

FINAL REPORT

**An Independent Review
of the Report**

**PROPOSED SUBSURFACE INTERIM MEASURES/
INTERIM REMEDIAL ACTION PLAN/
ENVIRONMENTAL ASSESSMENT
and
DECISION DOCUMENT
Operable Unit No. 2**

February 22, 1993



Rocky Mountain Universities Consortium



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Operable Unit No. 2

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The Rocky Mountain Universities Consortium was formed to provide independent review and assessment of environmental restoration efforts. It is comprised of universities from several Western states. Reviews are conducted independently by selected teams of faculty and research staff.

A current list of Consortium reviewers is available on written request from the Consortium office.

The Consortium Operating Committee approved issuance of this Final Report on February 22, 1993.

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EXECUTIVE SUMMARY

An independent review was conducted by the Rocky Mountain Universities Consortium of the report entitled "Proposed Subsurface Interim Measures/ Interim Remedial Action Plan/ Environmental Assessment and Decision Document". The report describes a pilot-scale research project of an in situ vapor extraction system (VES) designed to remove several volatile organic chemicals (VOCs) from soil. This VES is to be studied at three sites in Operable Unit 2 (OU2) at the Rocky Flats Plant. At these sites most of the VOCs lie below the water table as an immiscible phase and are thought to be the source of dissolved contaminant plumes in the ground water.

In general, the report is well written and well organized. It reflects that the authors have invested considerable time and effort into this project and appear to be knowledgeable about in situ volatilization technology. Such technology has been successfully applied at other sites for the removal of VOCs, but in the case where the VOCs were located in the unsaturated zone above the water table. Thus, one of the major uncertainties concerning application of VES technology to the Rocky Flats Plant (RFP) site is that most of the VOCs are located below the water table and perhaps in the underlying bedrock.

Control of the water table becomes a very critical factor for the success of this study. The water table must be lowered in order to expose the organic phase to the VES process. This will be very difficult to do and it may be impossible to remove significant quantities of these organics. However any removal will be beneficial and the report needs to stress that VES technology will be only one component of a larger system for contaminant removal, containment and treatment.

The objectives of this study and the criteria for its success or failure need to be more clearly defined. The data required from the pilot study to design a full scale VES should be clearly defined. Analysis of the pilot study results and the requirements for the detailed engineering design are not included in this report and are presumably to be included in a subsequent engineering report. Uncertainties in the specific design requirements limit the scope of this review, and, therefore, the review team is concerned that appropriate information may not be collected for a thorough performance evaluation.

There are discrepancies between the hydrogeology described in the report and dissolved contaminant plumes at the Rocky Flats Plant. These needed to be rectified.

The report proposes that pilot tests be made at three separate locations to evaluate the effect of various hydrogeologic conditions on the operation VES and its ability to remove VOCs. The review team is concerned that inadequate data would be obtained for understanding the performance of the process, in part because of funding limitation and in part because of the experimental design. Thus, the review team recommends that VES be tried at a single location and that sufficient detailed information be collected to allow a more complete understanding of the results of the project. For example, it is important that the horizontal and vertical movement of the vapor in the subsurface be monitored using sufficient, strategically located wells. Vertical movement of air could result in a short circuiting of the VES.

Additionally, steam or a combination of steam and air should be considered as the stripping gas. There are many advantages of steam over air alone. Variations among the three subsites suggest that a different combination of stripping temperature and stripping gas composition may be appropriate for each subsite.

Complementary modeling of the results of these pilot tests is recommended as a tool to assist in applying the results to a full scale system.

Better subsite data on soil texture, permeability, organic content and the like would be very helpful in establishing appropriate sets of conditions to be tested.

Treatability testing with artificially contaminated soils from all of the subsites likewise should be extremely useful in setting test conditions at each subsite.

Finally, the review team strongly recommends that a site wide groundwater remediation plan be designed for the Rocky Flats Plant and that the role of VES technology for source removal needs to be discussed relative to the overall needs and the alternatives.

REVIEW TEAM

The review team was comprised of four members: two groundwater engineers, one environmental engineer and an industrial chemical engineer.

SCOPE

The subject report considers methods to extract carbon tetrachloride, perchloroethylene and trichloroethylene and, by extension, other volatile organic compounds (VOCs) which contaminate the subsurface soil and ground water at Operational Unit 2 (OU2) of the Rocky Flats Plant. Vacuum vapor extraction is considered in particular. No attempt has been made to deal with any inorganic or radioactive contaminants, which may also be present.

GENERAL COMMENTS

With the exception of localized contamination amenable to soil excavation, the removal of chlorinated solvents from the subsurface sufficient to restore the soil and groundwater to their pre-contamination condition has not been demonstrated in the United States or elsewhere. The paucity of effective, proven technologies for removal of an immiscible, chlorinated solvent is a particularly acute problem. While numerous claims of success have been made for various technologies, there is little hard scientific data to support them. In our rush to undo and correct the mistakes of the past, a great deal of money has been spent on subsurface restoration with quite marginal returns.

The present "Proposed Subsurface Interim Measures/Interim Remedial Action Plan" focuses on vacuum vapor extraction. Interim remedial actions are implemented to eliminate, reduce or contain some eminent threat (e.g., off-site migration of contaminants or contamination of a well field). In the present case, the interim remedial action is justified to collect data needed to design a full scale system. The proposed actions constitute pilot study, a prudent and time honored step prior to commitment to the full scale system.

Vacuum vapor extraction systems have been used to remove a portion of an immiscible contaminant from the vadose zone. However, not all of the contaminant is removed, and it is not known what fraction can be removed. Such systems are usually operated until the contaminant concentration in the extraction gas falls to some very low level. Whether or not "cleanup" has been effected remains unknown.

The proposed study will attempt to measure the amount of contamination removed to judge the success of the test. The proposal argues that any contamination removed is an environmental benefit. Further, any contamination removed now is that much less that will have to be removed by pump-and-treat systems later. This approach does not consider the overall economics of cleanup.

Is it reasonable to judge the success of the pilot study solely on whether or not contamination is removed? Some contamination will be removed if there is any present. The salient question is what would be significant? That would depend on the total contamination, the cost of removal and other factors. How much are we willing to spend per kilogram of contamination removed? This seems especially pertinent given the fact that waters leaving the contaminated area are likely to do so with little or no reduction in contaminant concentration. In addition, the vadose zone may become re-contaminated from below if immiscible phase contaminants exist below the water table.

There is also a question of appropriate timing for removing the source of contamination. Are there financial advantages to spending the money for source removal at a future time near the completion of the pump-and-treat phase? Also, it appears that, by selection of vacuum vapor extraction as an interim remedial measure, a conscious prioritization of possible measures has been made. What about measures that rely on source containment? How does the proposed remedial action mesh with overall goals and strategies for the plant site as a whole?

The societal costs of attempts to effect groundwater restoration at Rocky Flats and elsewhere promise to be huge. Each action taken should be assessed in view of a set of overall goals and strategies, the benefit to the environment, the cost to society, and the realities of technology performance. A consistent, logical approach based upon sound science and engineering should be adopted and vigorously promoted with the relevant regulatory agencies and the public.

TECHNICAL ISSUES

Objectives of Pilot-scale Vapor Extraction Testing

The IM/IRAP/EA for OU2 at Rocky Flats Plant dated March 2, 1992 (the "report") addresses residual free-phase VOC contamination suspected in the subsurface within OU2. Information in the report indicates that the site hydrogeology consists of shallow ground water in an alluvium which extends to a depth of 18 feet below ground surface underlain by claystone bedrock. The principle VOCs are carbon tetrachloride, perchloroethylene (PCE), and trichloroethylene (TCE). The proposed VOC removal actions involve in situ vacuum-enhanced vapor extraction technology. The remedial actions are proposed specifically for the collection of information that will aid in the selection and design of final remedial actions. The removal action initially will be conducted on a pilot scale to enable collection of site-specific technology performance data, as specified on page 3-1 of the report.

Although information collection is identified as a major objective of the pilot-scale testing, few details regarding the specific information that will be gathered are presented in the report, nor is information presented about how the information will be used for design and for evaluating technical feasibility. The information needs and process by which technical feasibility can be evaluated requires information in the following areas:

1. What information is available regarding the performance of vapor extraction at other waste sites?
2. What theoretical or practical models are available which describe the performance of a vapor extraction system and what performance is expected at Rocky Flats Plant?
3. What contaminant distribution or hydrogeologic characteristics at Rocky Flats Plant suggest that VES will be successful, and what parameters are potentially problematic?

Other Sites

Vapor extraction is being employed for remediation at Superfund and other waste sites throughout the U.S. It would be helpful if the report presented a review of the performance history at this sites. For example, what has been observed regarding performance as a function of the types of contaminants, phase distribution of contaminants (i.e., dissolved versus NAPL (Non-Aqueous Phase Liquids)), extent of NAPL distribution within the subsurface, and type of NAPL (i.e., LNAPL (Lighter Non-Aqueous Phase Liquids) or DNAPL (Dense Non-Aqueous Phase Liquids))? Soil permeability is an important geologic variable, but what other geologic variables have been observed to be important?

Performance Models and Performance Expected at Rocky Flats Plant

Various information exists in the literature regarding performance models for vapor extraction systems, although these models are not addressed in the report. Models generally describe

system performance by assuming a homogeneous distribution of contamination. The more complex models consider kinetic factors, such as rates of desorption from soil, rates of diffusion through soil pores, and rates of volatilization from soil water or NAPL into soil gas. The more simple models assume that the distribution of a given VOC between gas and non-gaseous phases is at equilibrium. Have those models been considered in developing a performance expectation for Rocky Flats Plant?

In the absence of a stated performance expectation, it is unclear how system performance will be assessed. During phase 3 of the pilot testing, for example, what will be the basis for assessing whether continued operation of the vapor extraction systems will be beneficial?

On page 4-32 of the report, it is indicated that pilot test data will be evaluated with respect to: (1) mass of VOCs recovered per unit cost, (2) mass of VOCs recovered per unit time, (3) areal influence of vapor extraction system, (4) ability to successfully control the mobility of contaminants, and (5) ability to successfully dewater aquifer material if present. For the first three noted points, what numerical values correspond to a favorable evaluation?

On page 4-33 of the report, it is noted that system effectiveness will be evaluated by establishing initial conditions through collection of soil samples during the advancement of boreholes. Further, it is noted that post sampling will also be conducted. How many samples will be collected, and what specific analyses will be performed? How will the homogeneity (or lack thereof) in distribution of NAPL be determined?

Contaminant and Site Characteristics Necessary for Success

There are several indications in the report that certain characteristics may be necessary for vapor extraction to be successful at Rocky Flats Plant, but these characteristics are not clearly specified. For example, on page 4-6 of the report it is noted that application of the technology will be customized to the site-specific hydrogeologic and contaminant distribution conditions. What, specifically, are these conditions?

The report indicates that there are three planned phases for implementation of the pilot test: (1) location of test sites, (2) pilot testing, and (3) post-pilot operation. For phase 1, the report indicates that data from the Phase II RI will be used to pinpoint locations for the vapor extraction and injection wells. How, specifically, will the data be used? What will be the basis for assessing whether the data are sufficient to enable well location? What additional information would be provided by a soil survey?

With regard to the type of NAPL present, on page 4-23 of the report it is indicated that fluids stored at the 903 Pad consisted of lathe coolant consisting of hydrocarbon oils, carbon tetrachloride to varying proportions, hydraulic oils, vacuum pump oils, TCE and PCE. These components include non-aqueous phases which are both less dense and more dense than water. With these ingredients and in the absence of knowledge about relative quantities, it is not possible to assess whether LNAPL or DNAPL would be expected. On page 4-27, it is indicated that the presence of dissolved carbon tetrachloride and stained surface soils suggests the presence of free phase residual chlorinated solvents. It is possible that the elevated carbon tetrachloride

level reflects the presence of DNAPL, but it may also be attributed to the presence of an LNAPL containing relatively high amounts of dissolved carbon tetrachloride within the LNAPL phase. Analysis of the non-chlorinated hydrocarbon and total organic carbon content of the sample would be necessary to more definitively address this question. Also, it is possible that the noted soil staining can be attributed to chlorinated solvents, but the staining may have also been caused by hydrocarbon solvents. To what extent will the uncertainty regarding the type and presence of NAPL affect the expected performance of the vapor extraction system, and how will this be considered in evaluating effectiveness?

One assessment of suitability of test site conditions is the presence of DNAPL, as indicated on page 4-33 of the report. What is the basis for a 1-ppm level of hydrocarbon in the recovered soil vapor for assessing the presence of DNAPL? This concentration is noted in the report as being merely the detection limit of field instruments. What relevance does this concentration have to assessing the likelihood of acceptable performance of vapor extraction? Further, if the level is greater than 1 ppm, it is noted that the test duration will be determined while the test is in progress but in no cases will it exceed 3 months. What will be used to determine the test duration and what is the basis for discontinuing after 3 months? Later, on pages 4-55 and 4-65, it is indicated that a preliminary threshold of 0.5 lbs/day of VOCs will be used for determining success. Again, what is the basis of 0.5 lbs/day? Is this related to a performance model and, if so, how?

Chemical Processes

At each of the three subsites in OU2, there is evidence of the presence of a target contaminant, although the evidence varies from one subsite to the next. There is enough positive evidence, in fact, to infer that the target contaminant is present as a free-phase liquid at each subsite. Whether that is actually the case, the target contaminant has been found in the soil profile and there is a very strong probability that it exists in a sorbed state, on the site soils. Since we don't have detailed information on the site soils, we do not know how much is sorbed or how strongly.

Vapor extraction techniques have recently become quite popular across the United States for removing volatile hydrocarbons from contaminated sites. Their proposed use for all three of the OU2 subsites comes as no surprise. In fact, each of the three target contaminants has reportedly been removed from other sites using vapor extraction methods.

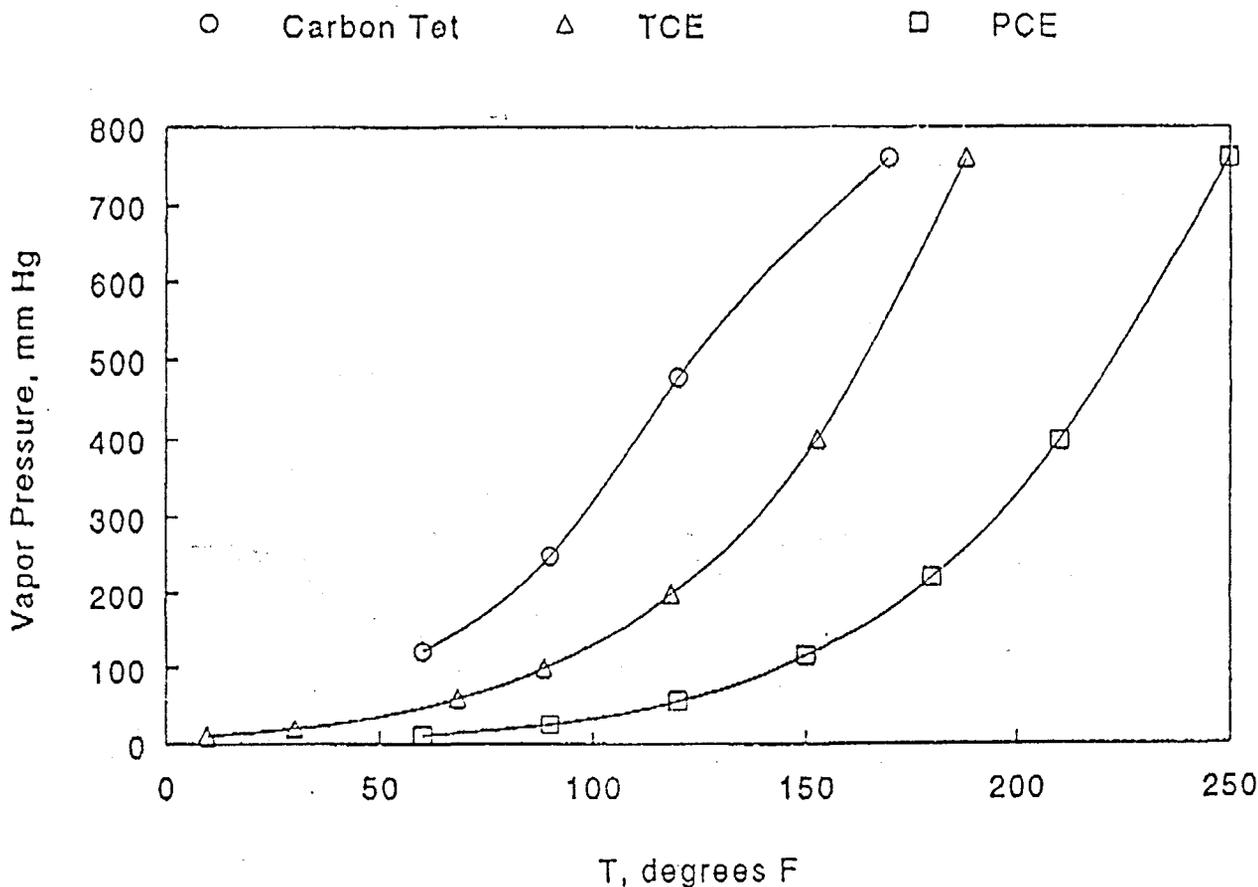
In order to successfully remove the three target contaminants from the three subsites at OU2, it is most important that any sizeable pools of VOC/DNAPLs be found and removed. Additionally, soils that are heavily contaminated with these materials will need to have these contaminants desorbed and flushed from the soil profile, along with amounts of the same compounds which are present in the soil profile but not sorbed. VOCs which are in the vapor state should be the most easily removed.

Wherever feasible, pools of VOC/DNAPLs probably should be pumped from the ground. This should be the safest and most positive of the measures available for cleaning up liquid pools of VOC/DNAPLS. Additionally, groundwater containing the target contaminants at significant

levels probably should be removed for treatment, but this issue should be decided in the context of the specific situation at each subsite.

It should be noted that a commercial technology exists for air sparging aquifers for VOC removal. It is claimed that the Groundwater Technology, Inc. process, resembling a stripping tower operation, also helps release hydrocarbons which are sorbed on the aquifer soils. This approach might be suitable for the 903 Pad and East Trenches subsites, the only subsites in OU2 which have a water-saturated zone, and which show significant contamination of an aquifer by a target contaminant.

While all three target contaminants are classed as VOCs, they are quite different from each other, suggesting that they should be treated somewhat differently. The volatilities of the three compounds are reflected in the vapor pressure curves, shown in Figure 1. It should be noted that the gas-phase equilibrium content of any one of these compounds, in contact with its liquid phase, is directly, proportional to its vapor pressure. Thus, carbon tetrachloride (CCl_4) is the most volatile of the three, followed by trichloroethylene (TCE) and tetrachloroethylene (PCE). This relationship suggests that CCl_4 can be removed at lower temperatures than the other two target contaminants, progressing to PCE as the one which may require the highest stripping temperature.



Based on EG&G Figure 2-7, which shows site hydrology, it appears that 5900 feet above sea level is a representative elevation for the Rocky Flats Plant site. This has two implications, at least.

1. If a DNAPL does exist at the site, its gas-phase equilibrium concentration, as a volume percent, will be higher at this elevation than at sea level, by a factor which is the quotient of sea level barometric pressure, 760 millimeters of mercury, divided by that at 5900 feet elevation, 610 mm Hg (est.), or 1.25. This means that on an equilibrium basis, less mass of stripping gas needs to be extracted at Rocky Flats than at sea level, for a certain amount of a DNAPL to be removed, other factors being equal. If the result of stripping with a reduced mass of gas is to produce a condition of gas-phase saturation, however, then the probable outcome is that a higher flow of stripping gas will eventually be employed.
2. Because of lower gas densities at the higher altitude, for an equal mass of stripping gas moved through the soil profile, the velocity through the soil will be proportionately greater at Rocky Flats than at sea level. This likely will result in larger soil-profile pressure drops than would be the case at sea level and might create a need for higher-capacity gas-handling equipment throughout the system.

The relationships for the tendencies of CCl_4 , TCE and PCE to desorb from site soils may resemble those of their vapor pressures, but probably are much less well-defined. We do not have the kind of soil information on which such tendencies could be readily estimated. Lacking this information, we can say only that temperature increases which would result in increased vaporization of pooled VOC/DNAPLs might likewise favor the desorption of sorbed VOC/DNAPLs from the site soils.

It should be noted that wintertime operation of VES system at the Rocky Flats Plant site will result in ambient air being drawn into the soil profile, at temperatures lower than those of the soil, tending to cool the soil and reduce the rates of volatilization and desorption. Likewise, the presence of liquid water, as at the 903 Pad and East Trenches subsites, can result in evaporation of water when air is drawn through the soil profile. This, also, has the effect of lowering this soil profile temperature, slowing the processes just named. These results may be offset, to some extent, by heating the stripping gas above ambient temperatures, as needed.

The preponderance of information which bears on the proposed VES systems at OU2 appears to favor somewhat elevated temperatures (at least equal to soil profile temperatures) to be employed, with PCE needing the highest temperatures, followed, in order, by TCE and CCl_4 . The two most straightforward ways of achieving higher stripping/vaporization/desorption temperatures are to:

1. Use heated air or other gas, injected into the soil profile and swept through the profile to an extraction well(s). At present, we are not aware of a need for a stripping gas other than air or, as discussed below, steam. Certainly, other gases would be more expensive than air and it is not apparent that they would offer any technical advantages.

The amount of heat needed must be transferred to the stripping air before the air is injected into the soil profile. Since heat input to the operation would rely entirely on the air stream's sensible heat, a site could require a fairly high injection temperature. If this will not cause nontrivial problems it may be tolerated. The unwanted volatilization of other materials present might be one such type of nontrivial problem.

Air has the advantage of not introducing unwanted materials into the subsurface, as compared with steam, which may condense, or other gases which theoretically may cause undesirable physical, chemical or biological effects in the subsurface.

2. Use steam as the stripping gas. A portable steam generator can provide steam on-site, fairly conveniently. Steam has the advantage that it carries a great deal of thermal energy, in the form of latent heat of vaporization. This can offset a great deal of sensible heat, which would be provided by air or other gases.

Additional heat can be provided in steam as well, by operating the generator well above atmospheric boiling point for water, or by running the exit steam from the generator through a heater.

The tendency of steam to condense and form liquid water in the soil profile may be a matter of some concern if other important contaminants are present at the site. Far and away the most important consideration concerning condensate, in our opinion, is whether the amount of condensate formed through using steam is nontrivial. Other factors, of course, are the overall resultant water content of the soil profile, the concentrations and solubilities of various contaminants on the site, the probability of the condensate contacting those contaminants, as well as the probability of transport of those contaminants and resultant impacts.

Any significant changes in soil profile chemistry from contact with the condensate would also be of potential concern, especially if the acid-base buffering capacity is greatly reduced. Again, the amount of condensate formed and resultant soil moisture content are key determinants in this relationship.

It is hard to overstate the advantage which steam has over air and other gases, in delivering heat to the soil profile. One pound of steam has a nominal latent heat of vaporization of 1,000 BTUs. The amount of air required to deliver the same amount of heat depends on the temperature of air injected into the soil profile, but in virtually all cases, the amount of air required to deliver that heat is much larger than the one pound of steam.

For example, if a pound of dry air is heated to 200 degrees F before injection, and allowed to cool to 60 degrees F in the soil, it will deliver about 34 BTUs (140°F temperature change $\times c_p$ of 0.242). In this temperature range, it will take about 30 pounds of air to deliver as much heat as 1 pound of condensing steam. Alternatively, and without accounting for change of C_p with temperature, it appears that it would take one pound of air, heated to 4260°F , to achieve the same amount of heat delivered.

Another alternative offers the potential benefits of both air and steam. It consists of using the two materials as a mixed stripping gas. If a compressed air source and steam source are coupled together, with independent control of the two inputs, a wide range of stripping gas compositions should become possible. This arrangement could be further enhanced by using a stripping gas heater to obtain the desired injection temperature.

If the system uses as much steam as needed to provide heat for the stripping operation, together with as much air as needed for effective sweeping of the soil profile, an optimized operation seems possible. The desired ratio of air to steam would vary from one site to another, depending upon site factors, such as VOC/DNAPLs present and their physical state(s), soil temperatures, soil characteristics and cleanup levels sought.

CONCLUSIONS AND RECOMMENDATIONS

1. The objectives of the research described in this report for the pilot scale vapor extraction system (VES) need to be more clearly defined.
2. The criteria for success or failure of the proposed VES technology similarly needs to be more clearly defined.
3. A site wide groundwater remediation plan needs to be developed for the Rocky Flats Plant.
4. The application of the VES technology for source removal will undoubtedly be an important part of this site wide groundwater remediation plan.
5. Sufficient data needs to be collected on the performance of the proposed VES technology to allow a thorough review of the results of the research project. This includes defining the data to be collected that are critical in the design of a full scale system. Also sufficient monitoring wells need to be installed to accurately define the horizontal and vertical flow of air/vapor in the subsurface.
6. There are discrepancies between the hydrogeology described in the report and dissolved contaminant plumes at the Rocky Flats Plant. These needed to be rectified. Additionally, the conceptual model of the hydrogeology at the three test sites needs to be rethought (particularly look at Reviewer C comments with these regards).
7. Consideration should be given in selecting only one site at this time for test evaluation; reduce the number of test sites from three to one. This has the advantage that all of the manpower and other financial resources could be directed towards collecting detailed information for one site for a better understanding of the results of the test.
8. It appears that air, steam, and air-steam mixtures all have some potential utility as stripping gases for the three subsites at OU2. Of the three, the air-steam mixture system is the one which may offer the greatest flexibility in delivering the desired combination of stripping gas volume and heat content. All three systems seem worthy of consideration.
9. Variations among the three subsites suggest that a different combination of stripping temperature and stripping gas composition may be appropriate for each subsite.
10. Better subsite data on soil texture, permeability, organic content and the like would be very helpful in establishing appropriate sets of conditions to be tested at each subsite.
11. Treatability testing with artificially contaminated soils from all of the subsites likewise should be extremely useful in setting test conditions at each subsite.

Appendix

Individual Reviewer Comments

Reviewer A

Reviewer A Comments

I GENERAL COMMENTS

I recommend a more thorough analysis of the potential advantages and disadvantages of source removal. There is little doubt in my mind that mass removal as proposed will not succeed in the elimination of the source to the extent that aqueous-phase contamination will cease to be produced. Also, mass removal cannot be expected to have any significant beneficial effect upon aqueous phase concentrations in the short run. These facts call into question the rationale for performing expensive mass removal operations that will result in incomplete source removal.

Among the arguments for mass removal are at least the following:

1. Minimizes the magnitude of environmental liability transferred to future generations.
2. Reduces the time required that pump-and-treat systems will have to be operated for dissolved plume control.
3. Lower cost per unit of mass removal as compared to subsequent pump and treat.
4. Reduces the potential for remobilization and further spread of the DNAPL.
5. Positive public relations

One might also use the following arguments as a rationale for not practicing mass removal:

1. Present technologies, including vacuum enhance vapor extraction, are inefficient and very costly.
2. Poor present-value economics.
3. Shifts limited manpower and financial resources away from perhaps more important activities such as plume migration control.
4. Expected environmental benefits are low in comparison to benefits that are achievable in other areas for the same expenditures.

I do not propose to know the correct decision. However, the societal costs of attempts to effect groundwater "cleanup" at Rocky Flats and elsewhere promises to be huge. I believe that each and every step should be assessed in the context of benefit to the environment, the cost to society and the realities of technology performance. A consistent, logical approach should be adopted and vigorously promoted with the relevant regulatory agencies and the public.

Thus, I question whether vacuum enhanced vapor extraction is an appropriate remedial measure at this time. I realize that a major objective is to collect design and performance data to be used in a subsequent FS study. However, it may turn out that containment of the source area by

hydraulic or physical barriers will have a more dramatic benefit on the reduction of pump-and-treat times and on environmental protection.

Financially I believe it is very important that the document clearly set out the criteria against which success will be judged. It seems likely that some mass will be removed but even more likely that much more mass will remain. Simply removing some mass is not a success in my mind. If the cost of the mass removal exceeds the economic benefits of reduced pump-and-treat times, then the system has not been a success.

II SPECIFIC COMMENTS

1. I have some concerns about the description of the hydrogeology. There are indications in the report that the claystone bedrock is "dry". How can this be when there exists an overlying water table in the alluvial sand and gravel?
2. Water, being a wetting fluid, will tend to spontaneously imbibe into the claystone bedrock. Organic liquid, being a nonwetting fluid, will not spontaneously imbibe into the claystone. Thus, the likelihood of water existing in the claystone is greater than the likelihood of organic liquid existing there. If the claystone is dry, why would one expect organic liquid to exist there?
3. Perhaps one possible scenario is that the water perched on the bedrock is highly ephemeral. When water is present it enters the cracks and fractures in the bedrock and is subsequently imbibed into the matrix. If the occurrence of water in the alluvium is sufficiently ephemeral, I suppose the claystone would be at low water contents. It seems, however, that this is stretching things. Even the thick unsaturated zone at Yucca Mountain, Nevada is rather wet.
4. If in fact the claystone bedrock is saturated, then the air flow patterns will not be as visualized. Instead of moving horizontally to the vapor extraction wells, the injected air will rise along preferential paths (probably the largest fractures) and pass into the alluvium.
5. Thus, it seems that the nominal condition with respect to saturation of the claystone bedrock is critical.
6. The potential for creating further downward migration of DNAPL by well construction should be considered/? how is it proposed to minimize this possibility?
7. What will happen to any DNAPL that might flow into the well with the other pumped fluids? I recommend that well construction be accomplished so as to provide for a DNAPL sump below the well screen.
8. My final comment relates to the assessment of system performance. A carefully accomplished mass balance would be more useful. This would involve an intense coring effort in order to estimate the initial contaminant mass. The fraction of the contaminant mass removed by the system could then be estimated as a function of time.

What other criteria for performance monitoring are contemplated and how will they be used to determine the feasibility of this approach at a new site? I suggest a rather detailed description be prepared of how the data and observations are to be used for feasibility and design decisions at untested sites.

Reviewer B

Reviewer B Comments

Here are my review comments. My review is based on Volume I, as I have not been provided with a copy of the appendices of this report.

1. Page 1-5, 6th line. In reference to opposition based on unproven performance for radionuclide removal and process upsets, what treatment processes were included in the proposed IM/IRA?
2. Page 1-5, first full paragraph. What is the status of the chemical precipitation/microfiltration units?
3. Pages 2-3, Section 2.1.2. Figure 2-2 does not provide a point of reference for the location of the 903 Pad, Mound Area, and East Trenches Area relative to the Rocky Flats Plant. Are these areas east-southeast of the Rocky Flats Plant, or are they east of the secured area within the buffer zone?
4. Page 2-31, end of first paragraph. I suspect that the evaporative concentration conceptual "model" is more a qualitative explanation for the elevated levels of dissolved solids (DS). Has actual modeling been conducted to assess expected levels of DS? A similar effort may be of interest with respect to assessing volatile losses of VOCs from the three OU areas.
5. Page 2-32, first eight lines. What are the maximum soluble levels of Pu and Am as a function of Ph? What is the specific interaction of Pu and Am with particulate matter? I suspect that Pu and Am were not observed in the filtrate and thus it was concluded that they were associated with filtered particulates. Is it possible that Pu and Am were dissolved but were adsorbed by the filter media? Is the more comprehensive filtration study underway?
6. Page 2-32, first full paragraph. What are background levels of Pu and Am? How much "above background" do Pu and Am occur? How do data suggest Pu and Am were released to soils via wind dispersion.
7. Page 2-34, Section 2.3.2. If soil samples have not been collected in the actual waste burial areas, where have they been collected from? How relevant are the collected samples?
8. Page 2-35, Section 2.3.2.2, Radionuclide Contamination. How do the aerial photos demonstrate surface contamination of soils with Pu and Am?
9. Page 2-46, last two lines. In reference to the source of airborne Pu contamination, should a qualifier such as potential or suspected be used?
10. Page 2-48, first six lines. How high were Pu concentrations? Is this vapor or Pu associated with dust?
11. Page 2-48, second paragraph under Section 2.3.6. What does "Apparent Pu and Am in surface water samples..." mean? Why "apparent"?

12. Page 2-48, last paragraph. Could evaporative concentration apply to solvents? What are levels of non-VOCs in the subsurface? Have constituents such as cutting, hydraulic, and mineral oils been analyzed for? What further investigation is contemplated?
13. Page 2-49, Section 2.4. Again, have analyses for non-volatile organics been conducted?
14. Page 3-1, first sentence. What is the basis for "suspected" qualifier? I believe that relevant evidence supporting this conclusion needs to be reviewed more thoroughly.
15. Page 4-1, first two sentences following the bullets. How is "suitable" defined? What will be the basis for selection of the locations?
16. Page 4-4, middle paragraph. Are bench-scale treatability studies involving dehalogenation solutions being conducted?
17. Page 4-5, top paragraph. Are chemical oxidation studies being performed?
18. Page 4-5, bioremediation. As more recent studies have suggested potential success of bioremediation, Rocky Flats Plant may wish to consider initiating studies to assess applicability to OU2.
19. Page 4-5, steam stripping. For this technology, increasing radionuclide mobility is desirable whereas for the other technologies it is undesirable. Is it a certainty that steam stripping will not result in migration of radionuclides to the water table?
20. Page 4-27, first paragraph. What is the basis for expecting that carbon tetrachloride comprises the majority of the VOCs released? Is soil straining a sign of a solvent spill or a sign of a spill containing a large quantity of straining materials (e.g., oils)? What fraction of the 5,000 gallons of fluids is chlorinated solvents and what fraction is hydrocarbon liquids? In the absence of analytical information about the levels of hydrocarbons in samples, one cannot dismiss the potential presence of LNAPLs. The evaporative concentration "model" further supports the likelihood that LNAPLs may be present.
21. Page 4-28, Vapor and Ground-Water Extraction. What will be the basis for assessing the effectiveness of these tests? Will it be based on a certain recovery rate? If so, what is the basis for the rate selected?
22. Page 4-32, bullets. How will the representativeness of the pilot site be assessed? What if the extraction well happens to be located adjacent to a hot spot?
23. Page 4-33, middle paragraph. How many samples will be collected?
24. Page 4-33, bottom paragraph. What is the basis for assessing adequacy of the test site? How will the absence of free-phase DNAPL be established? Other than detection limits, what is the basis for the 1 ppm threshold? What factors will affect the duration of the test?

25. Page 4-33. What yield of VOCs is expected? Has or will actual modelling be conducted?
26. Page 4-36, fifth line. The vacuum pump is upstream of the HEPA filters in the figure.
27. Page 4-37, fifth line. Why not incinerate directly (i.e., use incineration rather than activated carbon)?
28. Page 4-38, third paragraph. Will air be humidified to avoid drying the subsurface media?
29. Table 4-1. Second row of first two columns references VOC, whereas text references DNAPL. What will be accomplished by a clean air intake, as noted in the sixth row of column four. Is there a better reason for the 1 ppm threshold other than equipment detection limits (row 9, columns 1 and 2)? What is meant by assessing the feasibility of considering an alternative test site (row 9, column 4)? Can the evaluation criteria be quantified (row 10, column 3)?
30. Page 4-43, second paragraph. How well will vapor extraction work in the bedrock?
31. Page 4-44, second full paragraph. What mass recovery rate is expected? What rate would be necessary to cause condensation to be feasible? Is it likely that such a rate could be achieved at the site?
32. Page 4-44. Four table entries are not discussed in detail, as was promised in line 5, page 4-43.
33. Page 4-46, first full paragraph. How will the locations of source areas be confirmed? What will be the basis of a more promising test area?
34. Page 4-49, last two lines. Is it absolute that IHSS No. 113 satisfies the criteria, or is it believed, assumed, or expected?
35. Page 4-50, first paragraph. What did the remediation in May 1970 specifically involve? Could the high level of observed PCE be attributed to PCE dissolved in hydraulic oil?
36. Page 4-50, middle paragraph. How long after the May 1970 clean-up was the sampling conducted? What is the conclusion of the middle paragraph?
37. Page 4-52, first full paragraph. In reference to a sample in which PCE concentration exceeded its solubility limit, what was the specific concentration and what is PCE solubility? How do concentrations based on other samples compare to solubility? Could the emulsion of the PCE to PE in a hydrocarbon oil?
38. Page 4-55, first two lines. What is the basis for air injection at a rate equal to one-half of the combined extraction rate?
39. Page 4-55, last paragraph. What is the basis of a recovery rate of 0.5 lbs/day? (This also applies to the second paragraph on page 4-65.)

40. Page 4-60, second paragraph. Could this be TCE in oil or on sludge solids?
41. Page 4-61, last paragraph. Was ample filtered? If so, how?
42. Page 4-71, first paragraph. Is the adsorption mechanism for radionuclides known? Can this be exploited to optimize the adsorption by the floc? What will be the Ph of the permeate such that neutralization will be necessary?
43. Page 4-74, first two lines. Will the oxidation products include chloride?
44. Page 4-74, last paragraph. What is the status of the GAC system scheduled to be constructed in March 1992?
45. Page 4-76, first paragraph. Why not use polishing filters before GAC?
46. Page 4-77, lines four and five. Is it a certainty that evaporator vapors will be free of inorganic contaminants? Is it wise to send the recycled condensate to the Rocky Flats Plant process water supply?
47. Page 4-77, middle paragraph. Can the extra processing capacity be quantified?

Reviewer C

Reviewer C Comments

General Comments:

First I would like to say that the report is well written and well organized. The report reflects that the authors have put considerable time and effort into this proposed project and appear to be knowledgeable about the insitu volatilization technology proposed. Secondly, I agree that the insitu vacuum enhanced vapor extraction technique proposed is probably the best available technology (BAT) for the problem of remediating free phase volatile organic compounds (VOCs). However the VOCs considered here are DNAPLs (Dense Non-Aqueous Phase Liquids) with a specific gravity heavier than water. As such they migrate to the bottom of the aquifer where they slowly dissolve into the flowing groundwater. The insitu vacuum enhanced vapor extraction technology (ISV) has been applied elsewhere with varying degrees of success. Many site specific questions need to be answered about its application to Rocky Flats Plant site and the proposed project is primarily for research and development purposes (and rightly so). To quote the report "project success will therefore be gauged by the usefulness of the data collected with respect to final remedial design, not by the degree of cleanup achieved.... no matter how small the scale, the removal of free phase VOCs from the OU2 subsurface represents a positive environmental impact." I agree strongly with these two statements. The report explicitly states that this project is a R&D effort and should not be viewed as a final cleanup effort. I believe that the successful remediation of this site will require a combination of technologies (no single technology will solve the problem short of complete excavation of the site). I believe that pump and treat technology will be required to remediate the dissolved contaminant plume and ISV will be required for source control and remediation.

It has been my experience that the ISV technology has been most successful when the free-phase VOC is in the unsaturated zone where it can be readily contacted by the flowing air. I am less confident that this methodology will be successful when the free-phase VOC occurs in the saturated zone. This will require control of the water table which may or may not be successful in exposing the free-phase VOC. As such the R&D effort proposed here is a good start in answering this question. My only concern here is that reader is left with the impression that this R&D effort is the precursor to a full scale system that is capable of remediating the contaminated groundwater.

I very much like the observational/streamlined approach wherein it is recognized that the site cannot be fully characterized and it is a given that uncertainties will exist. Next these uncertainties are identified and contingency plans are made to address the potential deviations. This seems like a very reasonable approach. In many places the report lacks detail on how numbers were arrived at. The focus of the report was on achieving regulatory approval rather than engineering detail and justification. I would hope that the future test plans that are to be developed would bridge this information gap. Specific Comments on the report are to follow:

Specific Comments:

Section 1 -- INTRODUCTION:

Page 1-2: What are the data needed for a final remedial design that this R&D effort will provide? I think that this is a very critical question.

Page 1-6: Again I very much like the observational/streamlined approach given here. The key to this is the identification of reasonably probable uncertainties and the development of contingency plans. The concept is good but not enough detail was provided in general on contingency plans (this will be discussed more latter).

Section 2 -- SITE CHARACTERIZATION:

Fig 2-4: Primary reference is to this figure is to show the 4 main surface drainages. Title of this figure does not reflect that. Also I think that there are better maps than this one.

Page 2-16: "Groundwater flow is also controlled by paleochannels in the top of the bedrock." This quote refers to flow in the Rocky Flats Alluvium. What supporting documentation do you have? How does this affect groundwater flow patterns in the 3 pilot project areas?

Fig 2-7: This figure shows a groundwater high at the 903 Pad area. This Pad is asphalt covered. The groundwater high indicates the presence of potential recharge in this area? How can this be?

Page 2-30: Are there any hydrographs with time that show the seasonal fluctuation of water levels in the unconfined system?

Page 2-21: Where are wells 41-86 and 40-86 located? The very large very gradients between these wells indicates nearly vertical flow? How does it indicate relatively high contrast between the alluvial and bedrock hydraulic conductivities?

Page 2-35: What is considered the background levels for radionuclides? What level do you consider a problem for the proposed ISV project? Isn't the 903 Pad going to be a hot spot?

Figs 2-12 to 2-17: The figures for the dissolved contaminant plume for the VOCs in the alluvial aquifer system indicate groundwater flow direction to the Northeast. Whereas the dissolved contaminant plume for the bedrock indicates a direction of flow to the south east towards woman creek. Do you have an explanation for this? Can you draw a conceptual schematic diagram of the groundwater flow system (including surface drainage effects)? Am I reading these figures incorrectly but only TCE indicates the likelihood of a bedrock DNAPL source? Your proposed test site location for the 903 Pad doesn't relate to the observed bedrock contamination maps? According to figures 2-15, 2-16, and 2-17, I wouldn't expect any bedrock DNAPL source near the test site location?

General comment on section 2. I think that this section is a fairly good description of the hydrogeology of the overall Rocky Flats Plant site but lacks focus on the 903 Pad, mound, and east trenches areas. For example, there is no data given or discussion made about suspected unsaturated conditions in the bedrock at these sites. Does the 903 Pad prevent vertical recharge and thus one might suspect unsaturated alluvial aquifer conditions beneath it? Does the area of surface staining (defined from old photographs correlate to observed dissolved contaminant plumes?

Section 3 -- IDENTIFICATION OF OBJECTIVES:

Page 3-1: Need to be more specific what data is to be collected that will aid in latter ISV site design.

General comment on section 3. The title of this section is identification of objectives. I found very little related to this (I think)? I didn't get much worthwhile out of this section. I need to have someone explain to me again what this section says.

Section 4 -- PROPOSED ACTIONS:

Page 4-1: I agree that ISV (insitu vacuum enhanced vapor extraction) is the best available technology for source removal. However I do not think that enough qualifiers are place on what can be reasonably expected to be achieved using the ISV technology. Example -- page 4-3 "For this reason, classical remedial actions like groundwater extraction and above ground treatment will not remediate the site in a timely manner." Reading between the lines, this implies the proposed ISV technology will do so since it has not been eliminated from consideration. Won't a pump and treat system still be required to remediate the dissolved contaminant plume? I think that a combination of technologies will be required with ISV only being one of them. However I put at zero the likelihood that the ISV under full scale operation will remove all of the source DNAPL. I think that a discussion of an overall conceptual plan is needed for remediating the groundwater rather than trying to simply justify the ISV technology.

Pages 4-4 and 4-5: Good description of various insitu technologies available. I would like to see some references given here to support some of the statements made.

Page 4-10: What will happen to the HEPA filters when the test project is completed? Do you expect to recover radionuclides in the extracted vapor or is this only a safeguard?

Page 4-12: (Second line) What are these erosional control measures?

Page 4-23: Reference to well 1587 (see Figure 2-11 - which is Americium concentrations and doesn't seem to relate to the discussion). Are you sure this well is down gradient of spill area? Dissolved contaminant plume migration is to the northeast. Where is well 1587 located (do you have a well location map)? Is it a bedrock or alluvial well?

Page 4-24: What will radionuclides in the vapor do to your system? Will it shut it down? Also I couldn't find well BH1687 on Figure 2-9.

Fig 4-2: I don't think that the idealized conditions shown in this figure are realistically possible. I don't think that you can get an unsaturated bedrock beneath a saturated alluvial aquifer. Challenge -- Select any unsaturated flow model and try to create the conditions shown in this figure. I think that you will not be able to. Under the 903 PAD you may find unsaturated alluvium and unsaturated bedrock because the asphalt pad should prevent vertical recharge.

Page 4-27: From figures 2-15, 2-16, and 2-17 TCE seems to be the dominant VOC in the bedrock and not carbon tet. Also I think that more thought needs to be put on how to determine whether DNAPL pools exist at the site.

Page 4-28: Why not use modeling to investigate the well spacing effects and distribution of negative pressures.

Page 4-32: How is the areal influence of the vapor extraction system to be determined? How is the capability to successfully control the mobility of contaminants to be evaluated?

Page 4-33: How was the 1 ppm level decided upon as a critical concentration level? Where is the proposed location of the secondary site if the primary site is abandoned? I like the idea of the soil sample survey before and after the test. However where will the bore holes drilled relative to the extraction and intake wells? Can you show on a map the proposed number and location of these boreholes for soil sampling?

Page 4-40: Does the bidirectional flow at 903 Pad indicate this area is a source of recharge? Isn't this somewhat like Moses parting of the Red Sea? Where is the up gradient source of water for the 903 Pad area? How is the estimate of 1 gpm arrived at?

Page 4-42: (Table 4-1) I like the observational/streamlined approach. However I would like more detail than the 1 liners given in table 4-1. For example -- Potential deviation = Recoverable groundwater in the bedrock. Contingency = Retrofit existing vapor extraction wells with groundwater pumps. Given the low hydraulic conductivity of the bedrock will you be able to control the water table with the existing well spacing?

Page 4-46: Is not the presence of VOCs below the water table a factor in limiting success of the ISV technology at the Rocky Flats Plant site? My experience has been that the ISV technology has been most successful when the free phase VOC is in the vadose zone. I believe one of the real challenges at making it work at Rocky Flats Plant is that the free phase VOCs there may well be below the water table. Water table control measures may or may not be successful in exposing the free phase VOC.

Page 4-52: What justification do you have that the alluvium in the Mound area will be dry?

Page 4-53: What justification do you have that 6 feet of blank casing will stop short circuiting of the air flow? Same question about 10 radius of surface covering to prevent short circuiting? How will you know whether you have short circuiting in the field?

Page 4-55: What justification do you have for the injection rate to be 1/2 of the extraction rate? Why a success rate of .5 lbs/day of VOCs for the mound site but 1 ppm for the 903 Pad site?

Page 4-60: How will TCE mixed with oil or sludge affect the ISV system. Will this severely inhibit the ISV effectiveness? Could you in some cases have an LNAPL rather than a DNAPL?

Page 4-65: Again why is .5 lbs/day the critical level of success? Also why always estimate 1 gpm for all three sites? This implies that not a lot of thought was given in determining this pumping rate since conditions are very dissimilar at the three sites.

Fig 4-11: Can you achieve the desired drawdown with the proposed well spacing and pumping rates given the hydraulic conductivity of the sandstone bedrock?

Could slant drilling be used beneath the trench for both extraction well and soil sampling boreholes? Do you have any idea of the air flow pattern that will be developed? Will surface sealing be required?

Page 4-68: Reference to 3 years duration on wetlands impact. Should this be three months? How arrive at 1/20 of an acre impact on wetlands area?

Section 5 -- IMPLEMENTATION PLAN:

General comment -- This report was written with the focus to achieve regulatory compliance rather than to provide specific engineering detail. I would hope that test plans to be produced will provide significantly more engineering detail and justification. This is not only on the system design but also on how system effectiveness will be evaluated.

Reviewer D

Reviewer D Comments

The following is a commentary on the proposal document prepared by the staff of EG&G Rocky Flats, in DRAFT form, and dated March 2, 1992. The subject proposal has to do with the cleanup of known or suspected "free phase volatile organic compound (VOC)" contamination in an area of the Rocky Flats, Colorado facilities, designated as Operable Unit No. Two (OU2). This unit includes three subsites, known, respectively, as the 903 Pad Subsite, Mound Subsite, and East Trenches Subsite. Although not so defined in the EG&G report, "free phase" is taken here to mean "liquid". All three of these subsites appear to have similar problems, with underground contamination with VOCs, in particular those compounds known as Dense Non-Aqueous Phase Liquids (DNAPLs). The EG&G document contains specific proposals for all three subsites, both to gather more information about each of the three subsites and to clean up some of the inferred or known contamination at each.

SCOPE:

The following commentary is largely limited to addressing the dominant VOC/DNAPL for each of the subsites and EG&G's proposal for its cleanup. EG&G has recognized that other such compounds are present at each such site. It appears that they have taken the target (dominant) contaminant as a surrogate for all the VOCs present, in order to efficiently begin the planning which must be done for these sites. I will follow the same logic, which seems quite reasonable under the circumstances.

As to degree of cleanup, and especially the issue of compliance with ARARs, these are given little emphasis in this commentary, as being of less current interest than finding whether vacuum-assisted vapor extraction systems will likely contribute significantly to the cleanup of these subsites. CERCLA permits the use of remedial actions which do not produce ARARs compliance if they are part of a program which will produce compliance. Also, it is recognized here, as well as by EG&G, that there are other (VOC and non-VOC) types of contaminants known or suspected to be present at these three subsites; these other contaminants, present or not, are outside the scope of this commentary, as are economic factors.

COMMENTARY:

The following comments are broken into four sections, as follows:

- I. General
- II. 903 Pad Subsite
- III. Mound Subsite
- IV. East Trenches Subsite

I. GENERAL:

- A. It is evident from the EG&G report that information now in hand, about the underground conditions at all three subsites, is inadequate to the task of effectively and efficiently carrying out the cleanup of each of the three subsites.
- B. Rather than concurrently trying VES systems on three sites which may not be well understood, it might be more cost-effective to put in one system, on the one subsite which seems most likely to be in need of cleanup and/or most amenable to VES cleanup, while doing a more intensive study of the other two subsites. This study would be done to provide a higher degree of confidence as to the presence or absence of real problems, the definitions of those problems and the detailed site information needed to produce effective and efficient remedial designs. This approach would also allow the designers and operators of the cleanup systems to gain design and operating experience on one subsite, which they could apply in the design of subsequent systems.
- C. All three of the target contaminants of have the following physical characteristics in common:
 - 1. Specific gravities well above 1.0 .
 - 2. Severely limited solubilities in water.
 - 3. Substantial vapor pressures.
 - 4. Probable strong tendencies to be sorbed to soil particles, especially where soils have significant organic contents.

These commonalities suggest that similar remedial methods should work for all three contaminants.

- D. Despite commonalities in the three target contaminants, the three subsites and their inferred contaminants differ from each other sufficiently that it may not be possible to use highly similar remedial designs and procedures at all three or even two of the three subsites. I refer, here, to the different depths to bedrock, different types of bedrock, the presence or absence of groundwater, and significant differences in contaminant vapor pressures and sorption potentials.
- E. The use of unheated ambient air as the purging medium for these sites may fall short, because:
 - 1. The soil profile may be sufficiently cool to severely depress the vapor pressures of the target contaminants, so that they will be extracted and recovered only very slowly. This also potentially applies to VOC/DNAPLs sorbed to soil particles, which may hold these compounds strongly, at modest soil temperatures.

2. The infiltrating ambient air, in some seasons of the year, will be cooler than the soils in the profile being treated, resulting in cooling of the soils and further slowing the removal of the contaminants.
3. If the soil profile is moist, either from the water table or from precipitation events, the infiltration of ambient air will cause water evaporation and resultant cooling of the soil profile.

All of these factors suggest that the ambient air should be heated, at least to the point of not further cooling the soils. Heating the air above this point is a matter for separate evaluation, and may vary from one subsite to another.

- F. A careful review of the vapor pressure versus temperature relationships for all three target contaminants should be done, with special attention to the predicted or measured soil temperatures for all three subsites, and their effects on vapor pressures, soil-gas compositions and resulting stripping air volume requirements. This may very well be a critically important factor in arriving at an effective remedial design for each subsite.

Likewise, treatability studies probably should be done, relating desorption of contaminants to treatment temperatures and investigating the kinetics of desorption. Since organic matter contents of site soils have not been provided, this is an area on which I can not comment directly.

- G. EG&G has stated that the primary objective of the proposed actions is to gather more information about the subsurface conditions at all three subsites, recognizing that the present information base is inadequate to the overall task of cleaning up these subsites. Indeed, it seems possible that no serious problems with VOC/DNAPLs will be found to exist at any of the three subsites.

This prospect places an added burden on the process of selecting only a few sites (initially, only three) for the proposed actions. It includes the risk that poorly placed extraction or injection wells would tell the investigators very little about site hydrogeology and locations of DNAPL pools or contaminated groundwater plumes that would be of value to them in their overall task. For this reason, it appears that investigative efforts should be given a high priority, until it is established whether there are problems of the inferred type, where they are and how severe they are. This may permit the contractor's resources to be better used than in the proposed approach. In the absence of definite proof concerning the existence of such problems, a high level of confidence should be sought.

- H. At those locations where groundwater is contaminated with the target contaminants, depression of the water table by pumping is strongly indicated, both to get the contaminated groundwater out of an aquifer and to expose any liquid or sorbed DNAPLs present, for removal, presumably through air stripping.
- I. At any subsite where a DNAPL is found in a pumpable condition and a compatible setting, pumping of this material should be strongly considered. Pumping seems likely to be far more effective than in situ stripping, if pumping can be performed on a nontrivial scale.

- J. It appears that the use of steam for stripping will add about 1% moisture, by weight, for every 45 to 50°F increment, by which the soil is heated. This is based on the assumption that the soil is nominally dry, giving it a heat capacity of 0.2 to 0.22 BTU/pound,°F. While this does not seem to be a large gain in moisture content, its importance will depend on site-specific factors, such as pre-existing moisture levels, solubilities of important contaminants, the Ph-buffering capacities of the soil systems and the probability of contaminated condensate escaping the control of site operators.

If a soil contains a substantial amount of water, prior to steam-stripping treatment, its effective heat capacity will be greatly increased, adding to the amount of steam consumed and the amount of condensate produced.

- K. Heated air has the advantage of vaporizing and/or desorbing VOC/DNAPLs, without creating condensate. However, its action is limited to the use of its sensible heat, meaning that the amount of air used as a heating medium might be vastly greater than the amount of steam needed to perform the same function. This may or may not prove to be important, however, when the amount of air or steam used as a stripping vehicle (as opposed to heating) is taken into consideration.
- L. A stripping gas mixture of air and steam, resulting in a reduced (and controlled) amount of steam condensation, might be a worthwhile alternative to consider.
- M. There is the theoretical possibility, especially with the larger VOC molecules, that volatilization of these compounds will cause the formation of a moving front, with the result that some VOCs will condense as they encounter cooler soils. This has probably occurred at other sites where VES cleanup has apparently succeeded with some of the same target contaminants as those is OU2, so it may be manageable.

II. 903 PAD SUBSITE:

- A. It seems attractive to extract groundwater from this site, as described on page 4-28 of the EG&G report. Without the use of submersible pumps, however, the water level would probably not be controllable with the other system components that have been proposed.
- B. The diagram on page 4-35, titled Figure 4-6, Pilot Test Unit Vapor Extraction System, shows a vacuum pump protected against contamination only by an in-line condensate separator. If radioactive materials are present, this pump and its lubricant probably should be better protected against radioactive contamination.
- C. A cooling system for warm water is shown in Figure 4-6 and described on page 4-36. According to the text on page 4-36, "warm water exiting the exchanger is sprayed cooled (i.e., evaporative cooling) in a recirculation tank.". The system as described would probably not work well, since the interior of the spray tank would very quickly come to equilibrium, shutting down any further evaporation. In order for evaporative cooling to continue, a contact medium such as ambient air would need to be provided.

- D. In Figure 4-7, titled Pilot Test Unit Vapor Injection System, a gas-fired heater is shown for the purpose of heating the gases to be directed into injection wells. What is not clear from the figure is whether the combustion gases from the heater will be sent to the injection wells or whether a heat exchanger will be used to heat fresh ambient air for this service. Thermal efficiency and capital cost would favor injecting the combustion gases, but sensitivity concerning the injection of combustion products would favor the use of a heat exchanger.
- E. The use of the Observational/Streamlined Approach (Section 4.3.2.2), seems ideal for the type of activities planned in this project!
- F. In Table 4-1, the use of GAC adsorption is shown as being cost effective under expected conditions, but not if a deviation occurs, resulting in high VOC concentrations. This latter result seems counter to the usual considerations used in evaluating GAC adsorption; this subject should be revisited.

Further, the Contingency plan which calls for adding clean air to the vacuum pump intake also seems counter-intuitive. The likely result would be that the effective capacity of the system would be severely reduced, because of the increased gas volume created by the presence of the added air. If for some reason it is deemed desirable to add a "clean" gas to the vacuum pump inlet, consideration should be given to recycling gases from the downstream end of the process. This will minimize the amount of tail-gases which may be required to be cleaned for atmospheric release. This approach would also have the same tendency as added fresh air to overload the gas handling system.

- G. The target contaminant for this subsite is carbon tetrachloride (CCl₄). This substance was found 300 feet down-gradient from a known spill site, at a concentration in a groundwater sample of 6,400 micrograms/liter. The investigators have inferred that higher concentrations exist closer to the spill location and that "free phase" carbon tetrachloride is present at this subsite. This conclusion does not appear to be supported by the Soil Boring Volatile Organic Results, in Appendix A-1, pages 1 and 2. This apparent discrepancy may be a result of an inadequate soil VOC data base.
- H. Of the three target contaminants in Operational Unit #2, carbon tetrachloride easily has the highest vapor pressure, making it the most easily volatilized, other factors being equal. Even so, this compound exhibits a very strong relationship between temperature and vapor pressure. Some representative values are:

<u>Temperature, °F</u>	<u>V.P. mm Hg</u>
60	121
90	250
120	478
169.8(B.P.)	760

Clearly, volatilization from the liquid state is strongly favored by elevated temperatures. Merely raising the temperature from 60 to 120° F will increase the vapor pressure of liquid CCl₄ by a factor of about 4, with a commensurate increase in the gas phase equilibrium concentration of carbon tetrachloride.

Desorption also will be facilitated by increasing temperatures, but this will also be related to the matrix in which the material is sorbed. This dependence increases the need for performance of matrix-oriented treatability studies, which could be performed with simulated contamination, at whatever contaminant levels are deemed appropriate.

III. MOUND AREA SUBSITE:

- A. Based on the chemistry of groundwater samples taken at Well No. 0174, adjacent to and downgradient from the Mound Subsite, it is inferred that a considerable spill of perchloroethylene occurred at this subsite and that free-phase PCE has persisted at the site. In particular, a 1987 water sample showed an analysis of 528 mg/liter of PCE. This level greatly exceeds the PCE solubility level of 160 mg/liter in water.

Since this subsite has only about ten feet of alluvium, underlain by claystone, it seems probable that liquid PCE exists at a shallow depth, at this subsite. It is possible that liquid PCE has penetrated into vertical cracks in the claystone structure. EG&G believes that no recoverable groundwater exists at this subsite, but that small amounts of seasonal groundwater may be perched on the claystone structure.

- B. The use of separate sets of wells for the alluvium and bedrock makes sense from a point of view of positive control of the induced movement of DNAPLs which may exist at this subsite. It is not clear how much lateral separation is planned, between the sets of wells which will be used for these two tasks, however.

It seems prudent to make a sufficient physical separation between these operations so that an accidental crossover of vapor flows between systems is simply not going to happen. The same protection logically might be obtained by separating these operations in time, keeping the inactive systems shut in while the other systems are being operated.

- C. On page 4-55 of the EG&G report, it is proposed that vapor recovery wells be installed to a maximum depth of 30 feet into bedrock. To minimize the possibility of VOC/DNAPLs following the borehole into the bedrock structure, a drilling and well-construction technique might be used which would make it possible to deepen these wells in increments of, say 10 feet each, testing for liquids at each depth before proceeding to deeper drilling.
- D. The same comments concerning concentrations of VOCs in gas streams sent to GAC units would apply to Table 4-2 (page 4-57) as in item II-F, in the 903 Pad Subsite discussion section of this commentary.
- E. PCE has the lowest vapor pressure and possibly the strongest sorbing tendency of the three target contaminants, making it very likely the hardest to remove by VES operation.

IV. EAST TRENCHES AREA SUBSITE:

- A. The East Trenches Subsite shows potential for the presence of free-phase (liquid) trichlorethylene (TCE), based on the occurrence of 221.8 mg/liter of TCE in a groundwater sample taken from Well No. 3687, adjacent to this subsite. This is a significant fraction of the 1100 mg/liter solubility of TCE in water, suggesting the presence of free-phase liquid TCE. This subsite differs from the other two in OU2, in that it contains a substantial saturated zone in a sandstone structure that is near the surface. Contamination has been found in the saturated zone water and is inferred to exist as a free phase liquid at the interface beneath the sandstone structure.
- B. At page 4-63 of the EG&G report, it is stated that "Sandstone wells will be isolated from the alluvium by the installation of steel surface casing set in sandstone." I recommend that some lateral separation also be established, to be certain that there is no interaction between alluvium wells and sandstone wells.
- C. TCE is intermediate in vapor pressure, between carbon tetrachloride and PCE. Its B.P. for 60 mm Hg is 68°F, while that for 400 mm Hg is 152.6°. Thus, there could be significant benefit in heating the soil profile to volatilize any TCE liquid that is present. Its tendency to sorb to soils and to require heating for desorption is also expected to be intermediate between such tendencies of the other two principal VOC/DNAPLs.
- D. Table 4-3 (page 4-66) contains the same information in relation to the use of GAC vapor treatment, as for the 903 Pad and Mound subsites. Again, I would comment that the concern for poor performance caused by high VOC concentrations is counter to my understanding of the functioning of activated carbon systems.
- E. The East Trenches Subsite, in particular, would likely require heated stripping air or steam, to overcome the cooling induced by the evaporation of residual water, following the depression of the water table by pumping. Without this heating, removal of TCE would most likely be slow and, in the case of sorbed material, uncertain.
- F. At the top of page 4-67, the name "Mound" appears to have been accidentally used in place of East Trenches.

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