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WORK PLAN

DEVELOPMENT OF RISK-BASED TARGET MONITORING LEVELS

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Prepared for
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1.0 INTRODUCTION

The protection of human health and the environment is the primary goal of regulatory requirements for cleanup and corrective action. Risk assessment techniques can contribute significantly to strategy development, risk management, and evaluation of corrective action needs. Initially, an impact assessment will identify preliminary exposure pathways, media and chemicals of potential concern at the El Dorado Chemical Company (EDC) site. After this step, proposed target monitoring levels (TMLs) will be developed for each constituent of concern (COC) at the EDC site. The impact assessment will identify the constituents of concern. However, based on data from the Phase II Groundwater Assessment Report (Woodward-Clyde, June 1996) nitrate appears to be the only COC. The rationale for sulfate not being selected as a COC is discussed in Section 2.0 of this report. TMLs are concentrations of a COC below which adverse effects to the exposed receptor are not expected to occur based on site-specific inputs. Therefore, a TML represents a concentration of a COC below which additional actions are not necessary from a health risk standpoint. In addition to development of TML's based on the risk to human health, potential ecological receptors will be identified and the potential for exposure to constituents from the site will be evaluated. The TMLs will then be evaluated to determine if they are adequate to protect the environment.

1.1 OBJECTIVE

The objective of this document is to outline the plan for the risk-based development of TMLs, the process through which it will be carried out, and the exposure assumptions and toxicity parameters which will be used in developing the TMLs. The objective will be to evaluate the potential for exposure to the identified exposure media by receptor populations of concern to the EDC site. This will include the calculation of site-specific TMLs in groundwater based on the historical analytical data from the site, present site conditions and the potential for future exposure.

Environmental fate and transport modeling will be conducted to determine the potential for identified COCs to reach the target exposure population(s) at exposure point(s) via groundwater and will provide information indicating COC-specific TMLs, if appropriate.

The results will provide information to support risk management decision-making for the site.

2.0 CHEMICALS OF POTENTIAL CONCERN SELECTION PROCESS

The Phase II groundwater assessment included sampling and chemical analysis of groundwater from 22 monitor wells. The assessment identified nitrate as the groundwater contaminant at the site. Nitrate was detected in 17 of the monitor wells at concentrations ranging from 0.2 to 1,010 mg/l. Concentrations for 10 of the 22 monitor wells were above the Maximum Contaminant Level (MCL) for drinking water of 10 mg/l. Nitrate is generally relatively mobile in groundwater due to the solubility of most salts of nitrate and its relatively low sorption to soil. Under anaerobic conditions, however, it can be biodegraded in denitrification reactions. It can also be taken up by vegetation.

Nitrate was first regulated in the U.S. drinking water in 1962. Nitrate is a major nutrient for vegetation and is an essential nutrient for all living organisms. However, in excessive amounts, nitrate may produce infant methemoglobinemia (J.M. Montgomery, 1985). The EPA regulates nitrate as a primary drinking water standard. Based on the frequency of detection, mobility and concentrations relative to the MCL, nitrate is a constituent of concern which will be included in this risk-based development of TMLs.

The Phase II groundwater assessment detected sulfate in the 22 monitor wells at concentrations ranging from 3.3 to 809 mg/l. Only 5 of the 22 monitor wells exceeded the Secondary MCL (SMCL) of 500 mg/l. Sulfate is generally much less mobile than nitrate. Sulfate may precipitate with cations that commonly occur in groundwater such as calcium or magnesium, may be biodegraded and may undergo sorption with soils. Consequently, sulfate is generally much less mobile in groundwater than nitrate.

The regulation of sulfate in United States drinking water dates back to 1925, when a number of aesthetic parameters (color, odor and taste) were regulated by the United States Public Health Service. The regulation of sulfate is related to taste or aesthetics and not to health risk. Sulfate has a detectable taste and can have a laxative effect at higher concentrations, but has no chronic or acute toxicity health effects. It is currently regulated by the Environmental Protection Agency (EPA) as a secondary drinking water standard (J.M. Montgomery, 1985). The secondary goals represent reasonable goals for drinking water quality but are not federally enforceable. Because sulfate is a mineral which has no major toxicogenic health effects, exceeded the SMCL infrequently and by relatively low amounts, and is much less mobile than nitrate, sulfate will not be included in this risk assessment as a constituent of concern.

A TML will be determined for nitrate in groundwater. An ecological assessment will be conducted at the site to determine if the TML is protective of potential environmental receptors in surface water bodies that could receive discharge of groundwater from the site (i.e., Lake Kildeer and associated tributaries).

3.0
RISK ASSESSMENT MODEL

A quantitative human health-based risk assessment will be conducted for the EDC site. An evaluation of the potential risk to human receptors under a no further remedial action scenario will be performed. The objective of the risk assessment will be to develop site-specific target monitoring levels (TMLs) which are protective of human health and the environment.

To complete the risk assessment, the following information will be gathered and evaluated:

- Identification of potential human receptors
- Identification of potential exposure routes and current magnitude of exposure
- Identification of potential future exposure routes and probable magnitude of exposure
- Toxicity assessment of the COC
- Assessment of the inherent uncertainty associated with all of the above

The human health risk assessment model will include the following components:

- Data evaluation/COC identification
- Exposure assessment
- Toxicity assessment
- Development of a target monitoring concentration (TML)

The risk assessment model will follow current EPA guidance including Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual, Part A, (EPA, 1989) and Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual, Part B, Development of Risk-Based Preliminary Remediation Goals, (EPA, 1991). The risk assessment will incorporate standard estimates of exposure and intake parameters as appropriate from the EPA guidance. Additional guidances that will be used include EPA's Exposure Factors Handbook (EPA, 1989b), Dermal Exposure Assessment (EPA, 1992a) and toxicology databases including the Health Effects Assessment Summary Tables (HEAST; EPA, 1993, 1994, 1995) and the Integrated Risk Information (IRIS; EPA, 1996).

3.1 POTENTIAL RECEPTOR POPULATIONS

The following potential receptor populations will be evaluated in the exposure assessment portion of the risk assessment:

- Off-site residents (child and adult)
- Ecological receptors (biota in surface water)

These receptor populations were chosen based on current knowledge of the site and limited knowledge of the potential for off-site receptors to be exposed to the COC via groundwater. The existence of households outside the city limits of El Dorado which use groundwater for any purpose (i.e., household water, watering of yard or garden, etc.) is not documented. Therefore, the potential for exposure to off-site residents via use of groundwater will be considered. The completeness of the exposure pathway will be evaluated and documented in the risk assessment. If quantitative modeling evaluations (see Sections 5.0 and 6.0) indicate that the COC will reach a specific exposure point for a given receptor, then a TML based on exposure to that specific receptor population will be calculated.

3.2 SITE CONCEPTUAL EXPOSURE MODEL

The site conceptual exposure model is intended to summarize information on the anticipated primary sources of contaminants, chemical release mechanisms, transport media, potential receptors, exposure routes and subsequent complete exposure pathways for the identified COC at the EDC site. All potential exposure pathways are combined into the integrated site conceptual exposure model shown in Figure 1. This figure indicates the potentially complete and incomplete pathways. The complete pathways are considered to be potentially complete but are not known to be complete under site-specific conditions. An "I" designates a pathway which is incomplete due to site-specific conditions.

It should be noted that not all pathways are complete due to site-specific conditions of exposure. There are a number of components which must all be present to constitute a complete exposure pathway. A complete exposure pathway consists of the following elements:

- A source and mechanism of compound release to the environment;
- An environmental transport medium for the released compound;
- A point of potential human contact with the affected medium and potential receptors located at these points; and
- A human uptake route (intake of media containing site-related compound) at the point of exposure.

All four elements must be present for an exposure pathway to be complete and for exposure to occur. The receptors and sources of potential release preliminarily identified for the EDC risk assessment will be evaluated fully for the completeness or incompleteness of the identified potential pathways of exposure in the exposure assessment portion of the risk assessment.

3.3 EXPOSURE AND INTAKE ASSESSMENT

Input parameters define the magnitude, frequency and duration of exposure for the identified receptor populations. These parameters are chosen by making assumptions for each receptor population resulting in estimates for each of the pathways considered in the assessment.

The magnitude of exposure to a chemical (or intake) is a function of a number of assumptions, including variables that describe the exposed population (e.g., contact rate, exposure frequency and duration, and body weight). Each of these parameters can be described by a range of variables. Two types of exposure can be quantified: an average exposure and a reasonable maximum exposure (RME). The TML will be based on the RME exposure scenarios. The RME will be estimated using guidance provided in EPA's Risk Assessment Guidance for Superfund (RAGS) Volume 1, Part A (EPA, 1989a) and Volume 1, Part B (EPA, 1991) and is defined by selecting intake variable values so that the combination of all intake variables results in a maximum exposure that is reasonably expected to occur at the site. The RME represents approximately the 90th percentile exposure, that is, the exposure expected to occur in 1 of every 10 exposed individuals. The intent of the RME is to estimate a conservative, well above average, exposure case that is still within the range of possible exposures. In order to quantify RME exposures for the identified receptors at the site, medium-specific intake factors will be developed.

3.3.1 Intake Factors/Exposure Parameters

Since only those pathways which are deemed complete will be carried through the TML development it is anticipated that the following pathway will be quantitatively evaluated:

- Ingestion of water (IF_{oral}): off-site residents
- Dermal contact with water (IF_{derm}): off-site residents

The exposure assessment portion of the risk assessment will fully evaluate, define and document the potential exposures to the identified potential receptor populations. The pathways and receptors noted above are not considered the final complete exposure pathways, but rather a preliminary identification based on current site knowledge and conditions.

Intake factors for each exposure pathway are determined by assimilating inputs from all exposure assumptions used to quantify exposures. It is anticipated that the following equations will be used to define each intake factor.

(i) For ingestion of groundwater, the intake factor (1/kg·day) is defined as follows:

$$Intake\ Factor\ (IF_{oral}) = \frac{IR\ x\ EF\ x\ ED}{BW\ x\ AT}$$

where:

IR	=	Ingestion rate (1/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kilograms)
AT	=	Averaging time (days)

(ii) For dermal contact with water, the intake factor (1/kg·day) is calculated as follows:

$$Intake\ Factor\ (IF_{derm}) = \frac{SA\ x\ ET\ x\ EF\ x\ ED\ x\ PC\ x\ CF}{BW\ x\ AT}$$

where:

SA	=	Surface area exposed (cm^2)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
PC	=	Permeability constant (cm/hour)
CF	=	Conversion factor ($1/cm^3$)
BW	=	Body weight (kilograms)
AT	=	Averaging time (days)

3.4 ENVIRONMENTAL EVALUATION

The environmental evaluation for the site will include a one day visit by a biologist to collect information regarding the environmental setting of the site. Observations of possible ecological receptors and potential contaminant migration pathways will be recorded as part of the site visit. This information will be used to determine the presence or absence of complete exposure routes for ecological receptors and the potential for significant ecological impacts.

Prior to the site visit, available information regarding special designation receptors or environments (e.g., endangered species or critical habitats) will be compiled.

A site conceptual model will be prepared to summarize possible exposure pathways and transport processes. The model will serve as a simplified schematic of general categories of receptors and transport processes.

Site chemical data will be summarized and reviewed for comparison with ecological effects criteria such as ambient water quality criteria protective of freshwater organisms. If direct exposure of ecological receptors is not occurring (e.g., contaminants are confined to groundwater beyond the reach of plant roots or burrowing animals), modeling of contaminant migration to a point of exposure (e.g., an estimated point of surface water recharge) may be evaluated.

The environmental evaluation will be summarized and conclusions presented regarding whether or not the available data indicate potential for adverse ecological impacts.

The evaluation will be performed in accordance with EPA guidance as presented in the Framework for Ecological Risk Assessment (EPA, 1992b) and Risk Assessment Guidance for Superfund: Volume II (EPA, 1989c).

Default exposure parameters for the anticipated potential receptors, media and exposure routes are found in Tables 1 through 4.

3.5 TARGET MONITORING LEVEL EVALUATION

For this project, a target monitoring level (TML) will be calculated. In general, a TML is calculated by performing a risk assessment in reverse. Acceptable risk and hazard levels are identified and media concentrations that will not result in exposures exceeding the acceptable levels will be calculated. A TML is the concentration of each chemical in each exposure medium, in this case nitrate in groundwater, that corresponds to the apportioned risk or hazard.

In general, a TML for a noncarcinogenic COC, such as nitrate, is calculated as follows:

Target Hazard Quotient	Reference Dose	Chronic Daily Intake	Intake Factor	Target Monitoring Level (TML)
A	B	C	D	E

where:

Chronic Daily Intake = Target Hazard Quotient x Reference Dose (or reference concentration)

$$C = A \times B \text{ (for noncarcinogens)}$$

and

$$TML\ (mg/l) = \text{Chronic Daily Intake} \div \text{Intake Factor}$$

$$E = C \div D$$

EPA policy will be considered to establish acceptable hazard quotients (i.e., the ratio of chemical intake to a published critical toxicity value) used in the TML calculation. Sites with a hazard index (i.e., the sum of all hazard quotients) of 1.0 or less typically do not require remediation. The TML calculations will utilize a target hazard index (THI) of 1 for nitrate. Target noncarcinogenic hazards will be used in the chemical and media-specific estimation of a TML for the EDC site. A TML will be selected for nitrate at the site by choosing the lowest of the receptor-specific TMLs for nitrate.

3.6 GROUNDWATER TMLs

For noncarcinogenic groundwater exposures, ingestion and dermal pathways will be incorporated into the TML calculation as appropriate. A TML for groundwater will be calculated using the following equation:

Noncarcinogens:

$$\text{TML (mg/l)} = \frac{THI}{[(IF_{dw} \div RfD_d) + (IF_{ow} \div RfD_o)]}$$

where:

THI	=	Target hazard index (unitless)
IF_{dw}	=	Intake factor dermal groundwater (1/kg·day)
IF_{ow}	=	Intake factor oral groundwater (1/kg·day)
RfD_d	=	Reference dose dermal (mg/kg·day)
RfD_o	=	Reference dose oral (mg/kg·day)

The site-specific TML for nitrate will be used as a monitoring tool only to provide a site management tool at the property boundary. A TML for nitrate based on potential off-site receptors and exposures is not applicable to set a clean up level for on-site conditions. Therefore, the TML based on off-site receptors will be used as a trigger level to identify when or if further consideration of on-site conditions are warranted.

4.0 SITE HYDRAULIC AND MATRIX DEPENDENT INPUT PARAMETERS

Several site-specific input parameters will be utilized in developing the contaminant fate and transport model for the EDC site. This section discusses available site-specific hydraulic and matrix dependent transport properties. Modeling scenarios for the fate and transport modeling will be developed from the site-specific information and are discussed in Section 4.5.

4.1 LOCAL GEOLOGY

The Tertiary-aged Cockfield formation (part of the Claiborne Group) crops out over most of Union County and underlies the EDC site. This formation consists predominantly of sands, silts, and carbonaceous (calcitic) clays with minor amounts of interbedded lignite and gypsum. The formation can contain lenticular beds of lignitic sands in some areas. The formation thickness is approximately 200 feet in most of Union County. A thin veneer of quaternary-aged alluvial sediments overlay the Cockfield formation along the Ouachita River and its tributaries.

Recharge to the Cockfield aquifer is local. Groundwater occurs under water table, or unconfined conditions; however, locally semi-confined conditions have been demonstrated to exist in areas where the clay content of the sediments is high. Both conditions are present at the EDC site (Woodward-Clyde, June 1996). Water table configuration within the aquifer generally exhibits a subdued reflection of the local topography with flow toward surface drains (i.e., the valleys of the principal streams). This is apparent from the water table map prepared by Woodward-Clyde for the EDC site (Woodward-Clyde, June 1996).

AREA OF CONCERN

Area water levels in wells range in depth from near land surface in low-lying areas to as much as 50 feet on the largest hills and ridges. Discharge is primarily base flow to streams with lesser amounts of evapotranspiration.

Falling head tests on undisturbed samples collected from the Cockfield formation revealed coefficient of vertical permeability values ranging from 1.0 x 10^{-3} cm/sec for sandy materials to 5.0 x 10^{-8} cm/sec for the more clay-rich sediments. This wide range of permeability values is the result of the variable character of the sediments. Lithologic investigations have shown that the Cockfield formation is highly variable in clay content with some areas being predominantly clay and other areas being predominantly sand. Subsequently, the horizontal hydraulic conductivity of the aquifer, when considered as a whole, should be expected to be greater than the aquifer's vertical hydraulic conductivity. Areas of high clay content tend to perch groundwater on a local scale. Further, clay horizons can generate conditions termed semi-confined when the clayey material overlies more permeable zones and hydrostatic head is driven by recharge areas at higher elevations. These scenarios are present at the EDC site.

The Cook Mountain formation underlies the Cockfield formation in all areas of the region except where the younger sediments have been removed by erosion. The formation consists of low permeability clays and silty clays with lesser amounts of very fine sands. The formation acts as a lower confining unit (aquitard) for the Cockfield aquifer and an upper confining unit for the underlying aquifer.

Thickness of the confining unit is variable from approximately 50 feet to as much as 200 feet across the region. In the vicinity of the EDC facility, the thickness of the clays comprising the confining unit is estimated to be between 75 and 100 feet (McWreath, et. al., 1991).

Vertical hydraulic conductivity of the confining unit was estimated by Fitzpatrick, et. al. (1990) to range from 1 x 10^{-7} cm/sec to 1 x 10^{-10} cm/sec. The estimates are based on the results of their calibrated regional finite-difference model. Horizontal hydraulic conductivity of the Cook Mountain confining unit was established by the calibrated model to be 3.18 x 10^{-9} cm/sec. Therefore, both the vertical and horizontal hydrologic flow components are retarded by this formation.

4.1.1 Hydraulic Conductivity

Aquifer tests will be conducted on monitor wells EDC-4, EDC-13 and EDC-18. Hydraulic conductivity values (K) will be derived from an arithmetic average of these wells. The wells are spatially located across the site; therefore, a representative K value will be obtained for use in the model.

4.2 POROSITY

Based on effective porosity values determined by Freeze and Cherry (1979) for specific lithologies, a value of 0.30 will be utilized for the effective porosity of the uppermost saturated zone at the EDC site.

4.3 GROUNDWATER FLOW DIRECTION AND GRADIENT

A water table contour map is shown as Figure 6 of the Phase II Groundwater Investigation - Final Report (Woodward-Clyde, June 1996) for the uppermost saturated zone at the EDC site. The hydraulic gradient will be calculated based on groundwater contours from this map. The EDC site groundwater gradient is to the southeast. The regional groundwater gradient for Union County is also to the southeast towards the Ouachita River.

4.4 GROUNDWATER VERTICAL SEEPAGE VELOCITY

The transport of a dissolved solute such as nitrate is by means of advective transport with the groundwater with varying degrees of retardation of the solute transport relative to the water due to attenuation and degradation processes such as sorption and degradation. Consequently, the solute is expected to move at a slower velocity than the groundwater.

The USGS, in cooperation with the Arkansas Department of Health (ADH), published a report which specifically addressed the susceptibility of aquifers of Union County, Arkansas to contamination (Leidy and Taylor, 1992). The purposes of this investigation were to:

1) "Describe the general hydrogeology and groundwater flow system of Union County;

2) Identify potential sources of contamination; and

3) Provide an overview of the susceptibility of major aquifers to contamination."

The susceptibility of the deeper aquifers to contamination was addressed in part by computational estimates of the vertical rate of movement of water through confining units. Specifically, derivatives of Darcy's law were used, along with available information on confining unit thicknesses and characteristics and potentiometric surface data for the aquifers, to estimate the rates at which water moves vertically through the Cook Mountain formation and the Sparta Sand confining bed. The key variables used in making these estimates are:

- The thickness of the confining unit(s);
- The vertical hydraulic conductivity of the confining unit(s);
- The potentiometric or hydrostatic head difference between the aquifer above and the aquifer below the confining unit(s); and
- The effective porosity of the confining unit(s).

Based on information presented by Leidy and Taylor (1992), the thickness of the Cook Mountain formation in the vicinity of the EDC site is 95 feet. This thickness is based on a geophysical well log for an unspecified well that is reported to be located near the city of El Dorado's Water Supply Well No. 16. The referenced well location is approximately 8,000 feet (1.5 miles) southeast of the EDC Production Area. Based on water level measurements, Leidy and Taylor reported a hydrostatic head difference between the Cockfield aquifer and the Greensand aquifer in the vicinity of this same well of 90 feet. Leidy and Taylor used an effective porosity value of 0.35 for the Cook Mountain formation. The final variable used in Leidy and Taylor's travel time estimates is the vertical hydraulic conductivity of the Cook Mountain formation. This was assigned a value of 3.0×10^{-4} feet per day (1.06×10^{-7} cm/sec).

Using Leidy and Taylor's Equation 2 and the above values, Woodward-Clyde estimates the travel time for water vertically through the Cook Mountain formation in the vicinity of the EDC plant to be approximately 320 years. However, Woodward-Clyde notes that the vertical hydraulic conductivity value used by Leidy and Taylor is in the very upper end of values used by McWreath, et al., and Fitzpatrick, et al., in their models. These authors used a much lower vertical hydraulic conductivity value of 9×10^{-6} feet per day (3.18×10^{-9} cm/sec) for the areas in and around Union County, Arkansas. With this conductivity value and the other variables assigned as above, Woodward-Clyde estimates that the travel time for water through the Cook Mountain formation increases to 10,680 years.

The above information on the time required for groundwater to move from the Cockfield formation through the Cook Mountain formation aquitard to the Sparta aquifer is such that movement of dissolved constituents from the Cockfield formation to the Sparta aquifer should not be of concern. This information will be summarized in the report documenting development of TMLs.

4.5 MODEL DEVELOPMENT AND SELECTION

As discussed in Section 3.0, potential receptor populations have been developed for the EDC site. A TML in groundwater will be calculated for nitrate for each identified potential receptor population that is shown to be potentially exposed under current or future conditions. The TML will be calculated from the point of exposure. These exposure points are for the residential neighborhoods (off-site resident), ecological receptors (surface water biota) and the municipal well field located in El Dorado (off-site resident). Fate and transport modeling of the saturated zone will be performed to estimate future COC concentrations in groundwater so that a human health-based TML will not be exceeded when groundwater reaches the exposure point. The magnitude of the impact to groundwater is defined by the concentrations of the COC above TMLs at defined exposure points. The TML will then be evaluated to determine if it is also protective of ecological receptors.

4.5.1 Generalized Cross-Section

A generalized modeling cross-section for the EDC site will be developed using existing boring logs from Woodward-Clyde's recent investigation (Woodward-Clyde, June 1996). The geology presented in the modeling cross-section will be used in the saturated zone model to represent general site conditions. As discussed in Section 2,0, one COC (nitrate) will be modeled.

4.5.2 Model Selection

Woodward-Clyde plans to use the International Ground Water Modeling Center's (IGWMC's) Solute Program Package, Analytical Model for Transport of a Solute Plume from Point Sources in a Uniform Two-Dimensional Groundwater Flow Field (Plume2D) to simulate the transport of nitrate. Sorption and biodegradation processes can be simulated in the model. The Solute Program Package contains analytical resolutions of one, two or three-dimensioned advection-dispersion equations in uniform groundwater flow or in radial groundwater flow. Woodward-Clyde plans to use the two-dimensional advection-dispersion solutions for this project.

5.0
FATE AND TRANSPORT MODELING

5.1 MODEL ASSUMPTIONS

Horizontal transport modeling will be completed to address the potential transport of nitrate in the groundwater to the target exposure receptor locations. Woodward-Clyde plans to use the IGWMC Solute Program Package, Analytical Model for Transport of a Solute Plume from Point Sources in a Uniform Two-Dimensional Groundwater Flow Field (Plume2D) to simulate the horizontal transport of nitrate. Woodward-Clyde plans to use the Plume2D module of the Solute package to calculate the concentration distribution of a plume from point sources in two-dimensional regional flow.

Solute uses analytical solutions of the advective dispersive transport equation for a non-conservative tracer solution. Solute contains four groups of analytical solutions for one-, two- and three-dimensional transport of a solute in uniform groundwater flow. For this work, the solution module Plume2D is planned to be used. This solution assumes the solute to be well-mixed over the constant thickness of the aquifer resulting in an areal concentration distribution which is uniform with depth. The source is a vertical line source extending from the top to the base of the aquifer.

The assumptions on which the model is based are:

- Uniformly porous aquifer
- The aquifer is homogeneous and isotropic with respect to its hydraulic and transport characteristics
- The aquifer is infinite in areal extent and of constant thickness
- A source fully penetrates the aquifer
- The groundwater flow regime is fully-saturated
- One-dimensional steady-state uniform regional flow in the x-direction

- Pollutants are distributed instantaneously over the entire aquifer thickness beneath the source
- The density and viscosity of the solute in the source and in the aquifer are identical and do not change in time
- There is no solute advection or dispersion into or out of the confining layers

5.2 HORIZONTAL TRANSPORT MODEL INPUT PARAMETERS

The variables necessary for input into the model include: longitudinal dispersivity, lateral dispersivity, retardation factor, half life, number of point sources, source strength, elapsed time, coordinates of the source and coordinates of the grid. Input parameters for the groundwater flow portion of the modeling are discussed in Section 4.0. The following provides a brief description of how each solute transport input variable will be evaluated.

5.2.1 Longitudinal Dispersivity

The longitudinal dispersivity (reported in dimensions of length) represents the effects of porous medium properties on dispersion of the solute mass. The longitudinal dispersivity, when multiplied by the seepage velocity, yields the longitudinal dispersion coefficient. Woodward-Clyde plans to use a conservative value to be calculated by taking ten percent of the transport distance to the receptor location. For example, if the source was 1,000 feet from a receptor, the longitudinal dispersivity would be estimated to be 100 feet. A sensitivity analysis is planned to be performed on this parameter as described in Section 6.0.

5.2.2 Transverse Dispersivity

Woodward-Clyde plans to estimate the lateral dispersivity (reported in dimensions of length) to be ten percent of the longitudinal dispersivity.

5.2.3 Retardation Factor

Woodward-Clyde plans to estimate a retardation factor for nitrate based on literature review of available information on attenuation of nitrate in groundwater.

5.2.4 Biodegradation Rate

The half-life of nitrate will be estimated from literature values. The value of half-life used for this modeling will be the number of days needed for the concentration of nitrate in the groundwater to decrease by one-half due to anaerobic biodegradation.

5.2.5 Source

The source strength (kg·day) will be evaluated by trial and error until a nitrate concentration at the node at which the source was defined is similar to the known nitrate concentration in the groundwater in that area.

6.0
SENSITIVITY ANALYSIS OF INPUT PARAMETERS ON MODELED RESULTS

Woodward-Clyde plans to conduct sensitivity analyses for the horizontal fate and transport modeling. The purpose of the sensitivity analyses is to evaluate how sensitive the model is to a particular input parameter. For each parameter evaluated, a change in the model result will be compared to the relative amount by which the parameter was changed.

Woodward-Clyde plans to conduct sensitivity analyses for hydraulic conductivity, longitudinal and lateral dispersivity, retardation factor and half-life.

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TABLES

TABLE 1

POTENTIAL EXPOSURE PARAMETERS FOR DERMAL EXPOSURE TO GROUNDWATER USED FOR DOMESTIC PURPOSES BY OFF-SITE ADULT RESIDENTS (REASONABLE MAXIMUM EXPOSURE SCENARIO)

$$Intake\ Factor = \frac{SA \times ET \times EF \times ED \times PC \times CF}{BW \times AT}$$

Abbreviation	Description	RME
SA	Surface Area (cm^2) (1)	20,000
ET	Exposure Time (hrs/day) (2)	0.25
EF	Exposure Frequency (days/yr) (3)	350
ED	Exposure Duration (years) (4)	30
PC	Permeability Constant (cm/hr) (5)	0.0015
CF	Conversion Factor ($1/cm^3$)	0.001
BW	Body Weight (kg) (6)	70
AT	Averaging Time (days) (7)	
	Noncarcinogenic	10,950

NOTES:

1 The surface area for adult residents (20,000 cm^2) represents the average total body surface area for the respective receptors (EPA, 1992a).

2 The exposure time of 0.25 hr (15 min) correspondsto the RME assumption of time spent bathing each day by adult residents (EPA, 1992a).

3 An exposure time of 350 days/year assumes that the resident spends approximately two weeks away from home each year (EPA, 1991b).

4 The exposure duration of 30 years is the upper-bound estimate of time spent living in one residence (EPA, 1989b).

5 Compound-specific values regarding the permeability of the skin to nitrates will be utilized in the risk assessment. However, if compound-specific information is not available, an appropriate surrogate compound will be chosen to evaluate the potential for dermal absorption of nitrates.

6 The body weight of 70 kg is the average body weight of adult males (EPA, 1989b).

7 The averaging time is the time (in days) over which the exposure is assumed to occur; that is, 10,950 days (30 years) for noncarcinogenic effects (EPA, 1989a).

* Additional note: The above values represent default values for the use of groundwater as a household water source. Site-specific information will be used, as available, to substitute for any of the above parameters.

TABLE 2

POTENTIAL EXPOSURE PARAMETERS FOR INGESTION OF GROUNDWATER USED FOR DOMESTIC PURPOSES BY OFF-SITE ADULT RESIDENTS (REASONABLE MAXIMUM EXPOSURE SCENARIO)

$$\textit{Intake Factor} = \frac{IR \times EF \times ED}{BW \times AT}$$

Abbreviation	Description	RME
IR	Ingestion Rate (l/day)[(1)]	2.0
EF	Exposure Frequency (days/yr) [(2)]	350
ED	Exposure Duration (years) [(3)]	30
BW	Body Weight (kg) [(4)]	70
AT	Averaging Time (days) [(5)]	
	Noncarcinogenic	2,555

NOTES:

1 The ingestion rate of 2.0 1/day corresponds to the RME estimate of the amount of water ingested per day by the adult receptor (EPA, 1991b).

2 An exposure time of 350 days/year assumes that the resident spends approximately two weeks away from home per year (EPA, 1991b).

3 The exposure duration of 30 years is the average time spent living in one residence (EPA, 1989b).

4 The body weight of 70 kg is the average body weight of adult males (EPA, 1989b).

5 The averaging time is the time (in days) over which the exposure is assumed to occur; that is, 10,950 days (30 years) for noncarcinogenic effects (EPA, 1989a).

* Additional note: The above values represent default values for the use of groundwater as a household water source. Site-specific information will be used, as available, to substitute for any of the above parameters.

TABLE 3

POTENTIAL EXPOSURE PARAMETERS FOR DERMAL EXPOSURE TO GROUNDWATER USED FOR DOMESTIC PURPOSES BY OFF-SITE CHILD RESIDENTS (REASONABLE MAXIMUM EXPOSURE SCENARIO)

$$Intake\ Factor = \frac{SA \times ET \times EF \times ED \times PC \times CF}{BW \times AT}$$

Abbreviation	Description	RME
SA	Surface Area (cm^2) (1)	6,947
ET	Exposure Time (hrs/day) (2)	0.5
EF	Exposure Frequency (days/yr) (3)	350
ED	Exposure Duration (years) (4)	6
PC	Permeability Constant (cm/hr) (5)	0.0015
CF	Conversion Factor ($1/cm^3$)	0.001
BW	Body Weight (kg) (6)	14.5
AT	Averaging Time (days) (7)	
	Noncarcinogenic	2,190

NOTES:

1 The surface area for child residents represents the average total bodysurface area for the male receptor child (EPA, 1989b).

2 The exposure time of 0.5 hr (30 min) corresponds to the RME assumption of time spent bathing each day by the child receptor (EPA, 1991b).

3 An exposure time of 350 days/year assumes that the resident spends approximately two weeks away from home each year (EPA, 1991b).

4 The exposure duration is 6 years for the child receptor (0 to 6 years).

5 Compound-specific values regarding the permeability of the skin to nitrates will be utilized in the risk assessment. However, if compound-specific information is not available, an appropriate surrogate compound will be chosen to evaluate the potential for dermal absorption of nitrates.

6 The body weight of 14.5 kg is the average body weight of male children 0 to 6 years old (EPA, 1989a).

7 The averaging time is the time (in days) over which the exposure is assumed to occur; that is, 2,190 days (6 years) for noncarcinogenic effects (EPA, 1989a).

* Additional note: The above values represent default values for the use of groundwater as a household water source. Site-specific information can be used, as available, to substitute for any of the above parameters.

TABLE 4

POTENTIAL EXPOSURE PARAMETERS FOR INGESTION OF GROUNDWATER USED FOR DOMESTIC PURPOSES BY OFF-SITE CHILD RESIDENTS (REASONABLE MAXIMUM EXPOSURE SCENARIO)

$$Intake\ Factor = \frac{IR \times EF \times ED}{BW \times AT}$$

Abbreviation	Description	RME
IR	Ingestion Rate (l/day) (1)	1.0
EF	Exposure Frequency (days/yr) (2)	350
ED	Exposure Duration (years) (3)	6
BW	Body Weight (kg) (4)	14.5
AT	Averaging Time (days) (5)	
	Noncarcinogenic	2,190

NOTES:

1 The ingestion rate of 1.0 l/day corresponds to the RME estimate of the amount of water ingested per day by the receptor (EPA, 1989b).

2 An exposure time of 350 days/year assumes that the resident spends approximately two weeks away from home per year (EPA, 1991b).

3 The exposure duration of 6 years is the exposure duration for the child receptor (0 to 6 years).

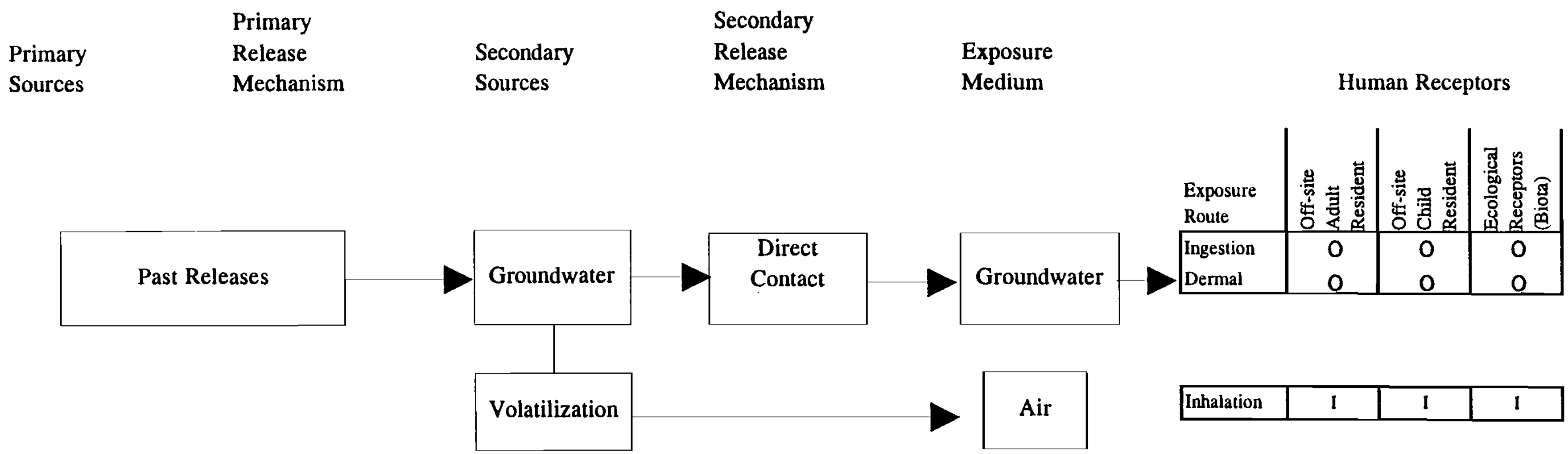
4 The body weight of 14.5 kg is the average body weight of male children 0 to 6 years old (EPA, 1989a).

5 The averaging time is the time (in days) over which the exposure is assumed to occur; that is, 2,190 days (6 years) for noncarcinogenic effects (EPA, 1989a).

* Additional note: The above values represent default values for the use of groundwater as a household water source. Site-specific information will be used, as available, to substitute for any of the above parameters.

FIGURES

EL DORADO CHEMICAL COMPANY
Site Conceptual Exposure Model



LEGEND
I Incomplete exposure pathway
O Potentially complete exposure pathway

Figure 1