Lawrence Livermore National Laboratory
University of California
Livermore, California 94551

UCRL-AR-125912

Response to U.S. EPA Comments on the LLNL/UC LUFT Cleanup Recommendations and California Historical Case Analysis

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Brendan P. Dooher
Stephen J. Cullen*
Lorne G. Everett*
William E. Kastenberg**
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Submitted to the California State Water Resources Control Board
and the United States Environmental Protection Agency
Underground Storage Tank Program

January 1997

***University of California, Santa Barbara**
****University of California, Berkeley**

Environmental Protection Department
Environmental Restoration Program and Division

Work performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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Response Summary

In June 1994, the State Water Resource Control Board (SWRCB) contracted with the Lawrence Livermore National Laboratory/University of California (LLNL/UC) Leaking Underground Fuel Tank (LUFT) Team to study the cleanup of LUFTs in California. The study consisted of the collection and analysis of data from California LUFT cases and a review of other studies on LUFT cleanups. Two final reports were submitted to the SWRCB in October and November 1995. These reports were entitled, *Recommendations To Improve the Cleanup Process for California's Leaking Underground Fuel Tanks (LUFTs)*, and *California Leaking Underground Fuel Tank (LUFT) Historical Case Analysis.*

The LLNL/UC LUFT Team recommendations report continues to receive considerable attention both within California and throughout the nation. Although many comments have been quite favorable, there persist several concerns regarding the report's findings and recommendations.

These concerns can be summarized as:

- The report's findings were based on a limited data set.
- The data set was biased because fractured rock cases were not included.
- The report's focus on benzene, without consideration of other petroleum constituents, e.g., MTBE, invalidate the report's recommendations.
- The report understated the impact on water wells and the overall magnitude of the problem caused by LUFTs.
- The report recommendation to use passive bioremediation means "doing nothing."

The LLNL/UC LUFT Team believes that these concerns are based on misinterpretation or misunderstanding of our reports. As risk-based corrective action and the use of passive bioremediation gain increased attention, it is important to conduct an open and factual dialog regarding key issues, and we appreciate the opportunity to respond to each of these concerns.

The report's findings were based on a limited data set

LLNL/UC LUFT Team strongly disagrees with the assertion that the number of sites used in this study was limited and believes this assertion misrepresents the facts. Our studies were intended to demonstrate the merit of evaluating historical data from a large numbers of cases to make risk-management decisions. The LLNL/UC LUFT Team has endeavored to use the best available data gathered over many years at great expense during the management of California's LUFT cleanup process. Using this data we have tried to identify broad, general trends that could be used to more efficiently manage LUFT risks and to develop reasonable findings, conclusions, and recommendations to improve the LUFT cleanup process. This best available data represents the information routinely used to manage the risk at California LUFT sites and were typically gathered using EPA protocols.

We believe that LUFT risk-management decisions should be site specific. We also believe that regional data gathering and analysis can be used to streamline site characterization and reduce costs. Sites located within similar hydrogeologic settings can share data. As more regional data is gathered, the uncertainties associated with LUFT characterization will be reduced and made more explicit.

The total number of LUFT cases in California at the time of our study was 29,000, which includes 8,500 closed and 20,500 open cases. Of the 29,000 total cases, 10,797 were identified as affecting groundwater. Of the groundwater cases, the SWRCB's database identified 5,698 cases that were beyond preliminary site assessment. We targeted 13 counties that represent the hydrogeologic settings and areas where most of the underground storage tanks are located in California. The 13 counties selected accounted for 3,340 of the 5,698 'characterized" cases, statewide. We randomly selected, and State Board staff sought files for, 1,831 of the 3,340 cases. In other words, we investigated 55% of the eligible cases in the 13 counties.

To have confidence in our estimates of plume transformation in space and time, we chose all cases with at least six monitor wells and eight sampling events. Of the 5,698 "characterized" groundwater cases statewide, 843 were potentially available for this kind of analysis. Thus, the 271 cases analyzed represent a sampling of 32% of the available population of cases, statewide. This represents an important effort that has recently been used as a basis for evaluating the extent, mass, and duration of LUFT hydrocarbon plumes in Texas.

Beyond excluding fractured rock, no attempt was made to restrict the hydrogeologic settings evaluated. Most LUFT releases in California occur in alluvial settings. Gas stations are typically clustered in urban areas, and in California these urban areas are commonly located in the Coastal Ranges sedimentary or valley alluvium hydrogeological provinces. Thus, most of the cases evaluated represent these hydrogeologic settings.

We believe that the data gathered during the historical case analysis represents an unprecedented effort, and the results of this data can be used to streamline the LUFT cleanup process within California.

The data set was biased because fractured rock cases were not included

An important objective in the historical case analysis technical study was to draw broad regional conclusions regarding appropriate risk-management strategies for LUFT releases. The objective was not to address every conceivable exposure scenario, but to address the dominant or most likely exposure scenarios and to recommend risk-management strategies that are protective, as well as technically and economically feasible.

Cases with LUFT releases into fractured rock settings were excluded because fuel hydrocarbon transport at fractured rock sites is complex, not well understood, and often poorly characterized. Fractured rock sites represent only a small percent of reported LUFT cases in California. The use of risk-assessment techniques can provide site-specific approaches to managing LUFT cleanups at fractured rock sites.

The report's focus on benzene, without consideration of other petroleum constituents (e.g., MTBE), invalidate the report's recommendations

One of our primary recommendations is to use risk-assessment procedures to evaluate each site. During risk-based corrective action, contaminants that pose any potential risks are identified. Gasoline is the major fuel that is released from LUFTs. Gasoline is much more mobile in subsurface media than other fuel hydrocarbons (FHCs) such as diesel or fuel oil. The associated risks with gasoline are much greater as well. By focusing on gasoline FHC sites, we chose the most conservative fuel type. Benzene, which is the most mobile and the highest risk constituent of non-oxygenated fuels, was used as a conservative indicator compound for gasoline.

At the time our studies were conducted, little historical case data was available regarding the environmental fate and transfer of MTBE. There still is a lack of available MTBE data, especially in regards to environmental impacts. The California SWRCB, in collaboration with the Department of Energy Office of Fossil Fuels, and Western States Petroleum Association, is currently evaluating the fate and transport of MTBE in subsurface environments. Additional recommendations to the SWRCB regarding MTBE are forthcoming.

MTBE does not readily biodegrade or attenuate. Furthermore, low taste-and-odor thresholds may be the key issue in determining impacts to beneficial use of groundwater and surface water resources. It is conceivable that MTBE may prove to be a greater threat than benzene to the beneficial use of California groundwater and surface water resources. The LLNL/UC LUFT Team believes that if MTBE is present at a LUFT site, passive bioremediation may not be a suitable remedial alternative.

The LLNL/UC LUFT Team strongly endorses the position that pollution prevention is a major cornerstone to acceptance of passive bioremediation as a remedial alternative. This pollution prevention program should include tank upgrades that specify double wall containment for tanks and piping, along with rigorous leak-detection procedures. The LLNL/UC LUFT Team recommends that MTBE should not be transported or stored in tanks or pipe lines that do not meet these strict pollution prevention standards.

The report understated the impact on water wells and the overall magnitude of the problem caused by LUFTs

It is possible to hypothesize a variety of scenarios where FHC may impact drinking-water wells. The purpose of evaluating as much of the available data as possible is to identify those scenarios with the greatest probability of occurrence. Risk-management strategies to address these most likely exposure scenarios can then be developed. This statement does not to imply that unlikely scenarios do not occur, e.g., that well construction standards will not be met or that rural drinking-water wells may occasionally be impacted. The LLNL/UC LUFT Team has recommended the use of risk-assessment procedures that will identify those special cases.

The LLNL/UC LUFT Team based its conclusion that FHCs have limited impacts on human health, the environment, or California's groundwater resources on several lines of evidence. The first line of evidence is the number of drinking-water wells, as reported to the Leaking Underground Storage Tank Information System (LUSTIS) that have been impacted by benzene, toluene, ethylbenzene, and the xylenes (BTEX) from any source. The second is the actual number of LUFT case sites that have specifically impacted drinking-water wells supplying 25 or more people. According to the California Department of Health Services database, which collects chemical data over three year intervals from over 12,000 public drinking-water wells throughout the state of California, and a SWRCB survey of benzene affected wells, less than six wells have been impacted by benzene attributable to LUFT releases. The current LUSTIS database shows that there have only been 35 reported impacts to surface water from 18,223 open LUFT cases. A third line of evidence, from a detailed examination by SWRCB staff of those LUSTIS case sites that have impacted private drinking-water wells in the California Central Valley region, found that all the affected wells were within 250 feet of the likely LUFT release location.

The historical case analysis technical study was used to provide insight into benzene plume behavior that may then account for the observed limited impacts to drinking-water wells. Based on the analysis of historical cases that represent the bulk of LUFT releases in California, 90% of the benzene plumes > 10 ppb are limited to a linear extent of about 260 feet and 92% of the plumes were found to be stabilized or decreasing in length. Further, the Texas Bureau of Economic Geology, in cooperation with U.S. EPA, recently evaluated plume lengths at 217 LUFT sites. This study included fractured limestone and karst rock sites. In this study, 75% of the plume lengths > 10 ppb were found to be limited to a linear extent of 250 feet and 97% of the plumes were found to be stabilized or decreasing in length. This limited extent of plume migration is consistent with and can account for the observed limited impact to drinking-water wells in California.

We recognize that "long plumes" exist, but these are rare, and FHC release sites with relatively short stable or decreasing plumes should not be treated in the same manner as sites with growing long plumes. Our recommendations focused on the 90% of the California LUFT cases where the cleanup process was not efficiently applied. In the 10% of the cases that may be regarded as high-risk cases with extended plumes, the existing cleanup process within California is working. These high-risk cases are relatively easy to identify and case workers often, should, and do devote a majority of their time to these cases.

The report recommendation to use passive bioremediation means "doing nothing"

Our key recommendations are to use risk-based corrective action (RBCA) during the evaluation of LUFT cleanups. During RBCA, appropriate site characterization must be performed to identify the risk to human and ecological receptors as well as probable future loss of natural resource beneficial uses. Moreover, we recommend removing free product and FHC-saturated soils as much as economically and technically feasible. This is not "doing nothing". The use of passive bioremediation is an active choice, made on a site-by-site basis, after appropriate site-risk characterization.

Based on our consideration of site conditions and the nature and extent of releases at a statistically significant number of California sites, we recommended that passive bioremediation be considered an appropriate, cost effective, and technically feasible remedial alternative for those sites identified as low risk. Further, at sites that have low potential exposure risks or impacts to beneficial use, a decision to apply passive bioremediation within a region or class of hydrogeologic settings is justified and appropriate when supported by data from that region or class of sites.

1. Introduction

In June 1994, the State Water Resource Control Board (SWRCB) contracted with the Lawrence Livermore National Laboratory (LLNL)/University of California (UC) Leaking Underground Fuel Tank (LUFT) Team to study the cleanup of LUFTs in California. This review was a collaborative effort among the SWRCB staff, LLNL, and UC LUFT Team members. Financial support for this effort was provided, in part, by the U.S. Environmental Protection Agency (USEPA), Region IX, Underground Storage Tank (UST) Program. The study consisted of the collection and analysis of data from LUFT cases and a review of other studies on LUFT cleanups. Two final reports were submitted to the SWRCB in October and November 1995. These reports were entitled, *Recommendations To Improve the Cleanup Process for California's Leaking Underground Fuel Tanks (LUFTs)*, and *California Leaking Underground Fuel Tank (LUFT) Historical Case Analysis.*

Prior to submittal, both LLNL/UC reports were subjected to extensive internal peer review within the LLNL as well as within each of the four UC campuses involved, UC Berkeley, UC Santa Barbara, UC Davis, and UC Los Angeles. The USEPA has reviewed both LLNL/UC reports and in February 1996, issued a fact sheet generally supporting the findings and recommendations. Both reports have received national attention and have been extensively reviewed by many interested parties. Subsequent to the EPA fact sheet, USEPA Office of Underground Storage tanks (OUST) submitted comments to the SWRCB on the LLNL/UC LUFT Team reports.

This document is a response to the OUST comments in the USEPA Memorandum, *Comments on the Lawrence Livermore Report on California's LUST Program*, from Lisa Lund, Acting Director, OUST, submitted to the SWRCB on June 26, 1996. EPA's comments were divided into two sections. The first section commented on the LLNL/UC LUFT Team's recommendations to improve the cleanup process for California's leaking underground fuel tanks (Rice et al., 1995a). A series of specific comments gathered from various USEPA national regions were also provided. The second section comments on the Historical Case Analysis (HCA) (Rice et al., 1995b). Additionally, specific technical USEPA comments on the HCA were also offered.

In general, the LLNL/UC LUFT Team found the EPA comments in the June memorandum to be a through review of our reports. There were also several comments that may have stemmed from a misinterpretation, or misunderstanding of the information provided in our reports. We have provided clarification in these instances.

The EPA comments are a compilation of the opinions expressed by a number of different individuals within EPA. Many comments are a statement of the EPA commentator's opinion and the LLNL/UC LUFT Team often agrees with these opinions. The LLNL/UC LUFT Team has offered a response to each comment even though some of the comments seem to be redundant.

Many of the opinions within the USEPA comments are offered without providing supporting data upon which the opinion is based. Without this supporting data, it is difficult for the reader to evaluate the merit and validity of these opinions. To foster an open dialog on important issues where the merit of positions can be evaluated, the LLNL/UC LUFT Team encourages the USEPA commentators to make public the data that forms the basis for their opinions, where appropriate.

The LLNL/UC LUFT Team studies were intended to demonstrate the merit of evaluating historical data from a large numbers of cases to make risk-management decisions. The LLNL/UC LUFT Team has endeavored to use the best available data gathered over many years at great expense during the management of California's LUFT cleanup process. Using this data we have tried to identify broad, general trends that could be used to more efficiently manage LUFT risks and to develop reasonable findings, conclusions, and recommendations to improve the LUFT cleanup process. This best available data represents the information routinely used to manage the risk at California LUFT sites and were typically gathered using EPA protocols.

Recently, the Texas Bureau of Economic Geology, in cooperation with U.S. EPA, gathered site, soil, hydrogeologic, and chemical analytical information on 605 LUFT sites in Texas (Mace et al., 1997). This study included fractured limestone and karst rock sites. Plume lengths and behaviors were evaluated in 217 of the sites using methods set out in the *California LUFT Historical Case Analysis*. This study found that the behavior and extent of LUFT plumes within Texas hydrogeologic settings is very similar to that observed in California.

We believe that LUFT risk-management decisions should be site specific. We also believe that regional data gathering and analysis can be used to streamline site characterization and reduce costs. Sites located within similar hydrogeologic settings can share data. As more regional data is gathered, the uncertainties associated with LUFT characterization will be reduced and made more explicit.

The LLNL/UC LUFT Team strongly endorses the position that a major cornerstone to the acceptance of applying passive bioremediation during LUFT cleanup is pollution prevention. This includes tank upgrades with double wall containment for tanks and piping, along with rigorous leak-detection procedures. Chemicals of concern that are not readily degraded through natural subsurface process, such as the gasoline additive, methyl-tertiary butyl ether (MTBE), should not be used in above ground or underground storage tanks that do not meet rigorous pollution prevention standards.

The LLNL/UC LUFT Team appreciates the opportunity to provide a response to the EPA OUST comments. As the use of risk-assessment techniques, such as risk-based corrective action (RBCA) and the use of passive bioremediation processes, where appropriate, gain increased acceptance from both USEPA and State, and local LUFT agencies, it is important to conduct an open and factual dialog regarding key issues that may be misinterpreted or misunderstood. The detailed responses by the LLNL/UC LUFT Team in this document are intended to continue this dialog.

2. Background

2.1. California Leaking Underground Fuel Tank (LUFT) Historical Case Analyses

The primary goal of The California LUFT Historical Case Analyses study was to support the revision of the LUFT cleanup process. California LUFT case historical data had been collected by State regulatory agencies for about ten years. Analysis of these data provided information about the fate and transport of fuel hydrocarbons (FHCs) released into California's diverse hydrogeologic settings. The LUFT case data also provides a basis for the future continuous evaluation of both past and future impacts of LUFT releases and potential impacts on human health, the environment, and groundwater resources.

Several key questions addressed by the analysis of the California LUFT case historical data are:

- Do FHC plumes behave in predictable ways?
- What factors influence the length and mass of FHC plumes?
- To what extent are FHC plumes impacting California's groundwater resources?

Data was collected primarily from the broad alluvial and fluvial geologic settings typical of the San Francisco Bay Area, Los Angeles Basin, and the Central Valley. This data represents California's highly populated areas where most gas stations are found and most LUFT releases occur. Study results may be applicable in similar settings throughout the State. The length of dissolved benzene plumes in groundwater at LUFT releases were evaluated over time to determine how these plumes behave. Over 1,800 LUFT cases were evaluated. Benzene was analyzed because it is the human carcinogen of greatest concern in fuel. It is relatively soluble in water, and cleanup standards are generally tied to benzene concentrations.

Ongoing efforts to refine plume length estimates show that 90% of the dissolved benzene plumes, even by conservative estimates, less than 260 feet in length at the 10 ppb limit of quantification. Most of these plumes were either stable or decreasing in length. Seventy percent of the plumes in the study sites were found in shallow groundwater, less than 25 feet below the ground surface.

The study concluded that with rare exceptions, petroleum fuel releases will naturally degrade in California's subsurface conditions. Removing the source of the release will speed the cleanup time. Source removal includes removing leaking tanks and lines, and removing free product and FHC-saturated soil as much as economically and technically feasible. The use of passive bioremediation still requires site characterization, an assessment of the potential FHC release risks, and an evaluation of the applicability of passive bioremediation. Further, as part of our recommendation to utilize passive bioremediation wherever possible, we advocate that its effectiveness be demonstrated and supported by a monitoring program on a site-specific basis. Once passive bioremediation is demonstrated to be appropriately applied to a site, no probable receptors exist, and unless there is a compelling reason otherwise, the site may be considered to be low risk and no further action may be required.

Although the term "passive bioremediation" is used repeatedly below, we wish to emphasize that this process is a subset of natural attenuation, and should be read as such, where appropriate, in both the comments and responses.

2.2. Recommendations to Improve the Cleanup Process for California Leaking Underground Fuel Tanks (LUFTs)

After reviewing California's LUFT program and related documents submitted as part of the Senate Bill 1764 Expert Committee overview, the LLNL/UC LUFT team developed the following list of recommendations that we believed would help the State deal with LUFT cleanups.

2.2.1. Utilize Passive Bioremediation as a Remediation Alternative Whenever Possible

- Minimize actively engineered LUFT remediation processes.
- Once passive bioremediation is demonstrated and unless there is a compelling reason otherwise, close cases after source removal and rely on passive bioremediation to cleanup FHCs.
- In general, do not use the UST Cleanup Fund to implement pump-and-treat remediation unless its effectiveness can be demonstrated.
- Support passive bioremediation with a monitoring program.

2.2.2. Immediately Modify the ASTM RBCA Framework Based on California Historical LUFT Case Data

- Perform LUFT historical case studies on soils-only cases to support development of a RBCA tier-one decision-making process.
- Use LUFT historical case data to modify ASTM RBCA to reflect California's site-specific exposure pathways and quantify the uncertainty in the assumptions that are used during risk evaluations.
- The modified ASTM RBCA tier-one decision-making process should encompass a majority of California's LUFT cases and facilitate and encourage the utilization of passive bioremediation.

2.2.3. Apply a modified ASTM RBCA framework as soon as possible to LUFT cases where FHCs have affected soil but do not threaten groundwater

- There are no existing barriers to implementing ASTM RBCA at LUFT sites where FHCs have only affected soils.
- Perform LUFT historical case studies on soils-only cases to support RBCA tier-one development.

2.2.4. Modify the LUFT regulatory framework to allow the consideration of risk-based cleanup goals higher than MCLs

- Modify SWRCB policies to remove barriers to applying a modified ASTM RBCA framework to FHCs affecting groundwater.
- Once SWRCB policy barriers have been removed, apply ASTM RBCA process to LUFT cases where FHCs have affected groundwater.

2.2.5. Identify a Series of LUFT Demonstration Sites and Form a Pilot LUFT Closure Committee

- LUFT demonstration sites should be chosen to:
  - Act as training grounds for implementation of a modified ASTM RBCA process.
  - Facilitate the implementation of a revised LUFT decision-making process.
  - Test recommended sampling and monitoring procedures and technologies to support passive bioremediation.
  - Confirm cost effectiveness of the modified ASTM RBCA process.
- A pilot LUFT closure committee, made up of scientific professionals from universities, private industry, and state agencies, should be set up to make professional interpretations and recommendations regarding LUFT evaluations and closures at the demonstration sites.

3. EPA General Comments on LLNL/UC LUFT Recommendations

3.1. Recommendation 1—Utilize Passive Bioremediation as a Remediation Alternative Whenever Possible

EPA Comment

In general, cleanup decisions need to be risk-based, and made on a site-by-site basis, with all exposure pathways and chemicals of concern evaluated and monitored.

Response

The LLNL/UC LUFT Team agrees that LUFT risk-management decisions should be site specific and individual sites should be examined in light of the risk posed to receptors, the applicability of passive bioremediation, and any probable future losses of the beneficial use of the groundwater resource. We also believe that regional data gathering and analysis can be used to streamline site characterization and reduce costs. Sites located within similar hydrogeologic settings can share data. As more regional data is gathered, the uncertainties associated with LUFT characterization will be reduced and made more explicit.

One of our key recommendations is to characterize the risk at a given site as part of the LUFT cleanup process. A risk-based decision-making process provides a common framework to systematically address LUFT cleanup. On a site-specific basis, risk-assessment techniques can be used to identify all chemicals of concern and potential pathways of exposure.

For a risk to exist, there must be a source of a hazard, a receptor, and a pathway that connects the two. All three factors must be addressed to determine whether a LUFT release poses a risk to human health, safety, the environment, or the beneficial uses of groundwater. If the source, pathway, or receptor are at all times absent, there is, by definition, no risk.

If the risk of affecting receptors (humans or ecosystems) is low, then the following risk-management strategy is appropriate and cost effective: a) remove and upgrade leaking underground tank and lines, b) perform source removal as much as economically and technically feasible, and c) use passive bioremediation at low-risk sites, whenever possible.

Further, as part of our recommendation to utilize passive bioremediation wherever possible, we advocate that the effectiveness of passive bioremediation be demonstrated and supported by a monitoring program on a site-specific basis.

EPA Comment

EPA does not advocate one cleanup technology over another; rather the focus is on determining the appropriate technology to use, taking into consideration both the conditions of the site, and the nature and extent of the release.... Both active and passive processes can be shown to be protective of human health and the environment under appropriate site conditions.

Response

The LLNL/UC LUFT Team approach evaluates data to identify a dominant FHC release scenario and formulate a risk-management strategy for that scenario that balances technical and economic feasibility, along with the need for protection of human health, the environment, and beneficial uses of water. At issue is the necessity to effectively allocate limited environmental remediation resources, e.g., is the high cost of actively engineered remediation, in any form, warranted at a significant proportion of California LUFT release sites? Based on our consideration of site conditions and the nature and extent of releases at a statistically significant number of California sites, we recommended that passive bioremediation can be considered an appropriate, cost effective, technically feasible remedial alternative for those sites identified as low risk. Active remediation should not be attempted unless compelling reasons exist, e.g., the site is a high-risk site where receptors are being threatened.

EPA Comment

Decisions to use natural attenuation as a remedy should not be made for an entire state, region, or cross-geographic class of sites.

Response

Our data indicates that passive bioremediation can be expected to occur at a large proportion of the sites within the alluvial hydrogeologic settings where the study was conducted. A decision to consider the applicability of passive bioremediation within a region or class of hydrogeologic settings may be fully justified and appropriate when supported by an evaluation of data from that region or class of sites. Our recommendation includes the need to demonstrate passive bioremediation at a site. Information from previous investigations at nearby sites and other historical regional data can be used to provide evidence of passive bioremediation.

EPA Comment

If compounds are present that do not readily biodegrade or attenuate (e.g., methyl-tertiary-butyl-ether or MTBE), passive bioremediation may not be a suitable remedial alternative or may need to be supplemented with other remedial technologies.

Response

We agree with this comment. The LLNL/UC LUFT Team recommends that MTBE should not be used in above ground or underground tanks that do not meet strict pollution prevention and leak detection standards, including double wall containment for tanks and piping.

EPA Comment

EPA strongly recommends source removal and requires free-product removal to the maximum extent practicable as determined by the implementing agency.

Response

The term" source removal" has many meanings. For this discussion, a "primary source" means the leaking tank and any associated fuel-distribution piping. A "secondary source" means any fuel hydrocarbons that remains in such quantities as to threaten human health, the environment, or probable beneficial uses of groundwater. Typically this means free or floating product, but there must be a probable threat to human health or the environment. FHCs that are residual (sorbed to a soil matrix) may release small amounts of FHC constituents through volatilization or advection. Although the LLNL/UC LUFT Team recommends the removal of these secondary sources to the point of residual saturation, we find that the recommendation for secondary source removal by the SB1764 Expert Committee (1996) is more detailed and explicit. It states:

> ...In most cases, floating product should be removed to at least the point of residual saturation; the decision to remove floating product should be made on a site-specific basis depending on the risk posed by the product and the benefits, in terms of risk reduction, that may be provided by the product recovery....Although such cases may be rare, the adopted risk-based decision-making framework should be flexible enough to allow a no-action alternative to be considered for such sites (SB1764 E.C., 1996).

Such an approach is much more consistent with risk-based principles and the need for site-specific evaluation than an all-encompassing non-site-specific recommendation to remove floating free product to the maximum extent possible in every case.

EPA Comment

Passive bioremediation should NOT be interpreted to mean "doing nothing."

Response

Our key recommendations are to use risk-based corrective action (RBCA) during the evaluation of LUFT cleanups. During RBCA, appropriate site characterization must be performed to identify the risk to human and ecological receptors as well as probable future loss of natural resource beneficial uses. Moreover, we recommend removing free product and FHC-saturated soils as much as economically and technically feasible. This is not "doing nothing". The use of passive bioremediation is an active choice, made on a site-by-site basis, after appropriate site-risk characterization.

3.2. Recommendation 2—Immediately Modify the American Society for Testing and Materials (ASTM) RBCA Framework Based on California's Historical LUFT Case Date

EPA Comment

We recommend that California use a step-wise approach for implementing its RBCA framework. The historical LUFT case data study is a first step in this direction. However, additional information and input from stakeholders is necessary to ensure that the appropriate policy decisions are made.

Response

We agree with this comment. Our last recommendation states that California should identify a series of LUFT demonstration sites, and form a pilot LUFT closure committee to facilitate the implementation of a revised LUFT decision-making process. The State of California has embraced this recommendation and is coordinating a Petroleum Hydrocarbon Cleanup Demonstration Program (PHCDP) sponsored by the Department of Defense (DoD) and the SWRCB.

3.3. Recommendation 3—Apply a Modified ASTM RBCA Framework as Soon as Possible to LUFT Cases Where Fuel Hydrocarbons (petroleum) Have Affected Soil but do not Threaten Groundwater

<u>**EPA Comment**</u>

EPA would strongly encourage the State to consider the limits of the LLNL study, and to ensure that other pathways, geologic settings, and chemicals of concern are incorporated into the design of an RBCA process.

Response

In general, we agree with this comment. Again, the LLNL/UC LUFT Team focused on dominant LUFT release scenarios in California. Most LUFT releases in California occur in alluvial and fluvial settings. Gas stations are typically clustered in urban areas, and these urban areas in California are commonly located in the Coastal Ranges sedimentary or valley fluvial and alluvial hydrogeologic provinces. Thus, most of the cases evaluated represent these hydrogeologic settings. We have stated that a risk-assessment approach to LUFT cleanups will provide guidance to reasonably manage risks to ecosystems, groundwater beneficial use, and human health, balanced with technical and economic feasibility. A risk-based approach will address all pathways, receptors, and chemicals of concern, irrespective of hydrogeologic setting.

<u>**EPA Comment**</u>

EPA believes that the RBCA process allows for the use of passive bioremediation, where it is appropriate, as determined on a site-specific basis.

Response

We agree with this comment.

<u>**EPA Comment**</u>

The recommendations document concludes that fuel hydrocarbons have limited impacts on human health, the environment, or California's groundwater resources. The limitations of the technical study certainly do not support the broad implications of this statement.

Response

This comment raises an issue without elaborating on the basis for concern. The technical study limitations that do not support our conclusion regarding groundwater impacts are not clearly identified in this comment. The historical case analysis technical study does have limitations that are specifically identified; further, our conclusions were only made with respect to the groundwater pathways.

It was not the intent of the LLNL/UC LUFT Team to intentionally exclude or overlook pathways other than groundwater ingestion; however, data were not generally available to evaluate other pathways. Either these other pathways were seldom of concern or data quality could not support analysis.

The LLNL/UC LUFT Team based its conclusion that FHCs have limited impacts on California's groundwater resources on several lines of evidence not derived from the historical case analysis technical study. The first line of evidence is the number of drinking-water wells, as reported to the Leaking Underground Storage Tank Information System (LUSTIS, 1995) that have been impacted by benzene, toluene, ethylbenzene, and the xylenes (BTEX) from any source. This information is typically reported to the EPA. The second is the actual number of LUFT case sites that have specifically impacted drinking-water wells supplying 25 or more people. According to the California Department of Health Services (DHS, 1995) database, which collects chemical data over 3-year intervals from over 12,000 public drinking-water wells throughout the State, and a SWRCB survey of benzene affected wells, less than 6 wells have been impacted by benzene attributable to LUFT releases. A third line of evidence, derived from a detailed examination by the SWRCB of those LUSTIS case sites that have impacted private drinking-water wells in the California Central Valley region (Rempel, 1995), found that all the affected wells were within 250 feet of the likely LUFT release location.

The historical case analysis technical study was used to identify benzene plume behavior that may then account for the observed limited impacts to drinking-water wells. Based on the analysis of historical cases that represent the bulk of LUFT releases in California, 90% of the benzene plumes >10 ppb are limited to an areal extent of about 260 feet and 92% of the plumes were found to be stabilized or decreasing in length. In the Texas Bureau of Economic Geology study, which included fractured limestone and karst rock sites, 75% of the plume lengths > 10 ppb were found to be limited to a linear extent of 250 feet and 97% of the plumes were found to be stabilized or decreasing in length. This limited extent of plume migration can account for the observed limited impact to drinking-water wells in California.

EPA Comment

EPA does not agree with the claims of protection to groundwater afforded by well construction standards, or that urban areas on public water systems may not need to have the same stringent cleanup requirements as aquifers providing drinking-water supplies.

Response

It is possible to hypothesize a variety of scenarios where FHC may impact drinking-water wells. The purpose of evaluating large amounts of data is to identify those scenarios with the greatest probability of occurrence. Risk-management strategies to address these most likely exposure scenarios can then be developed. This does not imply that unlikely scenarios do not occur, e.g., that well construction standards will not be met. The LLNL/UC LUFT Team has recommended the use of risk-assessment processes that will identify those special cases, e.g., a rural drinking-water well that may be impacted or an urban area supplied by shallow groundwater for drinking-water purposes.

EPA Comment

A blanket policy regarding urban centers should not guide cleanup efforts, but should again be site-specific or specific to individual urban areas.

The LLNL study focused on urban areas with very specific lithologic characteristics, and thus, excluded many other conditions that could be of concern. Other potential pathways of exposure, more complex geologic conditions, and more complete consideration of contaminant composition could all lead to a higher level of concern at LUFT sites.

Response

Beyond excluding fractured rock, no attempt was made to restrict the hydrogeologic settings evaluated. Most LUFT releases in California occur in fluvial and alluvial settings. Gas stations are typically clustered in urban areas, and these urban areas in California are commonly located in the Coastal Ranges sedimentary or valley fluvial and alluvial hydrogeologic provinces. Thus, most of the cases evaluated represent these hydrogeologic settings. Excluding fractured rock, these hydrogeologic settings are among the most complex settings encountered in California.

An important objective in the historical case analysis technical study was to draw broad regional conclusions regarding appropriate risk-management strategies for LUFT releases. The objective was not to address every conceivable exposure scenario, but to address the dominant or most likely exposure scenarios and to recommend risk-management strategies that are protective as well as feasible with respect to cost and technical capabilities. On a site-specific basis, risk assessment can be used to identify all potential pathways of exposure, or determine whether the contaminant composition at a site warrants a higher level of concern.

3.4. Recommendation 4—Modify the LUFT Regulatory Framework to Allow the Consideration of Risk-Based Cleanup Goals Higher than MCLs

EPA Comment

In cases where there is no plan for current or future use of groundwater for human consumption, alternative cleanup levels may be appropriate on a case-by-case basis. However, time frames for neutralization or degradation of contaminants should be considered within the context of possible future use.

Response

The LLNL/UC LUFT Team agrees partly with what is stated in this EPA comment. We believe, however, that the consideration of possible future uses is too broad a requirement. Many improbable but possible future uses may be imagined for a particular site. It is more realistic to consider the future uses that are likely to occur. In fact, the California Water Code as stated by the Porter Cologne Act (1994) specifically states the "probable future beneficial uses of water" must be considered when formulating water quality objectives. The matter of time frames associated with probable future beneficial uses of water must be carefully considered.

3.5. Recommendation 5—Identify a Series of LUFT Demonstration Sites, and Form a Pilot LUFT Closure Committee

EPA Comment

EPA supports the establishment of demonstration projects to test the new RBCA process, facilitate implementation, recommend sampling and monitoring procedures, outline a process of technology decisions, and confirm the cost effectiveness of the process and its results. EPA is actively participating in efforts to identify LUFT demonstration sites and form a pilot LUFT closure committee to test the recommendations of the LLNL report in California.

Response

The LLNL/UC LUFT Team appreciates EPA's support of this recommendation. This recommendation is currently being implemented, and a member of EPA's Region IX office is acting as a member of the DoD PHCDP Oversight committee.

4. Response to Specific Comments on LUFT Recommendations Report

<u>EPA Comment 1</u>. ***Technical Feasibility, "Complete Cleanup"—p. EX-2, pp. 10-1. The report states, "If a [fuel hydrocarbon] FHC source is removed, passive bioremediation processes [i.e., natural attenuation] act to naturally reduce FHC plume mass and to eventually complete the FHC cleanup." EPA strongly supports source removal or control to diminish the ongoing degradation of our environment.***

The report should clearly describe what is meant by "complete" cleanup and should also describe the potential risks, if any, associated with the FHCs that are thought not to degrade as readily as the BTEX parameters. A potential problem with the report pertains to the claim of "complete" cleanup. The completeness of a natural attenuation cleanup is controversial because it invokes the debate as to whether or not the benzene, toluene, ethylbenzene, and xylene (BTEX) components of FHCs are really the only parameters of concern. While the evidence does indicate BTEX constituents are readily degradable in some settings, in other settings BTEX has been shown to resist degradation for 10 years. Program implementors may also at times be reluctant to allow for natural attenuation because of the uncertain risks associated with the longer-chain FHCs and additives such as methyl-tertiary butyl ether (MTBE) that could remain in the environment for potentially long and unknown periods of time after BTEX is gone.

Response

The term "complete cleanup" means that no residual hazards are associated with the site, and the site can be used without restriction. Several issues are associated with determining "how clean is clean enough." One issue is the time frame for anticipated beneficial use of the site; another is the technical feasibility of removing all traces of FHCs at a site. Eventually, all of the more volatile and soluble FHCs, even MTBE, will be degraded or attenuated to below detection limit concentrations, even without active remediation. In a small proportion of cases this process will occur over several decades; perhaps as long as a century. Decades may be a tolerable period of time for natural degradation processes to operate if the FHCs are (1) relatively immobile in the subsurface soil at a depth where human or ecological exposure is highly unlikely, or (2) where groundwater beneficial use is not probable. As previously discussed, risk assessment can be used to identify low-risk sites where the time required for passive bioattenuation to complete the cleanup of residual FHC is allowable.

The LLNL/UC LUFT Team maintains that no reasonable amount of active remediation will be able to remediate long-chain FHC molecules to non-detect levels. From a fate and transport perspective, these long-chain molecules are not as likely to be mobilized in the subsurface and, therefore, do not represent a "dynamic" risk. They can represent a "static" risk, whereby if encountered during drilling or excavations encounter them, an individual may be exposed. Their exposure will be limited, however, due to the relatively low taste-and-odor thresholds associated with long-chain FHCs.

<u>EPA Comment 2.</u> ***Technical Feasibility, Plume Migration—p. EX-2, p. 11. The report uses the finding that benzene plumes tend to stabilize in relatively short distances from the release site as part of its justification for assuming minimal associated risks. This relatively short distance is described later in the report (page 11) as 250 feet. The distance of 250 feet might in some settings, such as a large Resource Conservation and Recovery Act (RCRA) Subtitle C facility, have little actual impact to receptors; however, such migration for a small site, like a gas station, could result in groundwater contamination beneath numerous off-site properties. Furthermore, some documented BTEX plumes have extended nearly one mile from the source of the release. Also, 250 feet of potential migration might, in a number of settings, result in detrimental impacts to ecological receptors. Because no two sites are identical, the risk associated with potential migration should be evaluated on a site-specific basis.***

Response

We agree with these statements. We recognize that "long plumes" exist, but they are the minority, and FHC release sites with relatively short stable or decreasing plumes should not be treated in the same manner as sites with long growing plumes. Our recommendations focused on the 90% of the California LUFT cases where the cleanup process could be improved. In the 10% of the cases (with extended plumes) that may be regarded as high-risk cases, the existing cleanup process in California is working. These high-risk cases are relatively easy to identify, and case workers often devote most of their time to these cases.

As part of the risk-assessment process, all potential pathways are evaluated, and if detrimental impacts to ecologic receptors are likely, the site should be regarded as high risk, irrespective of plume length. However, there is little evidence for significant ecological impacts from FHC plumes. The current LUSTIS database (1996) shows that there have only been 35 reported impacts to surface water from 18,223 open LUFT cases.

A distinction must be made between those actions that must be taken to manage an identified risk to a receptor and those actions that may be taken to preserve equity loss due to a perceived or imagined risk. Clearly, public funds should not be expended to preserve an equity loss. It is a business decision rather than a risk-management decision.

<u>EPA Comment 3.</u> ***Technical Feasibility, Effectiveness of Pump-and-Treat—p. EX-2 and 11. The report states, "Remedial alternatives that utilize pump-and-treat are recognized as being ineffectual at reaching MCL groundwater cleanups for FHCs in many geologic settings." While we recognize pump-and-treat has limitations, the report's finding is an overgeneralization. Many of the references cited in the report, which deal with the limitations of pump-and-treat, focus primarily on subsurface media containing non-aqueous phase liquids (NAPLs) which act as continued sources of contamination, when describing limitations of pump-and-treat, the report should identify whether the stated limitations pertain to source areas of contamination or the associated dissolved plumes.***

Also, to provide a balanced approach, we believe the report should present examples of where pump-and-treat has proven to be effective. The National Research Council (NRC 1994) indicated well-design pump-and-treat systems generally should be able to restore the groundwater in reasonable periods of time for sites with uniform geologic characteristics and where contaminants are present in the dissolved phase. Granted, the problem is that many settings has non-aqueous phase contamination and non-uniform geologic conditions. However,

examples do exist where pump-and-treat has been used successfully to restore aquifers when sources were eliminated or controlled, and especially where biodegradation associated with FHCs is also occurring (NRC, 1994). Pump-and-treat can aid biodegradation by replenishing electron acceptors and nutrients.

An additional limitation of this report is that it focuses on the ineffectiveness of pump-and-treat to achieve cleanup levels, while not mentioning that pump-and-treat is effective at halting further migration at most sites. Halting all or part of plume migration will likely still be necessary at a large number of sites to prevent or minimize resource damage and the threat of exposure.

Response

Many of the references cited in the recommendations report do address subsurface media containing non-aqueous phase-liquids. These references state that one of the primary reasons that the pump-and-treat method is ineffectual in remediating dissolved plumes is that FHCs sorbed to soil particulates tend to be retained and are released slowly, limiting mass removal rates. The recommendations report does indicate that pump-and-treat has achieved risk-based cleanup goals in the exceptional cases where the FHC source was quickly controlled and removed, and a relatively small dissolved FHC plume had not diffused deeply into the solid materials in a shallow aquifer.

Other EPA commentors state, on page 12 of these comments, under the section "Natural Attenuation and Alternative Remedial Technologies," that pump-and-treat as well as overexcavation "are both conventional technologies that EPA does not recommend for most circumstances. Instead, EPA has been supporting the use of alternative technologies for contaminated soils and groundwater because EPA recognizes the limitations inherent in pumping and treating groundwater."

We disagree that a large number of sites exist where it is necessary to halt the plume migration. We question the economics of performing active remediation on dissolved plumes in any situation where no potential receptors are at risk and plume migration is halted by natural processes at a relatively short distance from the release site. Although active remediation, such as pump-and-treat, may help reduce plume mass, significant reduction can occur with time, even without pump-and-treat, due to passive bioremediation. The historical case analysis technical study found that in cases where pump-and-treat was reportedly used in conjunction with overexcavation of the secondary source, the likelihood of decreasing the plume's average benzene concentrations with time improved only by about 30% compared to instances where no active remediation was reportedly performed.

EPA Comment 4. ***Applicability of ASTM Risk-Based Corrective Action (RBCA)—p. EX-2 and 14. The reports states that applying a RBCA approach will provide guidance to reasonably manage risks to human health, ecosystems and beneficial uses. These are issues that California may want to address in designing their RBCA program.***

We agree with this comment.

EPA Comment 5. ***Recommendations, Use Passive Bioremediation Whenever Possible—p. EX-3 and 19. The report recommends, "Once passive bioremediation is demonstrated and unless there is a compelling reason otherwise, close cases after source removal and rely on passive bioremediation to cleanup FHC." Furthermore, the report recommends, "In general, do not use the UST cleanup fund to implement pump-and-treat remediation unless its effectiveness***

can be demonstrated." As noted above, at least this recommendation emphasizes source control. However, this recommendation would in essence establish natural attenuation as a "presumptive remedy." The Agency supports using the concept of presumptive remedies to streamline environmental actions at hazardous waste sites however, experience in the UST program has shown that site-specific decisions on remedial options are the most efficient and cost-effective. Although the evidence is compelling for natural attenuation of FHCs in some settings, we do not believe the track record exists currently to establish natural attenuation as a presumptive remedy for the full range of petroleum release sites that are found in the field, nor does the UST program endorse the presumptive remedy approach for leaking USTs.

Response

It is difficult to evaluate this comment because the data to support the EPA position against the use of LUFT presumption remedies is not discussed or provided. As stated in the full recommendation, "Utilize passive bioremediation as a remediation alternative whenever possible. Once passive bioremediation is demonstrated, and unless there is compelling reason otherwise, close cases after source removal to the point of residual saturation." Decisions to use passive remediation may be site specific, based on demonstration of performance through monitoring. However, there are sites where passive remediation should be the only option used, or where relatively small amounts of characterization are required to draw conclusions as to the associated risk.

Based on the historical case analysis technical study, we believe that the evidence is compelling for passive bioremediation of FHCs at most California LUFT release sites. Though passive bioremediation occurs most everywhere, it does not occur in the presence of high FHC concentrations in secondary source areas. Some special conditions may exist where nutrients such as nitrates or sulfates are limited and, thus, the rates of biodegradation are limited. For this reason, we have recommended that passive bioremediation be demonstrated at sites where its application is being considered. A primary line of evidence is the presence of a stable or decreasing plume. A secondary line of evidence is the depletion of the groundwater electron receptors that are used during biodegradation of FHCs.

EPA Comment 6. ***Recommendations, Conduct Pilot Studies—p. EX-4, and 20. We agree with the report's recommendation for pilot studies; such studies should also be used to form the basis for any new state policy and guidance dealing with natural attenuation. However, we recommend collecting additional data (e.g., electron acceptors, and geochemical indicators) during the pilot studies.***

Response

We agree with the EPA's recommendations to collect electron acceptor and geochemical data at the demonstration sites, and this data gathering process is being implemented.

EPA Comment 7. ***Section 4.1.3, Use of Well Construction Standards—p. 5. The report indicates that FHC impact of the referenced 11 private wells may have been prevented if the wells had been constructed following California standards. The report seems to be suggesting that there is no reason to cleanup FHCs in shallow aquifers because the groundwater in these aquifers should not be available for human consumption. We agree that new wells should be installed in a manner that minimized the threat of contamination; however, the construction specifications for existing wells, which previously were uncontaminated, should***

not be used as a reason to ignore or justify the presence of FHCs. Relying on construction standards to justify a lack of potential exposure from shallow FHC contamination is not appropriate. Many shallow aquifers are still used for human consumption, are sources of recharge for deeper aquifers, and are also important from an ecological protection perspective.

Response

Within California, well construction standards are currently used to reduce present and future exposure to a variety of contaminants in shallow groundwater, and such standards may have prevented FHC releases from impacting wells. Furthermore, it is not practical to regulate contaminants such as releases from sanitary sewers and septic tanks. For this reason, shallow suburban and urban groundwaters are often not used for drinking, and a drinking-water pathway to a human receptor from a LUFT release into these shallow waters is highly unlikely. When a risk-assessment process is applied to the large number of LUFT releases in these shallow groundwaters that are already degraded, the risk from the groundwater ingestion pathway can be considered minimal. Although well construction standards may not be used to justify a lack of exposure, the presence of a variety of biological and other contaminants more hazardous than FHCs often prevent the use of shallow groundwaters as a drinking-water supply.

The point we wish to make is that the cleanup of these shallow degraded groundwaters is not urgent in most cases. These sites are good candidates for the application of passive bioremediation to achieve cleanup. During risk assessment of the site, all other pathways are considered, including potential vertical migration of FHCs to deeper aquifers.

EPA Comment 8. ***Section 5.4, Current Understanding of Passive Bioremediation Processes—p. 17. The report claims that passive bioremediation can restore contaminated groundwater, "...in approximately the same time period as can be expected using actively engineered cleanups." Specific references should have been provided to support such a significant statement. EPA's experience with active and passive remediation options does not support such conclusions.***

Response

Studies from Buscheck (1996) and Borden et al. (1996) indicate first order attenuation rates of benzene ranging from 0.55% per day to 0.05% per day. If a site is (1) assumed to have an initial average benzene groundwater concentration of 1,000 µg/L, (2) the above decay rate limits are the 95th and 5th percentile degradation rates, respectively, in a lognormal distribution, and 3) no continuing source feeds the plume, 52% of sites will have average benzene plume concentrations below 1 ppb in 12 years, and 95% of sites will have average benzene plume concentrations below 100 ppb in 12 years. This mass removal rate is well within the order of magnitude of mass removal rates expected for pump-and-treat, and cleanup may be considered to be approximately within the same time frame as expected for pump-and-treat. An important assumption in this estimate is that no continuing secondary source is delivering benzene mass to the groundwater. In cases where passive bioremediation is observed to take longer periods of time, it is very likely that secondary sources have not been removed or even discovered.

We are requesting specific references to support EPA's statement that their experience with active and passive remediation options does not support our conclusion. We are interested in reviewing those sites, that in EPA's experience, do not support these conclusions as to the order of magnitude. Most research has been on active remediation of sites rather than passive, and our database of sites is perhaps the largest to date.

<u>Comment 9</u>. ***Section 5.5, There are a Few Situations Where Pump-and-Treat Should be Attempted—p. 17. The report indicates that the NRC report, mentioned above, concluded that conventional pump-and-treat systems will be able to restore contaminated groundwater to drinking water standards at only a limited number of sites. This is an oversimplification of the NRC report's findings, and using the term "limited" provides an inadequate picture of the potential successful applications of pump and treat. When referencing the NRC report, it is important to describe its findings in the appropriate context. For example, the NRC report evaluated 77 sites and rated them in categories 1 through 4; according to the relative ease of groundwater cleanup as a function of contaminant chemistry and subsurface conditions. The report concluded: 2 out of the 77 sites should be able to be restored (category 1); 14 additional sites should be able to be restored but with a greater degree of uncertainty (category 2); restoration is possible at 29 additional sites but is subject to significant uncertainty and partial cleanup may be a more realistic scenario (category 3); and, restoration at the remaining 42 sites is unlikely (category 4). Therefore, the NRC report concluded that pump-and-treat could either partially or totally restore the contaminated groundwater at 45 (or 58%) out of the 77 sites studied. Note also that the 77 sites include a wide variety of sites including but not limited to FHC release sites.***

Response

This comment does a good job of summarizing the NRC findings and this summary, in our opinion, fully supports our position. Only 2 of 77 evaluated sites studied were able to be restored to drinking-water standards. This number indeed represents limited effectiveness. If a greater degree of uncertainty is tolerable, the number of sites where pump-and-treat may be expected to reach drinking-water standards could be 16 of 77. In our opinion, these results are indicative of significant limitations.

Furthermore, EPA recognizes the limitations of pump-and-treat methods. EPA states on page 12 of their USEPA OUST comments, under the section "Natural Attenuation and Alternative Remedial Technologies," that pump-and-treat as well as overexcavation "are both conventional technologies that EPA does not recommend for most circumstances. Instead, EPA has been supporting the use of alternative technologies for contaminated soils and groundwater because EPA recognizes the limitations inherent in pumping and treating groundwater." USEPA goes further to state, "Even worse, pump-and-treat systems can actually smear or spread contamination when water-table levels fluctuate."

<u>Comment 10</u>. ***Section 5.7, Modifications Would be Necessary for the ASTM RBCA Framework to be Used in California—p. 18. The report emphasizes excavation approaches for dealing with the source of FHC. The report should mention that other approaches, such as bioventing, might in some settings provide cost-effective alternatives to excavation.***

Additionally, this section states that a monitoring program and a plume management program would be established while plumes are remediated using passive bioremediation. The report's earlier recommendation that sites should be closed after source removal (page EX-3), p. 19, seems to imply that this monitoring and plume management would take place at "closed" sites. It was our understanding that a closed" site typically warrants no further regulatory involvement. If this is true, who then would be overseeing the monitoring program to ensure protectiveness and that the long-term monitoring is still being

conducted? We do agree that it is appropriate for the level of regulatory oversight to correspond to site-specific factors including potential risks. EPA would support a "monitoring only" site status, which would not be the same as closure.

Response

We agree that bioventing might in some settings provide cost-effective alternatives to excavation. Our reports were intended to focus on the historical case data available. In the cases evaluated, we found little or no data that provided information on bioventing.

We fully recommend that "once passive bioremediation is demonstrated and unless there is a compelling reason otherwise, close cases after source removal to the point of residual FHC saturation....support passive bioremediation with a monitoring program." We also recommend that once plume stability or passive bioremediation have been demonstrated, that such cases may be closed if there are no potential risks associated with the site. This recommendation provides latitude for sites to be evaluated on a case-by-case basis regarding the amount of characterization and monitoring required to demonstrate passive bioremediation prior to closure. It is not our intent that a "monitoring only" site status be implied from this recommendation.

5. Reponse to USEPA Comments on the LLNL Historical Case Analysis

5.1. The Potential for Inappropriate Application of Study Results

EPA Comment

The study was designed to focus on the geologic settings and petroleum release scenarios which would represent a large majority of the LUST sites in California. The report authors recognized that the study had limitations and stated that only more predictable release scenarios were investigated. It is important to realize that petroleum compounds beyond benzene (e.g., Methyl-tertiary-butyl-ether (MTBE), polycyclic-aromatic hydrocarbons (PAHs)) were not evaluated; exposure pathways beyond ground water impacts (e.g., air, surface water, soil) were not reviewed in detail; the study did not review certain geological conditions (e.g., bedrock, fractures, karst); and, the number of fully characterized contaminant plumes in ground water included in the study was limited to 271 sites compared to over 10,000 LUST sites statewide that impact ground water and a total of 28,000 LUST sites. Some of these compounds, exposure pathways, geologic settings, and release scenarios not evaluated in this study may constitute higher risk sites. As a result, the recommendations made in the LLNL report should not be applied to sites or scenarios which differ dramatically from the parameters of the study.

Response

We agree with portions of EPA's summary of the study limitations. The study did not evaluate MTBE, polycyclic-aromatic-hydrocarbons, metals, or radionuclides. The study focused on groundwater exposure pathways and did not evaluate surface water, soil ingestion, vapor inhalation, or ecological pathways in detail. The study excluded fractured bedrock settings. To address these pathways and settings, we recommended the use of risk-assessment protocols.

We disagree with the assertion that the number of sites used in this study was limited. We believe that this assertion misrepresents the facts, and we provide the following data for clarification.

The total number of LUFT cases in California is now 29,000, which includes 8,500 closed and 20,500 open cases. Of the 29,000 total cases, 10,797 were identified as affecting groundwater. Of the groundwater cases, the SWRCB's database identified 5,698 cases that were beyond preliminary site assessment. It is this population of 5,698 cases that are available for any kind of analysis.

We targeted 13 counties that represent geographic diversity within the state and the areas where most of the underground storage tanks are located. We emphasized that fractured rock areas were excluded and, therefore, offered no guidance for cases in fractured rock. The 13 counties selected accounted for 3,340 of the 5,698 "characterized" cases, statewide. We randomly selected, and State Board staff sought files for, 1,831 of the 3,340 cases. In other words, we investigated 55% of the eligible cases in the 13 counties. This number represents an unprecedented effort.

Due to inadequate characterization, miscoding, missing information, etc., we were able to use approximately 1,200 cases where each had at least three monitor wells and four quarters of sampling data. Furthermore, to have confidence in our estimates of plume transformation in space and time, we chose all cases (271) with at least six monitor wells and eight sampling events. In other words, of the 5,698 "characterized" groundwater cases statewide, 843 were potentially available for this kind of analysis. Thus, the 271 cases analyzed represent a sampling of 32% of the available population of cases, statewide. This number represents a very high sample proportion and can in no way be characterized as "a limited data set." EPA has not provided information on the proportion of LUFT cases they base their opinions upon.

Some bias may be introduced by examining the population of 843 cases with best available data and applying it to the population of 5,698 (which in turn represents the 10,797 cases identified as affecting groundwater). In examining the 843 cases, this bias is conservative, as cases with higher average concentrations of benzene in groundwater tend to have a greater number of monitor wells and longer periods of sampling. Thus, we believe that the 271 cases represent the most complex and "worst" cases of the data set.

After the report was published, we compared the characteristics of the 271 cases with the remaining 1,200. We found our conclusions unchanged regarding the relationships observed between key hydrogeologic variables and plume characteristics.

In summary, the 271 cases conservatively represent the groundwater cases in the 13 counties examined. We find it logical to conclude that these cases are also representative of those cases throughout the State with similar hydrogeology. It should be pointed out that the NRC "only" used 77 cases to prepare their report on "Alternatives for Groundwater Cleanup."

It is not apparent how this study can be characterized as being limited based on 271 cases. Only the recent Texas study approaches the number of cases investigated, covers the geographic area investigated, or compares the dynamics of plume behavior as this case does. To draw such a conclusion misrepresents the facts and the importance of the study.

5.2. Limitations in Data Collection and Analysis

EPA Comment

Although broad recommendations were drawn from the case studies, only a narrow subset of sites were actually studied. The study was limited to investigating benzene concentrations and plume lengths. The study did not indicate the type of fuel release (e.g., gasoline, diesel fuel, jet fuel or fuel oils) evaluated, which is significant and ultimately influences the selection of appropriate remediation methods. For example, benzene is a primary component of gasoline, but present only in minor amounts in heavier fuels (e.g., diesel, fuel oil).

Furthermore, benzene is only one of many indicator (e.g., BTEX, MTBE, PAHs) chemicals used to track fuel contamination. Benzene is relatively more soluble and exhibits the highest vapor pressures when compared to other BTEX constituents. Benzene, therefore, preferentially dissolves into the aqueous phase and is the most likely to volatilize, disperse, and biodegrade. The transport of benzene in ground water is also retarded by adsorption.

Historically, the analysis of petroleum releases has been centered on benzene for two good reasons. Benzene has been established as a human carcinogen and tends to be the, most mobile and persistent of the BTEX compounds in ground water plumes. However, MTBE has proven to be more mobile and considerably more persistent than benzene. While the health effects of MTBE are not as well established, EPA's Office of Water has a draft health advisory on MTBE which ranges from 20-200 parts per billion (ppb). This health advisory is due to be finalized in the fall of 1996.

Cases were only evaluated where ground water was impacted. Sites where only soil was impacted were not reviewed as well as sites with ground water contamination with fractured bedrock. Whole counties with predominately bedrock geology were also not included. A possible approach to reduce this bias in the study would have been to first look at the distribution of site properties such as the types of contaminants (e.g. gasoline, jet fuel) and the geology and the hydrogeology of the sites, then select and analyze a series of sites representing this distribution. If inadequate data is available at these sites, additional data should be gathered to support this review. If this report is going to be used to support revision to the LUST corrective action process, it needs to be supplemented by a realistic assessment of the problems at all types of sites.

Response

The purpose of this study was not to consider every possible release scenario in California, but evaluate dominant or most likely scenarios and develop cost-effective and risk-management approaches based on large populations of data. Our preceding response explains our disagreement with the statement "only a narrow subset of sites were actually studied."

Although data on benzene distributions and plume lengths were among the major results of the study, we disagree that our study was limited to these data. In our summary of groundwater chemistry results, we also included TPH-gasoline as well as toluene, ethylbenzene, and xylenes. Because benzene, toluene, ethylbenzene, xylene are generally not analyzed at diesel and fuel oil releases, sites with benzene data typically involve gasoline releases. We agree with EPA that the choice of analytes are significant. LUFT sites typically have no jet fuel components, and gasoline is the major fuel that is released from LUFTs. Gasoline is a much more mobile FHC than diesel or fuel oil, and the associated risks are much greater as well. By focusing on gasoline FHC sites, we chose the most conservative fuel type. Furthermore, by choosing benzene, which is the most mobile and the highest risk constituent of non-oxygenated fuels, we showed further conservatism.

At the time the California LUFT historical case analysis was conducted, sparse data were available regarding MTBE. The California SWRCB, in collaboration with the Department of Energy Office of Fossil Fuels, and Western States Petroleum Association, is currently evaluating the fate and transport of MTBE in subsurface environments. Additional recommendations to the SWRCB regarding MTBE are forthcoming. As USEPA points out, MTBE has proven to be more mobile and considerably more persistent than benzene. Furthermore, low taste-and-odor thresholds may be the key issue in determining an impact to beneficial use of groundwater and surface water resources. It is conceivable that MTBE may prove to be a greater threat than benzene to the beneficial use of California groundwater and surface water resources.

The spatial resolution of typical LUFT case soil sampling is inadequate to draw meaningful conclusions. We did attempt to cover the major hydrogeologic areas of the State, as put forward in Heath (1984) and Thomas and Phoenix (1976). As stated above, as it is currently beyond the scope of this, or any similar levels of effort, to analyze fractured flow of FHCs. The vast majority of sites in California are not found in fractured rock environments, and when they are, risk-assessment protocols can be applied to these fractured rock cases. When a population is defined, as we have for 13 counties studied, the statistical techniques applied and conclusions reached are not considered biased.

5.3. Exposure Pathways

EPA Comment

The objectives of the analysis of the site data, as defined in the report, were to determine 1. the factors influencing the length and mass of the plume; 2. whether the plume behaved in predictable ways; and 3. how the plumes are impacting ground water resources. No objective consideration was given to the ecological and health receptors impacted at these sites as well as the sites excluded from this study. There was a pre-determination that other routes of exposure, i.e. besides ground water, were not significant. The impacted health and ecological receptors should have been key criteria in the analysis of the site data.

The study focused on public ground water supplies as the primary exposure pathway for contamination from leaking USTs. The report went on to conclude that this was not a significant pathway in California. However, all of the cases examined were located in alluvial settings with releases in the uppermost water-bearing unit (or shallow aquifer). The report goes on to comment that the current well construction standards are sufficient to prevent migration to deeper water bearing units which are used as drinking water sources in California.

Through well construction standards may be protective for preventing contamination of drinking water supplies by shallow contamination (though not in fractured rock or bedrock settings) other exposure pathways may also be of concern. These exposure pathways include air, soil, and surface water. MTBE, Benzene and other aromatic hydrocarbons present in petroleum fuels are volatile and can rapidly migrate great distances through the subsurface.

Volatile hydrocarbons present several threats to health and safety. Vapors can be inhaled as they vent to the atmosphere from the soil and they can build up to deadly and potentially explosive concentrations in excavations, buildings, basements, parking garages, utility vaults, and other enclosed spaces. Sites with soil-contamination which comprise about 50 percent of the total leaking UST universe also were not evaluated. Surface water contamination was also overlooked, which can contaminate drinking water supplies or recreational resources (e.g., swimming, fishing).

Response

EPA has made an unsupported assumption that a pre-determination was made that other routes of exposure (i.e., besides groundwater) were not significant or were overlooked. In general, risk-assessment procedures will adequately identify all probable exposure pathways at a LUFT release site and ensure that they are not overlooked. It was not the intent of the LLNL/UC LUFT Team to intentionally exclude or overlook pathways other than groundwater ingestion; however, data were not generally available to evaluate other pathways. Either these other pathways were seldom of concern or data quality could not support analysis.

A goal of the study was to use the best available data that are routinely used to manage the risk at LUFT sites to identify any broad, general trends that could be used to more efficiently manage LUFT risks. The historical case data available were typically gathered using USEPA protocols. We found that data were not available or inadequate to conduct a complete risk assessment at each site in the study and to address the various pathways mentioned in this comment.

The study was intended to begin to demonstrate the merit of evaluating historical data from a large number of cases to make risk-management decisions. We anticipated that gaps in historical case data would be encountered, and the identification of these data gaps could help risk managers adjust site characterization procedures and data management protocols to effectively use all available date to make the best possible risk-management decisions. We found that many critical parameters required to support risk assessment are typically not gathered and that gathered data too often are not used in the risk-management process. We suggest that a similar historical case analysis on a National basis would identify data collection deficiencies in the national programs, and strengthen risk-based corrective action.

Based on reporting of surface water impacts by the SWRCB LUSTIS quarterly report sent to USEPA, minimal surface water impacts have resulted from FHC releases at LUFT sites in California. These limited impacts are not surprising, considering the limited distance that non-oxygenated FHCs travel. MTBE may be another issue. Since the LLNL/UC LUFT Team's two reports were prepared, significant surface water impacts from MTBE have been observed. However, these observed surface water impacts are not the result of LUFT releases, and preliminary indications are that they result from the use of two-stroke engines during surface water recreation.

5.4. Geologic Conditions

EPA comment

Soil characteristics were explained for all of the sites in the study as consisting of multiple soil layers, with clay being fairly widespread. It is apparent that a significant amount of effort went into excluding certain types of less predictable cases (e.g., fractured bedrock, karst, data outliers) from the pool of cases that were ultimately analyzed.

It also appears that a value of 1 x 10-3 cm/s (sand and/or fill) is used as a default value for hydraulic conductivity to determine primary plume pathways (Table 4, page 9). For approximately one-half (the 50% quantile) of the sites, this value (0.001 cm/s) is fairly close to the reported average (0.00082 cm/s). For the 90% quantile however, the reported value of hydraulic conductivity is 0.023 cm/s, or 23 times faster than the default value. For the 99% quantile, the reported value is 0.08 cm/s, or 80 times faster than the default value.

It is also appears that there is some confusion with regards to ground water velocity and hydraulic conductivity. Actual ground water velocities are determined by addressing hydraulic gradient and effective porosity. Effective porosity may range from 0.05 to 0.33 which could increase ground water velocity by a factor of 3 to 20. the effect is that the true average linear ground water flow velocities could be significantly higher than those reported and used in the report to assess the effects of contamination.

Response

This comment has an unsubstantiated claim that "significant effort went into excluding certain types of less predictable cases (e.g., fractured rock, data outliers) from the pool of cases that were ultimately analyzed." This implies that somehow the data was manipulated to achieve a predetermined result. We have explained in detail why fractured rock sites were excluded and clearly stated this limitation. Furthermore, in reference to the "data outliers," it is good scientific practice to omit data that have been shown to be erroneous. During an exploratory phase of data analysis, we performed iterative examination of data relationships using scatter diagrams and frequency distributions. Apparent outliers were reported to the data entry team, who checked the original data and made corrections if data entry errors were found. If the data were verified as being correct, then the outlier remained in the data set and was part of the analysis.

The values given in Table 4 were for summation purposes only. The only use of the hydraulic conductivity presented in Table 4 is for estimating groundwater flow velocity at a site. It is not used for plume length estimations or any other calculation in this study.

EPA has commented that "there appears to be some confusion in regards to groundwater velocity," though EPA itself uses the term "faster" when discussing hydraulic conductivity. Although hydraulic conductivity uses the units of velocity, the term actually indicates a soil permeability, or resistance to flow for non-turbulent velocities. To state that a hydraulic conductivity is "23 times faster than the default value...or 80 times faster than the default value," misrepresents what hydraulic conductivity is. What we refer to as groundwater flow velocity is "Darcy Velocity" or specific discharge, and not a true velocity.

5.5. Data Extrapolations

EPA comment

Although the study examined more than 1,500 LUFT cases, only 271 cases were evaluated in detail for benzene concentrations and plume length. Of these 271 cases varying percentages ranging from 12% to 23.3% were considered to have exhausted plumes based on the definition used and parameters examined. It is unclear how these numbers correspond with the assertion later in the report that 17% of plumes are exhausted (Figure 13). However, the concept of "exhausted" plumes and plume life cycles needs to be clarified and further substantiated with bioattenuation data before making broad recommendations as to the appropriateness of natural attenuation for the 21,000 active cases or 10,000 active ground water cases in California.

Along similar lines, it is unclear how the average computed volume of contaminated ground water was calculated for one site and extrapolated to 10,000 ground water sites. A number of 0.70 acre-feet was cited as the average volume of water contaminated by benzene at each site. It is unclear, what methods were used to determine this per site figure. This average number does not appear to include depth calculations and it is hazy in what situations a value of 1 ppb or 10 ppb was used to estimate plume volume. Secondly, the average volume is applied to 10,000 sites, although the vase majority of these sites do not conform to the size selection criteria used for this study. Third, the total basin volume of ground water is based on an estimate that is over 20 years old (the source is from 1975). It is likely that this number has decreased over the last 20 years as consumption has increased and water quality has decreased due to industrial,

commercial, and agricultural development. It is also unclear whether this number is for useable ground water supplies, or just total ground water supplies, which would lead to inflation of the data. While the volume of contamination (e.g., 7060 acre-feet) may be useful for comparison of resource allocation, it is of little use in assessing environmental risk, the real concern is whether actual or potential receptors are exposed to the contamination on a site-specific basis.

Response

Buscheck et al. (1996) and Mace et al. (1997) affirms our discussions on plume life history. In our study, 47 (17%) out of 271 plumes evaluated fit the "exhausted" criteria of having an insignificant trend and an average plume concentration of <10 µg/L (See Table 8, pg. 12, Rice et al., 1995). The application of these data to LUFT cases in California is fully addressed in our response to the concern for potential inappropriate application of study results.

A very conservative method was used to estimate average plume volume. The parameters used are specified in Table 1, pg. 5 (Rice et al., 1995). Plume volume is defined as (plume length) x (plume width) x (plume depth). Plume length and width were generated by the error function plume length model. The 90% quantile plume length estimated to 1 ppb was used. Plume depth is defined as the 90% groundwater depth range plus an additional dispersion depth. The dispersion depth was estimated to be 0.1 X plume length.

The basis for the claim that a vast majority of the 10,000 groundwater sites do not conform to the site selection criteria is not clear, and it is difficult to evaluate this comment. We believe, contrary to EPA's assertion, that the 271 sites are an appropriate (if not biased to the worst case scenario) statistical representation of FHC plumes in California, and the use of this volume estimate is indeed appropriate to discuss the potential impact to 10,000 sites.

A more recent estimate by the Department of Water Resources (DWR, 1994) of groundwater storage is approximately 850 million acre-feet, which is a decrease of approximately 17%. Therefore, the storage capacity that is affected by LUFT sites is estimated at 0.0006%, as opposed to 0.0005%.

We understand that this discussion has little to do with assessing whether receptors are impacted. However, it was our desire to compare the LUFT impacted volumes to the overall groundwater resource "designated" for municipal use. Often, California Regional Water Quality Control Boards designate all groundwater as municipal use by default, whether these waters are usable or not.

5.6. Defining Plumes and Plume Models

EPA comment

The authors of the report are very clear that the estimations of plume length are intended to be used only during the analysis of available data and is not intended as a widely applied methodology for characterizing plumes at individual sites. The report clearly states that there may be strong controlling variables that may not be measured. Although this point is appropriately stressed throughout the report, the authors have still noted that average plume lengths rarely exceed 250 feet, and implied that this data can be used in a generic sense. It is unclear, how this number was calculated.

Many of the analytical methodologies employed in this study require a substantial number of simplifying assumptions. Assumptions always restrict the applicability of a methodology to a particular set of conditions. Models are one type of analytical methodology that are particularly sensitive to simplifying assumptions.

The report states that, the models used to estimate plume dimensions assume that plumes have a center, or a source area, that can be roughly estimated by the spatial center of mass of the contaminant distribution. The models also assume that contaminant concentrations will generally decline with distance from the center of the plume in all directions. These assumptions appear to imply (although possibly incorrectly) that the source area and plume center of mass are located at the same point in space. Flowing ground water typically elongates a plume in one direction away from the source area. Rarely, if ever, are wells (or other observation points) located at the source. Often the exact location of the source is never known. In the case of a pulse (discontinuous) source, the plume center of mass may migrate downgradient away from the course, and if there is no future release, the plume may completely detach from the source.

The study recognizes that the error function model frequently returns substantially smaller predicted plume lengths than the exponential model. It is unclear when the authors used the exponential (linear) plume model or the error-function (non-linear) plume model, however, it is clear that plumes could have easily been underestimated. The authors indicated (by telephone) that the error function model provided the "best fit". It should be noted that it is not appropriate to use the error function model for this study since it is generally used with continuous point sources in an anisotropic subsurface environment in the absence of a predominant ground water flow direction. The sites in this study, however, appear to have uniform geologic conditions with ground water flowing at most sites. Furthermore, the authors eliminated certain plume configurations which did not fit their idealized plume when using the exponential plume model and only accepted plumes with closed isocontours (ellipses).

Plume lengths were estimated on the basis of the 10 ppb isocontour line. This results in lengths being substantially underestimated. A far more relevant number would be 1 ppb (or even 0.5 ppb, which is the method detection limit). Without an accurate 1 ppb isocontour, the total mass of fuel hydrocarbons in the plume cannot be accurately calculated. The 1 ppb isocontour represents California's cleanup level for benzene. The 5 ppb isocontour represents the MCL for benzene. It is unclear why 10 ppb was chosen.

Response

In appendices B, C, and D of the Historical Case Analysis Report we document and discuss the assumptions, implementation, and limitations of the methods used to estimate plume lengths. Both models provide estimates of the uncertainties associated with the fitting of a plume length to a given set of spatial data.

Precision is frequently expressed in terms of variability in a measure, often in terms of percent relative standard deviation. The relative deviation is a measure of how much variability is encountered during repeated measures of a known standard. Accuracy is expressed in terms of percent bias in a measure compared to a known standard.

By presenting quantile information on plume lengths, the variability in the population of plume lengths is explicitly expressed. Furthermore, as indicated in the Historical Case Analysis Report, a pilot study was performed in which estimated plume lengths compared well to plume lengths derived from best professional judgment and commercial isocontouring software packages. Finally, by selecting the 271 sites with the most monitor wells and the longest monitoring periods, a bias is introduced toward sites with higher average concentrations of benzene. This bias is conservative.

To date, as part of ongoing data quality assurance and quality control, the SWRCB staff has independently evaluated the plume lengths of the 271 sites used for plume length estimations. They chose those 210 cases where the average plume benzene concentration was >10 ppb. They found that 90% of the plumes lengths determined, using best professional judgment, were less than 340 feet at the 10 ppb groundwater concentration limit, and less than 380 feet at the 1 ppb limit (SWRCB, 1996). The results of this validation process indicated good agreement with the plume lengths estimated during the Historical Case Analysis study.

What we refer to as the plume length estimation model is a "model" in the same fashion that the least-squares-fit of a line is a model. It may tell how closely a line is linear, or whether it follows a polynomial function. The model is used to fit a shape to data gathered during a point in time. For the methodology used here, we used the general shapes derived from an error function fall-off and an exponential fall-off to represent the plumes. We emphasize that no transport estimations are involved in plume length estimations.

We recognize that the use of a "spatial average" as the plume center may not accurately represent the true source area. The center of mass was used to represent the source area because, as EPA points out, the location of the source area is not well known.

The EPA commentation incorrectly assumes that sites in this study appear to have uniform geologic conditions with unidirectional groundwater flow at most sites. Complex heterogeneous alluvial settings characterize most of the sites in this study and should not be considered uniform. Though groundwater may be uniformly flowing at many sites, its overall velocity is low at many locations and the direction of flow can change radically. Under these conditions, we believe the use of the error function model is very appropriate. The "models" used an error function "shape" to encapsulate the plume and to find its boundaries, just as the Gaussian exponential shape was also used to encapsulate and find the boundaries. This may be considered a "probability domain" within which a plume most likely will reside. The exact shape of the plume interior was not critical to this part of the investigation.

Plume lengths could be calculated for any desired isoconcentration contour. We decided to use the 10 ppb length as a practical limit of estimation because of the inherent uncertainties associated with groundwater sampling and analysis. Though benzene instrumental detection limits of 0.5 ppb are achievable on laboratory standards, expectations to reach this level of precision are unrealistic in field practice across many sites.

We believe that EPA's policy of regulating to method detection limits or MCLs is technically infeasable and does not significantly change risk-management decisions. The movement to 1 ppb does not substantially change our conclusions or recommendations. We agree that an accurate mass may not be estimated for a 10 ppb plume, but there are other substantial uncertainties, such as placement of monitor wells, even when the 1 ppb limit is used.

Additionally, all attenuation rates were analyzed using a different method than that used during plume length estimations. Specifically, we applied a statistical method that used spatial averages derived through planar triangulation to estimate "mass," so that various shapes would be properly considered. Furthermore, the temporal averages and trends were derived using a method of bootstrap resampling to determine the confidence intervals. Therefore, we used two independent methods: one method examined plume length; the other determined plume mass. Both methods resulted in similar conclusions.

5.7. Biodegradation Data

EPA comment

As the study indicates, within the historical LUST case analysis data set, few measurements of inorganic ions which may be indicative of biodegradation were found. Data was evaluated for 41 sites for dissolved oxygen levels, other geochemical data was not available. The average dissolved oxygen measurements for the 41 sites was 3.8 mg/l. Although this is described as unusually low and anaerobic, this appears to be relatively high level of dissolved oxygen especially for ground water and substantially higher than would be expected if aerobic biodegradation was occurring. Typically dissolved oxygen levels collected from wells within fuel hydrocarbon plumes undergoing biodegradation are less than 1 mg/l. Contrary to the reports interpretation, these apparently high average dissolved oxygen levels may actually indicate that biodegradation is not occurring to a significant degree. Again EPA supports and recommends that more data (e.g., electron acceptors, geochemical indicators, biodegradation products) be collected to better understand this issue.

Response

No major conclusions were drawn from these data. Specifically though, on page 18 under "Other Needed Data," we state:

> Routine measurements of inorganic ions are very important. These measurements are inexpensive and can often be performed in the field. These measurements in conjunction with a determination of plume stability can form an a priori argument that biotransformations are occurring and can be utilized as part of a remediation and risk-management strategy. Much variability was observed in O_2 measurements **from monitor wells in which FHCs were not detected**, and the 50% quantile of these observations was unusually low, 3.8 mg/L dissolved O_2. This may indicate that the anaerobic zone extends beyond the area within a plume where FHCs are present, and care must be taken when establishing background measurements used during an evaluation of passive bioremediation processes.

EPA misstates our position that these samples are indicative of wells where hydrocarbons were detected; the above explicitly states that this is not the case. We suggest that an anaerobic shadow may have formed beyond the plume, which would, contrary to EPA's position, show that degradation was taking place. We support the use of biodegradation indicators as a secondary line of evidence of degradation.

5.8. Natural Attenuation and Alternative Remedial Technologies

EPA comments

The effectiveness of natural attenuation as a remedial option is compared only to pump-and-treat and overexcavation. These are both conventional technologies which EPA does not recommend using for most circumstances. Instead, EPA has been supporting the use of alternate technologies for contaminated soils and ground water because EPA recognizes the limitations inherent in pumping and treating ground water. Contaminant mass removal rates often flatten out and may never achieve cleanup levels. When the systems are operated after recovery rates plateau, operating costs continue, but the site does not become cleaner. Even worse, pump-and-treat systems can actually smear or spread contamination when water table levels fluctuate. EPA also does not support extensive overexcavation, because this approach tends to lead to large volumes of soil being transported to another location without treatment

In the one case where the authors acknowledged using soil vapor extraction (SVE) in conjunction with pumping and treating, it was noted that there was no additional benefit. This is not entirely surprising since SVE is a soil remediation technology and is not likely to have much impact in the short run on dissolved fuel hydrocarbon concentrations. SVE will remediate soil contamination in the long run by removing the lingering or residual source of fuel hydrocarbons, and help to remove the source of dissolved contamination.

It is interesting to note, however, that the analysis of "exhausted" plumes did state that pump-and-treat and overexcavation did have significant influences in reducing dissolved concentrations of fuel hydrocarbons for shallow contamination. An unstated implication of this observation that is especially relevant for soil only sites is that soil contamination can act as a long term lingering source of dissolved phase and vapor phase fuel hydrocarbons in which active remediation may be required. Finally, EPA strongly endorses the report's recommendation that source removal occur prior to allowing the use of natural attenuation.

There is no mention of the use of bioventing for remediation of USTs. This is one of the fastest growing segments in the remedial options for clean-up of USTs. It is very economical, averaging $50/ton, and it raises the issue of balancing the longer term monitoring costs and the longer term liability with natural attenuation versus moving ahead with a low cost treatment option and minimizing liability.

Another dimension that has not been considered in deciding whether to take an active or passive remediation approach to site management is time. Whether the regulatory agencies or responsible party is willing or able to allow for the time it may take for natural attenuation to occur is a critical issue. As an example, if the owner wants to sell the property, they may be in a much better position to do so after the site has been closed out.

Response

The LLNL/UC LUFT Team understands the concept of an asymptotic limit for subsurface contaminant mass removal. We also do not support massive overexcavation of sites. Our intent was to show that for shallow sites, where overexcavation did take place, there was a higher statistical significance that the plume would show a site-averaged concentration <1 ppb for shallow groundwaters. A probability of 0.185 as opposed to 0.432 is statistically significant. This factor is also important when considering that shallow sites are more likely to act as sources for inhalation pathways.

We agree with EPA's opinion regarding bioventing.

We agree that time required for the passive bioremediation process to operate is an important consideration. A distinction must be made between those actions that must be taken to manage an identified risk to a receptor and those actions that may be taken to preserve equity loss due to a perceived or imagined risk. Clearly, public funds should not be expended to preserve an equity loss. It is a business decision rather than a risk-management decision.

6. Response to Detailed Comments on Historical Case Analysis Study

<u>Comment 1</u>. ***Introduction, P. 1. The statement that this report can be used to "...draw broad regional conclusions about FHC fate and transport...". should be tempered with the knowledge that a risk-based corrective action decision making process is highly site specific.***

Response

We agree that risk-assessment decisions should ultimately be site specific. We also believe that regional data gathering and analysis can be used to streamline site characterization. Sites located within similar hydrogeologic settings can share data. As more regional data are gathered, the uncertainties associated with the risk-assessment decision will be reduced and made more explicit.

<u>EPA Comment 2</u>. ***Methods, p. 2. It is significant that certain types of geology (i.e., fractured bedrock) were excluded from the report. The report should not be used to draw conclusions in areas which have different characteristics than the sites studied.***

Response

In our opinion, the hydrogeology did represent the majority of non-fractured rock environments found in California. As stated previously, we believe the problem of fractured rock contaminant transport is a low-proportion, intractable one, and fractured rock LUFT cases must be considered on a site-by-site basis.

<u>EPA Comment 3</u>. ***Methods, p. 2. "The target counties were selected to represent a geographic cross section with large urban populations and a high proportion of the state's USTs." High risks can occur in rural areas, where there is a greater dependence upon groundwater and often shallow groundwater.***

Response

We recognize that high risks may occur in rural areas, where private wells may be impacted. Risk-based protocols can identify these risks. Additionally, our findings that the majority of plumes are relatively small and in steady-state will apply to rural areas as well as to urban areas.

<u>EPA Comment 4</u>. ***Section 2.2, p. 3.***

a) Although the report clearly states the focus was on benzene, it is important to note the risk posed by other contaminants of concern (COCs). A site-specific RBCA analysis accounts for all COCs which might have been released at a site, including less degradable petroleum constituents.

b) The terms "apparent outliers" and "appropriate corrections" should be defined or further clarified by the authors. Does this mean certain data sets were excluded from the analysis? The same issue applies to the term "well characterized" which is used later on this page. The basis which supports the use of this term should be clarified in the report.

c) The report mentions that "...many sites in the data set had small numbers of installed monitoring wells...". It is unclear from the report whether the majority of the wells were placed in or near the source zones at the LUST sites. Many site characterizations wrongly focus on the "corners" or property boundaries of the sites, because of the responsible party's desire to make sure off-site impacts are defined. The likelihood of this should be investigated.

Response

a) Benzene, being the most mobile of the non-oxygenated FHCs, as well as a carcinogen with the lowest MCL, is an appropriate indicator compound. It is surprising that this statement is made in light of EPA's support of the use of RBCA Tier 1 screening levels, which do not consider additivity effects, and where benzene, due to its high-cancer potency factor and its relatively high concentration in non-oxygenated fuels, drives the LUFT risk-management process.

b) "Apparent outliers were reported to the data entry team, who checked the original data and made appropriate corrections as needed." Placed in context, this statement refers to corrections of data that were input incorrectly (such as 120 feet of groundwater depth where a 12-foot depth was typical). These data corrections were part of a QA/QC effort that followed transcription of approximately 300,000 data fields into electronic form. Well characterized sites are those that had at least eight quarters of groundwater sampling data and six wells.

c) The point is taken, and sites are being examined by the LLNL/UC LUFT Team and the SWRCB in relation to the plume and property boundaries.

EPA Comment 5. ***Section 2.3, p. 4. The report states that certain data were "...either not available or not entered into the historical LUFT case data set." Data such as hydraulic conductivity and other parameters were estimated. While it may be common to sometimes estimate these types of parameters, the estimates are mainly based on field tests. What the report appears to be stating is that it was often necessary to estimate because the data was unavailable. Because one of the strongest conclusions reached involved LUFT plumes statistically not exceeding 250 feet, the lack of site-specific data calls to question the conclusion. These data are critical in determining the rate at which groundwater travels (and therefore, petroleum contamination) and also in risk-based decision making. Also, the report did not consider the effects of pumping in nearby drinking water or other types of wells which could increase the local groundwater gradient and the associated rate of contamination movement.***

Response

Hydraulic conductivity was not used in any plume algorithm, because, as stated previously, a plume shape was fit to x and y coordinates and to concentration levels at a "snap shot" in time. Therefore, the assertion that the lack of hydraulic conductivity data calls into question the conclusion of the plume lengths is incorrect. If the approach was one that used the advective-dispersion equation and involved the transport of benzene with time, we would agree; however, it was not used, and therefore EPA's comment is not applicable.

EPA Comment 6 . ***Section 2.4, p. 4. The report uses simple approximations to describe the shape of water tables at LUFT sites, which is highly dependent upon site specific conditions. The report acknowledges that the approximations "...cannot be expected to accurately describe the shape of the water table..." under other conditions.***

Response

Although water tables may vary greatly in their surficial shape, for the scale of most LUFT sites, water tables are essentially planar. This information was used to estimate groundwater velocity and direction only, and was not used in any plume length algorithm.

<u>EPA Comment 7</u>. ***Table 1, p. 5. Groundwater flow velocity is described as being calculated as: hydraulic conductivity X 1,034.6 ft/yr. It appears that 1,034.6 ft/yr is the default value for hydraulic conductivity and the phrase "hydraulic conductivity" should be replaced by "hydraulic gradient" in the equation. In addition, hydraulic conductivity multiplied by hydraulic gradient results in the discharge velocity of groundwater. The actual rate of movement of water through the subsurface (seepage velocity) is calculated by multiplying hydraulic conductivity by hydraulic gradient and dividing by effective porosity. Finally, plume depth is described as being calculated as: groundwater depth range + plume depth x estimated dispersion coefficient). However, it appears "plume depth" should be replaced by "plume length" in this equation.***

Response

We agree that "hydraulic conductivity" should be replaced by "hydraulic gradient" in the referenced equation. Furthermore, "plume depth" should be replaced by "plume length" in the equation for plume depth. This typographic error has been corrected.

<u>EPA Comment 8</u>. ***Section 2.5, p. 6. Hydrogeologic profiles were averaged using spatial variations which assumed water tables to be planar. Boundaries of water table planes were unable to be clearly defined because of the lack of pertinent data. These facts also call to question the conclusions drawn later in the report.***

Response

We disagree for two reasons: (1) On a small scale, the likelihood is small that groundwater gradient will change naturally in a very short distance if it already is fairly planar, and (2) the gradient was not used for any computational purposes.

<u>EPA Comment 9</u>. ***Section 2.6, p. 6. Under the discussion of plume lengths, the report would be enhanced if the basis for the term "best professional judgment" was clarified in the text. Again the plume length conclusion is key throughout the report, and it would help if specific judgments such as those discussed in the report were further defined.***

Response

Best professional judgment applies here, as well as in the report, to the plumes that may be hand drawn by a competent hydrogeologist on a site map, using the generalized direction of the gradient, likely source area, well locations, and associated groundwater concentrations in those wells.

<u>EPA Comment 10</u>. ***Section 2.7, p. 7. With respect to outliers, the report acknowledges the existence of the "...variable nature of the concentration measurement..." such as non-detect wells being sampled more often. If it was unclear within the data collection phase that individual site characterization reports showed this bias, the conclusions drawn by this report would be biased as well. It is unclear whether of not these outliers (i.e., wells with higher benzene***

concentrations) may represent individual sites with potentially higher risk which State LUST staff have the responsibility, under current programs, to determine potential or actual risk to nearby receptors.

Response

We agree with EPA's assertion that "State LUST (LUFT) staff have the responsibility....to determine potential or actual risk to nearby receptors," but when comparing up to 1,200 different plumes, one metric was required. As EPA recognizes earlier in its comments, "The authors of the report are very clear that the estimations of plume length are intended to be used only during the analysis of available data and is not intended as a widely applied methodology for characterizing plumes at individual sites."

<u>EPA Comment 11</u>. ***Section 3.1, p. 7. The report acknowledges the "…high variability observed in the O_2 measurements in monitoring wells…". The report concludes that natural attenuation processes are accounting for small or non-expanding plume lengths; more investigation of specific natural attenuation monitoring parameters are needed to support this conclusion. This comment is not intended to imply that natural attenuation does not occur, rather that data within the report does not support the conclusion.***

Response

We disagree with EPA's claim that the small size of benzene plume lengths observed does not support the position that passive bioremediation is occurring widely. Considering the distribution of concentrations detected, and the ubiquitousness of gasoline releases, we view the issue from a theoretical standpoint. FHC plumes would be significantly larger if passive bioremediation and, specifically, biodegradation, were not a factor. Even the current effort of ASTM to develop a Remediation by Natural Attenuation (RNA) document states that plume stability and trends should be used as the first line of proof. We believe the limited extent of plume lengths is exceptionally strong supporting evidence, whether geochemical indicators were present or not. We made no attempt to link these indicators to any statement concerning large scale biodegradation because of the limited dataset available.

<u>EPA Comment 12</u>. ***4.2, p. 15. The statements made under the discussion of possibilities to explain the random scatter of observed plume lengths support concerns over the accuracy of the data collected versus actual conditions at the sites. Several examples of text include: a) "There may be strongly controlling variables that are not measured.", b) "... information regarding the magnitude of FHC releases sources are typically poor.", c) "Information regarding the activity of bioremediation is also typically lacking.", d) "...data on hydrogeologic variables may be poorly taken...", e) "Each site is unique and complex". Each of these statements are impacting the data, the statistical analysis and therefore the conclusions drawn. Strong attention should be given to the later statement that "...findings that are observed during this primary analysis phase must be interpreted with caution."***

Response

All these statements are immaterial in considering the measurement of plume length. They are applicable when discussing attempts to predict plume lengths. Our warning that results should be interpreted with caution is a standard scientific statement used for preliminary evaluations. We recognized that the results may be somewhat controversial; however, more recent evaluations by the SWRCB and other independent researchers continue to support our conclusions.

EPA Comment 13. ***4.4, p. 17. The report acknowledges that "...the complexity of site uniqueness may be high in the group of sites represented in the LUFT historical case data set..." is an important consideration. Again, the conclusions drawn must also take into consideration the importance of site specific factors. The report clearly points out that many of these factors were not available in the data sets.***

Response

The major conclusions of the Historical Case Analysis report were based on three variables: 1 & 2) easting-northing coordinates (x-y locations) of the monitor wells, and 3) the well-specific concentrations. No site complexity diminishes these points.

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