyclopentene	6	0.03 - 0.08	10
Cyclohexene	6	0.03	10
Alkyl Benzenes			
Benzene(d)	6	0.12 - 3.50	6,7,8,9, 10,11,12

Compound	Number of Carbons	Concentration (Weight Percent) (a)	Reference
Toluene(d)	7	2.73 - 21.80	5,6,7,8, 9,10,11,12
o-Xylene(d)	8	0.68 - 2.86	6,9,10,12
m-Xylene(d)	8	1.77 - 3.87	10
p-Xylene(d)	8	0.77 - 1.58	10
1-Methyl-4-ethylbenzene	9	0.18 - 1.00	10
1-Methyl-2-ethylbenzene	9	0.19 - 0.56	6
1-Methyl-3-ethylbenzene	9	0.31 - 2.86	6,9,10,11
1-Methyl-2-n-propylbenzene	10	0.01 - 0.17	6,9,10
1-Methyl-3-n-propylbenzene	10	0.08 - 0.56	9,10
1-Methyl-3-isopropylbenzene	10	0.01 - 0 12	10
1-Methyl-3-t-butylbenzene	11	0.03 - 0.11	10
1-Methyl-4-t-butylbenzene	11	0.04 - 0.13	10
1,2-Dimethyl-3-ethylbenzene	10	0.02 - 0.19	6,10
1,2-Dimethyl-4-ethylbenzene	10	0.50 - 0.73	6
1,3-Dimethyl-2-ethylbenzene	10	0.21 - 0.59	6,9
1,3-Dimethyl-4-ethylbenzene	10	0.03 - 0.44	6,10
1,3-Dimethyl-5-ethylbenzene	10	0.11 - 0.42	6,10
1,3-Dimethyl-5-t-butylbenzene	12	0.02 - 0.16	10
1,4-Dimethyl-2-ethylbenzene	10	0.05 - 0.36	6,10
1,2,3-Trimethylbenzene	9	0.21 - 0.48	6
1,2,4-Trimethylbenzene	9	0.66 - 3.30	6,9,10,11
1,3,5-Trimethylbenzene	9	0.13 - 1.15	6,9,10
1,2,3,4-Tetramethylbenzene	10	0.02 - 0.19	6,10
1,2,3,5-Tetramethylbenzene	10	0.14 - 1.06	6,9,10
1,2,4,5-Tetramethylbenzene	10	0.05 - 0.67	6,9,10
Ethylbenzene(d)	8	0.36 - 2.86	6,9,10, 11,12
1,2-Diethylbenzene	10	0.57	9
1,3-Diethylbenzene	10	0.05 - 0.38	6,9,10
n-Propylbenzene	9	0.08 - 0.72	6,9,10
Isopropylbenzene	9	<0.01 - 0.23	6,9,10,12
n-Butylbenzene	10	0.04 - 0.44	6,9,10
Isobutylbenzene	10	0.01 - 0.08	9,10
sec-Butylbenzene	10	0.01 - 0.13	9,10
t-Butylbenzene	10	0.12	9
n-Pentylbenzene	11	0.01 - 0.14	10
Isopentylbenzene	11	0.07 - 0.17	10

Compound	Number of Carbons	Concentration (Weight Percent) (a)	Reference
Indan	9	0.25 - 0.34	6
1-Methylindan	10	0.04 - 0.17	10
2-Methylindan	10	0.02 - 0.10	10
4-Methylindan	10	0.01 - 0.16	10
5-Methylyindan	10	0.09 - 0.30	10
Tetralin	10	0.01 - 0.14	10
Polynuclear Aromatic Hydrocarbons			
Naphthalene(d)	10	0.09 - 0.49	6,10
Pyrene	16	Not quantified	6
Benz(a)anthracene	18	Not quantified	6
Benz(a)pyrene	20	0.19 - 2.8 mg/kg	6
Benzo(e)pyrene	20	Not quantified	6
Benzo(g,h,i)perylene	21	Not quantified	6
Elements			
Bromine		80 - 345 µg/g	3
Cadmium		0.01 - 0.07 µg/g	1
Chlorine		80 - 300 µg/g	3
Lead(b)		530 - 1120 µg/g	8
Sodium		<0.6 - 1.4 µg/g	3
Sulfur(c)		0.10 - 0.15	(ASTM)
Vanadium		<0.02 - 0.001 µg/g	2,3
Additives			
Ethylene dibromide(d)		0.7 - 177.2 ppm	4
Ethylene dichloride(d)		150 - 300 ppm	8
Tetramethyl lead			
Tetraethyl lead			

a. Conversion from other units assumed 0.75 specific gravity.

b. ASTM specification, maximum, unleaded gasoline, 0.013 g/l maximum, conventional grade gasoline, 1.1 g/l. Title 13, CAC, Section 2253.2, maximum, leaded gasoline other than leaded high octane gasoline, 0.8 g/gallon maximum, leaded high octane gasoline, 1.0 g/gallon. Federal standards, January 1, 1986, maximum, 0.1 g/gallon.

c. ASTM maximum, unleaded gasoline, 0.10 weight percent. Conventional grade gasoline, 0.15 weight percent, Title 13, CAC, Section 2252, maximum 300 ppm by weight.

d. Compounds for which AALs are being developed.

References

1. American Petroleum Institute, 1985a. Cadmium: Environmental and Community Health Impact. Washington, D. C. EA Report API 137C.

2. American Petroleum Institute, 1985b. Vanadium: Environmental and Community Health Impact. Washington, D. C. EA Report API 137D.

3. C. Block and R. Dams, 1978. Concentration Data of Elements in Liquid Fuel Oils as Obtained by Neutron Activation Analysis. Journal of Radioanalytical Chemistry 46, 137-144.

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7. Harold E. Guard, James Ng, and Roy B. Loughlin, Jr., 1983. Characterization of Gasolines, Diesel Fuels, and Their Water Soluble Fractions. Naval Biosciences Laboratory, Oakland, CA, September 1983.

8. H. J. McDermott and S. E. Killiany, 1978. Quest for a Gasoline TLV Am. Ind. Hyg. Assoc. J. 39, 110-117, February 1978.

9. National Research Council, 1981. The Alkyl Benzenes. National Academy Press, Washington, D. C.

10. W. N. Sanders and J. B. Maynard, 1968. Capillary Gas Chromatographic Method for Determining the C3-C12 Hydrocarbons in Full-Range Motor Gasolines. Analytical Chemistry 40(3), 527-535.

11. Mark E. Myers, Jr., Janis Stollsteiner, and Andrew M. Wims, 1975. Determination of Hydrocarbon-Type Distribution and Hydrogen/Carbon Ratio of Gasolines by Nuclear Magnetic Resonance Spectrometry. Analytical Chemistry pp(12), 2010-2015.

12. L. L. Stavinoha and F. M. Newman, 1972. The Isolation and Determination of Aromatics in Gasoline by Gas Chromatography. Journal of Chromatographic Science pp(9), 583-589.

APPENDIX J

CHEMICAL COMPOSITION OF DIESEL FUEL

Compound	Number of Carbons	Concentration (Weight/ Percent)	Reference
Straight Chain Alkanes			
n-Nonane	9	0.1	6,7
n-Decane	10	0.5 - 2	1,2,6,7
n-Undecane	11	0.98 - 9	1,2,6,7
n-Dodecane	12	0.96 - 11	1,2,6,7
n-Tridecane	13	1.1 - 10	1,2,6,7
n-Tetradecane	14	1.1 - 9	1,2,6,7
n-Pentadecane	15	1.0 - 7	1,2,6,7
n-Hexadecane	16	1.2 - 6	1,2,6,7
n-Heptadecane	17	1.2 - 6	1,2,6,7
n-Octadecane	18	0.82 - 5	1,2,6,7
n-Nonadecane	19	0.53 - 4	1,2,6,7
n-Eicosane	20	0.23 - 3	1,2,6,7
n-Heneicosane	21	1	1,2,7
n-Docosane	22	< 0.2	1,2,7
Branched Alkanes			
2-Methylheptadecane	18		7
2,6,10,14-Tetramethyl-pentadecane	19		1
2,6,10,14-Tetramethyl-pentadecane	20		1
Alkyl Benzenes			
Benzene	6		7
Toluene	7		7
o-Xylene	8		7
m-Xylene	8		7
2-Ethyltoluene	9		7
3-Ethyltoluene	9		7
4-Ethyltoluene	9		7
Isopropylbenzene	9		7
1,2,3-Trimethylbenzene	9		7
1,2,4-Trimethylbenzene	9		7
1,3,5-Trimethylbenzene	9		7
1,2,3,5-Tetramethylbenzene	10		7
1,2,4,5-Tetramethylbenzene	10		7
Pentamethylbenzene	11		7
Biphenyl	12		7

Compound	Number of Carbons	Concentration (Weight/ Percent) (a)	Reference
Polynuclear Aromatic Hydrocarbons			
Naphthalene(d)	10	0.13	6,7
Methylnaphthalene	11	0.57 - 0.91	6,7
2,3,5-Trimethylnaphtalene	13		7
Fluorene	13		7
Phenanthrene	14		4
Anthracene	14		4
Pyrene	16		4
Benz(a)pyrene	20	0.07 ug/kg	4,8
Benzo(b)flouranthene	20		4
Benzo(g,h,i)perylene	21		4
Elements			
Barium		0.007 - 0.7 ug/g	3
Cadmium		0.001 - 0.07 ug/g	3
Calcium		0.1 ug/ml	6
Chromium		0.01 - 0.7 ug/g	3
Cobalt		0.007 - 0.1 ug/g	3
Copper		0.01 - 0.3 ug/g	3
Lead		0.1 ug/ml	6
Molybdenum		<0.001 - 0.07 ug/g	3
Nickel		0.007 - 0.1 ug/g	3
Selenium		0.001 - 0.03	3
Vanadium		0.0007 - 0.003 ug/g	3
Zinc		0.01 - 3 ug/g	5

Notes

a. Conversion from other units for gasoline assumed 0.75 specific gravity.

b. ASTM specification, max., unleaded gasoline, 0.013 g/l max., conventional grade gasoline, 1.1 g/l, Title 13, CAC, Section 2253.2, max., leaded gasoline other than leaded high octane gasoline, 0.8 g/gal max., leaded high octane gasoline, 1.0 g/gal. Federal standards, January 1, 1986, max., 0.1 g/gal.

c. ASTM max., unleaded gasoline, 0.10 weight percent conventional grade gasoline, 0.15 weight percent, Title 13, CAC, Section 2252, max. 300 ppm by weight.

d. Compounds for which AALs have been or are being developed.

References

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APPENDIX K

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

AAL	Applied Action Level
AA	Atomic Absorption Spectrometry
AL	Action Level
AQMD	Air Quality Maintenance District
ARB	Air Resources Board (State)
BTX	Benzene, Toluene, Xylene used for gasoline analysis
BTX&E	Benzene, Toluene, Xylene, and Ethylbenzene
C_4, C_{12}	$C_4 = 4$ carbons in a chain, e.g., $CH_3CH_2CH_2CH_3$; $C_{12} = 12$ carbons in a chain
°C	Degrees centigrade
C.E.G.	Certified Engineering Geologist
cu. yds.	Cubic yards
DHS	Department of Health Services (State)
EDB	Ethylene dibromide
EDC	Ethylene dichloride
EPA (or U. S. EPA)	United States Environmental Protection Agency
FID	Flame Ionization Detector
g	Gram; 1/1000 of a kilogram
GC	Gas chromatography
GC/FID	Gas chromatography/flame ionization detector
GC/MS	Gas chromatography/mass spectrometry
GC/PID	Gas chromatography/photoionization detector

H&SC	California Health and Safety Code
HCl	Hydrochloric acid
H_2SO_4	Sulfuric acid
HV	Hydrocarbon Vapor
IR	Infrared (light wavelength)
Kg	Kilogram
LEL	Lower explosive limit
LUFT	Leaking underground fuel tank
MCL	Maximum contamination level
mg	Milligram
mg/kg	Milligram/kilogram
mg/l	Milligram/liter
mm	Millimeters
Na_2SO_3	Sodium sulfite
NIOSH	National Institute for Occupational Health and Safety
O_2	Oxygen
OSHA	Occupational Safety and Health Act
OVA	Organic Vapor Analyzer
pH	A measure of acidity. Relates to hydrogen ion concentration of an aqueous solution. The lower the pH number the more acidic the solution. pH 7 is neutral; pH 1 is most acidic; pH 14 is most alkaline.
PID	Photoionization detector
ppm	Parts per million (mg/l or mg/kg)
ppb	Parts per billion (µg/l or µg/kg)
PVC	Polyvinyl chloride
QA	Quality assurance
QC	Quality control

RG	Registered Geologist
RWQCB (or Regional Board)	Regional Water Quality Control Board
SWRCB (or State Board)	State Water Resources Control Board
TLV	Threshold limit value
TPH	Total petroleum hydrocarbons
TRPH	Total recoverable petroleum hydrocarbons
UEL	Upper explosive limit
μg	Microgram; 1/1000 of a milligram
μg/g	Microgram/gram
μg/l	Microgram/liter
μg/ml	Microgram/milliliter
μl	Microliter; 1/1,000,000 of a Liter
UV	Ultraviolet (light wave length)
VOA	Volatile organic analysis
>	Greater than
<	Less than
≥	Greater than or equal to

APPENDIX L

GLOSSARY

Applied Action Level (AAL) -- A criterion which delineates a concentration of a substance (e.g., benzene) in a medium (e.g., water) which, when exceeded, is determined to present a significant risk of an adverse impact to a biological receptor. (See California Site Mitigation Decision Tree Manual, 1986.)

Accuracy -- Degree of agreement between a measured value and a true or expected value.

Acidify -- Add acid to lower pH.

Action Level (AL) -- A DHS recommended acceptable limit for drinking water. An AL is similar to a tolerance level, but not enforceable.

Acute toxicity -- Toxic symptoms that develop shortly after exposure, usually within 24 hours.

Aliphatic -- Carbon atoms linked in a chain-like formation; includes alkanes and alkenes.

Aliquot -- Dividing a sample into two or more equal parts; implies an exact division of a quantity. An aliquot of a field sample (soil or water) is often used for analysis in a laboratory.

Alkanes -- Hydrocarbon compounds (e.g., $CH_3CH_2CH_3$) that do not contain double or triple bonds between carbons. Alkanes can form straight chains or cyclic structures such as cyclohexane.

Alkenes -- Straight chain hydrocarbon compounds that contain one or more double or triple bonds between carbons.

Aquifer -- An underground geological formation that contains water and is capable of yielding water to a well or spring; a water-bearing formation.

Aquitard (Aquiclude) -- An underground geological formation that is impermeable to or impedes the movement of water.

Aromatic Hydrocarbons -- Compounds containing one or more benzene rings (a six-carbon ring structure with alternating double bonds between carbons).

Backwash -- Reversal (downward) of waterflow in well to remove fines and enhance production.

Barrier Well -- A well installed to intercept and pump out a plume of contaminated ground water.

Basin Plan -- A water quality control plan adopted by the Regional Water Quality Control Board and approved by the State Water Resources Control

Board that includes actual and potential uses of ground and surface water and water quality objectives to protect the designated uses.

Biological Transformation -- Structural alteration of a chemical by an organism. In regard to fuel, it refers primarily to the decomposition of organic compounds by microorganisms.

Bentonite Grout -- An aluminum silicate clay to which a small amount of magnesium oxide is added that swells and forms a viscous suspension when mixed with water. Upon drying, it forms a hard cement-like material. It is commonly used to refill and seal soil coring holes and as a fill or grout material around well casings or to fill and seal off abandoned wells

Borehole -- An uncased well drill hole.

Cancer -- The development of a malignant tumor or abnormal formation of tissue.

Capillary Fringe -- An increasingly moist area that is in continuity with and lies between the saturated zone and the unsaturated zone.

Carcinogen -- A substance or agent that produces cancer.

Casing -- Steel or plastic tubing that is welded or screwed together to line a borehole.

Cone of Depression -- A cone-shaped depression that is formed in a water table when ground water is removed.

Confidence Level (confidence limit, 95 percent) -- A level of data reliability achieved by setting a percent confidence limit. A 95 percent confidence limit is the limits of the range of analytical values within which a single analysis will be included 95 percent of the time.

Confined Aquifer -- An aquifer whose upper and/or lower boundaries are confined by an impermeable geologic formation, e.g., a clay layer; an aquifer in which ground water is under pressure, e.g., artisan conditions.

Confining Layer -- An aquitard or impermeable layer that confines the limits of an aquifer.

Chronic Toxicity -- Toxic symptoms that develop after repeated low-level exposure. Often effects are not immediately apparent.

Dissolved Product -- The water-soluble fuel components; namely, benzene, toluene, and xylene.

Drainage Well -- A well installed to drain water at or near ground surface.

Dry Well (Dry Hole) -- A well that does not extend into the water table or saturated zone.

Environmental Fate -- What happens to a chemical once it is released or escapes into the environment.

Flow Path -- The direction in which ground water is moving.

Fracture -- A break in the geological formation, e.g., a shear or fault.

Free Product -- Fuel product accumulated on top of the ground water that is recoverable by well withdrawal methods. Free product is often mobile

Gradient -- The rate of inclination of a slope. The degree of deviation from the horizontal.

Ground Water -- Water beneath ground surface.

Head Space -- The air space at the top of a water or soil sample.

Hydrocarbon -- Organic chemicals such as benzene or tetrachloroethylene that contain atoms of carbon and hydrogen.

Hydrogeology -- Scientific considerations relating to geological formations, soil surface water, and especially ground water.

Hydraulic Continuity -- A water bridge or connection between two or more geological formations.

Hydrophobic -- Tendency not to dissolve in water.

Inorganic -- A chemical substance that does not contain carbon.

Leachate -- Liquid that percolates through soil (or other material) and contains soluble materials picked up from soil.

Leukemogen -- A substance that causes leukemia.

Microgram (μg) -- One-thousandth part of a milligram (mg); one-millionth part of a gram; one-billionth part of a kilogram.

Mitigation -- Reduction or alleviation of a problem. For example, the process of cleaning up a contaminated site in order to return it to an environmentally acceptable state.

Monitoring Well -- A well installed to routinely observe ground water levels or to systematically collect water samples and analyze these for chemical pollution.

Mutagen -- A substance or agent that causes genetic changes or transformations.

Neurotoxic -- Poisonous to nerve cells.

Organic -- A carbon-containing compound.

Perched Aquifer -- A body of water or water formation located above an impermeable geological formation.

Percolate -- Water moving through soil.

Permeability -- The degree to which a medium such as soil allows another medium such as water to pass through it.

Piezometer -- A well with a short slotted screen (one to five feet) for measuring a potentiometric surface or elevation of the water table.

Piezometer Nest -- Multiple well completions in the same borehole with each well screened over a different interval.

Plume -- A mass of contaminated water extending outward from the source.

Potentiometric Surface -- The surface that represents the level to which water will rise in tightly cased wells.

Precision -- The degree to which a measurement is reproducible.

Purge (wells) -- Pumping out well water to remove drilling debris or impurities; also conducted to bring fresh ground water up into the casing for sample collection. The latter is a means of collecting a representative water sample from the aquifer being investigated.

Purgeable Organic -- An organic chemical with a high vapor pressure that can be removed from water by bubbling a nonreactive gas such as helium in the water.

Reagent -- A substance used in chemistry to detect, measure, or produce another substance.

Recharge Area -- Replenishment of an aquifer by a natural process such as addition of water at ground surface, or by an artificial system such as addition through a well.

Remedial Action -- Action taken to correct a problem such as fuel contamination of soil and ground water.

Representative Sample -- A sample that is assumed not to be significantly different than the population of samples available. In fuel leak investigation, samples are often selected to be representative of the worst case situation.

Runoff -- Overland movement of water, rainfall, a discharge, etc.

Saturated Zone -- An underground geologic formation in which the pore spaces or interstitial spaces in the formation are filled with water under pressure equal to or greater than atmospheric pressure.

Screen -- Perforations in a well casing and usually located near the bottom of the well or at selected depths to tap perched aquifers.

SESOIL -- A computer model for predicting the movement/transport of a chemical in the vadose zone.

Surface Resistivity (Electric Soil Survey) -- A technique that measures relative values of the earth's electrical resistivity. The technique is used to define subsurface geologic and hydrologic conditions.

Teratogen -- A substance or agent that causes development of abnormal structures in an embryo.

Threshold Dose -- The minimum exposure dose of a chemical that will evoke a stated or nontoxicological response.

Threshold Limit -- A chemical concentration above which adverse health or environmental effects may occur.

Toxicity -- The harmful effect produced by exposure to a substance.

Transmissivity -- The transmission rate of water (based on a unit width of an aquifer) relative to a hydraulic gradient.

Tremie Pipe -- A pipe used to fill the annular space (space between soil and outside of well casing) from the bottom up when completing a well installation or when sealing an abandoned well.

Unconfined Aquifer -- An aquifer whose upper level can extend to ground surface.

Unsaturated Zone -- The area between ground surface and the underground water table. Interstitial spaces in this zone contain moisture (water) and air.

Vadose Zone -- The unsaturated area between ground surface and the water table.

Vapor Pressure -- The pressure exerted by a vapor in equilibrium with its liquid or solid phase.

Water Table -- The top of the saturated zone where unconfined ground water is under atmospheric pressure.

Well Log -- A record of installation of a well. It includes construction specifications of the well, depth, owner, location, a description of the soil profile, and it is prepared by the well driller. Well log records are maintained by the State Department of Water Resources, some county agencies, and the.U. S. Geological Survey.

Withdrawal -- Water pumped out of a well.

APPENDIX M

GENERAL REFERENCES

An attempt was made to include references that are both readily obtainable and useful as educational or reference material. No attempt was made to include all of the important publications in the vast literature relating to underground fuel leaks. Other publications are available from the American Petroleum Institute (1220 L Street, Northwest, Washington, D.C. 20005), the National Water Well Association (6375 Riverside Drive, Dublin, Ohio 43017), and state and federal agencies. Relevant papers may appear in Ground Water, Ground Water Monitoring Review, Environmental Science and Technology, Journal of the American Water Works Association, Environmental Toxicology and Chemistry, and in many other journals.

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