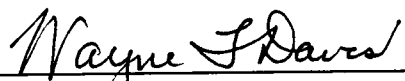
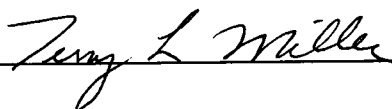
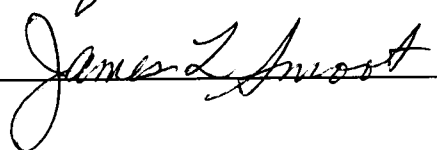


To the Graduate Council:

I am submitting herewith a thesis written by Irene Datskou entitled "Use of the Multimedia Environmental Pollutant Assessment System (MEPAS) in a Baseline Risk Assessment." I have examined the final copy of this thesis for form and content and recommend that be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental Engineering.


Wayne T. Davis, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Associate Vice Chancellor
and Dean of The Graduate School

USE OF THE MULTIMEDIA ENVIRONMENTAL POLLUTANT ASSESSMENT
SYSTEM (MEPAS) IN A BASELINE RISK ASSESSMENT

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Irene Datskou
August 1993

DEDICATION

This Thesis is dedicated to my family
Panagiotis, George, and Christs

ACKNOWLEDGMENTS

Few scientific endeavors have ever been the product of a sole investigator, and this certainly has not. Without the help of several individuals this study would never have been completed.

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ABSTRACT

A risk assessment has been performed for two waste sites that are part of the Department of Energy (DOE) complex. The Multimedia Environmental Pollutant Assessment System (MEPAS) has been used for the risk assessment to be performed. Population and Maximum Individual Risks have been estimated as well as risks from noncarcinogenic contaminants. MEPAS is a set of computer analysis tools that calculates exposure and human health risk estimates for waste sites, based on the initial problem as was specified by the user. MEPAS is not intended for detailed analysis of an individual site, but rather to compare risks among groups of sites.

The first site that has been analyzed here used to be a burial ground for a wide variety of radioactive, organics, and inorganic wastes. There is a nearby well that is used almost daily. In 1973 it was determined that significant amounts of radioactivity were escaping from the burial ground to soil and to groundwater. The risks to the receptors using the well have been assessed, and a comparison was made between predicted and measured concentrations. MEPAS overpredicted the concentrations by at least an order of magnitude.

The second site was a waste pit and it is believed that it is the source of a groundwater uranium plume that is located 7000 ft away. A risk assessment has been performed for this site, and the model predicted and measured concentrations have been compared. The model overpredicted the concentrations by at least an order of magnitude.

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ACRONYMS AND ABBREVIATIONS

ANL	Argonne National laboratory
CERCLA	Comprehensive Environmental Response, Compensation, and En
CSM	Conceptual Site Model
DOE	Department of Energy
EIS	Environmental Impact Statement
EPA	Environmental protection Agency
ER	Environmental Restoration
FEMP	Fernald Environmental Management Production
ICRP	International Commission on Radiological Protection
MEI	Maximum Exposed Individual
MEPAS	Multimedia Environmental Pollutant Assessment System
NEPA	National Environmental Policy Act
NOAA	National Oceanic Atmospheric Administration
PEIS	Programmatic Environmental Impact Statement
PSZ	Partially Saturated Zone
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recover Act
RfD	Reference Dose
SZ	Saturated Zone
VOC	Volatile Organic Compound
WM	Waste Management
cfs	cubic feet per second
fps	feet per second
ft	feet

mi ²	square miles
nCi/l	nanoCurie per liter
pCi/l	picoCurie per liter

CHAPTER 1

INTRODUCTION

1.1 Background

For several decades, the U.S. Department of Energy (DOE) and its predecessor agencies have been involved in a wide range of activities that have generated hazardous substances, both chemical and radioactive. The enactment of environmental regulations such as the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Resource Conservation and Recovery Act (RCRA) require that action be taken to identify and reduce or eliminate, in an environmentally responsible manner, the potential hazards related to past and current disposal activities.

On October 22, 1990, DOE announced its intent to prepare a Programmatic Environmental Impact Statement (PEIS) in accordance with the National Environmental Policy Act (NEPA), which requires federal agencies to prepare an Environmental Impact Statement (EIS) on major federal actions that may significantly effect the environment (DOE, 1992). An integral part of the PEIS includes the estimation of human health risk posed by hazardous waste sites within the DOE complex and the estimation of the potential risk reduction provided by a range of remedial action alternatives. To estimate near- and long-term human health risks associated with contaminant releases, a computer code entitled the Multimedia Environmental Pollutant Assessment System (MEPAS) was selected.

MEPAS simulates the transport of chemical and radioactive contaminants

through environmental media to potential human exposure points. MEPAS is a set of computer programs that calculates exposure and human health risk estimates for waste sites, using generally accepted models to simulate the movement of contaminants through the environment to human receptors (Whelan, *et. al.*, 1987). The model considers four major transport pathways for contamination migration: groundwater, overland, surface water, and atmospheric. Each pathway is described by empirically, analytically, and/or semianalytically based mathematical algorithms.

Sites and facilities within the DOE complex are evaluated and categorized into groups (source categories) that represent unique types of sites or facilities (source types). Source categories perform similar functions and share similar physical characteristics. The following source categories can be found within the DOE complex:

- contaminated facilities
- buried wastes
- contaminated soils
- contaminated surface water
- contaminated groundwater.

The facilities source category refers to buildings or structures that are characterized by occupation or access by humans on a regular or semi-regular basis. Sites and facilities classified under the buried waste category include sites used for the dumping or disposal of solid or liquid wastes. The soils source category refers to both surface (surficial) soils and the partially saturated (vadose) subsoils. The surface water source category includes both flowing (lotic) surface water sites and standing (lentic) surface water impoundments, either of which may contain contaminated sediments. Groundwater refers to both confined and unconfined aquifers (perched aquifers are included with unconfined aquifers).

Two release sites were analyzed for this thesis. The two sites are not in proximity to each other and each one represents a different source category. One of these sites represents the groundwater source category and the other one represents the buried waste source category.

A baseline human health risk evaluation was performed for both release sites.

Risks or health effects posed by contaminants are documented as the endpoints of the human health risk assessment. The endpoints considered are as follows:

- hazard index
- cancer fatalities
- cancer incidence (fatal and nonfatal)
- adverse genetic effects.

Cancer risks (from chemical carcinogens and radionuclides) are estimated for both on-site and off-site populations and maximally exposed individuals (MEI). The MEIs are the individuals on-site and off-site who receive the highest individual dose within the given population. Health effects (from noncarcinogens) are estimated only for the MEI.

The health effect endpoints, for total population risks, are not expressed as percentages but as the total number of individuals who may potentially experience adverse health effects. Health effects from noncarcinogens are evaluated by comparing the exposure level over a specified time period (e.g., lifetime) with a reference dose (RfD) derived for a similar exposure period. This ratio is known as the Hazard Index, which indicates the possibility for systemic toxic effects (EPA, 1992).

Cancer incidence (both fatal and nonfatal cancers), for chemical carcinogens, is estimated using cancer potency factors. Cancer potency factors represent an upper bound estimate of the probability of a carcinogenic response per unit intake of a chemical over a lifetime (EPA, 1992). Cancer fatalities, cancer incidence, and genetic effects from exposure to radionuclides are derived by multiplying the cumulative effective dose equivalent by fatal risk factors as taken from ICRP 60 (ICRP, 1991).

In addition to the risk assessment, MEPAS predicted concentrations were compared to "real", measured, concentrations for the same exposure location. The concentrations predicted by the model were plotted against the sampling data presented in site characterization reports. These site characterization reports are results of the ongoing environmental monitoring and surveillance program at the site. A site characterization report that was published by N.W. Golchert in 1991 contains annual maximum and average concentrations for several sampling periods within a year.

The second site studied in this report is a buried waste site. The same comparison between measured concentrations and MEPAS predicted concentrations was performed also for this site. The site was in use between 1959 and 1977. It is estimated that it contains approximately 248,000 pounds of uranium and 880 pounds of thorium. It is believed that this site is the source of groundwater contamination. A ^{238}U groundwater plume has been formed approximately 7,000 feet away from the release site. The necessary assumptions that have to be put into the model were discussed and were applied so that the groundwater plume could be shown where it is today.

1.2 Baseline Human Health Risk Evaluation

This is termed a baseline human health risk evaluation because all data and analyses were not discounted in any way to reflect an improvement in conditions that might occur if remediation of the release sites were undertaken. Risks posed by the release sites are estimated by evaluating exposure pathways. An exposure pathway is the course a chemical or a physical agent takes from a source to a potential receptor. The identification of exposure pathways of concern is determined by evaluating all the components necessary to complete a potential exposure pathway. These components are as follows:

- source and transport medium (or media)
- potential receptors
- exposure routes (*i.e.*, ingestion, inhalation)

For an exposure pathway to be considered complete, each of these components must exist and must be linked to the others. A conceptual site model (CSM) illustrates transport media and exposure route relationships at a site, serving as a tool for illustrating whether an exposure pathway is complete.

Estimating the magnitude of human health risk posed by a site requires the identification of potential receptors and the extent of their access to the release site.

Access to a release site is determined by the institutional controls at the site. Institutional controls at hazardous waste sites are remedial actions that mitigate health risks by limiting human activities or access to the site (White *et al.*, 1992). Institutional controls act by physically restricting land-use of the site; for example, by erecting and maintaining fences with security guards, patrols and warning signs.

The baseline human health risk evaluation examined two levels of institutional controls:

- No Institutional Controls
- Institutional Control in Perpetuity

No Institutional Controls

According to the National Contingency Plan (NCP), which implements the regulatory requirements established by CERCLA, a baseline risk assessment must consider risk in the absence of institutional controls. The baseline risk assessment should address the potential land use associated with the highest level of exposure and risk. During the periods of no institutional controls it is assumed that a subsistence farm family of four lives at the release site. The on-site farm family is assumed to obtain drinking water and irrigate crops and water animals from ground water drawn at the site. The total intake of farm products by an individual of the family is assumed to be the following: leafy vegetables, 30 kg/yr; other vegetables, 640 kg/yr; meat, 98 kg/yr; and milk, 276 kg/yr (EPA, 1992).

Health risks estimates for the farm family would be far greater than actual current public risks with institutional controls. However, if the risks for the farm family are unacceptable, then this argues that institutional controls should remain in place to prevent those risks from actually occurring.

Institutional Controls in Perpetuity

For this scenario the release site is assumed to be operational with indefinite limited public access. The individuals that serve as receptors under this scenario are the population within a 50-mi radius . Potential exposure routes are defined based on 1980-census data and site-specific information.

1.3 Risk Characterization

1.3.1 Quantification Of Carcinogenic Risk

For carcinogenic contaminants, risks were estimated as the excess probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen via a specific pathway.

Simultaneous exposures to several radionuclides and chemical via more than one pathway can be assessed. The risk of developing cancer from simultaneous exposure to several contaminants is based on the assumption that carcinogenic risks are additive (EPA, 1989b).

EPA has established a target risk range of $1\text{E-}6$ to $1\text{E-}4$ for risks from exposure to radionuclides and chemicals (EPA, 1990c). When a baseline risk assessment indicates that an individual's cumulative risk, derived using reasonable maximum exposure assumptions for either current or future land use, exceeds $1\text{E-}4$ (i.e., 1 in 10,000 chance of developing cancer), action is generally warranted at the site. For sites where this cumulative risk to an individual is less than $1\text{E-}4$, action generally is not warranted. However, EPA has expressed a preference for remediation to achieve the more protective end of the target risk range (1 in 1,000,000 or $1\text{E-}6$ chance of developing cancer).

1.3.2 Quantification of Noncarcinogenic Risk

The potential for noncarcinogenic effects on health is evaluated by comparing an exposure level with a reference dose (RfD) (EPA, 1989a). This ratio of exposure to toxicity is called a hazard quotient. The hazard quotient assumes that a level of exposure exists (reference dose RfD) below which it is unlikely for a receptor to experience adverse health effects. If the exposure (E) exceeds this threshold (i.e., if E/RfD exceeds unity), the potential exists for noncarcinogenic effects to develop. As a rule, the greater the value of E/RfD above unity the greater the level of concern (EPA, 1989a). However, the ratios of E/RfD shouldn't be interpreted as probabilities; a ratio of 0.001 does not mean that there is a one in a thousand chance of the effect to occur, but it indicates only that the estimated intake is 1000 times less than the reference dose. In the case of simultaneous exposure of a receptor to several chemicals, a hazard index (HI) will be calculated as the sum of the hazard quotients.

1.4 MEPAS Framework

The MEPAS code is a physics-based method that integrates source-term, transport, and exposure models to compute risk indicators for hazardous and radioactive waste sites. MEPAS uses empirical, analytical, and semi-analytical mathematical algorithms and a pathways analysis. It has the ability to transport contaminants through and between multiple environmental media, including subsurface or ground water, surface water, overland and atmospheric media. In addition the model can simulate the exposure to the population through food chain, ingestion, inhalation and dermal contact and estimate the health effects associated with the defined exposure (Whelan et al., 1987). The health risk indicators computed by MEPAS, such as population risk maximum individual risk, time of arrival of contamination, reflect the results of the multimedia source term, transport, and exposure assessment.

To use MEPAS the user first defines the environmental problem to be evaluated. The user must characterize the hazardous substances present, potential sources of

releases, determine appropriate transport and exposure pathways, receptor locations, and determine the number of individuals exposed or potentially exposed. After the problem is defined and structured, MEPAS uses a transport model to predict contaminant concentrations at the specified exposure points via the specified pathways. Using these predicted concentrations, MEPAS calculates three measures of risk: the Hazard Potential Index (HPI), a measure of population risk, the Maximum Individual Risk (MIR), a measure of individual risk, and the reference dose (RfD), an estimate of health effects for a noncarcinogenic chemical (Whelan *et al.*, 1987).

The HPI is used as a measure of the potential for human health impact from the release unit in question. It combines the potential human health impacts from all transport and exposure pathways of concern for a given constituent. The HPI has the following characteristics:

- reflects toxicity and mobility of a constituent
- considers time of contaminant arrival
- considers the size of population exposed

The MIR is based on the highest exposure from each of the pathways identified for the release site. The total intake for the individual is the sum of the highest intakes for each exposure pathway. The MIR is reported in addition to HPI.

In MEPAS, risks are assessed in 100 successive 70-yr time intervals (each corresponding to an average human lifespan), for a total of 7,000 years. Exposure point concentrations are always averaged within each 70-yr interval: the MIR and HPI are based on these average concentrations. Exposure variations within each 70-yr time period are not addressed.

1.5 Modeling Assumptions

Several modeling assumptions are made in the baseline evaluation. For the farm family, it is assumed that the well where they draw the water from is located at the site boundary, where no plume dispersion has occurred. For off-site receptors the exact locations where domestic wells are located are evaluated. Also, because MEPAS does not currently partition, environmental concentrations are assumed to be constant (*i.e.*, concentrations were not reduced by loss due to removal processes such as volatilization, leaching, and biodegradation). Thus the model assumes that all of the contamination is released to each medium (*i.e.*, the exposure concentrations were assumed to be 100% of the estimated concentration in air, soil, or ground water). Note that this assumption will likely cause overestimates of actual risks.

CHAPTER 2

THE MULTIMEDIA ENVIRONMENTAL POLLUTANT ASSESSMENT SYSTEM (MEPAS): MATHEMATICAL FORMULATIONS

Computer models, no matter how complex, represent simplifications of real-world conditions. Complex computer codes are usually developed to address detailed mechanistic phenomena, hence the large number of input parameters. Simplified codes handle less of the detailed phenomenological aspects of the real-world conditions by combining many of these aspects into fewer parameters. The following sections review the mathematical formulations for contaminant transport in the groundwater, and atmospheric environments as used by MEPAS.

2.1 Groundwater Pathway

The groundwater component of MEPAS provides estimates of groundwater contaminant concentrations and/or fluxes at various transporting medium interfaces (*i.e.*, water table surface and edge of stream) and at withdrawal wells (Whelan *et. al.*, 1987).

Contaminant concentrations at transporting medium interfaces and withdrawal wells provide contaminant levels for the exposure assessment component of the model.

Contaminant fluxes at transporting medium interfaces represent boundary conditions for the next medium that is to simulate contaminant migration and fate (*e.g.*, groundwater contamination entering a surface water environment).

2.1.1 Introduction

The migration and fate of contaminants through the groundwater (*i.e.*, subsurface) environment are described by the three-dimensional advection-dispersion equation for solute transport. The results are based on semi-analytical solutions (*e.g.*, solutions that require numerical integration) that are well established in the scientific literature (Whelan *et. al.*, 1987). To increase the computational efficiency of the integration, limits of the integration are also identified. A schematic diagram illustrating the groundwater environment is presented in Figure 2.1-1.

2.1.2 Assumptions of the MEPAS Groundwater Component

The groundwater model accounts for mobility, persistence, advection, and hydrodynamic dispersion of the specific constituent in the groundwater environment. The mobility is described with an equilibrium coefficient that assumes instantaneous adsorption/desorption between the soil matrix and pore water. Persistence is described with a first-order degradation/decay coefficient and for radionuclides the groundwater component accounts for decay as well. Advection is described by a constant, unidirectional flow in the vertical direction in the partially saturated zone (PSZ) and by a constant, unidirectional flow in the longitudinal direction in the saturated zone (SZ). Hydrodynamic dispersion is described in three dimensions. In addition, other assumptions built into the code are:

- All aquifer properties are homogeneous and isotropic
- Flow in both the PSZ and SZ is uniform. MEPAS uses a one-dimensional, unsteady, semianalytical code to simulate contaminant leaching and movement through the PSZ.

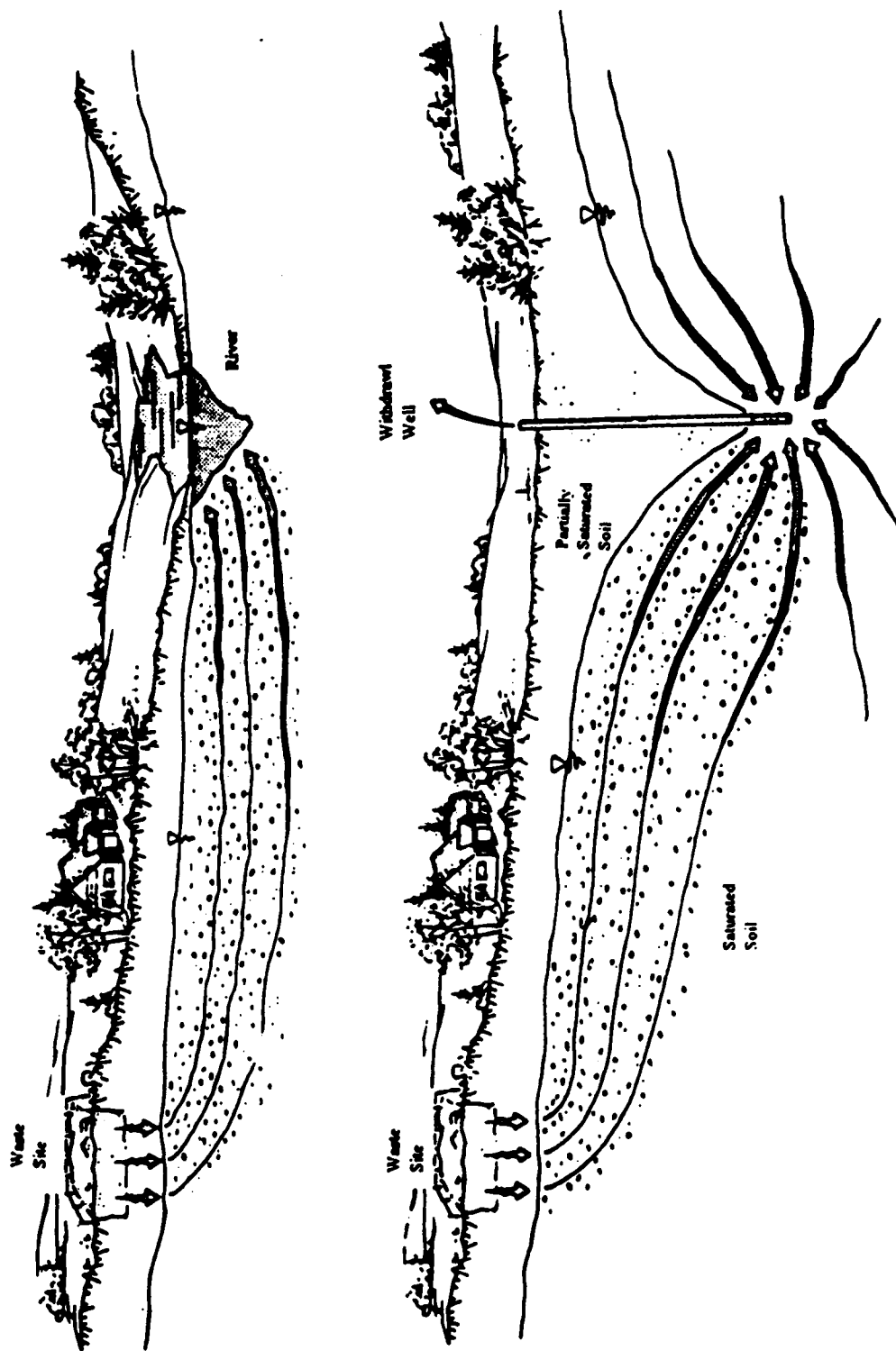


Figure 2.2-1 Schematic Diagram Illustrating the Atmospheric Environment (Source: Whelan et. al., 1987).

- The predominant movement of the leachate in the SZ is assumed to be in the direction of the groundwater flow.
- The groundwater environment is free of initial contamination .
- The effects of withdrawal well drawdown and other transient stresses on the saturated aquifer are not considered in the semianalytical solutions. Hydraulic gradients and flow velocities are assumed to be provided by the user.

2.1.3 Advection-Dispersion Equation

The advection-dispersion equation for solute movement through a porous medium with a constant, steady-state flow velocity forms the basis for all groundwater solution algorithms. A partial differential equation is used to describe advective, dispersive contaminant transport with degradation/decay through the subsurface environment:

$$\frac{\partial C}{\partial t} + u^* \frac{\partial C}{\partial x} = E^*_x \frac{\partial^2 C}{\partial x^2} + E^*_y \frac{\partial^2 C}{\partial y^2} + E^*_z \frac{\partial^2 C}{\partial z^2} - \lambda C \quad (1)$$

in which: $u^* = u / R_f$.

u = the x-component groundwater (pore water) velocity.

R_f = retardation factor.

$E^* = E / R_f$.

E_x, E_y, E_z = dispersion coefficients in the flowing voids in the x-, y-, and z- directions respectively.

$R_f = 1 + \beta k_d / n_e$ (for the saturated zone).

$R_f = 1 + \beta k_d / \theta$ (for the partially saturated zone).

where: C = dissolved concentration in the liquid phase in voids filled with

flowing water.

λ = time constant.

β = bulk density (g/ml).

k_d = equilibrium coefficient (ml/g).

θ = moisture content (fraction)

n_e = effective porosity (fraction).

By solving the above equation with the appropriate boundary and initial conditions a set of semianalytical expressions is obtained that characterize the transport of contaminants through the partially saturated and saturated groundwater zones. These expressions are based on Green's functions and have been reported by several researchers (Whelan, *et al.*, 1987). These equations are generalized for arbitrary time-varying releases by using the convolution integral as presented below (Whelan *et al.*, 1987):

$$C(\tau) = \int f(t) C_i(\tau-t) dt \quad (2)$$

where:

- $C(\tau)$ = contaminant concentration at time τ (g/ml).
- τ = time over which contaminant concentration is computed (s).
- $f(t)$ = source term expressed as a temporally varying contaminant flux (g/s or Ci/s).
- C_i = instantaneous solute concentration at location x , y , and z , and time $(\tau - t)$ for an instantaneous source release (cm^3 or l).

In an attempt to preserve computational accuracy and to help ensure an efficient implementation time, upper and lower integration were defined by the MEPAS developers such that a reasonable and efficient time frame could be developed for defining the source term for routing contaminants through successive media.

The integration limits can be approximated by a) assuming a point source and its accompanying analytical Green's function solution in the direction of flow, b) taking the second derivative with respect to time, c) setting the derivative to zero, and d) iteratively solving for the upper and lower integration limits.

2.1.4 Mixing Length

When a contaminant travels through a medium from a waste site to a receptor of concern, such as a well, the contaminant is temporally and spatially redistributed. Because contaminant levels are spatially distributed at any designated receptor, one contaminant concentration does not describe the spacial distribution unless the fully mixed condition exists (Droppo *et. al.*, 1989). Because the exposure component of MEPAS requires only temporally distributed contaminant concentration per receptor location, the contaminant concentration of the fully mixed region is used. A vertical mixing length is used when computing the contaminant levels at a well.

The vertical mixing length is the vertical distance over which contamination at a well is considered fully mixed. Over this vertical region, the contaminant concentration is assumed to be uniformly mixed in the vertical direction and is used in computing the potential risk to populations surrounding the well (Whelan *et. al.*, 1987).

At some distance downgradient from a waste site releasing contaminants to an aquifer of constant depth, the concentration near the surface of the water table can be considered to be fully mixed over some distance in the vertical direction. The vertical dispersion is not influenced by the vertical dimensions of the aquifer close to the point of release; the mixed region is considered to be very small (Whelan *et. al.*, 1987). As the vertical dimension of the aquifer becomes more of an influence in the spatial distribution of the contaminants, the mixed region increase in vertical extent until a fully mixed condition exists over the depth of the aquifer.

2.1.5 Retardation Factor

The retardation factor is used as a measure of the mobility of the constituent in a porous media. It represents the ratio of the mean pore water velocity to the mean contaminant migration velocity and can be expressed in a number of ways. One representation is as follows (Whelan et. al., 1987):

$$R_f = \frac{n}{n_e} + \frac{\beta}{n_e} k_d \quad (3)$$

where β = bulk density (g/ml)

k_d = equilibrium coefficient (partition or distribution) (ml/g).

The groundwater algorithm used by MEPAS currently employs the following equation:

$$R_f = 1 + \frac{\beta}{n_e} k_d \quad (4)$$

In this equation it is assumed that dead-end pore spaces exist in the porous medium through which no water or contaminants flow. In this equation the ratio of total-to-effective porosity is set to unity. This equation assumes that matrix diffusion does not take place. Using equation (2) the user can set the retardation factor equal to unity (for k_d equaling zero), thereby, resulting in a more conservative calculation as the contaminant movement is now retarded to a lesser degree.

2.1.6 Measured Concentrations in the Groundwater Environment

Often, contaminant levels have been measured in nearby drinking-water or observation wells prior to a complete remedial investigation at a waste site. Instances also occur where monitored contaminant levels are available, but the nature, extent, and sometimes source of contamination are unknown.

A risk assessment methodology should be flexible enough to handle cases where only monitored information is available from which to perform an analysis. The version of MEPAS used for the present study (MEPAS Version 2.3g) does not have that capability. However, a newer version of MEPAS to be released late 1993 is to provide the user with such a flexibility.

The MEPAS methodology will be structured to allow investigators to assess the human health impact by directly using the monitored information for the contaminants in concern in the risk analysis. In that case, no waterborne modeling will be performed.

If monitoring information is used, the MEPAS methodology requires the investigator to supply a representative concentration for each constituent being analyzed. This single concentration is assumed to be temporally constant, although first-order degradation/decay can be included in the analysis. Using measure concentrations in the groundwater environment represents a significant improvement for MEPAS.

2.1.7 Summary

In the subsurface environment, contaminants migrate through a partially saturated or saturated groundwater zone. MEPAS is using a one-dimensional, unsteady, semianalytical code to simulate contaminant leaching through the partially saturated zone. The predominant movement of the leachate in the saturated zone is assumed to be in the direction of the groundwater flow (Droppo *et al.*, 1989). Solutions for the advection-dispersion equations for the partially saturated and saturated zones have been formulated in terms of an instantaneous contaminant release (Whelan *et al.*, 1987).

2.2 Atmospheric Pathway

Complex phenomena are associated with the migration and fate of contaminants released to the atmosphere. The atmospheric component of MEPAS considers release mechanisms and characteristics, dilution, washout by cloud droplets and precipitation, and deposition on the underlying surface cover. The atmospheric pathway component computes contaminant levels as a function of direction and distance that coincides with population centers surrounding a release unit. Inhalation represents the major route of exposure to contaminants via the atmospheric pathway. MEPAS also considers the ingestion route of exposure through the food chain, from wet and dry deposition on vegetation, and subsequent ingestion of contaminated food materials derived from the soils. In addition, external dose can be addressed, though its effects are usually insignificant as compared to the inhalation exposure route.

2.2.1 Introduction

The long-term average exposure in the atmospheric pathway is based on a 70-year increment which represents the sum of exposures from individual atmospheric plumes. The approach taken for modeling the long-term, average exposures involves a weighted summation of exposures from individual hourly average plumes. Exposures are computed for a matrix of cases spanning ranges of ambient atmospheric conditions. Climatological data are used to represent the average conditions of the area surrounding the site of interest. These climatological summaries are in terms of the average frequency of occurrence of the various combinations of ambient atmospheric conditions and these frequencies allow for the computation of long-term, average exposure by a weighted summation of the matrix of exposures. A schematic diagram illustrating the atmospheric pathway is presented in figure 2.2-1.

The atmospheric pathway considers contaminant air concentrations and deposited surface concentrations. Air concentrations are needed for inhalation pathways, and surface concentrations resulting from dry and wet removal processes are needed for

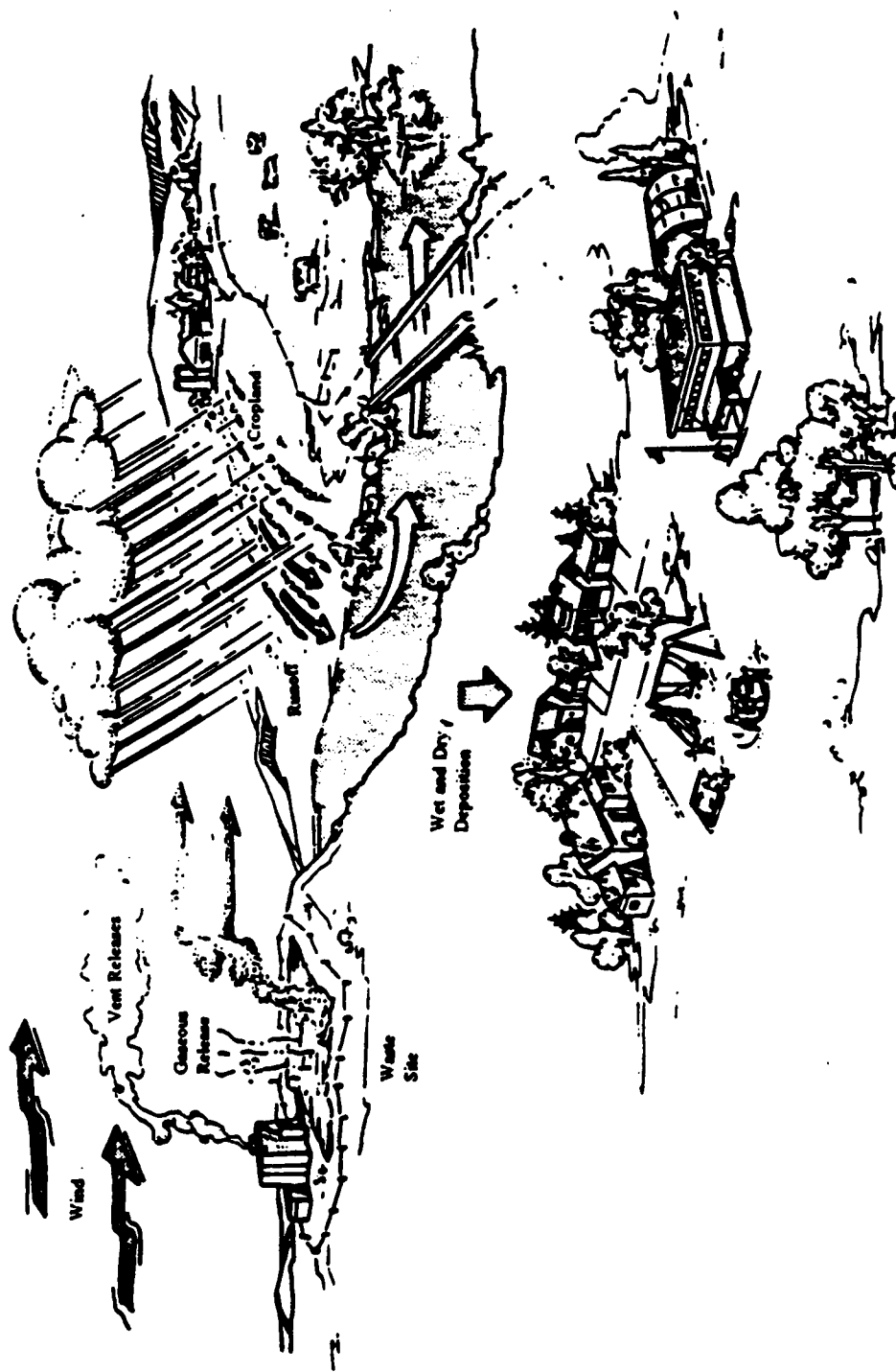


Figure 2.1-1 Schematic Diagram Illustrating the Groundwater Environment: a) Contaminant Levels or Fluxes at a Surface Water Boundary and b) Contaminant Levels at a Withdrawal Well (Source: Whelan et al., 1987).

overland transport and for ingestion pathways.

The implementation of emission rates are accomplished in MEPAS using seven deposition classes which represent the constituent properties. Depending on the properties of a constituent the constituent is assigned to a dispersion class. The constituent data base in MEPAS contains a default entry for deposition class for each constituent. Table 2.2-1 presents the definition of deposition classes as used by MEPAS.

Table 2.2-1 Definition of Deposition Classes as used by MEPAS

Deposition Class	Class of Constituent
1	particles with average radius = 7.5μ
2	particles with average radius = 3.0μ
3	particles with average radius = 0.3μ
4	gas with moderate surface resistance (s/cm)
5	nondepositing gas
6	gas emission that deposits as Class 1 particle
7	gas with fast deposition rate (zero surface resistance)

2.2.2 Suspension of Surface Particles

Particulate fugitive releases of contaminants are defined as emissions resulting from the suspension of exposed surface contamination. The potential for suspension of contaminants varies greatly because of the wide variety of surface types and activities expected on the surfaces. The suspension of particles may occur because of wind

action, local activity such as animal grazing, or vehicular traffic, walking, or earth moving. Such events greatly increase the fugitive particulate releases compared to an undisturbed surface (Droppo *et. al.*, 1989).

2.2.3 Volatilization Component

The volatilization component is usually a secondary pathway of concern when compared with groundwater, surface water, stacks, and suspension. However, under certain conditions, the volatilization pathway can dominate the human health impact of an environmental problem. MEPAS provides two methods of addressing volatilization:

- the volatilization rates are computed by the model
- the volatilization rates are input by the modeler.

The user can choose from the following list the most appropriate description for the specific release site under analysis:

- Landfill / with or without gas generation
- Spills, leaks, land farms
- Ponds, rivers, lagoons

2.2.4 Transport, Dispersion, and Deposition

Once the contaminant material is airborne, the material is transported and dispersed by air movement. The contaminants will be carried by the winds, and the atmospheric contaminant concentration will be reduced by dispersion and deposition processes. Controlling parameters include the distance and direction from the inactive waste site and local wind conditions and stability.

The MEPAS atmospheric component is using six classes of atmospheric stability to characterize the dispersion rates. The atmospheric classes are designated by the letters A to F and are commonly referred to as the Pasquill stability categories (Droppo *et. al.*, 1989).

A standard straight-line, sector-averaged Gaussian model was selected as the basis of the atmospheric pathway model.

The Gaussian diffusion equation for the concentrations of a contaminant in a plume downwind of a continuous point-source release (Whelan et al. 1987) is given by:

$$C_k = \frac{Q_k}{2\pi\sigma_y\sigma_z u} \exp\left[-\frac{y^2}{2\sigma_y^2}\right] f(z, H, \sigma_z) \quad (5)$$

where: C_k = time-averaged value of concentration for contaminant form k (g/m³)

Q_k = emission rate for the specific constituent (g/s)

k = index on element contaminant form

x, y, z = positions in a cartesian coordinate system that are oriented such that the x -axis is in the directional of the mean horizontal wind vector, the y -axis is crosswind, and z -axis is vertical height above local ground level (m).

σ_y = standard deviation of the distribution of the material in a plume in the y -direction.

σ_z = standard deviation of the distribution of the material in a plume in the z -direction.

u = average value wind speed in the x -direction at the height of the plume centerline (m/s).

H = effective height of release over local ground level (m).

$f(x, H, \sigma_z)$ = functional relationship for the vertical variation of plume concentrations (dimensionless).

The function $f(x, H, \sigma_z)$ in equation (3) has the form of a sum of exponential terms representing the Gaussian dispersion from the actual plume as well as virtual images (Whelan et al. 1987). As a practical matter, the summation can be truncated after a few terms centered on zero. MEPAS uses a range -4 to +4 (Droppo et al. 1989).

The average concentration is computed by multiplying the integrated concentration formula as appears in equation (3) by the frequency of a given set of conditions divided by the width of the sector at the distance of interest.

The sector-averaged concentration for one set of wind speed, direction, and stability conditions is given by (Droppo et al. 1989):

$$C_{ik}(x,z) = Q_k R_k(x) \sqrt{\frac{1}{2\pi}} \frac{n}{U_i \sigma_{z_j} 2\pi x} f(z, H, \sigma_{z_i}) \quad (6)$$

where: $C_{ijk}(x,z)$ = sector-averaged atmospheric concentrations for wind speed i , stability condition j , and contaminant k (g/m³).
 form
 i = index on wind speed
 j = index on stability conditions.
 $R_k(x)$ = deposition and/or decay plume source depletion fraction, which varies as a function of the position x of the plume for contaminant form k (dimensionless).
 u_i = wind speed central value for wind speed interval class i (m/s).
 σ_{z_i} = standard deviation of concentration in vertical for stability class j .
 n = number of wind direction sectors ($n = 16$).
 $(2\pi x / n)$ = sector width.

The removal of the contaminants from the atmospheric plume is computed using the depletion factor term $R_k(x)$. $R_k(x)$ is a function of the radioactive decay, chemical

decay, dry deposition decay, and wet deposition decay.

The average air concentration near the earth's surface is input to the inhalation component of the health assessment. The average air concentration $C(x,y)$, at ground level is computed as the sum of concentrations over the i, j, k indices, given by (Droppo et al. 1989):

$$C(x,y) = \sum \sum \sum [f_{ij} C_{ijk}(x,z)] \quad (7)$$

where: f_{ij} = climatological fraction frequency of occurrence of the wind speed (i) and stability class (j) conditions within the specified direction (dimensionless).

The table of frequencies of occurrence of the f_{ij} values is referred to as a joint frequency summary. These data are available as STAR summaries from the National Climatic Data Center, National Oceanic Atmospheric administration, NOAA, in Asheville, North Carolina.

2.2.5 Summary

The prediction of contaminant movement through the atmospheric pathway uses algorithms that address atmospheric suspension/emission of contaminants at a site and the subsequent transport, diffusion, and deposition of these airborne contaminants. Input to the model includes site-specific climatological information such as wind speed and direction, stability, and precipitation. Output from the model consists of average air and surface contaminant levels that are then used in the inhalation and ingestion components, respectively, of the exposure assessment analysis. The surface contaminant levels also represent input to the overland transport components of MEPAS.

2.3 Exposure Component

One key feature of the exposure component is the estimation of the average exposure. The exposure models included in MEPAS are as follows:

- drinking water ingestion
- aquatic food ingestion (fish and invertebrates)
- crops
- animal products
- water immersion (domestic bathing and swimming)
- soil ingestion
- inhalation

The exposure assessment portions of MEPAS are based on models recommended by the U.S. Nuclear Regulatory Commission (NRC) that are similar to models used by other organizations involved in radiological exposure assessments (NRC 1977).

The exposure analysis provides the average individual dose for each contaminant. Two types of dose are calculated in MEPAS. One for radionuclides, and is expressed as the effective whole-body dose equivalent received from each contaminant over the lifetime of an average member of the population. The dose for the chemicals is expressed as the average daily intake of each contaminant by an average member of the population.

CHAPTER 3

GROUNDWATER PLUME SITE: Argonne National Laboratory (ANL)-Plot M

3.1 Introduction

Argonne National Laboratory (ANL) is a DOE energy research and development laboratory with several principal objectives. ANL began operations during the World War II effort to develop an atomic bomb. At the present time it conducts a broad program of research in the basic energy and physical, chemical, material sciences, and serves as an important engineering center for the study of nuclear and nonnuclear energy sources. ANL occupies 1,700 acres in DuPage county, Illinois. The site is 27 miles southwest of downtown Chicago and 24 miles west of Lake Michigan. Waterfall Glen Nature Preserve, a 2,041-acre nature preserve operated by the DuPage county forest preserve district, completely enriches the ANL site. From 1947 to 1954, the ANL was located 3 miles east of its current location in what is now part of the Palos Park Forest Preserve. This preserve is now a public recreation area.

3.2 Description of Site

Plot M, an inactive burial ground for a wide variety of radioactive, organic, and inorganic wastes, is located off-site on public land in the Palos Park Forest Preserve. Figure 3.2-1 presents the area surrounding ANL and Plot M. The only portion of the Forest Preserve in the immediate area of Plot M that is developed for public use is the Red Gate Woods picnic area, although small numbers of individuals use the remote areas of the Preserve (Golchert, 1992). The site was fenced through most of its

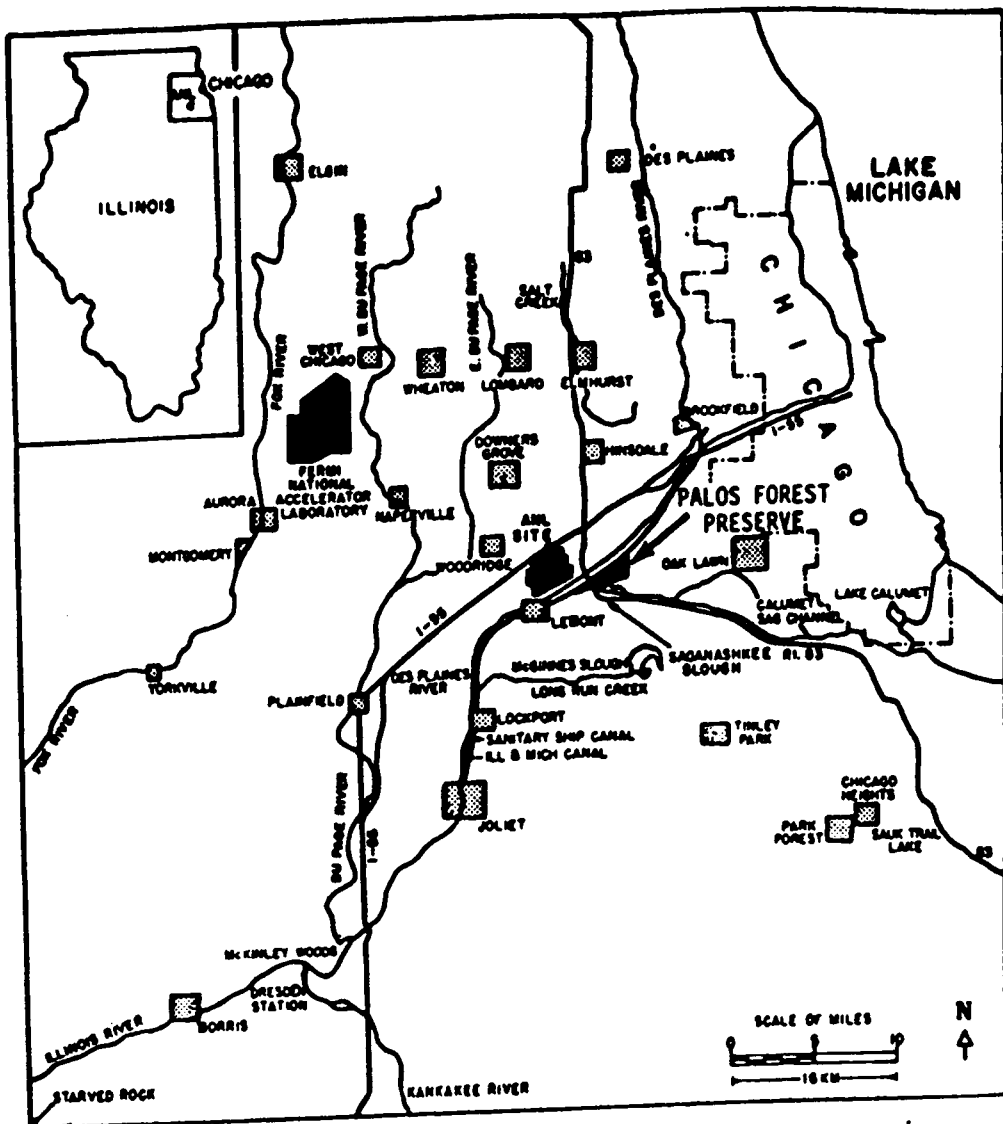


Figure 3.2-1 ANL and Plot M Location (Source: Golchert, 1987).

operating life, and from July 1949 until January 1956 the waste disposal site was undisturbed. In 1956 the site was covered by an inverted concrete cap to reduce infiltration of precipitation. Releases from the site are contaminating the groundwater with tritium and potentially other radionuclides, organics, and inorganics. The site may be releasing the same contaminants to the surface water as well.

3.2.1 Contaminants of Concern

Plot M area is a less than 1-acre waste burial site that was used from 1943 to 1949. The types of material disposed of varied over the years. These included liquid wastes, animal carcasses, and a variety of contaminated materials. Various alternatives, including removal of the waste, were evaluated in the early 1950s. It was decided that waste removal would be too risky for the workers and the environment. Instead, an inverted concrete box extending 8 feet below the ground was constructed in 1956 over the plot. The top of the box was 1 foot thick and was covered with an additional 2 feet of soil and seeded with grass . Uncertainty about the exact location of the graves that were used for the waste disposal as early as 1946, however, raises the question as to whether all the waste is covered under the inverted box.

Releases from the site are contaminating the groundwater with tritium and potentially other radionuclides, organics, and inorganics. The following table (table 3.2-1) presents the constituents and their expected quantities that may pose potential risk to human health.

Table 3.2-1 Constituent Inventory for Plot M

Contaminants	Inventory
Manganese	3.26E5 g
Strontium-90	1.78E-3 Ci
Sulfate	2.27E8 g
Tritium	3.99E2 Ci
Lead	1.69E3 g

3.2.2 Physical Characteristics / Environmental Setting

3.2.2.1 Soil

The Palos Park Forest Preserve lies in the Calumet Sag Channel and Des Plaines River valleys and is bordered on the north and northwest by the Des Plaines River and the Chicago Sanitary and Ship Canal and to the south by the Calumet Sag Channel. The terrain is wooded and slopes for 725 feet above sea level to 625 feet above sea level at the canal (DOE, 1988).

3.2.2.2 Hydrogeology

The soils at ANL consist of 50 to 150 feet of glacial till overlying dolomite bedrock of Niagaran and Alexandrian dolomite. Older dolomites and sandstones underlie these formations. The beds are nearly horizontal. Two principal aquifers are used as water supplies in the vicinity of ANL. The upper aquifer is the Niagaran and Alexandrian dolomite that is about 200 ft thick and is recharged by precipitation (PNL, 1992). The lower aquifer is the Galesville sandstone that lies between 500 ft and 1500 ft below the surface. Maquoketa shale separates the upper dolomite aquifer from the underlying sandstone aquifer and that shale retard hydraulic connection between the two

aquifers (Golchert *et al.*, 1991).

3.2.2.3 Surface Water

Surface water at Palos Park consists of swamps, ponds, and intermittent streams. When there is sufficient water, the intermittent stream that drains Plot M, flows from the highest point, past Plot M, then continues near the Red Gate Woods well and discharges into the Illinois and Michigan Canal (Golchert *et al.*, 1991). .

3.2.2.4 Climate

The climate of the region can be categorized as being continental with relatively cold winters and hot summers. The area is subject to frequently changing weather as storm systems move from the Great Plains toward the east. The weather is slightly modified by Lake Michigan, that is about 24 miles east of Palos Park. An average of 33 inches of precipitation fall each year (Golchert *et al.*, 1991). .

3.3 Baseline Alternative

The baseline alternative addresses risks posed by a release site when no remedial actions occur. The following exposure scenarios were considered for this alternative

- No Institutional Controls
- Institutional Controls in Perpetuity

For each of these two scenarios a different set of receptors was assumed.

- A hypothetical farm family, representing conditions of no institutional controls
- Actual off-site populations representing conditions of institutional controls at the release site

3.3.1 No Institutional Controls

Before construction of the concrete cap in 1956, infiltrating water from precipitation leached tritium and other contaminants to the ground water system. The pattern of contaminant concentration in the plume, especially tritium, indicates that it is not an accumulation of 13 annual slugs (1943-1956) but rather a single slug due to

above-normal recharge in 1 year (Olimpio, 1984). Although at the present time, Plot M area has become a public recreational area there is a form of institutional controls since the land-use is restricted, as well as well-drilling is prohibited. Assuming, however, elimination of these prohibitions, potential exposure pathways for an on-site hypothetical farm family include exposure to contamination transferred to the groundwater, surface water and food chain. Since the contamination is treated as a groundwater problem other pathways, such as direct soil ingestion, air, runoff to surface water can be eliminated. Figure 3.3-1 illustrates the site conceptual model that represents the periods of no institutional controls.

The following potential contaminant transport pathways were modeled for the baseline alternative under no institutional controls:

- Plot M → Groundwater → Receptor
- Plot M → Groundwater → Surface water → Receptor

Plot M → Groundwater → Receptor

The groundwater in the area has been confirmed to contain elevated levels of tritium, sulfate, and manganese (Golchert, 1992). Start date of the ranking is set at 1943 (PNL, 1992). According to permeability studies at Plot M the partially saturated zone is described as glacial till consisting mostly of silt (60%) and clay (30%) (Olimpio, 1984). The saturated zone (sz) was modeled as sandy loam (DOE, 1991), and the effective porosity was calculated according to MEPAS guidelines while the total porosity and the bulk density of the sz were chosen as the representative values (PNL, 1989). The on-site well is located 150 feet from the site and is assumed to be used by the farm family for bathing, irrigation of crops, and water of animals, as well as a drinking water source. Climatological data was obtained from the O'Hare International airport (PNL, 1992).

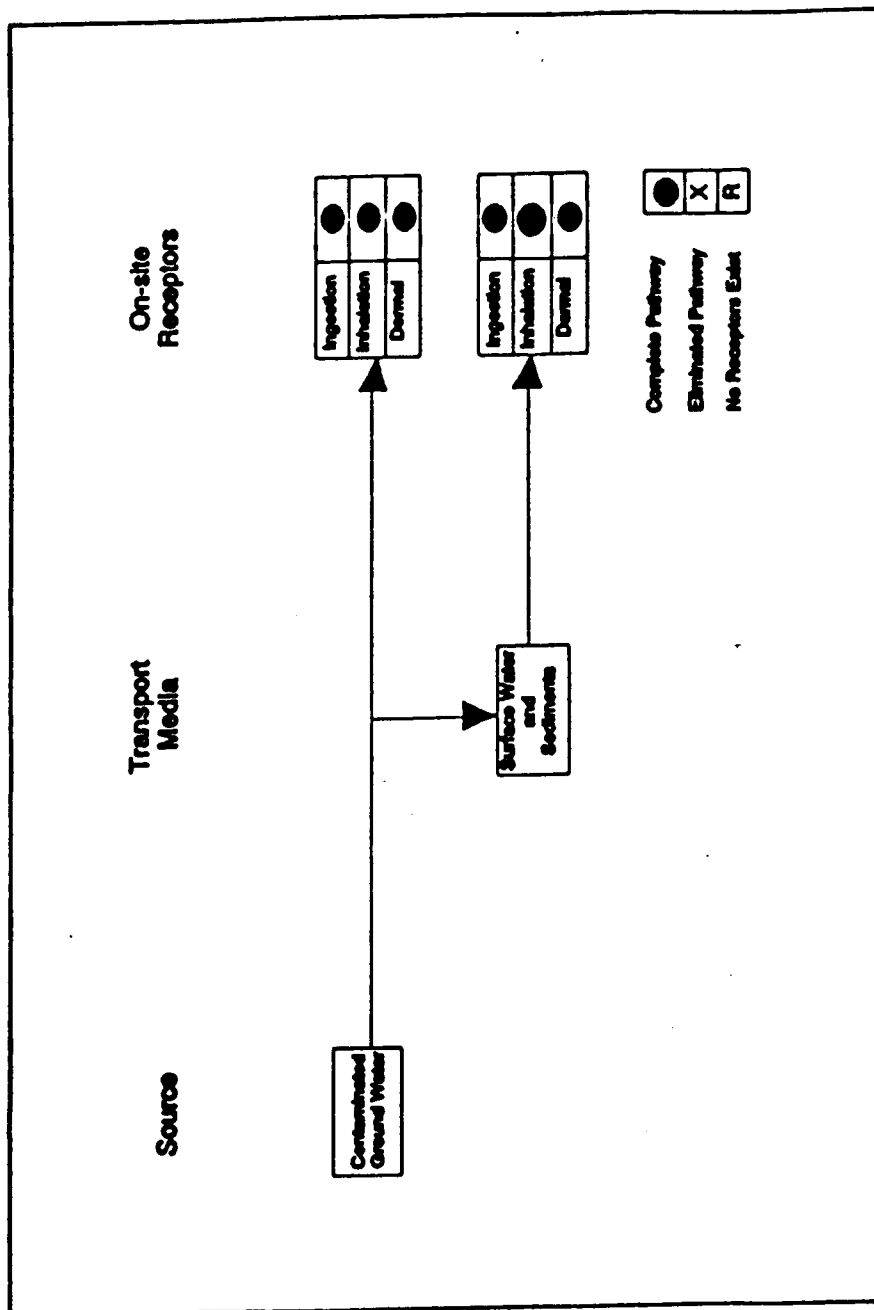


Figure 3.3-1 Conceptual Site Model for the Contaminated Groundwater Plume: No Institutional Controls Scenario

Plot M → Groundwater → Surface Water → Receptor

Based on hydraulic gradients determined from data published in Golchert, 1987b, the groundwater under the Plot M migrates toward the Des Plaines river. The Des Plaines river is going to serve as surface water receptor that the farm family uses for recreational and fishing activities. It is assumed that these activities occur 2,000 ft away from the site that is the nearest downgradient portion of that surface water body. The Des Plaines River is assumed to be 200 ft wide and 3 ft deep. The river flow velocity is taken as 1.499 fps with a discharge of 900 cfs (DOE, 1991). The concentrations used are the same as those for the groundwater pathway.

3.3.2 Institutional Controls in Perpetuity

Due to inadequate physical and institutional control, radioactive and hazardous wastes disposed of in Plot M could result in unacceptable human exposures from human or natural disruption, and is resulting in soil, groundwater, and surface water contamination. The first indication that significant amount of radioactive material was leaving the site was in 1973 when elevated levels of tritium were detected in two nearby hand-pumped wells and the tritium was found to be migrating from the burial plot into the surrounding soil and aquifers. Additionally in 1986, samples collected from the Red Gate Woods picnic area well showed manganese and sulfate levels elevated above Illinois drinking water standards (Golchert, 1992).

The following potential contaminant transport pathways were modeled for the baseline alternative under institutional controls.

- Plot M → Groundwater → Receptor
- Plot M → ~~X~~Groundwater → Surface Water → Receptor

The conceptual site model for that scenario is presented in Figure 3.3-2.

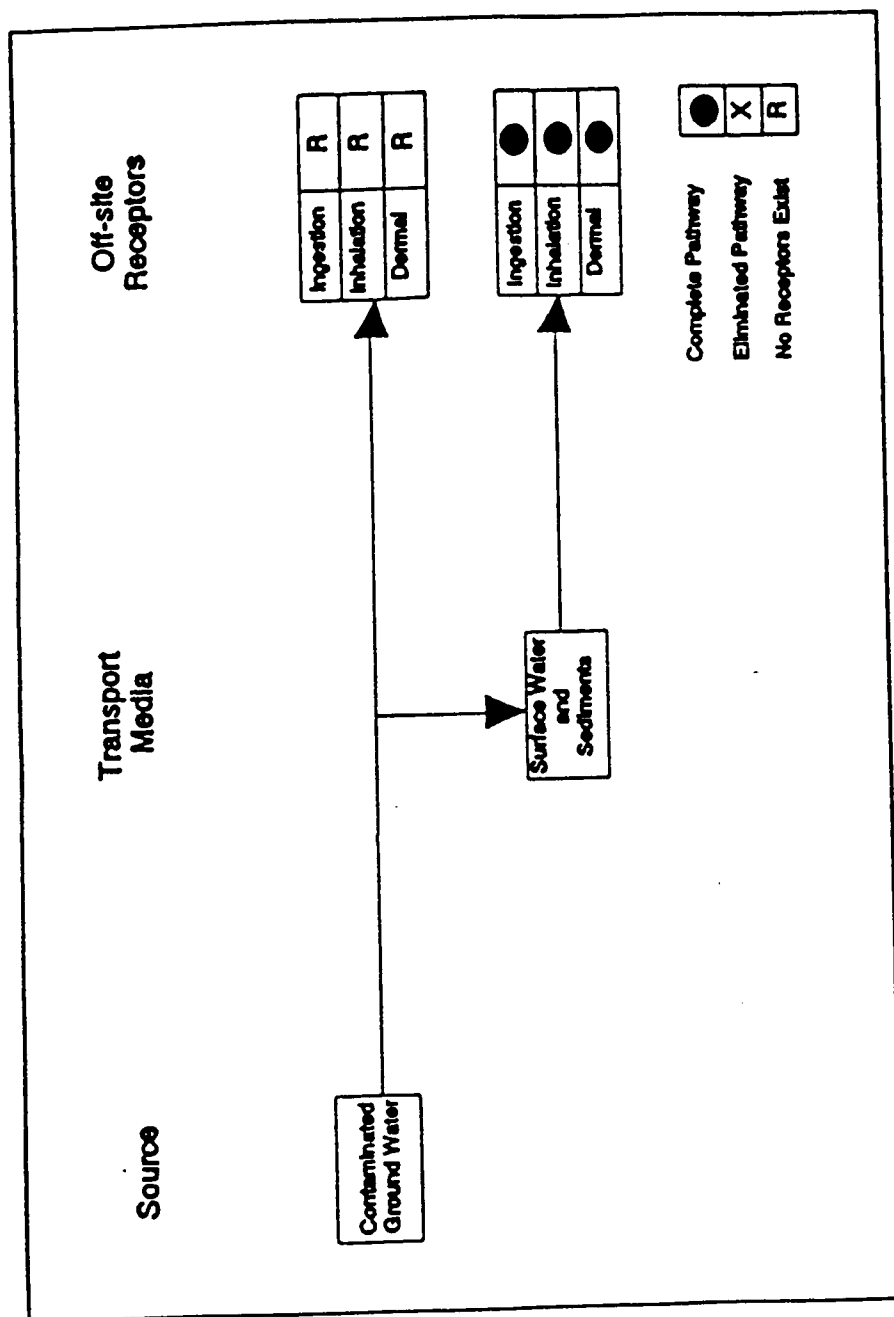


Figure 3.3-2 Conceptual Site Model for the Contaminated Groundwater Plume: Institutional Controls Scenario

Plot M → Groundwater → Receptor

Individuals at risk are those using potentially contaminated groundwater. Experiments and sampling of the Red Gate Woods picnic well had indicated that tritium moved at the till-dolomite interface and in the uppermost fractures in the dolomite. In July 1988, a well was installed in the Red Gate Woods picnic area (#5160) to replace the existing well (#5167) as drinking water supply for visitors to this area. (Golchert, 1992). This will be referred to as the Red Gate Woods North well (#5160) and is going to serve as the groundwater receptor, since that is the well that provides the greatest potential radiation exposure to the public.

The groundwater users in the area include an average of 32 visitors that obtain their drinking and showering water untreated from the #5160 well, that is located 1,100 ft from the plot. Cook County Forest Preserve records (DOE, 1991) show 35,000 visitors annually; that number represents 96 people daily. Assuming each visit lasts 8 hours the conservative estimate for the exposed population will be:

$$96 \text{ people} \times (8\text{hr}/24\text{hr}) = 32 \text{ people}$$

Because of the type of well and the type of usage at the well, water is assumed to be ingested immediately upon withdrawal and is assumed not to have any treatment (DOE, 1991). The Red Gate Woods North well was cased 20 ft into the dolomite to seal off fractures assumed to contain tritiated water. Extending the casing 20 ft into the dolomite and cementing the void between the casing and dolomite was expected to prevent tritium from entering the new well via the fractures (Golchert, 1992).

Plot M → Groundwater → Surface Water → Receptor

The receptor at the Des Plaines river have been changed to reflect potentially exposed population under institutional controls. To be conservative, all exposure is assumed to occur one mile downstream of ANL with an exposed population of 220 people and a river discharge at that point of 900 cfs (DOE, 1991). The Des Plaines

river discharges into the Illinois river that is used for recreational activities by 553,396 people. These activities are assumed to occur downstream where the discharge rate of that river is 10,960 cfs (DOE, 1991).

3.4 Human Health Risk Evaluation

Public health risks from exposure to contaminants are reported as cancer risks and health effects and are estimated for both populations and maximally exposed individuals (MEIs). Population health effects are presented as cancer fatalities, cancer incidence, and adverse genetic effects. Cancer incidence includes both fatal and nonfatal cancers. For the MEIs, the health effects are the probabilities of dying from cancer, developing cancer, and experiencing adverse genetic effects.

3.4.1 Risks During No Institutional Controls

The hypothetical farm family, using the contaminated water underneath the release site incurs considerable risk. Although every constituent showed an amount of risk, tritium and manganese were the predominant risk-producing contaminants. MEI and population risks for tritium are $1.68\text{E-}4$ and $1.02\text{E-}3$, respectively. The hazard index for ingestion for manganese exceeds "unity" which indicates that the exposure intake is greater than the RfD. Public health risks associated with exposure at the ground water plume are presented in Table 3.4-1.

3.4.2 Risks During Institutional Controls in Perpetuity

During periods of institutional controls, the constituent that poses the highest risk is again tritium with a population risk of $5.28\text{E-}5$ and with a MEI risk of $1.64\text{E-}6$. Health risks associated with the institutional controls in perpetuity scenario are presented in Table 3.4-2.

Table 3.4-1 Public Health Risks Associated With Exposure at the GW plume for the on-site receptor (ANL-Plot M) During
Periods of no Institutional Controls.

Contaminants	Population Health Effects					Maximum Individual Health Effects				
	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (person-rem)	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (rem)	Hazard Index Inhalation	Hazard Index Ingestion
Strontium-90	3.95E-5	1.36E-4	1.15E-5	0.0794	5.60E-6	1.91E-5	1.50E-6	0.0112	N/A	N/A
Yttrium-90	9.05E-7	3.11E-6	2.41E-7	0.0018	2.21E-7	7.62E-7	5.92E-8	0.0004	N/A	N/A
Tritium	2.97E-4	1.02E-3	7.89E-5	0.5966	4.89E-5	1.68E-4	1.35E-5	0.0989	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	0.102
Manganese	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	> 1
Sulfate	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	0.786
Total	3.37E-4	1.16E-3	8.97E-5	0.678	5.50E-5	1.88E-4	1.46E-5	0.1110	<0.001	> 1

Table 3.4-2 Public Health Risks Associated With Exposure at the GW plume for the off-site receptors (ANL-Plot M)
During Periods of Institutional Controls.

Contaminants	Population Health Effects				Maximum Individual Health Effects					
	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (person-rem)	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (rem)	Hazard Index Inhalation	Hazard Index Ingestion
Strontium-90 Yttrium-90 Tritium	1.46E-6 1.12E-7 1.54E-5	5.00E-6 3.90E-7 5.28E-5	3.90E-7 3.00E-8 4.09E-6	0.0029 0.0002 0.0309	4.31E-8 3.31E-9 4.80E-7	1.51E-7 1.10E-8 1.64E-6	1.10E-8 8.76E-10 1.32E-7	8.56E-5 6.6E-6 0.0009	N/A N/A N/A	N/A N/A N/A
Lead Manganese Sulfate	N/A N/A N/A	N/A N/A N/A	N/A N/A N/A	N/A N/A N/A	N/A N/A N/A	N/A N/A N/A	N/A N/A N/A	N/A N/A N/A	<0.001 <0.001 <0.001	4.7E-3 <0.001 9.5E-2
Total	1.70E-5	5.82E-5	4.51E-6	0.0341	5.25E-7	1.81E-7	1.42E-7	1.06E-3	<0.001	6.9E-2

Table 3.4-3 Public Health Risks Associated With Exposure at the GW Plume

Contaminants	Population Health Effects				Maximum Individual Health Effects ^a						
	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (person-rem)	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (rem)	Hazard Index Inhalation	Hazard Index Ingestion	
No Institutional Control ^a	3.37E-4	1.16E-3	8.97E-5	0.6780	5.5E-5	1.88E-4	1.46E-5	0.1110	<0.001	> 1	
Institutional Control in Perpetuity ^b	1.70E-5	5.82E-5	4.51E-6	0.0341	5.25E-7	1.81E-7	1.42E-7	1.06E-3	<0.001	6.90E-2	

^a Per on-site population of 4.

^b Per off-site population of 553,396.

3.5 Monitoring Program

The monitoring program at Plot M is designed to monitor elevated hydrogen-3 (as tritiated water) concentrations at the picnic well used by the public. From these concentrations the migration pathway of water from the burial grounds to the well in question can be determined, and the radiological and non-radiological environment of the area can be characterized. Samples are collected from biweekly to annually, depending on past results. The site follows the guidance for monitoring at DOE facilities, although it is recognized that Plot M is not a DOE facility.

According to site reports concerning the results of the monitoring program the radioactivity remaining at Plot M does not endanger the health or safety of the public visiting the site or those living in the vicinity. Table 3.5-1 presents annual hydrogen-3 concentrations (for certain years maximum and average) in the Red Gate Well (Golchert, 1992).

The uncertainties associated with individual concentrations given in the following table are the statistical counting errors at the 95% confidence level. In such cases the following uncertainties apply (Golchert et al 1983).

Concentration (nCi/l)	Uncertainty (% of Concentration)
0.2-1.0	25-5
1-10	5-1
> 10	1

Table 3.5-1 Tritium Concentrations in the Red Gate Woods Well

Year	Average Concentration (nCi/l)	Maximum Concentration *	Model Predicted Concentration (nCi/l)
1974	7.0	N/A	27.26
1975	6.6	N/A	27.26
1976	6.1	N/A	22.68
1977	8.2	N/A	22.68
1978	7.5	N/A	22.68
1979	7.1	N/A	18.86
1980	7.0	N/A	18.86
1981	4.3	N/A	18.86
1982	4.8	9.2	15.69
1983	2.2	3.0	15.69
1984	1.2	2.7	15.69
1985	1.0	2.5	13.05
1986	1.3	3.4	13.05
1987	1.6	3.3	13.05
1988	0.18	0.48	13.05
1989	0.30	0.46	10.85
1990	0.12	0.25	10.85
1991	0.05	0.21	10.85

* N/A: Not Available

The current program at the site consists of sample collection and analysis of air, surface and subsurface water and bottom sediment. Hydrogen-3 in the Red Gate Woods picnic well was still detected, but the average and maximum concentrations were significantly less than found earlier. Tritiated water continues to be detected in a number of wells, boreholes, dolomite holes, and a surface stream. For many years it was the only radionuclide found to have migrated in measurable quantities. Analyses since 1984 have indicated the presence of low levels of Strontium-90 in water from a number of boreholes next to Plot M. the available data does not allow a firm conclusion as to whether the presence of this nuclide is the result of recent migration or movement that may have occurred before the capping of the Plot.

3.6 Model Predicted Concentrations

MEPAS was used to estimate concentrations at the Red Gate Woods well, at the same location where the site characterization report was reporting measured concentrations for tritium. The MEPAS predicted concentrations at this location are presented in Table 3.5-1 together with the measured average and annual concentrations for easy comparison.

For every case MEPAS predicts higher concentrations than the measured ones. A graph of the concentrations presented in Table 3.5-1 has been developed as it is presented in Figure 3.6-1. In addition, from Figure 3.6-1 it can be seen that the MEPAS estimated concentrations do not decrease with the same rate as the measured ones. For this reason the MEPAS predicted concentrations for several lifetimes are also plotted so that one will get an idea as to how the concentrations drop as time passes. These concentrations are presented in Figure 3.6-2.

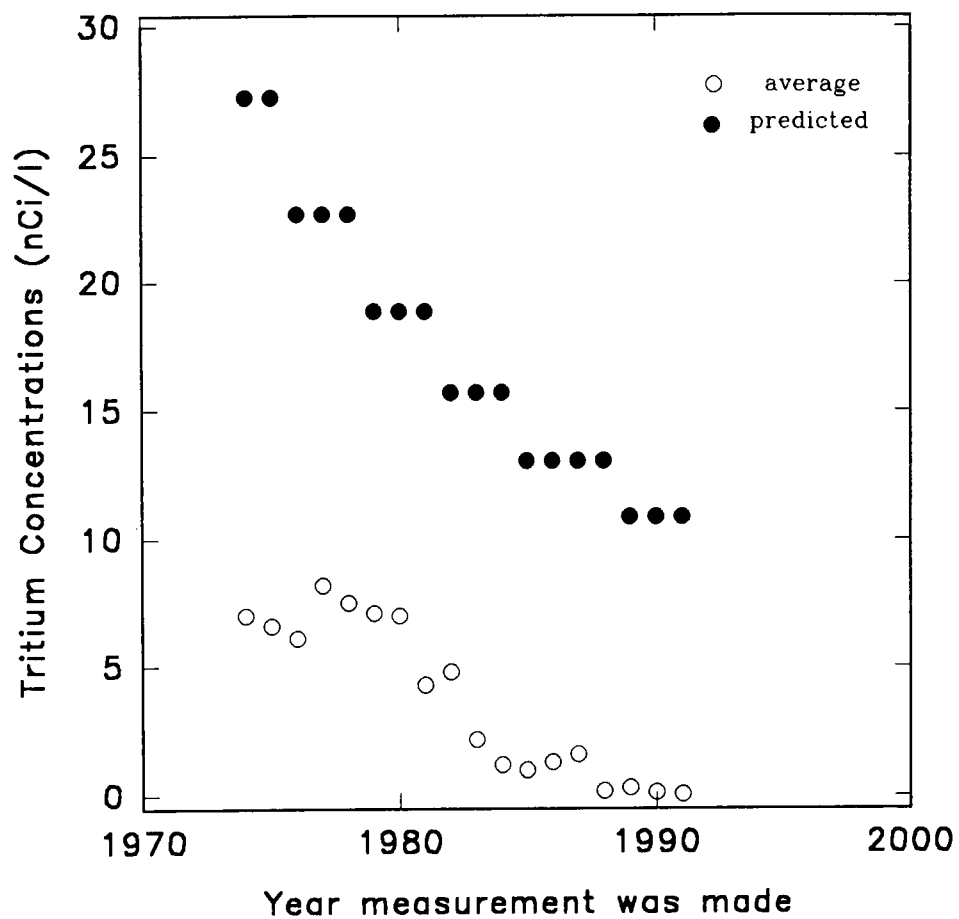


Figure 3.6-1 Monitoring and MEPAS Predicted Tritium Concentrations at the Red Gate Woods Well.

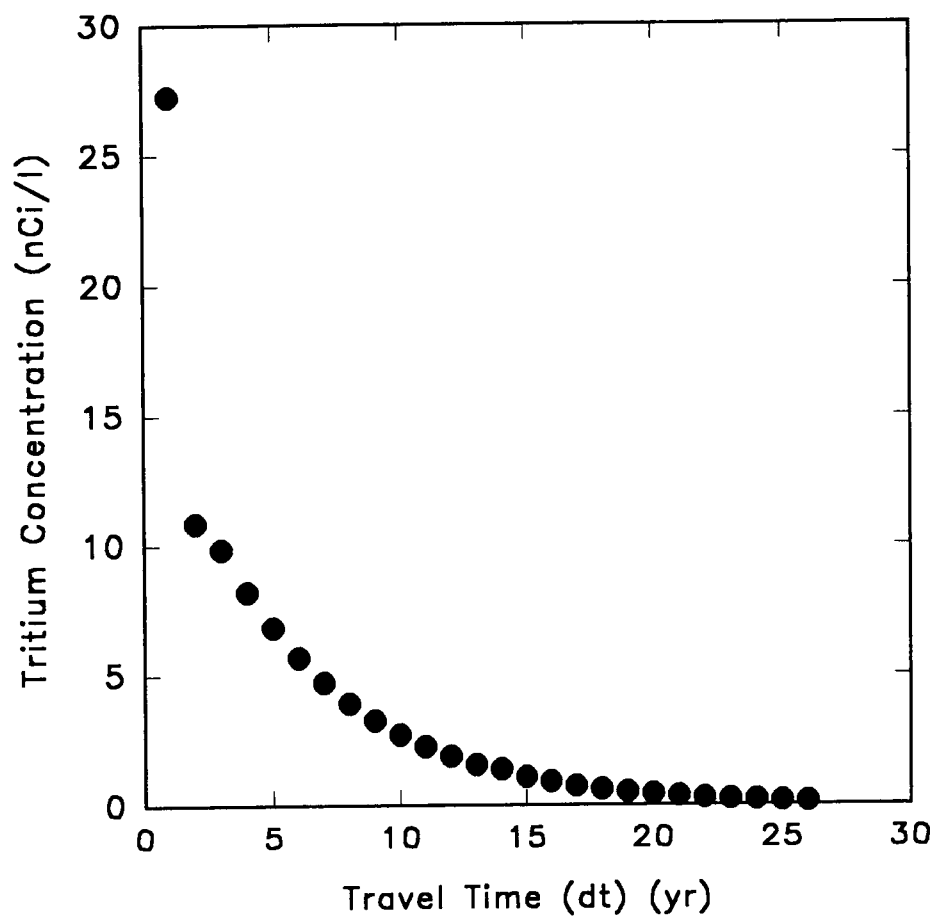


Figure 3.6-2 Tritium Concentrations (nCi/l) predicted by MEPAS at ANL-Plot M (dt = 20 years).

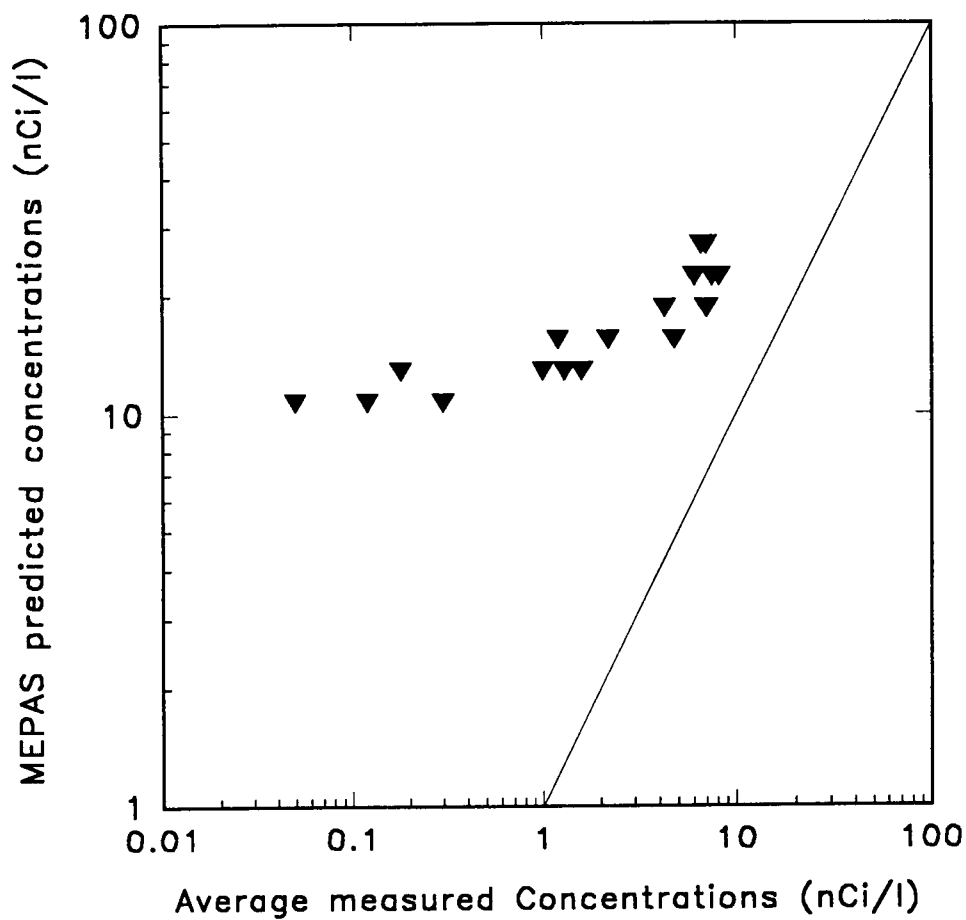


Figure 3.6-3 Tritium Concentrations (nCi/l): MEPAS Predicted Concentrations versus Average Monitoring Well Concentrations for ANL-Plot M.

CHAPTER 4

BURIED WASTE SITE: FERNALD ENVIRONMENTAL MANAGEMENT PROJECT (FEMP)-WASTE PIT 3

4.1 Introduction

The Fernald Environmental Management Project (FEMP) is a contractor-operated facility involved in the production of uranium for the needs of other U.S. Department of Energy (DOE) facilities. From 1951 to 1989, this continued to be the purpose of the FEMP. Small amounts of thorium were produced at the FEMP on several occasions from 1954 to 1975. The FEMP currently serves as the thorium repository for DOE, and maintains long-term storage facilities for a variety of thorium (DOE 1992a). The FEMP site occupies 1,050 acres in rural area approximately 15 miles northwest of Cincinnati, Ohio. A wide variety of hazardous and radioactive wastes are generated by FEMP activities. The accumulated releases of those wastes into the environment over the last 35 years have resulted in the contamination of air, soil,

surface water, and ground water.

The area surrounding the FEMP is largely rural, with some recent suburbanization. The site lies in both Hamilton and Butler counties, with an estimated population of more than 24,000 within a 5-mile radius. More than 2.5 million people live within a 50-mi radius of the site. Both counties sustain substantial industry as well as the farming grain crops and the raising of dairy and beef cattle. FEMP property at the perimeter of the site is used extensively by local farms for cattle pasture. Major communities in southwestern Ohio and the FEMP location are presented in Figure 4.1-1(DOE 1992b).

4.2 Description of Site

Waste Pit 3 is a disposal unit primarily for wet solid wastes located in the northwest section of the facility. Waste Pit 3 is part of the Operable Unit 1 (OU1) at FEMP. It was constructed in 1959 into an existing clay layer and lined with an additional foot of clay. The maximum depth of the pit is 27 ft and it contains an estimated 248,000 pounds of uranium and approximately 880 pounds of thorium. Waste Pit 3 has been out of service since 1977, when it was backfilled and covered with clean soil. In 1965 the pit capacity was increased to 248,000 yd³ by adding two feet to the existing pit walls which also increased the maximum depth of the pit to 27 ft. The OU1 is presented in Figure 4.2-1 (DOE, 1992b).

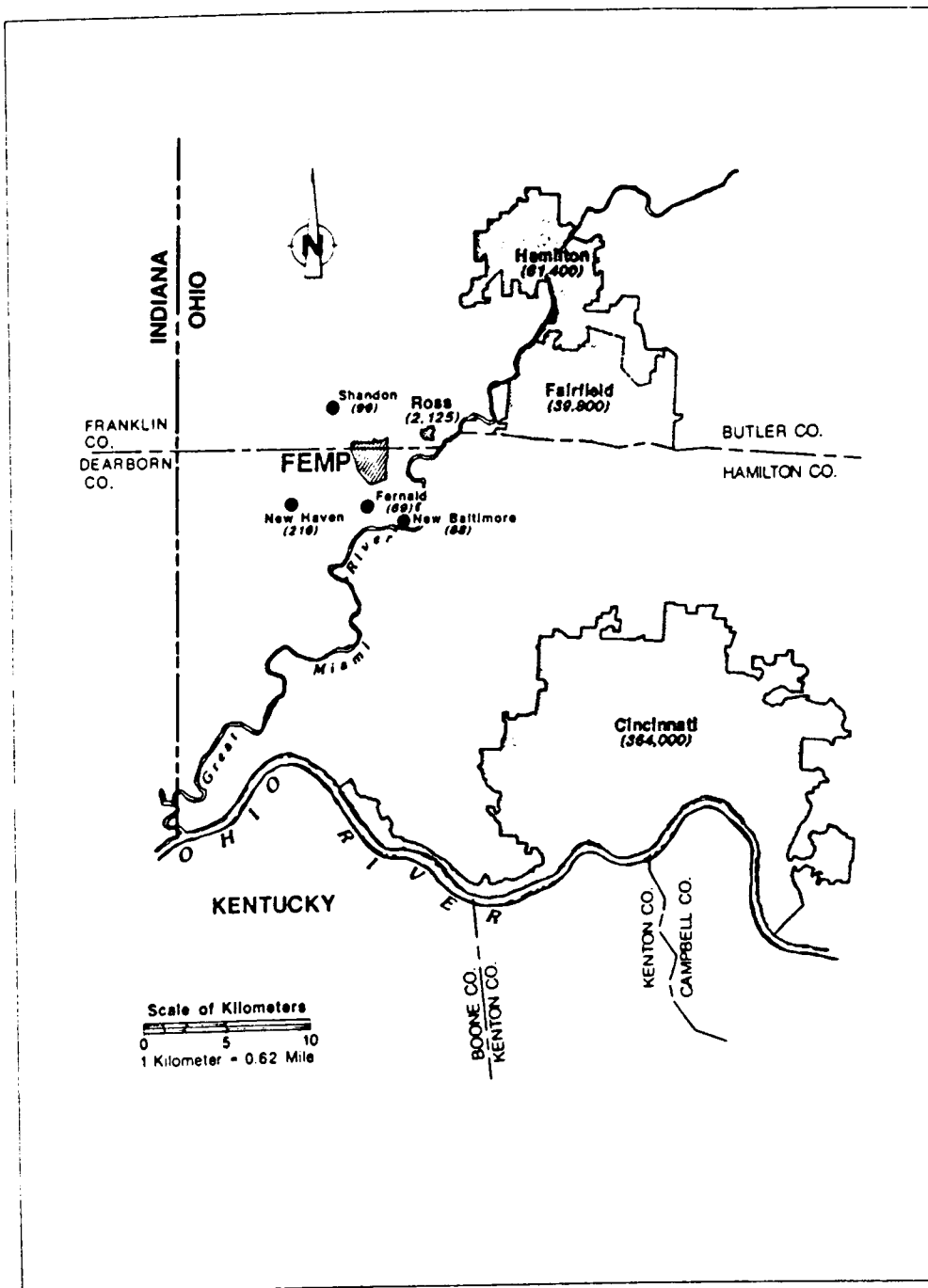


Figure 4.1-1 Major Communities in Southwestern Ohio and the FEMP location(DOE,1992b).

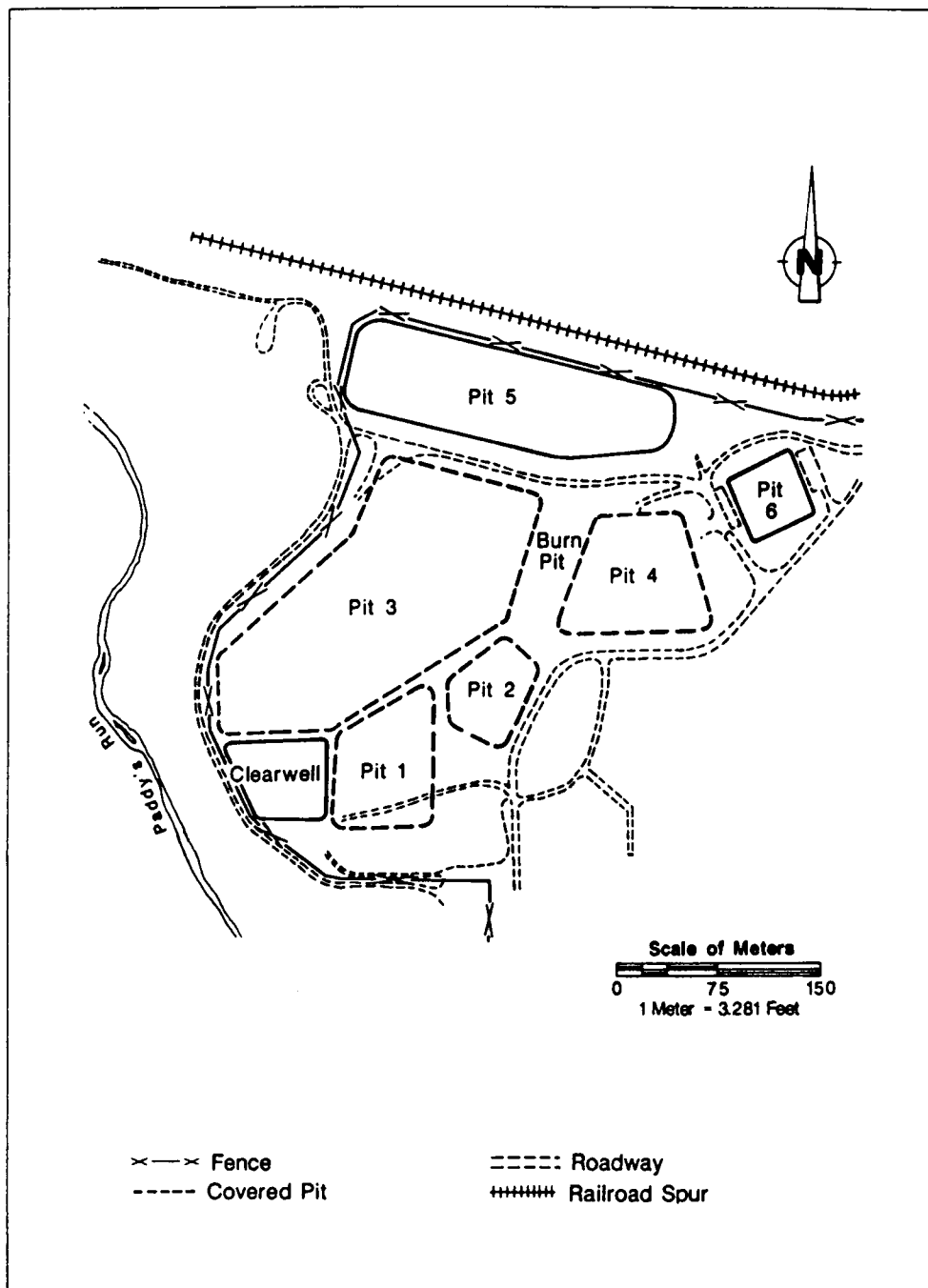


Figure 4.2-1 Operable Unit 1 (OU1) at FEMP (DOE, 1992b)

4.2.1 Contaminants of Concern

Waste Pit 3 was used as a settling basin for liquid effluent and slurries, primarily lime-neutralized raffinates. During the late 1960's the pit also received slag leach residues until the construction of waste pit 5.

Releases from the site are contaminating the groundwater with uranium and potentially other radionuclides, organics, and inorganics. The Table 4.2-1 presents the constituents and their expected quantities that may pose potential risk to human health.

Table 4.2-1 Constituent Inventory for Waste Pit 3

Contaminants	Inventory
1,1,1 Trichloroethane	5.47E3 g
Chromium VI	6.4E7 g
Chrysene	2.57E4 g
Methyle Chloride	1.44E4 g
Plutonium-238	2.10E8 Ci
Thorium-230	1.4E4 Ci
Trichloroethylene	2.08E3 g
Uranium	1.1E8 g
Uranium-234	3.894 Ci
Uranium-235	1.65 Ci
Uranium-238	5.86E2 Ci

4.2.2 Physical Characteristics/Environmental Setting

4.2.2.1 Soils

The soils at the FEMP site are derived from the glacial sediment. Most soil at the site consists of Fincastle-Xenia silt loam. The characteristics of this type of soil include

medium acidity, high agricultural productivity, and poor drainage.

4.2.2.2 Hydrogeology

The FEMP site is located on a dissected till plain left by Wisconsin Glaciation. Within the glacial overburden deposits there are numerous perched water-bearing zones that have limited interconnection (DOE, 1992a). The majority of these perched zones are of glaciofluvial origin and consist of small beds of highly sorted sands and gravels. These beds are probably the result of small meltwater streams that occurred along the ice margin and within the glacial itself. The bedrock in the vicinity of the site consists of predominantly flat-lying, olive-gray Ordovician Shales with thin interbedded layers of limestone. This shale forms the buried valley walls of the New Haven Trough. Hydraulic conductivities are highly variable with an expected range of $2.8\text{E-}2$ to 280 ft/day (Freeze and Cherry, 1979). At the FEMP, series of slug tests of water-bearing zones in the till found hydraulic conductivities ranging from 1.6 ft/day to $7.1\text{E-}3$ ft/day (DOE, 1992a). Porosities range between 22.1 and 36.7 percent, with a mean of 31 percent (Morris and Johnson, 1967).

4.2.2.3 Surface Water

The Great Miami River is the main surface water feature in the vicinity of the FEMP, and receives discharge from the installation as permitted by the National Pollutant Discharge Elimination System (NPDES). The river flows generally to the southwest recharging within 0.75 mi of the eastern boundary of FEMP. The drainage area of the Great Miami River is approximately 3,360 m² at the Hamilton gage, which is located 10 mi upstream from the FEMP effluent pipeline outfall (DOE, 1992b). The Great Miami River serves industries in the area and, hence, is not used extensively for recreational purposes. No known potable water users of the river exist downstream from the FEMP. Paddys Run, a tributary of the Great Miami River flows from north to south near the western boundary of the FEMP property. Paddys Run has historically received direct runoff from the western areas of the FEMP, including the silos and the waste storage areas (DOE, 1992b).

4.2.2.4 Climate

The climate of the southwestern Ohio is continental, characterized by wide variations in temperature throughout the year. The average monthly temperature ranges from a low of 32 degree F in January to a high of 76 degree F in July. The average annual precipitation is 38 inches, with fall the season of minimum rainfall. Data from the FEMP meteorological system, from which on-site measurements have been obtained since 1986, have been used by NOAA to analyze the local wind pattern at the FEMP. A study by International Technology Corporation (IT, 1986) has also shown that wind flow data from the Cincinnati Airport are sufficiently representative of local FEMP conditions. Prevailing winds are from the southwest and westsouthwest.

4.3 Baseline Alternative

As before for the groundwater site, the following exposure scenarios are going to be considered for the baseline evaluation:

- No Institutional Controls
- Institutional Controls in Perpetuity

The hypothetical farm family of four serves again as receptor for the periods of no institutional controls. However, for the institutional controls in perpetuity scenario the off-site documented populations serve as receptors.

4.3.1 No Institutional Controls

The following potential contaminant transport pathways were modeled for the baseline alternative under no institutional controls:

- Buried Waste → Groundwater → Receptor
- Buried Waste → Air/Surface Soil → Receptor

The conceptual site model for that scenario is presented in Figure 4.3-1. The surface water pathway has been eliminated because no surface water body is present at the facility.

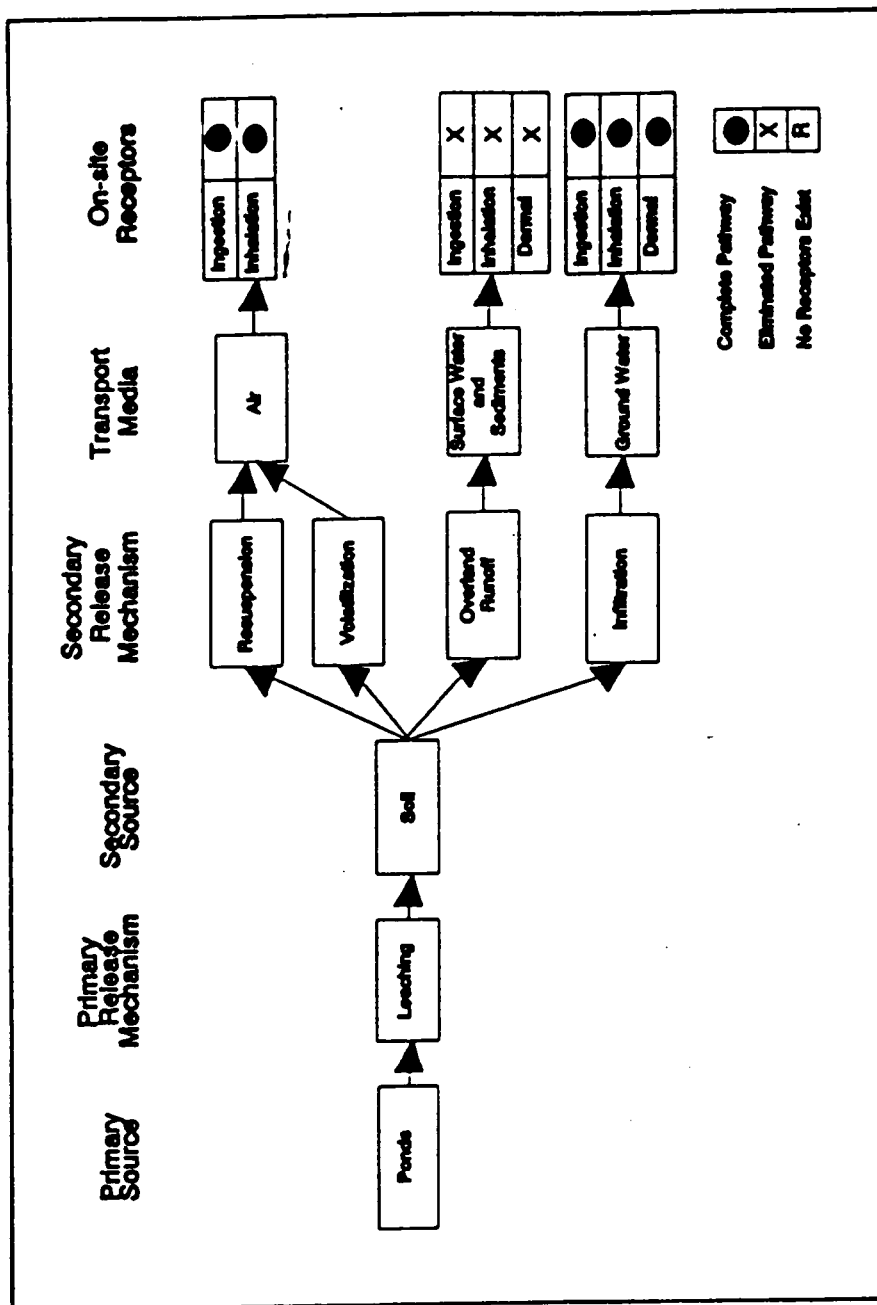


Figure 4.3-1 Conceptual Site Model for the Buried Waste Site: No Institutional Controls Scenario

Buried Waste → Groundwater → Receptor

The groundwater in the area has been confirmed to contain elevated levels of uranium (DOE, 1992). Start date of the ranking unit was set at 1959 since that was the year that the pit starting receiving waste. According to permeabilities studies at the area two partially saturated zones and one saturated zone can describe the hydrogeology of the site considering also the MEPAS limitations. The first PSZ was modeled as loam with 33 percent sand, 43 percent silt, and 24 percent clay. The second psz was modeled as loamy sand with the following soil characteristics: 77 percent sand, 20 percent silt, and 3 percent clay. The SZ was modeled as loamy sand with the same soil characteristics as the second PSZ. The on-site well was placed 318 ft away from the site and is assumed that it is used by the farm family for bathing, irrigation of crops, and water of animals, as well as a drinking water source. Climatological data was obtained from the nearby airport and the monitoring stations within the facility.

Buried Waste → Air/Surface Soil → Receptor

Contamination from the buried waste area may volatilize, deposit on surrounding soil, and reach receptors through the food chain. In addition, contaminants may cause exposure directly by inhalation. Since air transport of potential contaminants is considered a valid exposure scenario, the air pathway was evaluated for the hypothetical farm family. The population affected by inhalation of contaminants from the waste site includes four hypothetical receptors. Local climatological data were obtained from NOAA for the nearby airport and are assumed to be representative of the site.

4.3.2 Institutional Controls in Perpetuity

The following potential contaminant exposure pathways were evaluated for the baseline alternative for the institutional controls scenario.

- Buried Waste → Groundwater → Receptor
- Buried Waste → Air/Surface Soil → Receptor

The conceptual site model for that scenario is presented in Figure 4.3-2.

Buried Waste → Groundwater → Receptor

During periods of institutional controls, individuals at risk are those using potentially contaminated groundwater. The groundwater users have been identified and include 60 nearby residents. The ground water users in the area, and the exposure routes are presented in Table 4.3-1.

Table 4.3-1 Receptors for Groundwater at FEMP

Receptors	Exposure Routes	Number of People
Well #35	Drinking and Bathing	2
Well #38	Drinking and Bathing	2
South Paddys Run Wells	Drinking and Bathing	4
South Highway 128 Wells	Drinking and Bathing	4
Southwest Wells	Drinking and Bathing	12
Irrigation Wells	Irrigation to Crops Only	4
Wilson Co. Wells	Dermal Absorption	24
Agricultural Wells	All Exposure Routs	8

Buried waste → Air/Surface Soil → Receptor

Air transport of potential contaminants is evaluated for receptors within a 50-mi radius of the site. It is assumed that livestock and crops within the 50-mi radius could be affected by volatilized and resuspended contaminants. Thirty counties were evaluated as receptor locations.

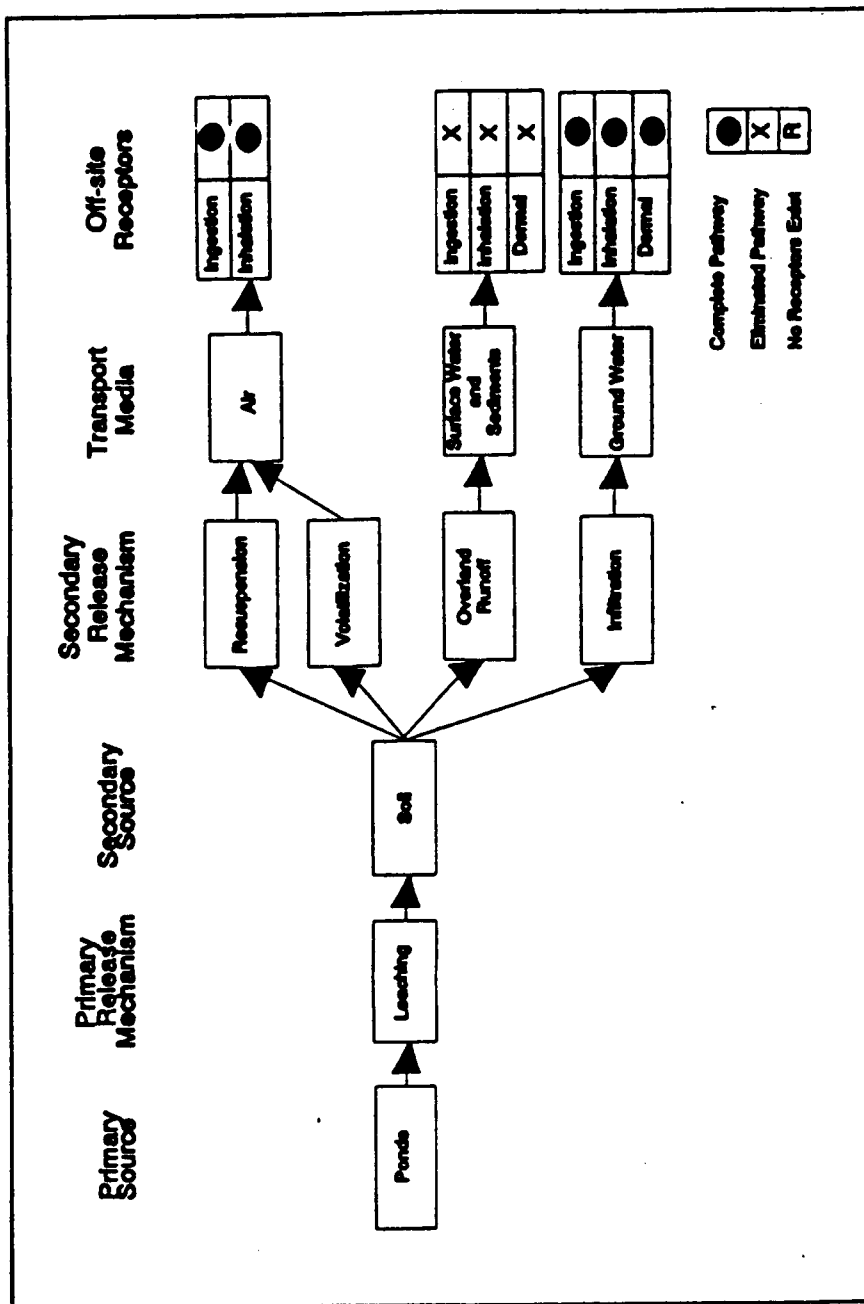


Figure 4.3-2 Conceptual Site Model for the Buried Waste Site: Institutional Controls Scenario

The potential ingestion of leafy vegetables, meat, and milk was evaluated for these counties as applicable based on county agricultural statistics. The surrounding population includes 2,743,642 potential receptors.

4.4 Human Health Risk Evaluation

Public health risks from exposure to contaminants are reported as cancer risks and health effects and are estimated for both populations and maximally exposed individuals (MEIs). Population health effects are presented as cancer fatalities, cancer incidence, and adverse genetic effects. Cancer incidence includes both fatal and nonfatal cancers. For the MEIs, the health effects are the probabilities of dying from cancer, developing cancer, and experiencing adverse genetic effects.

4.4.1 Risks During No Institutional Controls

The hypothetical farm family, using the water underneath the release site directly for all of its needs, incurs considerable risk. In addition, the contamination poses a risk to the family through the atmospheric pathway. However, the groundwater risks dominate. Health risks associated with the no institutional controls scenario are presented in Tables 4.4-1 and 4.4-2. Although almost every constituent showed risk for the groundwater pathway, uranium-238, 1,1,1-trichloroethane, and several metals were the predominant risk-producing contaminants. MEI and population risks for uranium 238 are $2.42\text{E-}1$ and $4.28\text{E-}1$, respectively. The hazard index for ingestion for cobalt, lead, and uranium exceeds "unity" which indicates that the exposure intake is greater than the RfD.

4.4.2 Risks During Institutional Controls in Perpetuity

During periods of institutional controls, the constituent that poses the highest risk is again uranium 238 with a population risk of $1.79\text{E-}1$ and with a MEI risk of $1.98\text{E-}2$. Health risks associated with the institutional controls in perpetuity scenario are presented in Table 4.4-3 and 4.4-4.

Table 4.4-1 Public Health Risks Associated With Exposure at the Buried Waste Site for the Groundwater Pathway During Periods of No Institutional Controls

Contaminants	Population Health Effects					Maximum Individual Health Effects				
	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (person-rem)	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (rem)	Hazard Index Inhalation	Hazard Index Ingestion
Plutonium 238	<1E-6	<1E-6	<1E-6	1.72E-6	<1E-6	<1E-6	<1E-6	1.86E-6	N/A	N/A
Thorium 230	6.45E-6	2.20E-5	1.71E-6	1.30E-2	2.22E-5	7.59E-5	5.90E-6	0.0446	N/A	N/A
Uranium 234	9.24E-4	3.16E-3	2.46E-4	1.86	5.20E-4	1.78E-3	1.38E-4	1.0444	N/A	N/A
Uranium 235	3.74E-4	1.28E-3	9.94E-5	0.7510	2.11E-4	7.21E-4	5.61E-5	0.4238	N/A	N/A
Uranium 238	1.25E-1	4.28E-1	3.33E-2	252.0	7.07E-2	2.42E-1	1.88E-2	142.1	N/A	N/A
1,1,1 Trichlorethane	N/A	2.22E-5	N/A	N/A	N/A	4.35E-6	N/A	N/A	N/A	N/A
Chromium VI	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Chrysene	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Methylene Chloride	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Trichlorethane	N/A	2.09E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Barium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	<0.001
Cobalt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	>1
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	>1
Uranium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	>1
Chromium VI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	>1
Total	1.27E-1	4.32E-1	3.36E-2	254.0	7.15E-2	2.44E-1	1.9E-2	144.0	<0.001	>1

Table 4.4-2 Public Health Risks Associated With Exposure at the Buried Waste Site for the Atmospheric Pathway During Periods of No Institutional Controls

Contaminants	Population Health Effects				Maximum Individual Health Effects					
	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (person-rem)	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (rem)	Hazard Index Inhalation	Hazard Index Ingestion
Plutonium 238	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	N/A	N/A
Thorium 230	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	N/A	N/A
Uranium 234	<1E-6	<1E-6	<1E-6	4.17E-4	<1E-6	<1E-6	<1E-6	3.16E-5	N/A	N/A
Uranium 235	<1E-6	<1E-6	<1E-6	1.68E-4	<1E-6	<1E-6	<1E-6	1.28E-5	N/A	N/A
Uranium 238	2.86E-5	9.76E-5	7.59E-6	5.74E-2	2.17E-6	7.43E-6	<1E-6	0.0043	N/A	N/A
1,1,1 Trichlorethane	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Chromium VI	N/A	1.13E-5	N/A	N/A	N/A	2.81E-6	N/A	N/A	N/A	N/A
Chrysene	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Methylene Chloride	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Trichlorethane	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Barium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	0.0250
Cobalt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	0.2280
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	>1
Uranium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	>1
Chromium VI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	>1
Total	2.86E-5	1.10E-4	7.59E-6	5.80E-2	2.17E-6	1.03E-5	<1E-6	4.41E-3	<0.001	>1

Table 4.4-3 Public Health Risks Associated With Exposure at the Buried Waste Site for the Groundwater Pathway During Periods of Institutional Controls

Contaminants	Population Health Effects				Maximum Individual Health Effects					
	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (person-rem)	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (rem)	Hazard Index Inhalation	Hazard Index Ingestion
Phonium 238	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	N/A	N/A
Thorium 230	1.89E-6	6.46E-6	5.03E-7	0.0004	1.37E-6	4.67E-6	3.63E-7	0.0027	N/A	N/A
Uranium 234	3.86E-4	1.32E-3	1.03E-4	0.7760	4.27E-5	1.46E-4	1.13E-5	0.0857	N/A	N/A
Uranium 235	1.57E-4	5.35E-4	4.16E-5	0.3150	1.73E-5	5.91E-5	4.60E-6	0.0347	N/A	N/A
Uranium 238	5.24E-2	1.79E-1	1.79E-1	105.0	5.80E-3	1.98E-2	1.54E-3	11.65	N/A	N/A
1,1,1 Trichlorethane	N/A	1.02E-5	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Chromium VI	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Chrysene	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Methylene Chloride	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Trichlorethane	N/A	1.07E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Barium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	<0.001
Cobalt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	0.3470
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	<1
Uranium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	>1
Total	5.30E-2	1.81E-1	1.41E-2	106.0	5.86E-3	2.00E-2	1.56E-3	11.80	<0.001	>1

Table 4.4-4 Public Health Risks Associated With Exposure at the Buried Waste Site for the Atmospheric Pathway During Periods of Institutional Controls

Contaminants	Population Health Effects					Maximum Individual Health Effects				
	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (person-rem)	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (rem)	Hazard Index Inhalation	Hazard Index Ingestion
Plutonium 238	<1E-6	<1E-6	<1E-6	5.43E-3	<1E-6	<1E-6	<1E-6	<1E-6	N/A	N/A
Thorium 230	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	<1E-6	N/A	N/A
Uranium 234	<1E-6	<1E-6	<1E-6	32.04	<1E-6	<1E-6	<1E-6	<1E-6	N/A	N/A
Uranium 235	<1E-6	<1E-6	<1E-6	14.60	<1E-6	<1E-6	<1E-6	<1E-6	N/A	N/A
Uranium 238	2.13E-6	7.27E-6	<1E-6	4.27E3	<1E-6	<1E-6	<1E-6	<1E-6	N/A	N/A
1,1,1-Trichlorethane	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Chromium VI	N/A	1.15E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Chrysene	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Methylene Chloride	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Trichlorethene	N/A	<1E-6	N/A	N/A	N/A	<1E-6	N/A	N/A	N/A	N/A
Barium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	<0.001
Cobalt	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	<0.001
Lead	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	<0.001
Uranium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	<0.001	<0.001
Chromium VI	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.88
Total	2.13E-6	7.27E-6	<1E-6	4.32E3	<1E-6	<1E-6	<1E-6	<1E-6	N/A	0.88

4.4.3 Public Health Risk Summary

The contamination present at the release site showed considerable risk to the hypothetical on-site receptors as well as to the off-site receptors. The contaminants that pose the greatest risk are uranium 238, 1,1,1 trichloroethane, cobalt, lead, and uranium. During the periods of no institutional controls, the highest risks are attributed to uranium 238 and uranium and the primary exposure route is the direct ingestion of the groundwater. For institutional Controls in perpetuity the same contaminants as above were the risk drivers.

A health risk summary table is presented for comparison between the two evaluated periods as Table 4.4-5 and Table 4.4-6.

Table 4.4-5 Population Risks Associated With Exposure at The Buried Waste Site

Periods	Population Health Effects			
	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (person-rem)
No Institutional Control ^a	1.27E-1	4.32E-1	3.36E-2	254.0
Institutional Control in Perpetuity ^b	5.30E-2	1.81E-1	1.41E-2	4430.0

^a Per on-site population of 4.

^b Per off-site population of 2,743,642.

Table 4.4-6 Maximum Individual Risks Associated With Exposure at The Buried Waste Site

Periods	Cancer Fatalities	Cancer Incidence	Hereditary Effects	Dose (person-rem)	Hazard Index Inhalation	Hazard Index Ingestion
No Institutional Control ^a	7.15E-2	2.44E-1	1.90E-2	0.0190	<0.001	> 1
Institutional Control in perpetuity ^b	5.86E-3	2.00E-2	1.56E-3	11.8	<0.001	> 1

^aPer on-site population of 4.

^bPer off-site population of 2,743,642.

4.5 Groundwater Flow at FEMP

Groundwater elevations in the FEMP area show a broad cyclic trend on an annual basis. This trend is created by seasonal fluctuations between recharge and discharge. maximum groundwater levels occur normally during the spring and early summer months, which are also the major recharge months. Minimum groundwater levels occur normally during the late fall and early winter months. This corresponds with the dry season for southern Ohio, which starts in generally in late summer or early fall and runs to late fall. For an average year, the groundwater experiences a fluctuation on the order of 4 to 5 ft, with increases occurring faster than decreases. The average recharge period is 4 to 5 months, while the average discharge period lasts 7 to 8 months. This is typical of the annual recharge-discharge cycle for southern Ohio.

The principal sources of groundwater recharge in the FEMP region are direct precipitation and stream infiltration. Infiltration of rainfall and snowmelt is the predominant regional source of groundwater recharge, providing approximately 12 in/yr to the water table (DOE, 1987).

Groundwater flow involves the flow of the Great Miami Aquifer and the movement of perched groundwater in the vicinity of the FEMP. A generalized flow diagram for the Great Miami Aquifer, based on 1986 water level contours is shown in Figure 4.5-1 (DOE, 1992). Several large volume well located southeast to FEMP have produced a pronounced and persistent cone of depression in the water table in the vicinity of the pumping zone. Groundwater elevations indicate that this region of depression influences groundwater patterns beneath the FEMP.

4.6 Groundwater Transport

The South Groundwater Contamination Plume is an area immediately south of FEMP with known levels of uranium contamination. This plume was identified as a result of the groundwater monitoring program that has been initiated at FEMP over the past seven years.

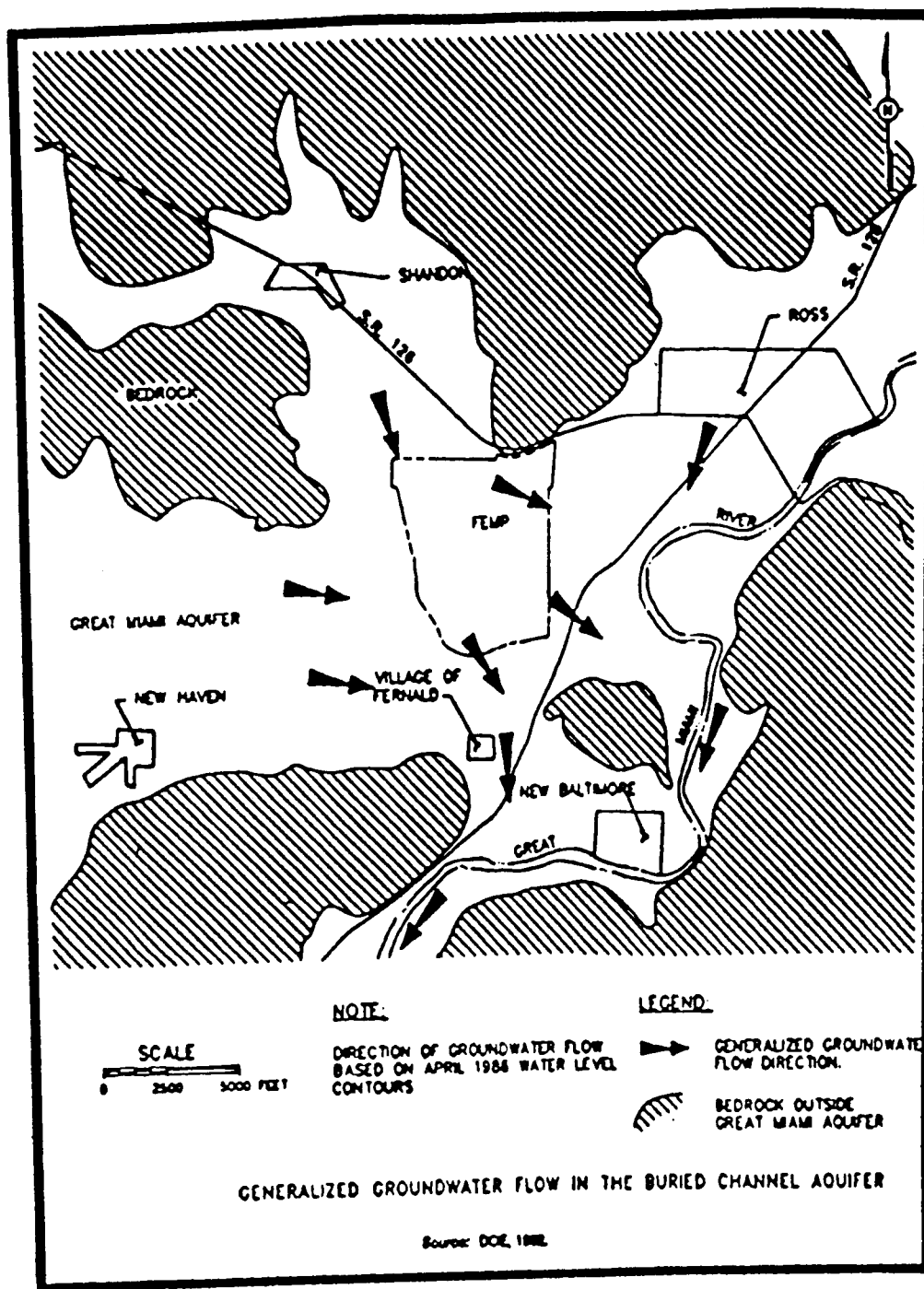


Figure 4.5-1 Groundwater flow in the vicinity of FEMP (DOE, 1992a)

The FEMP, as part of a response under CERCLA, has initiated a removal action to control further southward groundwater movement and to protect the groundwater environment (DOE 1992). Because of the magnitude of this project, the removal action has been divided into five parts:

- Supply an alternate water source to local population whose well water has shown contamination levels exceeding 22 pCi/l, which is the action level for uranium as agreed by EPA and DOE.
- Install recovery wells in the area identified
- Remove additional uranium from on-site wastewater
- Continue groundwater monitoring in the south plume location
- Continue groundwater modeling and additional groundwater investigations

The 22 pCi/l which corresponds to an allowable uranium concentration corresponds to $1.4E-4$ as the cancer incidence. The movement of uranium in the groundwater has been the key factor in determining the source of such contamination. The groundwater monitoring program has attributed the contamination to the Waste Pits area especially Waste Pit 3 (DOE, 1992a). However, almost none of the formally operating areas at the installation have been excluded from contributions to the south plume. It is just believed that because of the volume present at the waste pit 3 for so many years, that is probably the major source for the contamination.

In December 1990, a private well was sampled for uranium at the owners request. The well was located 2.5 mi south of the installation, and showed a total concentration of 5.5 pCi/l, well below the 22 pCi/l guideline. However, that result triggered several discussions between the surrounding population and the personnel at the facility. As a result FEMP has started a monitoring program for several of the domestic wells (that were mentioned in section 3.2.2.2), for on-site wells and wells located at the south plume. The south plume is located approximately 7,000 ft away from the waste pit 3.

Table 4.6-1 gives the concentrations for the domestic wells used by the surrounding population, the concentrations of the on-site monitoring well and the monitoring well located on top of the south plume, as they were published in 1992 site

characterization report (DOE 1992). In addition, the same table (Table 3.2-8) includes the MEPAS predicted concentrations for the exact same locations where the monitoring wells were located.

Table 4.6-1 Uranium Concentrations at several FEMP locations

Well	Average Concentration (pCi/l)	Model Predicted Concentration (pCi/l)
On-site	160.00	258.88
Plume Well	86.00	124.44
Well #35	1.30	9.05
Well #38	0.14	1.27
South Paddys Run Wells	2.78	9.70
South Highway 128 Wells	6.01	9.36
Southwest Wells	6.20	14.82
Irrigation Wells	5.50	8.25
Wilson Co. Wells	0.55	1.73
Agricultural Wells	5.20	9.27

The MEPAS predicted concentrations are plotted against the monitoring well concentrations as Figure 4.6-1. In addition, Figure 4.6-2 presents how the MEPAS predicted uranium concentrations on site the waste pit 3 are going to change for every lifetime. The same change in concentration is shown in Figure 4.6-3 for the South Plume.

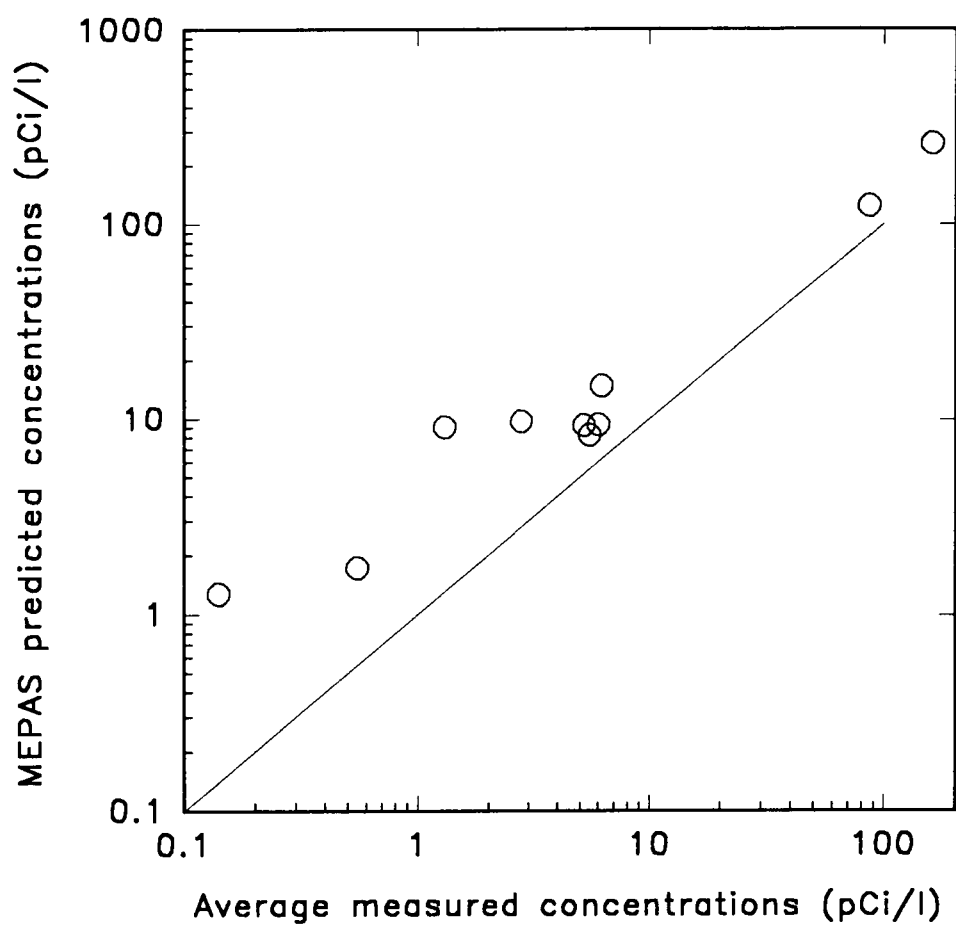


Figure 4.6-1 MEPAS Predicted Uranium Concentrations versus Monitoring Well Concentrations (pCi/l).

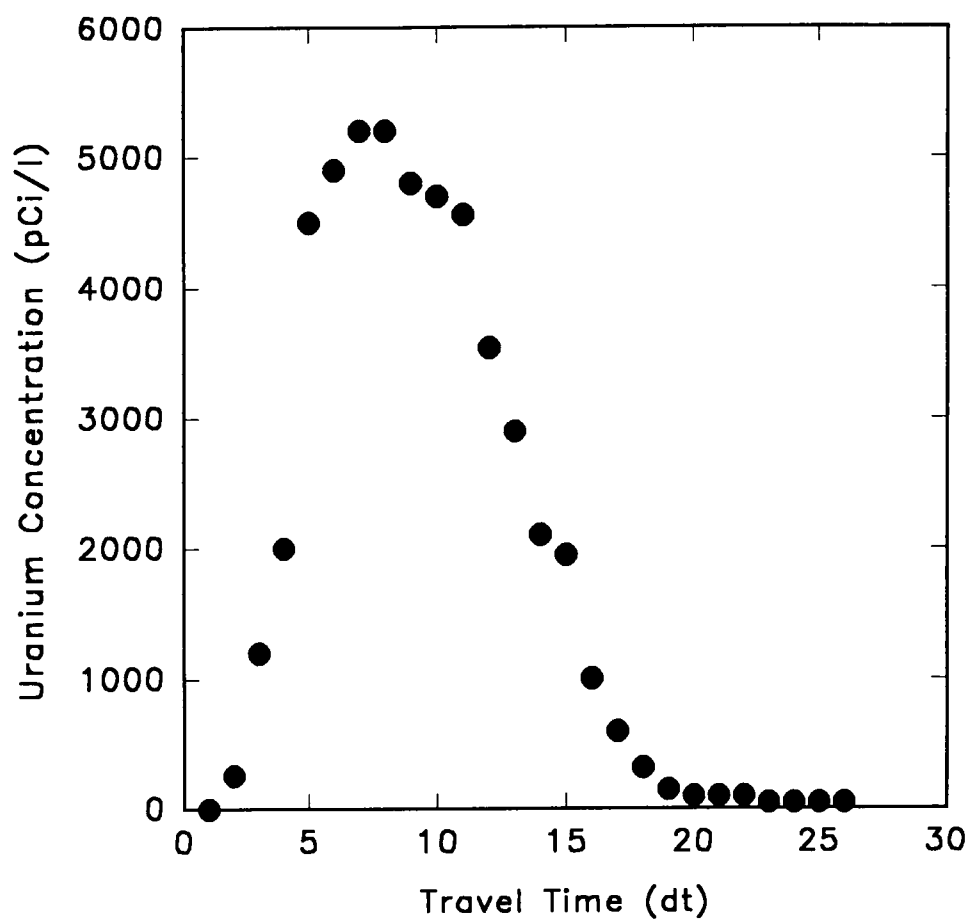


Figure 4.6-2 MEPAS Predicted Uranium Concentrations at FEMP Waste Pit 3
(dt = 70 years).

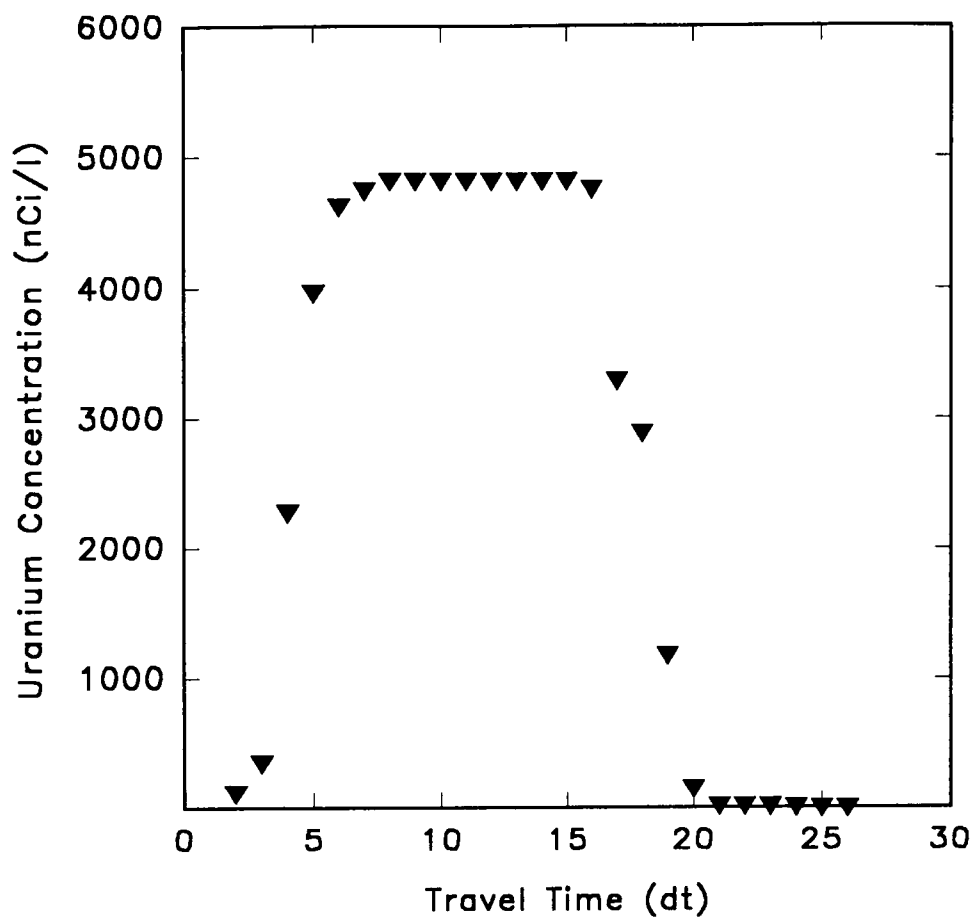


Figure 4-6-3 MEPAS Predicted Uranium Concentrations at FEMP South Plume
(dt = 70 years).

CHAPTER 5

DISCUSSION, RECOMMENDATIONS, AND CONCLUSIONS

5.1 Comparisons between predicted Concentrations and Actual Monitoring Data

The MEPAS model was used to assess risks at two DOE sites within the DOE complex. The estimated concentrations using MEPAS at given receptor locations were almost always an order of magnitude greater than the measured concentrations reported in site characterization reports. For both sites, the model was overpredicting. The two sites that were examined are not in proximity to one another, and the environmental setting changes significantly from one site to the other. The probable reason for consistently overpredicting concentrations is because of the built in conservatism that the model has rather than similarities between sites or constituents.

Three possible reasons for the overpredictions are: a) the model does not allocate mass between transport scenarios, b) the equation (3) for the retardation factor is highly conservative since no matrix diffusion is assumed to occur, c) the hypothetical well was located by MEPAS at the centerline of the contaminant plume whereas the monitoring wells are not located at the centerline of the contaminant plume.

In terms of its level of complexity and sophistication, MEPAS should be viewed

as a screening tool that can be used to estimate current and future risks posed by a site. Also, the possible presence of any fractures in the area that were studied has not been taken into consideration. If any fractures exist in the vicinity of the release sites or the vicinity of the monitoring wells they could have a dramatic effect on the values obtained from the monitoring wells, since the contamination plume could be diverted in a different direction from the direction of the monitoring well.

5.2 Recommendations

In this section several brief recommendations are provided. These recommendations are based on the discussions and analyses presented in the previous sections.

- **period of evaluation:** The period over which MEPAS evaluates risks (7000 years) does not appear appropriate for many of its applications. The reason for that is that great uncertainty is associated with risk estimates as predictions get further and further into the future. More importantly, risks hundreds of years in the future seem less relevant than more immediate risks to any reasonable prioritization applications (e.g., 5-year plans, 30-year DOE cleanup goal).
- **sensitive subpopulations:** MEPAS fails to consider sensitive subpopulations. Such subpopulations include persons who are more sensitive to chemical exposures, (i.e., infants, children, elderly, pregnant women). Chemical intake or exposure assumptions for those individuals can be considerably greater than average. Because the MEPAS methodology exclusively uses average intake or exposure assumptions, chemical or radiological intake for some sensitive subpopulations may be underestimated by MEPAS.
- **measured concentrations in the groundwater environment:** Using measured concentrations in the groundwater environment for estimating the health impact to

surrounding sensitive receptors represents a significant enhancement for MEPAS (MEPAS version 3.0). As opposed to relying only on transport modeling with its inherent uncertainties (MEPAS version 2.3) to predict contaminant concentrations, actual observed concentrations can be used in the assessment.

5.3 MEPAS Overview

Advantages of MEPAS

The model is able to address movements of contaminants through the soil, air, groundwater, and surface water. It includes 400 contaminants in a comprehensive database, and it is able to bypass computations if receptor concentrations are known (Version 3.0).

Limitations of MEPAS

It is difficult to analyze acute risks with MEPAS. The major limitation is that it considers transport scenarios separately; as a result, a mass balance will not be preserved, possibly overestimating exposures. Overestimation is not necessarily undesirable when there may be large uncertainties in the inventories of the contaminants. Currently, a mass balance modification is being developed and will be available in the near future.

Another limitation that can cause errors if the user does not have site-specific information is that the groundwater component assumes that all the wells are located in the center of the contaminant plume.

5.4 Conclusions

The implementation of MEPAS is designed to provide a ranking of environmental problems based on projected human-health impacts from long-term exposures (Droppo et. al., 1989). Applications of MEPAS should be limited to initial

screening and comparative rankings of environmental problems. For studying the details of a problem at a site, a site-specific approach should be employed. It is apparent that the model is suitable for the type of application for which it was derived: to provide a consistent basis for comparing relatively long-term risks across many sites.

Finally, it is noted that the initial concentrations and inventories, flux rates, and emission rates are arguably the most vital components of the risk characterization processes, particularly when using relatively elementary screening level models such as those contained in MEPAS. In many cases, the final risk numbers and risk estimates are essentially directly proportional to these values. Therefore if these values are based on site data for which there is a limited variation in the estimates of these parameters, uncertainty in the risk estimates will be reduced accordingly.

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VITA

Irene Datskou was born in Athens, Greece, on May 11, 1961. She attended primary and high school in Athens, Greece, and graduated from the 1st Lyceum of Athens in June 1979. She accepted an invitation to the Technische Universität in Berlin, West Germany, where she studied German for two years. In September of 1982 she was accepted in the Physics department of the University of Ioannina, Greece. In the fourth year of her studies she transferred to the University of Tennessee in Knoxville and graduated in June of 1986 with a Bachelor of Science degree in Physics.

In September of 1986 she accepted a graduate teaching assistantship at the University of Tennessee in Knoxville. In March of 1987 she joined the Photophysics Group at the Oak Ridge National Laboratory. She received the Master of Science degree in Physics in June 1988. Up until December 1991 she was teaching at the Physics department, and doing research at the Oak Ridge National Laboratory. In January 1992, she joined the Environmental Engineering program at the University of Tennessee and she received the Master of Science degree in August 1993.

Currently she is the head of the public health risk team at the Risk Analysis Section at the Oak Ridge National Laboratory Center for Risk Management.