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Selection of Exposure Scenarios, Computer Models, and Data Collection Requirements for Human Health Risk Assessments

Draft - 1.0

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EG&G ROCKY FLATS

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Prepared by:

DAMES & MOORE

of the EBASCO Team

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

DRAFT 1.0

SELECTION OF EXPOSURE SCENARIOS, COMPUTER MODELS, AND DATA COLLECTION REQUIREMENTS FOR HUMAN HEALTH RISK ASSESSMENTS

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the subject study is to develop a site-wide methodology for the performance of exposure assessment as part of the Baseline Risk Assessments of the Operable Units at the Rocky Flats Plant (RFP). Since these Baseline Risk Assessment studies will be used to evaluate current and future public and environmental impacts and to derive cleanup criteria, it is important to obtain early agreement by all parties involved regarding the specific exposure scenarios and modeling techniques to be used at the RFP.

1.2 SCOPE

A human health risk assessment is divided into four functional activities: data collection and evaluation, exposure assessment and documentation, toxicity assessment and documentation, and risk characterization. The focus of this study will be on the exposure assessment and the data requirements associated with exposure assessment. This study is intended to meet the following objectives:

- Define exposure scenarios to be used in performance of Baseline Risk Assessments;

- Review the draft demographics report for applicability and usefulness in scenario definition;

- Review environmental fate and transport models against selection criteria, site characteristics and site data requirements;

- Compare modeling parameter requirements with identified on-going site characterization programs;

- Evaluate — Recommend the most appropriate contaminant fate and transport computer models for use in Baseline Risk Assessments at the Rocky Flats Plant.

The most important deliverables from this study are two technical memoranda which are requested of DOE by EPA in an Interagency Agreement. The purpose of these memoranda are to:

- "describe the present, future potential and reasonable use exposure scenarios with a description of the assumptions made and the use of data. This memorandum shall be submitted prior to the required submittal of the Baseline Risk Assessment for each OU; and

- describe the fate and transport models that will be utilized, including a summary of the data that will be used with these models. Representative data shall be utilized and limitations, assumptions and uncertainties associated with the models shall be documented."

This study is intended to meet the requirements of these two technical memoranda on a general, site-wide basis. They will form the guidelines for the OU-specific memoranda to be submitted prior to each Baseline Risk Assessment.

2.0 TECHNICAL MEMORANDUM NO. 1 - DEFINITION OF POTENTIAL EXPOSURE SCENARIOS

Exposure assessment is the estimation of the magnitude, frequency, duration, and route of exposure to humans. The exposure setting for the RFP will be characterized by identifying potentially exposed populations in the present and future use scenarios. Once populations have been identified and characterized, exposure pathways will be traced from sites to the exposed population. Exposure pathways consist of four elements:

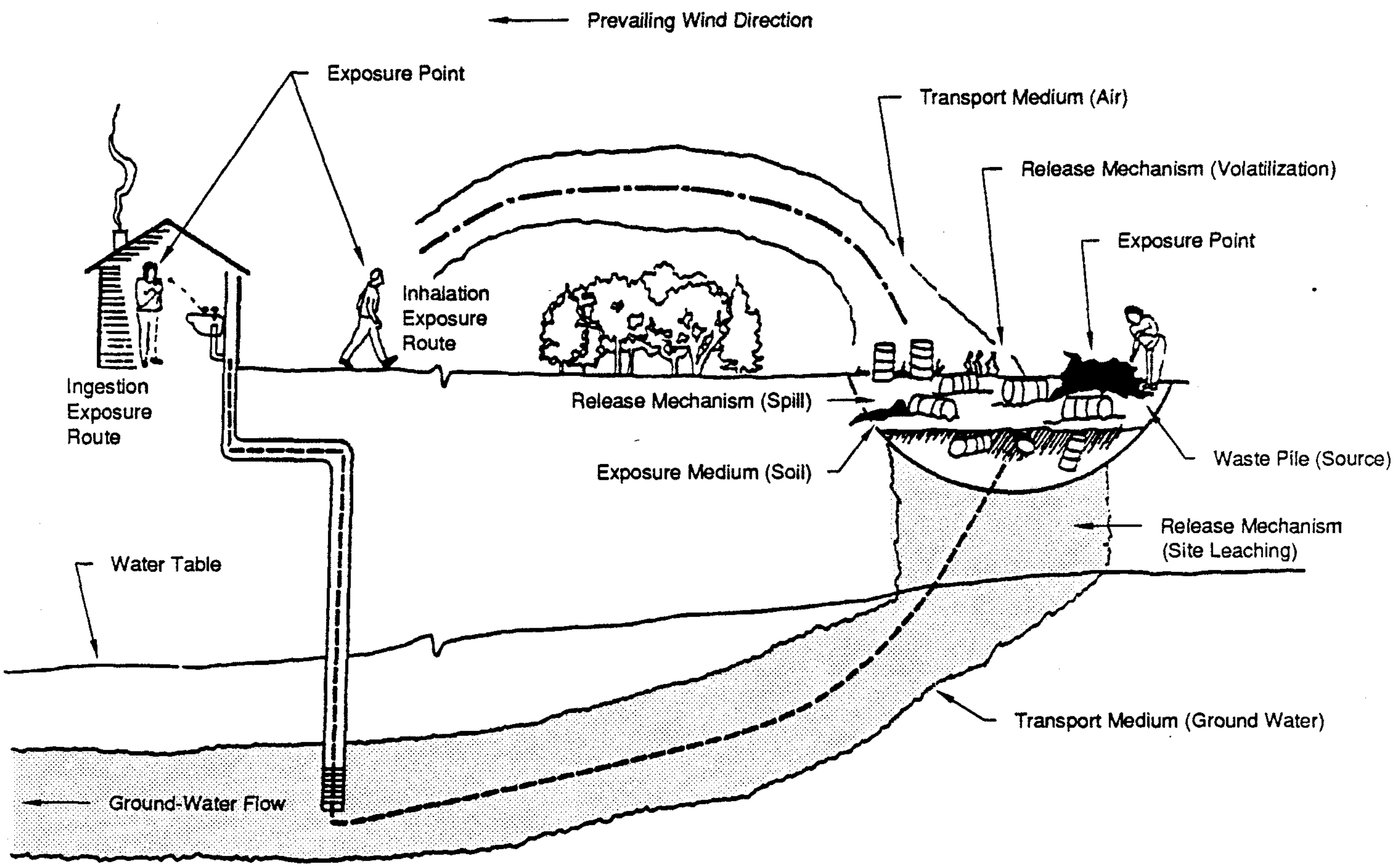
- A source and mechanism of chemical release to the environment;
- An environmental transport medium (e.g., air, groundwater, fugitive dust emissions, contaminant movement through soil, soil runoff into water bodies, etc.) for the released chemical;
- A point of potential human contact with the contaminated medium, also referred to as a receptor -- this can be breathing air, drinking water supplied from surface water or groundwater or contaminated food or contaminated soil --that is accessible to human populations; and
- A route of entry in humans, either inhalation, ingestion, or dermal contact with the contaminated medium.

These elements are shown pictorially on Figure 2-1.

This section describes the methods used by Dames & Moore to define the exposure scenarios to be analyzed in the Baseline Risk Assessment. The exposure assessment for the RFP site is based on exposure scenarios that define the potentially exposed populations, frequencies, and duration of potential exposures, the possible exposure pathways, and the concentrations in air, food, water or soil that potentially contact these populations through the exposure pathways.

Figure 2-1

Illustration of Exposure Pathways



SOURCE: Risk Assessment Guidance for Superfund
Human Health Evaluation Manual,
Part A Interim Final, July, 1989

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2.1 Potentially Exposed Populations

Pathway analysis and exposure assessment are directly impacted by the assumed category of land use by postulated receptors. The Baseline Risk Assessment will require an evaluation of both current and future land uses. The categories of land use to be evaluated as part of this assessment include:

- Agricultural;
- Residential;
- Commercial/Industrial.

Each category of land use has a suite of unique parameters associated with it including assumed population densities, lifestyles and eating habits.

There are currently (1989) 2,201,340 people living within 50 miles of the Rocky Flats Plant (RFP). It is projected that this number will grow steadily to 3,119,309 by the year 2010. Both now and in the future, approximately 14 percent of these inhabitants live within 10 miles of the site (EG&G, 1990). None of the land use categories can be eliminated based on these projections.

Since it is possible that some form of institutional control may remain in effect after site closure, scenarios involving both restricted and unrestricted access to the site will be investigated.

Therefore, in addition to the on-site and offsite cases of each of the three land uses listed above, it is proposed that intruder scenarios be investigated under the case where some type of institutional control is assumed. The potentially exposed populations of receptors are:

- Offsite Agricultural Farmer
- Onsite Agricultural Farmer
- Offsite Resident
- Onsite Resident
- Offsite Commercial/Industrial Worker
- Onsite Commercial/Industrial Worker
- Onsite Explorer Discoverer Intruder

Finally, it must be noted that the proposed revision of the National Contingency Plan (NCP) calls for the identification and mitigation of environmental impacts from the site and selection of remedial actions that are protective of environmental organisms and ecosystems. Therefore impacts to ecological receptors will need to be evaluated, consistent with EPA's Environmental Evaluation Manual (EPA, 1989b).

2.2 Sources of Potential Exposure

Sources of potential exposure from the Rocky Flats site are:

- Volatilization of chemical contamination to the air;
- Emission of fugitive dust with chemical or radiological contamination, potentially resulting in airborne concentrations of these constituents, and deposition of dusts on foliage of crops and soils off-site;

- Soil ingestion from direct contact with contaminated soils by individuals entering the site;
- Percolation to groundwater and subsequent dispersion and intake;
- Contamination of surface water and subsequent dispersion and intake; and
- Dermal absorption of contamination due to contact with contaminated soil or water.

The pathways of exposure from sources (constituents in soil at the site) to potential receptors (nearby residents) have associated with them a set of mathematical equations and models used to estimate the level of exposure at the receptor. This section presents the calculations, methods and assumptions used to estimate contaminant fate and transport in the environment except where computer models would be used (e.g., groundwater transport). The results of this analysis are concentrations in breathing air, food and soil that human receptors could potentially contact.

2.2.1 Emissions of Fugitive Dusts to Air

Particulate contamination in shallow surface soils may become resuspended with fugitive dusts and dispersed in air. These contaminants can potentially provide inhalation exposures to downwind populations. Additionally, these chemicals may become deposited on backyard gardens, potentially providing exposure through the foodchain.

Particulate emissions at the site may be caused by three major processes: (1) wind turbulence; and (2) vehicle travel on unpaved surfaces; and 3) resuspension due to human activities (e.g., site excavations and remedial activies). Additional information on methods to evaluate active resuspension scenarios are described in the Plan for Prevention of Contaminant Dispersion (D&M 1990). The emissions factor equations were developed by EPA (1985a). These models estimate emission rates of respirable (less than 10 microns in diameter or PM10) particles.

The selection of the emissions factor equations were based on the erodibility of the surface material. Based on observation of the site, the surface would be classed as a "limited reservoir" of erodible material. This classification is based on observation of nonerodible elements in the surface material, including stones, vegetation and paved surfaces. Such surfaces have high friction velocities (minimum wind speed needed to resuspend dust particles), and wind-generated emissions from such surfaces decay sharply with time as the particle reservoir is depleted (EPA, 1985a). The annual average rate of respirable particulate emissions is estimated with the following equation:

$$E = \frac{0.83 \text{ x } f \text{ x } P(u^{+}) \text{ x } (1\text{-}V)}{(PE/50)^{2}}$$

where:

E	=	Annual average PM10 emission rate (mg/m^2-hr)
f	=	Frequency of disturbance per month
u+	=	Fastest windspeed for the period between disturbances (m/s)

$P(u^+)$	=	Erosion potential, or the quantity of erodible particles on the surface prior to the onset of wind erosion (g/m^2)
V	=	Fraction of surface area covered by continuous vegetation (0 equals bare soil)
PE	=	Thornwaite's Precipitation Evaporation Index, used as a measure of average soil moisture content (unitless).

The erosion potential is dependent upon the fastest windspeed as follows:

$$P(u+) = 6.7 \times (u^+ - u)$$

where:

u is the friction threshold windspeed (m/s) measured at a typical weather station sensor height of 7 m. The friction threshold windspeed for the site is converted to the equivalent windspeed at 7 m as follows:

$$u = u^*/0.4 \times \ln(z/zo)$$

where:

u^*	=	threshold friction velocity at ground surface
z	=	Height above surface, 7 meters, in this case (cm)
z_o	=	Roughness height (cm)

A roughness height of 1 cm is typically used in this calculation. The friction threshold windspeed is related to the mode of the particle size distribution, which is typically determined from sieving the soil in the field.

Constituent emission rates (Q) are estimated from the emission factor described above as follows:

$$Q = a \times E \times 0.001$$

where:

Q = Emission rate of constituent (g/m^2-s)
a = Concentration in soil (mg/kg)
E = Emission factor for PM10 (kg/m^2-s)

The factor of 0.001 is used to convert mg to g.

2.2.2 Atmospheric Dispersion and Deposition

Environmental fate and transport analyses for the inhalation exposure pathway (and deposition-crop-ingestion pathway) involve modeling fugitive dust emissions from the soil, modeling the dispersion of those emissions in air, and modeling deposition onto crops and soil in backyard gardens.

The source term required for any model is the emission rate from the soil (g/m^2-s) and the surface area of the emission. The emission rate is dependent upon the concentration in soil; concentration in soil and surface area must be estimated from site contour maps.

For a given emission rate, the dispersion model will estimate the concentration in the air, expressed in units of micrograms of pollutant per cubic meter of air (ug/m^3). Receptors are located on a Cartesian grid, with the origin at one corner of the area source. The receptor spacing is selected to place the closest receptor approximately 100 meters downwind from the edge of the area source. A unit emission rate of 1 g/m^2-s is assumed in the modeling, with the concentration of each pollutant emitted determined by multiplying the model output (in units of $ug/m^3/g/m^2$-s) by the pollutant emission rates estimated in Section 2.2.1. Concentrations in air are used directly to estimate inhalation exposure.

Deposition of particles onto the ground is used to evaluate exposures through the foodchain. Deposition is assumed to be proportional to concentration in air. Deposition is estimated using a proportionality constant referred to as a deposition velocity. The deposition velocity is expressed in units of centimeters per second (cm/s).

The calculation used to determine steady state concentrations in the soil, assuming both deposition and removal processes is derived from NRC Regulatory Guide 1.109 (NRC, 1977), and is as follows:

$$Cs = \frac{D \times 0.001 \times [1 - \exp(-k \times T)]}{d \times M \times k}$$

where:

Cs = Concentration in soil (mg/kg)

T	=	Facility lifetime (yr)
D	=	Deposition flux (ug/m2-yr)
k	=	First-order elimination rate constant (yr-1)
d	=	Density of soil (kg/m3)
M	=	Mixing depth in soil (m)

0.001 represents the conversion from ug to mg.

The first order elimination rate constant (k) approximates the effects of leaching from the root zone on concentrations in soil. The method for estimating k was obtained from Baes and Sharp (1983):

$$k = \frac{Vw/O}{d \times [1 + (p \times Kd/O)]}$$

where:

Vw	=	Infiltration rate of water in soil (cm/year)
O	=	Volumetric content of water (mL/cm^3), assumed to be 0.32
d	=	The depth from which pollutant is leached (cm), assumed to be 15 cm
Kd	=	Distribution coefficient between soil and water (mL/g)
p	=	Bulk density of the soil (g/cm^3), assumed to be 1.5.

Vw is calculated as precipitation minus evapotranspiration rates.

2.2.3 Direct Contact with Soils

Constituents detected in shallow surface soils may potentially provide ingestion and dermal exposures to individuals that come into direct contact with those soils when they are dispersed offsite.

It must be noted that contamination concentrations in soil exhibit spatial variability. In most risk assessments, the evaluation of health risks from direct contact with contaminated soils is deterministic and is based on a single concentration that is "representative" of the variability in the soils data. A representative value may be a summary statistic, such as a mean, geometric mean or median. There is a level of uncertainty in estimated health risks based on a single concentration in soil; health risks may be overestimated or underestimated if the value does not adequately represent the variability in the soil data. Therefore, the arithmetic mean concentration is typically used for this calculation.

2.2.4 Ingestion of Contaminated Water

Pollutant concentrations in water are calculated using the ground-water and/or surface water fate and transport models (see Section 3.0). Then, in accordance with the exposure scenario developed, a chronic daily intake of contamination is calculated and the impacts assessed using on the radiological dose conversion factor, cancer potency, slope, and hazard index, as applicable.

2.2.5 Ingestion of Contaminated Crops

Pollutant concentrations in crops are assessed by estimating deposition onto above-ground foliage and/or update from interstial water accumulation through roots from the soil.

The calculation of pollutant concentrations on crop surfaces from particle deposition is as follows:

$$Cpd = \frac{D \times 0.001 \times r \times [1 - \exp(-kc \times S)]}{Y \times kc}$$

where:

Cpd	=	Concentration in plants from deposition (mg/kg)
D	=	Deposition flux (ug/m^2-day)
r	=	Interception fraction (unitless)
S	=	Growing season (days)
kc	=	Particle weathering rate constant (day-1)
Y	=	Plant density or vegetative yield (kg/m^2)

The uptake of contamination through roots from the soil is typically modeled as follows:

$$Cps = PS \times Cs$$

where:

Cps	=	Concentration in plants from soil uptake (mg/kg)
PS	=	Soil to plant transfer coefficient (mg/kg wet weight in vegetable per mg/kg dry weight in soil)
Cs	=	Concentration in soil (mg/kg)

Finally, the total concentration in plants is equal to the sum of the concentrations from deposition and soil uptake.

2.2.6 Estimate of Volatile Organic Compound Emissions

Volatile organic compounds (VOC) in subsurface soils may volatilize over time and be carried to a receptor in air. These chemicals could be introduced to downwind populations through air dispersion and inhalation.

One possible model for estimating VOCs emissions from soil vapor is the covered-landfill emission model developed by Farmer et al. (1980). This model is used to predict emissions from a covered landfill based on Fick's First Law of diffusion. Diffusion of chemicals to the soil surface is described by diffusion relationships developed by Millington (1961). The model is presented as follows:

$$Q = D(P_A^{10/3}/P_T^{2})(C/L)A$$

where:

Q = Emission rate (g/s); – define

D = Diffusion rate of the chemical in air (cm^2/s);

P_A = Air filled soil porosity (dimensionless);

P_T = Total soil porosity (dimensionless);

C = Concentration of the chemical in the soil vapor at depth L (g/cm^3);

L = Depth of soil cover (cm); and

A = Surface area of the emission source.

The diffusion rates are obtained from Shen (1982). P_T is calculated as follows:

$$P_T = 1 - (b/d)$$

where:

b = Bulk density of soil;
d = Soil particle density.

P_A is calculated as follows:

$$P_A = P_T - W$$

where W is the volumetric water content of soil at field capacity.

This model is intended to estimate steady-state emission rates associated with a specific concentration in soil vapor found at a specific depth. Estimated emissions from this model are conservative in that they do not account for depletion of VOCs from soil over time.

2.2.7 Ingestion of Milk from Dairy Cows

Another potential source of exposure is from the ingestion of milk which is produced from dairy cows. The cows obtain drinking water from the same source used for domestic drinking water. The cows obtain their feed from onsite sources and therefore consume feed with the same activity concentration as that grown in the vegetable garden. The concentration of contaminated milk (m) is calculated as follows:

$$C_m = \{(C_{iw})(Q_{mw}) + (C_{iv})(Q_{mf})\} \quad (F_{im})$$

where:

C_m	=	Concentration in milk (mg/l)
C_{iw}	=	Concentration of contaminant i in water (mg/l)
C_{iv}	=	Concentration of contaminant i in feed (mg/kg)
Q_{mw}	=	Daily intake of water by dairy cows (L/day)
Q_{mf}	=	Daily intake of feed by dairy cows (kg/day)
F_{im}	=	Equilibrium ratio for dairy cows; concentration in milk relative to daily intake (mg/L in milk per mg/day intake)

2.2.8 Ingestion of Meat from Beef Cattle

Finally, the ingestion of contaminated meat from a local farm which raises beef cattle (or slaughters their dairy cows) represents another potential source of exposure. The cattle obtain drinking water from the same source used for domestic drinking water. The cattle obtain feed from onsite sources and therefore consume feed with the same activity concentration as that grown in the vegetable garden. The concentration of contaminated beef (b) is calculated as follows:

$$C_b = \{(C_{iw})(Q_{bw}) + (C_{iv})(Q_{bf})\} (F_{ib})$$

where:

C_b	=	Concentration of contaminants in beef (mg/kg)
C_{iw}	=	Concentration of contaminant i in water (mg/l)
C_{iv}	=	Concentration of contaminant i in feed (mg/kg)
Q_{bw}	=	Daily intake of water by beef cattle (L/day)
Q_{bf}	=	Daily intake of feed by beef cattle (kg/day)
F_{ib}	=	Equilibrium ratio for beef cattle; concentration in meat relative to daily intake (mg/kg in beef per mg/day intake)

2.3 Exposure Scenarios

Consistent with the scope of work, both the maximally exposed individual (MEI) and reasonable maximum exposure (RME) scenarios will be developed for both the present and future land use scenarios. The potentially exposed populations described in Section 2.1 have been reviewed for applicability to each of these cases to develop the recommended exposure scenarios to be used for the Baseline Risk Assessment.

Baseline risk assessments for RFP will be based on exposure scenarios that describe the potentially exposed populations, frequencies, and durations of potential exposure, the possible exposure pathways, and the concentrations of chemicals in air, soil or food that potentially contact these populations through the exposure pathways.

Exposure scenarios for two cases are developed in this section: a worst case exposure scenario and a reasonable maximum exposure scenario. The worst case scenario describes potential exposure of a maximally exposed individual (MEI), a hypothetical individual who is at the geographical location of highest potential exposure to chemical concentrations originating from the site. Health risks of the MEI that are acceptable would be considered acceptable for any other individual (EPA, 1986a). The RME scenario is defined as the highest exposure that is reasonably expected to occur at a site at the upper 95 percent confidence level. Developing a scenario for estimating RME necessarily involves the use of professional judgement (EPA, 1989a).

A health risk assessment can be based on either of these two scenarios for the two specific purposes. The two scenarios are used to explore the uncertainty in assumptions used to estimate health risks, hence identifying sensitive assumptions that most significantly influence estimated health risks. The worst case scenario reflects guidance provided by the EPA's Superfund Public Health

Evaluation Manual (EPA, 1986a). The RME scenario reflects newer guidance provided by the EPA's Risk Assessment Guidance for Superfund: Human Health Evaluation Manual (EPA, 1989a). This approach provides reviewers with the opportunity to observe the differences in health risk estimates created by the evolution of risk assessment guidelines.

For each of these two cases, both present and future land uses have been investigated to develop exposure scenarios which account for impacts to known receptors and to hypothetical populations in the future. Therefore, exposure scenarios for four major cases are explored here:

- Present maximally exposed individual
- Future maximally exposed individual
- Present reasonable maximum exposure
- Future reasonable maximum exposure

To aid in the development of these exposure scenarios, chapter two of the "Draft Rocky Flats Demographic Report" (EG&G 1990)) has been reviewed for population estimates and projections.

2.3.1 Present Maximally Exposed Individual

Of the potential receptors presented in Section 2.1, the agricultural farmer is recommended for the maximally exposed individual (MEI), a hypothetical individual whose lifestyle, eating habits and geographical location yield the highest potential exposure. In general, the impacts to the onsite agricultural farmer yield the most restrictive cleanup criteria. However, for the present case, since there are currently no onsite residents at the Rocky Flats Plant, the offsite agricultural farmer scenario is recommended. The resident and commercial/industrial worker scenarios would include pathways which form a subset of those of the agricultural farmer and would therefore be less restrictive. Therefore, since agricultural farmers do exist in the area (Rockwell, 1988), this scenario is recommended for the present MEI case.

The assumptions which form this scenario are as follows:

- An individual is conservatively assumed to be exposed to chemical and radiological concentrations in soil immediately offsite over an entire 70 year lifetime;

- This hypothetical individual lives from birth in a residence near the site, has daily contact with soils immediately offsite, ingesting a significant quantity of soil transported from the site on a daily basis;

- This hypothetical individual eats all of his vegetables and fruits from a backyard garden receiving dust deposition from the site;

- This hypothetical individual is located continuously at the geographical location with the highest estimated exposures from concentrations in air, providing a worst case estimate of inhalation exposure;

- This individual drinks all his water from a potable water source which has been contaminated through air and/or water pathways;

- This individual raises dairy cattle which drink the water and eat the feed which has been contaminated through air and/or water pathways; and

- Worst case estimates of chemical and radiological concentrations in soil are assumed to be represented by arithmetic mean concentrations.

2.3.2 Future Maximally Exposed Individual

Again, the agricultural farmer scenario is recommended for the MEI, but in the future case, an onsite scenario is hypothesized. At some time in the future, unrestricted release of previously contaminated areas is assumed to occur. As with the present case, the resident and commercial/industrial worker scenarios would be less restrictive than the agricultural farmer scenario. Since current population growth in the area is only 1percent per year (Rocky Flats Demographics Report 1990) and no major land use changes are anticipated, it is assumed that agricultural farmers will continue to live and work in the Rocky Flats area. Therefore, the future maximally exposed individual will be an onsite agricultural farmer under the following assumptions:

- An individual is conservatively assumed to be exposed to chemical and radiological concentrations in soil at the site over an entire 70 year lifetime;
- This individual has unrestricted access to soils at the site;
- This hypothetical individual lives from birth in a residence at the site, has daily contact with soils at the site, ingesting a significant quantity of soil from the site on a daily basis;
- This hypothetical individual eats all of his vegetables and fruits from a garden planted in "contaminated soils";
- This hypothetical individual is located continuously at the geographical location with the highest estimated exposures from concentrations in air, providing a worst case estimate of inhalation exposure;
- This individual is located continuously at the geographical location with the highest exposure from penetrating ("external") radiation;

- This individual drinks all his water from a potable water source which has been contaminated through air and/or water pathways;

- This individual raises dairy cattle which drink the water which has been contaminated through air and/or water pathways and which eat the feed which has been grown in the contaminated soil; and

- Worst case estimates of chemical concentrations in soil are assumed to be represented by arithmetic mean concentrations.

2.3.3 Present Reasonable Maximum Exposure

For the present reasonable maximum exposure, an offsite agricultural farmer scenario is recommended. This scenario will be similar to the present MEI scenario, but more limited and reasonable assumptions are made concerning exposure as follows:

- A hypothetical individual is assumed to be exposed to radiological and chemical concentrations in soil at the site for a 70 year lifetime, however exposures are intermittent and less frequent than the worst case scenario;

- This hypothetical individual eats a significant fraction of vegetables and fruits from a backyard garden receiving dust deposition from the site. However, much of his food comes from offsite sources (e.g., fish, poultry);

- Concentrations in air used to estimate inhalation exposure are averaged to account for time spent away from the site. Exposures during times away from the site are assumed to be zero;

- The individual consumes all his water from a potable water source which has been contaminated through air and/or water pathways;

- This individual raises dairy cattle which drink the water and eat the feed which has been contaminated through air and/or water pathways; and

- Reasonable maximum estimates of chemical concentrations in soil are assumed to be represented by geometric mean concentrations.

2.3.4 Future Reasonable Maximum Exposure

The offsite agricultural farmer is also recommended for the future RME scenario. As with the present scenario, the assumed exposures are intermittent and less frequent than the MEI scenarios.

- The same individual is assumed to be exposed to radiological and chemical concentrations in soils immediately offsite for a 70 year lifetime, however exposures are intermittent and less frequent than the worst case scenario;

- Access to the site is restricted, so that this individual has no access to the site;

- This hypothetical individual eats a significant fraction of vegetables and fruits from a backyard garden receiving dust deposition from the site. However, much of his food comes from offsite sources (e.g., fish, poultry);

- Concentrations in air used to estimate inhalation exposure are averaged to account for time spent away from home. Exposures during times away from home (e.g., at school) are assumed to be zero;

- The individual consumes all his water from a potable water source which has been contaminated through air and/or water pathways;

- This individual raises dairy cattle which drink the water and eat the feed which has been contaminated through air and/or water pathways; and
- Reasonable maximum estimates of chemical concentrations in soil are assumed to be represented by geometric mean concentrations.

Since it is likely that some form of institutional control may remain in effect after site closure, investigation of an onsite intruder scenario is also recommended. The assumptions of this scenario may vary depending upon whether or not it is assumed that process systems and buildings are completely dismantled following decommissioning or remediation. For the purposes of this document it is assumed that decontaminated facilities are left in place.

The explorer intruder is assumed to enter the sealed/locked process building or another sealed/locked facility out of curiosity or with the intention of engaging in salvage operations. The individual intruder is assumed to spend an appreciable portion of a workday inside the facilities.

The exposure pathways to be considered include direct exposure to penetrating radiation, inhalation of suspended contamination, inhalation of airborne contamination generated while exploring and/or searching for salvageable material and ingestion of removable surface contamination transferred to the hands.

2.3.5 Recommended Exposure Scenarios

It should be noted that development of less than the most restrictive cleanup criteria carries with it the possibilities of requiring deed restrictions on future land use. However, as mentioned earlier, use of the MEI scenarios reflects dated EPA guidance which has been superseded. Therefore, the RME scenarios are still recommended for baseline risk assessment.

3.0 TECHNICAL MEMORANDUM NO. 2 - ENVIRONMENTAL FATE AND TRANSPORT ANALYSIS MODELS

Contaminant fate and transport computer models currently available have been evaluated, compared and reviewed with respect to their applicability for use in the Baseline Risk Assessment. The most appropriate contaminant fate and transport computer models have been recommended for use in the Baseline Risk Assessment of the RFP. The models screened in this study include both the "EPA models" which have been verified and approved for use by EPA as well as some of the "non-EPA models" which includes the balance of models available to the general public. The models presented in this section are not meant to be an exhaustive compilation of all exposure assessment models; nor do they represent all the different types of models which may be useful in risk assessment. Instead, this section describes accepted, commonly-used environmental fate and transport and dose-response models that were either: (1) taken from the list of EPA's "risk assessment" models compiled in the Superfund Risk Assessment Information Directory (EPA, 1986b); or (2) selected from publications and references using professional judgement on the applicability of a model in the risk assessment process.

The models have been loosely divided into four groups:

- Unsaturated zone and groundwater dispersion models;
- Surface water dispersion models;
- Airborne dispersion models; and
- Exposure assessment models

The models are assessed on the basis of both technical and management objectives. Models in each discipline are evaluated with regard to a range of technical criteria applicable to their application. However, to screen appropriate models, the following four criteria were used for all disciplines:

- The selected model(s) should, with or without minor adaption, be capable of simulating the transport processes and site conditions existing at the Rocky Flats Plant site.
- The models should be capable of accomplishing the study objectives; they should have the appropriate degree of sophistication, i.e., they should be neither too simplistic and approximate nor too complex and elaborate, requiring extensive input data for calibration and implementation which may be hard to obtain.
- The models should have been tested and validated for application in situations similar to that at the Rocky Flats Plant site.
- The model code and documentation should be complete, should have undergone adequate peer review, and as far as possible, should be available in public domain.

These criteria have been established as policies of the EPA by working groups consisting of nationally-recognized modeling committees (van der Heijde and Park, 1986).

The objective in selecting codes is to provide a representative set of tools for quantifying and evaluating the likely impacts of site closure alternatives. As discussed in earlier sections, the site-specific conceptual models should guide the formulation of the mathematical models and, hence, the selection of computer codes. Without knowledge of each facility, it would be incorrect to prescribe specific computer codes for site-specific application. Also, experience with those codes that are finally selected to simulate facility, transport, and exposure pathways is essential for a basic understanding of the performance assessment modeling. Typically, several computer codes will be used in the course of a performance assessment. These include groundwater flow and transport codes, atmospheric transport codes, surface water transport codes, and possibly, exposure assessment codes.

3.1 Unsaturated Zone and Saturated Zone Ground-Water Flow and Mass Transport Models

The overall objective of the unsaturated/saturated zone risk assessment is to develop an exposure assessment for human and animal populations resulting from transport of contaminants from the Rocky Flats Plant site through ground water pathways. Long-term exposure potential will be evaluated, and the assessment will require one or several detailed models of ground-water flow and transport at the site. Potential pathways include migration through the saturated zone to nearby streams and surface-water impoundments, migration through the saturated zone to ground-water discharge areas, and migration through the saturated zone into deeper aquifers beneath the site.

The purposes of this section are:

- To discuss the criteria used to select appropriate models for simulating ground-water flow and mass transport in the unsaturated and saturated zone at the site;

- To review models that are relevant to site hydrogeologic conditions and contaminant conditions;

- To recommend the most applicable subsets of models from the list of relevant models based on the general hydrogeologic conditions at the site. The models in a particular subset will be able to address different objectives in the overall site characterization and risk assessment; and

- To review the site data available in the context of the ground-water model data requirements.

The ground-water flow system beneath the Rocky Flats Plant site occurs in alluvium and bedrock. The bedrock is primarily claystone and sandstone. The degree of hydraulic connection between the alluvium and bedrock is unknown, however ground water in the alluvium is generally unconfined and not perched. Ground-water recharge occurs as infiltration from precipitation, leakage from streams, canals and surface-water impoundments, and leakage from waste impoundments. Ground-water discharge occurs as evaporation, evapotranspiration, seeps and springs, and discharge to streams, canals and surface-water impoundments.

3.1.1 Discussion of Selection Criteria

Ground-water model selection criteria falls into three categories (Bond and Hwang, 1988): (1) objectives criteria, (2) technical criteria, and (3) implementation criteria.

Objectives criteria are used to separate models into two groups: those that are designed for general or screening studies, and those that are designed for detailed studies. General or screening studies are for: (1) rapid, first-cut comparisons between sites for the purpose of ranking sites; and (2) gaining an understanding of the important factors at a particular site affecting transport and fate of contaminants. Such studies are often used when there are many sites to characterize or compare, or during the initial phases of field investigations when there are little field data available. Models that are appropriate for general or screening studies are analytical, compartmental, or very simple numerical models (one dimensional, or simple two dimensional models). Model data requirements are limited and predicted results should be regarded as preliminary and relative.

The purposes of detailed studies are to assess facility performance, environmental impact, and the safety of remedial solutions. Detailed studies are often used as field investigations progress and the quantity of available data increases in amount, complexity, and variety. Appropriate models are most often numerical models, because they can incorporate complex heterogeneity, boundary conditions, and a variety of specific contaminants. Numerical models are typically more difficult to develop, calibrate, maintain, and evaluate than analytical or compartmental models. The predicted results are generally more reliable and realistic.

There are two general categories of detailed studies: site-wide and local. Site-wide studies address issues that concern the entire site. These issues might include: (1) The amount of time it might take a contaminant to migrate to the boundary of the site, (2) the effect of conditions outside the site on the transport and fate of contaminants within the site, or (3) the concentrations that are likely to occur in ground water if the contaminant reaches the site boundary. Local studies address issues that concern individual sources or a subset of sources.

Examples would be: (1) studying the factors that affect unsaturated-zone flow beneath a leaky waste pond, (2) assessment of remedial alternatives, (3) assessing the relative importance of various parameters, and (4) the guidance of field programs.

Technical criteria are used to select models that are capable of addressing the important technical issues. The selected model must be able to incorporate important mass transport and transformation processes, and to adequately simulate the important domain characteristics and material/fluid properties. The technical criteria must be applied within the context of the objectives criteria.

For mass transport and transformation processes, the selected model must be able to incorporate the important factors that affect transport of contaminants, such as advection and hydrodynamic dispersion. The selected model must also be able to simulate chemical processes that affect the concentration of a contaminant, such as decay, adsorption, or biodegradation.

For the domain configuration, the selected model must be able to represent the physical system adequately. Components of the physical system may include:

- confined and unconfined flow;
- horizontal and vertical flow;
- saturated and unsaturated conditions;
- variation in layer thicknesses;

- spatial distribution and temporal variations in boundary conditions (such as ground-water recharge, discharge, and pumpage);and
- spatial distribution and temporal variations in contaminant sources (such as point or aerial sources, types of contaminants, and concentrations).

All of these conditions occur at the Rocky Flats Plant site.

For fluid(s) and material properties, the selected model must be able to incorporate relevant variations in material and fluid properties. These include:

- porous or fractured media;
- horizontal and vertical variations in material properties (such as hydraulic conductivity, porosity, etc.);
- single fluid, multi-fluid (multi-phase), or liquid and gas/vapor-phase flow; and
- flow affected by density variations or temperature gradients.

At the Rocky Flats Plant site, fracture flow, multi-phase flow, fluid density variations, and temperature gradients are not likely to be important.

After the objectives and technical criteria have been resolved, implementation criteria are used to select the ~~final~~ applicable model or set of models. Implementation criteria address the following questions:

- Is the model in the public domain or is it proprietary?
- Is the model readily available and is the model well documented?

- Has the model been verified against analytical solutions?. Are the verification data sets available and well documented?

- Has the model been applied successfully at other sites (i.e., "field-tested")?

- Has the model(s) been verified by EPA

Model selection criteria can be grouped into four general criteria:

- The selected model(s) must be able to adequately simulate site conditions.

- The selected model(s) must be able to satisfy the objectives of the study. The model(s) should be neither too simple nor too complex. delete

- The selected model(s) must be verified, and reasonably well field tested.

- The selected model(s) must be well documented, peer reviewed, and available.

3.1.2 Discussion of Models Versus Selection Criteria

There are several different types of models. Analytical models embody mathematical solutions to the equations that govern ground-water flow and mass transport. Numerical models embody approximations to the governing equations using finite difference or finite element techniques. Stochastic models contain descriptions of ground-water flow and mass transport in terms of statistics and statistical distributions, and they often employ a combination of statistical and numerical methods. Compartmental models incorporate the law of mass conservation, and are composed of a combination of numerical and statistical methods. However, the compartmental models do not solve the ground-water flow and mass transport equations.

Ground-water flow and mass transport models that are applicable to the site are listed and described in Tables 3-1, 3-2, and 3-3. The information in these tables was obtained from van der Heijde, El-Kadi, and Williams (1988); Bond and Hwang, (1988); and Dames & Moore (1985). The models in these tables were selected based on general site hydrogeologic conditions: unconfined flow, unsaturated and saturated flow, horizontal and vertical flow, adsorption, and radioactive, chemical or biological decay. All of the numerical models (finite difference and finite element) can simulate unconfined flow, solute transport, and incorporate adsorption (MODPATH is the only exception: it is a particle-tracking model, and thus cannot incorporate hydrodynamic dispersion or adsorption). All of the analytical/compartmental models can simulate adsorption, and some can incorporate unconfined flow.

Table 3-1 lists important information about each model, and indicates whether each model satisfies the four selection criteria listed at the end of section 3.1.1. Table 3-1 is arranged according to the type of model: analytical, compartmental, stochastic, finite difference, or finite element. Within each type, the models are listed alphabetically according the name of the model. Tables 3-2 and 3-3 give a general description of each model. Table 3-2 is ordered the same as Table 3-1 (the finite difference models are listed first in alphabetical order), except that the models are listed in groups of five for ease of reading. Table 3-3 is similar in layout to Table 3-2.

TABLE 3-1
RELEVANT GROUND-WATER MODELS FOR TRANSPORT AND FATE RISK ASSESSMENT

Name	Source (1)	Spatial Dimensionality	Orientation (2)	Type (3)	Public Domain Code?	Satisfaction of Selection Criteria (4) 1	2	3	4
AGU-10	IGWMC	1,2	H,V	A	Yes?	N	N	N	N
AT123D	IGWMC	1,2,3	H,V	A	No	N	N	N	Y
GETOUT	ANL	1	H?	A	No	N	N	N	N
MASCOT	BMI	1,2,3	H,V	A	No	N	N	N	N
ONE-D	IGWMC	1	H?	A	Yes?	N	N	N	N
SOLUTE	IGWMC	1,2,3	H,V	A	Yes?	N	N	N	Y
GLEAMS	EPA	1	V?	C	Yes	N	N	N	Y
RUSTIC	EPA	1	V	C/S	Yes	N	N	N	N
SESOIL	EPA	1	V	C/S	Yes	N	N	N	Y
RANDOM WALK	ISWS	1,2	H	FD/S	Yes?	N	N	N	Y
BIOPLUME II	RU	2	H	FD	No	Y	Y	N	Y
HST3D	USGS	3	-	FD	Yes	Y	Y	N	N
IDNMIG	SNL	2	H?	FD	No	Y	Y	N	N
MOC	USGS	2	H	FD	Yes	Y	Y	N	N
MOCNRC	USGS	2	H	FD	Yes	Y	Y	N	Y
MODPATH	USGS	3	-	FD	Yes	N	N	Y	Y
SATRA-CHEM	USGS	2	H,V?	FD	Yes	Y	Y	N	N
SWANFLOW	GEOTRANS	3	-	FD	No	Y	Y	Y	Y
SWIFT	ANL	3	-	FD	No	Y	Y	Y	Y
SWIPR	USGS	3	-	FD	Yes?	Y	Y	N	N

TABLE 3-1--Continued
RELEVANT GROUND-WATER MODELS FOR TRANSPORT AND FATE RISK ASSESSMENT

Name	Source (1)	Spatial Dimension-ality	Orientation (2)	Type (3)	Public Domain Code?	Satisfaction of Selection Criteria 1 2 3 4 (4)
TARGET	D&M	1,2,3	H,V	FD	No	Y Y Y Y
TRACR3D	LANL	3	-	FD	No	N N N N
FLOTRA	ACRI	2	H,V	FD?	No	Y Y N N
GASOLINE	USGS	1	V	FD?	Yes	N N N N
MMT-DRPW	PNL	3	-	FD?	No	Y Y N N
VADOSE	ACRI	2	H,V	FD?	No	Y Y N N
CFEST	PNL	3	-	FE	No	Y Y N Y
CHAINT	RI	2	H,V?	FE	No	Y Y N N
DSTRAM	HGLI	2,3	H,V	FE	No	Y Y N N
FECWASTE	ORNL	2	V	FE	No	N N N Y
FEMTRAN	SNL	2	V	FE	No	Y Y N N
FEMWASTE	ORNL	2	H	FE	No	N N N Y
FLAMINCO	GEOTRANS	3	-	FE	No	Y Y Y Y
GGCP	GA	2	H	FE	No?	N N Y Y
GREASE2	GEOTRANS	3	-	FE	No	Y Y Y Y
GROWKWA	DHL	2	H	FE	No	Y N N N
GS2	WWLI	2	H,V	FE	No	Y Y N N
GS3	WWLI	3	-	FE	No	N N N N
MAQWQ	UA	3?	?	FE	Yes?	Y Y N N
MOFAT	EST	2	H,V	FE	No	Y Y N Y
MOTIF	AEC	1,2,3	-	FE	No	Y N N N
ROCMAS-HS	LBL	2	H?	FE	No	N N N N

TABLE 3-1--Continued
RELEVANT GROUND-WATER MODELS FOR TRANSPORT AND FATE RISK ASSESSMENT

Name	Source (1)	Spatial Dimension-ality	Orientation (2)	Type (3)	Public Domain Code?	Satisfaction of Selection Criteria 1 2 3 4 (4)
SATURN2	GEOTRANS	2	V	FE	No	Y Y N N
SEFTRAN	GEOTRANS	2	H	FE	No	N N Y N
SHALT	INTERA	2	H	FE	No	N N Y N
SOTRAN	UPH	2	H?	FE	No	Y Y N N
SUTRA	USGS	2	H,V	FE	Yes	N N Y Y
TRAFRAP-WT	IGWMC	2	H	FE	Yes?	N N N Y
TRANQL	LANL	1	H?	FE	No	N N N N
VAM2D	HGLI	2	H,V	FE	No	Y Y N N
VAM3D	HGLI	2,3	H,V	FE	No	Y Y N N
BIO-1D	GEOTRANS	1	H?	FE?	No	N N N N

(1) Source acronymns:

ACRI - Analytic and Computational Research, Inc.
AEC - Atomic Energy of Canada
ANL - Argonne National Laboratory
BMI - Battelle Memorial Institute
D&M - Dames & Moore
DHL - Delft Hydrologic Lab
EPA - U.S. Environmental Protection Agency
EST - Environmental Services and Technology
GA - Golder Associates
GEOTRANS - GeoTrans, Inc.
HGLI - HydroGeoLogic, Inc.
IGWMC - International Ground Water Modeling Center
INTERA - INTERA, Inc.

TABLE 3-1--Continued
RELEVANT GROUND-WATER MODELS FOR TRANSPORT AND FATE RISK ASSESSMENT

ISWS - Illinois State Water Survey
LANL - Los Alomos National Laboratroy
LBL - Lawerence Berkley Laboratory
ORNL - Oak Ridge National Laboratory
PNL - Pacific Northwest Laboratory
RI - Rockwell International
RU - Rice University
SNL - Sandia National Laboratory
UA - University of Arizona
UPH - University of Port Harcourt
USGS - U.S. Geological Survey
WWLI - Waste, Water and Land, Inc.

(2) Orientations:

H - horizontal
V - vertical (cross sectional)
"-" - 3-D model

(3) Model types:

A - analytical
C - compartmental
FD - finite difference, numerical
FE - finite element, numerical
S - stochastic

Note: model types may be mixed.

(4) Selection criteria (section 2.2.1.1):

1. Model is capable of simulating site transport and flow conditions.
2. Model is capable of accomplishing study objectives.
3. Model has been verified and field tested.
4. Model has been adequately reviewed, is well documented, and is available.

TABLE 3-2
NUMERICAL MODEL DESCRIPTIONS

Name (1)	Decay (2)	Variably Saturated	Density Coupled	Heat-Flow Coupled	Multi-phase Flow	Chemical Reactions	Ion Exchange	Biodeg-radation	Other
BIOPLUME II	No	No	No	No	No	No	No	Yes	
HST3D	Yes	No	Yes	Yes	No	No	No	No	
IDNMIG	Yes(C?)	No	No	No	No	No	No	No	
MOC	Yes	No	No	No	No	No	No	No	
MOCNRC	Yes(C?)	No	No	No	No	No	No	No	
MODPATH(*)	No	No	No	No	No	No	No	No	Avection Only
SATRA-CHEM	No	No	No	No	No	Yes	Yes	No	
SWANFLOW	No	Yes	No	No	Yes	No	No	No	
SWIFT	Yes	No	Yes	Yes	No	Yes	Yes	No	
SWIPR	No	No	Yes	Yes	No	No	No	No	Isotropic ?
TARGET	Yes	Yes	Yes	Yes	No	No	No	No	
TRACR3D	Yes	No	No	No	Yes	No	No	No	Deformable
FLOTRA	Yes	Yes	Yes	Yes	No	Yes	No	No	
GASOLINE	Yes	Yes	No	No	Yes	No	No	Yes	
MMT-DRPW	Yes	No	No	No	No	Yes	Yes	No	
VADOSE	Yes	Yes	Yes	Yes	No	Yes	No	No	
CFEST	Yes	No	Yes	Yes	No	No	No	No	
CHAINT(*)	Yes(C)	No	Yes	No	No	No	No	No	
DSTRAM	Yes	No	Yes	Yes	No	No	No	Yes	
FECWASTE(*)	Yes	No	No	No	No	No	No	Yes	
FEMTRAN(*)	Yes(C)	Yes	No	No	No	No	No	No	
FEMWASTE(*)	Yes	No	No	No	No	No	No	Yes	
FLAMINCO	Yes	Yes	No	No	No	No	No	No	
GGCP	Yes	No	No	No	No	Yes	No	No	
GREASE2	No	No	Yes	Yes	No	No	No	No	

TABLE 3-2--Continued
NUMERICAL MODEL DESCRIPTIONS

Name (1)	Decay (2)	Variably Saturated	Density Coupled	Heat-Flow Coupled	Multi-phase Flow	Chemical Reactions	Ion Exchange	Biodeg-radation	Other
GROWKWA	Yes	No	No	No	No	Yes	Yes	No	
GS2	Yes	Yes	No	No	No	No	No	No	
GS3	No	Yes	No	No	No	No	No	No	
MAQWQ(*)	Yes	No	No	No	No	No	No	No	
MOFAT	Yes	Yes	Yes	No	Yes	No	No	No	
MOTIF	Yes	Yes	No	Yes	No	No	No	No	
ROCMAS-HS(*)	Yes	No	No	No	No	Yes	No	No	
SATURN2	Yes	Yes	No	No	No	Yes	No	No	
SEFTRAN	No	No	Yes	Yes	No	No	No	No	
SHALT	Yes	Yes	Yes	Yes	No	Yes	No	No	
SOTRAN	Yes	No	No	No	No	No	No	Yes	
SUTRA	No	Yes	Yes	Yes	No	Yes	No	No	
TRAFRAP-WT	Yes	No	No	No	No	Yes	No	No	
TRANQL	No	No	No	No	No	Yes	Yes	No	
VAM2D	Yes	Yes	No	No	No	No	No	Yes	
VAM3D	Yes	Yes	No	No	No	No	No	Yes	
BIO-1D	Yes	No	No	No	No	No	No	Yes	

(1) "*" idicates a model that requires the output from another model.
(2) "C" indicates a model that incorporates chain decay.

TABLE 3-3
ANALYTICAL, COMPARTMENTAL, AND STOCASTIC MODEL DESCRIPTIONS

Name	Decay (1)	Variably Saturated	Multi-phase	Chemical Reactions	Ion Exchange
AGU-10	Yes	No	No	No	No
AT123D	Yes	No	No	No	No
GETOUT	Yes(C)	No	No	No	No
MASCOT	Yes(C)	No	No	No	No
ONE-D	Yes	No	No	No	No
RUSTIC	Yes	Yes	Yes	No	No
SOLUTE	Yes	No	No	No	No
GLEAMS	Yes	Yes	No	No	No
SESOIL	Yes	Yes	Yes	No	No
RANDOM WALK	Yes	No	No	Yes	No

(1) "C" indicates a model that incorporates chain decay.

From Table 3-1 it is apparent that six models are best suited to represent the Rocky Flats Plant site: GREASE2, MOC, SWIFT, FLAMINCO, TARGET, and SWANFLOW. Other models may be best for special conditions, such as simulating biodegradation (BIOPLUME II, BIO-1D), geochemical interactions (TRANQL), chain decay (CHAINT), or volatilization (GASOLINE). Of the six models. MOC is probably too simplistic, and SWANFLOW is probably too complex.

delete subjective

Each of the six possible models is suited to address particular problems. The conditions under which each class of model is applicable are as follows:

- two dimensional, horizontal models: commonly applied to saturated zone flow in which the ground water flow (and transport) are primarily horizontal. Vertical flow and vertical variation in contaminant concentrations are negligible compared to horizontal variations. Selected models are: MOC and TARGET.

- two dimensional, vertical (cross-sectional) models: commonly applied to localized unsaturated/saturated zone flow, in which flow is primarily vertical. The vertical section is usually oriented in the direction of horizontal flow (if any). Selected models are: FLAMINCO and TARGET.

- three dimensional models: commonly applied to areas where horizontal and vertical flow are important. Selected models are: GREASE2, SWIFT, FLAMINCO, TARGET, and SWANFLOW.

3.1.3 Model Parameter Requirements Versus Site Data Availability

Specific data requirements for ground-water flow and mass transport models include:

Fluids and Contaminants

- background or initial concentrations of dissolved species
- temporal measurements of concentrations
- types of dissolved species
- decay constants for radioactive and organic species
- molecular diffusion coefficients
- fluid density and viscosity as a function of concentration
- geochemical data (solubility, potential reactions, Henry's constant, etc.)

Hydrogeologic Conditions

- distribution of hydrostratigraphic units
- saturated thickness
- unsaturated thickness
- hydraulic conductivities (for all fluids if necessary, and for saturated and unsaturated conditions)
- anisotropy of hydraulic conductivity
- moisture characteristic curves (unsaturated zone)
- nature and distribution of clays
- organic carbon content
- effective porosity
- Specific Retention

- dispersivities
- specific storage coefficients
- nature and distribution of important minerals (if any)
- adsorption distribution coefficients (K_d)
- ion exchange capacities
- soil/rock bulk densities
- retardation factors (a function of K_d, porosity, and bulk density)
- topographic information
- meteorologic data (precipitation rates, temperature, humidity, etc.)
- locations of hydraulic head and concentration measurements
- measurements of hydraulic head (spatial and temporal)
- distribution, duration, and rates of natural and artificial recharge
- distribution, duration, and rates of natural and artificial discharge
- distribution, duration, rates, concentration, and constituents of contaminant sources.

<u>Model</u>

- domain size (location of sources and receptors)
- spatial grid or mesh
- time increment

- simulation period

Model data requirements can be grouped into general categories:

- Framework/Material Properties: hydraulic conductivities, clay content, porosity, density, thickness, etc.

- Boundary Conditions (Recharge/Discharge): distribution, duration, and rates of natural and artificial recharge and discharge.

- Contaminant Sources/Sinks: distribution, duration, rates, concentration, and constituents of contaminant sources.

- Hydraulic Head/Saturated Thickness: locations of hydraulic head and measurements of hydraulic head.

- Concentrations: background or initial concentrations of dissolved species, temporal measurements of concentrations, types of dissolved species.

- Adsorption: K_d, ion exchange capacities, nature and distribution of clays, organic carbon content, etc.

- Decay/Degradation: decay constants for radioactive and organic species.

- Geochemistry: molecular diffusion coefficients, fluid density and viscosity, geochemical data, etc.

- Meteorology: precipitation rates, temperature, humidity, etc.

- Unsaturated-Zone Parameters: moisture characteristic curves, etc.

- Multi-Phase Flow Parameters: fluid density and viscosity, types of fluids, geochemical data, sources/sinks, etc.

These groups are listed in Tables 3-4 and 3-5, which show model data requirements for each model, and site-specific data availability. In general, model predictions will be most sensitive to framework/material properties, boundary conditions, and contaminant sources/sinks.

Personnel at EG&G (Rocky Flats Plant) and the 1988 environmental report for the site (Rockwell International, 1988) were consulted concerning data availability (Table 3-5). Relative to ground-water flow and mass transport modeling, Mr. Gregory Underburg was contacted. In general, most required data for ground-water and mass transport modeling have been measured both locally and site-wide. Areas in which data for modeling are lacking include the following: adsorption, geochemistry, meteorology, and unsaturated zone parameter category. Either plans for data collection exist, or field studies are underway in all these areas, particularly adsorption, meteorology, and unsaturated-zone parameters. It was also noted that there is a lack of recharge-rate/infiltration-rate data, but collection of these data are also planned. In general, the planned field program for ground water hydrology at the site is adequate to meet the needs of ground-water and mass-transport modeling. However, the quality of the data being collected is unknown.

delete

3.1.4 Conclusions on Model Selection

Ground-water flow and mass transport model selection is based on four general criteria: (1) The selected model(s) must be able to adequately simulate site conditions, (2) the selected model(s) must be able to satisfy the objectives of the study (~~the model(s) should be neither too simple nor too complex~~), (3) the selected model(s) must be verified, and reasonably well field tested, and (4)

delete

Table 3-4

Data Requirements for Ground-Water Flow and Transport Models

	Framework/ Material Properties	Boundary Conditions (Recharge/Discharge)	Contaminant Sources/ Sinks	Hydraulic Head/ Saturated Thickness	Concentrations	Adsorption	Decay/Degradation	Geochemistry	Meteorology	Unsaturated-Zone Parameters	Multi-Phase Flow Parameters	Other (1)
AGU-10	●	●	●	●	●	●	●					
AT123D	●	●	●	●	●	●	●					
GETOUT	●	●	●	●	●	●	●					
MASCOT	●	●	●	●	●	●	●					
ONE-D	●	●	●	●	●	●	●					
SOLUTE	●	●	●	●	●	●	●					
GLEAMS	●	●	●		●	●	●		●	●		
RUSTIC	●	●	●		●	●	●		●	●	●	
SESOIL	●	●	●		●	●	●		●	●	●	
RANDOM WALK	●	●	●	●	●	●	●	●				
BIOPLUME II	●	●	●	●	●	●	●					
HST3D	●	●	●	●	●	●	●					●
IDNMIG	●	●	●	●	●	●	●					
MOC	●	●	●	●	●	●	●					
MOCNRC	●	●	●	●	●	●	●					
MODPATH	●	●	●	●	●	●						
SATRA-CHEM	●	●	●	●	●	●		●				
SWANFLOW	●	●	●	●	●	●				●	●	
SWIFT	●	●	●	●	●	●	●	●				●
SWIPR	●	●	●	●	●	●						●
TARGET	●	●	●	●	●	●	●			●		●
TRACR3D	●	●	●	●	●	●	●				●	●
FLOTRA	●	●	●	●	●	●	●	●		●		●
GASOLINE	●	●	●	●	●	●	●			●	●	
MMT-DRPW	●	●	●	●	●	●	●	●				
VADOSE	●	●	●	●	●	●	●	●		●		●
CFEST	●	●	●	●	●	●	●					●
CHAINT	●	●	●	●	●	●	●					●
DSTRAM	●	●	●	●	●	●	●					●
FECWASTE	●	●	●	●	●	●	●					
FEMTRAN	●	●	●	●	●	●	●			●		
FEMWASTE	●	●	●	●	●	●	●					
FLAMINCO	●	●	●	●	●	●	●			●		
GGCP	●	●	●	●	●	●	●	●				
GREASE2	●	●	●	●	●	●						●
GROWKWA	●	●	●	●	●	●	●	●				
GS2	●	●	●	●	●	●	●			●		
GS3	●	●	●	●	●	●				●		
MAQWQ	●	●	●	●	●	●	●					
MOFAT	●	●	●	●	●	●	●			●	●	●
MOTIF	●	●	●	●	●	●	●			●		●
ROCMAS-HS	●	●	●	●	●	●	●	●				●
SATURN2	●	●	●	●	●	●	●	●		●		
SEFTRAN	●	●	●	●	●	●						●
SHALT	●	●	●	●	●	●	●	●		●		●
SOTRAN	●	●	●	●	●	●	●					
SUTRA	●	●	●	●	●	●		●		●		●
TRAFRAP-WT	●	●	●	●	●	●	●	●				●
TRANQL	●	●	●	●	●	●		●				
VAM2D	●	●	●	●	●	●	●			●		
VAM3D	●	●	●	●	●	●	●			●		
BIO-1D	●	●	●	●	●	●	●					

● - Data Required

(1) Other: Data Required for Density-Coupled Heat Flow, and for Fracture Flow.

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Table 3-5
Data Availability

DATA CLASSIFICATION (1)	SITE WIDE (2)	LOCAL (3)	SPARSE (4)	UNKNOWN/ LITERATURE (5)
Framework/Material Properties	●	●		●
Boundary Conditions (Recharge/Discharge)	●	●		
Contaminant Sources/Sinks	●	●		
Hydraulic Head/ Saturated Thickness	●	●		
Concentrations	●	●		
Adsorption			●	●
Decay/Degradation				●
Geochemistry			●	●
Meteorology	●		●	●
Unsaturated-Zone Parameters			●	●
Multi-Phase Flow Parameters				●
Other (6)				●

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(1) - Data classifications are explained in detail in section 3.1.3

(2) - Data are available on a site-wide basis.

(3) - Detailed data are available for some OU's.

(4) - Only sparse data are available.

(5) - No data are available. Some data may be estimated or obtained from other published data.

(6) - Other: data availability for density-coupled and heat flow, and for fracture flow.

the selected model(s) must be well documented, peer reviewed, and available. Based on these criteria and the model descriptions, six models have been ~~selected and are recommended~~ evaluated for potential use at the Rocky Flats Plant site. The six models are: GREASE2, MOC, SWIFT, FLAMINCO, TARGET, and SWANFLOW.

3.2 Surface Water Dispersion/Dilution Models

The objective of the proposed surface-water modeling is to develop an exposure assessment for human and or animal populations resulting from the transport of pollutants from the Rocky Flats Plant site through surface-water pathways. It is desirable to evaluate exposure potential for both short-term (event-based) and long-term surface-water flow conditions. The short-term (event-based) evaluation would require the analysis of contaminant concentration resulting from a specific storm, such as a 25-year 24-hour storm. The long-term evaluation would require continuous simulation of the rainfall-runoff and contaminant transport processes.

The Rocky Flats Plant occupies an area of about 500 acres. The interior storm drainage system for the plant site is comprised of a number of interconnected pipes, manholes, and open drains. The general ground slope in the site vicinity is from west to east. The northern portion of the site area is drained by the north fork of Walnut Creek. The central and eastern portion is drained by the south fork of Walnut Creek which originates near the center of the site area. Surface runoff from a small portion near the southern edge of the site area is drained by Woman Creek which flows from west to east, about 200 to 500 feet south of the site boundary. Immediately east of the site boundary, streamflows of the north and south forks of Walnut Creek and Woman Creek pass through a series of holding ponds. These creeks form the sources of surface water supplies to two water supply reservoirs: Stanley Lake and Great Western Reservoir.

The contaminant sources and potential surface-water pathways for the transport of contaminants from the plant site to human or animal populations include the following:

- Deposition and accumulation of contaminated material on the ground surface, roof tops, and surfaces of equipment within the plant site;
- Release of partially treated dissolved and suspended pollutants into the drainage system;
- Transport of dissolved and suspended pollutants by washoff and erosion resulting from precipitation and overland flows;
- Transport and dispersion of dissolved and suspended pollutants through the interior drainage system and the aforementioned creeks; and
- Mixing and accumulation of dissolved and suspended pollutants in the holding ponds, Stanley Lake, and Great Western Reservoir; consumption of the same by aquatic organisms and other animals; and entry into the public drinking water supply.

3.2.1 Discussion of Selection Criteria

The computational steps required to simulate the transport processes described in the previous section are as follows (US EPA, 1987a):

- **Identification of the physical and chemical properties of potential contaminants likely to be found on the ground surface drainage system with treated wastewater from the plant.** - This can be accomplished by a review of available water quality data, chemical analyses of soils within the plant site, NPDES permits, and relevant studies and reports. The objective of this study component is to quantify source contamination and to assess whether the source contaminants are soluble in water, will be transported as suspended sediment, and will be subject to degradation and transformation during their transport with surface water.

- **Nonpoint Source Runoff Simulation** – The selected nonpoint source runoff model should be capable of simulating the process of erosion from the site area along with that from the remaining portions of the respective watersheds under normal, seasonal and annual climatic conditions, and also during severe storm events.

- **Surface-Water Flow Simulation** – The selected surface water flow model should be capable of routing surface runoff and pollutant loads from the Rocky Flats Plant site and other catchments through the creeks and holding ponds described previously. All three creeks for which routing computations are made are relatively narrow with fairly long travel paths. Therefore, it will be reasonable to assume uniform concentrations (i.e., complete mixing) of pollutants in the flows reaching the water bodies (reservoirs) at their downstream ends.

- **Surface Water Transport Simulation** – The selected surface-water transport model should be capable of simulating the dispersal of dissolved or suspended pollutants transported by the aforementioned creeks through the respective holding ponds and in the Stanley Lake and Great Western Reservoirs.

The selection criteria for surface-water models which could accomplish the above have been presented previously 3.0 and can be summarized as:

- Ability to simulate site conditions;
- Satisfy management objectives of study without requiring excessive input data;
- Demonstrated verification and field testing; and
- Well-documented, peer reviewed and available in public domain.

3.2.2 Discussion of Models Versus Selection Criteria

The models which could be adapted to simulate the processes described in the previous section are listed in the following paragraphs and summarized in Table 3-6.

A. **Nonpoint Source Runoff Models** – The objective of these models is to estimate the quantity of surface runoff and pollutants generated by different watersheds.

(1) Agricultural Runoff Model (ARM-II) (EPA, 1978) -- It is a continuous simulation model and includes degradation, adsorption/desorption, and reaction of chemical constituents. It requires sediment loading parameters as input and was intended to be used for small agricultural areas. Since estimation of erosion is a key component of the study and Universal Soil Loss Equation (USLE) or Modified Universal Soil Loss Equation (MUSLE) is the preferred approach (EPA 1988), this model may not adequately meet the study objectives.

Table 3-6

Summary of Relevant Surface Water Models

NAME	TYPE	SOURCE	DESCRIPTION	SATISFACTION OF SELECTION CRITERIA [b]			
				1	2	3	4
(a) NONPOINT SOURCE RUNOFF MODELS							
(1) ARM-II	CS	USEPA (1978)	Predicts runoff volumes and concentration of dissolved and absorbed nutrients in runoff	Y	N	N	Y
(2) NPS	CS	USEPA (1976)	Predicts runoff hydrograph, sediment and pollutant loads and concentrations as a function of time	Y	N	N	Y
(3) ACTMO	CS	USDA (1975)	Predicts streamflow hydrograph, watershed erosion, and quantity of chemicals in runoff	Y	Y	N	Y
(4) CREAMS	CS	USDA (1975	Predicts surface runoff, erosion, sediment delivery to water body, and concentrations of chemicals	Y	Y	N	Y
(5) SWMHM	CS	USEPA (1982 a)	Produces hydrographs and pollutographs at specified locations	Y	Y	N	Y
(6) HSPF	CS	USEPA (1984 a)	Predicts surface runoff and pollutant concentrations at specified locations and times	Y	N	N	Y
(7) SEDMOT-II	EB	U. of Kentucky (1981)	Predicts surface runoff and sediment load from watersheds	Y	Y	N	Y
(b) SURFACE WATER FLOW MODELS							
(1) HEC-6	CS, 1-D	USACE (1977)	Produces water surface and stream bed profiles and concentrations of suspended sediments	Y	Y	Y	Y
(2) MICHRIV	Analytical	USEPA (1984 b)	Predicts dissolved and suspended pollutant concentrations as a function of distance	Y	N	Y	Y
(3) HSPF	CS	USEPA (1984 b)	Produces routed river flow and pollutant hydrographs	Y	N	Y	Y
(4) WQRRS	CS, 1-D	USACE (1978)	Routes flows and water quality constituents through rivers and reservoirs	Y	Y	Y	Y
(5) SEDMOT-II	EB	U. of Kentucky (1981)	Routes runoff and sediment hydrograph through channels	Y	Y	Y	Y
(8) CHTRN	1-D	Yeh (1962)	One-dimensional, transient model for routing organic chemicals through streams	Y	N	N	N

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Table 3-6 (Continued)

NAME	TYPE	SOURCE	DESCRIPTION	SATISFACTION OF SELECTION CRITERIA [b]			
				1	2	3	4
(7) TOXIWASP	3-D	USEPA (1983)	Three-dimensional, transient model for routing organic chemicals with decay	Y	N	N	Y
(8) DYNHYD3	CS, 2-D	USEPA (1979)	Routes chamical constituents through tidal streams	N	N	N	Y
(9) QUAL2E	1-D	USDA (1987)	Routes up to 15 chemical constituents through streams with constant flow and waste loads	Y	Y	N	Y
(10) MEXANS	3-D	Onishi	Routes metal loadings with complex dynamics through non-tidal aquatic systems	N	N	N	Y
(11) PDM	Prob.	USEPA (1986 b))	Estimates percent of times comcentrations are exceeded	N	N	N	Y
(12) SERATRA	2-D	Onishi & Wiss (1982)	Preforms transient routing of sediment in streams	Y	N	N	Y
(13) TO DAM	1-D	Onishi, et al (1982)	Performs transient simulation of comtaminants in rivers and estuaries	N	N	N	Y
(14) WASP3	3-D	Onishi, et al (1982)	Routes contaminants through streams	Y	Y	N	Y
(15) WQAM	1-D	Mills, et al (1982)	Estimates contaminant concentrations in streams and estuaries using hand *calculator*	N	N	N	Y
(16) WASTOX	3-D	USEPA (1985)	Simulates pollutant transport with decay in rivers, lakes, estuaries	Y	N	N	Y
(17) FETRA	2-D	Onishi (1981)	*Performs finite-element simulation of* pollutant transport in rivers with decay	Y	N	N	Y
(b) SURFACE WATER TRANSPORT MODELS							
(1) SLSA	Analytical	HydroQual (1981)	Produces water surface and stream bed profiles and concentrations of suspended sediments	Y	N	N	Y
(2) HEC-8	CS, 1-D	USACE (1977)	Predicts dissolved and suspended pollutant concentrations as a function of distance	Y	Y	N	Y
(3) HSPF	CS, 1-D	USEPA (1984 (b))	Produces routed river flow and pollutant hydrographs	Y	N	Y	Y
(4) CE-QUAL-R1	CS, 1-D	USEPA (1986 (A))	Routes flows and water quality constituents through rivers and reservoirs	Y	Y	Y	Y
(4) WQRRS	CS, 1-D	USACE (1978)	Routes flows and water quality constituents through rivers and reservoirs	Y	Y	Y	Y

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Table 3-6 (Continued)

NAME	TYPE	SOURCE	DESCRIPTION	SATISFACTION OF SELECTION CRITERIA [(b)]			
				1	2	3	4
(6) CE-QUAL-W2	CS, 2-D	USAWES (1986(B))	Simulates water quality in rivers and reservoirs	Y	N	Y	Y
(7) SEDMONT II	EB	U. of Kentucky (1981)	Predicts peak and settleable concentration of sediments in reservoirs	Y	Y	Y	Y
(8) CHNTRN	1-D	Veh (1982)	One-Dimensional model intended for coastal waters	Y	N	N	N
(9) TOXIWASP	3-D	USEPA (1983)	Three-dimensional model, transient model for routing organic chemicals	Y	N	N	Y
(10) CTAP	3-D	Burns, et al	Three-dimensional steady-state model for routing chemicals with decay	Y	N	N	Y
(11) SERATRA	2-D	Onishi & Wiss (1982)	Performs transient routing of sediments in reservoirs	Y	N	N	Y
(12) EXAMS	3-D	USEPA (1982 (b)) (1982)	Simulates transport of synthetic chemicals in aquatic systems	Y	N	N	Y
(13) Variable-Density Hydrodynamic Model	3-D	USEPA (1988 (c)) (1982)	Simulates the movement of pollution in thermal discharges in coastal waters	Y	Y	N	Y
(14) TOXIC	3-D	Schnoor, et al (1981)	Simulates the movement of pollution due to pesticides in reservoir	Y	Y	N	N
(15) WQAM	1-D	Mills, et al (1982)	Estimates contaminant concentrations in lakes, and estuaries using desktop calculator	N	N	N	Y
(16) WASTOX	2-D	USEPA (1985)	Simulates pollutant transport with decay in rivers, lakes, and estuaries	Y	N	N	Y
(17) FETRA	2-D	Onishi (1981)	Performs finite-element simulation of pollutanat transport with decay in completely mixed lakes	Y	N	N	Y

(a) CS=Continuous Simultaion; EB=Event Based; 1-D=One-Dimensional; 2-d D=Two-Dimensional; 3-D=Three-Dimensional

(b) 1. The model is capable of simulating site conditions with or without minor adaptation.

2. The model can address managment objectives. ie, has the appropriate degree of sophistication (neither too simplictic and rudimentary nor too sophisticated and complex).

3. The model has been tested and validataed for the type of situation expected at the Rocky Flats Plant Site.

4. The model code and documentation are available in public domain, are complete, and have undergone adequate review.

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(2) NPS Model (EPA, 1976) -- It is a continuous simulation model. It simulates the sediment transport process as the detachment and subsequent transport of fines and requires sediment loading parameters and sediment accumulation and removal rates from impervious areas for dry periods as input. It does not simulate decay or degradation of pollutants. Since estimation of erosion using USLE is a key component of the study, this model may not meet the study objectives.

(3) Agricultural Chemical Transport Model (ACTMO) (USDA, 1975) -- It is a continuous simulation model and can simulate snowmelt and runoff from one or more catchments. It estimates erosion using USLE and can model adsorption, degradation, or mineralization of chemicals. The model is applicable to agricultural chemicals. However, it may be possible to adapt it to other types of contaminants as well.

(4) Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems (CREAMS) (USDA, 1980) -- It estimates catchment runoff using daily or hourly precipitation data, erosion using USLE, sediment transport using transport capacity, and decay and degradation of chemicals using specified coefficients. The model is applicable to agricultural areas. However, it may be possible to adapt it to the conditions at the Rocky Flats Plant site.

(5) Storm Water Management Model (SWMM) (EPA, 1982a) -- It is a continuous simulation model designed to simulate multiple urban catchments with conventional and conservative pollutant loadings. It simulates erosion using USLE and deposition and sediment delivery using specified deposition ratios and washoff functions. This model can be adapted for use for the Rocky Flats Plant site.

(6) Hydrologic Simulation Program - Fortran (HSPF) (EPA, 1984a) -- It is a very complex continuous simulation model. The sediment transport simulation includes settling, deposition,and scouring using specified coefficients for soil detachments, sediment influx, and sediment washoff. The chemical quality constituents associated with sediment are

modelled using specified washoff and scour potency factors. The model simulates adsorption/desorption processes separately for sand, silt, and clay contained in the bed material or in suspension. This model can be adapted for used for the Rocky Flats Plant site. However, the data requirements are extensive and the calibration and implementation of the model is tedious and labor-intensive. In the absence of adequate calibration, the accuracy of the results may not be better than other relatively simpler models.

(7) SEDIMOT II - Hydrology and Sedimentology Model (Univeristy of Kentucky, 1981) -- It is an event-based model and simulates sediment erosion using USLE or MUSLE for specified storms and watershed characteristics. This model can be adapted to simulate nonpoint source runoff contamination for the short-term (event-based) condition at the Rocky Flats Plant site.

B. **Surface Water Runoff Models** -- The function of these models is to route surface runoff and pollutants through the streams in the study area.

(1) Scour and Deposition in Rivers and Reservoirs (HEC-6) (USACE, 1977) -- It is a one-dimensional, transient numerical model and simulates sediment transport in river and reservoir systems with tributary inflows. It can perform continuous simulation and can be adapted to model the situation at the Rocky Flats Plant site.

(2) MICHRIV (EPA, 1984ba) -- It is an analytical steady-state model to simulate adjective transport of a pollutant through river reaches without dispersion, but with degradation. It predicts pollutant concentrations in dissolved and particulate forms as a function of distance. It can be adapted for use on the river reaches of the Rocky Flats Plant site.

(3) Hydrologic Simulation Program - Fortran (HSPF) (EPA, 1984a) -- As stated previously, it is a very complex continuous simulation model. It uses the kinematic wave

approximation for channel routing and can perform reservoir routing as well. It can be adapted to model the flow situation at the Rocky Flats Plant site.

(4) Water Quality for River-Reservoir Systems (WQRRS) (USACE, 1978) -- It is a spatially one-dimensional and horizontally averaged continuous simulation model. This model has a stream hydraulics and a stream water quality component. The stream hydraulics component is similar to the HEC-2 or HEC-6 models of the U.S. Army Corps of Engineers (USACE, 1973, 1977). The model is very complex and difficult to calibrate. It can be adapted to simulate the water quality in the streams and reservoirs downstream of the holding ponds in the vicinity of the Rocky Flats Plant site. It may be difficult to simulate all the holding ponds using this model.

(5) SEDIMOT II Hydrology and Sedimentology Model (University of Kentucky, 1981) - It is an event-based model and performs flow and sediment routing through channels and connected holding ponds for a specified storm. It can be adapted for surface water flow modeling of the situation at the Rocky Flats Plant site.

(6) Channel Transport Model (CHTRN) (Yeh, 1982) -- It is a one-dimensional, transient model to simulate the transport of organic pollutants through rivers, lakes, estuaries, and coastal waters. The model has to be coupled with a hydrodynamic model for estimation of flow dynamics. It requires extensive input data and setup time for calibration and implementation. The model has not undergone adequate field testing and peer review at this time and, therefore, may not be suitable for the present application.

(7) Chemical and Stream Quality Model (TOXIWASP) (EPA, 1983a) -- It is a three-dimensional transient model for simulating the transport of organic pollutants with comprehensive second-order decay through rives, estuaries, and lakes. It is a very data-intensive model and requires extensive labor (150-300 hours) for setup. This model

appears to be too complex and elaborate to meet the modeling objectives of the Rocky Flats Study. For the streams and reservoirs at the Rocky Flats Plant site, three-dimensional dispersion in not important.

(8) DYNHYD3 (EPA, 1979) -- It is a two-dimensional continuous simulation hydrodynamic model for tidal streams. It may not be appropriate for the non-tidal and non-estuarian streams in the vicinity of the Rocky Flats Plant site without significant adaptations.

(9) Enhanced Stream Water Quality Model (QUAL 2E) (EPA, 1987b) -- This model can simulate steady-state or dynamic transport of up to 15 chemical constituents in well-mixed streams where advection and dispersion are dominant only in the longitudinal direction. Hydraulically, it is limited to the simulation of time periods during which both stream flow and input waste load are constant. This model can be adapted for use for the streams in the vicinity of Rocky Flats Plant site. It may require some effort to simulate monthly varying stream flows using this model.

(10) Metals Exposure Analysis Modeling System (MEXAMS) (Onishi, undated) -- It is a three-dimensional, steady-state compartmental model designed for modeling of metal leadings in non-tidal aquatic systems. It simulates complex metal dynamics, requires extensive input, and may not be suitable for the conditions at the Rocky Flats Plant site. The model contains built-in data based for thermodynamic properties of 7 metals and may need significant adaptations for use for other contaminants.

(11) Probabilistic Dilution Model (PDM) (EPA, 1988b) -- This model estimates the percent of times a given concentration level may be exceeded in a stream based on statistical distribution of daily volume flow and estimates of dilution based on mass balance. This model will not meet the objectives of the present study where deterministic rather probabilistic estimates are warranted.

(12) Sediment-Contaminant Transport (SERATRA) (Onishi and Wise, 1982) -- It is a transient, two-dimensional (longitudinal and vertical) sediment transport model with algorithms to simulate complex sediment transport and decay mechanisms for organic pollutants for rivers and lakes. The model has been tested with field data. It requires extensive input data and labor (about 750 manhours) for setup, assuming all input data are readily available. This model may be adapted for use for the Rocky Flats Plant site. but may be unnecessarily complex to meet the study objectives.

(13) Transient One-Dimensional Degradation and Migration Model (TO DAM) (Onishi, et al, 1982) -- It is a transient, one-dimensional model to simulate the transport of contaminants in rivers and estuarine systems with second order decay mechanisms. It requires channel and flow characteristics to be provided as data developed by another hydrodynamic model. It requires extensive data as input. The model documentation has not been adequately reviewed and may not be available at this time.

(14) Water Quality Analysis Simulation Program (WASP3) (EPA, 1986c) -- This model simulates contaminant transport in streams in one, two, or three dimensions. The contaminants that can be simulated include biochemical oxygen demand, dissolved oxygen dynamics, nutrients, and eutrophication, bacterial contamination, and toxic chemicals. This model can be adapted for application to the streams in the vicinity of Rocky Flats Plant site. It is similar to QAUL 2E, described previously.

(15) Water Quality Assessment Methodology (WQAM) (Mills, et al., 1982) -- It is a simplistic, one-dimensional steady-state model to estimate contaminant concentrations in rivers, lakes, and estuaries. The computations can be made by hand calculators. This model may be too simplistic and rudimentary to meet the objectives of the proposed study.

(16) Estuary and Stream Quality Model (WASTOX) (EPA, 1985b) -- It is a transient three-dimensional model to simulate

pollutant transport with sophisticated second-order organic decay kinetics in rivers, lakes, and estuaries. It requires flows between model compartments as input. The flows have to be estimated by another hydrodynamic flow model. It requires extensive input data for calibration and implementation. The setup time is estimated to be 150-300 manhours. Compared to models that can simulate both hydrodynamics and contaminant transport through streams, this model may not be efficient for the Rocky Flats Plant site. For the streams at the project site, three-dimensional simulation may not be required.

(17) Finite-Element Transport Model (FETRA) (Onishi, 1981) -- It is a transient two-dimensional (longitudinal and lateral) finite-element model to simulate the transport of contaminants through rivers, estuaries, coastal systems, and completely mixed lakes including second-order decay mechanisms for organic pollutants. This model has to be coupled with a hydrodynamic model to generate flow characteristics. The model has been coupled with a hydrodynamic model to generate flow characteristics. The model has been field validated. It requires extensive data for calibration and extensive labor and time for setup and execution. Compared to models that can simulate both hydrodynamics and contaminant transport through streams, this model may not be efficient for the present study.

C. **SURFACE WATER TRANSPORT MODELS** -- The purpose of these models is to route surface runoff and pollutants through the reservoirs in the study area.

(1) Simplified Lake/Stream Analyses (SLSA) (Hydro Qual, 1981) -- It is an analytical model and can be used to analyze the steady-state, zero-dimensional mixing of pollutants in Stanley and Great Western reservoirs. The model accounts for sediment suspension exchange between the water column and bed sediments, and degradation, but not for dispersion. The model is a good tool for preliminary screening, but may be to rudimentary to simulate the situation at the Rocky Flats Plant site.

(2) Scour and Deposition in Rivers and Reservoirs (HEC-6) (USACE, 1977) -- As stated previously, it is a transient model and simulates sediment deposition in a reservoir based on particle sizes of the incoming suspended material. It can be adapted to model the sedimentation in the reservoirs near the Rocky Flats Plant site. This model cannot simulate the mixing of dissolved constituents.

(3) Hydrologic Simulation Program - Fortran (HSPF) (USEPA, 1984b) -- As stated previously, it is a very complex and sophisticated model and can perform continuous simulation of water quality in lakes and reservoirs, It can be adapted to simulate mixing in Stanley Lake and Great Western Reservoirs.

(4) A Numerical One-Dimensional Model of Reservoir Water Quality (CE-QUAL-R1) (US AWES, 1986a) -- It is a spatially one-dimensional and horizontally averaged continuous simulation model. It conceptualizes the reservoir as a vertical sequence of horizontal layers where the contaminants are uniformly distributed in each layer. The model simulates inflows, outflows, entrainment, vertical diffusion, and interactions of a number of water quality constituents. It is a fairly complex model. It can be adapted to simulated the water quality of Stanley Lake and Great Western Reservoirs.

(5) Water Quality for River-Reservoir Systems (WQRRS) (USACE, 1978) -- This model is very similar to CE-QUAL-R1 described previously as far as simulation of reservoir water quality is concerned. In addition, it has a stream hydraulics and stream water quality component. Once the continuous flows for the streams leading to Stanley Lake or Great Western Reservoir are estimated by the selected surface runoff model, This model can be adapted to simulate the stream and reservoir water quality. The holding ponds can be simulated by treating them as a composite reservoir. The data requirements for this model are fairly extensive.

(6) A Numerical Two-Dimensional., Laterally-Averaged Model of Hydrodynamics and Water Quality (CE-QUAL-W2) (US AWES, 1986(b)) -- It is a two-dimensional, laterally average, continuous simulation, finite-difference model for reservoir water quality simulation. It accounts for vertical and longitudinal diffusion, entrainment, and interaction among various water quality constituents. The model is more complex and sophisticated and much more difficult to use than CE-QUAL-R1, described previously. It can be adapted for simulating the water quality of Stanley Lake and Great Western Reservoirs.

(7) SEDIMOT II Hydrology and Sedimentology Model (University of Kentucky, 1981) -- As stated previously, it is an event-based model and simulates sediment deposition and trap efficiency of reservoirs and concentrations of suspended sediments in the reservoirs. It can be adapted to simulate the situation at the Rocky Flats Plant site. However, it cannot simulate the mixing of dissolved constituents.

(8) Channel Transport Model (CHNTRN) (Yeh, 1982) -- A brief description of this model is presented under Surface Water Runoff Models. Since this model is presented under Surface Water Runoff Models. Since this model has not undergone adequate testing and peer review, it is not considered appropriate for the Rocky Flats Plant site.

(9) Chemical and Stream Quality Model (TOXIWASP) (EPA, 1983) -- This model is described under Surface Water Runoff Models. It will require some adaptation to be applied to Stanley Lake and Great Western Reservoirs. The conditions at the Rocky Flats Plant site may not warrant three-dimensional transient modeling. Therefore, this model is not considered suitable for the present study.

(10) Chemical Transport and Analysis Program (CTAP) (Burns, et al, 1982) -- It is a steady-state three-dimensional compartmental model to simulate the transport of pollutants through non-tidal aquatic systems with comprehensive second-order decay kinetics for organics. It requires extensive

input data and about 350 manhours for installation and setup, assuming all data are readily available. This model can be adapted for use for the Rocky Flats Plant site. However, the physical conditions at the Rocky Flats Plant site may not warrant three-dimensional simulation.

(11) Sediment-Contaminant Transport (SERATRA) (Onishi and Wise, 1982) -- This model is described under Surface Water Runoff Models. It can be adapted for the simulation of contaminant transport through the streams and reservoirs in the vicinity of the Rocky Flats Plant site. However, as stated previously, the model is complex, requires extensive data, and is labor intensive requiring about 760 manhours for setup.

(12) Exposure Analysis Modeling System (EXAMS) (EPA, 1982b) -- This model can simulate one, two, or three-dimensional transport of synthetic organic chemicals in aquatic systems using a set of fundamental process models that accept standard chemical parameters and limnological data as input. It can be adapted for use at the Rocky Flats Plant site.

(13) Time-Dependent, Three-Dimensional, Variable Density Hydrodynamic Model (EPA, 1988c) -- This model estimates the movement of pollutants in thermal discharges in harbors, bays, lake basins, entire lakes, estuaries, and marine coastal areas. In particular, it estimates velocities, temperatures and salinity. Since the Rocky Flats Plant area is not a coastal environment, this model may not be appropriate for this study without significant adaptations.

(14) Toxic Organic Substance Transport and Bioaccumulation Model (TOXIC) (Schnoor, et al, 1981) -- It is a quasi-dynamic three-dimensional compartment model to simulate complex biological uptake mechanisms like pesticides in reservoirs and aquatic impoundments. It is a good model to estimate biological pollution, but lacks proper simulation of chemical fate mechanisms. User support for this model is limited and no user manual is available. Therefore, this model is not suitable for the present study.

(15) Water Quality Assessment Methodology (WQAM) (Mills, et al, 1982) -- As stated under Surface Water Runoff Models, this model may be too simplistic to meet the objectives of this study.

(16) Estuary and Stream Quality Model (WASTOX) (EPA, 1985b) -- As explained under Surface Water Runoff Models, compared to other models, it may not be very efficient for simulation of contaminant transport through streams. If it is not used for streams, then it may not be prudent to use it only for the reservoirs. Its capability to simulate three-dimensional transient situations may not be called upon or warranted in the present study.

(17) Finite-Element Transport Model (FETRA) (Onishi, 1981) -- As explained under Surface Water Runoff Models, it can simulate only completely mixed lakes. In the case of Stanley Lake and Great Western Reservoirs, the variation of contaminant concentrations in the vertical direction may be important because of potential for stratification during severe winter conditions. In that case, this model may be too simplistic as far as the simulation of reservoirs is concerned.

3.2.3 Model Parameter Requirements Versus Site Data Availability

As stated in Section 3.2, an important consideration in the selection of surface water models is the input data requirements associated with the use of a particular model. The required input data must be commensurate with the objectives and degree of detail of the proposed study and feasibility of adequate data acquisition. The data required for the implementation of the models described previously are summarized in Table 3-7. The estimated data availability is outlined in Table 3-8.

Table 3-7
Data Requirements for Surface Water Models*

Model	PRECIPITATION	SOLAR RADIATION	TEMPERATURE	RELATIVE HUMIDITY	WIND VELOCITY	AREAS	GROUND SLOPE	SOIL COVER	STREAM CROSS SECTIONS	SEDIMENT LOAD	SEDIMENT DISCHARGE	SEDIMENT DENSITY	SEDIMENT SIZES	RESERVOIR INFLOW	RESERVOIR OUTFLOW	RESERVOIR CAPACITY	SOIL ERODIBILITY	IMPERVIOUS AREA	SEDIMENT LOADING PARAMETERS	DISPERSION, DECAY, REACTION DEGRADATION COEFFICIENTS	SOIL MOISTURE PARAMETERS	STREAM FLOWS
(a) Nonpoint Source Runoff Models																						
ARM-II	•					•	•	•											•	•		
NPS	•					•		•											•		•	
ALTMO	•					•	•	•					•				•	•		•	•	
CREAMS	•					•	•	•					•				•	•		•		
SWMM	•					•	•	•									•	•	•		•	
HSPF	•	•	•	•	•	•	•	•	•			•	•				•	•	•	•	•	
SEDIMOT II	•					•	•	•	•			•	•				•	•				
(b) Surface Water Runoff Models																						
HEC-6			•						•	•	•	•	•									•
MICHRI									•	•	•	•	•						•	•		•
HSPF	•	•	•	•	•				•	•	•	•	•						•	•		•
WQRRS	•	•	•	•	•				•	•	•	•	•									.
SEDIMOT II									•	•	•	•	•									
CHNTRN	•	•	•	•	•				•													
TOXIWASP	•	•	•	•	•				•	•	•	•	•							•		•
DYNHYD3	•	•	•	•	•				•											•		•
QUAL 2E	•	•	•	•	•				•	•	•	•	•							•		•
MEXAMS	•	•	•	•	•				•											•		•
PDM										•									•			•
SERATRA			•						•	•	•	•	•						•	•		•
TODAM			•						•	•	•	•	•						•	•		•
WASP3	•	•	•	•	•				•	•	•	•	•							•		•
WQAM										•									•	•		•
WASTOX	•	•	•	•	•				•	•	•	•	•						•	•		•
FETRA	•	•	•	•	•				•	•	•	•	•						•	•		•
(c) Surface Water Transport Models																						
SASA										•	•	•	•	•	•	•				•		•
HEC-6			•							•	•	•	•	•	•	•			•			•
HSPF			•							•	•	•	•	•	•	•			•	•		•
CE-QUAL-R1			•							•	•	•	•	•	•	•			•	•		•
WQRRS			•							•	•	•	•	•	•	•			•	•		•
CE-QUAL-W2			•						•	•	•	•	•	•	•	•			•	•		•
SEDIMOT II										•	•	•	•	•	•	•			•			•
CHNTRN	•	•	•	•	•					•	•	•	•	•	•	•			•	•		•
TOXIWASP	•	•	•	•	•					•	•	•	•	•	•	•			•	•		•
C TAP	•	•	•	•	•					•	•	•	•	•	•	•			•	•		•
SERETRA	•	•	•	•	•					•	•	•	•	•	•	•			•	•		•
EXAMS	•	•	•	•	•					•	•	•	•	•	•	•			•	•		•
Variable Density Hydrodynamic Model	•	•	•	•	•					•		•		•	•	•			•	•		•
TOXIC	•	•	•	•	•					•	•	•	•	•	•	•			•	•		•
WQ AM										•				•	•	•			•	•		•
WASTOX	•	•	•	•	•					•	•	•	•	•	•	•			•	•		•
FETRA	•	•	•	•	•					•	•	•	•	•	•	•			•	•		•

* A general description of data requirements is included here. Refer to User's Manuals for detailed descriptions of input.

07/02/90 MOD-DATA.DWG

Table 3-8
Data Availability

DATA CLASSIFICATION	SITE WIDE (1)	LOCAL (2)	SPARSE (3)	UNKNOWN/ LITERATURE (4)
Meteorological (Precipitation, Temperature, etc.)	●			●
Topographical (Slope, Areas, etc.)	●	●		
Stream Cross Sections		●	●	
Stream Flow		●	●	
Water Chemistry		●	●	
Sediment Chemistry			●	
Soil Cover	●			●
Impervious Area	●			●
Soil Erodibility				●
Soil Moisture				●
Sediment Load/Discharge				●
Sediment Loading Parameters				●
Sediment Density				●
Sediment Size			●	●
Reservoir Inflow			●	●
Reservoir Outflow			●	●
Reservoir Capacity		●		●
Dispersion/Decay/Reaction/ Degradation Coefficients				●

(1) - Data are available on a state-wide basis.

(2) - Detailed data are available for some locations.

(3) - Only sparse data are currently available.

(4) - Some data may be estimated of obtained from other published data.

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In order to construct Table 3-8, personnel at the RFP were contacted concerning surface-water sampling and collection of relate data. Mr. Peter Folger provided a summary of past and future data collection. In general, most of the basic data required for surface-water modeling (i.e., meteorology, topography, soil cover, stream cross-sections and stream flows) have all been collected regularly over an area encompassing the whole plant site. Soil moisture parameters and reservoir flow balance data are one year. Dispersion, decay, reaction and degradation coefficients will not be measured at the site. However, these parameters may, for modeling purposes, be extracted from the literature. The primary category of lacking data is sediment characterization. Sediment load, discharge, density, and loading parameters may not be available from the literature. Limited sediment sampling is planned. These data are vital to most of the surveyed surface water models.

3.2.4 Conclusions on Model Selection

Using the descriptions of different models and selection criteria presented in the previous section, the following surface water models are judged to be most appropriate for exposure assessment study for the Rocky Flats Plant site.

(1) Nonpoint Source Runoff Models -- From the standpoint of data requirements, history of applications, and meeting the objectives of the study with reasonable accuracy, SWMM (EPA, 1982a) appears to be the most appropriate model for continuous simulation for this component of the study. The next best choices appear to be CREAMS (USDA, 1980) and ACTMO (USDA, 1975), respectively. If the scope of the study permits extensive data collection and acquisition and sufficient time to complete the study, then HSPF (EPA, 1984a) appears to be the best choice.

For event-based simulation, SEDIMOT-II (University of Kentucky, 1981) appears to be the best choice. This model does not simulate the transport of dissolved constituents. Concentrations of these constituents can be estimated by approximate analytical approaches.

(2) Surface Water Runoff Models -- For the simulation of continuous stream flow and pollutant transport, HEC-6 (USACE, 1977) and WQRRS (USACE, 1978) appear to be the most appropriate choices. HEC-6 can simulate flow and sediment transport whereas WQRRS can model all other water quality parameters including total suspended solids. If the scope of the study warrants extensive data collection and acquisition and sufficient time for completion of the study, then HSPF (USEPA, 1984a) appears to be the preferred model.

For routing storm runoff and sediment load generated by that runoff through the streams and holding ponds, SEDIMOT-II (University of Kentucky, 1981) appears to be the best choice.

(3) Surface Water Transport Models -- For continuous simulation of reservoir sedimentation and water quality HEC-6 (USACE, 1977) and WQRRS (USACE, 1978) are judged to be the best choices. As far as the simulation of reservoir water quality is concerned, CE-QUAL-R1 (USAWES, 1986a) and WQRRS are very similar models. However, WQRRS is preferred here because it can simulate both stream and reservoir water quality. If the scope of the study permits adequate time for extensive data collection, then the more sophisticated HSPF (EPA, 1984b) model will be appropriate.

For event-based simulation of sediment routing through Stanley Lake and Great Western Reservoirs, SEDIMOT-II (University of Kentucky, 1981) appears to be the preferred model.

3.3 Airborne Dispersion Models

The objective of the proposed airborne dispersion modeling is to provide estimates of concentrations and surface deposition resulting from routine and accidental releases of pollutants to the atmosphere. Based on these predictions, an exposure assessment for airborne pollutants will be developed.

The meteorological conditions which affect the Rocky Flats Plant are greatly influenced by the Rocky Mountains to the west. These mountains act as a barrier to moisture approaching from the west. The site is affected by local nighttime drainage winds which follow the gentle west to east slope.

The major airborne pathways which should be considered for the Rocky Flats Plant are:

- Short distance plume downwash associated with high winds, impacting local populations.
- Long distance transport of airborne contaminants toward the densely populated Denver metropolitan area.
- Dry deposition of large particulates, released from stacks and from disturbed open areas during high winds.
- Wet and dry deposition of acidic pollutants, and resultant effect on sensitive populations and protected areas (e.g., Class I PSD[1] areas).
- Airborne modeling of dense gas releases during periods of light drainage winds.

---

[1] Prevention of Significant Deterioration

Model overview

Airborne dispersion models can be categorized into four basic classes, these are: gaussian, numerical, empirical and physical models.

Gaussian models, which are most widely used by regulatory agencies, are simple analytical models that deal with both transport and dilution of airborne contaminants. These models are developed to treat a variety of specific problems that exist between the time a contaminant is first released into the atmosphere, ant the time it reaches the exposure receptor. Gaussian models are the least costly to implement, but usually have extensive limitations which require the use of a combination of models to cover the problem at hand.

Numerical dispersion models are more costly to implement than Gaussian models, but are better suited to deal with complex components effecting dispersion, such as reactive chemistry, complex wind/turbulence distributions, complex terrain and transient conditions.

Empirical models are used for case-specific modeling where sufficient field data exist. These models describe a cause and effect relationship between the source term data and ultimate receptor concentration data. Predictions from these models may be extrapolated to produce predictions for alternate sources or receptor locations.

The last class of models, physical models, involve laboratory testing of scaled down versions of actual site conditions. For example, testing of the aerodynamic downwash from an obstacle, and its effect on a stack effluent plume, could be simulated in a wind tunnel.

Airborne model components

The selected model must be capable of representing the physical system adequately. The calculation of airborne contaminant concentrations involve consideration of three components of the physical system. They are conditions at the source, intermediate zone and receptor locations.

The source characteristics which may require simulation include:

- Emission state (i.e., gaseous, liquid or solid, dense or buoyant pollutant).
- Emission characteristics (i.e., reactivity, decay, concentration, and instantaneous, continuous or variable rate of pollutant emission).
- Source type (i.e, ground-level or elevated point sources, line or area sources and associated volumes).

Conditions intermediate between the source and the receptor are the most important factors effecting receptor concentrations. This component of the model is the most susceptible to error. The site characteristics which may require simulation include:

- Meteorological conditions (i.e., wind speed and direction, stability, mixing depth, precipitation, temperature, and variations of these parameters with time).

- Dispersion assumptions (i.e., Gaussian, non-Gaussian, or empirical description of pollutant behavior).

- Special conditions (i.e., deposition, chemical transformation, buoyancy, or aerodynamic downwash).

- Time domain (i.e., short term (hourly, daily), or long term (annual) simulations).

- Terrain characteristics (i.e., flat, rolling, or complex topography).

Conditions at the receptor location must also be adequately represented by the model. Receptor characteristics include:

- Height (i.e., ground level or elevated receptor)

- Location (i.e., stationary or variable receptor location).

3.3.1 Discussion of Selection Criteria

The selection of airborne dispersion models for the Rocky Flats Plant site must consider the above mentioned site conditions. In addition, several other management objectives must be considered in model selection. Four general selection criteria have been used to evaluate the airborne dispersion models:

- Ability to simulate source, receptor and atmospheric conditions at the Rocky Flats Plant site;

- Satisfy study objectives without requiring excessive input data;

- Demonstrated field testing and validation; and

- Well-documented, peer-reviewed and available in the public domain.

3.3.2 Discussion of Models Versus Selection Criteria

The models which could be used to simulate the airborne transport and dispersion of contaminants from the Rocky Flats Plant are described in Tables 3-9 and 3-10. Table 3-9 provides a ranking of each model against the selection criteria, and references for model sources. Table 3-10 provides a summary of the atmospheric model capabilities for the three components of the physical system discussed in Section 3.3. Detailed model documentation may be obtained from the references.

3.3.3 Model Parameter Requirements Versus Site Data Availability

Specific data requirements for airborne dispersion models may be grouped into the following general categories:

- pollutant characteristics
- source characteristics
- topography
- meteorological data
- receptor characteristics.

TABLE 3-9
RELEVANT ATMOSPHERIC MODELS FOR TRANSPORT AND FATE RISK ASSESSMENT

Name	Source (1)	Model Type (2)	Public Domain Code?	Satisfaction of Selection Criteria (3) 1 2 3 4
AIRDOSE	EPA	G	Yes	Y Y N Y
BLP	ERT	G	Yes	Y Y Y Y
CALINE3	FHA	G	Yes	Y N Y Y
CDM	EPA	G	Yes	Y N Y Y
COMPLEX±	EPA	G	Yes	Y Y Y Y
INPUFF2	EPA	G	Yes	Y Y Y Y
ISCST	EPA	G	Yes	Y Y Y Y
LONGZ	EPA	G	Yes	Y N N Y
MESOPUFF2	EPA	G	Yes	Y Y N Y
MPTER	EPA	G	Yes	Y N Y Y
PAL	EPA	G	Yes	Y Y N Y
PTPLU	EPA	G	Yes	Y Y N N
SCREEN	EPA	G	Yes	Y Y N Y
SHORTZ	EPA	G	Yes	Y N N Y
TEM	TACB	G	No	Y N N Y
DEGADIS 2.0	USC	G/E	Yes	Y Y N Y
RTDM	ERT	G/E	Yes	Y Y Y Y
EKMA	EPA	E	Yes	N N Y Y
RPM	EPA	E	Yes	Y N N Y
RVD 2.0	EPA	E	Yes	Y Y N Y
IMPACT	RADIAN	N	No	Y N N Y
RADM	D&M	N	No	Y Y N Y

(1) Source acronymns:

D&M - Dames & Moore
EPA - U.S. Environmental Protection Agency

(2) ERT - Environmental Research and Technology, Inc.

FHA - Federal Highway Administration
RADIAN - RADIAN Corp.
TCAB - Texas Air Control Board
USC - U.S. Coast Guard

TABLE 3-9--Continued.
RELEVANT ATMOSPHERIC MODELS FOR TRANSPORT AND FATE RISK ASSESSMENT

Model types:

G - Gaussian
E - Empirical
N - Numerical

Note: model types may be mixed.

(3) Selection criteria (section 3.0):

1. Model is capable of simulating site transport and flow conditions.

2. Model is capable of accomplishing study objectives.

3. Model has been verified and field tested.

4. Model has been adequately reviewed, is well documented, and is available.

Table 3-10
Atmospheric Model Descriptions

Model Name	EMISSION CHARACTERISTICS								SOURCE TYPE				TIME DOMAIN			SPECIAL CONDITIONS						RECEPTOR CONDITIONS		
	GASEOUS	LIQUID	SOLID	REACTIVITY	DECAY	INSTANTANEOUS	CONTINUOUS	VARIABLE RATE	AREAS	STACKS	VOLUMES	LINE	SHORT TERM (1)	LONG TERM (2)	INSTANTANEOUS (3)	DEPOSITION	CHEMICAL TRANSFORMATION	BUOYANCY	AERODYNAMIC DOWNWASH	COMPLEX TERRAIN	SIMPLE TERRAIN	GROUND-LEVEL RECEPTORS	ABOVE-GROUND RECEPTORS	LONG-RANGE TRANSPORT (4)
AIR DOSE	●		●		●	●	●			●				●		●	●				●	●		
BLP	●		●		●		●			●		●	●					●					●	
CALINE 3	●						●					●	●			●					●	●		
CDM	●		●		●		●		●	●				●							●	●		
COMPLEX I	●		●		●		●			●			●	●						●			●	
INPUFF 2	●		●			●	●	●		●	●		●		●	●					●	●		
ISCST	●		●		●		●	●	●	●	●		●	●		●			●		●		●	
LONGZ	●		●		●		●		●	●	●			●		●			●	●	●	●	●	
MESOPUFF 2	●		●	●	●	●	●	●	●	●			●		●	●	●				●		●	●
MPTER	●		●		●		●			●			●	●						●			●	
PAL	●		●		●		●		●	●		●	●								●		●	
PTPLU	●		●		●		●			●			●								●		●	
SCREEN	●		●		●		●		●	●			●						●	●	●	●	●	
SHORTZ	●		●		●		●		●	●	●		●			●			●	●	●	●	●	
TEM	●		●		●		●		●	●			●								●	●		
DEGADIS 2.0	●	●			●	●	●	●		●			●				●	●			●		●	
RTDM	●		●		●		●						●							●			●	
EKMA	●			●			●	●			●		●				●				●	●		
RPM	●		●	●	●	●	●		●	●			●		●		●							
RVD 2.0	●				●	●	●	●	●						●			●			●	●		
IMPACT	●		●	●	●		●		●	●			●				●			●	●	●	●	●
RADM	●		●		●		●	●	●	●			●			●					●		●	●

07/26/90 TBL3-10.DWG

(1) Short Term: Hourly to Daily

(2) Long Term: Annual

(3) Instantaneous: Up to Five Minutes

(4) Long Range Transport: > 50 Kilometers

Table 3-11 provides a summary of the atmospheric model data needs for each of these categories. Model predictions will be most sensitive to the conditions prevailing between the source and the receptor.

Table 3-12 summarizes the site-specific data available for the same categories listed in Table 3-11.

Personnel at the Rocky Flats Plant were consulted regarding availability of meteorological and air quality data in and around the plant site (Table 3-11). The 1980 EIS (U.S. Department of Energy, 1980) was also used for purposes of identifying both regional and local data sources. Ms. Wanda Busby, at RFP, provided information regarding availaibility of data at Rocky Flats. An extensive amount of meteorological data have been collected on-site at the RFP. A meteorological tower, instrumented at the 10, 25 and 50 meter levels has been collecting wind and turbulence data since 1984. Meteorological data are also availabe at other locations throughout the site. Precipitation, humidity, and solar radiation data have also been collected on the plant site. Some air quality data have also been collected, especially particulate concentrations. Total Suspended Particulate data has been collected at nearly 50 sites around the plant and in certain population areas. This large amount of particulate data could serve as a model validation database.

Region meteorological data also esixts at Boulder (with data avaialable from a 300 meter tower), at Stapleton Airport (with upper air data for use in mixing height determinations) and at Greeley. Long-term climatological data from Stapleton can be compared with RFP on-site data for use in comparing year to year variations between the sites.

Table 3-11
Atmospheric Model Data Needs

Model Name	POLLUTANT CHARACTERISTICS				SOURCE/ RECEPTOR CHARACTERISTICS				GEOMETRY	METEOROLOGICAL DATA									
	CONCENTRATIONS (1)	HALF-LIFE	REACTIVITY RATES	PARTICAL SIZE/DENSITY	SOURCE LOCATIONS	SOURCE ELEVATIONS	RECEPTOR LOCATIONS	RECEPTOR ELEVATIONS	BUILDING DIMENSIONS (2)	VERTICAL WIND PROFILES	TEMPERATURE	MIXING DEPTH	TURBULENT INTENSITIES	PASQUILL STABILITY CLASS	WIND SPEED/DIRECTION	HOURLY - SEQUENTIAL	"WORST CASE" (3)	ANNUAL - "STAR" (4)	MUTIPLE SITES (5)
AIR DOSE		●	●	●	●	●	●	●		●	●	●		●	●	●		●	
BLP		●		●	●	●	●	●		●	●	●		●	●	●			
CALINE 3				●	●	●	●	●		●	●	●		●	●	●			
CDM		●			●		●	●		●	●	●		●	●		●	●	
COMPLEX		●			●	●	●	●		●	●	●		●	●	●			
INPUFF 2		●		●	●		●	●		●	●	●		●	●	●	●		
ISCST		●		●	●	●	●	●	●	●	●	●	●	●	●	●			
LONGZ		●		●	●	●	●	●	●	●	●	●		●	●			●	
MESOPUFF 2		●	●	●	●	●	●	●		●	●	●	●	●	●	●			
MPTER		●			●	●	●	●		●	●	●		●	●	●			
PAL		●		●	●	●	●	●		●	●	●		●	●	●			
PTPLU		●								●	●	●		●	●		●		
SCREEN		●			●	●	●	●	●	●	●	●		●	●		●		
SHORTZ		●		●	●	●	●	●	●	●	●	●	●	●	●	●			
TEM		●		●	●	●	●	●		●	●	●		●	●	●			
DEGADIS 2.0		●		●	●	●		●		●	●	●	●	●	●	●			
RTDM		●			●	●	●	●		●	●	●	●	●	●	●			
EKMA	●		●	●	●		●				●	●				●			
RPM	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●
RVD 2.0		●		●	●		●	●		●	●	●		●	●		●		
IMPACT	●	●	●		●	●	●	●		●	●	●	●	●	●	●			●
RADM		●			●	●	●	●		●	●	●	●	●	●	●			

07/26/90 TBL3-11.DWG

(1) Includes Background Concentrations

(2) Includes Surface Topography and Other Surface Features Such as Trees

(3) Worst Case: Hypothetical Worst Possible Meteorological Conditions

(4) STAR: Stability Array

(5) Multiple Meteorological Monitoring Sites

Table 3-12
Data Availability

Category	Data	Site Wide (5)	Local (6)	Sparse (7)	Unknown/ Literature (8)
POLLUTANT CHARACTERISTICS	CONCENTRATIONS (1)			●	
POLLUTANT CHARACTERISTICS	HALF-LIFE	●			
POLLUTANT CHARACTERISTICS	REACTIVITY RATES				●
POLLUTANT CHARACTERISTICS	PARTICAL SIZE/DENSITY	●			
SOURCE/ RECEPTOR CHARACTERISTICS	SOURCE LOCATIONS	●			
SOURCE/ RECEPTOR CHARACTERISTICS	SOURCE ELEVATIONS		●		
SOURCE/ RECEPTOR CHARACTERISTICS	RECEPTOR LOCATIONS		●		
SOURCE/ RECEPTOR CHARACTERISTICS	RECEPTOR ELEVATIONS		●		
GEOMETRY	BUILDING DIMENSIONS (2)		●		
METEROLOGICAL DATA	VERTICAL WIND PROFILES			●	
METEROLOGICAL DATA	TEMPERATURE	●	●		
METEROLOGICAL DATA	MIXING DEPTH	●		●	
METEROLOGICAL DATA	TURBULENT INTENSITIES				●
METEROLOGICAL DATA	PASQUILL STABILITY CLASS	●	●		
METEROLOGICAL DATA	WIND SPEED/DIRECTION	●	●		
METEROLOGICAL DATA	HOURLY-SEQUENTIAL	●	●		
METEROLOGICAL DATA	"WORST CASE"	●	●		
METEROLOGICAL DATA	ANNUAL-"STAR"	●	●		

07/26/90 TBL3-12.DWG

(1) Includes Background Concentrations

(2) Includes Surface Topography and Other Surface Features, Such as Trees

(3) Worst Case: Hypothetical Worst Possible Meteorological Conditions

(4) STAR: Stability Array

(5) Data Available on a Site-Wide Basis

(6) Data are Available for Specific Locations

(7) Only Sparse Data Are Available

(8) Data Have Not Yet Been Collected or Can Be Estimated from Literature Values

Most data required for the airborne dispersion models are currently available, and therefore no major effort in further data collection should be required. If wind field descriptions need to be developed, some supplemental short-term meteorological monitoring may be warranted.

3.3.4 Conclusions On Model Selection

Using the selection criteria presented in Section 3.3.1, the following models are recommended for application at the Rocky Flats Plant site.

1. Complex Terrain Models

   The preferred model for complex terrain is COMPLEXI. This is essentially a screening model. If a more refined modeling analysis is required, RTDM should be used. RTDM requires more intensive meteorological data, although it is capable of handling a worst case "fictitious" data set, and therefore application of RTDM might be limited, given availability of data for an RFP operating unit.

2. Simple Terrain Models

   The ISCST model is the preferred model for used with simple terrain (receptors having an elevation equal or less that the source elevation). ISCST is capable of handling point, area, and volume sources. ISCST can account for gravitational settling and deposition. Time variability of emission rates also make this model, by far, the most comprehensive one available.

3. Instantaneous Models

INPUFF is the recommended model for treatment of instantaneous and quasi instantaneous releases from point sources. This model can also be adapted for use with short duration open burning emissions.

3.4 Exposure Assessment Models

In this section general guidance will be given describing exposure assessment models that are suited for use at the Rocky Flats Plant. The primary objective of an exposure assessment is to make a reasonable estimate of the maximum exposure to individuals and critical population groups.

Radiological exposure assessment is similar to that for chemical exposures; however, beyond the inhalation, ingestion, and absorption; radiological exposure must include external radiation effects, radioactive decay and ingrowth factors among others. Synergistic effects should also be considered and discussed in the Risk Characterization section of the Human Health Risk Assessment.

A number of models have been developed specifically for radionuclides, some of which can also accommodate chemical contaminants. With the presence of plutonium, uranium, and other radionuclides at RFP, models having features such as radioactive decay and daughter growth involving large radionuclide databases are necessary.

This section has been organized to present general guidance in the following areas:

- Model selection criteria will be discussed with respect to RFP site conditions and based upon the EPA model selection criteria.
- Specific exposure assessment models will be summarized and compared to the selection criteria.
- Model parameter requirements will be provided in a tabular form and compared to available site data.
- Conclusions will be presented and recommendations for a specific model(s) will be provided.

3.4.1 Discussion of Selection Criteria

The same four criteria as used in previous sections are used as a basis for the screening methodology for all of the models. Models are evaluated with regard to a range of technical criteria are identified and, in this case, exposure assessment is the primary application. The four criteria have been addressed below:

- The selected model should be capable of simulating the transport processes and site conditions at RFP. Site conditions at RFP involve various forms of radioactive material and therefore the model should be capable of handling cross pathway migration of radionuclides.
- The models should be capable of accomplishing the study objectives, not too simplistic or too complex. Most of the exposure assessment models run on a personal computer and are designed to be "user friendly" given that the operator has adequate

background knowledge of environmental fate and transport pathway analysis and a working knowledge of radioactive materials at RFP.

- The models should have been tested and validated for application in situations similar to that at RFP. All of the models described in this section have been validated and used extensively by the EPA, DOE and others.
- The model code and documentation should be complete and should have undergone peer review. All the models discussed in this section have been reviewed either by the Oak Ridge Radiation Shielding and Information Code organization, the EPA, or the DOE.

3.4.2 Discussion of Models vs. Selection Criteria

Computer codes which have potential application to the Rocky Flats Plant are discussed in this section. Each system code is discussed briefly in the following paragraphs.

3.4.2.1 PATHRAE

The PATHRAE family of codes (PATHRAE-EPA, PATHRAE-RAD, and PATHRAE-HAZ) have features which make them applicable to a wide range of nuclear and hazardous waste disposal analyses. These features are briefly identified below. One advantage of PATHRAE is that a version for nonradioactive hazardous species has also been developed and applied to activities at the Savannah River Plant. Thus, by adopting the PATHRAE codes as system codes, the problem of addressing both radioactive and nonradioactive species can be handled with a high degree of consistency.

Up to ten scenarios by which contaminants may reach humans can be considered using PATHRAE. These scenarios include:

1) Groundwater migration with discharge to a river;

2) Groundwater migration with discharge to a well;

3) Surface erosion of the cover material and waste and subsequent contamination of surface water;

4) Saturation of waste and surface water contamination (bathtub effect);

5) Food grown on the waste site;

6) Biointrusion into the waste;

7) Direct gamma exposure;

8) Inhalation of contaminated dust on site;

9) Inhalation of radon gas and radon daughters on site; and

10) Inhalation of contaminated particulates off site (from an on-site incinerator, trench fire, or dust resuspension).

The PATHRAE methodology is comprehensive and models both off-site and on-site pathways through which individuals may come in contact with the waste. The off-site pathways include groundwater transport to a surface river or well, surface (wind or water) erosion, and atmospheric transport. The on-site pathways of concern arise principally from worker exposures during operations and from post-closure site reclamation (intruder) activities such as living and growing edible vegetation on site and drilling wells for irrigation or drinking water.

For each of the pathways which have been included in PATHRAE, the dose from each contaminant is calculated as a function of time. These doses are then summed to give the total dose for the pathway at each time of interest. The dose to the critical population group from all pathways is then computed, assuming the entire contaminant inventory is accessible through each pathway.

A real advantage of PATHRAE is its simplicity of operation and presentation while still allowing a comprehensive set of contaminants and pathways to be analyzed. Site performance for "developing cleanup criteria" can be readily investigated while the number of parameters needed to define the problem is kept at a minimum.

3.4.2.2 PRESTO

The PRESTO family of codes is a series of computer programs written under the direction of the EPA for analyzing the health impacts and risks associated with the post-operational phase of low-level waste (LLW) disposal facilities. All major human exposure pathways are considered. The PRESTO family codes include PRESTO-EPA, PRESTO-CPG, PRESTO-BRC, AND PRESTO-DEEP. The PRESTO-BRC and PRESTO-DEEP were developed for "below regulatory concern" and deep well injection, respectively. Another version of PRESTO, PRESTO-II, has been derived from PRESTO-EPA by Oak Ridge National Laboratory.

The structure of PRESTO-EPA is representative of all PRESTO family codes. The PRESTO-EPA code is modular and allows submodels or subroutines to be replaced, if necessary. Many of the submodels included in PRESTO were developed for other types of assessments and have been adapted for use in estimating health effects from residual radioactive materials.

Three types of submodels are used in PRESTO-EPA: unit response, bookkeeping, and scheduled event. The unit response submodels calculate the annual response for a process. For example, unit response models calculate the annual infiltration through an intact trench cap, the annual average atmospheric dispersion coefficient and annual average erosion of the trench cap.

The bookkeeping submodels keep track of the results of unit response submodels and user-supplied control options. Bookkeeping activities include maintaining water balances, material balances and the calculation of post-simulation residual activities.

Scheduled event submodels consider "representative" events such as cap failure, basement construction, initiation of scheduled mechanical suspension of dust, the timing of which is governed by user-specified (scenario) control parameters. Dust and resuspension factors for plutonium contaminated soils are particularly useful for RFP.

Average concentrations of each radionuclide in environmental media (such as well water or the atmosphere) over the assessment period are used to calculate radionuclide concentrations in foodstuffs. Foodstuff information, human ingestion rates, and breathing rates are utilized to calculate the annual average radionuclide intake per individual in a local population by ingestion and inhalation. These intake data are used by the exposure and risk submodels in the DARTAB sequence to estimate dose rate and health risk. DARTAB utilizes the EPA RADRISK methodology and database (based on ICRP 26/30). This database would have to be modified to incorporate ICRP 26 organ weighting factors. The health risk estimation methodology assumes that each member of the local population is a member of a cohort that is exposed to constant, averaged radionuclide concentration levels.

PRESTO-II differs from the original EPA code in a number of respects. First, PRESTO-II utilizes a different approach for computing infiltration through the trench cap. The input data-intensive calculation of trench-cap infiltration used in subroutine INFIL of PRESTO-EPA has been replaced by a simpler approach that computes this important variable from experimentally determined permeability and hourly precipitation values. Other approaches to infiltration have also been added as options: 1) use of yearly precipitation values; 2) user-specification of infiltration; and 3) estimation of trench cap infiltration as a fraction of calculated watershed infiltration. All of these methods provide values for infiltration through an intact trench cap. Infiltration through failed portions of the cap is computed in a separate calculation.

Watershed infiltration, an important variable for determining radionuclide weathering from the surface soils, is determined in PRESTO-II using a parametric evapotranspiration equation. This evapotranspiration model has been verified over a wide range of climates and reasonable estimates of water balance have been obtained for more than 100 river basins. A streamlined algorithm for describing radionuclide transport through subsurface pathways is also implemented in the PRESTO-II code.

3.4.2.3 ON-SITE/MAXI1

ON-SITE/MAXI1 considers scenarios which are established for a maximally exposed individual (an intruder) and provides a means of determining the resulting radiation dose to that individual. Only radionuclides are considered.

In ONSITE/MAXI1 five scenarios are identified as being of potential interest in assessing doses to intruders at disposal sites similar to the conditions to be expected at RFP:

1) External Exposure Scenario - An individual is assumed to work in an area previously used for on-site disposal. Surface soil contamination, waste buried at various depths or entry into a room (or vault) that is used for waste storage or disposal are considered.

2) External Exposure Plus Inhalation Scenario - An individual is assumed to work in an area with limited surface-soil contamination and is exposed to external sources and resuspended dusts.

3) Agricultural Scenario - An individual is assumed to raise his annual diet (or a fraction of it) in soil contaminated by the on-site disposal of radioactive waste. External exposure, ingestion, and inhalation of resuspended radionuclides in soil are considered.

4) Irrigation/Drinking-Water Scenario - An individual is assumed to use a water supply contaminated by radionuclides from an on-site disposal site for irrigation and/or drinking. In addition, external exposure and inhalation of resuspended radionuclides that are deposited on the surface of the soil by the irrigation water are considered. A severe limitation of this scenario as implemented by the code is that the user must provide the radionuclide concentrations at the receptor location. That is, ONSITE/MAXI1 does not model the releases and waterborne transport of radionuclides.

5) User-Defined Scenario - The user may construct his own scenario by selecting exposure pathways and defining conditions described in the ONSITE/MAXI1 computer software package.

ONSITE/MAXI1 utilizes a default environment defined for on-site disposal, however, this scenario is applicable to the conditions at RFP. This environment assumes intruder activity at an on-site low-level waste disposal site. The reference environment is based on a site with an area of 1 ha; however, area correction factors may be included to consider smaller sites. The intruder may be exposed to radioactive contamination via any of the following pathways: external exposure, inhalation of resuspended contaminants, ingestion of farm products grown on a contaminated site, consumption of drinking water from a contaminated well, or ingestion of aquatic food products from a contaminated water source. For external exposure, wastes may be located on the surface, buried at various specified depths, or stored in a room-type structure. For inhalation and ingestion, the default parameters used in defining the reference environment are based on those found in NRC Regulatory Guide 1.109. The intruder's entire diet for the reference environment consists of vegetables, fruits, and animal products grown on the site. Note also that ONSITE-MAXI1 is only applicable to on-site exposure scenarios.

3.4.2.4 RESRAD

RESRAD is a code developed by the Department of Energy for establishing residual radioactive material guidelines for the FUSRAP/SFMP program. Thus RESRAD is directed toward evaluating the impacts of contaminated soils. Some modification is likely required before RESRAD can be used extensively in evaluating alternatives for release of contaminated sites. Given the generic nature of system performance codes, however, it would not be unreasonable to evaluate applicability further. RESRAD is the most recent of the codes discussed here and the interactive user environment advantageous.

3.4.2.5 AIRDOS - EPA

This model was developed by the EPA Office of Radiation Programs, Las Vegas, Nevada. The code was designed to calculate the effective dose equivalent to maximally exposed individuals as required under 40 CFR Part 61, National Emission Standards for Hazardous Air Pollutants (NESHAPS). The model comes in a vax version CAAC-476 and more recently in a PC version (CCC-542/CAP-88). Both versions are recommended by the EPA specifically for DOE facilities under Subpart H of 40 CFR Part 61 (EPA,1989c). The PC version does not have the ability to calculate population doses as required by DOE Orders, and there is a limited list of radionuclides that can be utilized under the PC version. Neither of the AIRDOS-EPA versions to date are capable of adequately accounting for the dose contribution from Radon and Radon daughters are not at all accounted for.

The EPA-AIRDOS computer code estimates radionuclide concentrations in air; rates of deposition on ground surfaces; ground surface concentrations; intake rates via inhalation of air and ingestion of meat, milk, and fresh vegetables; and the accompanying radiation doses to man from these airborne releases of radionuclides.

A modified Gaussian plume model is used to estimate both horizontal and vertical dispersion of radionuclides released. Radionuclide concentrations in meat, milk, and fresh produce consumed by man are estimated by coupling the output of the atmospheric transport models with the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.109 (NRC, 1977) terrestrial food chain models. Dose conversion factors derived from the metabolic models described by the International Council on Radiation Protection (ICRP, 1979) are input into the code, effective dose equivalents are calculated for individuals residing at each distance and direction. User input is required to provide actual residence locations. Organ dose equivalents are also estimated for the bone marrow, lungs, endosteal cells, stomach wall, lower large intestine wall, thyroid, liver, kidney, testes, ovaries and total body through the following exposure modes: 1) immersion in air containing radionuclides; 2) exposure to ground surfaces contaminated by deposited radionuclides; 3) inhalation of radionuclides in air; and 4) ingestion of "contaminated" food grown within 80 kilometers (km) of the site.

The code is used to estimate the Annual Effective Dose Equivalent, the Committed Effective Dose Equivalent, and the associated organ dose equivalents for the "maximally exposed individual", which is re-defined as a location where a person actually resides. Additionally, the collective population dose within an 80 km radius of the site can also be calculated.

3.4.2.5.1 DARTAB

The DARTAB computer code combines information on environmental concentrations with dosimetric and health effects data to provide tabulations of predicted impacts of radioactive airborne effluents. Health impacts are calculated using radionuclide intake rates and dosimetric and health effects information. DARTAB is independent of both the environmental transport code used to derive estimates of environmental concentrations and the origin of the dosimetric and health effects data. Thus, DARTAB eliminates the need to write similar coding in every environmental transport code in order to calculate doses and health impacts. The DARTAB computer code was developed at Oak Ridge National Laboratory (ORNL) at the request of the U.S. Environmental Protection Agency (EPA) to be used by that agency as part of a methodology to evaluate health risks to man from atmospheric releases of radionuclides.

It is important to note that the approach to estimation of radiological health impacts as used in DARTAB is applicable only to low-level chronic exposure, since the health effects and dosimetric data were based on low-level chronic intakes. High-level exposures would lead to health effects estimates which are nonlinear with respect to exposure or intake. DARTAB and the dosimetric and health effects database <u>can not</u> be used with either short-term or high-level intake of radionuclides.

3.4.2.5.2 RADRISK

The RADRISK code is used to generate a database of dosimetric and health effects information for various nuclides of potential interest in environmental assessments. This data base can then be used in environmental assessments, given appropriate computer software. It is the purpose of DARTAB to provide the software which accepts the environmental exposure to and intake rates of the released material and combine these quantities with the information in the dosimetric and health effects database to yield tabulations of radiological health impacts.

3.4.3 Discussion of Input Parameters Versus Site Data

Input parameters relevant to characterization for the PRESTO and PATHRAE codes are given in Table 3-13. As can be seen in this table, many of the parameters discussed in previous sections are required. A review of input requirements for other systems codes such as ON-SITE/MAXI1 and RESRAD produce similar lists of parameters.

The available site data varies by operable unit (OU) and ranges from very little to comprehensive. The data quality for the existing RFP database remains uncertain at this time. No data validation studies have been identified regarding model parameter input data, qualification of uncertainty, or completeness of information as compared to modeling needs. Each OU has been studied separately under a varying set of criteria and objectives. In previous sections of this report model parameter requirements have been compared to existing available site data. Technical contacts were made with EG&G personnel via phone conversations regarding site data. A model parameter "checklist" was utilized in summarizing existing databases. The level of detail during this interview process was limited to general areas as described within the model parameters.

The exposure assessment database combines the databases from all of the previous sections plus the chemical and radiological contaminants. Operational Unit specific databases regarding chemical and radiological databases are also incomplete. The informational needs are identified by the various tables included in this and previous sections. The methods for data collection and evaluation are presented in Section 4.0 of this report.

TABLE 3-13

CODE PARAMETERS RELEVANT TO SITE CHARACTERIZATION

	PRESTO-II	PATHRAE-RAD	AIRDOS-EPA
Average annual precipitation	X		X
Average barometric pressure	X		
Irrigation rate	X	X	
Ratio observed to actual sunshine	X		
Average ambient temperatures (monthly)	X		X
Average dew point (monthly)	X		
Volume waste disposed in a facility		X	
Facility plan dimensions	X	X	X
Facility (waste) thickness	X	X	
Cap thickness	X	X	
Facility porosity	X		
Annual activity release fraction	X		X
Ratio cap to watershed infiltration	X	X	
Facility permeability	X		
Annual site infiltration	X	X	
Distance bottom of facility to aquifer	X	X	

TABLE 3-13 (Continued)
CODE PARAMETERS RELEVANT TO SITE CHARACTERIZATION

	PRESTO-II	PATHRAE-RAD	AIRDOS-EPA
Distance to intruder well	X	X	
Groundwater velocity (horizontal)	X	X	
Aquifer thickness	X		
Aquifer dispersion angle	X		
Aquifer porosity	X	X	
Vadose zone porosity	X		
Vadose zone permeability	X	X	
Longitudinal dispersivity		X	
Traverse dispersion coefficients		X	
Vadose zone fractional saturation		X	
Vadose zone residual saturation		X	
Vadose zone soil index		X	
Fraction of spillage		X	
Gravitational fall velocity	X		X
Mean wind speed	X	X	X
Deposition velocity	X	X	X
Lid height	X		X
Hosker roughness factor	X		X

TABLE 3-13 (Continued)
CODE PARAMETERS RELEVANT TO SITE CHARACTERIZATION

	PRESTO-II	PATHRAE-RAD	AIRDOS-EPA
Fraction of time wind blow toward population	X	X	X
User provided Chi/Q	X		X
Parameterization of resuspension	X		X
Resuspension rate (mechanical)	X	X	X
Stability class	X	X	X
Universal soil loss equation parameterization	X		X
Porosity, surface soil	X	X	
Soil density	X	X	
Flow rate of nearest stream/river	X	X	
Location, vertical and horizontal extent of surface contaminated areas	X	X	X
Runoff	X	X	
Surface erosion rate		X	
Waste density	X	X	X
Waste container life time		X	
Inventory in each facility/area	X	X	
Extent of any initial contamination on surface	X		
Initial activity in stream	X		X

TABLE 3-13 (Continued)
CODE PARAMETERS RELEVANT TO SITE CHARACTERIZATION

	PRESTO-II	PATHRAE-RAD	AIRDOS-EPA
Initial activity in air	X		X
Solubility in trench	X	X	
Distribution coefficient surface soil	X		
Distribution coefficient trench	X		
Distribution coefficient vadose zone	X	X	
Distribution coefficient aquifer	X	X	
Leach constant		X	

3.4.4 Conclusions on Model Selection

The following exposure assessment models are recommended to be used in conjunction with the model selections of previous sections in support of a human health risk assessment to be performed for each OU at the Rocky Flats Plant site.

- PRESTO-EPA, written by the EPA, calculates health effects to an exposed population from radioactivity escaping from shallow-land burial sites. This scenario is similar to the environmental conditions at RFP. DARTAB is used as a subroutine to calculate fatal cancers and genetic defects. RADRISK is a database containing the necessary radionuclide data and dose conversion factors required to run the model. This model is recommended due to the simplistic operating requirements and the overall ability to account for all exposure pathways and scenarios. PRESTO-EPA is available in a PC version.

- PATHRAE - The PATHRAE family of codes have multifunctions which enable them to handle a diverse mixture of radioactive and non-radioactive constituents. The present and future land use scenarios at RFP project many combinations of potential exposure from hazardous chemical and radioactive contaminants. On-site pathways are included from remediation activities, this is particularly useful as each OU is remediated separately versus site-wide remediation occurring at one time. The code is fairly simplistic to operate and is available on a PC.

4.0 DATA COLLECTION AND EVALUATION

In this section, data requirements of available contaminant fate and transport models are evaluated and data quality objective guidelines for the data are defined. Also, certain modelling parameters can have a profound effect on the accuracy and viability of the output (e.g., time-step used on iterative models). Therefore, the sensitivity of some of these parameters are evaluated and direction provided for the models to be recommended, as applicable. In addition, the dataset necessary to provide defensible exposure assessment values are evaluated and appropriate guidance provided.

4.1 Data Collection

This section discusses procedures for acquiring environmental, chemical release and exposure data for quantitative human health risk assessments at hazardous/radioactive or mixed waste sites.

4.1.1 Data Types

The data types required for the human health risk assessment include:

- contaminant identities;
- contaminant concentrations in key sources and media;
- source characteristics; and

- environmental characteristics that may affect fate, transport, and persistence of contaminants.

All risk assessment data needs should be identified as early as possible in the RI/FS process. This can usually be done at the site scoping meeting (EPA 1988d). Only data which completely satisfies the risk assessment data collection objectives can be used in the risk assessment. Background information on data quality objectives is addressed in Data Quality Objectives for Remedial Response Activities (EPA 1987c,d).

4.1.2 The Scoping Meeting

An aim of the scoping meeting is to develop specific project plans. These include the work plan and the sampling and analysis plan (SAP). The work plan and the SAP are based, in part, on the compilation and evaluation of existing data, the identification of further data needs, and the design of a data collection program to meet these needs. The compilation of existing data should include biological data, contaminant sources, contaminant fate data, quality assurance information, and precision and accuracy information. precision + accuracy is generally part of the analytical QA plan

If the conceptual understanding of the site is poor and the collection of site-specific data would greatly enhance the scoping effort, then a limited field investigation may be undertaken as an interim scoping task prior to developing the work plan.

Data already collected should be reviewed in accordance with existing guidelines (EPA 1987c). Data found to be acceptable should then be used to formulate a conceptual model of the site that identifies all potential or suspected sources of contamination, types and concentration of contaminants detected at the site, potentially contaminated media, and potential exposure pathways, including receptors.

4.1.3 Modeling Parameter Needs

Model data requirements are presented in Section 3.0. It is preferable to obtain site-specific values for as many of these input parameters as is feasible. However, EPA recognizes that if a model is not sensitive to a particular parameter, or if obtaining site-specific data would be too time consuming or too expensive, then a default parameter value may be used.

4.1.4 Background Sampling Needs

Background sampling may be required, in each medium of concern at or near the site in areas not influenced by ~~site~~ contamination, to distinguish site-related contamination from naturally occurring or anthropogenically generated levels of chemicals. The sampling plan must be designed to ensure that the number of samples collected are sufficient for any statistical hypothesis testing. Guidance on statistical methods is provided by EPA (1988e,f,g, 1989d).

Data from air monitoring stations and ground-water wells should be compared individually to background levels. The reason for this is that monitoring data cannot usually be combined because the placement of the monitoring points is purposive; in this case, sampling cannot be considered to be random sampling from a population.

As the number of individual comparisons with background data increases so does the probability of making a Type I error, i.e., rejection of the null hypothesis that there is no difference between onsite results and background levels. The design of sampling plans to minimize this kind of error is discussed by EPA (1989e).

A small number of background samples increases the likelihood of making a Type II error, i.e., failure to reject the null hypothesis when it is false, because large data differences, in this case, may not be statistically significant.

A statistically significant difference between onsite chemical soil concentrations and background should not, by itself, trigger a cleanup action. The toxicological significance of the contamination must be assessed.

4.1.5 Preliminary Identification of Potential Human Exposure

A preliminary identification of potential human exposure provides essential information for the sampling and analysis plan. It is necessary to collect information on media of concern. These include currently contaminated media or any currently uncontaminated media that may become contaminated in the future due to contaminant transport.

Within each operable unit the media of concern are to be sampled. Operable units should have non-overlapping boundaries and together should account for the entire area of the site.

Consideration of chemical properties is essential when devising sampling plans. For example, it may not be necessary to analyze ground water for a highly insoluble chemical.

Chemical species should be reported, e.g., valence states of metals, when toxicity is species-dependent.

4.1.6 Soil Sampling

Soil is a source both of contaminants released into other media and of direct contact exposure. Hence, the number, location, and type of samples collected from soils should be carefully determined. Guidance on soil sampling is provided in EPA documents (1986d,e, 1987e, 1989d).

Because of soil heterogeneity both the collection of representative samples can be difficult and the variation of analytical results can be significant. However, compositing samples should be avoided because this causes dilution which can obscure actual contaminant concentrations.

The sampling plan should consider characterization of hot spots through extensive sampling and observation because these may have a significant importance on direct contact exposures.

Sampling depths should be applicable to the exposure pathways and contaminant transport routes of concern and should be chosen purposively within that depth interval. It is preferable that surface samples be obtained from the shallowest depth that can be practically obtained.

4.1.7 Ground Water Sampling

Detailed information on ground water sampling can be found in EPA documents (1985c, 1987e,f, 1988e,f,h, 1989f).

Detailed consideration must be given to the quantification of hydrogeologic properties, the location and depth of wells necessary to adequately characterize the extent of contamination, and the potential for contaminant transport.

The analysis of filtered and unfiltered samples can provide important information on the mobility of contaminants by revealing the degree to which contaminants are partitioned between the aqueous phase and suspended particulate matter. Should a significant difference between the solution and suspended matter phases be detected then the result must be examined carefully for correct sampling technique and for well construction artifacts. A filter size of 0.45 mm may screen out some potentially mobile particulates to which contaminants are adsorbed and thus may under-represent contaminant concentrations. Pumping at too high a velocity may entrain particulates to which contaminants may be adsorbed and lead to an over-estimate of contaminant concentrations. Oxidation may lead to the formation of insoluble species which may under-estimate chemical concentrations. Well construction may elevate metal concentrations through corrosion.

~~The justification for not collecting filtered or unfiltered samples must always be stated in the sampling plan.~~

should be referenced in the data quality objective plan

4.1.8 Surface Water and Sediment Sampling

Nearby surface water bodies potentially receiving discharge from the site must be sampled. The sampling strategy ought to enable the identification of the contaminant source. Detailed guidance for surface water and sediment sampling is given in EPA and ASTM documents (EPA and COE 1981, EPA 1984b, EPA 1985d,e, EPA 1987e,f,g, ASTM, undated).

When lotic (free flowing) waters are sampled, samples should be collected across the channel, starting downstream moving upstream, and taking into consideration any upstream facilities that might affect flow volume or water quality.

When lentic (still) waters are sampled, samples should be taken through the thermal stratification. For small shallow ponds one or two samples may be adequate. Sediment sampling in flowing water should be conducted commencing downstream then moving upstream. Disturbance to sediment should be minimized. Sampling must always be conducted in a way that elucidates exposure pathways.

4.1.9 Air Sampling

Site-specific data should be collected in accordance with specific guidance for developing an air sampling plan for Superfund sites (EPA 1989g). EPA has issued numerous other guidance documents (EPA 1983b, EPA 1987e, EPA 1988i, EPA 1989h,i,j).

4.1.10 Biota

Sampled organisms should be those that are likely to be consumed by humans. Guidance on biota sampling is provided by SDA (1977) and EPA (1985e, 1987e, and 1989b,k).

Chemical concentrations should be measured in edible portions of the biota. Sampling should be conducted at representative seasonal times, and attention should be paid to any special food preferences.

4.1.11 Overall Strategy for Sample Collection

Sampling strategy guidance and statistical performance measures are contained in EPA documents (1985f, 1986d,f, 1987c,d,h,i, 1988i,j,k, Freeman 1989, EPA 1989d). Aspects of overal strategy are discussed below:

The error introduced by sampling procedures must be considered during the development of data quality objectives. Factors that can introduce sampling error include sampling/handling variability and the variability of contaminants as a function of location and time. These influences are essentially site specific. Analytical errors are largely site independent.

4.1.11.1 Sampling Strategy

The design of a sampling strategy is largely dependent on factors unique to each site, e.g., geology and hydrogeology. The sampling strategy will be, in part, dependent on the extent of previous sampling; it will also depend on whether or not the sampling is for site characterization or site validation.

It is more cost effective to conduct the sampling in a phased approach. In this way, uncontaminated areas located in an initial purposive sampling program can be omitted from the extensive investigation that better define the extent of contamination in contaminated areas.

The steps in a phased approach include the review of existing information and data, field screening, and intrusive sampling. Field screening, using field instruments, provides only a broad indication of the likelihood of contamination in a particular area. Intrusive sampling includes all methods in which a physical sample from the media of concern is obtained and analyzed to give exact information concerning the physical features or concentration of contaminants.

Questions which the sampling strategy should be designed to answer include:

- which media are contaminated?
- what is the average contamination?
- what is the maximum contamination?
- what is the mass and volume of the contamination?
- what area of the site is contaminated?
- what is the vertical and horizontal extent of contamination?
- What is the source of contamination

4.1.11.2 Sampling/Handling Variability

Sampling/handling variability is any introduced by the sampling and/or handling procedures which results in a contaminant concentration in the sample different from that in the medium sampled, e.g., variability due to cross contamination;. This kind of error, which is difficult to qualify, is minimized by using trained sampling personnel working in accordance with standard operating procedures (SOPs).

4.1.11.3 Temporal and Spatial Variability

Should it be expected that contaminations follow a cyclical pattern in time, then the period of the variation should be ascertained and sampling conducted over the cycle to obtain a representative sample.

Annual or seasonal sampling should be considered in order to account for variation in concentration of chemicals at seasonal extremes. To account for the variability of time series data, the collection and analysis of data must be carefully planned with the requirements of the final analysis incorporated in the sampling strategy. For example, if time series analysis is to be undertaken then the separation in time between sampling events must be carefully considered.

Spatial variability of contamination is to be expected and can be analyzed using ~~geostatistics.~~ geostatistical techniques

4.1.11.4 Sample Types

Two types of samples may be collected at a site: grab samples, which represent a single unique part of a medium collected at a specific location and time; and, composite samples, which are combined samples from different locations and/or times. Grab samples are preferable to composite samples for soil sampling because compositing introduces additional uncertainty in contaminant concentrations. However, for average concentrations over specified time periods in air and water media, compositing will be necessary.

4.1.11.5 Sampling Patterns

Purposive sampling while very useful for site contaminant characterization is not to be employed for risk assessment. The bias in data may lead either to an over-estimate or an under-estimate of the true conditions of the site. While there are some positive features to random sampling, systematic sampling, i.e., sampling on a regular grid whose coordinate origin is chosen randomly within an operable unit, is preferable in that it ensures that the sampling effort is uniform. Average concentrations obtained using systematic sampling require the calculation of special confidence intervals (EPA 1988i).

Subdivision of the site into operable units for which separate data are collected will assist in reducing data variability. When setting power and certainty estimates a statistician ought to be consulted in determining the minimum number of samples to be collected to achieve each objective.

When acquiring data which will be used to make general inferences concerning site characteristics it is important that samples provide complete coverage of the area of interest and that sample locations do not introduce bias. Bias in a data set causes the means of the data to be systemically different from the true mean.

4.1.11.6 Grid Systems

The majority of environmental sampling utilizes sampling at the grid intersections of a two dimensional square grid. The grid spacing can be selected on the basis of the knowledge of the typical areal extent of contamination at the site. If the typical site contamination can be assumed to spread over a circular area, then the grid spacing can be selected so as to guarantee a chosen probability of finding the contamination.

Stratification refers to the process of locating samples within distinct populations of strata. Stratification can be used to better define the vertical and horizontal extent of the contamination. This involves sampling, both horizontally and vertically, at points purposively located at regular intervals within squares of the grid, and at points located at regular intervals along the grid lines, about a grid intersection point at which contamination has been found.

4.1.11.7 Quality Control Samples

Various types of samples may be obtained during a remedial investigation in order to provide quality control information for data interpretation. Quality control samples are discussed below.

4.1.11.7.1 The Sampling Protocol

The sampling protocol for a risk assessment should include:

- a statement of the study objectives;
- procedures for sample collection, preservation, handling, and transport; and
- analytical strategies that will be used.

The emphasis of the sampling protocol should be on documentation of the conditions under which the sampling occurred and on the precision of the sample collector.

4.1.11.7.2 Sampling Devices

Sampling devices must neither add contaminants to nor deplete contaminants from the sample. Collecting procedures should not alter the medium sampled.

4.1.11.7.3 Special Analytical Services (SAS)

Special Analytical Services may be required if detection limits are needed which are below those obtained under the standard methods used by EPA Routine Analytical Services (RAS) or there are chemicals other than those on the Target Compound List (TCL) suspected at the site. SAS is discussed by EPA (1988l).

4.1.11.7.4 Background Samples

A background sample is one taken from the media characteristic of the site but outside the zone of contamination. This data should be defined as either natural or anthropogenic chemical contamination resulting from a source or sources other than the site undergoing the assessment.

I don't think background should be determined in an anthropogenic zone (natural or man influenced)

4.1.11.7.5 Critical Samples

Critical data points are sample locations for which valid data must be obtained in order for the sampling event to be considered complete, i.e., these are the vital sampling points. At these points it may be appropriate to collect a duplicate sample. Critical data points should be identified in every completeness statement developed during the data quality objective process.

4.11.1.7.6 Collocated and Replicate Samples

Collocated samples are independent samples collected in such a manner that they are equally representative of the parameter(s) of interest at a given point in space and time. Collocated samples, when collected, processed, and analyzed by the same organization, provide intralaboratory precision information for the entire measurement system including sample acquisition, homogeneity, handling, shipping, storage, preparation and analysis.

Replicate samples are samples that have been subdivided into two or more portions at some step in the measurement process. Each portion is then carried through the remaining steps in the measurement process. For field replicated samples, precision information would be gained on sample homogeneity, handling, shipping, storage, preparation and analysis. For analytical replicates, precision information would be gained on preparation and analysis.

Collocated samples can be used to estimate the overall precision of a data collection activity. Sampling error can be estimated by the inclusion of collocated and replicated versions of the same sample. If a significant difference in precision between the two subsets is found, it may be attributed to sampling error. As a data base on field sampling error is accumulated, the magnitude of sampling error can be estimated.

EPA recommends the inclusion of collocated and replicated samples in field programs:

- for ground surface water one collocated sample out of every 20 investigative samples should be collected (replicated samples could be substituted where appropriate); the samples should be spread out over the sampling event, preferably at least one per day of sampling; and

- for soil, sediment and solids one field replicated or collocated sample out of every 20 investigative samples should be collected (to estimate sampling error, collocated and field replicated samples should be of the same investigative sample); these samples should be spread out over the sampling event, preferably at least one per day of sampling.

4.1.11.7.7 Split Samples

Split samples are replicate samples sent to different laboratories. They serve as an oversight function in assessing the analytical portion of the measurement process.

4.1.11.7.8 Trip and Field Blanks

Trip blanks generally pertain to volatile organic samples only. Trip blanks are prepared prior to the sampling event in the actual sample containers and are kept with the investigative samples throughout the sampling event. They are packaged for shipment with the other samples and sent for analysis. There should be one trip blank included in each sample shipping container. At no time after their preparation are the sample containers to be opened before they reach the laboratory.

Field blanks are samples which are obtained by running analyte-free deionized water through sample collection equipment, after decontamination, and putting it in appropriate sample containers for analysis. These samples, which should be included in a sampling program as appropriate, are used to determine if decontamination procedures have been sufficient.

EPA suggests that blanks be collected in sampling programs in the following way:

- For ground and surface water, field blanks should be submitted at the rate of one field blank/matrix/per day or one for every 20 investigation samples, whichever results in fewer samples; and trip blanks should be included at a frequency of one per day of sampling, or as appropriate; and

- For soil, sediment, and solids, field blanks should be submitted at the rate of one for every 20 investigative samples for each matrix being sampled, or as appropriate.

4.1.11.7.9 Matrix Spikes

Many samples exhibit matrix effects in which other sample components interfere with the analysis of contaminants of interest. Matrix spikes provide the best measurement of this effect. When done in the field, immediately after collection, they also provide a measurement of sampling, handling and preservation error. The field matrix spike provides the best overall assessment of the accuracy of the entire measurement system. However, these are not generally recommended because of the high level of expertise required for proper preparation.

Often spiking is carried out in the laboratory to estimate the accuracy of the analytical method, reported as a percent recovery, for the site sample materials.

4.1.12 The Workplan and the Sampling and Analysis Plan (SAP)

The workplan documents the decisions and evaluations made during the scoping process and presents all anticipated future tasks involved in conducting the risk assessment. The SAP specifies the sampling strategies, the number, types, and locations of samples, and the level of quality control. The SAP consists of a Quality Assurance Project Plan (QAPP) and a Field Sampling Plan (FSP). The work plan and the SAP are written by the personnel who will be involved in the collection of samples, but must be reviewed by all personnel who will be using the resulting sample data for data completeness and methodological acceptability.

I do not think this sentence is relevant

The Workplan should describe:

- background sampling;
- quantification of all exposures;
- data needs for statistical analyses;
- data needs for fate and transport models;
- sample analysis/validation;
- data evaluation; and
- assessment of risks.

The SAP should include:

- a statement of the risk assessment objectives;

- detailed QA/QC procedures associated with sampling;
- detailed, site-specific procedures that will be followed to ensure the quality of the resulting samples; and
- information on sample location and frequency, sampling equipment and procedures, and sample handling task analysis.

Any proposed changes to the SAP must comply with SAP objectives.

this sentence may not always be true

4.1.13 Review of Field Investigation Outputs

Data obtained should be promptly reviewed to assess whether or not project objectives are being met. Changes to plan because of practical field difficulties should be thoroughly documented and the effects on the risk assessment evaluated.

4.2 Data Evaluation

For the evaluation of data, EPA (1989a) proposes a nine step organization of chemical data into a form appropriate for a baseline risk assessment. The steps are:

(1) gather all data available from the site investigation and sort by medium;

(2) evaluate the analytical methods used;

(3) evaluate the quality of data with respect to sample quantitation limits;

(4) evaluate the quality of data with respect to qualifiers and codes;

(5) evaluate the quality of data with respect to blanks;

(6) evaluate tentatively identified compounds;

(7) compare potential site-related contamination with background;

(8) develop a set of data for use in the risk assessment; and

(9) if appropriate, further limit the number of chemicals to be carried through the risk assessment.

Any changes to this step-wise process should be reviewed with the EPA Remedial Project Manager (RPM), and changes are to be fully documented. The involvement of the RPM in the decision-making process, and the documentation of all changes, including the reasons for the changes, are basic. requirements of the data evaluation process. The outcome of the data evaluation process is:

- the identification of a set of chemicals and radionuclides that are likely to be site-related; and
- reported concentrations that are of acceptable quality for use in the quantitative risk assessment.

The chemicals and radionuclides remaining in the quantitative risk assessment, based upon this evaluation, are sometimes referred to as "chemicals of potential concern".

4.2.1 STEP 1 : Combining and Sorting Data

All site data should be gathered together, ordered by medium, and presented in a readily understood format. An acceptable data presentation format is shown in Table 4-1. Any data which is to be left out of the final data set should be discussed with the RPM and then fully documented in the risk assessment report.

Data which were collected at the same location but at different times, if not significantly different and of comparable quality (i.e., if similar methods of analysis and similar QA/QC procedures were followed), may be grouped into the media-sorted set. Should the time-separated data differ significantly then it may be necessary to qualitatively analyze the impacts of temporal changes. Whichever course of action is pursued, the RPM should be consulted.

4.2.2 STEP 2 : Evaluation of Analytical Methods

Data should be further sorted by analytical method. Only data obtained by methods of approved rigor should be used in the risk assessment. Analytical results which may be broad indicators of contamination, e.g., TOC, or results of insensitive analytical methods, e.g., portable field instrument analyses, are not appropriate for quantitative risk assessment. Similarly, results for which QA/QC performance measures are unknown, few or nil should be eliminated from further quantitative use, although this same data may be useful in qualitative discussions of risk.

TABLE 4-1

EXAMPLE OF OUTPUT FORMAT FOR VALIDATED DATA

	Area X								
Sample Medium	Soil			Soil			Soil		
Sample ID	SRB-3-1			SRB-3-1DU			SRB-3-2		
Sample or Screen Depth	0-1'			0-1'			2-4'		
Data Collected	12/14/87			12/14/87			12/10/87		
Units	ug/kg			ug/kg			ug/kg		
Blanks or Duplicates				Duplicate					
ChemicaCRQL	Concentration	Qualifier	CRQL	Concentration	Qualifier	CRQL	Concentration	Qualifier	
Arochlor-1016	80	80	U	80	80	U	2000	2000UJ	
Arochlor-1221	80	80	U	80	80	U	2000	2000UJ	
Arochlor-1232	80	80	U	80	80	U	2000	2000UJ	
Arochlor-1242	80	80	J	80	42	J	2000	2000UJ	
Arochlor-1248	80	30	J	80	36	J	2000	2000UJ	
Arochlor-1254	160	120	J	160	110	J	2000	1800J	
Arochlor-1260	160	210		160	220		2000	2100	

The outcome of this step is a set of site data that has been developed according to a standard set of sensitive, chemical-specific methods, e.g., SW-846 Methods (EPA, 1986d), EPA 600 Methods (EPA, 1984c), CLP Statements of Work (EPA, 1988e,m), and QA/QC procedures that are well documented and traceable. Even so, the data can only be accepted when the remaining steps of the data evaluation process have been executed.

Data which were collected at the same location but at different times, if not significantly different and of comparable quality, i.e., if similar methods of analysis and similar QA/QC procedures were followed, may be grouped into the media-sorted set. Should the time-separated data differ significantly then it may be necessary to qualitatively analyze the impacts of temporal changes. Whichever course of action is pursued, the RPM should be consulted.

4.2.3 STEP 3 : Evaluation of the Quantitation Limits

This step involves the evaluation of quantitation and detection limits (QLs and DLs) for all of the chemicals assessed at the site. There are several cases to be considered.

Firstly, there are a number of substances currently on the Contract Laboratory Program (CLP), Target Compound List (TCL) and Target Analyte List (TAL) for which the Contract-Required Quantitation Limits (CRQLs) exceed either the corresponding reference concentrations for noncarcinogenic effects or the 10^{-4} incremental risk level for cancer using standard EPA assumptions for body weight and daily ingestion rate. In these cases the following steps may be taken.

When CRQLs exceed reference concentrations, then lower detection limits should be stipulated before the investigation begins. However, if Special Analytical Services (SAS) was not specified before work began, or the chemical was not detected in any sample from a particular medium at the QL, then it may be necessary to undertake a screening-level risk assessment using the Sample Quantitation Limits (SQLs) and then compare this risk with that posed by other onsite chemicals. Depending on the outcome of this assessment it may be necessary to:

- re-analyze selected samples, at lower QLs, if a sufficient amount of each sample remains; or, less preferably,
- eliminate the chemical from the quantitative risk assessment, noting that if the chemical were detected at a lower QL then it could contribute significantly to the estimated risk.

Secondly, in some cases the laboratory may report an unusually high SQL due, perhaps, to unavoidable matrix interferences. In these cases it may not be possible to reduce the SQLs using SAS procedures or other methods. In this case, the results with the unusually high SQLs should be excluded from the quantitative risk assessment if they cause the calculated exposure concentration to exceed the maximum detected concentration for the remaining samples of a particular set.

Thirdly, when some results are at the SQL the results are neither to be omitted from the analysis nor set to zero. The results should be taken to be one-half the SQL or the SQL if there should be some information to indicate which is more likely to be the better approximation. Most likely there won't be any clarifying information and the sensitivity of the risk assessment to the two approximations may be investigated by studying cases using first one approximation then the other.

Finally, when a laboratory reports limits other than SQLs then every effort should be made to obtain the actual SQLs because they are the lowest measured value which can be "trusted". When the SQL cannot be obtained, then for CLP sample analyses, the CRQL should be taken as the SQL with the understanding that these limits may overestimate or underestimate the actual SQL. When non-CPL methods have been used, the method detection limit (MDL) may be used for the SQL. However, the MDL will generally underestimate the SQL because the MDL does not account for sample characteristics or matrix interferences. The instrument detection limit (IDL) should rarely be used for non-detects because it does not account for any variability other than that arising from instrument operation.

The hierarchy of detection limits is IDL < MDL < SQL. As the hierarchy is traversed from left to right, more sources of analytical variability are accounted for. The CRQLs are chemical-specific, sample-independent limits set by the EPA which should be routinely and reliably achieved in the analyses of a variety of sample matrices. Therefore, depending on the nature of the particular sample the CRQLs may lie below or above the SQLs.

Generally, if a chemical is not detected in any samples of a particular medium then the data should be reported as either the SQL or CRQL with the U qualifier (see below) and subsequently eliminated from further consideration. However, if information exists that indicates that the chemicals are present, they should be retained for consideration in subsequent analyses.

At this stage, chemicals for which measurable concentrations (i.e., positive data) are reported, to which no uncertainties are attached concerning either the assigned identity of the chemical or the reported concentrations, are appropriate for use in the quantitative risk assessment.

4.2.4 STEP 4 : Evaluation of Qualified and Coded Data

Qualifiers and codes, usually related to QA/QC problems, are sometimes attached to data either by laboratory personnel conducting the analyses or by the data validation personnel. All qualified data must be carefully considered before being used in the quantitative risk assessment.

A list of generic laboratory qualifiers and data validation qualifiers are shown in Tables 4-2 and 4-3, respectively. The qualifiers do vary between regions and periodically vary within regions. It is crucially important to obtain the qualifier definitions operative at the time of the data analysis. The meaning of data qualifiers should never be guessed.

Should data possess both laboratory and data validation qualifiers, the data validation qualifier in all circumstances takes precedence. Where laboratory qualifiers alone appear then they are to be evaluated. In cases of uncertainty check with laboratory and/or data validation personnel.

Data qualifiers, and other site-specific factors, determine how data are to be used in a risk assessment. Data of qualified concentration but of unqualified identity should be included in the assessment.

TABLE 4-2

CLP LABORATORY DATA QUALIFIERS AND THEIR POTENTIAL USE
IN QUANTITATIVE RISK ASSESSMENT

Qualifier	Definition	Indicates Uncertain Identity?	Indicates Uncertain Concentration?	Include Data in Quantitative Risk Assessment?
Inorganic Chemical Data:[a]				
B	Reported Value is <CRDL, but >IDL.	No	?	Yes
U	Compound was analyzed for, but not detected.	Yes	Yes	?
E	Value is estimated due to matrix interferences.	No	Yes	Yes
M	Duplicate injection precision criteria not met.	No	Yes	Yes
N	Spiked sample recovery not within control limits.	No	Yes	Yes
S	Reported value was determined by the Method of Standard Additions (MSA).	No	No	Yes
W	Post-digestion spike for furnace AA analysis is out of control limits, while sample absorbance is <50% of spike absorbance.	No	Yes	Yes
*	Duplicate analysis was not within control limits.	No	Yes	Yes
+	Correlation coefficient for MSA was <0.995.	No	Yes	Yes

(continued)

TABLE 4-2 (continued)

CLP LABORATORY DATA QUALIFIERS AND THEIR POTENTIAL USE IN QUANTITATIVE RISK ASSESSMENT

Qualifier	Definition	Indicates Uncertain Identity?	Indicates Uncertain Concentration?	Include Data in Quantitative Risk Assessment?
<u>Organic Chemical Data:</u>[b]				
U	Compound was analyzed for, but not detected.	Yes	Yes	?
J	Value is estimated, either for a tentatively identified compound (TIC) or when a compound is present (spectral identification criteria are met, but the value is <CRQL).	No, for TCL chemicals; Yes, for TICs	Yes	?
C	Pesticide results were confirmed by GC/MS.	No	No	Yes
B	Analyte found in associated blank as well as in sample.	No	Yes	Yes
E	Concentration exceeds calibration range of GC/MS instrument.	No	Yes	Yes
D	Compound identified in an analysis at a secondary dilution factor.	No	No	Yes
A	The TIC is a suspected aldol-condensation product.	Yes	Yes	No
X	Additional flags defined separately.	--	--	--

-- = Data will vary with laboratory conducting analyses.

[a]Source: EPA 1988a.
[b]Source: EPA 1988b.

TABLE 4-3

VALIDATION DATA QUALIFIERS AND THEIR
POTENTIAL USE IN QUANTITATIVE RISK ASSESSMENT

Qualifier	Definition	Indicates Uncertain Identity?	Indicates Uncertain Concentration?	Include Data in Quantitative Risk Assessment?
<u>Inorganic and Organic Chemical Data:</u>[a]				
U	The material was analyzed for, but not detected. The associated numerical value is the SQL.	Yes	Yes	?
		No	Yes	Yes
J	The associated numerical value is an estimated quantity.	Yes	Yes	No
R	Quality control indicates that the data are unusable (compound may or may not be present). Re-sampling and/or re-analysis is necessary for verification.	--	--	--
Z	No analytical result (inorganic data only).	--	--	--
Q	No analytical result (organic data only).	Yes	Yes	?
N	Presumptive evidence of present of material (tentative identification).[b]			

-- = Not applicable.

[a]Source: EPA 1988 c,d.

[b]Organic chemical data only.

The J qualifier, meaning that the data is estimated, is most commonly encountered. J-qualified concentrations should be used in the same way aspositive data that do not have this qualifier. Appropriate caveats should be added if risk is assessed to be significant.

Validated, R-qualified data are to be rejected. If the data were qualified under the now superseded laboratory qualification system then the R-qualifier refers to estimated data due to a low spike recovery. In this case the data should be used in the risk assessment but significant outcomes should be covered by caveats based on the best knowledge of the data quality.

4.2.5 STEP 5 : Evaluation of Data Quality With Respect To Blanks

Field blanks, usually HPLC-grade water for groundwater, surface water, and leachate samples, and clean sand for soil and sediment samples, pass through the same field (and laboratory) procedures as field samples. These samples provide a means of identifying contaminants introduced during sampling.

The laboratory blank (reagent blank) has a similar function to the field blank with respect to the identification of contaminants introduced during laboratory preparation and analysis of samples.

Trip blanks are sealed pure water or clean sand samples which accompany containers to the field and back to the laboratory. Trip blanks enable checks to be made of contamination of samples which may arise from sample handling other than that involved in actual sample collection.

For certain common laboratory contaminants (EPA, 1988n,o) EPA recommends that sample results be considered positive only if the concentrations in the sample exceed ten times the maximum amount detected in any blank. If common laboratory contaminants are less than ten times the level of contamination noted in the blank, then they should be completely eliminated from the sample results. For all other contaminants, regarded by EPA to be non-common laboratory contaminants, results are to be taken as positive only if the measured concentrations exceed five times the maximum amount detected in any blank. Measured values less than this limit are to be classified as non-detects and the limit taken to be the quantitation limit for the chemical in that sample. Again, if all samples contain less than five times the level of contamination noted in the blank, then that chemical should be eliminated from the set of sample results.

4.2.6 STEP 6 : Evaluation of Tentatively Identified Compounds

Tentatively identified compounds (TICs) are substances not on the EPA's TCL but which are detected during sample analyses.

When few TICs are present, i.e., relative to the number of identified TAL and TCL compounds, and there is no historical evidence that a particular TIC may be present or that the TIC concentration may be high, TICs should not be included in the risk assessment.

When many TICs are present (i.e., relative to the number of identified TAL and TCL compounds), or there is good reason to believe that the TICs may be present and, perhaps, in high concentrations, then SAS should be used to identify and positively and reliably measure their concentrations prior to their use in the risk assessment.

EPA recognizes that it may not be possible, within practical constraints, to identify or measure the concentrations of the TIC with certainty. In this case, the chemical should be included in the risk assessment but all uncertainties should be noted.

4.2.7 STEP 7 : Comparison of Samples With Background

Background data should be obtained from samples collected from areas of the site or in the vicinity of the site which are unaffected by site contaminants. Reliance should not be put on non-site specific published data. The RPM should be consulted to help decide how comparisons with background data are to be made.

The site risk assessment must:

- contain the justification for the elimination of any chemicals based on a comparison with background levels;
- contain an overview of the type of comparison made with background samples; and
- evaluate background risk, including contributions from anthropogenic sources, independently of the site contaminant risk; the risk shall be assessed by the RPM in the context of the site remediation.

If inorganic chemicals are present at the site at naturally occurring levels they may be eliminated from the site quantitative risk assessment.

Organic chemicals should not be eliminated from the risk assessment unless a very strong case can be made for so doing. The presence of organic chemicals in background samples may indicate that the area from which the samples were taken has been affected by site contaminants and should be included in the site risk assessment.

4.2.8 STEP 8 : Data Set For Use In The Risk Assessment

At this stage of the data evaluation a compilation by medium should be made of all samples to be used in the risk assessment.

A list of chemicals, by medium, will also be needed for the risk assessment. This list shall include chemicals:

- positively detected in at least one sample using RAS or SAS methods including chemicals with no qualifiers and qualifiers indicating known identity but unknown concentration, but excluding samples with unusually high detection limits;
- with detected levels significantly above levels of the same chemicals detected in blanks;
- with detected levels significantly above naturally occurring levels of the same chemicals;
- classified as TICs associated with a site history or SAS identified; and/or

- which are transformation products of chemicals demonstrated to be present.

Non-detects, which may be at the site, also may be included if an evaluation of risk at the detection limit is required.

4.2.9 STEP 9 : Optional Reduction in The Number of Chemicals

In some cases there may be a large number of potentially site-related chemicals. Because of this, quantitative health risk assessments will generate a large amount of data which, by its nature, can lead to considerable difficulty in understanding. Therefore, it may be necessary to reduce the number of chemicals included in the risk assessment without eliminating the most important effects. An alternative, and a preferred option, to reducing the number of chemicals included in the analysis, is to group together in the main text of the report the list of chemicals that contribute 99 percent of the risk; the remainder of the chemicals can be presented in the Appendices.

However, if a reduction in the number of chemicals is required then activities which must be conducted before undertaking any reduction include:

- consultation with the RPM;
- consideration of the procedure for documenting the elimination rationale;
- an examination of site historical information chemicals for which there is a reliable association with site activities should be retained;

- consideration of concentration and toxicity of the chemicals; a chemical detected at low concentrations if it is a carcinogen should be retained;

- an examination of the mobility, persistence, and bioaccumulation potential of the chemicals; highly mobile or long-lived or bioaccumulatable chemicals should be retained;

- consideration of special exposure routes;

- consideration of the amenability to treatment; chemicals difficult to treat should be retained;

- an examination of applicable or relevant and appropriate requirements (ARARs); all chemicals with ARARs should be retained; and

- an examination of the need for the procedures.

Reductions in numbers of chemicals can be achieved by grouping chemicals into classes; e.g., the polycyclic aromatic hydrocarbons can be grouped together and the associated carcinogenic risk evaluated assuming the current sole potency factor applies to all members of the class.

Caution should be exercised when grouping chemicals:

- chemicals should not be grouped solely by toxicity characteristics;

- neither all carcinogenic nor all non-carcinogenic chemicals should be grouped without regard to structure, activity, or other chemical similarities; and

- potential over- or under-estimates of risk must be discussed in the report.

Chemicals may be considered for elimination from the risk assessment if:

- they are detected infrequently in one or perhaps two environmental media;
- they are not detected in any other sampled media or at high concentrations; and
- there is no reason to believe that the chemical may be present.

The RPM may use modeling to assess the spatial extent of chemicals which are infrequently detected. When setting cut-off frequencies of detection the following EPA requirement should be satisfied: if, for example, a five percent detection rate in all samples of a medium is set then at least twenty samples of the medium should be analyzed.

Chemicals expected to be present should not be eliminated from the risk assessment. Chemicals infrequently detected but with concentrations that greatly exceed reference concentrations should not be eliminated. Chemicals infrequently detected in soil should not be eliminated as a site contaminant if the same chemical is frequently detected in groundwater.

Chemicals that are:

- essential human nutrients;
- present at low concentrations (i.e., only slightly elevated above naturally occurring levels); or

support the calculation of exposure concentrations in the exposure assessment portion of the risk assessment (see Tables 4-4 & 4-5).

Requirements for the presentation of data collection and evaluation results are summarized below. The introduction should discuss:

- the steps involved in data evaluation in bullet form;
- the steps employed in the optional screening procedure, if used;
- historical data and current data, if used;
- whether site-specific considerations were used in data collection and evaluation; and
- general uncertainties concerning the quality associated with either the collection or the analysis of samples.

Next discuss:

- the samples from each medium selected for use in the quantitative risk assessment;
- the method of sample collection, including information on the number and location of samples; and
- the reasons for excluding any samples prior to data evaluation (excluded data may be used for qualitative discussions).

The data evaluation should be discussed:

- for those media that are potential sources of contamination for other media;
- either by medium, by medium within each operable unit, or by discrete areas within each medium in an operable unit;

NOTICE:

The page 137 of this document is out of sequence and is being refilmed after page 138.

The Administrative Record Staff

- toxic only at very high doses (i.e., much higher than those that could be associated with contact at the site),

need not be considered further in the quantitative risk assessment.

However, prior to eliminating such chemicals from the risk assessment, they must be shown to be present at levels that are not associated with adverse health effects.

A concentration-toxicity screen can be used to identify chemicals in a particular medium that most likely contribute significantly to risks calculated for exposure scenarios involving that medium. The most conservative toxicity values for a chemical should be used in the analysis. Chemicals for which there are no toxicity values cannot be screened and must be discussed in the risk assessment as chemicals of concern.

The risk factor for a chemical in a medium, useful only in the screening process, is the largest measured concentration of the chemical in the medium divided by the relevant reference dose or potency slope factor. The risk factor divided by the sum of risk factors for a medium provides a measure of relative risk for the chemical in the medium. Chemicals having a relative risk less than some agreed arbitrarily small cut-off can be eliminated from the risk assessment.

4.2.10 STEP 10 : Summary of Presentation of Data

The section of the risk assessment report summarizing the results of the data collection and evaluation should be titled "Identification of Chemicals of Potential Concern". Information in this section should be presented in ways that readily

TABLE 4-4

EXAMPLE OF TABLE FORMAT FOR PRESENTING CHEMICALS SAMPLED IN SPECIFIC MEDIA

Table X
Chemicals Sampled in Medium Y
(and in Operable Unit Z, if appropriate)
Name of Site, Location of Site

Chemical	Frequency of Detection[a]	Range of Sample Quantitation Limits (units)	Range of Detected Concentrations (units)	Background Levels
CHEMICAL A	3/25	5 - 50	320 - 6400	100 - 140
CHEMICAL B	25/25	1 - 32	16 - 72	--

-- = Not Available

* Identified as a chemical of potential concern based on evaluation of data according to procedures described in text of report.

a Number of samples in which the chemical was positively detected over the number of samples available

TABLE 4-5

EXAMPLE OF TABLE FORMAT FOR SUMMARIZING CHEMICALS OF POTENTIAL CONCERN IN ALL MEDIA SAMPLED

Table W
Summary of chemicals of
Potential Concern at Site X,, Location Y
(and Operable Unit Z, if applicable)

Chemical	Soils (mg/kg)	Groundwater (ug/L)	Surface Water (ug/L)	Sediments (ug/kg)	Air (ug/m^3)
CHEMICAL A	5 - 1000	--	2 - 30	--	--
CHEMICAL B	0.5 - 64	5 - 92	--	100 - 45,000	--
CHEMICAL C	--	15 - 890	50 - 10,000	--	--
CHEMICAL D	2 - 12	--	--	--	0.1 - 940

-- = Not available

- by source area for each medium, if several source areas with different types and concentrations of chemicals exist;

- including sample or data deficiencies for a particular medium;

- separating surface soils data from subsurface soils data;

- presenting groundwater results by aquifer; and

- separately treating surface water/sediment results by the specific water body sampled.

For each medium identify the chemicals for which samples were analyzed and list the analytes that were detected in at least one sample. If any detected chemicals were eliminated from the quantitative risk assessment, based on the evaluation of data, then the reasons for the elimination should be provided.

General trends in the data, locations of hot spots, and any trends in data in time should be discussed.

The data presentation format should include a separate table that includes all chemicals detected in a medium, for each medium sampled, or for each medium within an operable unit. All chemicals that have been determined to be of potential concern, based on the data evaluation, should be designated in the table with an asterisk (*) to the left of the chemical name.

For each chemical, report:

- the frequency of detection in each medium;

- the range detected or quantified values in the samples, i.e., the minimum and maximum detected values;

- the range of sample-specific reported QLs (only report CRQLs and MDLs, etc., when SQLs are not available) excluding eliminated values; and

- the naturally occurring concentrations with footnote sources.

The identity of the samples used in determining concentrations presented in the above table should be listed in a footnote.

The final table contains a list of the chemicals of potential concern presented by the medium within each operable unit (see Table 4-5).

5.0 SUMMARY

A study was performed in which exposure scenarios, computer models and data collection methods were selected for use in Baseline Risk Assessments of Rocky Flats Plant Operable Units. These Baseline Risk Assessments will be performed in the near future for each of the identified Operable Units. This study meets the following objectives:

- Define exposure scenarios to be used in performance of Baseline Risk Assessments;
- Review the draft demographics report for applicability and usefulness in scenario definition;
- Review environmental fate and transport models against selection criteria, site characteristics and site data requirements;
- Compare modeling parameter requirements with identified on-going site characterization programs; and
- Recommend the most appropriate contaminant fate and transport computer models for use in the Baseline Risk Assessment at the Rocky Flats Plant.

The impetus for performing this study is an Interagency Agreement between DOE and EPA to provide two technical memoranda which:

- "describe the present, future, potential and reasonable use exposure scenarios with a description of the assumptions made and the use of data. This memoranda shall be submitted prior to the required submittal of the Baseline Risk Assessment for each OU; and
- describe the fate and transport models that will be utilized, including a summary of the data that will be used with these

models. Representative data shall be utilized and limitations, assumptions and uncertainties associated with the models shall be documented."

This study is intended to meet the requirements of these two technical memoranda on a general, site-wide basis.

5.1 Development of Exposure Scenarios

Seven general potentially exposed populations or receptors are defined. None could be excluded based on projections in the draft "Rocky Flats Demographics Report" (EG&G, 1990). Also, the sources of potential exposure are identified:

- Volatilization of chemical contamination to the air;
- Emission of fugitive dust with chemical or radiological contamination, potentially resulting in airborne concentrations of these constituents, and deposition of dusts on foliage of crops and soils off-site;
- Soil ingestion from direct contact with contaminated soils by individuals entering the site;
- Percolation to groundwater and subsequent dispersion and intake;
- Contamination of surface water and subsequent dispersion and intake; and
- Dermal absorption of contamination due to contamination due to contact with contaminated soil or water.

The mathematical equations which are used to estimate the level of exposure at the receptor are briefly described for each source/pathway except where computer models would be used (e.g., groundwater transport).

The exposure scenarios for four major cases are developed:

- Present maximally exposed individual
- Future maximally exposed individual
- Present reasonable maximum exposure
- Future reasonable maximum exposure

Each of these cases are developed in terms of the potential receptors and sources identified earlier to form a set of assumptions which form the conditions of each exposure scenario. Even though use of less than the most restrictive exposure scenario carries with it the possibility of requiring deed restrictions on future land use, the reasonable maximum exposure scenarios are recommended for baseline risk assessment. This is consistent with EPA's most recent guidance (EPA, 1989a).

5.2 Environmental Fate and Transport Analysis Models

Contaminant fate and transport computer models currently available have been evaluated, compared and reviewed with respect to their applicability for use in the Baseline Risk Assessment. The most appropriate contaminant fate and transport computer models have been recommended for use in the Baseline Risk Assessments of RFP.

The models analyzed in this study include both the "EPA models" which have been verified and approved for use by EPA as well as some of the "non-EPA models" which include the balance of models available to the general public. The models analyzed are accepted, commonly-used environmental fate and transport and dose-response models that were either: (1) taken from the list of EPA's "risk assessment" models compiled in the Superfund Risk Assessment Information Directory; or (2) selected from publications and references using professional judgement on the applicability of a model in the risk assessment process. There are countless other models besides those which may also be acceptable and applicable.

The models have been loosely divided into four groups:

- Unsaturated zone and groundwater dispersion models;
- Surface water dispersion models;
- Airborne dispersion models; and
- Exposure assessment models

The objective in selecting codes is to provide a representative set of tools for quantifying and evaluating the likely impacts of site closure alternatives. Without additional information, it would be incorrect to prescribe specific computer codes for site-specific applications. Also, experience with those codes that are finally selected to simulate facility, transport, and exposure pathways is essential for a basic understanding of the performance assessment modeling. Typically, several computer codes will be used in the course of a performance assessment. These include groundwater flow and transport codes, atmospheric transport codes, surface water transport codes, and possibly, exposure assessment codes.

The criteria used to select models appropriate for use at the Rocky Flats Plant are shown below. The selected model(s) must:

- be able to adequately simulate site conditions;
- be able to satisfy the objective of the study (should be neither too simple or too complex);
- be verified, and reasonably well field tested; and
- be well documented, peer reviewed, and available.

The models are evaluated against these criteria, site conditions and data input requirements to arrive at a group of models which would be most appropriate for use at the Rocky Flats Plant. In addition, personnel involved in data acquisition programs underway at the RFP site have been contacted to identify areas where data availability may further limit the ability to use some models.

should we use "evaluated" rather than selected

Groundwater: Based on these criteria and the model descriptions, six groundwater models have been selected for potential use at the RFP site. This six models are: GREASE2, MOC, SWIFT, FLAMINCO, TARGET, and SWANFLOW. Each of the six possible models is suited to address particular problems. The conditions under which each class of model is applicable are as follows:

- two dimensional, horizontal models: commonly applied to saturated zone flow in which the ground water flow (and transport) are primarily horizontal. Vertical flow and vertical variation in contaminant concentrations are negligible compared to horizontal variations. Selected models are: MOC and TARGET.

- two dimensional, vertical (cross-sectional) models: commonly applied to localized unsaturated/saturated zone flow, in which flow is primarily vertical. The vertical section is usually oriented in the direction of horizontal flow (if any). Selected models are: FLAMINCO and TARGET.

- three dimensional models: commonly applied to areas where horizontal vertical flow are important. Selected models are: GREASE2, SWIFT, FLAMINCO, TARGET, and SWANFLOW.

Of these models, TARGET may be the best possible choice because of its versatility, availability, ease of use, level of documentation, and degree of field testing.

Surface Water: Based on the selection criteria and model descriptions, eight surface water models have been selected for potential use at the Rocky Flats Plant site. Where extensive data collection and evaluation permits, the HSPF model is recommended. Otherwise, for each of three applications, different models are more appropriate than others:

- Nonpoint Source Runoff Models -- From the standpoint of data requirements, history of applications, and meeting the objectives of the study with reasonable accuracy, SWMM, appears to be the most appropriate model for continuous simulation for this component of the study. The next best choices appear to be CREAMS, and ACTMO, respectively. If the scope of the study permits extensive data collection and acquisition and sufficient time to complete the study, then HSPF appears to be the best choice.

For event-based simulation, SEDIMOT-II appears to be the best choice. This model does not simulate the transport of dissolved constituents. These constituents can be estimated by approximate analytical approaches.

- Surface Water Runoff Models -- For the simulation of continuous stream flow and pollutant transport, HEC-6 and WQRRS appear to be the most appropriate choices. HEC-6 can simulate flow and sediment transport whereas WQRRS can model all other water quality parameters including total suspended solids. If the scope of the study warrants extensive data collection and acquisition and sufficient time for completion of the study, then HSPF appears to be the preferred model.

  For routing storm runoff and sediment load generate by that runoff through the streams and holding ponds, SEDIMOT-II appears to be the best choice.

- Surface Water Transport Models -- For continuous simulation of reservoir sedimentation and water quality HEC-6 and WQRRS are judged to be the best choices. So far as the simulation of reservoir water quality is concerned, CE-QUAL-R1 US AWES and WQRRS are very similar models. However, WQRRS is preferred here because it can simulate both stream and reservoir water quality. If the scope of the study permits adequate time for extensive data collection, then the more sophisticated HSPF model will be appropriate.

  For event-based simulation of sediment routing through Stanley Lake and Great Wester Reservoirs, SEDIMOT-II appears to be the preferred model.

Airborne Dispersion: A number of models are available for airborne dispersion modeling. Since the scope of application covers many broad areas, a grouping was developed to allow easier model selection based on the particular modeling requirements for an RFP operating unit:

- Complex Terrain Models -- The preferred model for complex terrain is COMPLEX1. This is essentially a screening model. If a more refined modeling analysis is required, RTDM should be used. RTDM requires more intensive meteorological data, although it is capable of handling a worst case "fictitious" data set, and therefore application of RTDM might be limited, given availability of data for an RFP operating unit.

- Simple Terrain Models -- The ISCST model is the preferred model for use with simple terrain (receptors having an elevation equal to or less than the source evaluation). ISCST is capable of handling point, area, and volume sources. ISCST can account for gravitational settling and deposition. Time variability of emission rates also make this model, by far, the most comprehensive one available.

- Instantaneous Models -- INPUFF is the recommended model for treatment of instantaneous and quasi instantaneous releases from point sources. This model can also be adapted for use with short duration open burning emissions.

Exposure Assessment: Radiological exposure assessment is similar to that for chemical exposures; however, beyond the inhalation, ingestion, and absorption, radiological exposure must include external radiation effects, radioactive decay and ingrowth factors among others. Synergistic effects should also be considered and discussed in the Risk Characterization section of the Human Health Risk Assessment.

A number of models have been developed specifically for radionuclides, some of which can also accommodate chemical contaminants. With the presence of radioactive materials at RFP, models having features such as radioactive decay and daughter in-growth may be particularly useful.

Of the codes analyzed, the PATHRAE family of codes (PATHRAE-EPA, PATHRAE-RAD, and PATHRAE-HAZ) have features which make them applicable to a wide range of nuclear and hazardous waste disposal analyses. One advantage of PATHRAE is that a version for nonradioactive hazardous species has also been developed and applied to activities at the Savannah River Plant. Thus, by adopting the PATHRAE codes as system codes, the problem of addressing both radioactive and non-radioactive species can be handled with a high degree of consistency.

The PATHRAE methodology is comprehensive and models both off-site and on-site pathways through which individuals may come in contact with the waste. The off-site pathways include groundwater transport to a surface river or well, surface (wind or water) erosion, and atmospheric transport. The on-site pathways of concern arise principally from worker exposures during operations and from post-closure site reclamation (intruder) activities such as living and growing edible vegetation on-site and drilling wells for irrigation or drinking water.

5.3 Data Collection and Evaluation

Data requirements of available contaminant fate and transport models are evaluated and data quality objective guidelines for the data are defined. Also, certain modeling parameters can have a profound effect on the accuracy and viability of the output (e.g., time-step used on iterative models). Therefore, the sensitivity of some of these parameters are evaluated and direction provided for the models to be recommended, as applicable. In addition, the dataset necessary to provide defensible exposure assessment values are evaluated and appropriate guidance provided. Guidance is provided in each of the following areas:

- data types
- the scoping meeting
- modeling parameter needs
- background sampling needs
- preliminary identification of potential human exposure
- soil sampling
- ground water sampling
- surface water and sediment sampling
- air sampling
- biota sampling
- overall strategy for sample collection
- work plan and sampling and analysis plan preparation
- data review

It is recommended that field sampling programs incorporate and follow this guidance to yield data which will hold up to subsequent data evaluation and incorporation in the Baseline Risk Assessment.

For the evaluation of data, EPA (1989) proposes a nine step organization of chemical yield data which will hold up to subsequent data evaluation and incorporation in the Baseline Risk Assessment.

For the evaluation of data, EPA (1989) proposes a nine step organization of chemical data into a form appropriate for a baseline risk assessment. The steps are:

(1) gather all data available from the site investigation and sort by medium;

(2) evaluate the analytical methods used;

(3) evaluate the quality of data with respect to sample quantitation limits;

(4) evaluate the quality of data with respect to qualifiers and codes;

(5) evaluate the quality of data with respect to blanks;

(6) evaluate tentatively identified compounds;

(7) compare potential site-related contamination with background;

(8) develop a set of data for use in the risk assessment; and

(9) if appropriate, further limit the number of chemicals to be carried through the risk assessment.

Guidance is provided for the strict compliance with each of these steps as well as the final step of data presentation. Any changes to this step-wise process must be reviewed by the EPA Remedial Project Manager (RPM), and all changes are to be fully documented. The outcome of the data evaluation of the data evaluation process is:

- the identification of a set of chemicals that are likely to be site-related; and
- reported concentrations that are of acceptable quality for use in the quantitative risk assessment.

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