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“A Cost Benefit Analysis of California’s Leaking Underground Fuel Tanks”

by

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Abstract

California has 28,000 leaking underground fuel tanks. Approximately 7,000 have been actively remediated at a cost of \$1 billion. It will cost roughly \$3 billion to actively remediate the remainder. This paper demonstrates that it is not worth incurring these costs. We show that *passive*, or *intrinsic*, bioremediation (“exploiting the metabolic activity of microorganisms to transform or destroy contaminants”) is the most cost-beneficial remediation technology to employ.

## I INTRODUCTION

California began to regulate underground storage tanks (USTs) in 1983 when it was judged that they posed a threat to the state's groundwater resources. Anyone who has been in California in the nineteen-nineties has seen the result; closed gas stations with their USTs ripped out. Federal regulations, as well as state law, require that all operating USTs must be upgraded or replaced by 1998.

In 1984, there were approximately 200,000 USTs in California containing fuel hydrocarbons (FHCs) - which are mainly gasoline, diesel fuel, and fuel oil.<sup>1</sup> Of these, about 28,000 were leaking. Roughly 7,000 have been remediated which leaves some 21,000 still to go.

The "Barry Keene UST Cleanup Trust Fund Act" of 1989 imposed an aggregate storage fee, or tax, of six-tenths of a cent (i.e., six mills or \$0.006) for each gallon of petroleum placed in a UST to pay for the cleanup of LUFTs.<sup>2</sup> Owners of gasoline USTs are responsible for the first \$5,000 of cleanup costs per site, except that residential tank owners do not have a deductible. Cleanup costs over and above this are re-imbursed from the UST Cleanup Trust Fund up to a maximum of one million dollars. The owner is responsible for all costs over the maximum. Note that the polluter is not paying to clean up his pollution, the public is.

The average cost of cleaning up each LUFT site is about \$150,000. Given that there are roughly 20,000 LUFT sites remaining to be cleaned up, the cost will be almost \$3 billion. Roughly \$1 billion has already been spent on the 7,000 sites already cleaned up, so the total cost of the program will eventually run about \$4 billion. This estimate is conservative. It does not

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<sup>1</sup> All figures in this section are from Rice et al., [1995]. Co-author of this paper Everett is included among the et al.

include the deductibles; it does not include costs over \$1 million; and it does not allow for the fact that as the UST upgrade and replacement program continues, new LUFTs will be discovered.

This paper attempts to establish whether it is worthwhile incurring these costs.

## II Some Elementary Hydrology

Most laymen are unfamiliar with our subterranean environment. When questioned about groundwater, they will express the view that there are great lakes beneath the surface or even swiftly moving rivers and streams. Nothing could be further from the truth. Groundwater occupies the interstices between soil particles and, in general, flows slower than molasses. In fact, rates of groundwater flow are usually on the order of centimeters per year to roughly 100 meters per year depending on a lot of things, but, especially, the soil's porosity. Porosity means the volume of open spaces in the subsurface. By and large, porosity is dictated by soil particle size. For example, sand and gravel have high porosity and, thus, the highest rates of groundwater flow, while clay has low porosity and, therefore, one of the lowest rates of groundwater flow.

A schematic diagram of a LUFT is illustrated in Figure 1 after the leak has been stopped. There will be residual hydrocarbons in the soil as well as hydrocarbon vapors emanating from them. Free product pools on top of the water table where it dissolves into the groundwater forming a plume which develops in the direction of the groundwater flow.

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<sup>2</sup> This fee increased to 7 mills in November, 1995, to 9 mills in January, 1996, and is set to be increased to 12 mills in January, 1997. The fee is scheduled to end in 2005. Welcome to the world of "revenue enhancement".

As Rice et al. [1995, p.10] observe, “subsurface microorganisms have been using petroleum hydrocarbons as a food source long before man began using them as an energy source.” As a result., a hydrocarbon plume’s length and mass will stabilise *in spite of the presence of an active source* (i.e., leak) *that may be continually dissolving new hydrocarbons into the plume.* In effect, a dynamic equilibrium is established wherein aerobic (oxygen using) and anaerobic (non-oxygen using) bugs devour the margins and core of the plume, respectively, at the same rate as the source is augmenting it. When the source is removed, the same processes cause both the mass of the plume and its dimensions to decay to zero over time. This is known as intrinsic or passive, bioremediation -- “exploiting the metabolic activity of microorganisms to transform or destroy contaminants”, [National Research Council, 1994, p.286].<sup>3</sup> The rate at which intrinsic bioremediation occurs depends on many things such as the type and concentration of contaminants, the rate of groundwater flow, the site’s hydrogeochemistry, ..., etc.<sup>4</sup> Decay rates of 50 percent per year have been observed, but it can be much slower.<sup>5</sup>

The alternative to passive remediation is active remediation. This can take several forms such as pump and treat, air sparging, vacuum extraction and bioventing, steam stripping, thermal desorption, ..., etc.<sup>6</sup> Of these alternative technologies, by far the most commonly used between 1985 and 1995 was pump and treat. This technique captures contaminated groundwater using extraction wells. The contaminated water is then treated above ground to reduce the FHCs to the maximum contaminant levels (MCLs) allowed in drinking water under the Safe Drinking Water

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<sup>3</sup> The end products of this intrinsic bioremediation process, by the way, are carbon dioxide and water. Voila, Perrier Water avec un soupçon de benzène!

<sup>4</sup> See Farr et al. [1996, p.9]. Co-author Carrington-Crouch of this paper is included among the et al.

<sup>5</sup> See Rice et al. [1995, p.11].

<sup>6</sup> See NRC [1994, Chapter 4] for a detailed discussion of these alternative technologies.

Act. Above ground treatment involves one, or more, of the following: air stripping, filtering through granular activated charcoal, biodegradation, and combustion, etc.

FHCs consist of about 240 organics including benzene, toluene, ethylbenzene, and xylenes (BTEX). Of these, benzene is the most troublesome because it is a known carcinogen. The federal MCL for benzene in drinking water is 5 ppb (“parts per billion”). However, California has adopted the stricter MCL for benzene of 1 ppb.<sup>7</sup> Rice et al. [1995, p.13] found that the average volume of 1 ppb benzene plumes was 0.7 acre feet with an average length of around 250 feet.

At first blush one might think that all that is needed to clean up the groundwater in the average situation is to lift this 0.7 acre feet to the surface, treat it, and that is that. Unfortunately, it is not that simple. Clean water moves into the space vacated by the 0.7 acre feet lifted to the surface, and this clean water itself becomes contaminated. The problem is due to “adsorption”, i.e., the adherence of molecules to the surface of solids. When the original contaminated 0.7 acre feet is lifted to the surface, some FHCs remain behind sorbed to the soil particulates. It is these which contaminate the clean water moving into the vacated space. As a result, literally hundreds of 0.7 acre feet pore volumes of water may have to be lifted to the surface before all the FHCs are flushed off the contaminated solid particulates. As Rice et al. [1995, p.11] observe, “this flushing can be very slow and expensive and may take several tens of years to reach MCL’s”. The rate at which this flushing proceeds again depends on porosity. It is relatively easy to

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<sup>7</sup> California’s MCLs for the other components of BTEX (which are not known carcinogens) are much higher: toluene, 100 ppb; ethylbenzene, 680 ppb; and xylenes, 1,750 ppb.



extract water from sand and gravel; it is relatively difficult to extract it from clay. (Other factors, in addition to porosity, affect this extraction rate.)

### III WHAT IS A RECEPTOR?<sup>8</sup>

*Only* living things (i.e., people and biota) can be logically defined as a receptor. Soil and groundwater can *never* be defined as receptors. These are *pathways*. Soil and groundwater are inanimate. They feel no pain and it is impossible to “harm” them. Every Philosophy 101 student knows it is grossly anthropomorphic to assert the contrary. Do you think a molecule of H<sub>2</sub>O feels better or worse when a molecule of Jack Daniels nestles in alongside it? The question is absurd on the face of it, isn’t it? Equally, a water molecule doesn’t feel better or worse when a benzene molecule nestles up alongside it, either. So, it is absolutely essential when making policy to always bear in mind that *a receptor can only be a living thing, everything else is a pathway*.

### IV WHAT IS THE SIZE OF THE THREAT?

Hadley and Armstrong [1991] report that a survey of well testing data from 7,167 public water-supply wells in California between 1986 and 1989 revealed that just 10, or 0.1 percent, were affected by benzene. Rice et al. [1995, p.4] state that out of more than 12, 150 water-supply wells in California tested between 1986 and 1995, a mere 48, or 0.4 percent, had detectable benzene concentrations. Of these only 6, or 0.05 percent, could be blamed on LUFT releases. California’s State Water Resources Control Board, “the Board”, [1995] reviewed the state’s database of 28,051 LUFT cases. This extends over ten years and includes both active and closed cases. It found that 136, or 0.7 percent, LUFT sites have actually impacted water wells. On top of the fact that only a minuscule percentage of water-supply wells have been affected by

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<sup>8</sup> This material is lifted verbatim from Carrington-Crouch’s contribution to Farr et al. [1996, MR-3].

LUFTs, many of those were private-domestic water-supply wells and were the LUFT sites' own shallow onsite wells.<sup>9</sup>

### V PUMP, TREAT, AND THROW AWAY

Before 1996, the Board essentially treated all LUFTs as though they each posed equal threats to a receptor. Although this has proved to be wrong, the original reason why they did so in the mid nineteen-eighties was because intrinsic bioremediation was little understood then. It was thought that once an aquifer was contaminated it was only a matter of time before benzene would reach a municipal or domestic water-supply well. Remediation policy was developed in an atmosphere of “time bomb plumes”.<sup>10</sup>

With the benefit of hindsight, we now know that LUFTs can be divided into two categories. Those that are an actual, or potential, threat to a receptor; and those that are no threat whatsoever. It is the vast majority in the latter category that I would like to consider first.

Until 1996, the most commonly applied remediation technique was “pump and treat”. The price of water varies statewide. We have assumed an acre-foot is valued at \$1,316 (its value in Santa Barbara, a city which places a high value on water).<sup>11</sup> So the value of the water contaminated by the average 0.7 acre feet plume will be \$921 (i.e.,  $0.7 \times \$1,316$ ) *if it is clean and when it is used*. This is the benefit that society would obtain if the water was cleaned up and used.

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<sup>9</sup> Rice *et al.* [1995, p.5].

<sup>10</sup> Rice *et al.* [1995, p.4].

<sup>11</sup> The cost of an acre foot of water throughout most of the state is between \$700 and \$900.

But most pump and treat systems do not use the cleaned-up water. It is cleaned up and discharged to a sewer system, i.e., it is thrown away. Thus, “pump, treat, and throw away” provides no benefits to society at all in the “no threat” situations under discussion. That fact has been recorded in Table 1.<sup>12</sup>

The direct costs of pumping and treating include both capital costs and “operating” costs. And not only of the treatment system. As mentioned earlier, the contaminated region underground may have to be pumped more than one hundred times before all the sorbed contaminants are flushed out and the water remaining meets MCLs. Thus, up to 70 acre feet will be discharged to a sewer system. This raises the capital and operating costs of our sewer systems (many of which are already close to overload).

On top of the capital and operating costs of the treatment system and the sewage system, there are environmental costs. The wastes extracted have to be transported to a hazardous waste site. As well as generating risks to the workers, this contributes to air pollution. Air pollution costs will also have been increased generating the energy necessary to lift 70 acre feet of water to the surface for treatment. With “pump, treat, and throw away” in a “no threat” situation, there are no benefits and lots of costs - both internal and external.<sup>13</sup> This is counter-productive. All that has been achieved is the movement of contamination from one place where it was doing no harm to another place where it will do no harm. Of course, to even contemplate any form of

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<sup>12</sup> In cases where the plume does threaten a receptor, “pump, treat, and throw away” would have a benefit; namely, “harm avoided”.

<sup>13</sup> Naturally, there is no benefit in terms of “jobs (income) created”. There will be more income created in the bureaucracy and pump and treat industry, but less income in those industries where California’s motorists would otherwise have spent the money that is mulcted off into the Trust Fund.

Table 1: A Qualitative Cost-Benefit Analysis of “Pump, Treat, and Throw Away” in a “No Threat” Situation

	<u>Costs</u>	<u>Benefits</u>
	Site characterisation	
Treatment System	Capital Operating	None
Sewage System	Capital Operating	
Other	Monitoring Risk to workers Air pollution	

Table 2: A Qualitative Cost-Benefit Analysis of “Pump, Treat, and Use” in a “No Threat” Situation

	<u>Costs</u>	<u>Benefits</u>
Treatment System	Capital Operating	\$96,100
Sewage System	Capital Operating	
Other	Monitoring Risk to workers Air pollution Water distribution	

enhanced pump and treat technology in these “no threat” situations would be to pile Pelion on Ossa.

A specific, and typical, example of unnecessary remediation is provided by Remediation Technologies [1995, p.30]. The site is located in the Mojave desert. It is currently a vacant lot, but was an active gas station from 1945 to 1991. Soils were impacted by FHCs down to 110 feet bgs (“below ground surface”). The water table is more than 300 feet bgs and was not threatened. Moreover, the groundwater is not currently used for any purpose. “The site is currently a vacant lot and as such, there are no current receptors”, Remediation Technologies [1995, 5-32]. No biota were threatened either. Nonetheless, remediation began in 1994. A vapor extraction system was installed to remove the FHCs in the soil. The benzene level before treatment was 60 mg/k; after treatment it was 0.005 mg/kg. The direct cost to California’s motorists was \$260,000 (without considering the environmental costs). The only benefit was received by the owners of the gas station. A closure letter was issued and they were able to sell it.

Nature should be allowed to take its course in these “no threat” cases and intrinsic remediation relied upon to correct the situation. Monitoring should be kept to that absolute minimum necessary to confirm plume stability. And this monitoring should be done with extreme care. Poorly executed monitoring can open up new pathways for contaminants to spread.

## VI PUMP, TREAT, AND USE

We have just seen that “pump, treat, and throw away” is dumb. Somewhat paradoxically, “pump, treat, and use” is dumber. At first glance, it would seem bizarre to clean up 70 acre feet

of contaminated water at enormous cost only to throw it away. After all, is it worth \$96,100.

This seemingly illogical behavior is, however, entirely rational. To capture the water's value, it has to be conveyed to a point of beneficial use. There is, in other words, a new category of costs to be considered if the water is to be used; namely, water distribution costs. To convey 70 acre feet of water to a point of beneficial use is almost certainly going to cost more than the \$96,100 it is worth.<sup>14</sup> Thus, "pump, treat, and use" will have an even worse cost-benefit ratio than "pump, treat, and throw away". The costs and benefits of "pump, treat, and use" are shown in Table 2.

In summary, then, the optimal strategy in "no threat" cases is to do nothing except monitor on a minimal scale to confirm plume stability and allow nature to clean up the situation through passive bioremediation.

A similar conclusion applies to leaks into shallow aquifers already teeming with virulent bacteria and noxious run-off toxins. Since we are never going to use these under any conceivable circumstance why ever bother to clean up one small piece of them. California Well Standards governing the siting and construction of water wells protect us from these wells drawing water from sewers, storm drains, barn yards, nuclear waste dumps, septic fields,...., etc. Those same Standards will protect us from converting a "no threat" situation into a "threat" situation by preventing the siting of wells near known FHC plumes.

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<sup>14</sup> The proof of this pudding is in the eating. If the 70 acre feet could be delivered to a point of beneficial use for less than \$96,100, someone would take it and sell it. The treatment facility would surely let them have it for free rather than carry on discharging it to the sewer.

## VII "POTENTIAL THREAT" CASES

Given that a receptor can only be a living thing, the Board's goal becomes obvious. The Board's duty is to protect the people of California and its biota from exposure to contaminated groundwater at the least possible cost.

At a LUFT site that will only threaten people or biota at some time in the future (often many years), it is not wise to make good the quality of the groundwater now. First, technological progress will make cleanup in the future cheaper than cleaning up now. Second, if you clean it up now, it could become re-contaminated in the future and the first cleanup would be pure waste. Third, consider a site that will take \$500,000 to clean up now, but the contamination from that site is only going to threaten a receptor ten years from now. As stated, if the site is cleaned up now and the clean water is inventoried (underground) for ten years, the cost will be \$500,000. But consider the alternative. Clean up the site ten years from now when receptors are about to be impacted. Assuming an 8% discount rate, this cleanup can be achieved for a mere \$230,000 current dollars (because \$230,000 will accumulate to \$500,000 in ten years time at 8%).

If this example is at all typical, this change in approach (don't inventory clean water, deliver clean water,...., just in time") effectively doubles the Board's cleanup capability without asking for so much as a single additional penny from the UST Cleanup Trust Fund. The practice of cleaning up now to protect a receptor from being harmed ten years from now is equivalent to buying a house now but not moving in for ten years. The arguments presented here are not affected by inflation. In an inflationary environment the future cleanup cost increases, but so does the discount rate -- and in proportion. So, the cost in current dollars remains the same.



These considerations make it almost certain that the default case for groundwater cleanup will be at point of use (or “well-head treatment”).<sup>15</sup>

### VIII “ACTUAL THREAT” CASES

There are some LUFTs which present an immediate threat of harm to a receptor. These are where the Board should concentrate its active remediation resources. Real harm is about to be done and benefits will accrue to society if this harm is avoided.<sup>16</sup> Again, though, we want to capture those benefits at the least possible cost. Several steps should be taken. The source should be removed -- i.e., the leak should be stopped. Free product should be removed from the soil to the point of residual saturation. Free product should be removed from the water table. Well-head treatment should be undertaken if the cost of this treatment is less than the cost of developing another source of clean water. If not, the well should be closed and the alternative source developed.

### IX HOW IT CAME TO PASS

It will be apparent that we think the people of California have incurred costs to clean up LUFTs that far exceed any benefits from doing so. And they continue to do so. Why is this?

There are three reasons.

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<sup>15</sup> This paragraph, and the two previous paragraphs, were lifted (almost) verbatim from Carrington-Crouch’s contribution to Farr *et al.* [1996].

<sup>16</sup> It is worth noting that it is very difficult to harm people by poisoning them with benzene laced water. Benzene is not something stealthy like cryptosporidium. It announces its presence. Water which meets the federal MCL of 5 ppb benzene is completely undrinkable because of its foul taste and odor.

- (i) *Property Rights Problems.* Property rights in groundwater are poorly assigned. From a legal perspective, California's groundwater is not owned by the person whose property it underlies. It is owned by the state, i.e., collectively. The person whose property it underlies has "use rights" but not "ownership rights". As is well known, when property rights are poorly assigned the resource will be abused. Unauthorised users will treat other people's groundwater as a sink if they can get away with it. In essence, this is what occurred before 1984.<sup>17</sup>
- (ii) *LUFT Manual Problems.* As mentioned earlier, "the original LUFT Field Manual was prepared in an atmosphere of concern about time bomb plumes", Rice et al. [1995, p.4]. The creators of the LUFT Field Manual regarded groundwater as the ultimate receptor. This was a fatal mistake. Only living things, people or biota, are receptors. Everything else is a pathway. The LUFT Field Manual creators saw waste where it was not supposed to be and felt obliged to relocate it even though most of it was doing no harm to any (legitimate) receptor.
- (iii) *Public Choice Problems.* Using the original storage fee of \$0.006 for each gallon of petroleum placed in a UST to pay for LUFT cleanups, someone who drives 10,000 miles per year and gets 20 miles to the gallon will pay a tax of \$3 per year,  $(1,000/20) \times \$0.006 = \$3$ . This is small beer to even the poorest California motorist.<sup>18</sup> But it is not small beer to the beneficiaries of the aggregate proceeds of this tax (which is estimated to be \$1.5 billion when the storage fee program is ended in 2005).

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<sup>17</sup> An attempt to grapple with the problem of groundwater pollution through a more efficient assignment of property rights was made by Crouch et al. [1972, Chap.5] when the Clean Water Acts were under consideration.

Who are these beneficiaries? They are the owners and operators of LUFTs (responsible parties, or R.P.s); the water resources bureaucracy; and the cottage industry of LUFT consultants binding the R.P.s and the bureaucracy together. As is well known, when there is a small diffuse interest in reform, but a large concentrated interest in the status quo, the concentrated interest is likely to win out and bad laws and regulations will remain.

When a LUFT has contaminated the soil and groundwater of an R.P.'s property, that property will have a lower market value than it otherwise would. An R.P. clearly has a concentrated interest in having that contamination removed at the public's expense.

Given the rules of the Cleanup Trust Fund Act, an R.P. pays a minimal deductible then sits back while her property is cleaned up at public expense (to a maximum of \$1 million). This will raise the value of her property -- a benefit captured solely by the R.P., but paid for by the general public. Since the income of the average Californian is certainly less than the income of the average R.P., this transfer of income from the general public to the R.P.s is obviously regressive in its impact. Whatever is happening to that environmental principle, "make the polluter pay"? If more of the cleanup costs were borne by those who made the mess in the first place, we would "internalise the externality". In particular, such a precedent would provide a strong incentive for R.P.s to make absolutely sure the new tanks that must be installed by 1998 do not leak.

The bureaucracy's concentrated interest is two-fold: first the more regulations there are to enforce, and the more activities there are to be supervised, the bigger the budget that

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<sup>18</sup> It will rise to \$6 per year when the storage fee reaches its maximum in January 1997 of \$0.012.

will be required. And the bigger the budget, the better for the bureaucrat because it will mean more employees to supervise, probably a higher salary and certainly higher standing among her peers. Second, bureaucrats are, on the average, risk averse. Risk aversiveness is rational for a bureaucrat because, if things go wrong, the bureaucrat responsible is going to be held up to public obloquy, whereas if things go right, they get no praise. They, therefore, always tend to err on the side of excessive caution. No bureaucrat wants something bad to happen on their watch, however small the probability, so excessive environmental zeal is shown. This is costly, but only diffusely costly, to the public.

### X RECENT DEVELOPMENTS

The pernicious legal doctrine of “joint, several, strict, and retroactive liability” imparts a stigma to LUFT sites that makes them difficult to sell even when they pose an insignificant threat. A standard of strict liability means that a firm that generated contamination would be liable, without a need to show that the toxic contamination was due to negligence. Joint and several liability means that a firm found even *partially* responsible could be held liable for up to 100 percent of all costs incurred in remediating a site regardless of that firm’s proportional contribution to the damage. Retroactive liability means that current and previous owners can face cleanup costs for practices that occurred years before and that may well have been legal at

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the time.<sup>19</sup> These wicked legal principles make it impossible to sell or collateralise LUFT sites until the Board issues a “closure letter” attesting to the fact that remediation has been completed. This is the route to more “brownfields”. Thus, thousands of homeowners and business persons have been made needlessly miserable.

These R.P.s have exerted political pressure on the Board and in the state legislature in an attempt to correct the situation. Rice et al.'s [1995] report was commissioned by the Board to recommend ways to improve the cleanup process for California's LUFTs; and Farr et al.'s [1996] report resulted from Senate Bill 1764's injunction to the Board to appoint an advisory committee to make recommendations regarding improvements to the LUFT cleanup process.

With the Rice et al. [1995] report in hand and the SB 1764 Advisory Committee in session, in December, 1995, Mr. Walter Pettit, the Board's Executive Director, recommended what can only be described as a sea-change in the perspective and approach that should be taken toward cleaning up LUFTs.

In a letter dated December 8, 1995, and addressed to all regional water board chairpersons, all regional water board executive officers, and all local oversight program agency directors, he observed that the LLNL/LUFT team Reports indicated that “the impacts to the environment from leaking USTs were not as severe as once thought.” He also went on to note that the Reports present a convincing argument “that passive bioremediation should be considered as the primary remediation tool in most cases once the fuel leak source has been removed.”

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<sup>19</sup> This paragraph was lifted verbatim from Carrington-Crouch's contribution to Farr et al. [1995, MR-5].

In the light of the LLNL/LUFT team Reports, Mr. Pettit further recommended that local “cleanup oversight agencies should proceed aggressively to close low risk soil only cases” and for sites “affecting low risk groundwater ... that active remediation be replaced with monitoring to determine if the fuel leak plume is stable. Obviously, good judgement is required in all of these decisions. However, that judgement should now include knowledge provided by the LLNL report.”

In concluding, Mr. Pettit wrote that “What I propose ... represents a major departure from how we have viewed the threat from leaking USTs.” The Board’s Chair, and the Regional Board Chairs, were unanimous in support of the new perspective and approach to the cleanup process that Mr. Pettit recommended.<sup>20</sup>

It will be apparent to everyone, that we are in complete agreement with Mr. Pettit’s initiative and the risk-based approach to LUFT cleanups he has implemented.

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<sup>20</sup> This and the two previous paragraphs were lifted verbatim from Carrington-Crouch’s contributions to Farr et al. [1996, MR-2].

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