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AN SAB REPORT: REVIEW OF MMSOILS COMPONENT OF THE PROPOSED RIA FOR THE RCRA CORRECTIVE ACTION RULE

REVIEW OF THE OSWER & ORD DRAFT DOCUMENTATION AND. USER’S MANUAL AND RIA OF THE MMSOILS MULTIMEDIA CONTAMINANT, FATE, TRANSPORT, AND EXPOSURE MODEL

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

WASHINGTON, D.C. 20460

November 19, 1993

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

EPA-SAB-EEC-94-002

Honorable Carol M. Browner
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Re: Review of MMSOILS Component of the Proposed Regulatory Impact Analysis (RIA) for the RCRA Corrective Action Rule

Dear Ms. Browner:

The Science Advisory Board (SAB) is pleased to submit its report on review of the Agency's draft document entitled "MMSOILS: Multimedia Contaminant Fate, Transport and Exposure Model Documentation and User's Manual," dated September 1992. The MMSOILS (Multi-Media Contaminant, Fate, Transport and Exposure Model) document was developed jointly by the Office of Research and Development's (ORD's) Office of Health and Environmental Assessment (OHEA), Exposure Assessment Group (EAG) and the Office of Environmental Processes and Effects Research (OEPER). This report by the MMSOILS Model Review Subcommittee (MMRS) was prepared as part of the SAB's review of the "Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for .Solid Waste Management .Units: Proposed Methodology: for Analysis.". Our report resulted from the MMRS public reviews on April 22 and 23 and June 29, 1993.

The Agency, through the Office of Solid Waste and Emergency Response (OSWER) asked the SAB to review specific elements of the multi-media contaminant fate, transport and exposure model, MMSOILS, with regard to the methodology used to predict contaminant concentrations in the environment and the resultant implications on human health and ecological risk assessments. Specifically, the review dealt with:

a) the adequacy of methods for using a screening level model where there is substantial subsurface heterogeneity and/or where nonaqueous phase liquids (NAPLs) are present,

b) the appropriateness of the Agency's approach for aggregating releases from solid waste management units (SWMUs) in order to estimate concentrations at exposure points as a function of time, and

c) the adequacy of the Agency's approach for developing long-term effectiveness and failure scenarios for site remedies.

The OSW/ORD working group is to be commended for a well-coordinated and focused effort to develop a regulatory impact analysis (RIA) that will help the Agency and the Nation better understand the costs and benefits of the proposed rule. The Subcommittee wishes to recognize the responsiveness and progress made by the OSW/ORD working group to many of the recommendations made at the April 22-23, 1993 meeting and candidly displayed in detail at the June 29, 1993 meeting. The Subcommittee appreciates and recognizes the significant effort expended to date, the positive attitude and open candor displayed by the OSW/ORD working group in their presentations and interactions during the two review meetings. The Subcommittee considers the intraagency coordination represented by this RIA to be a "model approach" that the Agency would do well to adopt in other programs.

On the positive side, the Subcommittee observes that MMSOILS uses simple, conservative, and computationally efficient equations for estimating chemical transport via ground water, surface water, soil erosion, atmospheric, and food chain pathways. Pathway documentation is well organized with appropriate references. Applied mathematical formulae are widely used and accepted by the scientific community for use in simple situations. Underlying assumptions have been identified, clearly stated, and appear to be reasonable yet not overly restrictive. Given these strengths, MMSOILS, when applied to simplified case studies, might certainly be a valid screening tool for assessing the relative risks and costs associated with alternative regulatory options.

However, the Subcommittee notes that two problems create unquantifiable uncertainties that seriously diminish the utility of MMSOILS relative to its use in the draft Corrective Action Regulatory Impact Analysis (RIA), namely:

a) inaccurate input parameters; and

b) application of the model to cases outside its range of validity.

Inadequate input data are a consequence of sparse or inaccurate information, poor parameter estimation especially relative to source terms, and suspected over-reliance upon default parameters. The Subcommittee recommends a documented and thorough peer review of all aspects of the data base, focusing particularly on those parameters to which the results are most sensitive.

Equally serious is the **inappropriate application** of the MMSOILS model to scenarios for which it was not intended, such as sites with complex hydrogeological conditions or sites where NAPLs are present. To some extent, as discussed in the Subcommittee's full report, the latter could be addressed by means of appropriate revisions to model formulations. However, for a significant number of sites, the Subcommittee suspects that no generic model is likely to provide answers of acceptable quality. OSWER is generally aware of the limited usefulness of generic models for the analysis of complex environmental settings.

The Subcommittee also observes that **uncertainty analysis** for the RIA is in its infancy and will require much greater effort to meet the needs of the assessment process. Given the high stakes involved in terms of potential commitment of national resources, defensible estimates of the uncertainties associated with risks and benefits are critical, and the protocol followed to obtain such estimates deserves as much forethought and careful peer review as that required to obtain the central estimate. As a related issue, the Subcommittee is concerned that the simple protocol followed to obtain high-end risk estimates may be inadequate in that these estimates in some cases apparently gave rise to lower exposures than did the central tendency estimate.

Given these serious shortcomings, many of which were already recognized by the Agency, the most basic and pressing concern of the Subcommittee is whether the use of a generic model such as MMSOILS is appropriate as a basis for the assessment of regulatory costs and benefits at the national level, given the fate and transport estimates that comprise the model output may **be wrong by orders of magnitude for many complex sites**. We recommend that the Agency:

a) augment its RIA with cost/benefit estimates derived by alternative approaches, such as:

    1) utilizing assessment data generated for Superfund sites,

    2) using more sophisticated models with better-defined data to develop estimates for representative sets of waste sites, or

    3) applying site-specific models to analyze that relatively small number of facilities which MMSOILS results indicate dominate the total costs or risks, and

b) at a minimum, expert review of the latter cases should be undertaken to judge the reasonableness of model outputs.

This augmentation should help validate the present reliance on the screening studies that use MMSOILS model output as a starting point.

The SAB appreciates the opportunity to comment on the EPA's MMSOILS model. We are gratified that the Agency has brought this issue before us and look forward to receiving a summary of the EPA's response, particularly to the points raised in this letter to you.

Sincerely,

Dr. Raymond C. Loehr, Chair
Executive Committee
Science Advisory Board

Mr. Richard A. Conway, Chair
Environmental Engineering Committee
Science Advisory Board

Dr. C. Herb Ward, Chair
MMSOILS Model Review Subcommittee
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ABSTRACT

The MMSOILS Model Review Subcommittee (MMRS) of the Environmental Engineering Committee (EEC) of the EPA Science Advisory Board (SAB) has prepared a report on the Agency's Office of Solid Waste (OSW) MMSOILS Multimedia Contaminant Fate, Transport, and Exposure Model. This model and guidance document was developed as a technical resource for estimating potential health risks at sites contaminated by toxic wastes or spills of toxic chemicals.

The review by the SAB's MMRS dealt with the adequacy of methods for using a screening level model where there is substantial subsurface heterogeneity or where non-aqueous phase contaminants are present, the appropriateness of the Agency's approach for aggregating releases from solid waste management units (SWMUs) to estimate concentration at exposure points over time, and the adequacy of the Agency's approach for developing long-term effectiveness and failure scenarios for site remedies.

The general consensus of the MMRS was that the use of a multimedia pathway model for screening purposes could be an appropriate approach for developing risk and cost estimates for a national-level Regulatory Impact Analysis (RIA), as long as the input parameters are accurate and the model is not applied outside its range of validity. Furthermore, the Agency's use of a single model, to the extent defensible for each facility considered, was viewed by the MMRS as necessary in order to ensure consistency among model results. The major overriding concerns of the MMRS were: a) application of MMSOILS outside its range of validity; b) large uncertainties in input parameters; c) consequent large uncertainties in MMSOILS results; d) clear communication of this uncertainty to decision-makers; and e) presentation of the results in the draft RIA document in a scientifically defensible manner that communicates the uncertainties of the calculations and their implications for the cost/benefit analysis.

The MMRS recommended that the Agency augment the MMSOILS results with cost/benefit estimates derived by alternative approaches, such as utilizing assessment data generated for Superfund sites, using more sophisticated models with better-defined data to develop estimates for representative sets of waste sites, applying site-specific models to analyze that relatively small number of facilities which MMSOILS results indicate dominate the total costs or risks, and submission of selected case studies to expert panel review.

Key Words: Mathematical Models, Cleanup, Corrective Action, Regulatory Impact Analysis, RCRA Models

U.S. ENVIRONMENTAL PROTECTION AGENCY
Science Advisory Board
Environmental Engineering Committee
MMSOILS Model Review Subcommittee

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1. EXECUTIVE SUMMARY

In response to a request from the Office of Solid Waste and Emergency Response (OSWER), the Science Advisory Board (SAB) has reviewed several aspects of the draft Regulatory Impact Analysis (RIA) prepared in support of the Resource Conservation and Recovery Act (RCRA) Corrective Action Rule. At the October 1992 meeting, the SAB Executive Committee, recognizing the importance, complexity, and creativity of OSWER's work and its multi-disciplinary nature, established an ad hoc Steering Committee to assure that certain significant aspects of the RIA --both methodology and application --received appropriate attention from the relevant SAB standing Committees.

At a public meeting on January 29, 1993, the Steering Committee concluded, based on presentations by and discussions with OSWER staff, that four SAB committees, with appropriate inter-committee liaison participation, should review major segments of the RCRA Corrective Action RIA as follows: the Environmental Economics Advisory Committee (EEAC) would review the Contingent Valuation (CV) methodology and its application in the RIA; the Environmental Engineering Committee (EEC) would review the MMSOILS multi-media contaminant fate, transport and exposure model; the Ecological Processes and Effects Committee (EPEC) would review the ecological risk analysis; and the Environmental Health Committee (EHC) would review the human health risk assessment. In addition, the Steering Committee agreed to prepare an overview report to accompany the individual committee reports.

The MMSOILS Model Review Subcommittee (MMRS) of the EEC reviewed the Agency's draft document entitled "MMSOILS: Multimedia Contaminant Fate, Transport and Exposure Model Documentation and User's Manual," dated September 1992 (See Appendix B, Reference 6), as well as the supporting RIA and Appendices (See Appendix B, References 7 & 8). The draft documentation and user's manual was developed jointly by the Office of Research and Development's (ORD's) Office of Health and Environmental Assessment (OHEA) arid Office of Environmental Processes and Effects Research (OEPER). The MMRS report resulted from a review of the above draft documents and briefing materials at meetings on April 22-23, 1993 and June 29, 1993 (See Appendix A, and Appendix B; References 6 through 8).

1.1 Overall Comments

The OSW/ORD working group is to be commended for a well-coordinated and focused effort to develop a regulatory impact analysis (RIA) that will help the Agency and the Nation better understand the costs and benefits of the proposed rule. The Subcommittee wishes to recognize the responsiveness and progress made by the OSW/ORD working group to many of the recommendations made at the April 22-23, 1993 meeting and candidly displayed in detail at the June 29, 1993 meeting. The Subcommittee appreciates and recognizes the significant effort expended to date, the positive attitude and open candor displayed by the OSW/ORD working group in their presentations and interactions during the two review meetings. The Subcommittee considers the intraagency coordination represented by this RIA to be a "model approach" that the Agency would do well to adopt in other programs.

The consensus of the MMSOILS Model Review Subcommittee (MMRS) is that the use of a multimedia pathway model for screening purposes could be an appropriate approach for developing risk and cost estimates for a national-level RIA as long as the input parameters are accurate and the model is not applied outside its range of validity. The Agency's use of a single model, to the extent defensible, ensures consistency among model results.

The major overriding concerns of the MMRS are the application of MMSOILS outside its range of validity; large uncertainties in input parameters; consequent large uncertainties in MMSOILS results; clear communication of this uncertainty to decision-makers and the generation of credible guidance on exposure, risk, costs, and benefits. Consequently, the recommendations contained in this report are focussed at efforts to decrease the level of uncertainty, to validate the MMSOILS results by comparison with alternative, estimation methods, and to ensure that the results of the modeling exercise are expressed in the RIA background documents in a scientifically defensible manner that communicates the uncertainties of the calculations and their implications for the cost/benefit analysis.

1.2 Response to Charge

The following issues were presented in the charge to the Subcommittee. (Please note that numbers following specific observations and recommendations refer the reader to more detailed discussion in Section 3 of this review report.):

Issue 1. The adequacy of methods for using a screening level model to characterize situations where there is a substantial subsurface heterogeneity or where non-aqueous phase contaminants are present.

While the Subcommittee (the MMRS) agrees that a screening-level model may be appropriate for developing risk and cost estimates for a national-level RIA, the MMRS recommends that the current version of MMSOILS not be applied to the characterization of contaminant distributions in ground water in complex hydrogeological settings or where Non-Aqueous Phase Liquids (NAPLs) may be present. For these facilities, the MMRS recommends that alternative approaches to characterization should be used. Such approaches include modification of the MMSOILS ground water module to more accurately model contaminant movement in complex hydrogeologic settings; utilization of assessment data generated at Superfund sites; application of more sophisticated models with better-defined data to develop estimates for representative sets of waste sites; application of site-specific models to analyze that relatively small number of facilities which MMSOILS results indicate dominate the total costs or risks; and submission of these case studies to expert panel review to develop estimates of contaminant migration.

Issue 2. Appropriateness of the Agency's approach for aggregating releases from solid waste management units (SWMUs, the source terms for the contaminant modeling) to estimate concentration at exposure points over time.

The Subcommittee is concerned that the method of aggregation used to obtain the concentration distributions for application to individual wells may not conserve mass. Rather, it appears that the resulting apparent mass and the average concentrations for each concentric ring downgradient from the SWMUs will always exceed that from the untransformed plumes. Such an approach may nonetheless be defensible for the purposes of the RIA because it is conservative; however the MMRS recommends that the degree of conservatism be evaluated through comparison with a number of simulations which do not use this method of aggregation. Unduly conservative estimates can cause the inappropriate prioritization of risks. In addition, the MMRS recommends that the Agency evaluate whether movement of the contaminant plumes could result in a decreased concentration for population wells. The required transformations from cartesian to cylindrical coordinates should not require much computational effort compared with that required for the model to begin with.

Issue 3. Adequacy of the Agency's approach for developing long-term effectiveness and failure scenarios for site remedies.

The Subcommittee observes that the annual time scale for exposure estimates produced by MMSOILS may be inappropriate for many ecological applications. Typical organisms of concern exhibit short life spans, or critical stages in their complex life histories that occur at time scales substantially shorter than one year. Thus, the Subcommittee recommends the modification of MMSOILS to produce more realistically-scaled exposures for meaningful inputs to ecological risk analysis (Recommendation #13; also Section 3.2.8). The Subcommittee recommends that the ecological risk assessment component be constructed using the principles for ecological risk assessment as suggested by the Risk Assessment Forum. (Recommendation #9; also Section 3.2.5; See also Appendix B, Reference 23). The Subcommittee further recommends that ecologically relevant exposure scenarios be modified so as to be capable of simulating acute impacts from waste sites on aquatic environments due to surface run-off after major rain events. (Recommendation #10; also Section 3.2.5).

Issue 4. The implications of the fate and transport modeling assumptions on the ecological and human risk assessment.

The Subcommittee observes that certain hazardous agents are not easily controlled and may pose health risks beyond the substances discussed in the RIA. (Observation #43; Section 3.8.6). The Subcommittee recommends that the Agency revise its practices for assessing cancer and noncancer health risks so as to make them more consistent with one-another (Recommendation #40; Section 3.8.3). The Subcommittee also recommends that the Agency review its assumption of additivity of Hazard Indices, and additivity of risks across Class A (known) and Class C (suspected) carcinogens (Recommendation # 42; Section 3.8.5). The Subcommittee further recommends that the Agency review its discussion of critical health effects and correct any inaccurate information (Recommendation #41; Section 3.8.4).

The Subcommittee recommends that the Agency consider how the general validity of its exposure estimates might be tested by comparison with empirical field data. This is being recommended as a result of the observation by the Subcommittee that the translation of contaminant concentrations to estimates of exposure necessarily involves a long chain of assumptions and requires the adoption of parameter values of variable uncertainty (Recommendation #39; Section 3.8.2).

1.3 Additional Observations and Recommendations

1.3.1 Model Selection, Development, Formulation and Documentation

Recommendation 1. The MMRS recommends that the criteria and rationale for the selection of MMSOILS be more fully documented in the RIA so that the scientific and strategic bases for the selection will be clear to all concerned - regulator, regulated, and scientific/risk assessment/economic communities at large. (3.1.1)

Observation 2. The model uses simple, conservative, and computationally efficient equations for estimating chemical transport via ground water, surface water, soil erosion, the atmosphere, and foodchains. Mathematical formulae used to estimate transport rates for each pathway are widely used and accepted by the scientific community for application to simple situations. Underlying assumptions for each pathway model have been identified, are clearly stated, are reasonable and are not overly restrictive. However, for a significant number of sites, the MMRS suspects that no generic model is likely to provide answers of acceptable quality. OSWER is generally aware of the limited usefulness of generic models for the analysis of complex environmental systems, including aquifers. (3.1.2)

Recommendation 3. While documentation of the formulations for individual pathway models is well organized with appropriate references, the manual would benefit from another round of editing. (3.1.3)

Recommendation 4. Documentation for MMSOILS would benefit from a concise and explicit presentation of the model's basis, assumptions and limitations in a central location at the beginning of the user's manual. (3.1.4)

1.3.2 Possible Improvements to Model Formulations for Specific Processes

Recommendation 5. MMSOILS should be modified to make it capable of handling other, potentially more costly, types of SWMUs such as leaky sewer systems which are currently excluded from the RIA. Eventually these problematic SWMUs will be impacted by the proposed corrective action rule, so an estimate of their cost contribution to the implementation of the proposed rule should be developed. (3.2.1)

Recommendation 6. Because of the long time periods involved, the MMRS believes that it is critical that the role of natural biodegradation processes be explicitly incorporated into the ground water fate and transport pathway by the use of an appropriate biodegradation coefficient value. This function is essential and provides realism for actual mechanisms taking place. Even a small biodegradation coefficient would have a big impact. (3.2.2)

Recommendation 7. The MMRS recommends that the unsaturated-zone transport module be replaced with a simple kinematic model in order to make its treatment consistent with the other transport process models. (3.2.3)

Recommendation 8. The MMRS recommends that the Agency quantitatively assess the degree of conservation introduced by its method of plume aggregation through a comparison with simulations which do not use this method. As a part of this exercise, the Agency should quantitatively evaluate whether movement of the plumes could result in a decreased concentration for population wells. (3.2.4)

Recommendation 9. The MMRS recommends that the ecological risk assessment component be constructed using the principles for ecological risk assessment as suggested by the Risk Assessment Forum. (3.2.5)

Recommendation 10. The MMRS recommends that the ecologically relevant exposure scenarios be modified so as to be capable of simulating acute impacts from waste sites on aquatic environments due to surface run-off after major rain events. (3.2.5)

Observation 11. The MMRS is concerned that the MMSOILS model may not effectively estimate long-term consequences of remediation alternatives due to a suspected breakdown of mass balance as a result of model output post-processing. (3.2.6)

Observation 12. The MMRS notes that a major problem that must be confronted in the development of any multimedia model, such as MMSOILS, is the forcing of differently scaled environmental transport processes into a single model construct. Attempts to force disparate scales into a single model by selecting a compromise in time step will necessarily result in a loss of accuracy in model predictions. (3.2.7)

Recommendation 13. The Subcommittee recommends the modification of MMSOILS to produce more realistically-scaled exposures for meaningful inputs to ecological risk analysis. This recommendation results from the observation that the annual-time scale for exposure estimates produced by MMSOILS may be inappropriate for many ecological applications. Typical organisms of concern exhibit short life spans, or critical stages in their complex life histories that occur at time scales substantially shorter than one year. (3.2.8)

1.3.3 Issues of Parameter Estimation

Recommendation 14. The Subcommittee recommends that the Agency ensure that the uncertainty estimates in the RIA fairly reflect the uncertainties in quantification of the source term of the model input. The MMRS believes that the largest single source of uncertainty in the risk analysis is probably that related to quantification of the source term. Problems include sparse or inaccurate information on identification of types of wastes present (e.g., presence of NAPLs), on quantification of waste quantities, and on estimation of waste distribution. (3.3.1)

Recommendation 15. The MMRS recommends that the Agency consider the quantity and quality of waste information as a reasonable criterion or requirement for the inclusion of a particular facility in the facility selection process. The Subcommittee believes that the expected improvement of the confidence in the modeling results is obvious. (3.3.1)

Observation 16. The MMRS observes that the uncertainty of the waste transport calculations may be increased by the fact that the existing data that have been developed for SWMUs were generally not constructed or collected for the purpose of estimating risks to humans or to ecosystems, but rather for the purpose of defining the extent of contamination at a site rather than defining the exposures at or near the site. (3.3.1)

Recommendation 17. The MMRS recommends that the solubility models used for metals and organics be submitted to peer review to assess their scientific basis and limitations. (3.3.2)

Recommendation 18. The MMRS recommends that the input data for the case studies undergo peer review in order to evaluate a suspected over-reliance on the use of default parameter values. (3.3.3)

Recommendation 19. The MMRS recommends a documented and thorough peer review of all aspects of the data base, focusing particularly on those parameters to which the results are most sensitive. (3.3.4)

Recommendation 20. The MMRS recommends that the Agency build upon the extensive data base it has accumulated for the Corrective Action RIA, to begin the development of an extensive data base that could be tapped for other EPA programmatic efforts, such as for a comparable assessment of the risks associated with NORM wastes and radiologically contaminated sites. The intraagency modeling task force, the Ad Hoc Agency Task Force on Environmental Regulatory Modeling (AFTERM), may be an appropriate vehicle for organizing and coordinating such an effort in a manner that would be most beneficial to the potential users. (3.3.5)

1.3.4 Issues of Range of Model Validity

Recommendation 21. The MMRS recommends that the Agency evaluate the validity of each pathway model to assess the extent to which extreme events might be expected to contribute to the bulk of contaminant releases, and the extent to which the model may under - or over-estimate transport. (3.4.1)

Recommendation 22. For facilities in complex hydrogeological settings outside the range of validity of the MMSOILS model, the MMRS recommends that alternative approaches to characterization be used. Examples include the following modification of the ground water module in MMSOILS to more accurately model contaminant movement under these conditions; utilization of assessment data generated for Superfund sites; application of more sophisticated models with better-defined data to develop estimates for representative sets of waste sites; application of site-specific models to analyze that relatively small number of facilities which MMSOILS results indicate dominate the total costs or risks; and submission of these case studies to expert panel review to develop estimates of contaminant migration. (3.4.2)

Recommendation 23. The MMRS strongly endorses ORD's recommendation that the Agency develop an improved screening-level model for non-aqueous phase liquid (NAIL) transport, either by modification of the existing MMSOILS model or by conducting independent modeling exercises. (3.4.3)

Recommendation 24. The MMRS recommends that the Agency develop guidelines - perhaps including a requirement for peer review for key case studies -in order to assess the applicability of MMSOILS to specific cases. (3.4.4)

1.3.5 Issues Relating to Pathway Model Verification and Validation

Recommendation 25. The MMRS recommends that the Agency prepare a documented comparison of model predictions of chemical transport to field data that would strengthen the scientific credibility of the results and provide a basis . for readers to evaluate the model validity and magnitude of uncertainty. For similar reasons, the MMRS recommends that, for a subset of SWMUs[where ground water plume predictions are made by using MMSOILS, NATL/EPACMS models also be exercised so as to permit comparison of plume predictions. (3.5.1)

Recommendation 26. The MMRS recommends that documented validation exercises be undertaken for the remaining environmental transport pathways, e.g., aerosolization, volatilization, surface water runoff, and bioaccumulation, in order to assess the ability of these pathways models to provide meaningful input to the RIA. (3.5.2)

Recommendation 27. The MMRS recommends that the Agency, perhaps through AFTERM, develop generic guidelines for model calibration, verification and validation, including criteria for judging whether or not discrepancies among alternative modeling results or between calculated and measured field data are significant. In the case of MMSOILS, it recommends that the Agency undertake a root-cause analysis for discrepancies, where significant, in order to evaluate the potential for systematic bias in the modeling approach. (3.5.3)

1.3.6 Comments on Remediation Effectiveness

Recommendation 28. The MMRS recommends that the sensitivity of the RIA conclusions to these estimated remediation clean-up times be evaluated. This recommendation is made from the observation that experience gained from the Superfund program with respect to remediation effectiveness and time has shown that time estimates are commonly overly optimistic for ground water extraction systems. Because of unidentified sources, vadose zone contamination, heterogeneities, and the unknown presence of NAPLs, remediation has gone on at a number of sites for periods well in excess of initial estimates. (3.6.1)

Recommendation 29. The MMRS recommends that the Agency discuss the implications of unknown presence of NAPLs in the Corrective Action RIA. The MMRS observes that NAPLs are not always recognized during site characterization, and that this oversight may result in selection of a remediation system that is not appropriate for NAPLs, resulting in excessive remediation times and associated costs, and possibly in remediation goals not being achieved. (3.6.2)

Recommendation 30. The Subcommittee recommends that the Agency evaluate the sensitivity of the RIA analysis to assumptions about remediation effectiveness. The MMRS believes that, for some cases, especially cases in which NAPLs are present or those sites located in fine-grained soils and fractured or karst rock, the assumed extent of remediation effectiveness may be too high. (3.6.3)

Recommendation -31. The MMES recommends that a closer review be made of the derivation and scientific basis of the soil-water partition coefficient (K value) used in the post-processing of model results to calculate the change in concentrations at the exposure location. (3.6.3)

Recommendation 32. The MMRS recommends that the suite of remediation technologies used in the analysis be expanded to include biologically-based treatment technologies. The Subcommittee observes that a significant advantage of these treatment technologies is that,

where applicable, they may provide a more cost-effective treatment approach than other currently available remedial technologies. (3.6.4)

Recommendation 33. The MMRS recommends that the risk analysis be modified to recognize risks that may be incurred through the remediation process. (3.6.5)

1.3.7 Issues Relating to Assessment of Uncertainty

Recommendation 34. The MMRS recommends that guidance be provided in the MMSOILS user manual concerning why and how the user should obtain qualitative or quantitative estimates of the uncertainties associated with each pathway. (3.7.1)

Recommendation 35. The MMRS recommends that any numerical results emanating from the RIA analysis be presented as a range. The MMRS stresses that presenting results as "a number" tends to give the reader a false sense of accuracy which, in this instance, is particularly dangerous given the incompleteness of the input data set and our incomplete comprehension of the fate of hazardous constituents in the environment. (3.7.1)

Recommendation 36. The MMRS recommends that the MMSOILS model and results be subjected to more thorough, formal and comprehensive sensitivity and uncertainty analyses in order to identify the critical parameters associated with predictions of contaminant concentrations along various pathways. This information can then be used to determine what the critical data are for improving model predictions, and possibly to simplify the model structure without sacrificing accuracy or precision of model results. (3.7.1)

Recommendation 37. The MMRS recommends that the Agency review its risk estimation protocol. The MMRS is concerned. that the simple protocol followed to obtain high-end risk estimates may be inadequate, in that; these estimates in some cases apparently give rise to lower exposures than those generated using the central tendency estimate. (3.7.2)

1.3.8 Comments on Results for Health Risk Analysis

Observation 38. The MMRS observes that since health risks are the predominant focus of current environmental protection initiatives, the adequacy of risk estimates has to serve as the ultimate criterion of model relevance and accuracy. (3.8.1)

Recommendation 39. The MMRS recommends that the Agency consider how the general validity of its exposure estimates might be tested by comparison with empirical field data This is being recommended as a result of the observation by the MMRS that the translation of contaminant concentrations to estimates of exposure necessarily involves a long chain of

assumptions and requires the adoption of parameter values of variable uncertainty. (3.8.2)

Recommendation 40. The MMRS recommends that the Agency revise its practices for assessing cancer and noncancer health risks so as to make them more consistent with one another. (3.8.3)

Recommendation 41. The MMRS recommends that the Agency review its discussion of critical health effects and correct any inaccurate information. (3.8.4)

Recommendation 42. The MMRS recommends that the Agency review its assumption of additivity of Hazard Indices, and additivity of risks across class A (known) and Class C (suspected) carcinogens. (3.8.5)

Observation 43. The MMRS observes that certain hazardous agents are not easily controlled and may pose health risks beyond the substances discussed in the RIA. (3.8.6)

1.3.9 Comments on Use of MMSOILS in Corrective Action RIA

Recommendation 44. The MMRS recommends that the word "random" be deleted from any reference to the sample; the fact that various facilities were eliminated from the analysis for various reasons, some of which are quite valid, belies. the concept of the sample being "random."

Observation 45. The MMRS agrees that MMSOILS may be appropriate to use as a screening-level model at the national level, but observes that the model is actually used beyond screening in estimating the fate and transport of contaminants. The MMRS observes that the acceptability of uncertainties associated with model predictions must be evaluated in the context of model use. The model use determines the objective of any validation effort. If the model is used; in a screening mode, then greater uncertainties on the model outputs can be tolerated in making a coherent decision and validation efforts should focus on how well the model screens. If the model is to be used in estimating spatial-temporal values of contaminant concentrations, for example, to feed into a site-specific risk assessment, then validation requires comparisons with these kinds of data which are highly likely to need greater accuracy and precision, if the model is to effectively contribute to these estimations. Care must be taken in not confusing the two. different uses of the model and that such a distinction be made to the model users. (3.9.2)

Observation 46. The MMRS observes that, as an alternative to attempting to estimate a national average by aggregating the 38 site-specific applications of MMSOILS, it might be just as valid to use as much data as possible from the 5,800 sites to construct an "average" national waste site and apply the model to this single hypothetical site. This approach might be particularly effective given that the validity of each site-specific simulation is not held to be very accurate.

Analyzing the hypothetical site with the model might be more in-line conceptually with the notion of screening. (3.9.2)

Observation 47. The MMRS commends the Agency for having drafted such a well-organized and well-written report for such a highly complex issue as that for the Corrective Action RIA. However, the MMRS observes that the major goal of the RIA is to provide a quantitative estimate of the cost with incremental benefit for corrective actions, and it is commonly recognized -and accepted as a necessary reality -that the MMSOILS model application could derive exposure estimates no better than "order(s) of magnitude". Although the results may still be valuable for the purposes of screening, e.g., for assessing relative clean-up costs or cost versus incremental benefits between various sites, their utility is brought into question when the results are intended to be used for evaluating remediation costs, i.e., how meaningful it is when a cost estimate is given with a built-in uncertainty of one or more orders of magnitude, considering the total cost at the national level would probably involve hundreds of billions of undiscounted dollars? (3.9.3)

Recommendation 48. The MMRS recommends that the Agency give high priority to highlighting the uncertainties in the MMSOILS model screening effort and the propagation and perhaps magnification of that uncertainty in the subsequent estimates of exposure, risk, costs, and benefits, because of the critical importance of this aspect of the RIA. The MMRS observes that a major deficiency with the draft RIA relates to an inadequate representation of the magnitude of the uncertainties associated with the cost and benefit estimates. The MMRS further recognizes that communication of the relevance and implications of uncertainty analysis to decision-makers is a difficult and challenging problem. (3.9.4)

1.3.10 Other User Groups for MMSOILS

Recommendation 49. Because of the potential utility of MMSOILS for estimating ecological risks in relation to other EPA programmatic efforts, the MMRS recommends that this modeling construct continue to receive attention, both in terms of review and in resources, to ensure that it has utility beyond RCRA. (3.10.1)

Recommendation 50. On a longer-term perspective, the MMRS recommends that the Agency consider what might be its role in providing guidance to states as to the appropriate types of models to use for state-level screening calculations. (3.10.2)

Recommendation 51. The MMRS observes that the model documentation makes clear that MMSOILS is meant to be used by non-specialists. Consequently, the MMRS recommends that the manual be revised to contain stronger statements that emphasize the model limitations to such users, to recommend alternative models, and to emphasize the inapplicability of the model to site-specific evaluations. (3.10.3)

2. INTRODUCTION

2.1 Charge for SAB Review

In accordance with the charge to the MMSOILS Model Review Subcommittee (MMRS), [See Appendix A, Reference 1 (memorandum dated March 26, 1993 from Richard Guimond to Donald Barnes regarding Charge for SAB review of Regulatory Impact Analysis Supporting the Corrective Action , Regulation), as well as Appendix A, Reference 2 (a jointly-signed memorandum dated June 26, 1992 from Richard Guimond and Peter Preuss requesting a SAB review of the RCRA Corrective Action RIA), and Appendix A, Reference 3 (Federal Register, Vol. 58 (April 9, 1993), pg. 18395, which states the charge to the SAB)] the MMRS focussed on the technical aspects of the MMSOILS model. The specific issues that the Subcommittee was asked to address include:

Issue 1. The adequacy of methods for using a screening level model to characterize, situations where there is a substantial subsurface heterogeneity or where non-aqueous phase contaminants are present.

Issue 2. Appropriateness of the Agency's approach for aggregating releases from solid waste management units (SWMUs, the source terms for the contaminant modeling) to estimate concentration at exposure points over time.

Issue 3. Adequacy of the Agency's approach for developing long term effectiveness and failure scenarios for site remedies, and

Issue 4. The implications of the fate and transport modeling assumptions on the ecological and human risk assessment.

2.2 SAB Review Procedure

The primary review document is the EPA/ORD report, MMSOILS: Multimedia Contaminant Fate, Transport, and Exposure Model -Documentation and User's Manual (September 1992 draft; See Appendix A, Reference 4, as well as Appendix B, Reference 6). The Subcommittee also relied heavily upon the EPA/OSW Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units: Proposed Methodology for Analysis (including its Appendices)(March 1993 draft; See Appendix A, References 5 and 6, as well as Appendix B, References 7 and 8). These documents were addressed at a meeting of the MMSOILS Review Subcommittee (MMRS) of the Environmental Engineering Committee (EEC) in Arlington, VA on April 22-23, 1993, at which time the MMRS was also briefed by Agency staff on the selection, development and application of the MMSOILS models in the RIA (See Appendix A, References 7 through 12).

A second meeting was held on June 29, 1993 with some of the MMRS and Environmental Engineering Committee (EEC) members and consultants who wished to focus of the MMSOILS model and data [See Appendix A, Reference 13 (Federal Register, Vol. 58, No. 108, June 8, 1993, pg. 32122). Also, see Appendix A, References 13 through 19, for a listing of the briefing materials for the June 29, 1993 meeting]. The specific purpose of this meeting was to further discuss with the Agency staff the selection of the corrective action sample facilities, data sets, data acquisition and facility conceptualization process, as well as progress by the OSW staff on verification and validation of the MMSOILS model.

3. COMMENTS ON MODEL SELECTION, FORMULATION, DOCUMENTATION AND APPLICATION

3.1 MMSOILS Selection, Development, Formulation and Documentation

The Subcommittee would like to note that, while a number of recommendations are made in this report to improve the MMSOILS model and overall approach, such an approach lends itself well toward the context of better understanding and dealing with reducing risk concepts (See Appendix B, References 9, 10, 14 through 17 and 19). This approach also is a systematic way of characterizing and assessing ground water oriented and multi-media oriented approaches for grappling with the admittedly very complex, difficult, demanding and challenging risk assessment concepts that are being applied in a national context to deal with the Corrective Action RIA (See, for instance, Appendix B, References 1 through 5, 10 through 13 and 19 through 22).

3.1.1 Model Selection and Development

The OSW/ORD working group is to be commended for a well-coordinated and focused effort to develop a regulatory impact analysis (RIA) that will help the Agency and the Nation better understand the costs and benefits of the proposed rule for the final corrective action for solid waste management units. The Subcommittee considers the intraagency coordination represented by this RIA to be a "model approach" that the Agency would do well to adopt in other programs.

The consensus of the MMSOILS Model Review Subcommittee (MMRS) is that the use of a multimedia pathway model for screening purposes could be an appropriate approach for developing risk and cost estimates for a national-level RIA, as long as the input parameters are sufficiently accurate and the model is not applied outside its range of validity. The Agency's use of a single model, to the extent defensible ensures consistency among model results. The rationale -for the selection of MMSOILS for the corrective action RIA was explained during a briefing to the MMRS by OSW. The MMRS recommends that the criteria and rationale for the selection of MMSOILS as expressed in that briefing be more fully documented in the RIA so that the scientific and strategic bases for the selection will be clear to all concerned -regulator, regulated, and scientific/risk assessment/economic communities.

The major overriding concerns of the MMRS are: a) the application of MMSOILS outside its range of validity; b) large uncertainties in input parameters; c) consequent large uncertainties in MMSOILS results; d) the lack of clear communication of this uncertainty to decision-makers; and e) the generation of credible guidance on exposure, risk, costs, and benefits. Consequently, the recommendations contained in this report are focused at efforts to decrease the level of uncertainty, to validate the MMSOILS results by comparison with alternative estimation methods, and to ensure that the results of the modeling exercise are expressed in the RIA in a scientifically defensible manner that communicates the uncertainties of the calculations and their implications for the cost/benefit analysis.

3.1.2 Use of Standard Formulations

MMSOILS was selected by EPA for use as a screening model for simulation of contaminant transport from waste management units through multiple environmental pathways, and for evaluation of potential exposures and associated risks. The model uses simple, conservative, and computationally efficient equations for estimating chemical transport via ground water, surface water, soil erosion, the atmosphere, and foodchains. Mathematical formulae used to estimate transport rates for each pathway are widely used and accepted by the scientific community for application to simple situations. Underlying assumptions for each pathway model have been identified, are clearly stated, are reasonable and are not overly restrictive. For the most part, the representations used in MMSOILS for the various exposure pathways are consistent in their level of treatment. However, for a significant number of sites, the MMRS suspects that no generic model is likely to provide answers of acceptable quality. OSWER is generally aware of the limited usefulness of generic models for the analysis of complex environmental systems, including aquifers.

3.1.3 Documentation of Modeled Pathways

Documentation of the formulations for individual pathway models is well organized with appropriate references. However, the manual would benefit from another round of editing; a distracting aspect of the review draft is that several terms in the equations and figures have not been defined in the text (e.g., C_{wl}, C_{dwl} in equation 3-11, page 3-14 of the Users Manual). The MMRS recommends that each term be defined in three places in the manual: (a) in the beginning or end of each chapter in which it appears, (b) at the time each is first used in a given chapter, and (c) in the compilation of terms in Chapter 12. The terms should also be reviewed for internal consistency.- In at least one case, two different symbols have been used for the same parameter (Q_m, q_m). In another case, the same symbol (DF) has been used for two different parameters.

3.1.4 Documentation of Assumptions Underlying Multimedia Treatment

Basic underlying assumptions, such as the assumption in the ground water transport model of an "idealized homogeneous, uniform porous media," are dispersed throughout the manual. Documentation for MMSOILS would benefit from a concise presentation of the model's basis, assumptions and limitations in a central location at the beginning of the user's manual. The presentation should include descriptions of key aspects of the overall model structure, such as: modeling time frames for each pathway, whether the model assumes finite or infinite sources, whether the model is steady-state or dynamic, and how the model deals with competing mechanisms or pathways.

This introductory section should be sufficiently comprehensive that a knowledgeable reader could use it to quickly assess the level of sophistication of each pathway component in the MMSOILS model and thus develop a level of comfort with the predictions provided by the model. Chapter 2.0 of the user manual, "Applications and Limitations of the Methodology," does not fulfill this requirement, although it could be revised to do so. The cursory discussion presented in the section of questions that should be asked may be interesting but does not inform the user of the assumptions that were made in the model construction. Assumptions and their resulting model simplifications are crucial to the evaluation of the model. The brief section on model limitations also fails to discuss what the true limitation's are.

3.2 Possible Improvements to Model Formulations for Specific Processes

3.2.1 Additional Types of Solid Waste Management Units (SWMUs)

As currently constructed, MMSOILS is only capable of handling the more traditional SWMUS such as landfills and surface impoundments. Other, potentially more costly, types of SWMUs such as leaky sewer systems have been excluded from the analysis. Although they have been identified as SWMUs, few of these less traditional SMWUs have been remediated largely because no one really knows how to deal with them. Their remediation could be quite costly and result in disruption of industrial operations. Eventually these problematic SWMUs will be impacted by the proposed corrective action rule and will have to be addressed. Thus, an estimate of their cost contribution to the implementation of the proposed rule should be developed.

3.2.2 Recognition of Natural Biodegradation Processes in Ground Water Pathway

Approximately 130 years of simulations are made using the MMSOILS model to predict the existence, development or dissipation of ground water plumes. Because of the long time periods involved, it is critical that the role of natural biodegradation processes. be explicitly incorporated into the ground Water fate and transport pathway by the use of an appropriate biodegradation coefficient value. **This function is essential and provides realism for actual mechanisms taking place. Even a small biodegradation coefficient would have a big impact.** For instance, a value of only 0.0001/yr for the degradation coefficient of organic constituents in ground water will have a very large effect on the distribution of contaminants when taken over simulation periods much less than 130 years.

Neglecting the role of biodegradation processes in the transport model could result in overestimation of exposure concentrations. This omission might not be critical in screening applications where bias towards overestimation may provide appropriately conservative results. However, the literature continues to increase in terms of estimates of biodegradation of many organic contaminants and these data should be examined for possible use in MMSOILS. (See also comment 3.6.4 on biologically-based remediation technologies.)

3.2.3 Modeling Transport through the Vadose Zone

The finite element numerical model used for the partially saturated zone is adequate for the job, but it may not necessarily be consistent with the precision of other model components. This is especially true in light of other assumptions made in the RIA. For example, only a single layer (or small number of layers with only roughly estimated properties) was used to represent the unsaturated zone and the net infiltration rate was taken as piece-wise constant. Given these assumptions, simple kinematic models are appropriate and consistent with the rest of the transport process models. Kinematic models for flow and transport will conserve mass, can address step-wise constant infiltration rates, and will provide simple algebraic equations for use in the model.

3.2.4 Plume Aggregation in Groundwater Pathway

The method of aggregation used to obtain the concentration distributions for application to individual wells does not conserve mass. Rather, it appears that the resulting apparent mass will always exceed that from the untransformed plumes. While this approach is conservative, the degree of conservation should be evaluated through comparison with a number of simulations which do not use the method of aggregation. In addition, the question of whether movement of the plumes could result in a decreased concentration for population wells should be evaluated. The required transformations from cartesian to cylindrical coordinates should not require much computational effort compared with that required to operate the model.

3.2.5 Food-Chain Module

The food-chain module in MMSOILS is very synthetic and unrealistic. Food chains are highly site-specific and depend upon the gathering of the contaminant into the receptor environment, the structure of the ecological community, and the ultimate receptor of interest (humans or eagles or others). It makes considerable difference in the risk estimate whether the ecological community is terrestrial or aquatic and to what extent the contaminated food contributes to the total food in each trophic level. Furthermore, the efficiency of contaminant transfer from one trophic level to the next varies, and is dependent in part upon the octanol-water partition coefficient (K_{ow}) and molecular size of specific organic compounds.

The ecological risk assessment component should be constructed using recommendations structured in the SAB's report of the Ecology and Welfare Subcommittee of the Relative Risk reduction Strategies Committee of the SAB [See Appendix B, Reference 10 in particular, as well as Appendix B, References 9, 11 and 12, and the principles for ecological risk assessment as suggested by the Risk Assessment Forum, Appendix B, Reference 23.]

3.2.6 Mass Balance

The effectiveness of the model for estimating long-term consequences of remediation alternatives appears to be weakened by the breakdown of mass balance as a result of post-processing of model outputs (See also Section 3.2.4 regarding issues related to the method of aggregation and conservation of mass). The exponential decay of ground water contaminants as described represents one particular example of this apparent breakdown. Similar concerns for overall mass balance in MMSOILS remain. For example, if the combined degradation or transport along all pathways accounts for more contaminant mass than is available, the flux along each pathway is merely normalized according to the "demand.” This procedure may provide results of questionable accuracy given the different time scales applied to contaminant flux along different pathways.

3.2.7 Disparity in Relevant Time and Space Scales for Transport Mechanisms

One major problem that must be confronted in the development of any multimedia model, such as MMSOILS, is the forcing of differently scaled environmental transport processes into a single model construct. For example, the temporal dynamics of volatilization of organics may vary on the order of hours or less, given changes in microclimatic conditions that drive this process (e.g., temperature, wind velocity). Surface water runoff leading to transport of soils and dissolved contaminants is strongly event-driven, that is, local precipitation patterns and strong storms can move significant amounts of chemicals in time scales of hours. These dynamics contrast markedly with the slow movement of contaminants in ground water, where years to decades may be the relevant time scale.

Attempts to force the above disparate scales into a single model by selecting a compromise in time step will necessarily result in a loss of accuracy in model predictions. Parallel considerations apply in the spatial domain. Representing the spatial distribution .of ground water plumes of contaminants may allow a comparatively coarse spatial description of the waste site and surrounding region. To achieve comparable accuracy in estimating atmospheric transport, a more detailed spatial representation of the system may be necessary. Again, attempting, to force disparate spatial scales into a single model can produce inaccuracies in model results. Finally, the combination of time and space scale selections required in establishing a single model can compound problems outlined above.

3.2.8 Relevant Time Scales for Ecological Risk Assessment

At present the ecologically relevant exposure scenarios are inadequate. The known major source for acute impacts from waste sites on aquatic environments is surface run-off after major rain events. The MMSOILS model cannot simulate this in its present version. On a long-term basis, major effects can be due to biomagnification, changes in biodiversity, etc.

Methods for estimating ecological risk continue to evolve, e.g., the EPA Framework for Ecological Risk Analysis. Nonetheless, it is quite apparent that the methods will surpass simple multiplicative models of food chain accumulation and comparison of exposure concentrations to acute or chronic toxicity benchmarks. The annual time scale for exposure estimates produced by MMSOILS seems inappropriate for many ecological applications. Typical organisms of concern exhibit short life spans, or critical stages in their complex life history that occur at time scales substantially shorter than one year. Thus, an average annual concentration is not particularly useful as an input to many ecological risk assessments. Strong seasonal constraints are typically important, especially for temperate surface waters, e.g., streams and lakes. Thus, MMSOILS may have to be modified to produce more realistically-scaled exposures for meaningful inputs to ecological risk analysis.

3.3 Issues of Parameter Estimation

The MMRS notes that the use of inaccurate input parameters is a suspected major source of unacceptable errors and unreasonable magnitudes of uncertainties in MMSOILS results relative to their use in the draft Corrective Action RIA. Inappropriate input data are a consequence of sparse or inaccurate information, poor judgement in parameter estimation, and suspected overreliance upon default parameters. Regardless of the high quality of the model formulation, the quality of the outputs will retain the deficiencies of the inputs, and may well amplify them further. Agency personnel are clearly aware of problems in this area. Below are highlighted some of the parameters of greatest concern.

3.3.1 Source Term Parameters

Most members of the MMRS believe that the largest single source of uncertainty in the risk analysis was probably that related to quantification of the source term. Problems include sparse or inaccurate information on identification of types of wastes present (e.g., presence of NAPLs), on quantification of waste quantities, and on estimation of waste distribution. Given the time and budget constraints under which it is operating, it is highly questionable whether the Agency could significantly improve upon the extensive and thorough job it has already done in compiling the source-term data. Nonetheless, at a minimum, the Agency should ensure that the uncertainty estimates in the RIA fairly reflect the uncertainties in this aspect of the model input.

The MMRS believes that consideration of the quantity and quality of waste information should be a criterion for the inclusion of a particular facility in the facility selection process. As explained by the Agency in its presentations, the 79 sites were selected randomly from approximately 5,800 sites nation-wide; for many of these sites, information on the wastes is often sketchy or non-existent. Because a computer model cannot provide results that are any more precise or accurate than the input data used, there may be no issue more important than ensuring that the model input has the most accurate information possible on waste characteristics and history.

An appropriate criterion for facility selection might be a requirement for "waste information with both reasonable quality and quantity." Evaluation of the waste information against such a criterion should not take much additional effort or affect the purpose of the statistical selection process, particularly when less than 2% of the sample sites are chosen from 5,800 sites. The expected improvement of the confidence in the results from this study is obvious.

Another problem that may increase the uncertainty of the waste transport calculations is that the existing data that have been developed for SWMUs were generally not collected for the purpose of estimating risks to humans or to ecosystems. The data were collected to define the extent of contamination at a site, rather than defining the exposures at or near the site. The data are often deficient in providing information on environmental properties that influence the dynamics of releases to air, surface water, or ground water. In addition, the structure (dimensional distribution of materials, physical characteristics) and processes occurring at a site are only partial understood. These short-comings significantly affect the utility of input data.

3.3.2 Waste Release and Solubility

Predictions of ground water contamination and future growth in the plume are directly proportional to the mass of leachate assumed to be released to the subsurface from a SWMU. The release models used for metals and organics, while being good starting points, could be improved.

With regard to metals release, the model's use of the maximum observed concentrations near known source terms might over- or underestimate metal solubility depending on the environmental context of the waste site, e.g., pH, redox, aerobic/anaerobic, soil type, organic content of soils and ground water, etc. Perhaps some of the chemical speciation models e.g., MINEQL, might be examined to see if they can provide more meaningful estimates of the solubility, complexed, adsorbed, etc. fractions of metals for use in MMSOILS calculations.

With regard to organics release, it appears that using a multiplier of 100 to estimate organic leachate concentration is arbitrary at best. The choice of the 100 value incidently corresponds to the generic Dilution Attenuation Factor (DAF) of 100 used in the Toxicity Characteristic (TC) rule promulgated by the Agency in 1991. The ideal or the most reliable method for choosing leachate concentrations might involve choosing the most important solid phases for metals and perhaps aqueous solubilities based on Raoult's Law for most of the organic compounds. It is also recommended that only a fraction of the total mass of a chemical in the SWMUs be allowed/available for leaching instead of the entire 100%. [NOTE: It is recognized that there should be significant attention paid to what the fraction of total mass that would be allowed to leach might be.]

3.3.3 Use of Default Values

The MMRS suspects that the modelers relied more heavily than warranted on the use of default values, although this aspect is difficult to judge from the information provided by the Agency. Clearly, the OSW/ORD working group needs to address the issue of use of default values, making it very clear when they are used and why the default value makes sense for the particular application, in the absence of better data.

3.3.4 Peer Review of Data Base

The MMRS recommends a documented and thorough peer review of all aspects of the data base, focusing particularly on those parameters to which the results are most sensitive. Such a peer review does not need to involve the SAB, but occasional consultation with the SAB or the interagency modeling task force, ATFERM, on the approach and issues to be grappled with might be a useful exercise.

3.3.5 Data Base for Future Related Modeling Efforts

The MMRS recommends that the Agency build upon the extensive data base it has accumulated for the Corrective Action RIA, to begin the development of an extensive data base that could be tapped for other EPA programmatic efforts, such as for a comparable assessment of the risks associated with NORM wastes and radiologically contaminated sites. The intraagency modeling task force, AFTERM, may be an appropriate vehicle for organizing and coordinating such an effort in a manner that would be most beneficial to the potential users.

3.4 Issues of Range of Model Validity

MMSOILS was not designed to estimate contaminant transport and fate for chemicals in sites With complex hydrology, nor to assess: the environmental behavior of non-aqueous phase contaminants in ground water. However, these limitations should not necessarily be considered as weaknesses of the model. Complex sites and Non-Aqueous Phase Liquids (NAPLs) need to be addressed for the RIA; but remain outside the domain of applicability of the current; MMSOILS construct. The solution lies either in developing separate models to examine these issues or modifying the current MMSOILS so as to extend its applicability. Given the current state-of-the-art in our understanding and ability to model either complex hydrogeology or NAPLs, it may be some time before these aspects can be realistically introduced into MMSOILS. For example, stochastic modeling of ground water may contribute toward addressing the complex hydrogeology issue. The literature on this subject continues to grow; however, the complexity of these kinds of models may preclude their easy incorporation into a scheme such as MMSOILS. This is not to undermine the importance of these issues, but merely to emphasize that we are at the cutting edge of science in the development and applications of MMSOILS (albeit that MMSOILS deals with simple, conservative and computationally efficient equations for estimating chemical transport) and progress may be slow. Some additional questions about model validity and some suggestions for how the Agency might deal with this issue are provided below.

The Subcommittee offers the following comment on use of stochastic models and Monte Carlo models. Stochastic models are usually for simple hydrogeology, but with complex parameterization, and it is doubtful that they are or will be considered useful for a screening analysis. Further, these (the stochastic models) should be distinguished from Monte Carlo models which generally are simple deterministic models with random input data. The later are appropriate for uncertainty analysis with a screening model.]

3.4.1 Extreme Events

How well does the model deal with processes that are event-driven? These applications may be outside the range of validity of the model. Two examples are offered. First, the water-balance approach is not expected to work well for sites in arid regions in which average precipitation and evapotranspiration are approximately equal. Use of the balance approach would lead one to expect no recharge. While some infiltration and recharge in arid regions does occur as a result of extreme rainfall events, extreme rainfall events are typically associated with flash flooding. Recharge is more likely due to confluence of flows along arroyos, and can occur with "normal" rainfall events. Such recharge is localized, and probably should not be considered in the screening model calculations, unless a facility is placed along the ephemeral stream.]

The model appears to under-estimate waste transport via surface runoff. Net infiltration is calculated from precipitation less runoff and evapotranspiration. Runoff is calculated using the curve number method, which is based on daily rainfall amounts. Precipitation is provided through monthly rainfall amounts. Daily rainfall amounts are calculated by dividing the monthly rainfall by the average number of days with rainfall greater than 0.01" per month; .The "wet" days are then distributed uniformly though the month to calculate infiltration and runoff. This approach increases the likelihood of infiltration and decreases the potential for runoff. Runoff tends to occur when storms of greater than normal precipitation occur, or when storms occur on consecutive days. The approach may be conservative because the ground water pathway appears to dominate the exposures and risks. However, it is not clear that this was the intent. Actual daily rainfall data should be used for specific locales and regions where available.

The MMRS recommends that the Agency evaluate the validity of each pathway model to assess the extent to which extreme events might be expected to contribute to the bulk of contaminant releases, and the extent to which the model may under- or over-estimate transport.

3.4.2 Complex Sites

The Subcommittee observes that applicability of MMSOILS is limited by its inability to deal with complex sites. It is likely that critical investigations of the applicability of MMSOILS will turn up other complex sites beyond karst (e.g., a limestone region marked by sinks, abrupt ridges, irregular protuberant rocks, caverns and underground streams) and fractured rock. Sites in glacial till, such as former gravel pits, may also exhibit more complexity than MMSOILS could reasonably address.

For complex sites, the MMRS recommends that the Agency pursue alternative approaches and should develop a strategy that combines MMSOILS with an appropriate monitoring strategy. The outputs from such an effort can also be used to modify and improve the MMSOILS model.

3.4.3 NAPLs

The MMRS strongly endorses ORD’s recommendation that the Agency conduct a separate modeling exercise and obtain expert opinion to develop an improved screening-level modeling of NAPLs. For dense non-aqueous phase liquids (DNAPLs), a possible modification might be to locate the source term in the saturated zone: For light non-aqueous phase liquids (LNAPLs), a possible modification might be to use an alternative volatilization model. Four volatilization models are available, representing two conceptualizations of the process. One approach is based on Fick's first and second law, and gives classical solutions to the diffusion equation. The second approach combines Fick's first law with a moving boundary model for continuity. This is the "Landfarming Equation" of Thibodeaux and Hwang. A comparison between these approaches shows that the moving boundary model predicts fluxes that are smaller than the classical diffusion model by a factor of about 0.8 (square root of 2 divided by pi).

Given the level of accuracy expected from a screening model, these approaches provide essentially the same result. By choosing the moving boundary model, one can represent cases with a finite region of contamination, both with and without a cover, using simple algebraic equations. Use of an effective diffusion coefficient in soil along with appropriate partitioning relationships will also allow one to account for the presence of air, NAPLs, and water within the pore space, and partitioning of the constituent within the air, water, soil, and NAIL system.

3.4.4 Development of Guidelines for Assessing Model Applicability to Specific Cases

The MMRS recommends that the Agency develop guidelines in order to assess the applicability of MMSOILS to specific cases.

3.5 Issues Relating to Pathway Model Calibration, Verification and Validation

3.5.1 Ground Water Model

The ground water flow module has been verified by comparison of results to those of numerical models. However, documented comparison of model predictions of chemical transport to field data would strengthen the scientific credibility of the results and provide a basis for readers to evaluate the model validity and magnitude of uncertainty.

Another possible means to provide a limited validation of the ground water pathway component of MMSOILS is to compare its output to that of other peer-reviewed EPA models. The EPA Office of the Solid Waste (OSW) has developed and used EPA Composite Model for Landfills (NATL)/EPA Composite Model for Surface Impoundments (EPACMS) model for ground water transport and fate of contamination for the purpose of regulating RCRA wastes on the national level. MMSOILS is similar in many respect to the NATL/EPACMS models. Therefore, the MMRS recommends that, for a subset of SWMUs where ground water plume predictions are made by using MMSOILS, NATL/EPACMS models also be exercised so as to permit comparison of plume predictions.

3.5.2 Other Pathway Models

The MMRS strongly recommends that documented validation exercises be undertaken for the remaining environmental transport pathways, e.g., aerosolization, volatilization, surface water runoff, and bioaccumulation, in order to assess the ability of these pathway models to provide meaningful input to the RIA.

3.5.3 Guidelines for Calibration, Verification and Validation

The MMRS recommends that the Agency, perhaps through. AFTERM, develop generic guidelines for model calibration, verification and validation, including criteria for judging whether or not discrepancies among alternative modeling results or between calculated and measured field data are significant. In the case of MMSOILS, it recommends that the Agency undertake a root-cause analysis for discrepancies, where significant, in order to evaluate the potential for systematic bias in the modeling approach.

3.6 Comments on Remediation Effectiveness

3.6.1 Remediation Times

As part of the RIA process, experts have estimated the time for clean-up of contaminated sites. Experience cited in EPA's "19 Sites" (a 1989 publication; See Appendix B, References 24 and 25) and "24 Sites" (a 1992 publication; See Appendix B, References 26 and 27) documents has shown that these time estimates may be overly optimistic for ground water extraction systems. Even less is known about the operation and efficiency of other remedial systems. Because of unidentified sources, vadose zone contamination, heterogeneities, and the unknown presence of NAPLs, remediation has gone on at a number of sites for periods well in excess of initial estimates. In addition, for a number of these sites, the remediation goal has changed from site clean-up to plume containment. The impact of underestimating the clean-up time is that the clean-up costs will be underestimated, and the benefits associated with clean-up will be overestimated. The sensitivity of the RIA conclusions to these estimated remediation clean-up times should be evaluated.

3.6.2 Effect of Unknown Presence of DNAPLs on Remediation Times

MMSOILS and the RIA do not adequately address the presence of NAPLs. It is well recognized that NAPLs are not always recognized during site characterization. This may result in selection of a remediation system that is not appropriate for NAPLs, resulting in excessive remediation times and associated costs, and possibly in remediation goals not being achieved. NAPLs strongly influence the source term. Effective solubility and partition coefficients are far different when NAPLs are present, compared to their absence. The degree and timing of contamination events are different when NAPLs are mobile, as compared to cases with only dissolved phase contamination. These issues should be addressed in the Corrective Action RIA.

3.6.3 Remediation Effectiveness

According to the RIA documentation, most of the risk is associated with the ground water pathway. To calculate the benefits of corrective action, the MMSOILS model is run for each site to develop the extent and concentration of the plume over the time period of interest. The plumes are then aggregated to obtain the baseline or pre-remediation conditions. For sites requiring clean-up, a remedial action, plan is identified, and the effectiveness of each remedial scheme is assumed. The extent of remediation is applied to each plume, and the plumes are aggregated to provide the post-remediation concentration distributions. Exposures and risks are then calculated for the two conditions to evaluate the benefits of corrective action.

At least two questions arise with regard to this procedure. The first concerns the assumed level of remediation achieved with each applied technology. For some cases, especially NAPLs, the assumed extent of remediation may be too high. In fine-grained soils and fractured or karst rock, it is doubtful that complete remediation of LNAPLs is achievable. For DNAPLs the assumed levels of containment and remediation are also in question. The sensitivity of the RIA analysis to these assumed levels of remediation should be evaluated.

The remediation effectiveness predictions are, at times, made by using the MMSOILS model directly. But at other times the Agency has used post-processing through the use of a decay or a percent removed value. For simplicity reasons, several assumptions regarding failure of caps, liners and barriers etc., have been used. A simplified decay rate coefficient (K) has been employed to calculate the change in concentrations at the exposure location. In the case of ground water pump and removal remedy, it is very unclear as to how the K value is derived or how realistic this approach is in representing the appropriator of the response. It is recommended, therefore, that a closer review of the K value for choosing the quantitative number for sites be made.

3.6.4 Inclusion of Biologically-Based Remediation Technologies

The suite of remediation technologies used in the analysis -should be expanded to reflect the realities of emerging technologies. The principal defect is the parsimonious use of biologically-based treatment technologies. Although these may not at this time be considered as proven technologies, the scientific principles upon which the technologies are based are sound. It is therefore entirely reasonable to assume that over the 128-year time frame spanned by the analysis that these technologies will become widely used. The magnitude of uncertainty associated with these technologies is certainly no greater than that associated with the data base of source terms and transport parameters upon which the EPA has based its analysis.

A significant advantage of the biologically-based treatment technologies is that they will likely provide a more cost-effective treatment approach than other currently available remedial technologies.

3.6.5 Risks of Remediation

The MMRS recommends that the risk analysis be modified to recognize risks that may be incurred through the remediation process. It is conceivable that the very act of remediation could incur a higher level of risk than what would be reduced through remediation. This potential trap should be avoided by estimating the risks of remediation and including them in : the analysis.

3.7 Issues Relating to Assessment of Uncertainty

3.7.1 Uncertainty Estimation Protocol

No guidance is provided to the user as to how one can obtain a qualitative or quantitative estimate of the uncertainties associated with each pathway. Given the high stakes involved in terms of potential commitment of national resources, such an estimate is as important as, or possibly even more important than, the final result.

The MMRS recommends that any numerical results emanating from the RIA analysis must be presented as a range. Presenting results as "a number" tends to give the reader a false sense of accuracy which in this instance is particularly dangerous given the incomplete level of the input data set and our incomplete comprehension of the fate of hazardous constituents in the environment. Adding on the uncertainties associated with risk analysis even further expands the error bands.

The model should be subject to formal, comprehensive sensitivity and uncertainty analysis. Some initial efforts have been completed by the Agency, emphasizing the ground water pathway. Similar analyses should be completed for the other pathways in the model, and finally for the entire model.

Sensitivity analyses can be used to identify the critical parameters associated with predictions of contaminant concentrations along various pathways. This information can be used to determine what the critical data are for improving model predictions, and to simplify the model structure without sacrificing accuracy or precision of model results. Both applications of sensitivity results are important in increasing the capabilities of the model for site-specific use and in improving its utility in the RIA process.

3.7.2 Development of High-End Risk Estimates

The MMRS is concerned that the simple protocol followed to obtain high-end risk estimates may be inadequate in that this estimate in some cases apparently gave rise to lower risks than did the central tendency estimate. The Subcommittee recommends that the Agency review its protocol.

3.8 Interpretation of Results for Health Risk Analysis

3.8.1 Health Risk as the Assessment Endpoint

The model produces outputs which estimate concentrations in various environmental media over time. These concentrations in various media are then applied to various exposures gathered as an initial phase of risk assessment for the protection of humans and ecosystems. The result of the risk assessments comparing no-action and remedial action scenarios are then used as major inputs into a cost-benefit analysis. The use of various assumptions in exposure assessments as part of the risk assessment process has been highlighted previously as a major source for uncertainties in risk assessments.

Three documents refer to health risk assessment implications: MMSOILS (Documentation and User's Manual, the Corrective Action RIA draft, and appendices for the latter. See Appendix B; References 1 through 3). These implications are drawn from exposure analyses based on applying the models described in MMSOILS. Because health risks are the predominant focus of current environmental protection initiatives, the adequacy of risk estimates has to serve as the ultimate criterion of model relevance and accuracy.

3.8.2 Empirical Validation of Exposure Estimates

Section 9.0 of the MMSOILS document (See Appendix B; Reference 6) provides equations for determining exposure due to inhalation, ingestion, and dermal contact. (Section E of the RIA document addresses some of these as well.) The relevant variables come from the list on page 9-4, and includes 21 parameters, some of which are given default values in tables. These values, however, are simply guides to translating air, water, and soil concentrations into exposure estimates. These presumed concentrations are connected to human exposures through a long chain of assumptions. Because of this lack of direct coupling, questions arise about how the chain might be shortened. Are there any empirical data by which the models might be tested? Is there any way in which they might be acquired? Measures as simple as uptake by plants might be useful, for example. Or, analyses of animal carcasses at particular sites to which the modeling has been applied. Is empirical validation, the process by which theories and models are tested in science, out of the question?

3.8.3 Inconsistent Treatment of Cancer and Noncancer Health Risks

The other aspect of health risk assessment treated in these documents is described in the draft report on Regulatory Impact Analysis (See Appendix B; Reference 7) in the chapter on human health benefits (Chapter 7). Here, the ingenuity of the modeling effort encounters barriers that the Environmental Health Committee has noted in some of its reports, the most recent of which is entitled Superfund Site Health Risk Assessment Guidelines, February, 1993 (See Appendix B; Reference 20). One of these barriers is the EPA practice of adopting radically different approaches to cancer and noncancer risk assessment. Cancer risk is given as a probability; systemic endpoints are described by Reference Doses (RfDs). One example of the confusion this causes appears on page 7-15. Footnote 21 notes that cancer risk is calculated by averaging intake over a lifetime; that is, dose distribution is ignored. For noncancer risk, intake is averaged over exposure duration, with an averaging time of 9 years.

These assumptions can be disputed and might even be reversed in some instances. Perhaps more important, the averaging of assumptions could easily distort risk. For example, for both categories of risk, exposure during early and prenatal development might be the crucial values, and exposure peaks the major source of adverse consequences.

3.8.4 Inaccurate Identification of Critical Health Effects

Some of the other material also arouses suspicion about the adequacy of the modeling effort. The table in Exhibit 7-19a (See Appendix B; Reference 7) lists some of the agents driving noncancer effect levels. The critical health effects noted there are perplexing. For example, the critical health effect for chromium VI is given as central nervous system effects, which is contrary to the commonly known effects ascertained by neurotoxicologists; for nickel, it is reduced body and organ weight rather than hypersensitivity reactions; for toluene, a prototypical neurotoxicant, it is given as liver and kidney pathology. There are several other peculiar entries.

3.8.5 Questionable Treatment of Different Waste Classes

Another difficult problem is how to handle the kinds of mixtures found at RCRA sites. The properties of the Hazard Index, offered as a solution, cannot be applied automatically. For example, if 101 agents are identified, each with a Hazard Quotient of 0.01, the additivity assumption will yield a Hazard Index above 1.0. Would such a situation really present a bothersome risk?

Another additivity problem arises with cancer agents. The MMRS disagrees with the treatment noted on pages 7-56 to 7-57 (See Appendix B; Reference 7), in which agents with different weight-of-evidence classes are combined by adding risks, because the MMRS feels that it is misleading to add risks across class A (known) and class C (suspected) carcinogens. Despite the warning contained within the RIA that such a procedure may overstate the true cancer risk, the presentation of such combined results is bound to have an impact.

3.8.6 Other Sources of Hazardous Wastes

Finally, going beyond the contents of the current documents, it would be useful to point out, not just the intrinsic limitations of this rather ingenious and extensive modeling effort, but also where it might coincide with the full scope of EPA’s responsibilities. Certain agents are not easily controlled and may pose health risks beyond the substances discussed in these reports. Methylmercury, for example, is partially a product of fossil fuel combustion. Inorganic mercury is discharged when coal and oil are burned, ascends into the atmosphere!, travels in a global mercury cycle, returns to earth in rain, and is transformed to the toxic methyl form by organisms in the bottom sediment of bodies of water. Methylmercury travels up the food: chain in a continuous cycle of bioconcentration to lodge in fish that then reach human consumers. In keeping with the spirit of Reducing Risk (See Appendix B; References 9 through 12, and particularly Reference 10), such scenarios should be included in efforts such as the current reports.

3.9 Comments on Use of MMSOILS in Corrective Action RIA

3.9.1 Facility Selection Process

The facility sample used for the analysis is incorrectly characterized as being a “stratified, random sample.” The fact that various facilities were eliminated from the analysis for various reasons, some of which are quite valid, belies the concept of the sample being “random.” The MMRS suggests that the word "random" be deleted from any reference to the sample.

3.9.2 Use for National-Level Screening

The model is emphasized as a screening tool. However, it is also clear that the model is used beyond screening in estimating the fate and transport of contaminants. If the model is used in a screening mode, then validation efforts should focus on how well the model screens. If the model is to be used in estimating spatial-temporal values of contaminant concentrations, then validation requires comparisons with these kinds of data. Care must be taken in not confusing the two different uses of the model. Similarly, the uncertainties associated with model predictions must be evaluated in the context of model use. If screening is the emphasis, then perhaps greater uncertainties on the model outputs can be tolerated in making a coherent decision. If detailed characterizations of contaminant concentrations are needed, for example, to feed into a risk assessment, then it is likely that greater accuracy and precision will be required if the model is to effectively contribute to these estimations. The SAB has given modeling-related advice in a number of instances to the Agency, and the Subcommittee refers the staff to this (See Appendix B; References 11, 12, 13, 18, 19, 21, and 22).

Instead of attempting to estimate a national average by aggregating the 38 site-specific applications of MMSOILS, it might be just as valid to use as much data from the 5,800 sites to construct an "average" national waste site and apply the model to this single hypothetical site. This may be particularly effective given that the validity of each site-specific simulation is not held to be very accurate. Analyzing the hypothetical site with the model in this fashion might be more in line conceptually with the notion of screening. The Subcommittee wishes to remind and caution the Agency that a screening model can estimate the spatial-temporal values of concentrations; however, it is limited in the scenarios it can consider. Further, it (the screening model) is not suitable for site-specific applications where site details should be included in the model.

Subject to the reservations stated above, the MMRS agrees that MMSOILS may be an appropriate to use as a screening-level model at the national level.

3.9.3 Presentation of Results in Corrective Action RIA

The Agency is to be commended for having drafted such a well-organized and well-written report for such a highly complex issue as that for the Corrective Action RIA.

The MMSOILS model adopted for the study, as clearly stated by the Agency, was intended to be used as a screening tool. The assumptions made and approaches followed in the development of this model make the use of it appropriate for the screening exercise, but the current data base needs significant improvement. However, the major goal of the RIA is to estimate the cost with incremental benefit for corrective actions. Therefore a quantitative result is required from the study. It is commonly recognized -and accepted as a reality - that the MMSOILS model application could derive exposure estimates no better than "order(s) of magnitude". Although the results may still be valuable for the purposes of screening, e.g., for assessing relative clean-up costs or cost versus incremental benefits between various sites, their utility is brought into question when the results are intended to be used for evaluating remediation costs, i.e., how meaningful it is when a cost estimate is given with a built-in uncertainty of one or more orders of magnitude, considering the total cost at the national level would probably involve hundreds of billions of discounted dollars. In other, words, how can results at this level of confidence be used in the policy/regulation decision making process?

3.9.4 Presentation of Uncertainty Analysis in RIA

The major concern of the MMRS with respect to the contents of the RIA relate to an inadequate representation of the magnitude of the uncertainties associated with the cost and benefit estimates. For the RIA, how much uncertainty can you live with and still make an intelligent decision regarding the efficacy of RCRA clean-up. This issue again pertains to the use of MMSOILS as a screening model, versus a realistic process model for estimating exposure and fate concentrations.

3.10 Other User Groups for MMSOILS

3.10.1 Applicability to Other EPA Program Activities

The utility of MMSOILS for estimating ecological risks may loom in future importance, for example in relation to CERCLA. Therefore, the MMRS recommends that this modeling construct should continue to receive attention, both in terms of review and in resources, to ensure that it has utility beyond RCRA.

3.10.2 Use for State-Level Screening

On a longer-term perspective, the MMRS recommends that the Agency consider what might be its role in providing guidance to states as to the appropriate types of models to use for state-level screening calculations.

3.10.3 Other User Groups

The documentation makes it clear that MMSOILS is meant to be used by non-specialists. The manual needs stronger statements to emphasize the model limitations to such users, to recommend alternative models, and to emphasize the inapplicability of the model to site-specific evaluations. With regard to model limitations, the MMRS recommends that each pathway model include a summary table listing assumptions, and clearly stating the known parameter sensitivity alongside site characteristics which might invalidate model results or which would be expected to lead to results with order-of-magnitude uncertainties.

APPENDIX A - BRIEFING AND REVIEW MATERIALS

Review Materials for the April 22, 1993 SAB/EEC/MMRS Review Meeting:

1) U.S. EPA/OSWER, A memo entitled "Charge for SAB Review of Regulatory Impact Analysis Supporting the Corrective Action Regulation," signed by Richard J. Guimond, Assistant Surgeon General, U.S. Public Health Service and Deputy Assistant Administrator, Office of Solid Waste and Emergency Response to Dr. Donald G. Barnes, Director, Science Advisory Board, March 26, 1993

2) U.S. EPA/OSWER & ORD, A jointly signed memo entitled "Request for SAB Review of RCRA Corrective Action RIA," from Peter W. Preuss, Director, Office of Technology Transfer and Regulatory Support, and Richard J. Guimond, Assistant Surgeon General, U.S. Public Health Service and Deputy Assistant Administrator, Office of Solid Waste and Emergency Response to -: Dr Donald G. Barnes, Director, Science Advisory Board, June 26, 1992

3) U.S. EPA/SAB, Environmental Engineering Committee, MMSOILS Model Review Subcommittee, Notice of Subcommittee Open Meeting, Federal Register, Vol. 58, No. 67, Friday, April 9, 1993, p. 18395

4) U.S. EPA, "MMSOILS: Multimedia Contaminant Fate, Transport, and Exposure Model: Documentation and User's Manual," Office of Research and Development [Prepared by the Exposure and Assessment Group, Office of Health and Environmental Assessment and the Office of Environmental Processes and Effects Research], Washington, D.C. 20460, EPA XXX/XXX/XXX draft document dated September 1992

5) U.S. EPA, "Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units: Proposed Methodology for Analysis," Office of Solid Waste, March 1993.

6) U.S. EPA, "Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units: Proposed Methodology for Analysis," APPENDICES, Office of Solid Waste, March 1993

Briefing Materials from the April 22. 1993 SAB/EEC/MMRS Review Meeting:

7) U.S. EPA/OSW briefing entitled "Overview: Corrective Action Regulatory Impact Analysis, Proposed Methodology," Presented to the MMSOILS Model Review Subcommittee (MMRS) of the Environmental Engineering Committee (EEC), Science Advisory Board (SAB), by the Office of Solid Waste (OSW),. April 22, 1993

Briefing Materials from the April 22, 1993 SAB/EEC/MMRS Review Meeting: Continued:

8) U.S. EPA/OSW, briefing entitled "Application of the MMSOILS Model in the Corrective Action Regulatory Impact Analysis," Presented to the MMRS of the SAB's EEC by the Office of Solid Waste (OSW), April 22, 1993

9) U.S. EPA/OSW briefing entitled "Risk Assessment in the Corrective Action Regulatory Impact Analysis," Presented to the MMRS of the SAB's EEC by the Office of Solid Waste (OSW), April 22, 1993

10) U.S. EPA/OSW briefing entitled "Simulation of Remedy Effectiveness in the Corrective Action Regulatory Impact Analysis," Presented by the Office of Solid Waste (OSW) to the MMRS of the SAB's EEC, April 22, 1993

11) U.S. EPA/ORD briefing entitled "RCRA Corrective Action RIA: ORD Input on Significant Technical Issues," Prepared and Presented by Stephen G. Schmelling of the Robert S. Kerr Environmental Research Laboratory to the MMRS of the SAB's EEC, April 22, 1993

12) U.S. EPA/ORD briefing entitled "RCRA Corrective Action RIA: ORD Participation (Fate & Transport), Presented to the MMRS of the SAB's EEC, April 22, 1993

Briefing Materials from the June 29, 1993 SAB/EEC/MMRS Review Meeting:

13) U.S. EPA/SAB, Environmental Engineering Committee (EEC), MMSOILS Model Review Subcommittee, Notice of Subcommittee Open Meeting for June 29,.1993 on MMSOILS Review, -as well as EEC Open Meeting of June 30 -July 1, 1993, Federal Register, Vol. 58, No. 108, Tuesday, June 8, 1993, p.32122

14) U.S. EPA/OSW briefing entitled "Model Selection for the Corrective Action Regulatory Impact Analysis," Presented to the MMRS and selected specialists of the SAB's EEC by the Office of Solid Waste (OSW), June 29, 1993

15) U.S. EPA/OSW briefing entitled "Sample Selection for the Corrective Action Regulatory Impact Analysis," Presented to the MMRS and selected specialists of the SAB's EEC by the Office of Solid Waste (OSW), June 29, 1993

Briefing Materials from the June 29, 1993 SAB/EEC/MMRS Review Meeting: Continued:

16) U.S. EPA/OSW, an untitled summary sheet, which lists SAB Recommendations and the OSW/ORD Next Steps, one page, both sides, June 29, 1993

17) U.S. EPA/OSW briefing entitled "Facility Characterization in the Corrective Action Regulatory Impact Analysis," Presented to the MMRS and selected specialists of the SAB's EEC by the Office of Solid Waste (OSW), June 29, 1993

18) U.S. EPA/ORD briefing entitled "SAB Presentation on Corrective Action RIA: MMSOILS Model Validation and RIA Uncertainty Assessment," a presentation by Mr. Gerry Laniak of ORD-Athens, June 29, 1993

19) U.S. EPA/ORD untitled briefing comparing site-specific parameters by modeling teams, using central tendency and high-end estimates, and plots comparing the results of monitoring and modeling data by concentration (ppm), as well as plots on modeling and monitoring minimum curve and maximum error, a presentation by Mr. Gerry Laniak of ORD-Athens, June 29, 1993

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7) U.S. EPA, "Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units: Proposed Methodology for Analysis," Office of Solid Waste, March 1993

8) U.S. EPA, "Draft Regulatory Impact Analysis for the Final Rulemaking on Corrective Action for Solid Waste Management Units: Proposed Methodology for Analysis," APPENDICES, Office of Solid Waste, March 1993

9) U.S. EPA, Expert Panel on the Role of Science at EPA (Loehr, Goldstein, Nerode and Risser), "Safeguarding the Future: Credible Science!, Credible Decisions," EPA/600/9-91-050, March 1992

10) U. S. EPA, Memorandum entitled, "EPA Definition of Pollution Prevention," from F. Henry Habicht II, Deputy Administrator, to all EPA Personnel, May 28, 1992

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11) U.S. EPA/SAB, "Review of the EPA Office of Solid Waste's (OSW) Unsaturated Zone Code for the OSW Fate and Transport Model (FECTUZ)," Report of the Unsaturated Zone Code Subcommittee of the Environmental Engineering Committee (EEC), Science Advisory Board (SAB), EPA-SAB-EEC-88-030, July 12, 1988

12) U.S. EPA/SAB, "Resolution on Use of Mathematical Models by EPA for Regulatory Assessment and Decision-Making," Report of the Modeling Resolution Subcommittee of the Environmental Engineering Committee (EEC), Science Advisory Board (SAB), EPA-SAB-EEC-89-012, January 13, 1989

13) U.S. EPA/SAB, "Review of the CANSAZ Flow and Transport Model for Use in EPACMS," Report of the Saturated Zone Model Subcommittee of the Environmental Engineering Cornmittee (EEC), Science Advisory Record (SAB), EPA-SAB-EEC-90-009, March 27, 1990

14) U.S. EPA/SAB, "Reducing Risk: Setting. Priorities and Strategies for Environmental Protection," The report of the Science Advisory Board (SAB), Relative Risk Reduction Strategies Committee, EPA-SAB-EC-90-021, September 1990

15) U.S. EPA/SAB, "Relative Risk Reduction Project: Reducing Risk, Appendix A," The Report of the Ecology and Welfare Subcommittee of the Relative Risk Reduction Strategies Committee (RRRSC) of the Science Advisory Board (SAB), EPA-SAB-EC-90-021A, September 1990

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19) U.S. EPA/SAB, "Leachability Phenomena: Recommendations and Rationale for Analysis of Contaminant Release," A Self-Initiated SAB Report on leachability Phenomena by the Environmental Engineering Committee (EEC), EPA-SAB-EEC-92-003, October 29, 1991

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APPENDIX C - GLOSSARY OF TERMS AND ACRONYMS

ATFERM	(Ad Hoc) Agency Task Force on Environmental Regulatory Modeling
CANSAZ	Combined Analytical-Numerical Saturated Zone (Flow and transport model for use in EPACMS)
Class A	Known Human Carcinogen
Class C	Suspect Human Carcinogen
C_{wl}	Concentration of Chemical in Waste Layer (milligrams/kilogram)(For instance, see Section 3.1.3)
C_{dwl}	See K_{dwl}, below
CV	Contingent Valuation Methodology
DAF	Dilution and Attenuation Factor (For instance, see Section 3.3.2)
DF	Fraction of Day During Which Exposure Occurs (hours/24 hours)(For instance, see Section 3.1.3)
DNAPLs	Dense Non-Aqueous Phase Liquids
EAG	Exposure Assessment Group (U.S. EPA/ORD/OHEA)
EEAC	Environmental Economics Advisory Committee (SAB/EEAC)
EEC	Environmental Engineering Committee (SAB/EEC, also referred to as "The Committee")
EHC	Environmental Health Committee (SAB/EHC)
EPA	U.S. Environmental Protection Agency (U.S. EPA, or "The Agency")
NATL	EPA Composite Model for Landfills
EPACMS	EPA Composite Model for Surface Impoundments
EPEC	Ecological Processes and Effects Committee (SAB/EPEC)
FECTUZ	Finite-Element Code for Simulating Water Flow and Solute Transport in the Unsaturated Zone (Variably saturated porous media)
K	First order Coefficient, Which Measures Losses of Contaminant Due to Pumping (Also referred to as Simplified Decay Rate Coefficient) (For instance, see Section 3.6.3)
K_d	Decay Rate/Distribution Coefficient. Also Referred to as Soil-Water Partition Coefficient (milliliters/gram)
K_{dwl}	Solid-Water Partition Coefficient Between the Solid Waste and the Liquid Leachate (liters/kilogram). (Also referenced as C_{dwl}) (For instance, see Section 3.1.3)
K_{ow}	Water-Phase Mass Transfer Coefficient. (Also referred to as the Octanol-Water Partition Coefficient.) (For instance, see Section 3.2.5)
LNAPLs	Light Non-Aqueous Phase Liquids
MMSOILS	Mathematical Model for Soils (A Multi-Media Contaminant, Fate, Transport and Exposure Model.)
MINEQL	A Chemical Speciation Model (For instance, see Section 3.3.2)
MMRS	MMSOILS Model Review Subcommittee (U.S. EPA/SAB/EEC; Also referred to as "the Subcommittee")
NAPLs	Non-Aqueous Phase Liquids
NORM	Naturally-Occurring Radioactive Material
OEPER	Office of Environmental Processes and Effects Research (U.S. EPA/ORD)

OHEA	Office of Health and Environmental Assessment (U.S. EPA/ORD)
ORD	Office of Research and Development (U.S. EPA)
OSW	Office of Solid Waste (U.S. EPA)
OSWER	Office of Solid Waste and Emergency Response (U.S. EPA)
pH	Negative Log of Hydrogen Ion Concentration
Qm	Monthly Net recharge (cubic meters/month)(Also Referenced as q_m) (For instance, see Section 3.1.3)
qm	Monthly Net Recharge (cubic meters/month)(Also Referenced as Q_m) (For instance, see Section 3.1.3)
RCRA	Resource Conservation and Recovery Act
RfDs	Reference Doses
RIA	Regulatory Impact Analysis
SAB	Science Advisory Board (U.S. EPA)
SWMUs	Solid Waste Management Units
TC	Toxicity Characteristic
U.S.	United States

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Director, Office of Emergency and Remedial response (OERR)
Deputy Director, OERR
Director, Office of Solid Waste (OSW)
Deputy Director, OSW

EPA ATFERM Co-Chairs (Agency Task Force on Environmental Regulatory Modeling)
EPA Headquarters Library
EPA Regional Libraries
EPA Laboratory Libraries