**Environmental Settings for Selected U.S.
Department of Energy Installations—
Support Information for the Programmatic
Environmental Impact Statement and the
Baseline Environmental Management Report**

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May 1995

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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**ENVIRONMENTAL SETTINGS FOR SELECTED
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SUPPORT INFORMATION FOR THE PROGRAMMATIC
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Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

This report contains the environmental setting information developed for 25 U.S. Department of Energy (DOE) installations in support of the DOE's Programmatic Environmental Impact Study (PEIS) and the Baseline Environmental Management Report (BEMR). The common objective of the PEIS and the BEMR is to provide the public with information about the environmental contamination problems associated with major DOE facilities across the country, and to assess the relative risks that radiological and hazardous contaminants pose to the public, onsite workers, and the environment.

Environmental setting information consists of the site-specific data required to model (using the Multimedia Environmental Pollutant Assessment System) the atmospheric, groundwater, and surface water transport of contaminants within and near the boundaries of the installations. The environmental settings data describes the climate, atmospheric dispersion, hydrogeology, and surface water characteristics of the installations. The number of discrete environmental settings established for each installation was governed by two competing requirements: 1) the risks posed by contaminants released from numerous waste sites were to be modeled as accurately as possible, and 2) the modeling required for numerous release sites and a large number of contaminants had to be completed within the limits imposed by the PEIS and BEMR schedule. The final product is the result of attempts to balance these competing concerns in a way that minimizes the number of settings per installation in order to meet the project schedule while at the same time providing adequate, if sometimes highly simplified, representations of the different areas within an installation.

Environmental settings were developed in conjunction with installation experts in the fields of meteorology, geology, hydrology, and geochemistry. When possible, local experts participated in the initial development, fine tuning, and final review of the PEIS and BEMR environmental settings.

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Above all, this report would not be possible without the support of the numerous U.S. Department of Energy and contractor employees (at each of the installations discussed in this report) who generously took time from their important duties to meet with and assist our research staff in compiling environmental setting data. Our heartfelt thanks go out to each of these capable professionals.

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1.0 INTRODUCTION

This report presents the environmental setting information developed for 25 U.S. Department of Energy (DOE) installations in support of the DOE's Programmatic Environmental Impact Statement (PEIS) and the Baseline Environmental Management Report (BEMR). Environmental setting information consists of the site-specific data required by the PEIS and BEMR to model the atmospheric, groundwater, and surface water transport of contaminants within and near the boundaries of an installation. Other types of model input requirements, such as source term data (e.g., the number, type, condition, quantity, and release rate of contaminants) and receptor information (e.g., population distributions, location of groundwater wells, surface water intakes, and agricultural production data) are provided by other PEIS and BEMR tasks teams and are not discussed in this report.

The following sections provide a brief description of the purpose of the PEIS and BEMR, organization of the project, objective of the PEIS and BEMR Environmental Settings Task, data compilation approaches that are used to develop environmental setting data, and the organization of this report.

1.1 PURPOSE OF THE PROGRAMMATIC ENVIRONMENTAL IMPACT STUDY

The PEIS was initiated in 1989 to comply with requirements established by the National Environmental Policy Act (NEPA). The objective of the PEIS was to provide the public with information about the types of radiological and hazardous wastes and environmental contamination problems associated with major DOE facilities across the country, and to assess the relative risks that these wastes pose to the public, onsite workers, and the environment. The risk assessment aspect of the PEIS gives the project a scope that is broader than that required by a strict interpretation of the NEPA. However, this integral portion of the study not only provides valuable information for the public, it also brings the study into compliance with other major environmental legislation (e.g., the Resource Conservation and Recovery Act [RCRA]).

The PEIS has three major components: Waste Management (WM), Environmental Restoration (ER), and Decontamination and Decommissioning (D&D). Data gathering and modeling efforts are being conducted for each of these three components independently, but the results are being integrated at the highest levels in the project to provide a unified picture of the DOE complex.

The PEIS is designed to build on and complement the more detailed site characterization efforts that are currently being conducted at many individual DOE installations. Because of the broad overview nature of the PEIS, interpretation of installation-specific information

must be done with care. The results generated by the PEIS program are not intended to replace or supersede the more detailed studies being conducted at individual installations.

The final products from the PEIS will be used in several ways. All of the information gathered for the study will be released to the public. Project personnel are in the process of developing a "data-viewer," an integrated computer-based system that will allow users to query the PEIS database about different types of information for each of the installations for which data are available. In addition, the DOE has indicated plans to use the information gained from this study to identifying priority health or environmental remediation issues across the complex. Although the results from this study are not suitable for supporting detailed decision-making processes, it is expected to help guide the agency in identifying the most critical issues it needs to address on a complex-wide basis.

1.2 PEIS PROJECT ORGANIZATION

The PEIS is being managed for the DOE by a consortium of engineering firms known as the META/Berger Group. To support these firms, certain tasks within the PEIS have been delegated to Argonne National Laboratory (ANL), Oak Ridge National Laboratory (ORNL), and Pacific Northwest Laboratory (PNL). Specifically, the ANL has lead responsibilities for gathering and modeling much of the WM data. Responsibilities for supporting the ER studies are divided between the ORNL and the PNL. The ORNL has the lead for completing the environmental and human health risk assessments for all of the installations (except for the Hanford Site, which is being done at the PNL), and the ORNL is compiling the population data, exposure assessment data, and lists of possible receptors where the contaminants may come in contact with the public. The PNL has responsibilities for gathering information regarding actual release sites at the various installations across the DOE complex. This information includes factors such as the types of contaminants present and the inventory, mass, or concentration of contaminants released. In addition, the PNL is responsible for collating environmental setting data, the data that are used in the risk assessment modeling at the ORNL. Other tasks being conducted at both the ORNL and the PNL in support of the META/Berger data analysis activities include engineering assessments (e.g., remediation options and associated costs), and regulatory analyses.

1.3 PURPOSE OF THE BASELINE ENVIRONMENTAL MANAGEMENT REPORT

The FY 1994 National Defense Authorization Act required development of a Baseline Environmental Management Report (BEMR). The BEMR will provide a "baseline case" and a range of projected cost of the Environmental Management (EM) program. Included will be a description of each activity and the problem the activity addresses, the proposed remediation of problem if known, the estimated cost of completion of each activity, and a schedule for completion for each activity with milestones denoted.

1.4 ENVIRONMENTAL SETTING TASK

One of the major supporting tasks within the PEIS and BEMR, and the focus of this report, is the development of environmental settings for each of the installations within the DOE complex. A listing of the installations for which environmental settings have been completed is given in Table 1.1 and the locations of these installations are shown in Figure 1.1. The primary purpose of environmental settings is to allow the risk modelers to characterize environmental transport pathways for individual or groups of contaminants and, given realistic receptors, to use this information to prepare exposure and risk assessments.

Exposure and risk assessments for the PEIS are being done using the Multimedia Environmental Pollutant Assessment System (MEPAS) (Buck et al. 1989; Droppo et al. 1989). Environmental settings formulated for the PEIS must be compatible with the data input requirements of the MEPAS model. The MEPAS is a broad-based, generic tool that allows users to examine potential migration of a range of contaminants, including organics, metals, radionuclides, and carcinogens, along multiple transport pathways. Contaminant migration pathways include vadose and groundwater movement, and overland (i.e., runoff), surface water and atmospheric transport pathways. Exposure can occur via a large number of routes including direct consumption (e.g., drinking contaminated water, eating agricultural products irrigated with contaminated water), dermal contact (for example, through bathing in water drawn from a contaminated source or swimming in contaminated surface water), inhalation, and others.

The strength of MEPAS is that it allows risk assessors to obtain relative risk assessments for multiple contaminants that might occur along any of several potential exposure routes. One of the limitations of MEPAS, on the other hand, is that it cannot provide the detailed and quantitative risk estimates that might be obtainable from models that are developed specifically to address conditions found at individual sites.

The environmental settings data for each installation include components on climatology, atmospheric dispersion characteristics, hydrogeology, and surface waters. Parameters included in each of these four types of files are limited to those required by MEPAS. As such, the environmental setting descriptions do not necessarily reflect the complexity or diversity of conditions found at individual sites. Rather, the intent of these descriptions is to provide information that will enable the risk assessors to generate a reasonable relative risk number for each installation, within the limitations of the model. Because the model cannot accommodate the meteorologic, hydrologic, and geologic

**Table 1.1. List of DOE Installations for Which Environmental Settings
Were Prepared**

Argonne National Laboratory, Illinois
Brookhaven National Laboratory, New York
Fernald Site, Ohio
Hanford Site, Washington
Idaho National Engineering Laboratory, Idaho
Inhalation Technology Research Institute at Sandia, New Mexico
Kansas City Plant, Missouri
Laboratory for Energy and Related-Health Research, California
Lawrence Berkeley Laboratory, California
Lawrence Livermore National Laboratory, California
Los Alamos National Laboratory, New Mexico
Maywood Site (Formerly Utilized Site), New Jersey
Mound Site, Ohio
Nevada Test Site, Nevada
K-25 Installation at Oak Ridge, Tennessee
Oak Ridge National Laboratory (X-10 Facility), Tennessee
Y-12 Installation at Oak Ridge, Tennessee
Paducah Gaseous Diffusion Plant, Kentucky
Pantex, Texas
Pinellas Plant, Florida
Portsmouth Uranium Extraction Complex, Ohio
Rocky Flats Plant, Colorado
Sandia National Laboratory, New Mexico
Savannah River Plant, South Carolina
Tonawanda Site (Formerly Utilized Site), New York

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Figure 1.1. Location Map of the DOE Installations for Which Environmental Settings Were Prepared

complexity of installations, many, if not most, of the site descriptions (as represented by the MEPAS database) contain "obviously erroneous" entries. These "errors" are especially prevalent in the hydrogeologic files. These entries accommodate the needs of the risk model and should not be interpreted to represent actual hydrologic or geologic conditions at any individual site.

The number of environmental settings per installation varies. In all cases, each installation is represented by a single climatological file and, with a few notable exceptions for the large installations, most sites are modeled using a single set of atmospheric dispersion characteristics. The number of surface water settings varies widely from site to site, depending on the number and spatial distribution of surface waters at a site. The number of hydrogeologic settings also varies considerably among installations. The number chosen for each installation represents a compromise between the number of potential contaminant transport pathways found at each installation and the ability of the risk model to deal with the complexity in a coherent and reasonable manner.

1.4.1 Climatic Settings

Climatic data are important for all transport pathways. For example, wind and temperature data are important for determining volatilization rates of chemical compounds for the atmospheric pathway, precipitation data are important in estimating transport rates through the soil column to groundwater, and temperature and precipitation intensity information is important in modeling runoff. For the PEIS, each installation is typically assigned a single climatic environmental setting. There are two reasons for the lack of multiple climatic settings at installations. First, climatic conditions tend to remain relatively constant across the spatial extent of most installations. Second, the long-term monitoring of the meteorological parameters required to define a climatic setting is generally not available for more than one location at an installation. In fact, at some installations, sufficient onsite meteorological monitoring is not available to characterize all of the required climatic parameters. In such cases, offsite data from a nearby airport or National Weather Station office often provides the most climatologically representative set of information for an installation.

The climatic setting contains such annual-averaged information as the mean air temperature, precipitation amount, number of precipitation days, number of thunderstorm days, and mean wind speed. Monthly averages are required for some parameters, such as mean air temperature, precipitation amount, mean wind speed, cloud cover, and maximum and minimum average relative humidity. In addition, the climatic setting includes estimates of the top soil moisture capacity, climatic region, and precipitation-evaporation index. These parameters are described in more detail in the Appendix.

1.4.2 Atmospheric Dispersion Settings

Atmospheric dispersion data are needed to characterize the atmospheric transport pathway. Atmospheric dispersion is a combination of atmospheric transport and diffusion. Atmospheric transport can be estimated using information on local wind directions and speeds, while atmospheric diffusion can be estimated using information on the intensity of atmospheric turbulence. Because atmospheric turbulence is a difficult parameter to measure, the rate of mechanically and convectively induced turbulent mixing is usually approximated from more easily measurable meteorological parameters. The most popular turbulence-typing scheme involves the use of atmospheric stability classes (Randerson 1984). Traditionally, seven atmospheric stability classes, labeled "A" through "G", are used to estimate the turbulence intensity. Stability class "A" represents an unstable atmosphere characterized by the highest rate of turbulent mixing. The rate of turbulence decreases through the classes so that stability class "D" represents a neutral atmosphere with a moderate amount of turbulence mixing, and stability class "G" represents a very stable atmosphere with a low rate of turbulent mixing.

The atmospheric dispersion component of the environmental settings consists of a joint frequency distribution of wind direction, wind speed, and atmospheric stability. Typically, wind direction is characterized using 16 directional sectors which indicate the direction from which the wind is blowing. Wind speed can be characterized using up to six different speed classes. Atmospheric stability can be characterized using from six or seven stability classes. The distribution gives the relative frequency of time during an average year in which each potential combination of wind direction, wind speed, and atmospheric stability occurs. These parameters are described in more detail in the Appendix.

Most installations are generally described using only one atmospheric dispersion setting. Other installations, that are either quite large or have significant complex terrain and have meteorological monitoring at more than one location, can be described using two or more atmospheric dispersion settings. In all cases, boundaries between the atmospheric dispersion settings are set to coincide with those of the hydrogeologic settings; although an atmospheric dispersion setting will often cover the area of two or more hydrogeologic settings.

1.4.3 Surface Water Settings

Surface water environmental settings are needed for those perennial streams and rivers that provide a contaminant transport pathway for potential public exposure. The number of surface water settings for an installation varies from zero to three. Surface water parameters include the width, depth, and average flow rate of the river being characterized. These parameters are described in more detail in the Appendix.

1.4.4 Hydrogeologic Settings

Hydrogeologic settings are used to define the number and characteristics of the partially-saturated (vadose) zones and saturated zones beneath an area. Each individual hydrogeologic setting can include up to eight distinct partially-saturated zones and two saturated zones. Earlier versions of the MEPAS allowed only four distinct partially-saturated zones and one saturated zone.

For each hydrogeologic setting, the setting is divided into a number of distinct layers, or zones. Partially-saturated (PZ) zones are those layers, or combination of layers, in which significant vertical movement of contaminants occurs. In the majority of cases, PZs are not water saturated, so the vertical component of migration is the dominant one. If multiple PZs are described, these are distinguished in the database by numbering them sequentially from the uppermost layer downward to the saturated zone. Saturated zones (SZ) are water saturated layers in which there is the potential to transport contaminants laterally to receptors. Saturated zones include both natural aquifers and strata that have become saturated as the result of activities at an installation (i.e., disposal of process water via subsurface injection). If an area contains multiple, non-adjacent saturated zones, two (or more) discrete environmental settings may be prepared. The first of the settings would terminate at the base of the uppermost SZ. Other settings incorporate the SZ as one of the PZ layers, and, in doing so, sets the field capacity equal to the total porosity of the unit. It is the responsibility of the modeler to partition the relative amounts of contaminants being transported vertically or horizontally through these zones.

In most cases, the partially-saturated and saturated zones conform with known or recognized stratigraphic delimiters in an area. However, both adjacent and non-adjacent lithologic units with similar properties can be aggregated into a single PZ for modeling purposes with essentially no impact on the outcome of the model result. This is commonly done in areas with complex stratigraphies, or in areas for which units appear repetitively in the column.

The hydrogeologic setting database contains descriptive physical and chemical information about partially-saturated and saturated zones. For PZs this information includes layer thickness, soil type (i.e., percent sand, silt and clay), bulk density, total porosity, field capacity, saturated hydraulic conductivity, and longitudinal dispersivity. For SZs, this information includes layer thickness, soil type (i.e., percent sand, silt, and clay), bulk density, total and effective porosity, pore water velocity, and longitudinal, transverse and vertical dispersivities. These parameters are described in more detail in Table 1.2 and in the Appendix.

The structure of the MEPAS code limits the range and nature of several of the database parameters. In particular, the parameter "soil type" seems to create some uncertainty among users. Allowable model inputs are based on a limited set of U.S.D.A.

Soil Conservation Service textural classifications. The system is based on the relative percentages of sand, silt, and clay in the material (Figure 1.2); it disregards gravels and a wide range of lithologies that might be found at a site. Therefore, partially-saturated and saturated zones are described by the textural classification that most closely corresponds to the physical properties of the sand-silt-clay system, even though there may be no physical resemblance between the two. For example, at the Idaho National Engineering Laboratory (INEL), the pervasive vertically-fractured basalts underlying the area are described in the database as "sands" because the vertical migration of water through these basalt flows, when water is present, is better described by those characteristics included in the "sand" textural classification than by any of the other textural classes. However, beyond the confines of model usage, all would agree that there is no relationship between the basalt flows at INEL and true sand deposits found at numerous other locations.

For the purpose of characterizing the hydrogeologic properties of an installation, each installation was divided into one or more hydrogeologic environmental settings. Competing factors contributed to the number of hydrogeologic settings developed for each installation. Unique hydrogeologic conditions exist at each release site and influence both the pathway and rate at which contaminants can migrate. Therefore, sufficient environmental settings needed to be established to enable accurate modeling of the risks posed by contaminants released at closely spaced, but hydrogeologically distinct sites. However, the time it takes to complete most risk assessments for an installation is directly proportional to the number of hydrogeologic environmental settings. With so many installations, releases sites, and contaminants needing assessment for the PEIS and BEMR, it was important that the overall modeling effort be compatible with project deadlines. The final product is the result of attempts to balance these competing concerns in a way that minimizes the number of settings while at the same time providing adequate, if sometimes highly aggregated and oversimplified, representations of the different areas within an installation.

Table 1.2. Brief Description of the Parameters Included in the Hydrogeologic Environmental Setting Database

NAME	Applicable Zones	Description	DEFAULT	Page Location
Darcian velocity	PZ	This parameter describes the rate of infiltration of meteoric waters into the soil column below the rooting zone.	20% of average annual precipitation	
SOIL_C	PZ	The soil-type exponent, a constant used to estimate water retention in an unsaturated soil. Values may be listed for SZ units, but is not used in MEPAS.	Based on CLASS (see below)	2.5
THICK	PZ & SZ	Thickness of the unit. The datum is used to compute transport of contaminants through the unit, and to estimate the mass of soil present and potentially contaminated.	None	2.30 & 2.35
BULKD	PZ & SZ	The bulk density of the unit. This property is used help determine the degree of cementation, and void space in a unit.	Based on CLASS (see below)	2.31 & 2.36
TOTPOR	PZ & SZ	Total porosity, the quantity of void space including both interconnected and "cul-de sac" space in a soil or sediment.	Based on CLASS (see below)	2.31 & 2.34
FIELD C	PZ	Field capacity, the amount of water held in a soil by capillary action after gravitational water has been lost by percolation.	Based on CLASS (see below)	2.32
CONDUCT	PZ	Saturated hydraulic conductivity, the ratio of water flow velocity to the pressure gradient. Usually measured in a saturated medium.	Based on CLASS (see below)	2.32

Table 1.2 (continued)

NAME	Applicable Zones	Description	DEFAULT	Page Location
LDISP	PZ & SZ	Longitudinal dispersivity, the thickness in the direction of transport, of the zone which is experiencing active mixing with downstream waters.	= 0.01 * THICK (PZ) = 0.1 * DISTANCE (SZ)	2.32 2.36
TDISP	SZ	Transverse dispersivity, the distance, normal to (and horizontal to) the direction of travel of a groundwater that is involved in mixing.	= 0.002 * DISTANCE	2.37
VDISP	SZ	Vertical Dispersivity, the same as TDISP except that the mixing is examined in the vertical direction.	= 1.16×10^{-5} * DISTANCE	2.38
EFFPOR	SZ	Effective porosity is the percentage of the total volume of a rock or soil that is occupied by interconnected pore spaces. This is commonly referred to as the "active" volume during contaminant transport.	= 0.25 * (%_sand) + 0.15 * (%_silt) + 0.10 * (%_clay) BUT must be < TOTPOR	2.34
PVELOC	SZ	Pore fluid velocity is the rate of water flow through the saturated aquifer.	= (CONDUCT / EFFPOR) * hydraulic gradient	2.34

Table 1.2 (continued)

NAME	Applicable Zones	Description	DEFAULT	Page Location
DIST	SZ	The travel distance of the contaminants in the saturated zone from the point of release to the receptor. For this compilation, "obvious" receptor locations (usually, but not always from the hydrogeologic setting centroid to the setting or site boundary) were arbitrarily used. Data users should always compare their preferred DISTANCE against the value contained in the table. If they are different, then the user needs to reset default values for LDISP, TDISP, and VDISP before proceeding with model calculations.	None	2.36
CLASS	PZ & SZ	Soil textural class is a broad, general method for classifying the physical properties of soils. The systems is derived from the Soil Conservation Service scheme. If the medium is not a soil, a CLASS is selected that most closely represents the physical properties of the unit.	None	2.29 & 2.32
SAND	PZ & SZ	The nominal percentage of sand present in the soil or sediment.	Based on CLASS (see above)	2.29 & 2.33
SILT	PZ & SZ	The nominal percentage of silt present in the soil or sediment.	Based on CLASS (see above)	2.29 & 2.33
CLAY	PZ & SZ	The nominal percentage of clay present in the soil or sediment.	Based on CLASS (see above)	2.29 & 2.33

Table 1.2 (continued)

NAME	Applicable Zones	Description	DEFAULT	Page Location
OMC	PZ & SZ	The nominal percentage of organic matter present in the soil or sediment.	= 0.00	2.30 & 2.33
FE	PZ & SZ	The nominal percentage of iron and aluminum oxyhydroxides present in the soil or sediment.	= 0.00	2.30 & 2.33
PH	PZ & SZ	The equilibrium soil water or groundwater pH.	= 7.00	2.30 & 2.33

PZ = Partially saturated zone
SZ = Saturated zone

Figure 1.2. Textural Soil Classifications for MEPAS

1.5 DATA COMPILATION APPROACHES

As a starting point in this data gathering effort, data compiled for site-specific studies were reviewed. These data sources typically included: annual environmental reports, site environmental assessments and environmental impact statements, remedial investigation and feasibility studies, operable unit work plans, and draft reports from earlier environmental surveys.

The next step in the process was to contact technical experts at the installation being studied. Experts in the fields of meteorology, geology, hydrology, and geochemistry were contacted by members of the PEIS and BEMR Environmental Settings Task to provide technical guidance, including additional documentation, technical discussions, and information review.

The general outline of the climatic and atmospheric dispersion settings were easy to obtain and efforts in these technical areas were focused on the review of available data sources and the selection of the most climatologically representative data. Similarly, the development of surface water settings are relatively easy to accomplish using standard sets of published data.

The majority of time and effort for environmental settings was spent on the development of the hydrogeologic settings. Once the number and rough boundaries of hydrogeologic environmental settings were established based on the general hydrogeologic properties of the installation, the next step was to define the number of partially-saturated zones and saturated zones in the setting and assign values for each hydrogeologic parameter. Occasionally, this effort led to the revision of the number and boundaries of hydrogeologic settings. Other times, certain parameters could not be accurately characterized for a setting because of limitation on site-specific measurements. In such cases, data from neighboring areas or standard model default values are used to define particular parameters.

After draft environmental settings were completed for an installation, these settings were sent back to the installation for review, comment, and corrections by local technical experts. A number of installations chose not to participate in the evaluation of the environmental settings data. Individuals who assisted in the review of the data are noted in each site section. The values used to characterize the parameters in each settings were carefully documented; a reference for each data element is recorded with the data value in the official environmental settings database. This reference may be a published document, a draft document, a technical memo, a "best estimate" prepared by a technical expert (either at the installation or an environmental settings team member), or a standard default value. Once completed and reviewed by installation personnel, environmental settings data were forwarded to other PEIS and BEMR teams for use in various modeling applications and for storage in the project database.

1.6 PRESENTATION OF DATA

In the following 25 sections, environmental setting information is presented for each installation. The installations are presented in alphabetical order.

Each installation's section begins with a brief mention of the installation's mission, history, location, and ecology. This is followed by a discussion of the local climate, geology, and hydrology of the installation. This information is then used in the presentation of the environmental settings that were developed to characterize the installation's environment for PEIS and BEMR modeling purposes. A brief acknowledgement of the role the installation's technical experts had in formulating and reviewing the environmental settings is provided. References are listed at the end of each section and again as a complete list at the end of the report for the reader's convenience. At the end of each section, figures, exhibits, and tables are presented to provide quantitative and other information. These include figures showing the location of the installation and its environmental setting boundaries and stratigraphic columns for each environmental setting. Exhibits present key climate parameters and atmospheric dispersion characteristics (in the form of a joint frequency distribution of atmospheric stability, wind direction, and wind speed). Tables provided information on surface water features and the properties of each hydrogeologic environmental setting.

1.7 REFERENCES

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2.0 ARGONNE NATIONAL LABORATORY

Argonne National Laboratory's (ANL) mission within the DOE complex involves basic research in the physical and life sciences, and applied research related to the development of advanced nuclear, fossil fuel, conservation, and renewable energy resources and technologies.

The ANL is located on gently rolling land in northern Illinois approximately 43 km (27 mi) southwest of downtown Chicago (Figure 2.1). The lab is situated on a 6.9 km² (2.7 mi²) site in Du Page County, Illinois, although its main facilities occupy only about 0.8 km² (200 acres). From 1947 through 1954, the ANL was located 5 km (3 mi) east of its current location in what is now part of the Palos Park Forest Preserve. This preserve is a public recreation area. Most of the current installation consists of partially wooded former prairie and farmland and is surrounded by the 8.3 km² (2041 acre) Waterfall Glen Forest Preserve district. Outside the boundaries of the forest preserve, the area is characterized by low density residential neighborhoods, with some commercial buildings and industrial parks. Prior to settlement, the flat lying areas in the vicinity of the laboratory were probably dominated by tall-grass prairie, and the more steeply sloping areas along the southern boundary were probably forested. Ecologically, the laboratory is transitional between the tall-grass prairie and oak-hickory forest biomes.

2.1 CLIMATE

The ANL has a "humid continental warm summer" climate (Critchfield 1974). Meteorological data are available from onsite measurements and from measurements at Chicago's O'Hare International Airport. On average, the maximum daily temperature exceeds 32°C (90°F) on 16 days per year and is below 0°C (32°F) on 51 days per year; the minimum daily temperature is below 0°C (32°F) on 133 days per year and is below -18°C (0°F) on 14 days per year (DOC 1987c). July is the warmest month, with daily maximum and minimum temperatures averaging 28°C (83°F) and 17°C (63°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging -2°C (29°F) and -10°C (14°F), respectively (DOC 1987c).

Annual precipitation is on the order of 84 cm (33 in.), with about 65% falling from April through September. Measurable precipitation (defined as 0.025 cm [0.01 in] or greater) is recorded on an average of 127 days per year and the area experiences an average of 38 thunderstorm days per year. The average annual snowfall is 99 cm (39 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 12 days per year (DOC 1987c).

Winds are relatively uniform across the ANL. The prevailing wind direction measured at O'Hare is from the south-southwest. Wind speeds average about 4.5 m/s (10 mph) at about 6 m (20 ft) above ground level (DOC 1987c). Average wind speeds are highest in March (5.4 m/s [12 mph]) and lowest in August (3.5 m/s [8 mph]) (DOC 1987c).

2.2 GEOLOGY

Physiographically, the ANL sits on bluffs overlooking the Des Plaines River. The Des Plaines is a remnant drainage from glacial Lake Michigan (Golchert and Kolzow 1993). Currently, the river drains urban and suburban areas to the north and east of the laboratory. From the flood plain, bluffs rise sharply (15° to 60°) to an elevation of about 20 m (66 ft) above the river.

The ANL is situated on glacial till which are remnants of the Pleistocene glaciation. This till is divided into two units, the upper Wadsworth Till and a lower Lemont drift (Knowles et al. 1963; Golchert and Kolzow 1993). In the near surface zone, the Wadsworth Till is weathered, creating a storm-flow zone in which waters migrate laterally to the surface water discharges on the installation. Below this weathered zone, the Wadsworth becomes compact. Relative to the Lemont drift, the Wadsworth is characterized by having a higher clay content and lower permeability. The Lemont is also a compact, low-permeability unit, and it is believed to be water-saturated over most of its thickness. Bedrock in the area is a Paleozoic carbonate unit, the Niagaran Dolomite. The Niagaran Dolomite, in turn, overlies a series of shale, sandstone and carbonate units.

2.3 HYDROLOGY

There are several hydrologic transport zones of interest in the vicinity of the ANL. The Niagaran Dolomite is a regional aquifer of widespread use. The regional flow in the aquifer is toward the southeast and the Des Plaines River (Knowles et al. 1963). Flow in the Niagaran Dolomite is modified by local usage. The laboratory currently is using four water-supply wells, all finished in the Niagaran Dolomite. The ANL pumps an average of 3,000 to 3,400 m³ (800,000 to 900,000 gallons) per day from the aquifer (Golchert and Kolzow 1993), creating a local cone of depression in the east-central portion of the site. As a result, contaminants released to the aquifer in this area probably migrate toward the ANL's well field. This situation will change in the future, as the laboratory is now in the process of converting from local groundwaters supplies to a municipal supply obtained from Lake Michigan. When this conversion is completed, groundwater withdrawal from the Niagaran will be minor, and the migration of contaminants is expected to revert to the regional pattern of general groundwater movement toward the south-southeast.

Hydraulically, the Niagaran Dolomite is a semi-confined aquifer. Aside from the water supply wells, the only wells finished in the Niagaran Dolomite are located in the 317/319 area and in the vicinity of the Sanitary Landfill (Golchert and Kolzow 1993). Hydrostatic head measurements from these locations indicate static water levels as much as 3 m (10 ft) above the Niagaran Dolomite/Lemont drift contact. This suggests that in the undisturbed aquifer, the vertical gradient is from the Niagaran upward into the lower permeability drift. The implications of this observation for defining contaminant transport pathways at the installation are not presently clear.

The glacial tills, generally, are not productive aquifers, although water-bearing zones are present. The Lemont drift, which sits above the Niagaran Dolomite, is probably water-saturated but has a low permeability. Flow in the Lemont drift is poorly characterized, but for the purposes of the PEIS it should be considered to follow the hydraulic gradients observed in the Niagaran. Within the Wadsworth Member, monitoring wells are primarily either dry or appear to be only supplied by slow downward seepage of surface recharge. Occasionally, wells tap into sand lenses within the Wadsworth Member; these wells have limited production capacities. Although the 1992 Annual Environmental Report describes such zones as perched aquifers (Golchert and Kolzow 1993), their significance in transporting contaminants is questionable. For the purposes of the PEIS, it appears that their influence is too localized to warrant treatment as distinguishable features.

Significant surface water features in the vicinity of the ANL site are Sawmill Creek and the Des Plaines River. Sawmill Creek, situated along the eastern boundary of the installation, flows south-southeast toward the Des Plaines River. Sawmill Creek is a perennial stream and is currently the receiving body for effluent from the ANL treatment facilities. The Des Plaines River and the adjacent Chicago Sanitary and Ship Canal flow toward the southwest and eventually discharges into the Illinois River. The river is used for neither agricultural nor domestic supplies for more than 100 km (60 mi) downstream of the ANL. The quality of waters in both Sawmill Creek and the Des Plaines River is poor. Surface drainage within the ANL property is dominated by the two branches of Freund Brook. Generally, this brook supports only intermittent flows. Freund Brook drains east across the site into Sawmill Creek.

2.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the ANL for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 2.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 2.2

For PEIS modeling purposes, ANL is characterized using three hydrogeologic environmental settings (Figure 2.1): the Main area of the laboratory, the 317/319 area, and the Sanitary Landfill. Each setting has a base and a storm-flow subsetting. The primary distinguishing characteristics among the settings are the depths to the regional aquifer, and the distances and flow paths that contaminants would follow to reach surface water receptors. Figure 2.2 presents stratigraphic columns for each of these settings. Surface water data are presented in Table 2.1. Hydrogeologic data for the various settings are presented in Tables 2.2-2.7. A brief description of the hydrogeology of each environmental setting follows.

2.4.1 Main Laboratory Setting

The Main Laboratory setting encompasses the majority of the land area at the ANL. This setting is divided into a storm-flow zone and a base setting. For the base setting, the partially-saturated zone is a total of about 28 m (90 ft) thick. This is subdivided into three strata. These include a surface soil, modeled as 1.5 m (5 ft) thick; a weathered till, which also serves as the saturated zone for the storm flow regime and is modeled using a thickness of 3 m (10 ft); and Wadsworth till which is modeled to be about 23 m (75 ft). Underlying the partially-saturated zones are two saturated zones. The upper saturated zone is the Lemont drift, and is modeled with a thickness of 3 m (10 ft). The lower saturated zone is the Niagaran Dolomite. This is modeled to a total thickness of about 8 m (25 ft). Textural classifications for the different strata were chosen to have correct relative conductivities, although specific values for each horizon are not necessarily available. The distance parameter for the Main Laboratory setting is calculated as the approximate distance from the center of the setting to the Des Plains River. The storm-flow zone for the Main Laboratory is presumed to consist of a 1.5 m (5 ft) thick partially-saturated zone and a single 3 m (10 ft) thick saturated zone. The distance parameter for the storm-flow setting is estimated as the approximate distance between the center of the setting and the confluence of Freund Brook with Sawmill Creek.

2.4.2 317/319 Setting

The 317/319 setting, as with the Main Laboratory setting, is divided into storm-flow and base-flow settings. For the most part, the physical and chemical properties of the geologic materials within this setting are comparable to those described for the Main Laboratory. However, 317/319 is distinguished from the Main Laboratory in two ways. First, the thickness of the combined partially-saturated zones is considerable less than for the main portion of the laboratory. For this setting, the PZ-3 (the Wadsworth till) is presumed to average only about 14 m (45 ft). This shortening for the length of the partially-saturated zone could result in considerably shorter travel times for contaminants to reach the groundwater. Second, the distances and directions of travel for both the storm-flow and the base settings are different from the other settings. For the 317/319 area, lateral groundwater

movement is toward the Des Plains River rather than toward Sawmill Creek. This results in a distinctly different flow path for contaminants released within this particular setting.

2.4.3 Sanitary Landfill Setting

The third hydrogeologic setting is the Sanitary Landfill. This small facility on the western edge of the installation is an area in transition. Historically, the landfill has been an unlined/uncapped facility. Leachate from the landfill was able to discharge to both surface and groundwaters. Within the last several years, the site was capped with clay and soil, which has altered the historical flow paths of atmospheric deposition in the area. The physical and chemical characteristics of the individual horizons at the Landfill are comparable to those described at the other two hydrogeologic settings. However, for this setting, the thickness of the Wadsworth is being modeled as 38 m (125 ft), and the distances for contaminants to discharge to surface waters is notably different. For the storm-flow zone, waters are presumed to discharge into a wetland area immediately adjacent to the site. This distance is estimated as 152 m (500 ft). For releases to the regional aquifer, the distance parameter is estimated to be about 3.1 km (1.9 mi).

2.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the ANL are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Dick Hart supplied input into the development of the climate and atmospheric dispersion environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings include Norbert Golchert and Glenn Wittman. Following completion of the environmental settings, Norbert Golchert coordinated the onsite review and fine tuning of the settings data. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

2.6 REFERENCES

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Figure 2.1. Location and Environmental Settings for the Argonne National Laboratory (ANL). For PEIS modeling purposes, the ANL is divided into three environmental settings: the Main Area, the 317/319 Area, and the Sanitary Landfill.

Figure 2.2. Stratigraphic Columns for Argonne National Laboratory (ANL) Environmental Settings

EXHIBIT 2.1

Argonne National Laboratory Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite and at Chicago's O'Hare International Airport.

Station Name: O'Hare International Airport, Chicago, Illinois	Elevation: 200 m	Latitude: 41.98°N
Argonne National Laboratory	Elevation: 200 m	Latitude: 41.71°N

Annual Mean Air Temp:	49.2 °F	(O'Hare)	Reference (A)	Based on observations made from 1951-1980.
	49.9 °F	(ANL)	Reference (B)	Based on 4 years of observations.
Anemometer Height:	6 m	(O'Hare)	Reference (A)	
	61 m	(ANL)	Reference (B)	
Mean Annual Wind Speed:	10 mph	(O'Hare)	Reference (A)	Based on 28 years of observations.
	13 mph	(ANL)	Reference (B)	Based on 4 years of observations.
Fastest 1 Minute Speed:	58 mph	(O'Hare)	Reference (A)	Based on 28 years of observations.
Annual Precipitation:	33.3 in.	(O'Hare)	Reference (A)	Based on observations made from 1951-1980.
	35.9 in.	(ANL)	Reference (B)	Based on 4 years of observations.
Precipitation Days:	127 yr ⁻¹	(O'Hare)	Reference (A)	Based on 28 years of observations.
Thunderstorms Freq:	38 yr ⁻¹	(O'Hare)	Reference (A)	Based on 28 years of observations.

Avg Morning Mixing Ht:	490 m	Reference (C)
Avg Afternoon Mixing Ht:	1200 m	Reference (C)
Top Soil Moisture Capacity:	5.4 cm	Reference (C)

MEPAS Parameters:	Climatic Region Index:	4	Reference (C)
	Precipitation-Evaporation Index:	95	Reference (C)
	Soil Cons. Serv. Curve Number:	58	Reference (C)

MONTHLY AVERAGES							
	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
MONTH	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	21	1.6	11.6	6.8	11.1	76	71
Feb	26	1.3	11.4	6.9	9.8	77	70
Mar	36	2.6	11.8	7.2	12.5	79	65
Apr	49	3.7	12.0	6.8	12.5	77	57
May	59	3.2	10.5	6.3	11.0	77	54
Jun	69	4.1	9.1	6.0	10.3	78	55
Jul	73	3.6	8.1	5.5	9.9	82	58
Aug	72	3.5	8.0	5.7	9.1	85	61
Sep	65	3.4	8.8	5.9	9.8	85	63
Oct	54	2.3	9.8	6.1	9.3	82	64
Nov	40	2.1	10.9	7.2	10.3	81	70
Dec	28	2.1	10.9	7.3	11.5	80	71
	↓	↓	↓	↓	↓	↓	↓
Reference: ...	(A)	(A)	(A)	(A)	(A)	(A)	(A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part III Central Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- B: Hart, R. Correspondance with Argonne National Laboratory, Environmental Research Division, Atmospheric Research Section, 1994.
- C: Droppo, J.G., Jr., D.L. Streng, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 2.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Argonne National Laboratory. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made from 1989 through 1992.

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
A	NORTH	0.00000	0.00006	0.00015	0.00032	0.00006	0.00000
A	NORTH-NORTHEAST	0.00000	0.00018	0.00076	0.00141	0.00009	0.00006
A	NORTHEAST	0.00003	0.00023	0.00111	0.00167	0.00041	0.00000
A	EAST-NORTHEAST	0.00000	0.00009	0.00141	0.00238	0.00023	0.00000
A	EAST	0.00006	0.00021	0.00097	0.00047	0.00003	0.00000
A	EAST-SOUTHEAST	0.00006	0.00021	0.00041	0.00027	0.00003	0.00000
A	SOUTHEAST	0.00015	0.00012	0.00018	0.00018	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00003	0.00023	0.00021	0.00024	0.00006	0.00000
A	SOUTH	0.00000	0.00009	0.00035	0.00027	0.00009	0.00000
A	SOUTH-SOUTHWEST	0.00003	0.00003	0.00024	0.00065	0.00033	0.00000
A	SOUTHWEST	0.00000	0.00021	0.00061	0.00090	0.00041	0.00012
A	WEST-SOUTHWEST	0.00006	0.00018	0.00068	0.00112	0.00033	0.00021
A	WEST	0.00000	0.00000	0.00012	0.00103	0.00062	0.00035
A	WEST-NORTHWEST	0.00000	0.00000	0.00021	0.00041	0.00027	0.00009
A	NORTHWEST	0.00003	0.00000	0.00020	0.00027	0.00000	0.00000
A	NORTH-NORTHWEST	0.00000	0.00009	0.00044	0.00068	0.00000	0.00000
B	NORTH	0.00000	0.00018	0.00035	0.00021	0.00003	0.00000
B	NORTH-NORTHEAST	0.00003	0.00015	0.00100	0.00063	0.00006	0.00000
B	NORTHEAST	0.00003	0.00029	0.00077	0.00167	0.00021	0.00006
B	EAST-NORTHEAST	0.00003	0.00009	0.00100	0.00071	0.00009	0.00000
B	EAST	0.00009	0.00015	0.00070	0.00015	0.00003	0.00000
B	EAST-SOUTHEAST	0.00009	0.00026	0.00050	0.00024	0.00003	0.00000
B	SOUTHEAST	0.00003	0.00012	0.00032	0.00024	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00003	0.00015	0.00032	0.00047	0.00009	0.00000
B	SOUTH	0.00006	0.00023	0.00059	0.00074	0.00032	0.00000
B	SOUTH-SOUTHWEST	0.00000	0.00015	0.00029	0.00056	0.00047	0.00009
B	SOUTHWEST	0.00000	0.00026	0.00085	0.00115	0.00050	0.00012
B	WEST-SOUTHWEST	0.00006	0.00018	0.00091	0.00141	0.00068	0.00024
B	WEST	0.00003	0.00021	0.00041	0.00103	0.00050	0.00026
B	WEST-NORTHWEST	0.00000	0.00003	0.00021	0.00071	0.00030	0.00009
B	NORTHWEST	0.00006	0.00006	0.00032	0.00050	0.00006	0.00000
B	NORTH-NORTHWEST	0.00000	0.00012	0.00065	0.00124	0.00012	0.00000
C	NORTH	0.00003	0.00015	0.00068	0.00038	0.00006	0.00000
C	NORTH-NORTHEAST	0.00000	0.00035	0.00169	0.00124	0.00015	0.00000
C	NORTHEAST	0.00018	0.00021	0.00112	0.00150	0.00023	0.00018
C	EAST-NORTHEAST	0.00009	0.00015	0.00142	0.00112	0.00006	0.00000
C	EAST	0.00003	0.00024	0.00088	0.00032	0.00003	0.00000
C	EAST-SOUTHEAST	0.00000	0.00021	0.00047	0.00012	0.00000	0.00000
C	SOUTHEAST	0.00009	0.00024	0.00047	0.00038	0.00009	0.00000
C	SOUTH-SOUTHEAST	0.00009	0.00035	0.00086	0.00068	0.00015	0.00003
C	SOUTH	0.00009	0.00026	0.00074	0.00124	0.00027	0.00012
C	SOUTH-SOUTHWEST	0.00000	0.00032	0.00065	0.00083	0.00068	0.00006
C	SOUTHWEST	0.00003	0.00021	0.00103	0.00178	0.00080	0.00024
C	WEST-SOUTHWEST	0.00000	0.00021	0.00083	0.00203	0.00042	0.00038
C	WEST	0.00000	0.00024	0.00062	0.00130	0.00021	0.00053
C	WEST-NORTHWEST	0.00003	0.00026	0.00044	0.00098	0.00065	0.00009
C	NORTHWEST	0.00006	0.00029	0.00056	0.00103	0.00030	0.00021
C	NORTH-NORTHWEST	0.00015	0.00182	0.00589	0.00581	0.00103	0.00018
D	NORTH	0.00038	0.00185	0.00591	0.00450	0.00080	0.00006
D	NORTH-NORTHEAST	0.00035	0.00530	0.01326	0.01154	0.00135	0.00000
D	NORTHEAST	0.00062	0.00333	0.01158	0.01439	0.00307	0.00115
D	EAST-NORTHEAST	0.00039	0.00259	0.00888	0.00927	0.00191	0.00045
D	EAST	0.00068	0.00298	0.00735	0.00465	0.00053	0.00003
D	EAST-SOUTHEAST	0.00050	0.00287	0.00495	0.00247	0.00009	0.00003

EXHIBIT 2.2 (continued)

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
D	SOUTHEAST	0.00050	0.00433	0.00572	0.00366	0.00074	0.00018
D	SOUTH-SOUTHEAST	0.00062	0.00436	0.00888	0.00715	0.00153	0.00033
D	SOUTH	0.00062	0.00366	0.01110	0.01313	0.00433	0.00132
D	SOUTH-SOUTHWEST	0.00056	0.00422	0.00827	0.01267	0.00584	0.00181
D	SOUTHWEST	0.00047	0.00322	0.00896	0.01504	0.00468	0.00214
D	WEST-SOUTHWEST	0.00056	0.00472	0.00955	0.01244	0.00402	0.00343
D	WEST	0.00038	0.00376	0.00895	0.01127	0.00546	0.00425
D	WEST-NORTHWEST	0.00059	0.00304	0.00924	0.01118	0.00513	0.00154
D	NORTHWEST	0.00053	0.00284	0.00969	0.01050	0.00358	0.00092
D	NORTH-NORTHWEST	0.00047	0.00340	0.01090	0.00910	0.00141	0.00024
E	NORTH	0.00027	0.00101	0.00335	0.00236	0.00006	0.00000
E	NORTH-NORTHEAST	0.00042	0.00341	0.00816	0.00380	0.00009	0.00000
E	NORTHEAST	0.00393	0.00265	0.00742	0.00534	0.00045	0.00027
E	EAST-NORTHEAST	0.00036	0.00166	0.00798	0.00615	0.00075	0.00036
E	EAST	0.00027	0.00189	0.00869	0.00419	0.00015	0.00009
E	EAST-SOUTHEAST	0.00036	0.00160	0.00661	0.00298	0.00012	0.00006
E	SOUTHEAST	0.00056	0.00257	0.00791	0.00524	0.00066	0.00009
E	SOUTH-SOUTHEAST	0.00065	0.00254	0.00884	0.00649	0.00110	0.00030
E	SOUTH	0.00024	0.00290	0.01374	0.01915	0.00264	0.00060
E	SOUTH-SOUTHWEST	0.00051	0.00222	0.00982	0.02286	0.00802	0.00134
E	SOUTHWEST	0.00041	0.00220	0.00777	0.01651	0.00508	0.00097
E	WEST-SOUTHWEST	0.00032	0.00187	0.00827	0.01017	0.00225	0.00083
E	WEST	0.00074	0.00195	0.00813	0.00809	0.00193	0.00057
E	WEST-NORTHWEST	0.00030	0.00166	0.00731	0.00837	0.00125	0.00024
E	NORTHWEST	0.00024	0.00142	0.00683	0.00678	0.00071	0.00000
E	NORTH-NORTHWEST	0.00018	0.00230	0.00690	0.00725	0.00050	0.00000
F	NORTH	0.00009	0.00041	0.00098	0.00086	0.00000	0.00000
F	NORTH-NORTHEAST	0.00018	0.00154	0.00193	0.00059	0.00000	0.00000
F	NORTHEAST	0.00231	0.00145	0.00219	0.00103	0.00000	0.00000
F	EAST-NORTHEAST	0.00027	0.00077	0.00356	0.00227	0.00000	0.00000
F	EAST	0.00021	0.00086	0.00472	0.00198	0.00000	0.00000
F	EAST-SOUTHEAST	0.00015	0.00110	0.00398	0.00245	0.00000	0.00000
F	SOUTHEAST	0.00021	0.00083	0.00271	0.00272	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00006	0.00100	0.00235	0.00286	0.00003	0.00000
F	SOUTH	0.00021	0.00109	0.00363	0.00256	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00021	0.00106	0.00327	0.00416	0.00009	0.00003
F	SOUTHWEST	0.00021	0.00100	0.00309	0.00316	0.00018	0.00003
F	WEST-SOUTHWEST	0.00009	0.00086	0.00213	0.00305	0.00009	0.00000
F	WEST	0.00006	0.00059	0.00233	0.00287	0.00006	0.00000
F	WEST-NORTHWEST	0.00009	0.00015	0.00203	0.00216	0.00000	0.00000
F	NORTHWEST	0.00006	0.00039	0.00146	0.00200	0.00006	0.00000
F	NORTH-NORTHWEST	0.00006	0.00036	0.00133	0.00207	0.00003	0.00000
G	NORTH	0.00003	0.00024	0.00044	0.00050	0.00000	0.00000
G	NORTH-NORTHEAST	0.00012	0.00056	0.00062	0.00015	0.00000	0.00000
G	NORTHEAST	0.00153	0.00053	0.00100	0.00036	0.00000	0.00000
G	EAST-NORTHEAST	0.00003	0.00042	0.00068	0.00047	0.00000	0.00000
G	EAST	0.00003	0.00030	0.00047	0.00030	0.00000	0.00000
G	EAST-SOUTHEAST	0.00006	0.00044	0.00089	0.00089	0.00000	0.00000
G	SOUTHEAST	0.00009	0.00051	0.00130	0.00168	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00012	0.00047	0.00169	0.00100	0.00000	0.00000
G	SOUTH	0.00006	0.00062	0.00106	0.00044	0.00000	0.00000
G	SOUTH-SOUTHWEST	0.00009	0.00048	0.00153	0.00059	0.00000	0.00000
G	SOUTHWEST	0.00006	0.00045	0.00150	0.00062	0.00000	0.00000
G	WEST-SOUTHWEST	0.00006	0.00038	0.00077	0.00047	0.00003	0.00000
G	WEST	0.00012	0.00051	0.00077	0.00083	0.00000	0.00000
G	WEST-NORTHWEST	0.00015	0.00018	0.00056	0.00044	0.00000	0.00000
G	NORTHWEST	0.00003	0.00015	0.00056	0.00042	0.00000	0.00000
G	NORTH-NORTHWEST	0.00009	0.00021	0.00062	0.00057	0.00000	0.00000

Table 2.1. Surface Water Environmental Safety Data for Argonne National Laboratory

<u>Parameter</u>	<u>Units</u>	<u>Sawmill Creek</u>
Velocity	m/s	0.457
Depth	m	0.152
Width	m	4.57
Discharge	cms	0.292

Table 2.2. Hydrogeologic Environmental Setting Data for Argonne National Laboratory's Main Laboratory Base Flow Zone. Parameters are characterized for each of the setting's partially-saturated zones (PZ) and saturated zones (SZ).

Parameter	Units	PZ1	PZ2	PZ3	SZ1	SZ2
Darcian_velocity	m/yr	0.18	0.18	0.18	--	--
SOILC		7.75	7.75	10.4	7.12	4.9
Thickness	m	1.52	3.05	22.9	3.05	7.62
Bulk_density	g/cm3	1.35	1.35	1.36	1.42	1.48
Total_porosity	%	49	49	48.6	39.8	44.2
Field_capacity	%	37.5	37.5	42	--	--
Conductivity	m/day	0.10	0.10	0.04	--	--
Longitudinal_disp.	m	0.02	0.03	0.23	231.6	231.6
Transverse_disp.	m	--	--	--	46.3	46.3
Vertical_disp.	m	--	--	--	0.27	0.27
Effective_porosity	%	--	--	--	19.7	21.0
Velocity	m/day	--	--	--	0.01	0.06
Distance	m	--	--	--	2316.5	2316.5
Textural_class		silty clay loam	silty clay loam	silty clay	silt loam	sandy loam
%_sand	%	10	10	8	25	65
%_silt	%	58	58	47	63	25
%_clay	%	32	32	45	12	10
%_OMC	%	0	0	0	0	0
%_Fe	%	0	0	0	0	0
pH		7	7	7	7	8.3

Table 2.3. Hydrogeologic Environmental Setting Data for Argonne National Laboratory's Main Laboratory Storm Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.18	--
SOILC		7.75	7.75
Thickness	m	1.52	3.05
Bulk_density	g/cm3	1.35	1.35
Total_porosity	%	49.0	49.0
Field_capacity	%	37.5	--
Conductivity	m/day	0.10	--
Longitudinal_disp.	m	0.02	91.4
Transverse_disp.	m	--	18.3
Vertical_disp.	m	--	0.11
Effective_porosity	%	--	14.4
Velocity	m/day	--	6.1e-4
Distance	m	--	914.4
Textural_class		silty clay loam	silty clay loam
%_sand	%	10	10
%_silt	%	58	58
%_clay	%	32	32
%_OMC	%	0	0
%_Fe	%	0	0
pH		7	7

Table 2.4. Hydrogeologic Environmental Setting Data for Argonne National Laboratory's 317/319 Area Base Flow Zone. Parameters are characterized for each of the setting's partially-saturated zones (PZ) and saturated zones (SZ).

Parameter	Units	PZ1	PZ2	PZ3	SZ1	SZ2
Darcian_velocity	m/yr	0.18	0.18	0.18	--	--
SOILC		7.75	7.75	10.4	7.12	4.9
Thickness	m	1.52	3.05	13.7	3.05	7.62
Bulk_density	g/cm3	1.35	1.35	1.36	1.6	1.48
Total_porosity	%	49	49	48.6	39.8	44.2
Field_capacity	%	37.5	37.5	42	--	--
Conductivity	m/day	0.10	0.10	0.04	--	--
Longitudinal_disp.	m	0.02	0.03	0.14	96.3	96.3
Transverse_disp.	m	--	--	--	19.2	19.2
Vertical_disp.	m	--	--	--	0.11	0.11
Effective_porosity	%	--	--	--	19.7	21.0
Velocity	m/day	--	--	--	0.01	0.06
Distance	m	--	--	--	963.2	963.2
Textural_class		silty clay loam	silty clay loam	silty clay	silt loam	sandy loam
%_sand	%	10	10	8	25	65
%_silt	%	58	58	47	63	25
%_clay	%	32	32	45	12	10
%_OMC	%	0	0	0	0	0
%_Fe	%	0	0	0	0	0
pH		7	7	7	7	8.3

Table 2.5. Hydrogeologic Environmental Setting Data for Argonne National Laboratory's 317/319 Area Storm Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.18	--
SOILC		7.75	7.75
Thickness	m	1.52	3.05
Bulk_density	g/cm3	1.35	1.35
Total_porosity	%	49.0	49.0
Field_capacity	%	37.5	--
Conductivity	m/day	0.10	--
Longitudinal_disp.	m	0.02	96.3
Transverse_disp.	m	--	19.2
Vertical_disp.	m	--	0.11
Effective_porosity	%	--	14.4
Velocity	m/day	--	6.1e-4
Distance	m	--	963.2
Textural_class		silty clay loam	silty clay loam
%_sand	%	10	10
%_silt	%	58	58
%_clay	%	32	32
%_OMC	%	0	0
%_Fe	%	0	0
pH		7	7

Table 2.6. Hydrogeologic Environmental Setting Data for Argonne National Laboratory's Sanitary Landfill Base Flow Zone. Parameters are characterized for each of the setting's partially-saturated zones (PZ) and saturated zones (SZ).

Parameter	Units	PZ1	PZ2	PZ3	SZ1	SZ2
Darcian_velocity	m/yr	0.18	0.18	0.18	--	--
SOILC		7.75	7.75	10.4	7.12	4.9
Thickness	m	1.52	3.05	38.1	3.05	7.62
Bulk_density	g/cm3	1.35	1.35	1.36	1.6	1.48
Total_porosity	%	49	49	48.6	39.8	44.2
Field_capacity	%	37.5	37.5	42	--	--
Conductivity	m/day	0.10	0.10	0.04	--	--
Longitudinal_disp.	m	0.02	0.03	0.38	307.8	307.8
Transverse_disp.	m	--	--	--	61.6	61.6
Vertical_disp.	m	--	--	--	0.36	0.36
Effective_porosity	%	--	--	--	19.7	21.0
Velocity	m/day	--	--	--	0.01	0.06
Distance	m	--	--	--	3078.5	3078.5
Textural_class		silty clay loam	silty clay loam	silty clay	silt loam	sandy loam
%_sand	%	10	10	8	25	65
%_silt	%	58	58	47	63	25
%_clay	%	32	32	45	12	10
%_OMC	%	0	0	0	0	0
%_Fe	%	0	0	0	0	0
pH		7	7	7	7	8.3

Table 2.7. Hydrogeologic Environmental Setting Data for Argonne National Laboratory's Sanitary Landfill Storm Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.18	--
SOILC		7.75	7.75
Thickness	m	1.52	3.05
Bulk_density	g/cm3	1.35	1.35
Total_porosity	%	49.0	49.0
Field_capacity	%	37.5	--
Conductivity	m/day	0.10	--
Longitudinal_disp.	m	0.02	15.2
Transverse_disp.	m	--	3.05
Vertical_disp.	m	--	0.02
Effective_porosity	%	--	14.4
Velocity	m/day	--	6.1e-4
Distance	m	--	152.4
Textural_class		silty clay loam	silty clay loam
%_sand	%	10	10
%_silt	%	58	58
%_clay	%	32	32
%_OMC	%	0	0
%_Fe	%	0	0
pH		7	7

3.0 BROOKHAVEN NATIONAL LABORATORY

The Brookhaven National Laboratory (BNL) was originally used by the U.S. Army during World Wars I and II as Camp Upton. In 1947, the U.S. Atomic Energy Commission was given the title to the property. Ownership was transferred to the U.S. Energy Research and Development Administration in 1975, and then to the DOE in 1977. The BNL's mission has involved the design, construction, and operation of large research facilities, including particle accelerators, nuclear reactors, and synchrotron storage rings. The BNL is also involved in long-term research programs in the basic sciences and technological development. Numerous sites contaminated or potentially contaminated through the use, handling, accidental spills and historic releases of both radioactive and nonradioactive material have been identified at the BNL. In addition, municipal wastes, construction/demolition debris, chemical wastes, radioactive wastes, and laboratory animal carcasses have been disposed of in onsite landfills (SAIC 1993b).

Brookhaven National Laboratory is approximately 97 km (60 mi) east of New York City near the center of Suffolk County on Long Island (Figure 3.1). The facility contains approximately 21 km² (8 mi²), 75 % of which is vegetated with scrub oak and pine (SAIC 1992).

3.1 CLIMATE

The BNL has a "humid continental warm summer" climate (Critchfield 1974). Meteorological data are available from onsite measurements and from measurements at: MacArthur Airport in Islip, New York (located about 20 km [12 mi] west-southwest of the BNL) and John F. Kennedy International Airport (JFK), New York City (located about 80 km [50 mi] west of the BNL). On average, the maximum daily temperature exceeds 32°C (90°F) on 3 days per year and the maximum daily temperature is below 0°C (32°F) on 21 days per year; the minimum daily temperature is below 0°C (32°F) on 106 days per year and is below -18°C (0°F) about twice every 5 years (DOC 1987a; DOC 1992a). July is the warmest month, with daily maximum and minimum temperatures at MacArthur Airport averaging 26°C (79°F) and 18°C (64°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 3°C (37°F) and -5°C (23°F), respectively (DOC 1992a).

Annual precipitation at JFK is on the order of 106 cm (42 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 118 days per year and the area experiences an average of 22 thunderstorm days per year. The average annual snowfall is 64 cm (25 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 7 days per year (DOC 1987b). Data from onsite monitoring indicates annual precipitation at the BNL is on the order of 123 cm (48 in.) and

measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 164 days per year. Precipitation data are provided for both JFK and the BNL because the differences between precipitation measurements at the BNL and neighboring stations are larger than is reasonably expected.

Winds are relatively uniform across the BNL. There is no strongly prevailing wind direction at the installation; winds from the south-southwest, southwest, and west-northwest occur with the greatest frequency (a frequency of occurrence of slightly over 10% for each of these directions). Wind speeds at the BNL average about 7 m/s (16 mph) at about 110 m (355 ft) above ground level. Average wind speeds are highest in March and lowest in August (DOC 1987c).

3.2 GEOLOGY

Brookhaven lies in the Atlantic Coastal Plain Physiographic Province of Long Island. Atlantic Coastal Plain sediments exposed on Long Island are the result of the last two Pleistocene glaciations of North America which deposited glacially-derived sediments on the erosional surface of the Magothy Formation. The BNL is situated in the upper portion of Long Island's Peconic River Valley, bordered by two lines of low hills extending east-west along nearly the full length of the island. The topography of the BNL is generally flat to rolling with elevations varying between 13 and 37 m (44 and 120 ft) above sea level. The BNL is underlain by approximately 460 m (1500 ft) of unconsolidated sediments which have been divided into four distinctive units (SAIC 1992, 1993). These units include, from youngest to oldest, Upper Pleistocene unconsolidated deposits, Gardiner's Clay, the Magothy Formation, and the Raritan Formation.

The Upper Pleistocene deposits are the result of a glacial-fluvial depositional setting consisting largely of broadly stratified clean sand and gravel with little clay or silt. These deposits have been divided into three geologic units: surficial silt and clay, Ronkonkoma moraine and kame deposits, and a basal unidentified unit. The surficial silt and clay are found in a discontinuous lenses along the eastern portion of the installation. The Ronkonkoma outwash and moraine deposits are the most permeable portion of the Upper Pleistocene sediments and contain a majority of the Upper Pleistocene aquifer. These highly porous and permeable deposits allow precipitation to readily infiltrate with very little surface runoff. The basal unidentified unit is found across the southern portion of the site (SAIC 1992; IT 1993).

Underlying the Upper Pleistocene deposits is a layer of relatively impermeable material known as the Gardiner's Clay. The Magothy Formation consists of layers and lenses of gravels, silt, and clay. Highly permeable lenses of sand and gravel have been encountered in this formation, although correlation between wells is difficult due to their discontinuous nature. Locally, the Magothy is used extensively as a water supply (SAIC 1992; IT 1993).

The Raritan Formation overlies bedrock and is divided into two geologic units: the upper (Raritan) Clay Member and the Lloyd Sand Member. The Raritan Clay Member acts as an aquitard that restricts downward movement from the overlying aquifers to the underlying Lloyd Sand Member. The Lloyd Sand Member is considered an aquifer with moderate permeability. The surface of the underlying bedrock acts as an impermeable barrier to groundwater movement and is considered the bottom of the groundwater reservoir. Bedrock is believed to be Pre-Cambrian or early Paleozoic in age and consists of hard, dense schist, gneiss, and granite (SAIC 1992; IT 1993).

3.3 HYDROLOGY

Groundwater at the BNL generally occurs under unconfined conditions. Depth to groundwater across the BNL varies from less than 3 m (10 ft) in the northeast to approximately 24 m (80 ft) below land surface in the western and central portions of the BNL. Groundwater in the vicinity of the BNL moves predominantly in a horizontal, southerly direction to the Great South Bay, while taking a more easterly direction in the Peconic River watershed portions of the site. The aquifer below the BNL is comprised of three principal water-bearing units beneath the BNL: the Upper Pleistocene deposits, the Magothy Formation, and the Lloyd Sand Member of the Raritan Formation. These units are hydraulically connected and make up a saturated zone extending from a depth of 14 to 460 m (45 to 1,500 ft) below the land surface (SAIC 1992).

The Magothy aquifer is the thickest hydrogeologic unit on Long Island and is locally extensively used as a water supply. Where overlain by the Gardiner's Clay, the clay layer may act as a local confining unit between the Upper Pleistocene and the Magothy Formation, restricting the flow of groundwater between the glacial and Magothy aquifers. Where the Magothy aquifer is in direct hydraulic connection with the aquifer in the Upper Pleistocene deposits and not separated by a distinct confining unit, conditions within the Magothy may be semi-confined to unconfined allowing intercommunication between the glacial aquifer and the underlying Magothy aquifer (IT 1993). The Lloyd aquifer is a confined aquifer lying between bedrock and the Raritan Clay Member. The vertical hydraulic conductivity of the Raritan is 0.03 cm/day (0.001 ft/day), which greatly limits the downward movement of water into the Lloyd aquifer. Due to its depth and the low hydraulic conductivity of the overlying confining layer, the Lloyd Sand is considered a minor aquifer and is not included in the PEIS environmental settings (IT 1993).

Due to the gentle topography and porous soils, there is very little runoff or open water on the BNL site. Average recharge estimates are 58 cm (23 in.) per year for the area surrounding the BNL (SAIC 1992). The BNL is located in the western margin of the Manorville Basin which forms the upper drainage area of the Peconic River (SAIC 1993b). Surface drainage is poor in the Manorville drainage basin with much of the land near the river being swampy. Marshy areas in the northern and eastern portions of the BNL have the

potential of being a principal tributary of the Peconic River, although these areas have been essentially dry in recent years due to regional droughts and increased residential development (IT 1993).

3.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the BNL for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 3.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 3.2.

For PEIS modeling purposes, BNL is characterized using two hydrogeologic environmental settings (Figure 3.1): the Glacial Aquifer and the Magothy Aquifer. Each setting has two subsettings based on their drainage directions. Figure 3.2 presents stratigraphic columns for each of the two settings. A brief description of the hydrogeology of each environmental setting follows. Hydrogeologic data for the various settings are presented in Tables 3.1-3.5.

3.4.1 Glacial Aquifer Setting

The Glacial aquifer is located in the Upper Pleistocene deposits and is the uppermost aquifer at the BNL. The saturated zone extends from a depth of 13.7 m (45 ft) below ground surface to the top of the Gardiner's Clay which acts as a local confining unit between the Glacial aquifer and the Magothy aquifer. Thickness of the saturated zone is estimated at 44.4 m (145 ft) (see Table 2.2.1-1 of SAIC 1992). A porosity value of 33% and a specific yield of 24% are typical of the glacial material. The hydraulic conductivity of the glacial aquifer is 55 m/day (179 ft/day) based on time-drawdown data from aquifer pumping tests (Warren et al. 1968). Hydraulic gradient of the BNL ranges from 0.001 to 0.0009 based on measurements from May 1990 through November 1992. The specific yield value, the hydraulic conductivity, and the hydraulic gradient were used to calculate the groundwater flow velocity which ranges from 0.20 to 0.23 m/day (0.66 to 0.74 ft/day). Soil texture classification for the partially-saturated and saturated zone is estimated as sand based on geologic descriptions for the Upper Pleistocene material as clean sands and gravels with little silt or clay (IT 1993; SAIC 1992; Faust 1963). The remaining values for the glacial aquifer setting are various default values assigned according to guidelines defined in the MEPAS application guidance (Droppo et al. 1989b).

3.4.2 Magothy Aquifer Setting

The Magothy aquifer is located between the Gardiner's Clay and Raritan Clay Members, two low permeability fine-grained units which act locally as confining units.

Within the Magothy aquifer setting, there are three partially-saturated zones. Zones 1 and 2 are of the same thickness and description as the partially-saturated and saturated zones in the Glacial aquifer setting. In the second partially-saturated zone, the field capacity has been set equal to the total porosity in order to represent the zone as being saturated. Partially-saturated zone 3 consists of a total of 3 m (10 ft) of the Gardiner's Clay. The vertical hydraulic conductivity is estimated at 0.03 cm/day (0.001 ft/day) (IT 1993). The soil texture classification is clay based on geologic descriptions (IT 1993; SAIC 1992; Faust 1963). Remaining values for the Gardiner's Clay unit are default values assigned by the MEPAS model. Thickness of the saturated zone is 240 m (800 ft) based on values found in Table 2.2.1-1 of SAIC 1992. A porosity value of 25 %, a hydraulic gradient of 0.0006, and data from time-drawdown tests in the Magothy Formation were used to calculate a groundwater flow velocity ranging from 0.9 to 4.3 cm/day (0.03 to 0.14 ft/day) (Warren et al. 1968). The representative soil classification selected for the Magothy Formation is a sandy loam, based on sediment descriptions (Faust 1963). The remaining values for the Magothy aquifer setting are various default values assigned by the MEPAS model.

3.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the BNL are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Paul Michael supplied input into the development of the climate and atmospheric dispersion environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings include Robert Howe, Douglas Paquette, Victor Cassella, and Gail Penny. Following completion of the environmental settings, Douglas Paquette coordinated the onsite review and fine tuning of the settings data. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

3.6 REFERENCES

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Figure 3.1.

Location and Environmental Settings for the Brookhaven National Laboratory (BNL). For PEIS modeling purposes, the BNL is divided into two environmental settings: the Glacial Aquifer and the Magothy Aquifer. Both settings are found across the entire BNL complex, with their distinguishing characteristic being the distance and direction of flow paths. The northeastern half of the installation is in the Peconic River drainage; the remainder of the installation is in the Atlantic Ocean drainage.

Figure 3.2. Stratigraphic Columns for Brookhaven National Laboratory (BNL) Environmental Settings

EXHIBIT 3.1

Brookhaven National Laboratory Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at Brookhaven National Laboratory, MacArthur Airport, and J.F.K International Airport. For some parameters, data collected at Brookhaven differs significantly from data collected at neighboring airport monitoring stations. In such cases, it is suggested that data from the airport stations be used in place of onsite data.

Station Name: Brookhaven National Laboratory, Upton, New York	Elevation: 27 m	Latitude: 40.87°N
MacArthur Airport, Islip, New York	Elevation: 26 m	Latitude: 40.78°N
J.F.K. International Airport, New York, New York	Elevation: 4 m	Latitude: 40.65°N

Annual Mean Air Temp:	49.7 °F (Brookhaven) Reference (A)	
	53.1 °F (J.F.K.) Reference (B)	Based on observations made from 1951-1980.
Anemometer Height:	10.0 m (Brookhaven) Reference (A)	
	6.1 m (Islip) Reference (C)	
	6.1 m (J.F.K.) Reference (B)	
Mean Annual Wind Speed:	13.4 mph (Brookhaven) Reference (A)	Based on observations made from 1960-1991.
	9.3 mph (Islip) Reference (C)	Based on 3 years of observations.
Fastest 1-Min Wind Speed:	81.0 mph (Brookhaven) Reference (A)	
	52.0 mph (J.F.K.) Reference (B)	Based on 28 years of observations.
Annual Precipitation:	48.3 in. (Brookhaven) Reference (A)	
	41.8 in. (J.F.K.) Reference (B)	Based on 39 years of observations.
Precipitation Days:	164 yr ⁻¹ (Brookhaven) Reference (A)	Based on observations made from 1949-1973.
	118 yr ⁻¹ (J.F.K.) Reference (B)	Based on 28 years of observations.
Thunderstorms Freq:	16 yr ⁻¹ (Brookhaven) Reference (A)	Based on observations made from 1949-1952.
	22 yr ⁻¹ (J.F.K.) Reference (B)	Based on 28 years of observations.

Avg Morning Mixing Ht:	750 m	Reference (D)
Avg Afternoon Mixing Ht:	1100 m	Reference (D)
Top Soil Moisture Capacity:	5.2 cm	Reference (D)

MEPAS Parameters:	Climatic Region Index:	7	Reference (D)
	Precipitation-Evaporation Index:	126	Reference (D)
	Soil Cons. Serv. Curve Number:	58	Reference (D)

MONTHLY AVERAGES							
	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
MONTH	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	29	4.1	9.6	6.1	13.6	74	64
Feb	30	3.9	9.9	6.2	13.2	79	65
Mar	37	4.7	11.4	6.2	15.5	73	54
Apr	47	4.2	10.3	6.0	15.2	78	53
May	57	3.8	9.6	6.2	15.8	81	54
Jun	66	3.3	9.0	6.0	13.1	80	57
Jul	71	3.3	8.1	5.9	13.3	86	62
Aug	70	4.5	7.6	5.8	12.9	87	62
Sep	62	3.5	8.2	5.5	11.4	85	58
Oct	53	3.7	8.5	5.4	11.5	85	60
Nov	43	4.5	9.8	6.3	14.4	82	64
Dec	32	4.7	9.4	6.3	14.1	77	58
	↓	↓	↓	↓	↓	↓	↓
Reference: ...	(A)	(A)	(C)	(B)	(A)	(B)	(B)

References

- A: Unpublished technical data provided by correspondence with R.F. Howe, Deputy Manager, Office of Environmental Restoration, Brookhaven National Laboratory, February 16, 1993.
- B: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part I Eastern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
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EXHIBIT 3.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Brookhaven National Laboratory. Atmospheric stability was computed using BNL's gustiness categories and converted to the standard Pasquill-Gifford stability classes. Wind measurements were made on the onsite meteorology monitoring tower at an effective height of 100 m (330 ft) above ground level. Data are based on measurements made from 1980 through 1989.

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (m/s)					
		0 - 3	3 - 5	5 - 7	7 - 12	12 - 16	> 16
A	NORTH	0.00308	0.00411	0.00500	0.00447	0.00005	0.00000
A	NORTH-NORTHEAST	0.00326	0.00496	0.00447	0.00336	0.00004	0.00000
A	NORTHEAST	0.00309	0.00511	0.00490	0.00365	0.00003	0.00000
A	EAST-NORTHEAST	0.00260	0.00409	0.00335	0.00229	0.00007	0.00000
A	EAST	0.00190	0.00317	0.00246	0.00119	0.00007	0.00000
A	EAST-SOUTHEAST	0.00201	0.00264	0.00213	0.00121	0.00005	0.00000
A	SOUTHEAST	0.00169	0.00365	0.00203	0.00089	0.00006	0.00000
A	SOUTH-SOUTHEAST	0.00191	0.00347	0.00207	0.00112	0.00006	0.00000
A	SOUTH	0.00175	0.00430	0.00312	0.00198	0.00009	0.00001
A	SOUTH-SOUTHWEST	0.00204	0.00718	0.00976	0.00701	0.00020	0.00000
A	SOUTHWEST	0.00197	0.00531	0.00953	0.00811	0.00007	0.00000
A	WEST-SOUTHWEST	0.00232	0.00412	0.00404	0.00332	0.00006	0.00000
A	WEST	0.00259	0.00552	0.00613	0.00646	0.00038	0.00000
A	WEST-NORTHWEST	0.00373	0.00793	0.01145	0.01384	0.00114	0.00003
A	NORTHWEST	0.00315	0.00669	0.01005	0.01252	0.00093	0.00004
A	NORTH-NORTHWEST	0.00353	0.00616	0.00840	0.00825	0.00040	0.00000
B	NORTH	0.00115	0.00360	0.00571	0.00578	0.00008	0.00000
B	NORTH-NORTHEAST	0.00106	0.00334	0.00476	0.00402	0.00004	0.00000
B	NORTHEAST	0.00096	0.00357	0.00497	0.00414	0.00004	0.00000
B	EAST-NORTHEAST	0.00096	0.00340	0.00347	0.00259	0.00005	0.00000
B	EAST	0.00100	0.00332	0.00296	0.00150	0.00010	0.00000
B	EAST-SOUTHEAST	0.00093	0.00273	0.00255	0.00152	0.00007	0.00001
B	SOUTHEAST	0.00084	0.00321	0.00219	0.00111	0.00009	0.00000
B	SOUTH-SOUTHEAST	0.00093	0.00303	0.00230	0.00146	0.00009	0.00000
B	SOUTH	0.00123	0.00489	0.00404	0.00258	0.00013	0.00002
B	SOUTH-SOUTHWEST	0.00121	0.00754	0.01182	0.00903	0.00029	0.00001
B	SOUTHWEST	0.00086	0.00491	0.01069	0.00960	0.00010	0.00000
B	WEST-SOUTHWEST	0.00076	0.00310	0.00418	0.00359	0.00008	0.00000
B	WEST	0.00053	0.00260	0.00471	0.00582	0.00035	0.00000
B	WEST-NORTHWEST	0.00078	0.00298	0.00701	0.00974	0.00099	0.00003
B	NORTHWEST	0.00072	0.00280	0.00677	0.01071	0.00097	0.00006
B	NORTH-NORTHWEST	0.00101	0.00358	0.00739	0.00839	0.00050	0.00001
C	NORTH	0.00005	0.00020	0.00070	0.00230	0.00027	0.00001
C	NORTH-NORTHEAST	0.00005	0.00018	0.00056	0.00191	0.00012	0.00000
C	NORTHEAST	0.00005	0.00026	0.00076	0.00232	0.00034	0.00003
C	EAST-NORTHEAST	0.00007	0.00036	0.00099	0.00142	0.00008	0.00006
C	EAST	0.00006	0.00025	0.00057	0.00102	0.00022	0.00000
C	EAST-SOUTHEAST	0.00005	0.00021	0.00035	0.00108	0.00034	0.00009
C	SOUTHEAST	0.00004	0.00018	0.00032	0.00091	0.00049	0.00008
C	SOUTH-SOUTHEAST	0.00005	0.00017	0.00030	0.00101	0.00037	0.00017
C	SOUTH	0.00006	0.00027	0.00059	0.00184	0.00051	0.00014
C	SOUTH-SOUTHWEST	0.00006	0.00045	0.00217	0.00750	0.00110	0.00014
C	SOUTHWEST	0.00004	0.00034	0.00213	0.00624	0.00051	0.00003
C	WEST-SOUTHWEST	0.00006	0.00017	0.00095	0.00252	0.00009	0.00002
C	WEST	0.00003	0.00014	0.00079	0.00303	0.00020	0.00001
C	WEST-NORTHWEST	0.00004	0.00019	0.00119	0.00552	0.00079	0.00003
C	NORTHWEST	0.00003	0.00018	0.00102	0.00416	0.00088	0.00005
C	NORTH-NORTHWEST	0.00005	0.00022	0.00102	0.00321	0.00070	0.00011

EXHIBIT 3.2 (continued)

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (m/s)					
		0 - 3	3 - 5	5 - 7	7 - 12	12 - 16	> 16
D	NORTH	0.00024	0.00055	0.00115	0.00231	0.00029	0.00001
D	NORTH-NORTHEAST	0.00023	0.00040	0.00086	0.00192	0.00012	0.00001
D	NORTHEAST	0.00021	0.00043	0.00090	0.00232	0.00036	0.00003
D	EAST-NORTHEAST	0.00025	0.00054	0.00112	0.00145	0.00009	0.00006
D	EAST	0.00026	0.00038	0.00068	0.00106	0.00022	0.00002
D	EAST-SOUTHEAST	0.00029	0.00040	0.00040	0.00112	0.00036	0.00010
D	SOUTHEAST	0.00027	0.00033	0.00040	0.00096	0.00052	0.00010
D	SOUTH-SOUTHEAST	0.00027	0.00047	0.00044	0.00106	0.00039	0.00019
D	SOUTH	0.00028	0.00045	0.00077	0.00192	0.00054	0.00016
D	SOUTH-SOUTHWEST	0.00029	0.00065	0.00241	0.00786	0.00115	0.00015
D	SOUTHWEST	0.00028	0.00082	0.00290	0.00683	0.00054	0.00004
D	WEST-SOUTHWEST	0.00027	0.00056	0.00177	0.00330	0.00009	0.00003
D	WEST	0.00026	0.00060	0.00147	0.00349	0.00019	0.00002
D	WEST-NORTHWEST	0.00024	0.00069	0.00183	0.00577	0.00079	0.00003
D	NORTHWEST	0.00025	0.00059	0.00158	0.00425	0.00088	0.00005
D	NORTH-NORTHWEST	0.00021	0.00058	0.00155	0.00322	0.00072	0.00012
E	NORTH	0.00009	0.00020	0.00027	0.00007	0.00000	0.00000
E	NORTH-NORTHEAST	0.00009	0.00015	0.00020	0.00005	0.00000	0.00000
E	NORTHEAST	0.00008	0.00014	0.00014	0.00003	0.00000	0.00000
E	EAST-NORTHEAST	0.00008	0.00013	0.00010	0.00003	0.00000	0.00000
E	EAST	0.00009	0.00012	0.00009	0.00002	0.00000	0.00000
E	EAST-SOUTHEAST	0.00011	0.00012	0.00006	0.00001	0.00000	0.00000
E	SOUTHEAST	0.00010	0.00012	0.00007	0.00002	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00010	0.00017	0.00010	0.00002	0.00000	0.00000
E	SOUTH	0.00010	0.00017	0.00014	0.00004	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00011	0.00022	0.00030	0.00016	0.00000	0.00000
E	SOUTHWEST	0.00010	0.00028	0.00047	0.00029	0.00000	0.00000
E	WEST-SOUTHWEST	0.00009	0.00021	0.00037	0.00031	0.00000	0.00000
E	WEST	0.00010	0.00022	0.00033	0.00023	0.00000	0.00000
E	WEST-NORTHWEST	0.00009	0.00024	0.00036	0.00017	0.00000	0.00000
E	NORTHWEST	0.00009	0.00021	0.00033	0.00017	0.00000	0.00000
E	NORTH-NORTHWEST	0.00008	0.00021	0.00033	0.00011	0.00000	0.00000
F	NORTH	0.00262	0.00601	0.00812	0.00211	0.00000	0.00000
F	NORTH-NORTHEAST	0.00258	0.00444	0.00598	0.00143	0.00000	0.00000
F	NORTHEAST	0.00241	0.00404	0.00420	0.00102	0.00000	0.00000
F	EAST-NORTHEAST	0.00261	0.00383	0.00287	0.00104	0.00000	0.00000
F	EAST	0.00282	0.00348	0.00267	0.00061	0.00000	0.00000
F	EAST-SOUTHEAST	0.00325	0.00364	0.00188	0.00047	0.00000	0.00000
F	SOUTHEAST	0.00307	0.00357	0.00213	0.00059	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00297	0.00511	0.00283	0.00067	0.00000	0.00000
F	SOUTH	0.00314	0.00506	0.00418	0.00120	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00324	0.00667	0.00876	0.00456	0.00002	0.00000
F	SOUTHWEST	0.00310	0.00819	0.01385	0.00837	0.00001	0.00000
F	WEST-SOUTHWEST	0.00285	0.00620	0.01104	0.00910	0.00003	0.00000
F	WEST	0.00280	0.00659	0.00990	0.00663	0.00000	0.00000
F	WEST-NORTHWEST	0.00265	0.00723	0.01056	0.00499	0.00000	0.00000
F	NORTHWEST	0.00276	0.00612	0.00975	0.00484	0.00001	0.00000
F	NORTH-NORTHWEST	0.00241	0.00611	0.00991	0.00325	0.00000	0.00000

Table 3.1. Hydrogeologic Environmental Setting Data for Brookhaven National Laboratory's East Glacial Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.58	--
SOILC		4.05	4.05
Thickness	m	13.7	44.2
Bulk_density	g/cm3	1.64	1.64
Total_porosity	%	33	33
Field_capacity	%	9	--
Conductivity	m/day	54.6	--
Longitudinal_disp.	m	0.14	183.0
Transverse_disp.	m	--	36.6
Vertical_disp.	m	--	0.21
Effective_porosity	%	--	24
Velocity	m/day	--	0.21
Distance	m	--	1830
Textural_class		sand	sand
%_sand	%	95	95
%_silt	%	3	3
%_clay	%	2	2
%_OMC	%	0.06	0.06
%_Fe	%	0.61	0.61
pH		5.85	5.85

Table 3.2. Hydrogeologic Environmental Setting Data for Brookhaven National Laboratory's South Glacial Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.58	--
SOILC		4.05	4.05
Thickness	m	13.7	44.2
Bulk_density	g/cm3	1.64	1.64
Total_porosity	%	33	33
Field_capacity	%	9	--
Conductivity	m/day	54.6	--
Longitudinal_disp.	m	0.14	244.0
Transverse_disp.	m	--	48.8
Vertical_disp.	m	--	0.28
Effective_porosity	%	--	24
Velocity	m/day	--	0.21
Distance	m	--	2440
Textural_class		sand	sand
%_sand	%	95	95
%_silt	%	3	3
%_clay	%	2	2
%_OMC	%	0.06	0.06
%_Fe	%	0.61	0.61
pH		5.85	5.85

Table 3.3. Hydrogeologic Environmental Setting Data for Brookhaven National Laboratory's East Magothy Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ1</u>	<u>PZ2</u>	<u>PZ3</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.58	0.58	0.58	--
SOILC		4.05	4.05	11.4	4.9
Thickness	m	13.7	44.2	3.05	244.0
Bulk_density	g/cm ³	1.64	1.64	1.39	1.48
Total_porosity	%	33	33	47.5	25
Field_capacity	%	9	9	40	--
Conductivity	m/day	54.6	54.6	0.0003	--
Longitudinal_disp.	m	0.137	0.442	0.031	183.0
Transverse_disp.	m	--	--	--	36.6
Vertical_disp.	m	--	--	--	0.21
Effective_porosity	%	--	--	--	20
Velocity	m/day	--	--	--	0.027
Distance	m	--	--	--	1830
Textural_class		sand	sand	clay	sandy loam
%_sand	%	95	95	35	65
%_silt	%	3	3	15	25
%_clay	%	2	2	50	10
%_OMC	%	0.06	0.06	0	0
%_Fe	%	0.61	0.61	0	0
pH		5.85	5.85	7.0	7.0

Table 3.4. Hydrogeologic Environmental Setting Data for Brookhaven National Laboratory's South Magothy Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	SZ
Darcian_velocity	m/yr	0.58	0.58	0.58	--
SOILC		4.05	4.05	11.4	4.9
Thickness	m	13.7	44.2	3.05	244.0
Bulk_density	g/cm3	1.64	1.64	1.39	1.48
Total_porosity	%	33	33	47.5	25
Field_capacity	%	9	9	40	--
Conductivity	m/day	54.6	54.6	0.0003	--
Longitudinal_disp.	m	0.137	0.442	0.031	244.0
Transverse_disp.	m	--	--	--	48.8
Vertical_disp.	m	--	--	--	0.28
Effective_porosity	%	--	--	--	20
Velocity	m/day	--	--	--	0.027
Distance	m	--	--	--	2440
Textural_class		sand	sand	clay	sandy loam
%_sand	%	95	95	35	65
%_silt	%	3	3	15	25
%_clay	%	2	2	50	10
%_OMC	%	0.06	0.06	0	0
%_Fe	%	0.61	0.61	0	0
pH		5.85	5.85	7.0	7.0

Table 3.5. Hydrogeologic Environmental Setting Data for Brookhaven National Laboratory's Storm Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.58	--
SOILC		4.05	4.05
Thickness	m	13.7	44.2
Bulk_density	g/cm ³	1.64	1.64
Total_porosity	%	33	33
Field_capacity	%	9	--
Conductivity	m/day	54.6	--
Longitudinal_disp.	m	0.14	183
Transverse_disp.	m	--	36.6
Vertical_disp.	m	--	0.21
Distance	m	--	1830
Effective_porosity	%	--	24
Velocity	m/day	--	0.21
Textural_class		sand	sand
%_sand	%	95	95
%_silt	%	3	3
%_clay	%	2	2
%_OMC	%	0.06	0.06
%_Fe	%	0.61	0.61
pH		5.85	5.85

4.0 FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

The Feed Material Production Center is a DOE installation that was used to produce high-quality uranium metals for military defense. In 1991, DOE ended uranium metal production at Fernald and its mission changed to environmental cleanup and restoration. To reflect the new cleanup mission, DOE officially changed the name of the facility to the Fernald Environmental Management Project (FEMP).

The FEMP is located about 27 km (17 mi) northwest of Cincinnati, Ohio (Figure 4.1). The FEMP occupies 4.3 km² (1.6 mi²) on a terrace remnant of the Great Miami River. The FEMP has an average elevation of about 180 m (590 ft) above mean sea level, slightly higher than the surrounding bottom lands of the river valley. The topography of the FEMP slopes downward about 40 m (130 ft) from the northern to western boundary of the installation. The FEMP is located in a predominantly agricultural area; however, residential homes are located in proximity to the site fence line. Ecologically, the installation is located in a beech-maple forest ecotone, although only remnants of these forests remain in the area.

4.1 CLIMATE

The FEMP has a "humid continental warm summer" climate (Critchfield 1974). Meteorological data are available from onsite measurements and from measurements at the Greater Cincinnati Airport. On average, the maximum daily temperature exceeds 32°C (90°F) on 19 days a year and is below 0°C (32°F) on 30 days a year; the minimum daily temperature is below 0°C (32°F) on 109 days a year and is below -18°C (0°F) on 7 days a year (DOC 1987a). July is the warmest month, with daily maximum and minimum temperatures averaging 30°C (86°F) and 18°C (65°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 3°C (37°F) and -7°C (20°F), respectively (DOC 1987a).

Annual precipitation is on the order of 100 cm (40 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 129 days per year and the area experiences an average of 43 thunderstorm days per year. The average annual snowfall is 58 cm (23 in.) (DOC 1992a) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 7 days per year (DOC 1987a).

Winds are relatively uniform across the FEMP. The prevailing wind direction at 10 m (33 ft) above ground is from the southwest, although similarly high frequencies of winds from the west, west-southwest, and south-southwest are reported (Westinghouse 1992). Wind speeds at the Cincinnati airport average about 4.5 m/s (10 mph) at about 6 m (20 ft) above ground level (DOC 1987a). Wind speeds onsite average 4 m/s (9 mph) at about 60 m (200 ft) above ground level. Some of this difference may be the result of local topography;

the airport is situated on high, open terrain overlooking the Ohio River Valley and the FEMP meteorological tower is located on the edge of a heavily forested area. Average wind speeds at the airport are highest in March (5 m/s [11 mph]) and lowest in August (3 m/s [7 mph]) (DOC 1987a).

4.2 GEOLOGY

The FEMP is located in geologically complex terrain. The surficial material at the FEMP is a basal till, formed during the most recent glaciation. It is part of a remnant terrace system, formed when the tills in the area were eroded by surface waters. This basal till tends to have much finer-grained materials than the underlying aquifer, and as a result a lower permeability. The upper 4.5 m (15 ft) to 6 m (20 ft) of the till is weathered under portions of the installation, giving this near-surface material increased porosity and transmissivities relative to the rest of the till. Bedrock in the area consists of an Ordovician shale that contains interbeds of limestone. This relatively impermeable unit underlies the FEMP and forms the highland area surrounding the installation. At some point in the past, rivers cut deep, distinctive channels into the shales that underlie the basal till. These channels were filled by glacial outwash during the last several glacial retreats, and contain relatively coarse-grained (sand and gravel) debris. This material forms the bulk of the Great Miami Aquifer (GMA) (also called the Buried Valley Aquifer), a major source of potable water throughout much of western Ohio.

4.3 HYDROLOGY

The major groundwater resource in the area is the GMA. Water from this resource enters the site from areas north and west of the installation. Flow under the FEMP splits into two lobes, with one migrating eastward toward the Great Miami River and an industrial well field on the east side of the river, and the second lobe migrating toward the south. In addition to the GMA, the presence of perched water has been noted within the basal tills. These ephemeral features are thought to be laterally discontinuous and of limited volume.

The Great Miami River is the predominant surface water feature in the area. Located approximately 2 km (1.2 mi) east of the production area, it has an average annual flow rate of about 90 m³/s (3200 ft³/s), with a maximum and minimum flow rate of 1300 and 10 m³/s (46,000 and 350 ft³/s), respectively. Along the western edge of the FEMP property is a small, intermittent, southerly-flowing stream named Paddy's Run. The channel for Paddy's Run has cut through the low permeability basal tills and comes in contact with the underlying aquifer at a location west and slightly north of the main production areas. During periods of elevated groundwater levels, the regional aquifer acts as a source for water to the stream. Conversely, the stream can recharge water directly to the groundwater during periods of low

groundwater stands. Paddy's Run empties into the Great Miami River about 2.4 km (1.5 mi) south of the installation.

4.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the FEMP for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 4.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 4.2

For PEIS modeling purposes, the installation is characterized using three hydrogeologic environmental settings (Figure 4.1): East Northeast (ENE), Paddy's Run, and Southwest Productions Area (SWPA). Figure 4.2 presents stratigraphic columns for each of these settings. The ENE setting encompasses the FEMP's waste pit area and divides the production area along a northwest-southeast line. The Paddy's Run setting incorporates those areas along the margins of the stream and includes the inactive fly ash disposal area. The SWPA setting includes the areas between the ENE and Paddy's Run settings. A brief description of the hydrogeology of each environmental setting follows. Surface water data are presented in Table 4.1. Hydrogeologic data for the various settings are presented in Tables 4.2-4.4.

4.4.1 ENE Setting

The ENE includes the northern and eastern portions of the installation, with the boundary between this unit and the SWPA running approximately through the middle of the production area along a northwest-southeast line. The environmental setting includes the majority of the waste pits along Paddy's Run as well. Two characteristics distinguish this unit from other areas at the FEMP. The stratigraphy is dominated by glacial tills. The surface-most layer consists of about 1 m (3 ft) of loess. This is underlain by about 3 m (10 ft) of weathered and relatively permeable tills. The fresh basal till averages about 7.5 m (25 ft), and is less permeable than the overlying weathered materials. Finally, the ENE tills are supported on the GMA. In the vicinity of ENE, the upper 10.6 m (35 ft) of the GMA are unsaturated. This sandy, gravelly outwash deposit extends to bedrock. Approximately the lower 45 m (147 ft) of the GMA is saturated. Groundwater enters this unit primarily from the north and northwest, along the origins of Paddy's Run. After entering the property, the water generally flows toward the east and the Great Miami River. Contaminants entering the groundwater in this area would migrate toward the great bend area of the river.

4.4.2 SWPA Setting

The SWPA is bounded by the ENE area on the north and east, and by Paddy's Run to the west. Originating on the southern edge of the waste pit area, and including the uranium and thorium silos, this environmental setting includes the majority of the elevated areas (above the Paddy's Run floodplain) in the central portion of the installation. Surface deposits in the SWPA consist of lacustrine (lake bed) sediments. The uppermost unit averages about 4 m (13 ft) thick. Underlying the lacustrine silts is a thin (2 m [7 ft]) lens of transmissive sands. Fresh basal tills, similar to those described in the ENE setting, are located under the sand unit. In this area, the tills average about 4 m (13 ft) in thickness. The GMA underlies this material. The thickness of the GMA in this area is about 53 m (174 ft) of which the upper 8 m (26 ft) are unsaturated. The sandy units within the lacustrine deposits have been reported to hold perched water tables. However, little is known about the lateral extent of these ephemeral aquifers. As such, we elected to not treat these as a separate, water-saturated units capable of transporting contaminants laterally to potential receipts in the vicinity of the FEMP. Regional groundwater within the GMA at SWPA generally migrates toward the south, and eventually emerges at the Great Miami River. The flow path followed by waters in this area is distinct from that followed by waters underlying the ENE setting.

4.4.3 Paddy's Run Setting

Paddy's Run is a relatively complex area to model. The brook enters the property near the northwest corner of the property and flows southward. Along the northern third of this flow path, the brook is perched on compacted and relatively fresh tills. As such, the creek bed is effectively impermeable, and the creek is isolated from the underlying groundwater. Along this section of the creek, the area is considered as part of the ENE setting. In the vicinity of the silos, however, the creek erodes through the tills and comes in direct contact with the underlying GMA. At this point, the area becomes hydrologically complex, and it is distinguished as a separate environmental setting. During periods of high groundwater stands, as typically occurs during the late winter, spring, and early summer, the net hydrologic transfer can be from the aquifer into Paddy's Run. During these times, the groundwater supplements flow in the creek. As groundwater levels recede in mid-summer and fall, the situation is reversed. The brook contributes water to the groundwater. The primary transfer mechanism is seepage through the bottom of the creek bed. Because this seepage occurs over the length of the stream bed on the southern half of the property, there is a mechanism for transporting contaminants laterally in the stream before having them infiltrate into the groundwaters. MEPAS does not have the capability to model this type of a transport mechanism, so the development of the environmental settings attempted to compensate for this particular model limitation.

4.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for FEMP are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Tom Walsh and Ed Ray supplied input into the development of the climate and atmospheric dispersion environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings included Ron White, Ken Broberg, Steve Oberjohn, and Randy Jenke. Following completion of the environmental settings, Ken Broberg coordinated the on-site review and fine tuning of the data. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

4.6 REFERENCES

Critchfield, H.J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

U.S. Department of Commerce. 1987a. *Local Climatological Data Annual Summaries for 1986 Part I Eastern Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

U.S. Department of Commerce. 1992a. *International Station Meteorological Climate Summary. Version 2*. Compact Disc. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

Westinghouse Environmental Management Company of Ohio. 1992. *Annual Site Environmental Report for Calendar Year 1991*. FEMP-2275, Westinghouse Environmental Management Company of Ohio, Fernald, Ohio.

Figure 4.1. Location and Environmental Settings for the Fernald Environmental Management Project (FEMP). For PEIS modeling purposes, the FEMP is divided into three environmental settings: East Northeast (ENE), Paddy's Run, and Southwest Productions Area (SWPA).

Figure 4.2. Stratigraphic Columns for Fernald Environmental Management Project (FEMP) Environmental Settings

EXHIBIT 4.1

Fernald Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite and at the Greater Cincinnati Airport.

Station Name: Greater Cincinnati Airport, Cincinnati, Ohio	Elevation: 265 m	Latitude: 39.05°N
Fernald Meteorology Tower, Fernald, Ohio	Elevation: 175 m	Latitude: 39.30°N

Annual Mean Air Temp:	53.3 °F	(airport)	Reference (A)	Based on observations made from 1951-1980.
Anemometer Height:	6.1 m	(airport)	Reference (A)	
	60.0 m	(Fernald)	Reference (A)	
Mean Annual Wind Speed:	9 mph	(airport)	Reference (A)	Based on 39 years of observations.
	9 mph	(Fernald)	Reference (B)	
Fastest 1-Min Wind Speed:	46 mph	(airport)	Reference (A)	Based on 23 years of airport observations.
Annual Precipitation:	40.1 in.	(airport)	Reference (A)	Based on observations made from 1951-1980.
Precipitation Days:	129 yr ⁻¹	(airport)	Reference (A)	Based on 39 years of observations.
Thunderstorms Freq:	43 yr ⁻¹	(airport)	Reference (A)	Based on 39 years of observations.

Avg Morning Mixing Ht:	500 m	Reference (C)
Avg Afternoon Mixing Ht:	1450 m	Reference (C)
Top Soil Moisture Capacity:	0.8 cm	Reference (C)

MEPAS Parameters:	Climatic Region Index:	4	Reference (C)
	Precipitation-Evaporation Index:	103	Reference (C)
	Soil Cons. Serv. Curve Number:	79	Reference (C)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	29	3.1	10.7	7.5	12.0	78	68
Feb	32	2.7	10.8	7.3	11.1	78	64
Mar	42	4.0	11.9	7.3	13.2	77	60
Apr	54	3.6	8.4	6.9	12.5	76	54
May	63	3.8	8.6	6.7	11.5	80	55
Jun	71	4.1	8.0	6.2	10.6	82	56
Jul	75	4.3	6.8	6.0	10.0	85	57
Aug	74	3.0	6.9	5.8	9.0	88	58
Sep	68	2.9	7.7	5.6	7.8	88	57
Oct	55	2.5	8.6	5.7	8.3	83	56
Nov	43	3.1	11.7	7.1	10.9	80	64
Dec	34	3.0	11.0	7.5	12.1	79	69
Reference: ...	(A)	(A)	(B)	(A)	(A)	(A)	(A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part I Eastern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- B: Westinghouse Environmental Management Company of Ohio. 1992. Annual Site Environmental Report for Calendar Year 1991. FEMP-2275. Average wind speeds presented above for Fernald are based on the average of hourly wind data recorded at the Fernald meteorology tower from 1987-1989. Average values were computed at PNL from a FOXPRO data file (in a PKZIP format) sent to the PNL environmental settings team by Tom Walsh at Fernald.
- C: Droppo, J.G., Jr., D.L. Streng, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 4.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for the Fernald Environmental Management Project. Atmospheric stability is determined using the Pasquill-Gifford method. Winds were measured onsite at the 10 m (33 ft) level on the installation's meteorology tower. Data are based on measurements made from 1987 through 1989.

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
A	NORTH	0.000043	0.000428	0.000342	0.000300	0.000000	0.000000
A	NORTH-NORTHEAST	0.000171	0.000428	0.000813	0.000471	0.000043	0.000000
A	NORTHEAST	0.000300	0.000471	0.000770	0.000300	0.000000	0.000000
A	EAST-NORTHEAST	0.000043	0.000556	0.000899	0.000000	0.000000	0.000000
A	EAST	0.000000	0.000471	0.000214	0.000128	0.000000	0.000043
A	EAST-SOUTHEAST	0.000086	0.000086	0.000086	0.000000	0.000000	0.000000
A	SOUTHEAST	0.000000	0.000000	0.000000	0.000000	0.000000	0.000043
A	SOUTH-SOUTHEAST	0.000000	0.000000	0.000043	0.000086	0.000000	0.000000
A	SOUTH	0.000171	0.000043	0.000043	0.000000	0.000000	0.000000
A	SOUTH-SOUTHWEST	0.000342	0.000385	0.001584	0.000171	0.000000	0.000000
A	SOUTHWEST	0.000171	0.001027	0.003510	0.000599	0.000000	0.000000
A	WEST-SOUTHWEST	0.000043	0.001198	0.003082	0.000171	0.000000	0.000000
A	WEST	0.000171	0.001070	0.002611	0.000471	0.000000	0.000000
A	WEST-NORTHWEST	0.000342	0.000385	0.001113	0.000599	0.000000	0.000000
A	NORTHWEST	0.000171	0.000728	0.000385	0.000257	0.000000	0.000000
A	NORTH-NORTHWEST	0.000128	0.000300	0.000642	0.000300	0.000043	0.000000
B	NORTH	0.000086	0.000599	0.000642	0.000128	0.000000	0.000000
B	NORTH-NORTHEAST	0.000043	0.000342	0.000599	0.000171	0.000000	0.000000
B	NORTHEAST	0.000128	0.000728	0.001070	0.000086	0.000000	0.000000
B	EAST-NORTHEAST	0.000128	0.001198	0.000514	0.000214	0.000000	0.000000
B	EAST	0.000257	0.000599	0.000214	0.000043	0.000000	0.000000
B	EAST-SOUTHEAST	0.000043	0.000257	0.000043	0.000000	0.000000	0.000000
B	SOUTHEAST	0.000000	0.000043	0.000043	0.000000	0.000000	0.000000
B	SOUTH-SOUTHEAST	0.000128	0.000171	0.000043	0.000043	0.000000	0.000000
B	SOUTH	0.000043	0.000128	0.000214	0.000000	0.000000	0.000000
B	SOUTH-SOUTHWEST	0.000128	0.001027	0.001755	0.000257	0.000000	0.000000
B	SOUTHWEST	0.000471	0.001198	0.002525	0.000257	0.000000	0.000000
B	WEST-SOUTHWEST	0.000257	0.001926	0.001669	0.000214	0.000000	0.000000
B	WEST	0.000171	0.000899	0.001627	0.000214	0.000000	0.000000
B	WEST-NORTHWEST	0.000086	0.000813	0.001156	0.000257	0.000000	0.000000
B	NORTHWEST	0.000257	0.000685	0.000770	0.000257	0.000000	0.000000
B	NORTH-NORTHWEST	0.000257	0.000471	0.000770	0.000086	0.000000	0.000000
C	NORTH	0.000043	0.000942	0.001113	0.000300	0.000000	0.000000
C	NORTH-NORTHEAST	0.000171	0.000984	0.001027	0.000128	0.000000	0.000000
C	NORTHEAST	0.000214	0.001327	0.001412	0.000214	0.000000	0.000000
C	EAST-NORTHEAST	0.000385	0.002097	0.000599	0.000385	0.000000	0.000000
C	EAST	0.000642	0.001027	0.000214	0.000043	0.000000	0.000000
C	EAST-SOUTHEAST	0.000428	0.000599	0.000086	0.000000	0.000000	0.000000
C	SOUTHEAST	0.000086	0.000599	0.000128	0.000000	0.000000	0.000000
C	SOUTH-SOUTHEAST	0.000128	0.000342	0.000214	0.000000	0.000000	0.000000
C	SOUTH	0.000171	0.000813	0.000514	0.000086	0.000000	0.000000
C	SOUTH-SOUTHWEST	0.000342	0.001284	0.001412	0.000128	0.000043	0.000000
C	SOUTHWEST	0.000428	0.003510	0.002226	0.000257	0.000000	0.000000
C	WEST-SOUTHWEST	0.000642	0.003167	0.001883	0.000300	0.000000	0.000000
C	WEST	0.000257	0.001284	0.001327	0.000514	0.000000	0.000000
C	WEST-NORTHWEST	0.000214	0.001241	0.001712	0.000385	0.000000	0.000000
C	NORTHWEST	0.000257	0.001156	0.001070	0.000171	0.000043	0.000000
C	NORTH-NORTHWEST	0.000000	0.001284	0.000984	0.000043	0.000000	0.000000
D	NORTH	0.001755	0.007833	0.010230	0.001455	0.000000	0.000000
D	NORTH-NORTHEAST	0.002611	0.009845	0.011557	0.002146	0.000000	0.000000
D	NORTHEAST	0.003381	0.014296	0.011086	0.000899	0.000000	0.000000
D	EAST-NORTHEAST	0.004708	0.021744	0.011214	0.002311	0.000000	0.000000
D	EAST	0.004880	0.006848	0.001327	0.000128	0.000043	0.000000

EXHIBIT 4.2 (continued)

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
D	EAST-SOUTHEAST	0.003681	0.003253	0.000128	0.000043	0.000000	0.000000
D	SOUTHEAST	0.002825	0.002825	0.000599	0.000000	0.000000	0.000000
D	SOUTH-SOUTHEAST	0.002739	0.003424	0.001712	0.000257	0.000000	0.000000
D	SOUTH	0.002953	0.006206	0.002611	0.000428	0.000000	0.000000
D	SOUTH-SOUTHWEST	0.004965	0.012284	0.006677	0.002868	0.000000	0.000000
D	SOUTHWEST	0.006763	0.016222	0.010101	0.001755	0.000257	0.000000
D	WEST-SOUTHWEST	0.007619	0.012969	0.007191	0.002055	0.000128	0.000000
D	WEST	0.005736	0.010701	0.011557	0.002654	0.000000	0.000000
D	WEST-NORTHWEST	0.003253	0.009716	0.011000	0.001926	0.000000	0.000000
D	NORTHWEST	0.003210	0.008389	0.007833	0.001584	0.000128	0.000000
D	NORTH-NORTHWEST	0.002739	0.008475	0.005693	0.001541	0.000086	0.000000
E	NORTH	0.003125	0.005051	0.001284	0.000128	0.000000	0.000000
E	NORTH-NORTHEAST	0.002440	0.003852	0.001113	0.000300	0.000000	0.000000
E	NORTHEAST	0.002739	0.004366	0.000685	0.000043	0.000000	0.000000
E	EAST-NORTHEAST	0.007704	0.011386	0.002611	0.000000	0.000000	0.000000
E	EAST	0.007448	0.003424	0.000342	0.000000	0.000000	0.000000
E	EAST-SOUTHEAST	0.003981	0.001541	0.000214	0.000000	0.000000	0.000000
E	SOUTHEAST	0.004109	0.001969	0.000342	0.000000	0.000000	0.000000
E	SOUTH-SOUTHEAST	0.005436	0.003424	0.001327	0.000214	0.000000	0.000000
E	SOUTH	0.005222	0.005821	0.004152	0.001070	0.000000	0.000000
E	SOUTH-SOUTHWEST	0.009245	0.012841	0.008946	0.002440	0.000043	0.000000
E	SOUTHWEST	0.014639	0.021230	0.009716	0.001070	0.000043	0.000000
E	WEST-SOUTHWEST	0.016222	0.013226	0.004580	0.000984	0.000000	0.000000
E	WEST	0.011514	0.013055	0.005907	0.000257	0.000000	0.000000
E	WEST-NORTHWEST	0.008218	0.008518	0.004451	0.000942	0.000000	0.000000
E	NORTHWEST	0.007234	0.005436	0.002097	0.000300	0.000000	0.000000
E	NORTH-NORTHWEST	0.005094	0.004409	0.001198	0.000342	0.000000	0.000000
F	NORTH	0.001455	0.000086	0.000000	0.000000	0.000043	0.000000
F	NORTH-NORTHEAST	0.001455	0.000086	0.000043	0.000000	0.000000	0.000000
F	NORTHEAST	0.002012	0.000128	0.000000	0.000000	0.000000	0.000000
F	EAST-NORTHEAST	0.004280	0.001584	0.000043	0.000000	0.000000	0.000000
F	EAST	0.006206	0.000856	0.000000	0.000000	0.000000	0.000000
F	EAST-SOUTHEAST	0.004451	0.000043	0.000000	0.000000	0.000000	0.000000
F	SOUTHEAST	0.003467	0.000257	0.000000	0.000000	0.000000	0.000000
F	SOUTH-SOUTHEAST	0.002953	0.000171	0.000000	0.000000	0.000000	0.000000
F	SOUTH	0.003767	0.000300	0.000043	0.000000	0.000000	0.000000
F	SOUTH-SOUTHWEST	0.006506	0.001113	0.000000	0.000043	0.000000	0.000000
F	SOUTHWEST	0.011557	0.002739	0.000000	0.000000	0.000000	0.000000
F	WEST-SOUTHWEST	0.016393	0.003125	0.000128	0.000000	0.000000	0.000000
F	WEST	0.015537	0.001113	0.000043	0.000000	0.000000	0.000000
F	WEST-NORTHWEST	0.012627	0.000300	0.000043	0.000000	0.000000	0.000000
F	NORTHWEST	0.008004	0.000257	0.000043	0.000000	0.000000	0.000000
F	NORTH-NORTHWEST	0.003681	0.000899	0.000000	0.000000	0.000000	0.000000
G	NORTH	0.003381	0.000043	0.000000	0.000000	0.000000	0.000086
G	NORTH-NORTHEAST	0.003510	0.000000	0.000000	0.000000	0.000000	0.000000
G	NORTHEAST	0.002953	0.000043	0.000000	0.000000	0.000000	0.000000
G	EAST-NORTHEAST	0.003895	0.000257	0.000000	0.000000	0.000000	0.000000
G	EAST	0.006763	0.000342	0.000000	0.000000	0.000000	0.000000
G	EAST-SOUTHEAST	0.005607	0.000000	0.000000	0.000000	0.000043	0.000000
G	SOUTHEAST	0.002911	0.000000	0.000000	0.000000	0.000000	0.000000
G	SOUTH-SOUTHEAST	0.002483	0.000000	0.000000	0.000000	0.000000	0.000000
G	SOUTH	0.003809	0.000000	0.000000	0.000000	0.000000	0.000000
G	SOUTH-SOUTHWEST	0.006420	0.000086	0.000043	0.000000	0.000000	0.000000
G	SOUTHWEST	0.012541	0.000086	0.000000	0.000000	0.000000	0.000000
G	WEST-SOUTHWEST	0.016179	0.000214	0.000000	0.000000	0.000000	0.000000
G	WEST	0.020802	0.000043	0.000000	0.000000	0.000000	0.000000
G	WEST-NORTHWEST	0.020545	0.000086	0.000000	0.000000	0.000000	0.000000
G	NORTHWEST	0.013954	0.000342	0.000000	0.000000	0.000000	0.000000
G	NORTH-NORTHWEST	0.006977	0.000171	0.000000	0.000000	0.000000	0.000000

Table 4.1. Surface Water Environmental Data for the Fernald Environmental Managment Project

<u>Parameter</u>	<u>Units</u>	<u>Paddy's Run</u>	<u>Sawmill Creek</u>
Velocity	m/s	0.049	1.03
Depth	m	0.305	2.44
Width	m	7.62	38.1
Discharge	cms	0.114	96.6

Table 4.2. Hydrogeologic Environmental Setting Data for Fernald Environmental Management Project's PRA Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ1</u>	<u>PZ2</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.20	0.20	--
SOILC		5.39	4.38	4.38
Thickness	m	0.914	1.22	45.41
Bulk_density	g/cm3	1.35	1.7	1.7
Total_porosity	%	50	41.7	41.7
Field_capacity	%	40	4.54	--
Conductivity	m/day	0.01	13.7	--
Longitudinal_disp.	m	0.01	0.01	30.5
Transverse_disp.	m	--	--	3.05
Vertical_disp.	m	--	--	3.05
Effective_porosity	%	--	--	25.0
Velocity	m/day	--	--	0.49
Distance	m	--	--	305
Textural_class		loam	loamy sand	loamy sand
%_sand	%	33	77	77
%_silt	%	43	20	20
%_clay	%	24	3	3
%_OMC	%	0.46	0.39	0.39
%_Fe	%	0.13	0.13	0.05
pH		7.4	7.4	7.4

Table 4.3. Hydrogeologic Environmental Setting Data for Fernald Environmental Management Project's SWPA Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.20	0.20	0.20	0.20	--
SOILC		5.3	4.38	5.39	4.38	4.38
Thickness	m	3.96	2.13	3.96	7.92	45.1
Bulk_density	g/cm3	1.42	1.49	1.42	1.7	1.7
Total_porosity	%	46.3	43.7	47.5	41.7	41.7
Field_capacity	%	27.5	12	37.8	4.54	--
Conductivity	m/day	1.71	97.54	0.001	13.7	--
Longitudinal_disp.	m	0.61	0.31	0.61	1.52	30.5
Transverse_disp.	m	--	--	--	--	3.05
Vertical_disp.	m	--	--	--	--	3.05
Effective_porosity	%	--	--	--	--	25.0
Velocity	m/day	--	--	--	--	0.49
Distance	m	--	--	--	--	305
Textural_class		silt loam	loamy sand	loam	loamy sand	loamy sand
%_sand	%	11	75	33	77	77
%_silt	%	63	20	43	20	20
%_clay	%	26	5	24	3	3
%_OMC	%	0.58	0	0	0.39	0.39
%_Fe	%	0.07	0	2	0.13	0.05
pH		7	7	7.8	7.4	7.4

Table 4.4. Hydrogeologic Environmental Setting Data for Fernald Environmental Management Project's ENE Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.20	0.20	0.20	0.20	--
SOILC		5.39	5.39	5.39	4.38	4.38
Thickness	m	1.07	3.05	7.62	10.7	44.8
Bulk_density	g/cm3	1.42	1.35	1.42	1.7	1.7
Total_porosity	%	46.6	50	47.5	41.7	41.7
Field_capacity	%	23.5	40	37.8	4.54	--
Conductivity	m/day	4.57	0.01	0.001	13.7	--
Longitudinal_disp.	m	0.15	0.31	0.91	1.52	30.5
Transverse_disp.	m	--	--	--	--	3.05
Vertical_disp.	m	--	--	--	--	3.05
Effective_porosity	%	--	--	--	--	25.0
Velocity	m/day	--	--	--	--	0.49
Distance	m	--	--	--	--	305
Textural_class		loam	loam	loam	loamy sand	loamy sand
%_sand	%	40	33	33	77	77
%_silt	%	39	43	43	20	20
%_clay	%	21	24	24	3	3
%_OMC	%	0	0.46	0	0.39	0.39
%_Fe	%	0.05	0.13	2	0.13	0.05
pH		7	7.4	7.8	7.4	7.4

5.0 HANFORD SITE

The Hanford Site was acquired by the federal government in 1943. Initially it was dedicated to producing plutonium for national defense and managing the resulting wastes. In later years, programs at the Hanford Site were diversified to include research and development for advanced reactors, renewable energy technologies, waste disposal technologies, and cleanup of contamination from past practices. The Site's current mission involves waste management, environmental restoration, scientific research, and technology development (Woodruff et al. 1993).

The Hanford Site covers an area of 1450 km² (560 mi²) in south-central Washington State (Figure 5.1) and lies north of the confluences of the Columbia River with the Snake and Yakima Rivers. Except for residential and some industrial development to the south of the Hanford Site, lands surrounding the Site are primarily devoted to agriculture or are undeveloped. Ecologically, the Hanford Site represents a large, relatively undisturbed area of shrub-steppe ecosystem that contains numerous plant and animal species (Cushing 1992). The Columbia River forms the major natural aquatic habitat on the Hanford Site. Other natural aquatic habitats are associated with small spring-streams and seeps primarily located on the Fitzer/Eberhardt Arid Lands Ecology Reserve in the southwestern portion of the Site (Woodruff et al. 1993).

5.1 CLIMATE

The Hanford Site has a "mid-latitude semiarid" climate (Critchfield 1974). Meteorological data are available from onsite measurements at the Hanford Meteorology Station (located between the 200 West and East areas near the center of the site) and other onsite monitoring locations (Glantz and Islam 1988). On average, the maximum daily temperature exceeds 32°C (90°F) on 55 days per year and is below 0°C (32°F) on 24 days per year; the minimum daily temperature is below 0°C (32°F) on 115 days per year and is below -18°C (0°F) on 4 days per year (Stone et al. 1983). July is the warmest month, with daily maximum and minimum temperatures averaging 33°C (92°F) and 16°C (61°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 3°C (37°F) and -6°C (22°F), respectively (Stone et al. 1983).

Annual precipitation is on the order of 16 cm (6 in.), with over 40% falling during November, December, and January (Stone et al. 1983). The relatively low precipitation total is largely because of the rain shadow created by the Cascade Range, which lies between the Hanford Site and the Pacific Ocean. Measurable precipitation (defined as 0.01 in. or greater) is recorded on an average of 68 days per year and the area experiences an average of 10 thunderstorm days per year. Daily snowfall accumulations of 2.5 cm (1 in.) or greater occur

an average of 6 days per year (Stone et al. 1983); the average annual snowfall is 34 cm (13 in.).

Winds at the Hanford Site are strongly influenced by their proximity to local terrain features. The prevailing wind direction in the 200 Areas is from the west-northwest. In the southeastern portion of the site (300 and 400 Areas), the prevailing wind direction is generally from the southwest (Glantz et al. 1990). Wind speeds in the vicinity of the 200 Areas average about 3.4 m/s (7.7 mph) at about 15 m (50 ft) above ground level. Average wind speeds are highest in June (4 m/s [9 mph]) and lowest in November and December (3 m/s [6 mph]) (Stone et al. 1983).

5.2 GEOLOGY

The Hanford Site is located within the Pasco Basin, a structural and topographic depression on the Columbia Plateau underlain by the Miocene Columbia River Basalt Group and associated sedimentary interbeds. After cessation of the basalt eruptions, thick fluvial and lacustrine deposits of the Miocene-Pliocene aged Ringold Formation formed (Lindsey et al. 1991). Within the Pasco Basin, the Ringold Formation accumulated to a total thickness of up to 365 m (1200 ft) (Tallman et al. 1979).

During the late Pliocene to early Pleistocene, a period of regional erosion was followed by soil development and deposition of wind-blown sediments. These deposits are referred to as the Plio-Pleistocene Unit and the early "Palouse" soil, respectively (Bjornstad 1985; Thorne and Chamness 1992). These units are absent in the eastern portion of the Pasco Basin and have only been reported in the vicinity of the 200 West Area of the Hanford Site.

The Hanford formation was deposited during the Pleistocene by cataclysmic glacial-outburst floods. These floods inundated the Pasco Basin a number of times during the Pleistocene (Baker et al. 1991). As the flood waters gradually drained, deposition locally followed by erosion occurred. In general, fine-grained sediments occur near the margins of the basin and coarse-grained sediments are found in the central part where the flood currents were stronger. The coarser sand and gravel deposits are referred to as the coarse-grained facies, and the finer sand and silt units are referred to as slackwater facies (Baker et al. 1991).

Recent eolian and alluvial deposits overlie the Hanford formation. These deposits are primarily reworked Hanford formation sediments. The thickness of the eolian sediments varies from zero to more than 9 m (30 ft) in some sand dunes (Tallman et al. 1979).

5.3 HYDROLOGY

The uppermost unconfined aquifer at the Hanford Site occurs primarily within the Hanford formation and Ringold Formation sediments. The hydraulic conductivity in the Ringold Formation is often more than an order of magnitude lower than in the Hanford formation (Thorne and Chamness 1992). Before waste-water disposal began at the Hanford Site, the unconfined aquifer was almost entirely within the less transmissive Ringold Formation sediments (Thorne and Newcomer 1992). However, waste-water disposal operations in the 200 East and 200 West Areas have created groundwater mounds at these locations, and the water table is now in the more transmissive Hanford formation over much of the eastern portion of the Hanford Site (Thorne and Newcomer 1992). Due to the shutdown of Hanford Site production facilities, the water table is declining. This decline in the water table should continue until new equilibrium conditions are reached (Newcomer et al. 1992).

The Columbia River is the only significant surface water at the Hanford Site. The Hanford Reach is the portion of the river that extends from the Priest Rapids Dam upstream of the Hanford Site to the head of Lake Wallula downstream of the Hanford Site. The width of the river varies from approximately 300 m (980 ft) to 1000 m (3300 ft) within the Hanford Site (Woodruff et al. 1993). Maximum river depths are reported to range from 3 m (10 ft) to 12 m (40 ft) within the Hanford Reach, with typical maximum depths of approximately 8 m (25 ft). The velocity of the river current within the Hanford Reach varies from less than 0.9 m/s (3 ft/s) to greater than 3.4 m/s (11 ft/s) with an average annual discharge of 3400 m³/s (120,000 ft³/s).

Another surface-water feature in the vicinity of the Hanford Site is the Yakima River. This river approaches the southwestern boundary of the Hanford Site and discharges into the Columbia River about 12 km (7 mi) south of the installation. Within the Hanford Site, several ponds and ditches are associated with installation operations. The primary sources of natural recharge at the Hanford Site are several small ephemeral streams, including Cold Creek and Dry Creek, which drain areas to the west of the Hanford Site. Surface flow in these streams disappears into the surface sediments in the western part of the Site (Schalla et al. 1988). Small amounts of local recharge to the water table may occur, depending upon surface conditions and time of year. However, most precipitation at the Hanford Site is returned to the atmosphere through evapotranspiration. Artificial recharge to the unconfined aquifer at the Hanford Site occurs from liquid-waste disposal operations, mostly in the 200 East and 200 West Areas. Groundwater on the site generally moves from the recharge areas on the western portion of the site to the north and east, discharging to the Columbia River.

5.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and two joint frequency distribution exhibits are sufficient to address the climate and atmospheric dispersion characteristics of the Hanford Site for PEIS

modeling purposes. Meteorological data for the installation are summarized in Exhibit 5.1. Atmospheric dispersion data in the form of two joint frequency distributions of wind direction, wind speed, and atmospheric stability are summarized in Exhibits 5.2 and 5.3. The data in Exhibit 5.2 are characteristic of most of the site; data in Exhibit 5.3 are characteristic of the southeastern portion of the site, including the 300 and 400 Areas.

For PEIS modeling purposes, the Hanford Site is characterized using seven hydrogeologic environmental settings (Figure 5.1): the 200 East, 200 West, 100-N, 100-H, 300 Area, Southwest Region, and North of the Columbia River setting. Figure 5.2 presents stratigraphic columns for each of these settings. Important criteria used to establish the separate settings included the hydrogeologic characteristics of the Hanford formation, the location of the water table (either in the Ringold Formation or the Hanford formation), and the number of distinct hydrogeologic units that had been described at the various locations at the Hanford Site. The hydrogeologic input parameters selected for each setting are representative of the areas where the most significant waste sites occur within the setting. A brief description of the hydrogeology and a list of the hydrogeologic input parameters for each setting follows. Surface water data are presented in Table 5.1. Hydrogeologic data for the various settings are presented in Tables 5.2-5.8.

5.4.1 200 East Setting

The water table in the 200 East Area is contained within a number of hydrostratigraphic units (Connelly et al. 1992a). As a necessary simplification, the water table was placed at the contact between the Hanford coarse-grained facies and the Ringold Formation, which is true for the central and southern portion of the 200 East Area (Connelly et al. 1992a). Above the water table, the Hanford formation sediments were divided into three distinct partially-saturated zones: the Upper Hanford gravels, the Sandy Sequence, and the Lower Hanford gravels. The suggested thicknesses of these partially-saturated zones are 10 m (33 ft), 50 m (165 ft), and 19 m (62 ft), respectively (Connelly et al. 1992a).

The unconfined aquifer occurs primarily in the Ringold Formation sediments. The thickness of the unconfined aquifer in the 200 East Area has been reported to be up to 38 m (125 ft). However, a saturated zone thickness of 9 m (30 ft) was selected, which is the generally accepted thickness for the contaminated portion of the unconfined aquifer at the Hanford Site.

5.4.2 200 West Setting

The water table in the 200 West Area occurs in the Ringold Formation (Connelly et al. 1992b). Reported hydrostratigraphic units above the water table include 1) eolian deposits, 2) Hanford formation coarse-grained facies, 3) Hanford formation slackwater facies, 4) early "Palouse" soil, 5) the Plio-Pleistocene Unit, 6) the Upper Ringold, and 7) the unsaturated portion of the Ringold Unit "E." The five partially-saturated zones selected to represent this

environmental setting are 1) Hanford formation coarse-grained facies, 2) Hanford formation slackwater facies, 3) Plio-Pleistocene Unit, 4) Upper Ringold Formation, and 5) Ringold Unit "E.". The surficial eolian deposits were not included because of a lack of data for these deposits and their variable thickness. Because of the possibility that some of the early "Palouse" soil samples may have been misidentified, the Touchet Beds and early "Palouse" soil units were combined into a single layer. The upper Ringold unit is not continuous throughout the 200 West Area. However, this unit was included as a layer in the partially-saturated zone because it has a significant effect on infiltration in the 200 West Area.

In the 200 West Area, the unconfined aquifer occurs in the Ringold Gravel Unit E, except in the northwest part of the setting, where the aquifer also occurs in Gravel Unit A (Connelly et al. 1992b). The reported thickness of the unconfined aquifer is up to 84 m (274 ft) in the 200 West Area. However, the contaminated portion of the aquifer is generally accepted to be about 9 m (30 ft), so this thickness was selected for the saturated zone.

5.4.3 100-N Setting

In the 100-N setting, the water table is in the Ringold Formation (Gilmore et al. 1990). The partially-saturated zone consists of the Hanford formation coarse-grained facies and the unsaturated portion of the Ringold Formation. Measured values for the saturated hydraulic conductivity and porewater pH were not available for the Hanford formation in this area, so data from the Hanford formation in the 300 Area and 200 East Area, respectively, were used in developing input parameters for this setting. Similarly, the saturated hydraulic conductivity value for the Ringold Unit "E" in the 200 West Area was used to represent the Ringold Formation for the 100-N setting.

5.4.4 100-H Setting

In the 100-H setting, the Hanford formation consists of the coarse-grained facies. The water table in this setting is generally in the lower portion of the Hanford formation (Lindsey 1992). Therefore, a single partially-saturated zone was selected for this setting. Measured data for the saturated hydraulic conductivity in the partially-saturated zone were unavailable, so the representative measured value for the coarse-grained facies in the 300 Area was selected for the coarse-grained facies in the 100-H Area.

Because of higher transmissivities in the coarse-grained relative to the less permeable Ringold Formation, it is likely that most contaminant transport in this setting occurs in the saturated portion of the Hanford formation. Therefore, the input parameters for the saturated zone were based on the properties of the coarse-grained facies of the Hanford formation. The thickness of the saturated zone used for this setting is based on measurements of the average thickness of the saturated zone that contains contamination in the 100-H Area (Peterson and Connelly 1992).

5.4.5 300 Area Setting

The Hanford formation in the 300 Area setting consists of the coarse-grained facies. The water table in this setting is generally in the Hanford formation (Schalla et al. 1988), so a single partially-saturated zone was selected. Because transmissivities are higher in the Hanford formation than in the Ringold Formation, contaminant transport should preferentially occur in the Hanford formation sediments. Therefore, the parameters used to represent the saturated zone were based on the properties of the coarse-grained facies of the Hanford formation. Although the 100-H and 300 Area settings have many similarities, separate sets of input parameters were developed for these areas because of higher porewater velocities in the 300 Area setting.

5.4.6 Southwest Region Setting

Although few hydrogeologic data are available in published form for the Southwest Region setting, a separate environmental setting was developed for this portion of the Hanford Site because of differences in its hydrogeology relative to the other settings. The Hanford formation in this setting consists of sediments similar to the fine-grained Hanford formation sediments observed in the 200 West Area. The thickness of this layer was obtained from two borehole measurements. The characteristics of the Ringold Formation in the Southwest Region setting were assumed to be those of the Ringold Formation in the adjacent 200 West Area. The thickness of the partially-saturated zone was calculated by subtracting the thickness of the Hanford formation sediments from the total depth to water (Newcomer et al. 1992). The saturated zone properties in the Southwest Region setting were assumed to be the same as the those in the 200 West Area setting. Although there are relatively greater uncertainties associated with the hydrogeologic characterization of the Southwest Region setting in comparison to other Hanford Site environmental settings, these assumptions are expected to have little impact on risk assessment for the Hanford Site because of the limited amounts of contamination in this setting.

5.4.7 North of the Columbia River Setting

Limited data are available for the portion of the Hanford Site that lies north of the Columbia River. The sediments in this setting consist of mostly fined-grained sediments, and most of the environmental setting data used for this setting are based on the MEPAS default input parameters for this sediment type. The thickness of the partially-saturated zone was based on water-level measurements in wells across the Columbia River from the 100-F Area (Newcomer et al. 1992).

The thickness of the saturated zone was arbitrarily assumed to be the same as the generally accepted thickness of the contaminated portion of the unconfined aquifer on the Hanford Site that lies south and west of the Columbia River. The porewater velocity in the saturated zone was calculated from water-level data from the wells across the river from the

100-F Area and default parameters for saturated hydraulic conductivity and effective porosity for silt (Droppo et al. 1989). As in the Southwest setting, the assumptions and approximations used to develop the hydrogeologic characterization in this setting are expected to have a minimal impact on risk assessment because of the limited amounts of contamination that are present.

5.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for Hanford are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. The climate and atmospheric dispersion environmental settings were developed by Clifford Glantz, Marc Schwartz, and Larry Berg. The environmental settings were developed by Janet Schramke with information and technical review supplied by Michael Fayer, Paul Thorne, Kevin Lindsey, and Robert Peterson. Roger Dirkes provided the data for the surface water environmental setting. Additional assistance in data collection for was provided by John Buck, Melvin Campbell, Michele Chamness, Evan Dresel, Tyler Gilmore, Shannon Goodwin, Stuart Luttrell, Darrell Newcomer, Frank Spane, and Michael Connelly.

5.6 REFERENCES

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Figure 5.1. Location and Environmental Settings for the Hanford Site. For PEIS modeling purposes, the Hanford Site is divided into seven environmental settings: North of the Columbia River, 100-N, 100-H, 200 West, 200 East, 300 Area, and Southwest Regions.

Figure 5.2. Stratigraphic Columns for Hanford Site Environmental Settings

EXHIBIT 5.1

Hanford Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at the Hanford Meteorology Station.

Station Name: Hanford Meteorology Station, Hanford Site, Washington Elevation: 223 m Latitude: 46.57°N

Annual Mean Air Temp:	53.2 °F	Reference (A) Based on observations made from 1951-1980.
Anemometer Height:	15.2 m	Reference (A)
Mean Annual Wind Speed:	8 mph	Reference (A) Based on observations made from 1945-1980.
Fastest 1-Min Wind Speed:	80 mph	Reference (A) Based on observations made from 1945-1980. The value presented is the "peak gust", fastest-mile-of-wind is not measured.
Annual Precipitation:	6.3 in.	Reference (A) Based on observations made from 1951-1980.
Precipitation Days:	68 yr ⁻¹	Reference (A) Based on observations made from 1946-1980.
Thunderstorms Freq:	10 yr ⁻¹	Reference (A) Based on observations made from 1945-1980.

Avg Morning Mixing Ht:	400 m	Reference (B)
Avg Afternoon Mixing Ht:	1400 m	Reference (B)
Top Soil Moisture Capacity:	1.1 cm	Reference (B)

MEPAS Parameters:	Climatic Region Index:	2	Reference (B)
	Precipitation-Evaporation Index:	25	Reference (B)
	Soil Cons. Serv. Curve Number:	39	Reference (B)

MONTH	MONTHLY AVERAGES						
	TEMP. (°F)	PRECIP. (Inches)	WIND SPEED (MPH)	CLOUD COVER (10ths)	PRECIP. DAYS (#)	DAILY RH	
						MAX (%)	MIN (%)
Jan	30	1.0	6.4	7.9	9	82	65
Feb	38	0.6	7.1	7.6	7	80	58
Mar	44	0.4	8.5	6.8	6	70	40
Apr	52	0.4	9.0	6.4	5	62	32
May	61	0.5	8.9	5.9	5	60	30
Jun	69	0.5	9.2	5.3	5	55	28
Jul	77	0.2	8.7	2.9	2	47	21
Aug	75	0.3	8.0	3.4	3	50	23
Sep	66	0.3	7.5	4.1	3	58	28
Oct	53	0.5	6.6	5.8	5	72	40
Nov	40	0.8	6.1	7.7	8	80	62
Dec	33	1.0	6.1	8.1	10	83	71
	↓	↓	↓	↓	↓	↓	↓
Reference: ...	(A)	(A)	(A)	(A)	(A)	(A)	(A)

References

- A: Stone, W.A., J.M. Thorp, O.P. Gifford, and D.J. Hoitink. 1983. Climatological Summary for the Hanford Area. PNL-4622, Pacific Northwest Laboratory, Richland, Washington.
- B: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 5.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed at the Hanford Site's 300 Area Station. The 300 Area Station is located near the southwestern boundary of the Hanford Site. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made on-site at 10 m (33 ft) above ground level. Data are based on measurements made from 1982 through 1989.

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
A	NORTH	0.00000	0.00005	0.00004	0.00003	0.00002	0.00000
A	NORTH-NORTHEAST	0.00000	0.00022	0.00037	0.00008	0.00000	0.00000
A	NORTHEAST	0.00000	0.00025	0.00064	0.00002	0.00000	0.00000
A	EAST-NORTHEAST	0.00001	0.00060	0.00049	0.00000	0.00000	0.00000
A	EAST	0.00002	0.00090	0.00051	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00001	0.00084	0.00089	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00000	0.00029	0.00081	0.00004	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00002	0.00021	0.00040	0.00003	0.00000	0.00000
A	SOUTH	0.00001	0.00013	0.00050	0.00008	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00001	0.00033	0.00077	0.00038	0.00012	0.00000
A	SOUTHWEST	0.00000	0.00006	0.00062	0.00038	0.00011	0.00004
A	WEST-SOUTHWEST	0.00000	0.00010	0.00030	0.00030	0.00011	0.00000
A	WEST	0.00001	0.00007	0.00003	0.00003	0.00001	0.00001
A	WEST-NORTHWEST	0.00001	0.00003	0.00004	0.00002	0.00000	0.00001
A	NORTHWEST	0.00000	0.00002	0.00003	0.00002	0.00006	0.00000
A	NORTH-NORTHWEST	0.00000	0.00002	0.00008	0.00004	0.00000	0.00000
B	NORTH	0.00082	0.00377	0.00330	0.00117	0.00009	0.00002
B	NORTH-NORTHEAST	0.00062	0.00380	0.00529	0.00167	0.00012	0.00003
B	NORTHEAST	0.00054	0.00408	0.00486	0.00056	0.00005	0.00000
B	EAST-NORTHEAST	0.00090	0.00495	0.00127	0.00009	0.00002	0.00000
B	EAST	0.00073	0.00589	0.00225	0.00006	0.00000	0.00000
B	EAST-SOUTHEAST	0.00096	0.00621	0.00368	0.00010	0.00000	0.00000
B	SOUTHEAST	0.00092	0.00866	0.00503	0.00029	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00139	0.00608	0.00304	0.00021	0.00001	0.00000
B	SOUTH	0.00099	0.00383	0.00270	0.00057	0.00009	0.00000
B	SOUTH-SOUTHWEST	0.00102	0.00357	0.00613	0.00360	0.00068	0.00012
B	SOUTHWEST	0.00092	0.00297	0.00702	0.00532	0.00113	0.00046
B	WEST-SOUTHWEST	0.00077	0.00180	0.00295	0.00287	0.00080	0.00026
B	WEST	0.00059	0.00111	0.00069	0.00054	0.00022	0.00018
B	WEST-NORTHWEST	0.00063	0.00122	0.00051	0.00032	0.00004	0.00001
B	NORTHWEST	0.00084	0.00184	0.00075	0.00056	0.00015	0.00004
B	NORTH-NORTHWEST	0.00103	0.00370	0.00204	0.00045	0.00014	0.00000
C	NORTH	0.00076	0.00495	0.00457	0.00161	0.00011	0.00003
C	NORTH-NORTHEAST	0.00061	0.00348	0.00467	0.00131	0.00021	0.00003
C	NORTHEAST	0.00036	0.00250	0.00209	0.00031	0.00003	0.00000
C	EAST-NORTHEAST	0.00052	0.00209	0.00077	0.00007	0.00000	0.00000
C	EAST	0.00060	0.00323	0.00094	0.00008	0.00000	0.00000
C	EAST-SOUTHEAST	0.00074	0.00495	0.00237	0.00013	0.00002	0.00000
C	SOUTHEAST	0.00103	0.00820	0.00360	0.00034	0.00002	0.00000

EXHIBIT 5.2 (continued)

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
C	SOUTH-SOUTHEAST	0.00132	0.00574	0.00190	0.00016	0.00003	0.00000
C	SOUTH	0.00099	0.00384	0.00270	0.00065	0.00011	0.00000
C	SOUTH-SOUTHWEST	0.00132	0.00314	0.00606	0.00308	0.00060	0.00013
C	SOUTHWEST	0.00146	0.00255	0.00602	0.00541	0.00138	0.00058
C	WEST-SOUTHWEST	0.00128	0.00187	0.00316	0.00306	0.00068	0.00022
C	WEST	0.00108	0.00106	0.00112	0.00070	0.00027	0.00011
C	WEST-NORTHWEST	0.00093	0.00126	0.00053	0.00017	0.00010	0.00002
C	NORTHWEST	0.00107	0.00247	0.00149	0.00062	0.00025	0.00008
C	NORTH-NORTHWEST	0.00118	0.00547	0.00411	0.00099	0.00028	0.00000
D	NORTH	0.00096	0.00649	0.01164	0.00277	0.00048	0.00004
D	NORTH-NORTHEAST	0.00068	0.00343	0.00499	0.00195	0.00093	0.00029
D	NORTHEAST	0.00057	0.00196	0.00139	0.00072	0.00037	0.00027
D	EAST-NORTHEAST	0.00055	0.00203	0.00093	0.00030	0.00003	0.00006
D	EAST	0.00071	0.00336	0.00187	0.00020	0.00003	0.00000
D	EAST-SOUTHEAST	0.00086	0.00794	0.00477	0.00031	0.00003	0.00000
D	SOUTHEAST	0.00128	0.01397	0.00692	0.00055	0.00004	0.00000
D	SOUTH-SOUTHEAST	0.00183	0.01044	0.00356	0.00059	0.00006	0.00000
D	SOUTH	0.00152	0.00857	0.00574	0.00154	0.00026	0.00003
D	SOUTH-SOUTHWEST	0.00186	0.00670	0.01012	0.00692	0.00230	0.00077
D	SOUTHWEST	0.00214	0.00571	0.01143	0.01032	0.00574	0.00384
D	WEST-SOUTHWEST	0.00165	0.00436	0.00669	0.00685	0.00266	0.00088
D	WEST	0.00170	0.00385	0.00279	0.00196	0.00111	0.00030
D	WEST-NORTHWEST	0.00168	0.00391	0.00237	0.00143	0.00028	0.00002
D	NORTHWEST	0.00148	0.00563	0.00471	0.00454	0.00204	0.00044
D	NORTH-NORTHWEST	0.00139	0.00799	0.00931	0.00481	0.00106	0.00008
E	NORTH	0.00087	0.00556	0.00946	0.00158	0.00006	0.00000
E	NORTH-NORTHEAST	0.00047	0.00175	0.00286	0.00064	0.00008	0.00000
E	NORTHEAST	0.00047	0.00060	0.00045	0.00024	0.00010	0.00000
E	EAST-NORTHEAST	0.00032	0.00048	0.00030	0.00022	0.00003	0.00000
E	EAST	0.00056	0.00131	0.00056	0.00007	0.00000	0.00000
E	EAST-SOUTHEAST	0.00088	0.00494	0.00323	0.00007	0.00000	0.00000
E	SOUTHEAST	0.00116	0.00987	0.00416	0.00027	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00146	0.00804	0.00151	0.00022	0.00001	0.00000
E	SOUTH	0.00199	0.00632	0.00306	0.00058	0.00002	0.00000
E	SOUTH-SOUTHWEST	0.00148	0.00478	0.00414	0.00182	0.00043	0.00019
E	SOUTHWEST	0.00196	0.00404	0.00459	0.00307	0.00120	0.00054
E	WEST-SOUTHWEST	0.00201	0.00296	0.00285	0.00166	0.00036	0.00011
E	WEST	0.00159	0.00267	0.00107	0.00052	0.00008	0.00007
E	WEST-NORTHWEST	0.00155	0.00331	0.00070	0.00028	0.00002	0.00002
E	NORTHWEST	0.00142	0.00595	0.00261	0.00163	0.00047	0.00008
E	NORTH-NORTHWEST	0.00142	0.00757	0.00768	0.00194	0.00013	0.00002
F	NORTH	0.00104	0.00645	0.00693	0.00088	0.00007	0.00000
F	NORTH-NORTHEAST	0.00072	0.00199	0.00224	0.00040	0.00006	0.00000
F	NORTHEAST	0.00051	0.00076	0.00024	0.00010	0.00002	0.00000
F	EAST-NORTHEAST	0.00062	0.00061	0.00024	0.00012	0.00002	0.00000
F	EAST	0.00076	0.00183	0.00053	0.00007	0.00002	0.00000
F	EAST-SOUTHEAST	0.00130	0.00642	0.00334	0.00006	0.00000	0.00000

EXHIBIT 5.2 (continued)

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
F	SOUTHEAST	0.00146	0.01235	0.00529	0.00013	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00146	0.00868	0.00171	0.00021	0.00002	0.00000
F	SOUTH	0.00166	0.00690	0.00274	0.00033	0.00004	0.00001
F	SOUTH-SOUTHWEST	0.00201	0.00441	0.00434	0.00165	0.00035	0.00010
F	SOUTHWEST	0.00249	0.00362	0.00339	0.00288	0.00086	0.00067
F	WEST-SOUTHWEST	0.00177	0.00312	0.00223	0.00113	0.00019	0.00016
F	WEST	0.00201	0.00261	0.00086	0.00043	0.00008	0.00001
F	WEST-NORTHWEST	0.00214	0.00383	0.00065	0.00013	0.00000	0.00002
F	NORTHWEST	0.00192	0.00738	0.00259	0.00083	0.00028	0.00024
F	NORTH-NORTHWEST	0.00183	0.01053	0.00646	0.00122	0.00019	0.00005
G	NORTH	0.00061	0.00386	0.00290	0.00033	0.00000	0.00002
G	NORTH-NORTHEAST	0.00036	0.00126	0.00116	0.00014	0.00000	0.00000
G	NORTHEAST	0.00034	0.00035	0.00003	0.00010	0.00004	0.00000
G	EAST-NORTHEAST	0.00020	0.00037	0.00008	0.00007	0.00003	0.00000
G	EAST	0.00035	0.00096	0.00031	0.00000	0.00002	0.00000
G	EAST-SOUTHEAST	0.00089	0.00434	0.00183	0.00003	0.00000	0.00000
G	SOUTHEAST	0.00075	0.00719	0.00303	0.00002	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00105	0.00512	0.00113	0.00004	0.00000	0.00000
G	SOUTH	0.00110	0.00410	0.00195	0.00022	0.00000	0.00001
G	SOUTH-SOUTHWEST	0.00121	0.00353	0.00241	0.00093	0.00011	0.00006
G	SOUTHWEST	0.00191	0.00227	0.00180	0.00090	0.00050	0.00039
G	WEST-SOUTHWEST	0.00168	0.00217	0.00080	0.00063	0.00018	0.00008
G	WEST	0.00144	0.00191	0.00032	0.00020	0.00008	0.00000
G	WEST-NORTHWEST	0.00146	0.00258	0.00038	0.00007	0.00000	0.00000
G	NORTHWEST	0.00185	0.00411	0.00084	0.00035	0.00007	0.00000
G	NORTH-NORTHWEST	0.00145	0.00695	0.00301	0.00040	0.00010	0.00005

EXHIBIT 5.3

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed at the Hanford Meteorology Station. The station is located just outside the northeastern boundary of the 200 West Area. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made from 1982 through 1989.

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
A	NORTH	0.00017	0.00081	0.00015	0.00002	0.00000	0.00000
A	NORTH-NORTHEAST	0.00016	0.00064	0.00015	0.00000	0.00000	0.00000
A	NORTHEAST	0.00018	0.00060	0.00010	0.00003	0.00000	0.00000
A	EAST-NORTHEAST	0.00020	0.00057	0.00003	0.00003	0.00000	0.00000
A	EAST	0.00019	0.00046	0.00005	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00018	0.00059	0.00003	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00015	0.00071	0.00003	0.00002	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00009	0.00058	0.00007	0.00001	0.00000	0.00000
A	SOUTH	0.00014	0.00052	0.00005	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00013	0.00055	0.00010	0.00001	0.00000	0.00000
A	SOUTHWEST	0.00005	0.00047	0.00017	0.00018	0.00008	0.00001
A	WEST-SOUTHWEST	0.00003	0.00029	0.00028	0.00010	0.00003	0.00001
A	WEST	0.00006	0.00024	0.00011	0.00008	0.00000	0.00001
A	WEST-NORTHWEST	0.00008	0.00044	0.00010	0.00014	0.00001	0.00000
A	NORTHWEST	0.00022	0.00060	0.00018	0.00023	0.00006	0.00000
A	NORTH-NORTHWEST	0.00011	0.00071	0.00018	0.00005	0.00000	0.00000
B	NORTH	0.00390	0.00903	0.00203	0.00012	0.00000	0.00000
B	NORTH-NORTHEAST	0.00466	0.00726	0.00156	0.00040	0.00005	0.00001
B	NORTHEAST	0.00353	0.00584	0.00086	0.00023	0.00003	0.00001
B	EAST-NORTHEAST	0.00277	0.00412	0.00041	0.00008	0.00000	0.00000
B	EAST	0.00249	0.00418	0.00025	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00223	0.00479	0.00040	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00182	0.00421	0.00061	0.00005	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00134	0.00351	0.00061	0.00009	0.00001	0.00000
B	SOUTH	0.00131	0.00289	0.00059	0.00013	0.00003	0.00000
B	SOUTH-SOUTHWEST	0.00126	0.00241	0.00112	0.00055	0.00014	0.00001
B	SOUTHWEST	0.00129	0.00301	0.00227	0.00129	0.00053	0.00007
B	WEST-SOUTHWEST	0.00120	0.00290	0.00210	0.00166	0.00042	0.00019
B	WEST	0.00151	0.00301	0.00147	0.00078	0.00008	0.00006
B	WEST-NORTHWEST	0.00154	0.00453	0.00264	0.00107	0.00010	0.00000
B	NORTHWEST	0.00244	0.00863	0.00621	0.00199	0.00043	0.00007
B	NORTH-NORTHWEST	0.00315	0.01120	0.00322	0.00047	0.00003	0.00000
C	NORTH	0.00244	0.00632	0.00196	0.00024	0.00002	0.00000
C	NORTH-NORTHEAST	0.00239	0.00477	0.00204	0.00048	0.00015	0.00000
C	NORTHEAST	0.00237	0.00342	0.00090	0.00029	0.00005	0.00000
C	EAST-NORTHEAST	0.00195	0.00286	0.00054	0.00015	0.00004	0.00000
C	EAST	0.00156	0.00286	0.00036	0.00001	0.00000	0.00000
C	EAST-SOUTHEAST	0.00146	0.00312	0.00050	0.00000	0.00000	0.00000
C	SOUTHEAST	0.00162	0.00353	0.00086	0.00007	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00109	0.00258	0.00075	0.00015	0.00002	0.00000
C	SOUTH	0.00117	0.00235	0.00069	0.00025	0.00005	0.00001
C	SOUTH-SOUTHWEST	0.00105	0.00223	0.00152	0.00047	0.00015	0.00003
C	SOUTHWEST	0.00084	0.00290	0.00260	0.00150	0.00058	0.00010
C	WEST-SOUTHWEST	0.00111	0.00282	0.00353	0.00184	0.00036	0.00016
C	WEST	0.00117	0.00323	0.00243	0.00092	0.00004	0.00004
C	WEST-NORTHWEST	0.00162	0.00601	0.00527	0.00111	0.00022	0.00006
C	NORTHWEST	0.00200	0.00919	0.00917	0.00211	0.00069	0.00012
C	NORTH-NORTHWEST	0.00262	0.00805	0.00334	0.00057	0.00008	0.00000
D	NORTH	0.00126	0.00410	0.00182	0.00061	0.00020	0.00003
D	NORTH-NORTHEAST	0.00126	0.00317	0.00157	0.00130	0.00048	0.00009
D	NORTHEAST	0.00099	0.00240	0.00131	0.00086	0.00019	0.00000
D	EAST-NORTHEAST	0.00093	0.00272	0.00090	0.00032	0.00010	0.00000
D	EAST	0.00110	0.00336	0.00084	0.00005	0.00001	0.00000

EXHIBIT 5.3 (continued)

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
D	EAST-SOUTHEAST	0.00122	0.00393	0.00103	0.00005	0.00000	0.00000
D	SOUTHEAST	0.00114	0.00476	0.00258	0.00026	0.00000	0.00000
D	SOUTH-SOUTHEAST	0.00098	0.00345	0.00277	0.00103	0.00013	0.00001
D	SOUTH	0.00075	0.00322	0.00243	0.00134	0.00024	0.00009
D	SOUTH-SOUTHWEST	0.00085	0.00412	0.00339	0.00353	0.00150	0.00050
D	SOUTHWEST	0.00094	0.00539	0.00673	0.00736	0.00356	0.00090
D	WEST-SOUTHWEST	0.00103	0.00776	0.01176	0.00735	0.00193	0.00043
D	WEST	0.00121	0.00977	0.01242	0.00420	0.00059	0.00015
D	WEST-NORTHWEST	0.00103	0.01343	0.02264	0.01234	0.00278	0.00017
D	NORTHWEST	0.00120	0.01168	0.02047	0.01406	0.00526	0.00074
D	NORTH-NORTHWEST	0.00110	0.00691	0.00405	0.00138	0.00011	0.00000
E	NORTH	0.00064	0.00177	0.00060	0.00011	0.00002	0.00000
E	NORTH-NORTHEAST	0.00050	0.00112	0.00033	0.00021	0.00001	0.00000
E	NORTHEAST	0.00049	0.00085	0.00056	0.00012	0.00000	0.00000
E	EAST-NORTHEAST	0.00041	0.00095	0.00022	0.00006	0.00003	0.00000
E	EAST	0.00061	0.00120	0.00022	0.00001	0.00000	0.00000
E	EAST-SOUTHEAST	0.00088	0.00191	0.00041	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00078	0.00298	0.00161	0.00008	0.00004	0.00000
E	SOUTH-SOUTHEAST	0.00084	0.00272	0.00145	0.00014	0.00002	0.00000
E	SOUTH	0.00063	0.00237	0.00067	0.00026	0.00010	0.00000
E	SOUTH-SOUTHWEST	0.00077	0.00301	0.00140	0.00035	0.00012	0.00003
E	SOUTHWEST	0.00098	0.00454	0.00281	0.00117	0.00023	0.00006
E	WEST-SOUTHWEST	0.00081	0.00913	0.00668	0.00130	0.00015	0.00001
E	WEST	0.00093	0.01160	0.00836	0.00100	0.00007	0.00000
E	WEST-NORTHWEST	0.00110	0.01482	0.01635	0.00322	0.00056	0.00000
E	NORTHWEST	0.00101	0.01128	0.01240	0.00313	0.00072	0.00015
E	NORTH-NORTHWEST	0.00105	0.00480	0.00219	0.00030	0.00007	0.00000
F	NORTH	0.00222	0.00265	0.00032	0.00012	0.00001	0.00000
F	NORTH-NORTHEAST	0.00161	0.00191	0.00027	0.00010	0.00003	0.00000
F	NORTHEAST	0.00163	0.00136	0.00022	0.00008	0.00000	0.00000
F	EAST-NORTHEAST	0.00158	0.00141	0.00011	0.00000	0.00002	0.00000
F	EAST	0.00178	0.00201	0.00012	0.00001	0.00003	0.00000
F	EAST-SOUTHEAST	0.00251	0.00311	0.00024	0.00001	0.00000	0.00000
F	SOUTHEAST	0.00237	0.00405	0.00065	0.00005	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00181	0.00388	0.00088	0.00012	0.00002	0.00001
F	SOUTH	0.00214	0.00344	0.00054	0.00018	0.00008	0.00004
F	SOUTH-SOUTHWEST	0.00188	0.00387	0.00071	0.00036	0.00019	0.00005
F	SOUTHWEST	0.00207	0.00448	0.00131	0.00099	0.00024	0.00012
F	WEST-SOUTHWEST	0.00253	0.00939	0.00356	0.00078	0.00015	0.00003
F	WEST	0.00264	0.01265	0.00415	0.00048	0.00001	0.00000
F	WEST-NORTHWEST	0.00339	0.01481	0.00792	0.00188	0.00024	0.00000
F	NORTHWEST	0.00290	0.01212	0.00561	0.00198	0.00058	0.00004
F	NORTH-NORTHWEST	0.00265	0.00572	0.00112	0.00015	0.00002	0.00000
G	NORTH	0.00197	0.00141	0.00016	0.00001	0.00002	0.00000
G	NORTH-NORTHEAST	0.00159	0.00073	0.00006	0.00004	0.00002	0.00000
G	NORTHEAST	0.00143	0.00103	0.00002	0.00005	0.00001	0.00000
G	EAST-NORTHEAST	0.00133	0.00070	0.00003	0.00004	0.00000	0.00000
G	EAST	0.00154	0.00108	0.00004	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.00223	0.00196	0.00009	0.00000	0.00000	0.00000
G	SOUTHEAST	0.00268	0.00274	0.00025	0.00002	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00192	0.00220	0.00034	0.00003	0.00000	0.00000
G	SOUTH	0.00181	0.00192	0.00018	0.00004	0.00001	0.00002
G	SOUTH-SOUTHWEST	0.00167	0.00167	0.00033	0.00021	0.00011	0.00007
G	SOUTHWEST	0.00181	0.00297	0.00056	0.00053	0.00014	0.00002
G	WEST-SOUTHWEST	0.00234	0.00403	0.00140	0.00039	0.00008	0.00000
G	WEST	0.00232	0.00531	0.00160	0.00016	0.00000	0.00000
G	WEST-NORTHWEST	0.00328	0.00659	0.00313	0.00082	0.00010	0.00000
G	NORTHWEST	0.00305	0.00537	0.00247	0.00082	0.00010	0.00000
G	NORTH-NORTHWEST	0.00264	0.00290	0.00026	0.00006	0.00001	0.00000

Table 5.1. Surface Water Environmental Safety Data for the Hanford Site

<u>Parameter</u>	<u>Units</u>	<u>Columbia River</u>
Velocity	m/s	1.22
Depth	m	6.01
Width	m	457
Discharge	cms	3,430

Table 5.2. Hydrogeologic Environmental Setting Data for Hanford Site's 100 N Region Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	SZ
Darcian_velocity	m/yr	0.03	0.03	--
SOILC		4.05	4.38	4.38
Thickness	m	18.3	6.10	107
Bulk_density	g/cm3	2.0	1.9	1.9
Total_porosity	%	30	30	30
Field_capacity	%	9	12	--
Conductivity	m/day	12.2	1.81	--
Longitudinal_disp.	m	0.18	0.06	15.0
Transverse_disp.	m	--	--	3.0
Vertical_disp.	m	--	--	0.02
Effective_porosity	%	--	--	11.0
Velocity	m/day	--	--	3.29
Distance	m	--	--	150.0
Textural_class		sand	loamy sand	loamy sand
%_sand	%	89.8	87	87
%_silt	%	7.2	11	11
%_clay	%	3	2	2
%_OMC	%	0	0	0
%_Fe	%	0	0	0
pH		8.5	7	7.7

Table 5.3. Hydrogeologic Environmental Setting Data for Hanford Site's 100 H Region Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.03	--
SOILC		4.05	4.05
Thickness	m	15.2	3.05
Bulk_density	g/cm3	1.64	1.64
Total_porosity	%	38	38
Field_capacity	%	7.52	--
Conductivity	m/day	12.2	--
Longitudinal_disp.	m	0.15	15.0
Transverse_disp.	m	--	3.0
Vertical_disp.	m	--	0.02
Effective_porosity	%	--	26.0
Velocity	m/day	--	3.51
Distance	m	--	150.0
Textural_class		sand	sand
%_sand	%	91.2	91.2
%_silt	%	6.3	6.3
%_clay	%	2.5	2.5
%_OMC	%	0	0
%_Fe	%	0	0
pH		8.5	7.54

Table 5.4. Hydrogeologic Environmental Setting Data for Hanford Site's 200 East Region Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ2	SZ
Darcian_velocity	m/yr	0.03	0.03	0.03	--
SOILC		4.05	4.05	4.05	4.38
Thickness	m	10.0	50.0	19.0	9.1
Bulk_density	g/cm3	1.76	1.6	1.76	1.64
Total_porosity	%	36	42	36	18
Field_capacity	%	19	8.5	19	--
Conductivity	m/day	1.32	4.32	1.32	--
Longitudinal_disp.	m	0.10	0.50	0.19	50.0
Transverse_disp.	m	--	--	--	10.0
Vertical_disp.	m	--	--	--	0.06
Effective_porosity	%	--	--	--	10.0
Velocity	m/day	--	--	--	3.29
Distance	m	--	--	--	500.0
Textural_class		sand	sand	sand	loamy sand
%_sand	%	90	95	90	86
%_silt	%	9	3	9	12
%_clay	%	1	2	1	2
%_OMC	%	0	0	0	0
%_Fe	%	1.9	1.9	1.9	0
pH		8.5	8.5	8.5	7.7

Table 5.5. Hydrogeologic Environmental Setting Data for Hanford Site's 300 Area Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.03	--
SOILC		4.05	4.05
Thickness	m	12.2	10.4
Bulk_density	g/cm3	2.06	2.06
Total_porosity	%	26	26
Field_capacity	%	7.46	--
Conductivity	m/day	12.2	--
Longitudinal_disp.	m	0.12	50.0
Transverse_disp.	m	--	10.0
Vertical_disp.	m	--	0.06
Effective_porosity	%	--	23.2
Velocity	m/day	--	10.7
Distance	m	--	500.0
Textural_class		sand	sand
%_sand	%	92	92
%_silt	%	6	6
%_clay	%	2	2
%_OMC	%	0	0
%_Fe	%	0	0
pH		8.5	7.1

Table 5.6. Hydrogeologic Environmental Setting Data for Hanford Site's 200 West Region Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	PZ5	SZ
Darcian_velocity	m/yr	0.03	0.03	0.03	0.03	0.03	--
SOILC		4.05	5.39	4.38	4.9	4.38	4.38
Thickness	m	25.0	15.0	4.6	6.1	21.3	9.1
Bulk_density	g/cm3	1.75	1.65	1.65	1.9	1.76	1.76
Total_porosity	%	36	40	40	31	36	36
Field_capacity	%	11	13	18	7.2	12	--
Conductivity	m/day	10.4	1.97	58.6	1.73	1.81	--
Longitudinal_disp.	m	0.25	0.15	0.05	0.06	0.21	50.0
Transverse_disp.	m	--	--	--	--	--	10.0
Vertical_disp.	m	--	--	--	--	--	0.06
Effective_porosity	%	--	--	--	--	--	11.0
Velocity	m/day	--	--	--	--	--	0.18
Distance	m	--	--	--	--	--	500.0
Textural_class		sand	loam	loamy sand	sandy loam	loamy sand	loamy sand
%_sand	%	95	44.7	85.8	73	87	87
%_silt	%	3	55.3	12	25	11	11
%_clay	%	2	0	2.2	2	2	2
%_OMC	%	0	0	0	0	0	0
%_Fe	%	0	0	1.12	0	0	0
pH		8.5	7	7	7	7	7.9

Table 5.7. Hydrogeologic Environmental Setting Data for Hanford Site's Southwest Region Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ1</u>	<u>PZ2</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.03	0.03	--
SOILC		4.05	4.38	4.38
Thickness	m	14.2	24.2	9.14
Bulk_density	g/cm3	1.85	1.76	1.76
Total_porosity	%	32.7	36	36
Field_capacity	%	10	12	--
Conductivity	m/day	0.39	1.81	--
Longitudinal_disp.	m	0.14	0.24	200.0
Transverse_disp.	m	--	--	40.0
Vertical_disp.	m	--	--	0.23
Effective_porosity	%	--	--	11.0
Velocity	m/day	--	--	0.18
Distance	m	--	--	2000.0
Textural_class		sand	loamy sand	loamy sand
%_sand	%	91	87	87
%_silt	%	7	11	11
%_clay	%	2	2	2
%_OMC	%	0	0	0
%_Fe	%	0	0	0
pH		8.5	7	7.64

Table 5.8. Hydrogeologic Environmental Setting Data for Hanford Site's North of Columbia River Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.03	--
SOILC		5.3	5.3
Thickness	m	3.96	9.1
Bulk_density	g/cm3	1.48	1.48
Total_porosity	%	44.2	44.2
Field_capacity	%	28	--
Conductivity	m/day	0.88	--
Longitudinal_disp.	m	0.04	200.0
Transverse_disp.	m	--	40.0
Vertical_disp.	m	--	0.23
Effective_porosity	%	--	15.6
Velocity	m/day	--	0.05
Distance	m	--	2000.0
Textural_class		silt	silt
%_sand	%	8	8
%_silt	%	87	87
%_clay	%	5	5
%_OMC	%	0	0
%_Fe	%	0	0
pH		7	7

6.0 IDAHO NATIONAL ENGINEERING LABORATORY

The Idaho National Engineering Laboratory (INEL) is located on the Eastern Snake River Plain near the town of Idaho Falls (Figure 6.1). The INEL occupies 2300 km² (890 mi²) and has eight distinct operating areas. Activities at the INEL include the operation of nuclear reactors, a fuel processing plant, waste management facilities, and other supporting facilities. The topography of the INEL is flat to gently rolling with frequent lava outcrops. Mountains are located immediately to the northwest of the INEL and a low ridge line runs across the southeastern portion of the installation. Ecologically, the INEL represents part of a desert-shrub ecosystem that plays host to a diverse variety of desert flora and fauna.

6.1 CLIMATE

The INEL has a "mid-latitude semiarid" climate (Clawson et al. 1989). Meteorological data are available from onsite measurements at the Central Facilities Area Meteorology Station and other onsite monitoring locations (Clawson et al. 1989). On average, the maximum daily temperature exceeds 32°C (90°F) on 25 days per year and is below 0°C (32°F) on 60 days per year; the minimum daily temperature is below 0°C (32°F) on 214 days per year and is below -18°C (0°F) on 34 days per year (Clawson et al. 1989). July is the warmest month, with daily maximum and minimum temperatures averaging 31°C (87°F) and 9°C (49°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging -3°C (27°F) and -15°C (5°F), respectively (Clawson et al. 1989).

Annual precipitation is on the order of 22 cm (9 in.), with about 27% falling in May and June. Measurable precipitation (defined as 0.01 in. or greater) is recorded on an average of 69 days per year and the area experiences an average of 23 thunderstorm days per year. Daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 10 days per year; the average annual snowfall is 70 cm (28 in.) (Clawson et al. 1989).

Winds at the INEL are strongly influenced by the orientation of the bordering mountain ranges and the general orientation of the Eastern Snake River Plain. Local mountain-valley circulations, both nighttime drainage winds and upslope flows, are commonly observed across the installation. As a result of such local influences, significant variations in wind direction and speed are often observed across the installation. The prevailing wind direction in the Central Facilities Area (in the southwestern portion of the installation) is from the west-southwest. In the Technical Area North (in the northern portion of the installation), the prevailing wind direction is from the north. Wind speeds at the Central Facilities Area and Technical Area North average 3.4 m/s (7.5 mph) and 3.1 m/s (7.1 mph), respectively, at 6 m (20 ft) above ground level (Clawson et al. 1989). Average wind speeds at both

monitoring locations are highest in April (4 m/s [9 mph]) and lowest in December (2 m/s [5 mph]) (Clawson et al. 1989).

6.2 GEOLOGY

The Snake River Plain is a complex terrain dominated by Quaternary volcanics (Kuntz 1978; Anderson and Lewis 1989). Multiple episodes of eruptions have been punctuated by quiescent periods during which sedimentary interbeds accumulated in topographic depressions on the flow surfaces. Depending on the modes of deposition, textures of the sedimentary interbeds range from gravelly to relatively impermeable clays. Individual basalt flow groups range in thickness from 6 m (20 ft) to 52 m (170 ft). They tend to have brecciated upper and lower surfaces, and the main bodies of most flows are vertically fractured. The number of flows and flow groups varies from area to area. Near the Technical Area North, there are only two to three flow groups above the water table surface. Near the Radioactive Waste Management Center, there are 10 flow groups with more than 22 individual flows. These are separated by seven sedimentary interbeds (Anderson and Lewis 1989). In the Central Facilities Area, there are 23 flow groups with more than 40 flows above the regional water table. There are 15 to 20 sedimentary units in this area, many of them laterally discontinuous (Kuntz 1978).

6.3 HYDROLOGY

Although the general groundwater flow patterns at the INEL are understood (Barracough et al. 1981; Lewis and Jensen 1985), the subsurface is heterogeneous and, as a result, specific flow paths may be complex. The only aquifer of regional significance is the Snake River Plain Aquifer (Barracough et al. 1981; Lewis and Jensen 1985). Depths to this aquifer vary across the installation (Mann 1986; Anderson and Lewis 1989; Rightmire and Lewis 1987). In the northern portion of the INEL, the aquifer is about 60 m (200 ft) beneath the surface, and near the southwestern boundary, groundwater is at a depth of about 180 m (600 ft). Groundwater enters the INEL from the intermontane valleys to the north and from the Snake River Plain to the northeast. Across the installation, groundwater gradients are generally in southerly and southwesterly directions. Flow rates vary from less than 0.3 m (1 ft) per day in a low transmissivity zone underlying the playas to rates greater than about 4 m (12 ft) per day in several other areas. Water in this aquifer discharges to the Snake River several hundred kilometers down gradient from the installation. Perched water tables exist locally, especially in the area of the Idaho Chemical Processing Plant (ICPP) (Mann 1986). These ephemeral features are artifacts of subsurface discharge of large volumes of process water; they deflate quickly when discharge volumes are reduced. The significance of these perched water zones in terms of contaminant transport appears to be highly localized.

Surface drainage at the INEL does not connect to the Snake River (the largest major river in the region). Three river drainages do exist at the INEL: the Big Lost River enters the INEL at its southwestern boundary and the Little Lost River and Birch Creek enter the INEL at its northern boundary. During most years, the Big Lost River terminates near the installation boundary in a series of diversions ponds constructed during the 1970s. During episodes of high flow, surface water from the Big Lost River moves in the channel past several of the major facilities to a series of natural playas in the north central portion of the installation. During most years, all surface waters in the Little Lost River and Birch Creek watersheds are diverted to irrigation before entering the installation. During periods of high flow, surface waters from these two streams can reach the playas.

6.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and two joint frequency distribution exhibits are sufficient to address the climate and atmospheric dispersion characteristics of INEL for PEIS modeling purposes. Meteorological data for the installation are summarized in Exhibit 6.1. Atmospheric dispersion data in the form of two joint frequency distributions of wind direction, wind speed, and atmospheric stability are summarized in Exhibits 6.2 and 6.3. The data in Exhibit 6.2 (based on measurements from the Central Facilities Area) are characteristic of the southern two-thirds of the installation; data in Exhibit 6.3 (based on measurements from the Technical Area North) are characteristic of the northern third of the installation (i.e., the area described in Figure 6.1 as the Technical Area North environmental setting).

For PEIS modeling purposes, the INEL is characterized using five hydrogeologic environmental settings (Figure 6.1): the Technical Area North (TAN), the Playas, the Central Facilities Area (CFA), the Radioactive Waste Management Complex (RWMC), and the Argonne National Laboratory West (ANLW). Figure 6.2 presents stratigraphic columns for each of these settings. The five hydrogeological environmental settings have been identified based on the proximity of different areas to potential release sites, and on a number of distinctive transport characteristics associated with the hydrologic systems. Hydrogeologic data for the various settings are presented in Tables 6.1-6.5.

6.4.1 TAN Setting

The northern portion of the installation is described using the TAN hydrogeologic setting. This setting has the shallowest depth-to-groundwater (61 m) of any of the INEL hydrogeologic settings. The setting contains three partially-saturated zones and a single saturated zone. The surface zone (PZ1) is composed of Quaternary and Pleistocene lake bed deposits with moderately low permeability. These sediments overlie a number of basalt flow groups. These basalts tend to be vertically fractured and allow for a relatively high transmission of water downward through this zone. The deepest partially-saturated zone is a

thin sedimentary interbed. As with the surface zone, this interbed has a lower permeability relative to the basalt, and can act to inhibit the vertical migration of contaminants. The saturated zone in TAN is a thick sequence of basalts and interbedded sedimentary deposits. The physical properties of the saturated zone in this area are highly heterogeneous. Measured transmissivities vary by as much as eight orders of magnitude in wells separated by only a few kilometers (Goldstein and Weight 1982), although the range is generally less than this. Groundwater enters this hydrogeologic setting from both the northeast and from two intermountain river valleys north of the installation. Groundwater gradients in this area are fairly shallow, indicating the generally transmissive nature of the bedrock.

6.4.2 Playas Setting

Several features distinguish the playas hydrogeologic setting from other areas. Topographically, the playas are in the lowest area of the installation. Surface drainage, when there is any, flows to this area. Once collected in this series of basins, the waters either evaporate, or infiltrate into the subsurface. Surface waters from the Big Lost River, the Little Lost River and Birch Creek all have the potential to flow to the playas, although because of irrigation demands, flood water diversions, and other human influences, the playas receive surface water runoff only infrequently (i.e., on average, less than once every several years). The subsurface in the playas area is similar to the TAN hydrogeologic settings, but with the additional influence of having a major subsurface fault in the area (Kuntz 1978). This fault has, in effect, reduced the transmissivities in the saturated zone relative to areas both north and south of the playas, creating a zone with relatively steep hydraulic gradients (Barraclough et al. 1981; Lewis and Jensen 1985). There are no known release sites within the boundaries of the playas hydrogeologic setting, although some contaminants can reach the area as a result of surface waters ponding in the area.

6.4.3 Argonne National Laboratory West (ANLW) Setting

The hydrogeologic setting for which we were able to obtain the least amount of information was the ANLW. This area is located on the southern and eastern boundaries of the installation. A series of low-lying, northeast trending hills creates a surface water divide in this setting, although because of low precipitation rates and moderately permeable surface soils, runoff is rarely an issue. The subsurface within the ANLW is modeled along the lines of the CFA hydrogeologic setting, with major differences occurring in the thicknesses of the individual partially-saturated zones. Another distinguishing feature of the ANLW is that it lies farther to the east and, hence, contaminants deposited into the subsurface would be expected to follow different migration pathways.

6.4.4 Central Facilities Area (CFA) Setting

The CFA constitutes an area of major activities at the INEL. The hydrogeologic setting contains a number of major facilities including the ICPP, the Naval Reactor Facility,

and the Test Reactor Area. The CFA hydrogeologic setting is being modeled as having four partially-saturated zones and one saturated zone. Depth from ground surface to the water table is about 140 m (460 ft). The active portion of the saturated zone, that is the portion of the saturated zone in which contaminants are transported, is presumed to be about 75 m (245 ft) thick. The Big Lost River riverbed goes through this hydrogeologic setting. However, because of the diversion ponds constructed in the RWMC area, it rarely carries surface discharge. Groundwater within this setting comes primarily through the playas setting, although because of higher transmissivities, hydraulic gradients tend to be shallower in this area (Barraclough et al. 1981; Lewis and Jensen 1985). In addition to the Snake River Plain Aquifer, the regional water table work within the CFA has characterized the presence of localized perched waters. These ephemeral features are, apparently, the direct result of the subsurface discharge of process waters from the ICPP. Available evidence suggests that during periods of low discharge, the perched water table levels deflate quickly. The lateral extent of these perched water bodies is poorly characterized.

6.4.5 Radioactive Waste Management Complex (RWMC) Setting

The fifth hydrogeologic setting at the INEL is the RWMC. Located on the southern and western margins of the installation, the RWMC houses one major facility and several lesser operations. The Big Lost River enters this setting from the west. During most years, flow from the river is terminated in a series of diversion ponds constructed near the southwestern corner of the installation (Anderson and Lewis 1989). The stratigraphy within the partially-saturated zones at the RWMC is complex, consisting of a series of basalt flows and interbedded sediments (Anderson and Lewis 1989; Rightmire and Lewis 1987). As found in other areas within the INEL installation, the basalts in this area tend to be vertically fractured, and thus allow for the relatively rapid migration of contaminants downward through these zones. A number of the sedimentary interbeds in this area are, apparently, dominated by sands and gravels. As such, they also offer little resistance to the migration of contaminants. There is one sedimentary zone, however, that is predominantly fine grained and is capable of significantly retarding the migration of radionuclides. As a result of this distribution of hydraulic characteristics at the RWMC, this setting has been divided into four partially-saturated zones and one saturated zone. The surficial partially-saturated zone consists of surface sediments and soils. Zones 2 and 4 are modeled as vertically fractured basalts, and the third partially-saturated zone attempts to describe the fine-grained sedimentary interbed located at a depth of about 64 m (210 ft). Depth to groundwater in this area is greater than at other areas within the INEL. The total thickness of the partially-saturated zone is modeled as about 180 m (600 ft).

Groundwater moves off the INEL reservation through its southern boundary. This boundary includes sections of the RWMC, the CFA, and the ANLW hydrogeologic settings. This groundwater is discharged to surface waters several hundred kilometers down gradient at springs and seeps along the Snake River.

6.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the INEL are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Thomas Ferrara supplied input into the development of the climate and atmospheric dispersion environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings include Vicki Johnson, David Wessman, Ron Arnett, and Larry Mann. Following completion of the environmental settings, the settings were returned to Vicki Johnson for review and comments. The settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

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Figure 6.1. Location and Environmental Settings for the Idaho National Engineering Laboratory (INEL). For PEIS modeling purposes, the INEL is divided into five environmental settings: Technical Area North (TAN), the Playas, Central Facilities Area (CFA), Radioactive Waste Management Center (RWMC), and Argonne National Laboratory West (ANLW).

Figure 6.2. Stratigraphic Columns for Idaho National Engineering Laboratory (INEL) Environmental Settings

EXHIBIT 6.1

Idaho National Engineering Laboratory Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite at the Central Facilities Area and at Pocatello, Idaho.

Station Name: INEL - Central Facilities Area	Elevation: 1530 m	Latitude: 43.6°N
Pocatello, Idaho	Elevation: 1360 m	Latitude: 42.9°N

Annual Mean Air Temp:	42.0 °F	(CFA)	Reference (A)	Based on observations made from 1950-1988.
Anemometer Height:	6.1 m	(CFA)	Reference (A)	
Mean Annual Wind Speed:	8 mph	(CFA)	Reference (A)	Based on observations made from 1950-1964.
Fastest 1-Min Wind Speed:	78 mph	(CFA)	Reference (A)	Based on observations made from 4/50-10/64. The value presented is actually the "record peak wind gust", the fastest 1-min wind speed should be a little slower.
Annual Precipitation:	8.7 in.	(CFA)	Reference (A)	Based on observations made from 1950-1988.
Precipitation Days:	69 yr ⁻¹	(CFA)	Reference (A)	Based on observations made from 1950-1988.
Thunderstorms Freq:	23 yr ⁻¹	(Poc)	Reference (B)	Based on observations made at Pocatello, Idaho from 1950-1986.
Avg Morning Mixing Ht:	350 m		Reference (C)	
Avg Afternoon Mixing Ht:	2000 m		Reference (C)	
Top Soil Moisture Capacity:	1.0 cm		Reference (C)	

MEPAS Parameters:	Climatic Region Index:	2	Reference (C)
	Precipitation-Evaporation Index:	31	Reference (C)
	Soil Cons. Serv. Curve Number:	55	Reference (C)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	16	0.7	5.6	8.1	7.4	87	47
Feb	22	0.6	6.9	7.6	5.9	89	42
Mar	31	0.6	8.7	7.1	6.2	84	34
Apr	42	0.7	9.3	6.7	6.0	81	23
May	51	1.2	9.3	6.2	7.8	83	22
Jun	60	1.2	8.9	5.0	6.9	73	16
Jul	68	0.5	8.0	3.4	3.7	59	16
Aug	66	0.6	7.7	3.8	3.7	65	15
Sep	56	0.6	7.2	4.0	3.6	74	18
Oct	44	0.5	6.8	5.1	3.7	82	24
Nov	30	0.7	6.4	7.2	5.7	86	30
Dec	19	0.8	5.1	7.9	7.1	89	40
Reference: ...	(A)	(A)	(A)	(B)	(A)	(A)	(A)

References

- A: Clawson, K.L., G.E. Start, and N.R. Ricks. 1989. Climatology of the Idaho National Engineering Laboratory. 2nd Edition. DOE/ID-12118, Idaho Falls, Idaho.
- B: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part IV Western Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 6.2

Joint Frequency Distribution of Atmospheric Stability, Wind direction, and Wind Speed at Idaho National Engineering Laboratory (Central Facilities Area). Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made at 10 m (33 ft) above ground level. Data are based on measurements made from 1987 through 1991. Calms are included in the first wind speed class.

STAB CLAS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (M/S)					
		0.0-<1.6	1.6-<3.4	3.4-<5.6	5.6-<8.3	8.3-<11.0	≥11.0
A	NORTH	0.00292	0.00201	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00361	0.00291	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00379	0.00428	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00336	0.00408	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00283	0.00337	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00308	0.00298	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00285	0.00309	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00316	0.00454	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00318	0.00581	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00299	0.00579	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00227	0.00530	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00207	0.00337	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00155	0.00217	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00212	0.00194	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00189	0.00191	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00225	0.00171	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00034	0.00064	0.00043	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00078	0.00196	0.00059	0.00000	0.00000	0.00000
B	NORTHEAST	0.00107	0.00270	0.00054	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00018	0.00153	0.00043	0.00000	0.00000	0.00000
B	EAST	0.00011	0.00064	0.00031	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00013	0.00018	0.00020	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00029	0.00033	0.00018	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00035	0.00089	0.00079	0.00000	0.00000	0.00000
B	SOUTH	0.00046	0.00184	0.00117	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00029	0.00265	0.00214	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00019	0.00229	0.00235	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00028	0.00135	0.00115	0.00000	0.00000	0.00000
B	WEST	0.00009	0.00071	0.00071	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00000	0.00025	0.00033	0.00000	0.00000	0.00000
B	NORTHWEST	0.00003	0.00028	0.00051	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00011	0.00041	0.00041	0.00000	0.00000	0.00000
C	NORTH	0.00047	0.00082	0.00107	0.00003	0.00000	0.00000
C	NORTH-NORTHEAST	0.00132	0.00436	0.00189	0.00010	0.00000	0.00000
C	NORTHEAST	0.00122	0.00469	0.00250	0.00005	0.00000	0.00000
C	EAST-NORTHEAST	0.00053	0.00130	0.00097	0.00013	0.00000	0.00000
C	EAST	0.00016	0.00020	0.00025	0.00000	0.00000	0.00000
C	EAST-SOUTHEAST	0.00013	0.00008	0.00031	0.00000	0.00000	0.00000
C	SOUTHEAST	0.00010	0.00013	0.00036	0.00008	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00019	0.00087	0.00135	0.00005	0.00000	0.00000
C	SOUTH	0.00040	0.00125	0.00189	0.00010	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00033	0.00176	0.00482	0.00051	0.00000	0.00000
C	SOUTHWEST	0.00026	0.00201	0.00808	0.00087	0.00000	0.00000
C	WEST-SOUTHWEST	0.00022	0.00071	0.00354	0.00079	0.00000	0.00000

EXHIBIT 6.2 (continued)

STAB CLAS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (M/S)					
		0.0-<1.6	1.6-<3.4	3.4-<5.6	5.6-<8.3	8.3-<11.0	≥11.0
C	WEST	0.00000	0.00036	0.00161	0.00025	0.00000	0.00000
C	WEST-NORTHWEST	0.00005	0.00020	0.00074	0.00013	0.00000	0.00000
C	NORTHWEST	0.00008	0.00010	0.00071	0.00015	0.00000	0.00000
C	NORTH-NORTHWEST	0.00008	0.00033	0.00071	0.00015	0.00000	0.00000
D	NORTH	0.00366	0.01400	0.00727	0.00813	0.00247	0.00003
D	NORTH-NORTHEAST	0.00499	0.02621	0.01948	0.00696	0.00204	0.00076
D	NORTHEAST	0.00306	0.02050	0.02088	0.00691	0.00166	0.00031
D	EAST-NORTHEAST	0.00097	0.00426	0.00574	0.00258	0.00061	0.00000
D	EAST	0.00039	0.00120	0.00105	0.00043	0.00005	0.00003
D	EAST-SOUTHEAST	0.00030	0.00059	0.00076	0.00005	0.00000	0.00003
D	SOUTHEAST	0.00017	0.00084	0.00122	0.00038	0.00023	0.00000
D	SOUTH-SOUTHEAST	0.00039	0.00273	0.00291	0.00191	0.00046	0.00041
D	SOUTH	0.00088	0.00518	0.00558	0.00357	0.00130	0.00010
D	SOUTH-SOUTHWEST	0.00107	0.00949	0.01622	0.01400	0.00329	0.00041
D	SOUTHWEST	0.00211	0.01321	0.03088	0.04332	0.02473	0.00903
D	WEST-SOUTHWEST	0.00156	0.00892	0.01647	0.02053	0.01464	0.00854
D	WEST	0.00115	0.00301	0.00474	0.00367	0.00156	0.00031
D	WEST-NORTHWEST	0.00072	0.00107	0.00181	0.00133	0.00076	0.00015
D	NORTHWEST	0.00074	0.00079	0.00056	0.00066	0.00013	0.00003
D	NORTH-NORTHWEST	0.00146	0.00288	0.00250	0.00372	0.00064	0.00000
E	NORTH	0.00383	0.01107	0.00431	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00336	0.01308	0.00515	0.00000	0.00000	0.00000
E	NORTHEAST	0.00199	0.00640	0.00518	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00090	0.00247	0.00293	0.00000	0.00000	0.00000
E	EAST	0.00028	0.00079	0.00051	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00020	0.00061	0.00010	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00029	0.00099	0.00079	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00049	0.00184	0.00166	0.00000	0.00000	0.00000
E	SOUTH	0.00095	0.00367	0.00171	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00213	0.00673	0.00569	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00265	0.00785	0.01204	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00249	0.00635	0.00839	0.00000	0.00000	0.00000
E	WEST	0.00151	0.00298	0.00130	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00105	0.00127	0.00033	0.00000	0.00000	0.00000
E	NORTHWEST	0.00115	0.00102	0.00028	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00311	0.00329	0.00125	0.00000	0.00000	0.00000
F	NORTH	0.00872	0.00722	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00911	0.00854	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00587	0.00523	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00422	0.00413	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00370	0.00232	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00327	0.00235	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00359	0.00224	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00366	0.00413	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00553	0.00589	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00772	0.00972	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00725	0.00890	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00829	0.00681	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00712	0.00500	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00753	0.00421	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00844	0.00449	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00837	0.00487	0.00000	0.00000	0.00000	0.00000

EXHIBIT 6.3

Joint Frequency Distribution of Atmospheric Stability, Wind direction, and Wind Speed at Idaho National Engineering Laboratory (Technical Area North). Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made at 10 m (33 ft) above ground level. Data are based on measurements made from 1987 through 1991. Calms are included in the first wind speed class.

STAB CLAS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (M/S)					
		0.0-<1.6	1.6-<3.4	3.4-<5.6	5.6-<8.3	8.3-<11.0	≥11.0
A	NORTH	0.00273	0.00252	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00388	0.00342	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00504	0.00439	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00608	0.00627	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00708	0.00617	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00689	0.00548	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00619	0.00581	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00468	0.00635	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00457	0.00806	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00401	0.00650	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00239	0.00357	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00253	0.00247	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00201	0.00163	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00214	0.00181	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00211	0.00158	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00226	0.00173	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00039	0.00102	0.00054	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00069	0.00196	0.00071	0.00000	0.00000	0.00000
B	NORTHEAST	0.00138	0.00372	0.00069	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00142	0.00349	0.00074	0.00000	0.00000	0.00000
B	EAST	0.00117	0.00186	0.00038	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00102	0.00107	0.00020	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00063	0.00094	0.00031	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00040	0.00130	0.00041	0.00000	0.00000	0.00000
B	SOUTH	0.00034	0.00337	0.00125	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00049	0.00365	0.00255	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00025	0.00127	0.00143	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00013	0.00089	0.00079	0.00000	0.00000	0.00000
B	WEST	0.00000	0.00041	0.00054	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00003	0.00038	0.00054	0.00000	0.00000	0.00000
B	NORTHWEST	0.00003	0.00048	0.00038	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00022	0.00041	0.00038	0.00000	0.00000	0.00000
C	NORTH	0.00025	0.00150	0.00173	0.00023	0.00000	0.00000
C	NORTH-NORTHEAST	0.00105	0.00382	0.00189	0.00020	0.00000	0.00000
C	NORTHEAST	0.00147	0.00732	0.00186	0.00003	0.00000	0.00000
C	EAST-NORTHEAST	0.00154	0.00525	0.00166	0.00010	0.00000	0.00000
C	EAST	0.00090	0.00207	0.00054	0.00005	0.00000	0.00000
C	EAST-SOUTHEAST	0.00089	0.00084	0.00041	0.00000	0.00000	0.00000
C	SOUTHEAST	0.00060	0.00087	0.00048	0.00003	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00015	0.00079	0.00054	0.00013	0.00000	0.00000
C	SOUTH	0.00013	0.00186	0.00270	0.00020	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00028	0.00298	0.00770	0.00066	0.00000	0.00000
C	SOUTHWEST	0.00032	0.00099	0.00390	0.00025	0.00000	0.00000
C	WEST-SOUTHWEST	0.00017	0.00018	0.00173	0.00033	0.00000	0.00000

EXHIBIT 6.3 (continued)

STAB CLAS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (M/S)					
		0.0-<1.6	1.6-<3.4	3.4-<5.6	5.6-<8.3	8.3-<11.0	≥11.0
C	WEST	0.00012	0.00008	0.00099	0.00023	0.00000	0.00000
C	WEST-NORTHWEST	0.00000	0.00015	0.00064	0.00015	0.00000	0.00000
C	NORTHWEST	0.00010	0.00015	0.00097	0.00008	0.00000	0.00000
C	NORTH-NORTHWEST	0.00017	0.00056	0.00125	0.00031	0.00000	0.00000
D	NORTH	0.00188	0.03068	0.01418	0.00683	0.00245	0.00043
D	NORTH-NORTHEAST	0.00256	0.02453	0.01385	0.00352	0.00084	0.00041
D	NORTHEAST	0.00166	0.02139	0.01311	0.00298	0.00066	0.00018
D	EAST-NORTHEAST	0.00177	0.01216	0.00444	0.00143	0.00020	0.00005
D	EAST	0.00123	0.00484	0.00214	0.00084	0.00005	0.00005
D	EAST-SOUTHEAST	0.00068	0.00125	0.00084	0.00028	0.00003	0.00003
D	SOUTHEAST	0.00068	0.00133	0.00061	0.00013	0.00003	0.00003
D	SOUTH-SOUTHEAST	0.00030	0.00204	0.00163	0.00133	0.00013	0.00000
D	SOUTH	0.00017	0.00403	0.00546	0.00250	0.00051	0.00000
D	SOUTH-SOUTHWEST	0.00069	0.00778	0.01650	0.01941	0.00931	0.00286
D	SOUTHWEST	0.00150	0.00579	0.01270	0.01956	0.01522	0.00849
D	WEST-SOUTHWEST	0.00068	0.00125	0.00342	0.00329	0.00168	0.00054
D	WEST	0.00017	0.00059	0.00173	0.00130	0.00023	0.00008
D	WEST-NORTHWEST	0.00017	0.00099	0.00237	0.00173	0.00028	0.00008
D	NORTHWEST	0.00079	0.00357	0.00538	0.00711	0.00375	0.00107
D	NORTH-NORTHWEST	0.00164	0.02262	0.01283	0.02134	0.02203	0.01158
E	NORTH	0.00239	0.02420	0.00474	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00213	0.01346	0.00433	0.00000	0.00000	0.00000
E	NORTHEAST	0.00125	0.00586	0.00229	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00083	0.00201	0.00061	0.00000	0.00000	0.00000
E	EAST	0.00044	0.00079	0.00048	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00022	0.00069	0.00008	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00020	0.00079	0.00010	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00008	0.00115	0.00130	0.00000	0.00000	0.00000
E	SOUTH	0.00013	0.00178	0.00148	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00060	0.00441	0.00535	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00105	0.00311	0.00296	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00061	0.00153	0.00056	0.00000	0.00000	0.00000
E	WEST	0.00025	0.00110	0.00041	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00044	0.00133	0.00066	0.00000	0.00000	0.00000
E	NORTHWEST	0.00086	0.00449	0.00184	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00202	0.02264	0.00890	0.00000	0.00000	0.00000
F	NORTH	0.01195	0.01999	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.01124	0.01765	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00687	0.00841	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00523	0.00449	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00379	0.00245	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00317	0.00222	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00300	0.00204	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00320	0.00227	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00431	0.00258	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00583	0.00403	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00619	0.00495	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00692	0.00505	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00648	0.00482	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00785	0.00719	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00778	0.00768	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.01154	0.01341	0.00000	0.00000	0.00000	0.00000

Table 6.1. Hydrogeologic Environmental Setting Data for Idaho National Engineering Laboratory's TAN Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	SZ
Darcian_velocity	m/yr	0.04	0.04	0.04	--
SOILC		7.75	4.05	11.4	4.05
Thickness	m	12.2	53.3	3.05	75.0
Bulk_density	g/cm3	1.5	1.9	1.6	1.9
Total_porosity	%	49	20	42.5	20
Field_capacity	%	37.5	4.5	40	--
Conductivity	m/day	0.01	0.61	0.02	--
Longitudinal_disp.	m	0.12	0.55	0.03	89.9
Transverse_disp.	m	--	--	--	39.9
Vertical_disp.	m	--	--	--	10.0
Effective_porosity	%	--	--	--	15.0
Velocity	m/day	--	--	--	1.01
Distance	m	--	--	--	899
Textural_class		silty clay loam	sand	clay	sand
%_sand	%	20	100	20	100
%_silt	%	50	0	20	0
%_clay	%	30	0	60	0
%_OMC	%	0	0	0	0
%_Fe	%	5	10	5	10
pH		8.2	8	8	7.8

Table 6.2. Hydrogeologic Environmental Setting Data for Idaho National Engineering Laboratory's Playas Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	SZ
Darcian_velocity	m/yr	0.04	0.04	0.04	--
SOILC		7.75	4.05	11.4	4.05
Thickness	m	12.2	53.3	2.29	75.0
Bulk_density	g/cm3	1.5	1.9	1.6	1.9
Total_porosity	%	49	20	42.5	20
Field_capacity	%	37.5	4.5	40	--
Conductivity	m/day	0.01	0.61	0.02	--
Longitudinal_disp.	m	0.12	0.55	0.02	89.9
Transverse_disp.	m	--	--	--	39.9
Vertical_disp.	m	--	--	--	10.0
Effective_porosity	%	--	--	--	10.0
Velocity	m/day	--	--	--	0.50
Distance	m	--	--	--	899
Textural_class		silty clay loam	sand	clay	sand
%_sand	%	20	100	20	100
%_silt	%	50	0	20	0
%_clay	%	30	0	60	0
%_OMC	%	0	0	0	0
%_Fe	%	5	10	5	10
pH		8.2	8	8	7.8

Table 6.3. Hydrogeologic Environmental Setting Data for Idaho National Engineering Laboratory's CFA Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.04	0.04	0.04	0.04	--
SOILC		4.9	4.05	5.3	4.05	4.05
Thickness	m	18.3	27.4	15.2	76.2	75.0
Bulk_density	g/cm3	1.5	1.9	1.5	1.9	1.9
Total_porosity	%	45	20	45	20	20
Field_capacity	%	17.5	4.5	28	4.5	--
Conductivity	m/day	0.06	25.0	0.06	25.0	--
Longitudinal_disp.	m	0.18	0.27	0.15	0.27	89.9
Transverse_disp.	m	--	--	--	--	39.9
Vertical_disp.	m	--	--	--	--	10.0
Effective_porosity	%	--	--	--	--	15.0
Velocity	m/day	--	--	--	--	2.0
Distance	m	--	--	--	--	899
Textural_class		sandy loam	sand	silt	sand	sand
%_sand	%	60	100	10	100	100
%_silt	%	25	0	80	0	0
%_clay	%	15	0	10	0	0
%_OMC	%	0	0	0	0	0
%_Fe	%	5	10	5	10	10
pH		8.2	8	8	8	7.8

Table 6.4. Hydrogeologic Environmental Setting Data for Idaho National Engineering Laboratory's RWMC Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.04	0.04	0.04	0.04	--
SOILC		5.3	4.05	5.3	4.05	4.05
Thickness	m	3.05	70.1	16.8	93.0	75.0
Bulk_density	g/cm ³	1.5	1.9	1.5	1.9	1.9
Total_porosity	%	48.7	22.8	48.7	22.8	20
Field_capacity	%	28	4.5	28	4.5	--
Conductivity	m/day	1.2e-4	29.3	1.2e-4	29.3	--
Longitudinal_disp.	m	0.03	0.70	0.18	0.70	89.9
Transverse_disp.	m	--	--	--	--	39.9
Vertical_disp.	m	--	--	--	--	10.0
Effective_porosity	%	--	--	--	--	15.0
Velocity	m/day	--	--	--	--	2.0
Distance	m	--	--	--	--	899
Textural_class		silt	sand	silt	sand	sand
%_sand	%	10	100	10	100	100
%_silt	%	80	0	80	0	0
%_clay	%	10	0	10	0	0
%_OMC	%	0	0	0	0	0
%_Fe	%	5	10	5	10	10
pH		8.2	8	8	8	7.8

Table 6.5. Hydrogeologic Environmental Setting Data for Idaho National Engineering Laboratory's ANL_W Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.04	0.04	0.04	0.04	--
SOILC		4.9	4.05	5.3	4.05	4.05
Thickness	m	18.3	27.4	15.2	76.2	75.0
Bulk_density	g/cm3	1.5	1.9	1.5	1.9	1.9
Total_porosity	%	45	20	45	20	20
Field_capacity	%	17.5	4.5	28	4.5	--
Conductivity	m/day	0.61	25.0	0.06	25.0	--
Longitudinal_disp.	m	0.18	0.27	0.15	0.27	89.9
Transverse_disp.	m	--	--	--	--	39.9
Vertical_disp.	m	--	--	--	--	10.0
Effective_porosity	%	--	--	--	--	15.0
Velocity	m/day	--	--	--	--	2.0
Distance	m	--	--	--	--	899
Textural_class		sandy loam	sand	silt	sand	sand
%_sand	%	60	100	10	100	100
%_silt	%	25	0	80	0	0
%_clay	%	15	0	10	0	0
%_OMC	%	0	0	0	0	0
%_Fe	%	5	10	5	10	10
pH		8.2	8	8	8	7.8

7.0 INHALATION TOXICOLOGY RESEARCH INSTITUTE

The mission of the Inhalation Toxicology Research Institute (ITRI) is to determine the nature and magnitude of health effects on humans resulting from inhalation of airborne materials encountered in the workplace or the general environment. The initial research program was concerned with the health consequences of inhalation of airborne radionuclides. In the mid-1970s, the program was expanded to include the health effects associated with airborne chemicals released in the production and use of other energy-related technologies. Since the 1980s, the mission at the ITRI has become more generalized with an increased emphasis on understanding the basic biology of the respiratory tract and its response to inhaled materials (DOE 1992a).

The ITRI is located on Kirtland Air Force Base (KAFB) East approximately 16 km (10 mi) south of Albuquerque, New Mexico. KAFB and the Sandia National Laboratory (SNLA) occupy approximately 210 km² (82 mi²) on the eastern edge of the Albuquerque-Belen Basin, one of the largest of a series of north-south aligned basins in the Rio Grande trough (Figure 7.1). The ITRI occupies 0.6 km² (135 acres) on the southern boundary of the KAFB, approximately 30% of which are developed with research activities concentrated within half of this developed area. The southern boundary of the ITRI is adjacent to the Isleta Indian Reservation. The ITRI is located on a high, arid mesa, at approximately 1,700 m (5,600 ft) above mean sea level (msl) (DOE 1992a). Most of the area is relatively flat, sloping gently westward toward the Rio Grande (SNLA/DOE 1993b).

Four major North American physiographic and biotic provinces meet in the area of KAFB: the Great Basin, the Chihuahuan Desert, the Rocky Mountains, and the Great Plains. The Great Basin has the greatest influence of the four, but all have some influence over the biotic communities. Four vegetation formations are found in these communities: grassland, woodland, riparian scrubland, and riparian woodland. Vegetation at the ITRI is of the grassland community and includes sagebrush, cactus, and native grasses (DOE 1992a).

7.1 CLIMATE

The ITRI is located near the boundary between a "mid-latitude semiarid" and a "tropical semiarid" climate (Critchfield 1974). Meteorological data are available from measurements at the Albuquerque International Airport, located immediately west of KAFB, and some meteorological monitoring conducted within KAFB. On average, the maximum daily temperature exceeds 32°C (90°F) on 64 days per year and is below 0°C (32°F) on 5 days per year; the minimum daily temperature is below 0°C (32°F) on 120 days per year and is below -18°C (0°F) about once every 2 years (DOC 1987b). July is the warmest month, with daily maximum and minimum temperatures averaging 34°C (93°F) and 18°C

(65°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 8°C (47°F) and -5°C (22°F), respectively (DOC 1987b).

Annual precipitation is on the order of 21 cm (8 in.), with about 55 % falling from July through October. Precipitation is about double in the Manzano mountains to the east (McCord et al. 1993). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 60 days per year, and the area experiences an average of 42 thunderstorm days per year. The average annual snowfall is 28 cm (11 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 4 days per year (DOC 1987b).

The prevailing wind direction at the Albuquerque International Airport is from the southeast. Wind speeds average about 4 m/s (9 mph) at about 7 m (23 ft) above ground level. Average wind speeds are highest in April (5 m/s [11 mph]) and lowest in December (3.5 m/s [8 mph]) (DOC 1987b).

7.2 GEOLOGY

The Albuquerque-Belen Basin is a complex graben bordered by uplifted fault blocks. These fault blocks comprise the Sandia, Manzanita, and Manzano Mountains to the east and the Lucero uplift to the west. The fault blocks and the bedrock underlying the basin are composed of massive Precambrian crystalline basement rocks similar to those that compose the Sandia and Manzano Uplifts. Overlying the crystalline basement material is a sequence of Paleozoic limestones, sandstones, and shales that extend to a depth of 4600 m (13,000 ft) below land surface (McCord et al. 1993). The basin fill consists of up to 4400 m (14,500 ft) of Miocene-Pliocene aged Santa Fe Group, composed primarily of alluvial fan material from nearby mountains and fluvial material transported by rivers flowing through the Albuquerque-Belen Basin (McCord et al. 1993). Post Santa Fe Group units include fan, pediment, inset-terrace, eolian, and floodplain deposits (McCord et al. 1993).

The Albuquerque-Belen Basin is bounded on the east and west by complex fault zones consisting of four major fault systems. These fault systems include the Manzano, Hubbell Spring, Sandia, and Tijeras Faults. The Manzano Fault is located on the eastern edge of the SNLA/KAFB where the uplift of the Manzanito and Manzano Mountains occurred. The Sandia Fault lies at the front of the Sandia Mountains east of Albuquerque, and intersects the Tijeras Fault south of Thunder Range. The Hubbell Spring Fault runs parallel to the Manzano Fault along the eastern side of the Albuquerque Basin and is responsible for creating the Hubbell Bench, a natural bedrock bench where groundwater is 30 to 107 m (200 to 350 ft) lower on the west side of the fault than on the east side (McCord et al. 1993; SNLA/DOE 1993a). The Tijeras Fault is a major fault in the Tijeras rift zone that trends northeast with continuous exposure for approximately 50 km (30 mi). The Tijeras Fault is a left lateral wrench fault that exhibits scissor rotation of its blocks (SNLA/DOE 1993b).

purposes. Meteorological data for the installation are presented in Exhibit 7.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 7.2.

The SNLA/KAFB area is divided into three distinct hydrogeologic regions (HRs) (Figure 7.1): 1) HR1 occupies the western part of the SNLA/KAFB and is characterized by thick basin fill, 2) HR2 is situated between the Sandia fault-Tijeras fault complex, 3) HR3 occurs east of the fault complex on the Hubbell Bench and is characterized by shallow bedrock. For PEIS modeling purposes, the ITRI is characterized using one hydrogeologic environmental settings (Figure 7.1): the HR2 setting. This setting is based on hydrogeologic divisions developed in McCord et al. (1993). Figure 7.2 presents a stratigraphic column for the setting. Hydrogeologic data for the setting are presented in Table 7.1.

7.4.1 Hydrogeologic Region 2 Setting

The HR2 is the most structurally complex area on the SNLA/KAFB. The depth to bedrock is quite variable across the region resulting from the numerous, intersecting faults that occur in this area. The relationship between faulting and groundwater within this region is complex and poorly resolved; currently, little is known about the saturated zone flow across the fault complex. Environmental Restoration (ER) sites in HR2 are predominantly located in the southern half of the region over piedmont alluvium and away from bedrock outcrops in the north and east. The environmental setting developed for HR2 reflects the location of these ER sites and is not intended to summarize the geology of the entire hydrogeologic region. Piedmont alluvium occurs at the surface across most of the region, with an estimated depth of 23 m (75 ft) based on a maximum depth of 46 m (150 ft) across the SNLA/KAFB. Piedmont alluvium is underlain by coarse gravels, sand, silt, and clay of the Upper Santa Fe Group in the west and Paleozoic/Precambrian bedrock in the east. Total thickness of Upper Santa Fe Group sediments in HR2 is based on the Santa Fe Group isopach maps in the Albuquerque Area (SNLA/DOE 1993a). Isopach maps of Upper Santa Fe Group sediments in the northwestern portion of HR2 suggest a thickness of less than 150 m (500 ft) for sediments in the Sandia Fault Zone, plus an additional estimated 23 m (75 ft) of overlying piedmont-slope alluvium. Thickness of the partially-saturated zone was based on an average depth to water of 70 m (200 ft) for HR2 (McCord et al. 1993). Additional soil parameters are MEPAS model default values based on soil properties for the partially-saturated and saturated zones (Droppo et al. 1989). Hydrogeologic data for this setting are presented in Table 7.3

7.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the ITRI are based on publicly available documents written for DOE environmental programs. Site experts were contacted

7.3 HYDROLOGY

The structural regime at the SNLA/KAFB is a major factor in depths to groundwater and regional groundwater flow patterns. Waste sites east of major north-trending fault systems lie on thinner alluvial sections with shallow depths to bedrock compared to sites west of the fault system (SNLA/DOE 1993b). The hydrogeology east of the faults is poorly understood because there are few wells and the geology between the faults and the canyons of the Manzanita Mountains is complex. Valley fill is the principal aquifer in the region. The valley fill consists of unconsolidated and semiconsolidated sands, gravels, silts, and clays of the Santa Fe Formation. On the east side of the SNLA/KAFB, the valley fill is composed of heterogeneous alluvial fan deposits. West of the SNLA/KAFB, alluvial fan materials interfinger with predominantly finer-grained Rio Grande sediments. The aquifer is generally unconfined, with localized confining conditions created by discontinuous lenses of silt and clay. Pre-development groundwater flow in the Albuquerque-Belen Basin was to the southwest, away from the Manzano Mountains following the gradient of the Rio Grande. Heavy pumping of municipal wells by the city of Albuquerque has shifted groundwater flow to the northwest (SNLA/DOE 1993a).

The major surface water feature of the Albuquerque area is the Rio Grande, which flows southward with an annual average flow of $9.0 \times 10^9 \text{ m}^3$ (730,000 acre-ft) (SNLA/DOE 1993a). The Rio Grande flows in a southerly direction and is located approximately 18 km (11 mi) west of the ITRI site. Surface waters within the KAFB consist of ephemeral drainages whose flow is dominated by intense, short-duration summer thundershowers. The southern half of the ITRI drains generally southward into arroyos on the Isleta Reservation which then discharge into the Rio Grande. The major surface area drainage feature is the Tijeras Arroyo, which flows westward from the Sandia and Manzano Mountains to the Rio Grande. Tijeras Arroyo downstream of the KAFB drains a 326-km² (126-mi²) area that include some urban run-off, Tijeras Canyon, and the Arroyo del Coyote drainage (McCord et al. 1993). The Arroyo del Coyote drainage drains a 101-km² (39-mi²) area that includes Lurance Canyon, Madera Canyon, and much of the Manzano Base area. Arroyo del Coyote, Tijeras Arroyo, and all surface water features in the SNLA/KAFB are ephemeral streams, except for small portions of Arroyo del Coyote near Coyote Springs and G Spring, which are intermittent. Tijeras Arroyo is also intermittent approximately 3 km (2 mi) upstream of the KAFB boundary (McCord et al. 1993). Most of the floods in the Albuquerque area occur between May and October, during high-intensity thunderstorms. Floods in Tijeras Arroyo and Arroyo del Coyote are characterized by high peak flows, small volumes, and short durations (SNLA/DOE 1993a).

7.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the ITRI for PEIS modeling

and participated in the development and review of environmental settings for SNLA. Su Hwang and Gina Deola supplied input into the development of the climate and atmospheric dispersion environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings include Warren Cox, Franz Lauffer, Jim Krumhansl, and Jonathan Helper. Following completion of the environmental settings, Franz Lauffer coordinated the onsite review and fine tuning of the settings data. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

7.6 REFERENCES

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S9405048.12

Figure 7.1. Location and Environmental Settings for the Sandia National Laboratory Albuquerque (SNLA) and Inhalation Toxicology Research Institute (ITRI). For PEIS modeling purposes, the SNLA is divided into three environmental settings: HR 1, HR2, and HR3. The ITRI is characterized by a single environmental setting (HR2).

Figure 7.2. Stratigraphic Column for Inhalation Toxicology Research Institute (ITRI) Environmental Setting

EXHIBIT 7.1

Inhalation Toxicology Research Institute Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at Albuquerque International Airport.

Station Name: Albuquerque International Airport, Albuquerque, New Mexico Elevation: 1619 m Latitude: 35.05°N

Annual Mean Air Temp: 56.2 °F Reference (A) Based on observations made from 1951-1980.
 Anemometer Height: 7.0 m Reference (A)
 Mean Annual Wind Speed: 9 mph Reference (A) Based on 47 years of observations.
 Fastest 1-Min Wind Speed: 90 mph Reference (A) Based on 44 years of observations.
 Annual Precipitation: 8.1 in. Reference (A) Based on observations made from 1951-1980.
 Precipitation Days: 60 yr⁻¹ Reference (A) Based on 47 years of observations.
 Thunderstorms Freq: 42 yr⁻¹ Reference (A) Based on 47 years of observations.

Avg Morning Mixing Ht: 450 m Reference (B)
 Avg Afternoon Mixing Ht: 2600 m Reference (B)
 Top Soil Moisture Capacity: 2.8 cm Reference (B)

MEPAS Parameters: Climatic Region Index: 2 Reference (B)
 Precipitation-Evaporation Index: 46 Reference (B)
 Soil Cons. Serv. Curve Number: 41 Reference (B)

MONTH	MONTHLY AVERAGES						
	TEMP. (°F)	PRECIP. (Inches)	WIND SPEED (MPH)	CLOUD COVER (10ths)	PRECIP. DAYS (#)	DAILY RH	
						MAX (%)	MIN (%)
Jan	35	0.4	8.0	4.8	3.9	71	40
Feb	39	0.4	8.8	4.9	4.1	65	32
Mar	46	0.5	10.1	5.1	4.6	56	24
Apr	55	0.4	11.0	4.6	3.3	49	18
May	64	0.5	10.5	4.2	4.3	48	18
Jun	75	0.5	10.0	3.3	3.8	46	17
Jul	79	1.3	9.1	4.5	8.9	60	27
Aug	76	1.5	8.2	4.3	9.2	66	30
Sep	69	0.9	8.6	3.6	5.7	62	31
Oct	57	0.9	8.3	3.5	4.9	62	30
Nov	44	0.4	7.9	4.0	3.5	66	36
Dec	36	0.5	7.7	4.6	4.1	71	43
	↓	↓	↓	↓	↓	↓	↓
Reference: ...	(A)	(A)	(A)	(A)	(A)	(A)	(A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part II Southern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- B: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 7.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Inhalation Toxicology Research Institute. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made at the Albuquerque International Airport at 15 m (48 ft) above ground level. Data are based on measurements made from 1960 through 1964.

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
A	NORTH	0.00102	0.00103	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00018	0.00025	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00073	0.00030	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00042	0.00018	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00033	0.00016	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00056	0.00041	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00084	0.00041	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00042	0.00053	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00101	0.00142	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00079	0.00089	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00107	0.00158	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00104	0.00132	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00126	0.00128	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00097	0.00128	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00077	0.00105	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00043	0.00057	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00636	0.00379	0.00130	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00274	0.00201	0.00055	0.00000	0.00000	0.00000
B	NORTHEAST	0.00296	0.00144	0.00032	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00171	0.00087	0.00025	0.00000	0.00000	0.00000
B	EAST	0.00158	0.00073	0.00011	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00228	0.00082	0.00030	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00346	0.00180	0.00066	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00271	0.00203	0.00082	0.00000	0.00000	0.00000
B	SOUTH	0.00576	0.00521	0.00299	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00291	0.00464	0.00260	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00545	0.00598	0.00377	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00378	0.00532	0.00299	0.00000	0.00000	0.00000
B	WEST	0.00448	0.00491	0.00212	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00476	0.00464	0.00180	0.00000	0.00000	0.00000
B	NORTHWEST	0.00509	0.00393	0.00139	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00415	0.00374	0.00069	0.00000	0.00000	0.00000
C	NORTH	0.00168	0.00662	0.00683	0.00034	0.00002	0.00000
C	NORTH-NORTHEAST	0.00076	0.00253	0.00151	0.00005	0.00000	0.00000
C	NORTHEAST	0.00064	0.00132	0.00110	0.00000	0.00000	0.00000
C	EAST-NORTHEAST	0.00054	0.00057	0.00048	0.00009	0.00000	0.00000
C	EAST	0.00037	0.00048	0.00085	0.00023	0.00002	0.00000
C	EAST-SOUTHEAST	0.00081	0.00142	0.00089	0.00037	0.00009	0.00000
C	SOUTHEAST	0.00145	0.00279	0.00151	0.00027	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00101	0.00265	0.00212	0.00037	0.00002	0.00000
C	SOUTH	0.00192	0.00623	0.00623	0.00132	0.00034	0.00005
C	SOUTH-SOUTHWEST	0.00080	0.00358	0.00541	0.00128	0.00032	0.00005
C	SOUTHWEST	0.00110	0.00427	0.00594	0.00171	0.00018	0.00005
C	WEST-SOUTHWEST	0.00067	0.00308	0.00416	0.00114	0.00014	0.00005
C	WEST	0.00096	0.00313	0.00295	0.00091	0.00018	0.00005
C	WEST-NORTHWEST	0.00084	0.00311	0.00299	0.00062	0.00023	0.00000
C	NORTHWEST	0.00113	0.00390	0.00292	0.00037	0.00023	0.00000
C	NORTH-NORTHWEST	0.00095	0.00502	0.00395	0.00041	0.00005	0.00000
D	NORTH	0.00147	0.00495	0.01372	0.01541	0.00199	0.00016
D	NORTH-NORTHEAST	0.00058	0.00192	0.00352	0.00215	0.00011	0.00002
D	NORTHEAST	0.00058	0.00194	0.00281	0.00116	0.00014	0.00002

EXHIBIT 7.2 (continued)

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
D	EAST-NORTHEAST	0.00049	0.00064	0.00210	0.00361	0.00091	0.00021
D	EAST	0.00050	0.00116	0.00349	0.01306	0.00827	0.00400
D	EAST-SOUTHEAST	0.00060	0.00212	0.00573	0.01400	0.00808	0.00260
D	SOUTHEAST	0.00103	0.00301	0.00509	0.00413	0.00162	0.00027
D	SOUTH-SOUTHEAST	0.00065	0.00228	0.00450	0.00265	0.00039	0.00005
D	SOUTH	0.00118	0.00365	0.00911	0.00856	0.00313	0.00112
D	SOUTH-SOUTHWEST	0.00022	0.00183	0.00539	0.00824	0.00240	0.00032
D	SOUTHWEST	0.00088	0.00251	0.00573	0.00671	0.00210	0.00050
D	WEST-SOUTHWEST	0.00050	0.00171	0.00548	0.00669	0.00203	0.00078
D	WEST	0.00035	0.00167	0.00374	0.00553	0.00260	0.00066
D	WEST-NORTHWEST	0.00069	0.00164	0.00336	0.00742	0.00320	0.00096
D	NORTHWEST	0.00089	0.00217	0.00324	0.00810	0.00322	0.00073
D	NORTH-NORTHWEST	0.00067	0.00267	0.00553	0.00838	0.00142	0.00018
E	NORTH	0.00000	0.00589	0.02183	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00000	0.00333	0.00820	0.00000	0.00000	0.00000
E	NORTHEAST	0.00000	0.00251	0.00297	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00000	0.00171	0.00183	0.00000	0.00000	0.00000
E	EAST	0.00000	0.00194	0.00263	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00000	0.00553	0.00543	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00000	0.00877	0.00587	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00000	0.00493	0.00390	0.00000	0.00000	0.00000
E	SOUTH	0.00000	0.00511	0.00553	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00000	0.00263	0.00324	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00000	0.00274	0.00301	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00000	0.00231	0.00244	0.00000	0.00000	0.00000
E	WEST	0.00000	0.00206	0.00190	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00000	0.00222	0.00253	0.00000	0.00000	0.00000
E	NORTHWEST	0.00000	0.00201	0.00361	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00000	0.00311	0.00619	0.00000	0.00000	0.00000
F	NORTH	0.01361	0.02073	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00773	0.00998	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00986	0.00925	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00640	0.00441	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00723	0.00555	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.01348	0.01534	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.01779	0.02267	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00993	0.01228	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.01167	0.00963	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00382	0.00333	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00527	0.00370	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00416	0.00354	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00416	0.00313	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00534	0.00422	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00570	0.00557	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00660	0.00954	0.00000	0.00000	0.00000	0.00000

Table 7.1. Hydrogeologic Environmental Setting Data for Inhalation Toxicology Research Institute's HR2 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.04	--
SOILC		4.38	4.38
Thickness	m	61	114
Bulk_density	g/cm3	1.49	1.49
Total_porosity	%	43.7	43.7
Field_capacity	%	12	--
Conductivity	m/day	0.03	--
Longitudinal_disp.	m	0.61	563.9
Transverse_disp.	m	--	112.8
Vertical_disp.	m	--	0.66
Effective_porosity	%	--	23.0
Velocity	m/day	--	0.02
Distance	m	--	5639
Textural_class		loamy sand	loamy sand
%_sand	%	84	84
%_silt	%	12	12
%_clay	%	4	4
%_OMC	%	0	0
%_Fe	%	0	0
pH		6.8	6.8

8.0 KANSAS CITY PLANT

The Kansas City Plant (KCP) has been in operation since 1949 with its primary mission being the production and procurement of non-nuclear components for the DOE weapons program. Production efforts have concentrated on three primary areas: electrical and electronics work, mechanical products, and plastic products. No operations directly involving radioactive material or explosives normally associated with nuclear weapons are assigned to the KCP.

The KCP is located within the city limits of Kansas City, Missouri, on a 55-ha (136-acre) parcel of a 121-ha (300-acre) federal complex (Figure 8.1). The plant lies approximately 19 km (12 mi) south of downtown Kansas City. Low hills nearly encircle the plant, which is situated in a small river valley approximately 245 m (800 ft) above sea level. Land in the area surrounding the KCP is predominantly used for multiple family dwellings, commercial and industrial establishments, and public use. Bordering the KCP on the west is a major traffic artery (Troost Avenue), on the north a heavily wooded bluff and wildlife refuge, on the east the Blue River, and on the south Bannister Road and Indian Creek. Terrestrial habitats in the area surrounding the KCP include typical riparian woodlands, remnant oak-hickory woodlands, suburban lawns, and parks (DOE 1992c). The riparian forests are dominated by cottonwood and willows, with smaller more disturbed remnants of oak-hickory dotting the area.

8.1 CLIMATE

The KCP area is on the boundary of the "humid continental warm summer" and the "mid-latitude semiarid" climate (Critchfield 1974). Meteorological data are available from measurements at the Kansas City Downtown Airport in Kansas City, Missouri. On average the maximum daily temperature exceeds 32°C (90°F) on 44 days per year and is below 0°C (32°F) on 26 days per year; the minimum daily temperature is below 0°C (32°F) on 98 days per year and is below -18°C (0°F) on 4 days per year (DOC 1987c). July is the warmest month, with daily maximum and minimum temperatures averaging 33°C (91°F) and 22°C (71°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 3°C (37°F) and -7°C (19°F), respectively (DOC 1987c).

Annual precipitation is on the order of 74 cm (29 in.), with about 60% of this total occurring from April through September. Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 98 days per year and the area experiences an average of 49 thunderstorms per year. The average annual snowfall is 53 cm (21 in.) (DOC 1992a) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 6 days per year (DOC 1987c).

The prevailing wind direction at the airport is from the south. Wind speeds average about 4 m/s (10 mph) at about 7 m (22 ft). Average wind speeds are highest in March (5 m/s [12 mph]) and lowest in August (4 m/s [9 mph]) (DOC 1987c). Winds at the installation are affected by the urban setting.

8.2 GEOLOGY

The KCP is located within the Great Plains physiographic province along the southeastern flank of the Forrest City basin (DOE 1991a). Underlying the KCP is approximately 14 m (45 ft) of unconsolidated Quaternary alluvium resting on 730 m (2,400 ft) of Paleozoic-aged sedimentary rocks. A Precambrian crystalline basement complex underlies the Paleozoic sequence.

The alluvial deposits are the result of depositional and erosional cycles of the Blue River (DOE 1991a, 1993a). Unconsolidated alluvium partially fills a valley previously cut by the Blue River into the Paleozoic bedrock. The Paleozoic rocks underlying the alluvium are exposed in bluffs along valley margins. In general, the alluvium is composed of continuous and discontinuous zones of clayey-silt, sand, and gravel (DOE 1993a). Two more-permeable units exist at the KCP: an upper unit composed of thin-bedded sequences of clayey-silt with minor amounts of gravel and sand, and a basal gravel unit with a sand-silt-clay matrix (DOE 1991a, 1993a). A zone of clayey-silt separates the two units throughout portions of the site. Evaluation of soil samples indicate that there are only minor differences in the distribution of grain sizes between the upper unit and the clayey-silt zone (DOE 1991a). It is important to note that although the clayey-silt zone behaves as an aquitard, water is able to flow through the unit at a reduced rate.

The lower gravel unit is continuous throughout the site and ranges in thickness from less than 1 m to 2.5 m (2 to 8 ft) (DOE 1991a). Gravel clasts are predominantly composed of limestone and sandstone derived from the Paleozoic bedrock with sand, silt, and clay material as the matrix. Underlying the coarse-grained basal unit is the Pleasanton Group, composed of interbedded shale and sandstone units (DOE 1991a, 1993a). The shale units are extremely dense with no evidence of secondary porosity (DOE 1993a). Within the shale are two sandstone units, the Knobtown and the Hepler Sandstones. The units are typically fine-grained and well-cemented with silt and clay interbeds. Based on coreholes drilled across the KCP, the Knobtown sandstone underlies the alluvium in the central portion of the site. The Hepler Sandstone is separated from the overlying Knobtown Sandstone by an impermeable shale and is considered hydraulically isolated from the Knobtown Sandstone (DOE 1993a).

8.3 HYDROLOGY

Two major water-bearing units exist at the KCP: the unconsolidated alluvium and the underlying bedrock (DOE 1993a). All three of the previously discussed alluvial zones transmit water and compose the alluvial aquifer. The thickness of the alluvial aquifer ranges from less than 6 m (20 ft) near the Blue River to 12 m (40 ft) near the South Lagoon (DOE 1992d). In addition to the three alluvial aquifer zones, a backfilled channel of the ancestral Blue River located in the northeastern portion of the KCP should also be considered a fourth hydrostratigraphic zone. Hydraulic conductivity values for the backfilled material are generally an order of magnitude greater than the surrounding alluvial material (DOE 1992d). Potentiometric surface maps for the alluvial aquifer indicate groundwater flow directions at the KCP are primarily in two directions: south toward Indian Creek and east toward the Blue River (DOE 1991a, 1993a).

Shale units within the Pleasanton Group are generally considered too dense and lacking in secondary porosity to transmit water at the KCP. With the Hepler Sandstone effectively isolated from the Knobtown by a black shale unit, the only bedrock unit with aquifer potential at the KCP is the Knobtown Sandstone. Any reference to the Knobtown as an aquifer is made only in that it produces a limited water where it is thick enough for a well to be installed (DOE 1991a). These areas are rather limited across the KCP as the maximum thickness of the Knobtown is only 3 m (10 ft) and considerably less in areas where erosion has been substantial (DOE 1993a). Hydraulic conductivity measurements from the Knobtown are one to two orders of magnitude less than the overlying alluvium (DOE 1991a). These differences suggest that groundwater flow will be controlled by the overlying, more permeable alluvial aquifer. Consequently, where groundwater flow exists within the Knobtown, flow directions are identical to the alluvial aquifer. As a result, any contamination of the Knobtown can be described through comprehensive characterization of the alluvial aquifer system (DOE 1993a). Precipitation provides by far the largest volume of recharge at the KCP, with much smaller recharge quantities coming from leaky underground water and steam lines (DOE 1992d). Discharge from the alluvial aquifer primarily enters the Blue River and Indian Creek.

8.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the KCP for BEMR modeling purposes. Meteorological data for the installation are presented in Exhibit 8.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 8.2.

Hydrogeologic settings for the KCP are shown in Figure 8.2. For the purposes of the BEMR program, the characteristics of the two settings are essentially identical. The reason

for distinguishing the two settings is that contaminants associated with the groundwaters in each area have been observed to move in different directions and are released to the surface environment in different locations. Material from release sites in the eastern and northeastern portions of the installation migrate eastward or northeastward toward the Blue River. In contrast, materials from release sites in the central portions of the installation migrate toward the south and Indian Creek. Flow path lengths are slightly different for the two settings, but, otherwise, the pathways are virtually identical for the two hydrogeologic settings. Hydrogeologic data for the KCP environmental settings are presented in Tables 8.1 and 8.2.

8.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the KCP are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the review of environmental settings for this installation. Following completion of the environmental settings, Phil Keary (DOE) and Joe Baker (Allied Signal) coordinated the review and fine tuning of the settings data. Settings were accepted as appropriate for intended BEMR modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

8.6 REFERENCES

Critchfield, H.J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

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U.S. Department of Energy (DOE). 1993a. *Annual Groundwater Monitoring Report for Calendar Year 1992 - Kansas City Plant*. U.S. Department of Energy, Kansas City Plant, Kansas City, Missouri.

Figure 8.1. Location and Environmental Settings for the Kansas City Plant.

M bls = Meters below land surface

Figure 8.2. Stratigraphic Columns for Kansas City Plant Environmental Settings.

EXHIBIT 8.1

Kansas City Plant Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at Kansas City Downtown Airport.

Station Name: Kansas City Downtown Airport, Missouri

Elevation: 226 m

Latitude: 39.12°N

Annual Mean Air Temp: 56.3 °F Reference (a) Based on observations made from 1967-1986
 Anemometer Height: 22.0 ft Reference (a) Based on observations made from 1959-1986
 Mean Annual Wind Speed: 9.9 mph Reference (a) Based on observations made from 1946-1986
 Fastest 1-Min Wind Speed: 72.0 mph Reference (a) Based on observations made from 1948-1986
 Annual Precipitation: 29.3 in Reference (a) Based on observations made from 1941-1986
 Precipitation Days: 98 yr⁻¹ Reference (a) Based on observations made from 1941-1986
 Thunderstorms Freq: 49 yr⁻¹ Reference (a) Based on observations made from 1940-1986

Avg Morning Mixing Ht: 425 m Reference (b)
 Avg Afternoon Mixing Ht: 1380 m Reference (b)
 Top Soil Moisture Capacity: 4.90 cm Reference (b)

MEPAS Parameters: Climatic Region Index: 4 Reference (b)
 Precipitation-Evaporation Index: 94 Reference (b)
 Soil Cons. Serv. Curve Number: 71 Reference (b)

MONTHLY AVERAGES							
	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
MONTH	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	28.4	0.98	10.0	6.1	6	72	60
Feb	34.4	1.05	10.2	6.3	7	73	58
Mar	43.6	2.12	11.6	6.4	9	72	54
Apr	56.9	2.68	11.5	6.3	10	72	48
May	66.9	3.42	10.2	6.1	11	77	52
Jun	75.8	4.13	9.9	5.9	10	80	56
Jul	80.9	3.49	9.0	4.8	8	78	52
Aug	79.3	3.16	8.8	4.7	8	79	53
Sep	71.0	3.33	9.2	4.7	8	81	56
Oct	59.6	2.54	9.1	4.7	7	76	53
Nov	44.6	1.23	10.1	5.7	7	76	59
Dec	34.2	1.14	9.8	6.3	7	76	64
Reference: ...	(a)	(a)	(a)	(a)	(a)	(a)	(a)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part III - Central Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- B: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 8.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Kansas City International Airport. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made on-site at 6.7 m (22 ft) above ground level. Data are based on measurements made from 1989 through 1993.

STAB CLASS	WIND DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 24
A	NORTH	0.00017	0.00005	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00010	0.00007	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00014	0.00011	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00008	0.00009	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00018	0.00016	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00024	0.00023	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00016	0.00014	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00006	0.00007	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00020	0.00014	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00025	0.00014	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00010	0.00011	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00014	0.00011	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00020	0.00018	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00004	0.00005	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00035	0.00021	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00010	0.00011	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00049	0.00128	0.00146	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00031	0.00084	0.00071	0.00000	0.00000	0.00000
B	NORTHEAST	0.00028	0.00078	0.00043	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00031	0.00121	0.00119	0.00000	0.00000	0.00000
B	EAST	0.00064	0.00183	0.00137	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00030	0.00116	0.00128	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00035	0.00112	0.00096	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00018	0.00103	0.00096	0.00000	0.00000	0.00000
B	SOUTH	0.00051	0.00164	0.00187	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00019	0.00091	0.00107	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00037	0.00089	0.00089	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00031	0.00080	0.00048	0.00000	0.00000	0.00000
B	WEST	0.00029	0.00064	0.00057	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00032	0.00048	0.00041	0.00000	0.00000	0.00000
B	NORTHWEST	0.00035	0.00075	0.00050	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00034	0.00089	0.00059	0.00000	0.00000	0.00000
C	NORTH	0.00029	0.00164	0.00468	0.00119	0.00002	0.00000
C	NORTH-NORTHEAST	0.00013	0.00098	0.00283	0.00043	0.00002	0.00000
C	NORTHEAST	0.00020	0.00116	0.00228	0.00046	0.00000	0.00000
C	EAST-NORTHEAST	0.00027	0.00142	0.00240	0.00032	0.00000	0.00000
C	EAST	0.00028	0.00180	0.00443	0.00062	0.00000	0.00000
C	EAST-SOUTHEAST	0.00013	0.00126	0.00395	0.00073	0.00005	0.00000
C	SOUTHEAST	0.00021	0.00130	0.00420	0.00087	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00012	0.00105	0.00473	0.00132	0.00009	0.00002
C	SOUTH	0.00021	0.00153	0.00822	0.00441	0.00105	0.00023
C	SOUTH-SOUTHWEST	0.00014	0.00103	0.00466	0.00219	0.00046	0.00011
C	SOUTHWEST	0.00018	0.00119	0.00418	0.00107	0.00007	0.00000
C	WEST-SOUTHWEST	0.00015	0.00121	0.00320	0.00059	0.00005	0.00005
C	WEST	0.00028	0.00128	0.00301	0.00041	0.00007	0.00000
C	WEST-NORTHWEST	0.00013	0.00089	0.00231	0.00066	0.00005	0.00000
C	NORTHWEST	0.00012	0.00078	0.00235	0.00068	0.00014	0.00000

EXHIBIT 8.2 (continued)

STAB CLASS	WIND DIRECTIO FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 24
C	NORTH-NORTHWEST	0.00014	0.00110	0.00329	0.00048	0.00000	0.00000
D	NORTH	0.00086	0.00525	0.01614	0.02539	0.00486	0.00078
D	NORTH-NORTHEAST	0.00056	0.00317	0.00918	0.00852	0.00098	0.00011
D	NORTHEAST	0.00066	0.00443	0.00842	0.00553	0.00016	0.00000
D	EAST-NORTHEAST	0.00067	0.00411	0.00966	0.00667	0.00027	0.00000
D	EAST	0.00107	0.00607	0.01925	0.01226	0.00126	0.00005
D	EAST-SOUTHEAST	0.00066	0.00473	0.01564	0.00865	0.00030	0.00002
D	SOUTHEAST	0.00053	0.00317	0.01174	0.00986	0.00057	0.00009
D	SOUTH-SOUTHEAST	0.00025	0.00203	0.01354	0.01619	0.00224	0.00027
D	SOUTH	0.00053	0.00395	0.01925	0.07747	0.02532	0.00500
D	SOUTH-SOUTHWEST	0.00029	0.00217	0.00970	0.03055	0.00838	0.00203
D	SOUTHWEST	0.00029	0.00196	0.00724	0.01037	0.00180	0.00025
D	WEST-SOUTHWEST	0.00048	0.00215	0.00427	0.00495	0.00059	0.00021
D	WEST	0.00042	0.00251	0.00523	0.00840	0.00169	0.00057
D	WEST-NORTHWEST	0.00031	0.00265	0.00623	0.01372	0.00372	0.00107
D	NORTHWEST	0.00045	0.00288	0.00936	0.02025	0.00537	0.00189
D	NORTH-NORTHWEST	0.00044	0.00345	0.01082	0.01845	0.00326	0.00039
E	NORTH	0.00000	0.00317	0.00671	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00000	0.00258	0.00299	0.00000	0.00000	0.00000
E	NORTHEAST	0.00000	0.00224	0.00139	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00000	0.00354	0.00201	0.00000	0.00000	0.00000
E	EAST	0.00000	0.00582	0.00374	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00000	0.00388	0.00539	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00000	0.00272	0.00573	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00000	0.00231	0.01148	0.00000	0.00000	0.00000
E	SOUTH	0.00000	0.00304	0.02450	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00000	0.00142	0.00993	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00000	0.00139	0.00797	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00000	0.00119	0.00384	0.00000	0.00000	0.00000
E	WEST	0.00000	0.00203	0.00537	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00000	0.00164	0.00336	0.00000	0.00000	0.00000
E	NORTHWEST	0.00000	0.00137	0.00498	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00000	0.00171	0.00470	0.00000	0.00000	0.00000
F	NORTH	0.00076	0.00664	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00063	0.00493	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00054	0.00400	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00081	0.00477	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00120	0.00904	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00060	0.00721	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00049	0.00619	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00055	0.00717	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00076	0.00900	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00043	0.00379	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00047	0.00438	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00033	0.00363	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00063	0.00740	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00046	0.00546	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00037	0.00313	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00041	0.00381	0.00000	0.00000	0.00000	0.00000
G	NORTH	0.00133	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHEAST	0.00133	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTHEAST	0.00245	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST-NORTHEAST	0.00293	0.00000	0.00000	0.00000	0.00000	0.00000

EXHIBIT 8.2 (continued)

STAB CLASS	WIND DIRECTIO FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		<u>0 - 3</u>	<u>4 - 6</u>	<u>7 - 10</u>	<u>11 - 16</u>	<u>17 - 21</u>	<u>> 24</u>
G	EAST	0.00182	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.00119	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHEAST	0.00112	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00098	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH	0.00182	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHWEST	0.00175	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHWEST	0.00168	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST-SOUTHWEST	0.00084	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST	0.00126	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST-NORTHWEST	0.00105	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTHWEST	0.00091	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHWEST	0.00070	0.00000	0.00000	0.00000	0.00000	0.00000

Table 8.1. Hydrogeologic setting data summary of the Kansas City Plant (KCP), South Setting. MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ1</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.15	--
SOILC	--	8.52	8.52
Thickness	m	2.7	11.0
Bulk_Density	gm/cm3	1.39	1.39
Total_Porosity	%	47.7	47.7
Field_Capacity	%	34	--
Conductivity	m/day	0.46	--
Longitudinal_Displacement	m	0.03	67**
Transverse_Displacement	m	--	13.4**
Vertical_Displacement	m	--	0.08**
Effective_Porosity	%	--	20
Velocity	m/yr	--	4.9
Distance	m	--	670
Textural_Class	--	clay loam	clay loam
%_sand	%	31	31
%_silt	%	36	36
%_clay	%	33	33
%_OMC	%	0	0
%_Fe	%	0	0
pH	--	7	7

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

Table 8.2. Hydrogeologic setting data summary of the Kansas City Plant (KCP), East Setting. MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ1</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.15	--
SOILC	--	8.52	8.52
Thickness	m	2.7	11.0
Bulk_Density	gm/cm3	1.39	1.39
Total_Porosity	%	47.7	47.7
Field_Capacity	%	34	--
Conductivity	m/day	0.46	--
Longitudinal_Disp.	m	0.03	67**
Transverse_Disp.	m	--	13.4**
Vertical_Disp.	m	--	0.08**
Effective_Porosity	%	--	20
Velocity	m/yr	--	4.9
Distance	m	--	670
Textural_Class	--	clay loam	clay loam
%_sand	%	31	31
%_silt	%	36	36
%_clay	%	33	33
%_OMC	%	0	0
%_Fe	%	0	0
pH	--	7	7

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

9.0 LABORATORY FOR ENERGY AND HEALTH-RELATED RESEARCH

University of California, Davis (UC Davis) has conducted radiological studies on laboratory animals for the DOE since the 1950s (Schalla 1994). The initial studies were conducted at the UC Davis main campus with full scale studies at the Laboratory for Energy and Health-Related Research (LEHR) beginning in 1960. Portions of the LEHR had previously been used as the UC Davis campus landfill (DOE 1994a). In the early 1970s, a cobalt-60 irradiation facility was constructed at the site to study the effects of chronic exposure to penetrating gamma ray irradiation on bone marrow cells of beagles. The program was terminated in 1985. In 1975, a basic aerosol science program was initiated at the LEHR to evaluate the health effects of airborne materials. In 1983, the Toxic Pollutant Health Research Laboratory was established for the study of highly toxic and carcinogenic materials.

The LEHR is located in the southeastern portion of the Sacramento Valley in Yolo County (Figure 9.1). The facility encompasses a 6-ha (15-acre) portion of land located approximately 2.5 km (1.5 mi) south of the main UC Davis campus and the town of Davis. Topography at the LEHR plant is generally flat with an average elevation of approximately 15 m (50 ft) above mean sea level (Dames and Moore 1992). Land use in the vicinity of the LEHR is predominantly agricultural (DOE 1994a). Approximately 78% of land in the Yolo County is classified as farmland, with 38% being irrigated cropland. The LEHR is bounded on all sides by UC Davis research facilities. Approximately 40% of the LEHR is currently occupied by structures and paved areas, 20% is occupied by dog pens, and 5% is heavily vegetated with large deep rooted vegetation (Dames and Moore 1992).

9.1 CLIMATE

The LEHR area has a "dry summer subtropic" climate (a Mediterranean-type climate regime) (Critchfield 1974). Meteorological data are available from measurements at the Sacramento Municipal Airport in Sacramento, California. On average the maximum daily temperature exceeds 32°C (90°F) on 74 days per year and is below 0°C (32°F) once every 10 years; the minimum daily temperature is below 0°C (32°F) on 16 days per year and a temperature below -18°C (0°F) has not been recorded (DOC 1987d). July is the warmest month, with daily maximum and minimum temperatures averaging 34°C (93°F) and 14°C (58°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 11°C (53°F) and 3°C (38°F), respectively (DOC 1987d).

Annual precipitation at Sacramento is on the order of 43 cm (17 in.), with about 75% falling from November through March (DOC 1987d). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 58 days per year and the area experiences an average of 5 thunderstorm days per year. The average annual snowfall is less

than 1.3 cm (0.5 in.) (DOC 1992a) and a daily snowfall accumulation of 2.5 cm (1 in.) or greater occurs less than once every 20 years (DOC 1987d).

At Sacramento airport, the prevailing wind direction is from the southwest. Wind speeds average about 4 m/s (8 mph) at about 6 m (20 ft). Average wind speeds are highest in June (4 m/s [10 mph]) and lowest in November (3 m/s [6 mph]) (DOC 1987d).

9.2 GEOLOGY

The LEHR is located on sediments that were deposited in a large, asymmetrical structural trough in the Sacramento Valley (Dames and Moore 1992; DOE 1994a). Jurassic- to Eocene-aged sediments were primarily deposited in marine environments with younger, Miocene- to Recent-aged sediments deposited in continental environments. Marine and continental sediments in excess of 9,000 m (30,000 ft) are present along the valley axis. Due to offset of the valley axis, sediments on the western margin of the valley dip more steeply than those of the eastern margin.

Sediments underlying the LEHR are relatively flat-lying. The site and the surrounding area are located on low alluvial plains and fans associated with Putah Creek (Dames and Moore 1992; DOE 1994a). The sediments consist primarily of silts and clays with localized coarse-grained channel deposits. The thickness of the alluvial deposits is approximately 55 m (180 ft). Conformably underlying the fan deposits is the Plio-Pleistocene-aged Tehama Formation, the principal water-bearing unit on the west side of the Sacramento Valley (DOE 1994a). Surface soils at the LEHR are generally composed of a fine sandy loam that ranges in thickness from 0 to 3 m (0 to 10 ft) (Dames and Moore 1992).

9.3 HYDROLOGY

The regional groundwater source in the Sacramento Valley is primarily Pliocene-aged through Pleistocene-aged unconsolidated deposits and the older alluvium (DOE 1994a). Both unconfined and confined aquifers exist in the upper 914 m (3,000 ft) of sediments underlying the valley. No regionally identified confining units exist in the Sacramento Valley. Groundwater flow is generally west and east from the valley sides toward the center of the valley (DOE 1994a). Groundwater recharge is through leakage by streams and rivers, and direct infiltration from precipitation and irrigation.

Groundwater elevations below LEHR vary from approximately 12 m (40 ft) to 20 m (64 ft) below ground surface (DOE 1994a). Water depths are generally highest in early spring and lowest in late summer. Groundwater flow beneath the LEHR is toward the northeast. Recent investigations at the LEHR site divide the saturated zone into two hydrostratigraphic units: Hydrostratigraphic Unit 1 (HSU-1) and HSU-2 (Dames and Moore

1992; DOE 1994a; Schalla 1994). The division is based primarily on the stratigraphy present beneath the LEHR and hydrologic characteristics of the two units (DOE 1994). HSU-1 consists of fine-grained sediments from the water table down to approximately 24 m (80 ft) below ground surface (DOE 1994a; Schalla 1994). The fine-grained sediments consist of very fine-grained sandy silt or silty sand to sandy clay (Schalla 1994). HSU-2 consists of cobbles and gravels located between 24 and 41 m (80 and 135 ft) below ground surface (DOE 1994a). Although these two hydrostratigraphic units do not appear to be separated by a confining unit, they are two distinctly different water-bearing zones with different characteristics. Below HSU-2 is a lower clay zone several meters thick (Schalla 1994).

No natural surface waters exist at the LEHR. Putah Creek borders the southern portion of the LEHR and is separated from the site by its northern levee (DOE 1994a). Putah Creek originates on the eastern slopes of the Coast Range and flows generally southeast. Flow of water into Putah Creek along the reach bordering the LEHR is supplemented by discharge from the UC Davis Wastewater Treatment Plant. The outfall for the plant is located approximately 61 m (200 ft) west of the Old Davis Road, which is essentially the western boundary of the LEHR site.

9.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the LEHR for BEMR modeling purposes. Meteorological data for the installation are presented in Exhibit 9.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 9.2.

A single environmental setting has been developed to describe the LEHR based on the northwest flow of groundwater (Figure 9.2). A brief description of the environmental setting follows. Hydrogeologic data for the LEHR environmental setting is presented in Table 9.1. The average depth to groundwater beneath the LEHR is 16 m (52 ft) with approximately 4 m (13 ft) of water table fluctuation throughout the year (DOE 1994a). A single partially saturated zone (PZ1) with a thickness of 16 m (52 ft) is considered adequate to describe the vadose zone at the LEHR. Based on site descriptions, the average sediment composition is sandy loam (Dames and Moore 1992; DOE 1994a). Additional PZ1 parameters are MEPAS default values with the exception of bulk density, total porosity, and hydraulic conductivity values which were obtained from the Phase II Site Characterization Report for LEHR (Dames and Moore 1992).

The saturated zone setting is divided into two hydrostratigraphic units (HSU-1 and HSU-2) developed and described in previous studies (Dames and Moore 1992; DOE 1994a; and Schalla 1994). HSU-1 (SZ1) consists of fine-grained materials similar to PZ1 (sandy loam) with an average thickness of 8 m (26 ft) based on the presence of fine-grained material

from the water table to approximately 24 m (80 ft) below ground surface (DOE 1994a; Schalla 1994). HSU-2 (SZ2) consists of cobbles and gravel with an average thickness of 17 m (56 ft) (DOE 1994a). A soil classification of sand was selected to represent SZ2 as this value is the coarsest classification available using the MEPAS application guidance. Bulk density, total porosity, and effective porosity values for HSU-1 and HSU-2 were obtained or interpolated from groundwater model input values for the LEHR (Dames and Moore 1992). Groundwater pH values were averaged from Fall quarter, November 1991 sampling data for HSU-1 and HSU-2 (Dames and Moore 1992). All other data parameters are MEPAS default values.

9.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the LEHR are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the review of environmental settings for this installation. Following completion of the environmental settings, Salem Attiga (PNL) and Joe Niland (Dames and Moore) coordinated the review and fine tuning of the settings data. Settings were accepted by installation experts as appropriate for intended BEMR modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

9.6 REFERENCES

Critchfield, H.J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Dames and Moore. 1992. *Phase II Site Characterization Report - LEHR Environmental Restoration, University of California at Davis (FINAL DRAFT)*. Prepared for the U.S. Department of Energy by Dames and Moore, Davis, California.

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Figure 9.1. Location of the Laboratory for Energy and Health-Related Research.

Figure 9.2. Stratigraphic Column for Laboratory for Energy and Health-Related Research Environmental Setting.

EXHIBIT 9.1

Laboratory for Energy related Health Research Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at Sacramento.

Station Name: Sacramento, California Elevation: 5 m Latitude: 38.52°N

Annual Mean Air Temp:	60.6 °F	Reference (a)	Based on observations made from 1950-1986
Anemometer Height:	20.0 ft	Reference (a)	Based on observations made from 1960-1986
Mean Annual Wind Speed:	8.0 mph	Reference (a)	Based on observations made from 1949-1986
Fastest 1-Min Wind Speed:	70.0 mph	Reference (a)	Based on observations made from 1948-1986
Annual Precipitation:	17.1 in	Reference (a)	Based on observations made from 1939-1986
Precipitation Days:	58 yr ⁻¹	Reference (a)	Based on observations made from 1939-1986
Thunderstorms Freq:	5 yr ⁻¹	Reference (a)	Based on observations made from 1948-1986

Avg Morning Mixing Ht:	375 m	Reference (b)
Avg Afternoon Mixing Ht:	1500 m	Reference (b)
Top Soil Moisture Capacity:	2.69 cm	Reference (b)

MEPAS Parameters:	Climatic Region Index:	2	Reference (b)
	Precipitation-Evaporation Index:	41	Reference (b)
	Soil Cons. Serv. Curve Number:	21	Reference (b)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	45.3	4.03	7.4	7.2	10	90	72
Feb	50.3	2.88	7.7	6.3	9	88	62
Mar	53.3	2.06	8.8	5.6	8	85	53
Apr	58.2	1.31	8.9	4.6	5	81	44
May	64.9	0.33	9.3	3.5	3	80	35
Jun	71.3	0.11	9.8	2.2	1	78	31
Jul	75.6	0.05	9.0	1.1	0	76	28
Aug	74.7	0.07	8.6	1.5	0	78	29
Sep	71.7	0.27	7.7	1.9	1	77	32
Oct	63.9	0.86	6.6	3.3	3	80	39
Nov	53.0	2.23	6.2	5.7	7	86	59
Dec	45.5	2.90	6.7	6.8	9	90	71
Reference: ...	↓ (a)	↓ (a)	↓ (a)	↓ (a)	↓ (a)	↓ (a)	↓ (a)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Par IV - Western Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- B: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 9.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Sacramento. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made on-site at 6.1 m (20 ft) above ground level. Data are based on measurements made from 1989 through 1993.

STAB CLASS	WIND DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
A	NORTH	0.00043	0.00034	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00017	0.00011	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00010	0.00009	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00005	0.00005	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00010	0.00005	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00025	0.00014	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00020	0.00014	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00052	0.00030	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00151	0.00133	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00086	0.00078	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00128	0.00098	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00133	0.00103	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00142	0.00103	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00055	0.00046	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00065	0.00046	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00070	0.00050	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00203	0.00300	0.00089	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00101	0.00066	0.00009	0.00000	0.00000	0.00000
B	NORTHEAST	0.00058	0.00032	0.00002	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00040	0.00043	0.00011	0.00000	0.00000	0.00000
B	EAST	0.00059	0.00066	0.00002	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00085	0.00080	0.00018	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00086	0.00103	0.00027	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00142	0.00226	0.00075	0.00000	0.00000	0.00000
B	SOUTH	0.00387	0.00681	0.00389	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00226	0.00510	0.00425	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00229	0.00432	0.00386	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00220	0.00423	0.00279	0.00000	0.00000	0.00000
B	WEST	0.00256	0.00508	0.00286	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00192	0.00332	0.00217	0.00000	0.00000	0.00000
B	NORTHWEST	0.00175	0.00373	0.00199	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00257	0.00405	0.00204	0.00000	0.00000	0.00000
C	NORTH	0.00111	0.00418	0.00425	0.00080	0.00005	0.00000
C	NORTH-NORTHEAST	0.00030	0.00101	0.00053	0.00002	0.00000	0.00000
C	NORTHEAST	0.00026	0.00082	0.00016	0.00000	0.00000	0.00000
C	EAST-NORTHEAST	0.00010	0.00055	0.00005	0.00000	0.00000	0.00000
C	EAST	0.00034	0.00110	0.00016	0.00000	0.00000	0.00000
C	EAST-SOUTHEAST	0.00053	0.00169	0.00055	0.00002	0.00000	0.00000
C	SOUTHEAST	0.00060	0.00206	0.00142	0.00002	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00086	0.00345	0.00254	0.00021	0.00000	0.00000
C	SOUTH	0.00184	0.00764	0.01180	0.00213	0.00002	0.00000
C	SOUTH-SOUTHWEST	0.00089	0.00373	0.01345	0.00352	0.00007	0.00000
C	SOUTHWEST	0.00056	0.00254	0.00976	0.00338	0.00011	0.00000
C	WEST-SOUTHWEST	0.00059	0.00226	0.00437	0.00087	0.00002	0.00000
C	WEST	0.00096	0.00325	0.00352	0.00043	0.00000	0.00000
C	WEST-NORTHWEST	0.00082	0.00350	0.00428	0.00073	0.00002	0.00000
C	NORTHWEST	0.00078	0.00389	0.00645	0.00130	0.00011	0.00002
C	NORTH-NORTHWEST	0.00087	0.00423	0.00672	0.00144	0.00023	0.00005
D	NORTH	0.00127	0.00441	0.00384	0.00437	0.00101	0.00014
D	NORTH-NORTHEAST	0.00051	0.00190	0.00096	0.00027	0.00000	0.00000
D	NORTHEAST	0.00063	0.00142	0.00043	0.00002	0.00000	0.00000
D	EAST-NORTHEAST	0.00057	0.00137	0.00037	0.00011	0.00000	0.00000
D	EAST	0.00116	0.00313	0.00178	0.00041	0.00000	0.00000
D	EAST-SOUTHEAST	0.00147	0.00416	0.00469	0.00215	0.00046	0.00005
D	SOUTHEAST	0.00164	0.00672	0.00862	0.00556	0.00105	0.00014
D	SOUTH-SOUTHEAST	0.00197	0.00732	0.01267	0.00821	0.00169	0.00037
D	SOUTH	0.00283	0.00892	0.01896	0.01468	0.00046	0.00000

EXHIBIT 9.2 (continued)

STAB CLASS	WIND DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
D	SOUTH-SOUTHWEST	0.00103	0.00361	0.01569	0.02767	0.00135	0.00007
D	SOUTHWEST	0.00081	0.00233	0.01047	0.02845	0.00220	0.00007
D	WEST-SOUTHWEST	0.00074	0.00183	0.00345	0.00457	0.00025	0.00000
D	WEST	0.00080	0.00268	0.00167	0.00121	0.00005	0.00000
D	WEST-NORTHWEST	0.00083	0.00270	0.00300	0.00297	0.00034	0.00000
D	NORTHWEST	0.00100	0.00386	0.00494	0.00965	0.00156	0.00005
D	NORTH-NORTHWEST	0.00115	0.00382	0.00624	0.01557	0.00336	0.00041
E	NORTH	0.00000	0.00220	0.00204	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00000	0.00069	0.00032	0.00000	0.00000	0.00000
E	NORTHEAST	0.00000	0.00059	0.00018	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00000	0.00071	0.00000	0.00000	0.00000	0.00000
E	EAST	0.00000	0.00169	0.00034	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00000	0.00377	0.00174	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00000	0.00601	0.00368	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00000	0.00679	0.01082	0.00000	0.00000	0.00000
E	SOUTH	0.00000	0.00766	0.02712	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00000	0.00338	0.01990	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00000	0.00261	0.01180	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00000	0.00156	0.00206	0.00000	0.00000	0.00000
E	WEST	0.00000	0.00185	0.00085	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00000	0.00204	0.00286	0.00000	0.00000	0.00000
E	NORTHWEST	0.00000	0.00222	0.00563	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00000	0.00176	0.00629	0.00000	0.00000	0.00000
F	NORTH	0.00102	0.00407	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00065	0.00192	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00049	0.00156	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00047	0.00130	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00118	0.00389	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00245	0.01063	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00378	0.01992	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00475	0.02580	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00537	0.02673	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00207	0.01059	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00178	0.00780	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00096	0.00464	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00116	0.00407	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00123	0.00434	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00124	0.00659	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00107	0.00533	0.00000	0.00000	0.00000	0.00000
G	NORTH	0.00520	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHEAST	0.00482	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTHEAST	0.00317	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST-NORTHEAST	0.00469	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST	0.00659	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.01179	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHEAST	0.01382	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.01078	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH	0.01611	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHWEST	0.00495	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHWEST	0.00634	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST-SOUTHWEST	0.00507	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST	0.00583	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST-NORTHWEST	0.00583	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTHWEST	0.00380	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHWEST	0.00393	0.00000	0.00000	0.00000	0.00000	0.00000

Table 9.1. Hydrogeologic setting data summary of the Laboratory for Energy and Health-Related Research (LEHR). MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ1</u>	<u>SZ1</u>	<u>SZ2</u>
Darcian_velocity	m/yr	0.09	--	--
SOILC	--	4.90	4.90	4.05
Thickness	m	16	8.0	17.0
Bulk_Density	gm/cm3	1.7	1.7	1.7
Total_Porosity	%	35	35	20
Field_Capacity	%	17.5	--	--
Conductivity	m/day	0.23	--	--
Longitudinal_Disp.	m	0.16	18.3**	18.3**
Transverse_Disp.	m	--	3.7**	3.7**
Vertical_Disp.	m	--	0.02**	0.02**
Effective_Porosity	%	--	22	15
Velocity	m/yr	--	0.76	618.1
Distance	m	--	183	183
Textural_Class	--	sandy loam	sandy loam	Sand
%_sand	%	65	65	95
%_silt	%	25	25	3
%_clay	%	10	10	2
%_OMC	%	0	0	0
%_Fe	%	0	0	0
pH	--	7	7	7.81

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

10.0 LAWRENCE BERKELEY LABORATORY

The Lawrence Berkeley Laboratory (LBL) in Berkeley, California, is a multi-program national laboratory operated for the DOE by the University of California at Berkeley (UCB). The LBL was established in 1931 by Ernest O. Lawrence as a single-purpose accelerator-based research facility located on the UCB campus (LBL 1993). In 1939, the need for higher-energy accelerators resulted in the construction a larger facility at the present LBL site adjacent to the UCB campus. The major role of the LBL is to conduct basic energy research programs such as high-energy physics, nuclear physics, heavy-ion fusion, magnetic fusion energy, x-ray optics, biology, and medicine.

The LBL is located in Alameda County, California, 5 km (3 mi) east of the San Francisco Bay and 24 km (15 mi) northeast of the City of San Francisco (Figure 10.1). The facility encompasses a 14-ha (130-acre) portion of land on the west-facing slope of the Berkeley Hills above the main campus of the UCB. The western portion of the LBL is in the Berkeley city limits while the eastern portion is in the City of Oakland. Much of the area is urbanized, with the communities abutting each other. Some commercial areas are also found west of the site, including Berkeley's central business district (LBL 1992a). Portions of the area surrounding the LBL have been designated natural preservation and ecological study areas by the UCB. The native vegetation at the LBL has been modified by human influence (LBL 1992b). European annual grasses and eucalyptus trees and the introduction of European grazing animals over the past 200 years have significantly altered the population of native plants. Native redwood, oak, laurel, willows and brush populate the Blackberry and Strawberry Canyon areas.

Topography at the LBL is generally hilly with a large percentage of the site having slopes greater than 26 percent. Elevations range from 152 m (500 ft) above mean sea level at the western boundary to 320 m (1,050 ft) above mean sea level at the eastern boundary (LBL 1992a). As a result of the hilly terrain, grading and filling have often been necessary to provide suitable building sites for the laboratory. Areas have been filled with soil up to several meters thick in some of the original ravines and depressions.

10.1 CLIMATE

The LBL area has a "Marine" climate (Critchfield 1974). Meteorological data are available from measurements at the San Francisco International Airport in San Francisco, California. On average the maximum daily temperature exceeds 32°C (90°F) on 4 days per year and a maximum temperature below 0°C (32°F) has not been recorded; the minimum daily temperature is below 0°C (32°F) on 2 days per year and a temperature below -18°C (0°F) has not been recorded (DOC 1987d). July is the warmest month, with daily maximum and minimum temperatures averaging 23°C (73°F) and 12°C (54°F), respectively. January

is the coolest month, with daily maximum and minimum temperatures averaging 13°C (56°F) and 5°C (42°F), respectively (DOC 1987d).

Annual precipitation at San Francisco is on the order of 50 cm (20 in.), with about 80% falling from November through March (DOC 1987d). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 63 days per year and the area experiences an average of 2 thunderstorm days per year. The average annual snowfall is less than 1.3 cm (0.5 in.) (DOC 1992a) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur less than once every 20 years (DOC 1987d).

At the San Francisco airport, the prevailing wind direction is from the west through northwest. Wind speeds average about 5 m/s (11 mph) at 6 m (20 ft). Average wind speeds are highest in June (6 m/s [14 mph]) and lowest in December (3 m/s [7 mph]) (DOC 1987d).

10.2 GEOLOGY

The LBL is located on the eastern edge of a structural depression of Late Tertiary age that forms the San Francisco Bay (LBL 1992b). Three major units have been mapped on the site: the Moraga Formation, the Orinda Formation, and the Great Valley Sequence. The volcanic Moraga Formation covers primarily areas of higher elevation at the LBL. At LBL, the Moraga Formation encompasses a variety of rock types and textures including lavas, breccias, and agglomerates (LBL 1994a). Some are gradational to sedimentary rocks, and appear to be reworked fluvial or lacustrine deposits. The upper Miocene or lower Pliocene Orinda Formation underlies most of the LBL property (LBL 1992b). The Orinda Formation typically outcrops at the LBL as coarse gray-green or gray sandstones with conglomeratic lenses and finer gray or red-brown siltstone interbeds (LBL 1994a). Orinda rocks typically contain a dense clay-rich matrix, which in places is clast-supporting. Calcite may also be present as a cementing agent in these rocks. The western and southern parts of LBL are underlain by upper Cretaceous-aged rocks of the Great Valley Sequence, formerly designated as the "Chico formation" (LBL 1992b). These rocks generally are found in areas of lower elevations at LBL and consist of sandstones, siltstones, and shales typical of marine subtidal and near shore environments (LBL 1994a).

The soil profile developed at the LBL is generally a silty clay which typically is not greater than 0.6 m (2 ft) thick (LBL 1994a). Bedrock at the LBL is relatively weak and weathers deeply, resulting in a colluvial cover reaching up to several meters thick (LBL 1991). Colluvial deposits are primarily located along the bases of slopes and in concavities on the hillsides at the LBL (LBL 1994a). Grading activities have significantly altered the original topography at the LBL with cuts up to 12 m (40 ft) deep and fill up to 21 m (70 ft) in thickness. Fill material generally consists of expansive and non-expansive mineral material mixed with a significant proportion of organic, construction, and other debris (LBL 1994a).

Landslides are a common form of mass wasting in the Berkeley Hills (LBL 1994a). Landslides at LBL occur primarily within the Orinda Formation and at the Moraga/Orinda Formation contact and range from inactive and active translational and rotational slides to shallow mudflows and debris flows. The age of landslide deposits varies considerably from recently active features to landforms that were possibly emplaced millions of years ago.

The LBL site has complex structural geology (LBL 1992b). Two major faults have been identified in the vicinity of LBL, the Hayward Fault Zone and the Wildcat Canyon Fault. The northwest-trending right lateral Hayward Fault Zone is located to the west of the site and is seismically active. The Wildcat Canyon Fault is located on the eastern side of LBL and is inactive. Several other inactive faults also cut through the LBL.

10.3 HYDROLOGY

Highly complex groundwater conditions are present at the LBL as a result of complex geology and rugged terrain (LBL 1991, 1992a). Additionally, the site hydrogeology has been altered by a series of slope stabilization hydraugers (LBL 1992b). Non-hazardous hydrauger discharges feed into Blackberry Creek to the north and Strawberry Creek to the south of LBL (LBL 1991). Both creeks eventually drain into the City of Berkeley storm drainage system which then empties into the San Francisco Bay. Shallow groundwater is generally encountered within about 12 m (40 ft) of the ground surface (LBL 1992a). However, depths to groundwater across the LBL may vary from less than 3 m (10ft) to greater than 27 m (90 ft) (LBL 1994b). Year-round springs, annual surface seeps, and variable water levels in observation wells are all indicative of the discontinuous and localized aquifers present across the LBL (LBL 1991). These conditions are due to a combination of factors, including open-fracture volcanic flow rock, impervious claystone interbeds, permeable sandstone lenses, and irregular fracture patterns present in the bedrock. Shallow water-bearing units generally have low permeabilities (LBL 1992a). Water-bearing formations include unconsolidated colluvial material, sedimentary rocks, and volcanic rocks.

Despite the hydrologic complexities of the site, groundwater generally flows to the south and west and most likely recharges aquifers beneath the UCB campus and the City of Berkeley (LBL 1992b). Currently, groundwater is not used for drinking water at the LBL. The LBL's primary water supply is the East Bay Municipal Utility District's Shasta Reservoir.

Because of LBL's hillside location and moderate annual runoff, surface water drainage is prevalent (LBL 1993). Strawberry Creek drains the southern portion of the site, while Blackberry Creek drains the central portion (LBL 1992a). Both creeks are perennial and fed by springs in the summer, while their tributaries are ephemeral.

10.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the LBL for BEMR modeling purposes. Meteorological data for the installation are presented in Exhibit 10.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 10.2.

Hydrogeologic settings for the LBL are based on generalized groundwater flow paths and are shown in Figure 10.2. Hydrogeologic data for the LBL environmental settings are presented in Tables 10.1 through 10.3. The installation is divided into three distinct settings, one to describe storm flow conditions and the other two to characterize longer time-scale base flows. The storm flow hydrogeologic setting includes the whole site, and is intended to provide an exposure pathway that includes only the shallow subsurface and surface soils. LBL is unique among DOE installations in that it has significant slope stability problems. To alleviate some of these difficulties, the installation has installed numerous hydraugers throughout the site. Hydraugers are, essentially, wells drilled laterally into hill slopes. Their presence helps to increase shallow drainage from the soils, and thereby helps to increase slope stabilities. Runoff from the hydraugers is captured in a series of culvers and storm sewers, and is discharged to the local streams. Therefore, the storm flow setting attempts to capture this "short circuited" flow from the soils to the local surface water systems.

The two base flow settings are based on general groundwater divides existing on the site. The West hydrogeologic setting generally drains to Blackberry Creek, and the South setting drains toward Strawberry Creek. In both cases, users of the BEMR database need to be aware that the actual hydrologic conditions at the LBL are far more complex than can be represented by these settings. The installation is cross cut by several major faults, and flow paths within the regolith and underlying bedrock are convoluted because of poorly characterized land slides and related mass movement features. In both cases, groundwaters in the two hydrogeologic settings discharge directly into the corresponding creeks.

Two surface water systems are potentially affected by the LBL: Blackberry Creek and Strawberry Creek. As discussed above, both systems are captured by the City of Berkeley's storm sewer system, and are piped directly to San Francisco Bay.

10.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the LBL are based on publicly available documents written for DOE environmental programs. Site experts were contacted and chose not to participate in the development and review of environmental settings for this

installation. These simplified environmental settings are considered adequate for BEMR modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

10.6 REFERENCES

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Figure 10.1. Location and Environmental Settings for Lawrence Berkeley Laboratory (LBL) Site.

Figure 10.2. Stratigraphic Column for Lawrence Berkeley Laboratory (LBL) Environmental Settings.

EXHIBIT 10.1

Lawrence Berkley Laboratory Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at San Francisco International Airport.

Station Name: San Francisco International Airport, California
37.62°N

Elevation: 2 m Latitude:

Annual Mean Air Temp: 56.6 °F Reference (a) Based on observations made from 1927-1986
Anemometer Height: 20.0 ft Reference (a) Based on observations made from 1961-1981
Mean Annual Wind Speed: 10.5 mph Reference (a) Based on observations made from 1927-1986
Fastest 1-Min Wind Speed: 58.0 mph Reference (a) Based on observations made from 1949-1986
Annual Precipitation: 19.7 in Reference (a) Based on observations made from 1927-1986
Precipitation Days: 63 yr⁻¹ Reference (a) Based on observations made from 1927-1986
Thunderstorms Freq: 2 yr⁻¹ Reference (a) Based on observations made from 1940-1986

Avg Morning Mixing Ht: 500 m Reference (b)
Avg Afternoon Mixing Ht: 900 m Reference (b)
Top Soil Moisture Capacity: 4.18 cm Reference (b)

MEPAS Parameters: Climatic Region Index: 1 Reference (b)
 Precipitation-Evaporation Index: 44 Reference (b)
 Soil Cons. Serv. Curve Number: 41 Reference (b)

MONTH	MONTHLY AVERAGES						
	TEMP. (°F)	PRECIP. (Inches)	WIND SPEED (MPH)	CLOUD COVER (10ths)	PRECIP. DAYS (#)	DAILY RH	
						MAX (%)	MIN (%)
Jan	48.5	4.65	7.1	6.2	11	86	67
Feb	51.5	3.23	8.6	6.2	10	84	65
Mar	52.8	2.64	10.4	5.7	10	81	63
Apr	54.8	1.53	12.1	5.1	6	81	60
May	57.8	0.32	13.3	4.4	3	83	59
Jun	60.8	0.11	13.9	3.7	1	84	59
Jul	62.2	0.03	13.5	3.0	0	86	59
Aug	63.0	0.05	12.8	3.3	1	86	61
Sep	63.9	0.19	11.0	3.2	1	83	58
Oct	60.6	1.06	9.4	4.0	4	81	59
Nov	54.5	2.35	7.4	5.5	7	83	64
Dec	49.3	3.55	6.9	6.0	10	85	68
Reference: ...	↓ (a)	↓ (a)	↓ (a)	↓ (a)	↓ (a)	↓ (a)	↓ (a)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Par IV - Western Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- B: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 10.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for San Francisco Airport. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made on-site at 6.1 m (20 ft) above ground level. Data are based on measurements made from 1989 through 1993.

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	10 - 16	17 - 21	> 21
A	NORTH	0.00008	0.00025	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00010	0.00030	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00009	0.00027	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00008	0.00014	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00005	0.00007	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00004	0.00002	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00001	0.00002	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00001	0.00002	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00001	0.00002	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00003	0.00000	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00005	0.00007	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00001	0.00002	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00142	0.00279	0.00194	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00203	0.00534	0.00308	0.00000	0.00000	0.00000
B	NORTHEAST	0.00212	0.00621	0.00317	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00173	0.00466	0.00160	0.00000	0.00000	0.00000
B	EAST	0.00113	0.00196	0.00064	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00071	0.00080	0.00014	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00072	0.00050	0.00016	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00079	0.00030	0.00007	0.00000	0.00000	0.00000
B	SOUTH	0.00095	0.00048	0.00027	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00028	0.00018	0.00014	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00041	0.00018	0.00014	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00020	0.00014	0.00018	0.00000	0.00000	0.00000
B	WEST	0.00026	0.00023	0.00039	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00027	0.00030	0.00032	0.00000	0.00000	0.00000
B	NORTHWEST	0.00040	0.00030	0.00043	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00047	0.00059	0.00055	0.00000	0.00000	0.00000
C	NORTH	0.00069	0.00454	0.00384	0.00082	0.00014	0.00000
C	NORTH-NORTHEAST	0.00089	0.00594	0.00427	0.00021	0.00000	0.00000
C	NORTHEAST	0.00087	0.00605	0.00279	0.00002	0.00000	0.00000
C	EAST-NORTHEAST	0.00054	0.00420	0.00178	0.00000	0.00000	0.00000
C	EAST	0.00051	0.00422	0.00219	0.00002	0.00000	0.00000
C	EAST-SOUTHEAST	0.00036	0.00215	0.00132	0.00000	0.00000	0.00000
C	SOUTHEAST	0.00026	0.00274	0.00135	0.00002	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00048	0.00217	0.00053	0.00000	0.00000	0.00000
C	SOUTH	0.00085	0.00151	0.00057	0.00005	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00059	0.00071	0.00043	0.00027	0.00016	0.00002
C	SOUTHWEST	0.00030	0.00039	0.00080	0.00057	0.00009	0.00007
C	WEST-SOUTHWEST	0.00038	0.00078	0.00096	0.00094	0.00011	0.00000
C	WEST	0.00039	0.00094	0.00235	0.00384	0.00265	0.00080
C	WEST-NORTHWEST	0.00028	0.00112	0.00363	0.00521	0.00445	0.00105
C	NORTHWEST	0.00021	0.00119	0.00386	0.00623	0.00404	0.00050
C	NORTH-NORTHWEST	0.00035	0.00137	0.00281	0.00237	0.00043	0.00011
D	NORTH	0.00072	0.00363	0.00358	0.00425	0.00212	0.00094
D	NORTH-NORTHEAST	0.00053	0.00395	0.00253	0.00066	0.00018	0.00000
D	NORTHEAST	0.00067	0.00333	0.00190	0.00100	0.00011	0.00000
D	EAST-NORTHEAST	0.00065	0.00361	0.00196	0.00263	0.00009	0.00005
D	EAST	0.00045	0.00388	0.00276	0.00212	0.00030	0.00007

EXHIBIT 10.2 (continued)

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	10 - 16	17 - 21	> 21
D	EAST-SOUTHEAST	0.00051	0.00260	0.00406	0.00164	0.00014	0.00002
D	SOUTHEAST	0.00074	0.00377	0.00632	0.00388	0.00064	0.00005
D	SOUTH-SOUTHEAST	0.00083	0.00429	0.00616	0.00263	0.00048	0.00007
D	SOUTH	0.00160	0.00616	0.00751	0.00651	0.00199	0.00110
D	SOUTH-SOUTHWEST	0.00078	0.00377	0.00557	0.00575	0.00190	0.00091
D	SOUTHWEST	0.00084	0.00326	0.00623	0.00635	0.00162	0.00071
D	WEST-SOUTHWEST	0.00090	0.00573	0.01356	0.01116	0.00235	0.00048
D	WEST	0.00091	0.00646	0.03151	0.06413	0.02333	0.01007
D	WEST-NORTHWEST	0.00086	0.00495	0.02758	0.07939	0.03206	0.00904
D	NORTHWEST	0.00061	0.00313	0.01119	0.03863	0.01573	0.00253
D	NORTH-NORTHWEST	0.00033	0.00192	0.00190	0.00527	0.00151	0.00023
E	NORTH	0.00000	0.00176	0.00180	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00000	0.00169	0.00114	0.00000	0.00000	0.00000
E	NORTHEAST	0.00000	0.00158	0.00066	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00000	0.00128	0.00121	0.00000	0.00000	0.00000
E	EAST	0.00000	0.00114	0.00116	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00000	0.00112	0.00046	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00000	0.00244	0.00103	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00000	0.00358	0.00096	0.00000	0.00000	0.00000
E	SOUTH	0.00000	0.00715	0.00116	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00000	0.00413	0.00098	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00000	0.00413	0.00100	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00000	0.00553	0.00267	0.00000	0.00000	0.00000
E	WEST	0.00000	0.00623	0.01368	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00000	0.00575	0.03338	0.00000	0.00000	0.00000
E	NORTHWEST	0.00000	0.00313	0.01445	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00000	0.00123	0.00237	0.00000	0.00000	0.00000
F	NORTH	0.00067	0.00169	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00058	0.00144	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00037	0.00119	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00043	0.00105	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00061	0.00103	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00048	0.00068	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00075	0.00205	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00132	0.00400	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00266	0.00753	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00220	0.00667	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00202	0.00685	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00269	0.01066	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00272	0.01338	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00264	0.01313	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00118	0.00523	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00070	0.00187	0.00000	0.00000	0.00000	0.00000
G	NORTH	0.00096	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHEAST	0.00067	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTHEAST	0.00081	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST-NORTHEAST	0.00062	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST	0.00048	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.00081	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHEAST	0.00172	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00240	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH	0.00632	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHWEST	0.00412	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHWEST	0.00685	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST-SOUTHWEST	0.00546	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST	0.00551	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST-NORTHWEST	0.00297	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTHWEST	0.00110	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHWEST	0.00072	0.00000	0.00000	0.00000	0.00000	0.00000

Table 10.1. Hydrogeologic Setting Data Summary of the Lawrence Berkeley Laboratory (LBL), Stormflow Setting. MEPAS parameters are listed for the saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>SZ</u>
Darcian_velocity	m/yr	--
SOILC	--	10.40
Thickness	m	1
Bulk_Density	gm/cm3	1.36
Total_Porosity	%	48.6
Field_Capacity	%	--
Conductivity	m/day	--
Longitudinal_Displacement	m	18.3**
Transverse_Displacement	m	3.66**
Vertical_Displacement	m	0.02**
Effective_Porosity	%	13
Velocity	m/yr	1.0e+05
Distance	m	183
Textural_Class	--	silty clay
%_sand	%	8
%_silt	%	47
%_clay	%	45
%_OMC	%	0
%_Fe	%	0
pH	--	7

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

Table 10.2. Hydrogeologic Setting Data Summary of the Lawrence Berkeley Laboratory (LBL), West Setting. MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

Parameter	Units	PZ1	SZ
Darcian_velocity	m/yr	0.1	--
SOILC	--	5.30	5.30
Thickness	m	14.9	9.1
Bulk_Density	gm/cm3	1.48	1.48
Total_Porosity	%	44.2	44.2
Field_Capacity	%	28	--
Conductivity	m/day	2.16	--
Longitudinal_Displacement	m	0.15	18.3**
Transverse_Displacement	m	--	3.66**
Vertical_Displacement	m	--	0.02**
Effective_Porosity	%	--	15
Velocity	m/yr	--	3.89
Distance	m	--	183
Textural_Class	--	silt	silt
%_sand	%	8	8
%_silt	%	87	87
%_clay	%	5	5
%_OMC	%	0	0
%_Fe	%	0	0
pH	--	7	7

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

Table 10.3. Hydrogeologic Setting Data Summary of the Lawrence Berkeley Laboratory (LBL), South Setting. MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

Parameter	Units	PZ1	SZ
Darcian_velocity	m/yr	0.1	--
SOILC	--	5.30	5.30
Thickness	m	11.6	9.1
Bulk_Density	gm/cm3	1.48	1.48
Total_Porosity	%	44.2	44.2
Field_Capacity	%	28	--
Conductivity	m/day	2.16	--
Longitudinal_Displacement	m	0.12	30.5**
Transverse_Displacement	m	--	6.1**
Vertical_Displacement	m	--	0.04**
Effective_Porosity	%	--	15
Velocity	m/yr	--	4.75
Distance	m	--	305
Textural_Class	--	silt	silt
%_sand	%	8	8
%_silt	%	87	87
%_clay	%	5	5
%_OMC	%	0	0
%_Fe	%	0	0
pH	--	7	7

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

11.0 LAWRENCE LIVERMORE NATIONAL LABORATORY

Lawrence Livermore National Laboratory (LLNL) was established in 1952 to conduct nuclear weapons and controlled thermonuclear research. The laboratory performs research, development, and testing associated with the nuclear design aspects of all phases of the weapons cycle. The LLNL consists of two separate sites: the Livermore Site (Figure 11.1) and Site 300 (see Figure 11.2). The Livermore Site is located near the eastern boundary of the city of Livermore, California, about 55 km (35 mi) east of downtown San Francisco. Site 300 is located in the Altamont Hills of the Diablo Range, approximately 24 km (15 mi) east of the Livermore Site. A majority of materials testing and high explosives diagnostics work for the LLNL is conducted at Site 300.

The developed portion of the Livermore Site occupies 3.3 km² (1.3 mi²) in the Livermore Valley, a depression within the Diablo Range of the California Coast Range Province. With the growth of the city of Livermore, additional land has been acquired to provide an enhanced buffer between Livermore's facilities and encroaching development. The area surrounding the Livermore Site is used for residential, industrial, commercial, and agricultural activities (Sims et al. 1990). Site 300 occupies 30 km² (10 mi²) in the southeastern portion of the Altamont Hills, an area characterized by steep hills and ridges separated by ravines. The elevation at Site 300 ranges from about 150 m (500 ft) to 540 m (1800 ft) above sea level. The area surrounding Site 300 is used by other testing facilities and wind farms, for off-road vehicle recreation, and for grazing cattle and sheep. Ecologically, both sites are located within the California biotic province (DOE and University of California 1992). The Livermore Site is highly disturbed. Site 300 is predominantly a grassland community with isolated brush and shallow-rooted trees (Bryn et al. 1990). A blue oak woodland-type habitat borders the area to the south of Site 300. Within Site 300, smaller areas are dominated by riparian (primarily herbaceous) vegetation or by coastal scrub steppe (Sims et al. 1990).

11.1 CLIMATE

The LLNL area has a "dry summer subtropics" climate (a Mediterranean-type climate regime) (Critchfield 1974). Meteorological data are available from onsite measurements and from measurements at Stockton Metropolitan Airport in Stockton, California. On average, the maximum daily temperature exceeds 32°C (90°F) on 86 days per year and fails to raise above 0°C (32°F) only once every 10 years; the minimum daily temperature is below 0°C (32°F) on 22 days per year and a temperature below -18°C (0°F) has not been recorded (DOC 1987d). July is the warmest month, with daily maximum and minimum temperatures averaging 35°C (95°F) and 16°C (61°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 12°C (53°F) and 3°C (38°F), respectively (DOC 1987d).

Annual precipitation at Stockton is on the order of 36 cm (14 in.), with about 90 % falling from November through April (DOE 1987d). Measurable precipitation (defined as 0.01 in. or greater) is recorded on an average of 52 days per year and the area experiences an average of 38 thunderstorm days per year. A daily snowfall accumulation of 2.5 cm (1 in.) occurs less than once every 20 years (DOC 1987d). At Site 300, onsite monitoring indicates that annual precipitation is on the order of 27 cm (11 in.), about 25 % less than at Stockton.

At the Livermore Site, the prevailing wind direction is from the west through southwest. At Site 300, the prevailing winds are generally from the west-southwest. Local topographic features can cause significant variations in the wind direction and speed across Site 300. Wind speeds at the Stockton airport average about 3 m/s (7 mph) at about 6 m (20 ft) above ground level. Average wind speeds are highest in April and May (4 m/s [9 mph]) and lowest in November (2.6 m/s [6 mph]) (DOC 1987d).

11.2 GEOLOGY

Within the Livermore Valley, valley fill deposits can be divided into three units: Pleistocene and Holocene-age alluvial deposits, the Upper Livermore Formation, and the Lower Livermore Formation (Sims et al. 1990). The Upper Livermore Formation beneath the Livermore site consists of complexly interfingering alluvial sediments of highly variable permeability and thickness. The more permeable deposits vary in thickness from less than 1 m to 10 m. The less permeable deposits are commonly 1 to 7 m (3 to 23 ft) thick, but are locally as thick as 25 m (82 ft). Alluvial deposits of the Upper Livermore Formation are nearly identical to the overlying Pleistocene and Holocene-aged alluvial deposits. The Lower Livermore Formation is composed of both alluvial and lacustrine sediments. The permeable sediments of the Upper and Lower Livermore Formation are separated by a horizontally extensive, low-permeability confining layer that occurs near the top of the Lower Livermore Formation (Layton et al. 1990).

The geology of Site 300 is highly complex (Sims et al. 1990). Alluvium, colluvium, valley fill, and stream deposits dominate the surface of the site. Underlying these are late Tertiary and Quaternary non-marine sediments and terrace deposits. The bedrock underlying most of Site 300 consists chiefly of sedimentary rock of the Miocene Neroly Formation, an interbedded sequence of sandstones, siltstones, claystones, and conglomerates largely derived from volcanic rocks. The Neroly is underlain by sandstones and claystones of the early Miocene Cierbo Formation and Cretaceous Great Valley Sequence. Miocene rocks within the region exhibit complex facies variations and many lithologic dissimilarities due to different depositional environments. In addition to the complicated facies relationships, Site 300 has an extremely complex structural geology. The Patterson Anticline and two major faults (Elk Ravine and Carnegie) cross the site (DOE and University of California 1992). The Patterson Anticline crosses Site 300 near mid-site with a west-northwest/east-southeast

trend. South of the anticlinal crest, bedrock dips southerly toward Corral Hollow. North of the Patterson Anticline, sedimentary beds dip northeast into the trough of a subsidiary syncline (Bryn et al. 1990). The significance of these various facies in combination with the structural complexity of Site 300 is the effect these features have on the hydrology of the region (Kearney, Inc. 1988).

11.3 HYDROLOGY

The sediments underlying the Livermore Site constitute two water-bearing systems: an upper, shallow system in the alluvium and Upper Livermore Formation, and a lower, confined system in the Lower Livermore Formation. Little to no hydraulic communication exists between the sediments of the upper unit and the permeable deposits of the lower unit due to the presence of a confining layer in the upper 10 to 30 m (33 to 100 ft) of the Lower Livermore Formation (Layton et al. 1990). Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Groundwater flow in the valley moves toward the central east-west axis of the valley and then westward through the central basin (Sims et al. 1990).

Site 300 is a large, hydrogeologically diverse area due to the discontinuity of stratigraphic units and the complex structural geology across the region. For this reason, it would be inappropriate to attempt to define common hydrologic units across the entire site (Webster-Scholten 1993). In general, groundwater is found in two major water-bearing zones: an upper aquifer which occurs in the sandstones and conglomerates of the Neroly Formation, and a deeper, confined aquifer within sandstones of the Cierbo Formation or a lower member of the Neroly Formation (Kearney, Inc. 1988). Localized perched aquifers occur in channel and channel margin deposits predominantly of continental origin (Bryn et al. 1990). Environmental investigators at Site 300 have divided the area into discrete "hydrologic units." A hydrologic unit is defined as a group of one or more stratigraphic units that may be considered a single hydraulic system (Webster-Scholten 1993). For each of the six study areas, a unique set of hydrogeologic conditions have been defined and are described in detail below in the environmental settings section.

No perennial surface water exists in the vicinity of the Livermore site (Layton et al. 1990). When surface water is present, it generally drains from the Livermore site to the west through arroyos and intermittent streams. No continuously flowing streams are present in the Site 300 area. Elk Ravine is the major drainageway for most of Site 300; it extends from the northwest portion of the site to the east-central area. The primary drainage in the area around Site 300 is Corral Hollow Creek, an ephemeral stream that borders the site to the south and the southeast. Corral Hollow and Elk Ravine both drain eastward to the San Joaquin River Basin. Twenty-five springs have been identified at Site 300. Of these 25 springs, 19 are perennial, 4 are intermittent, 1 is actually a zone of shallow saturation and not a true spring, and 1 has no available information (Webster-Scholten 1993).

11.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the LLNL for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 11.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 11.2.

Hydrogeologic environmental settings for the LLNL are based on groundwater occurrences. For PEIS modeling purposes, the Livermore Site is modeled using one environmental setting (Figure 11.1). The setting has one partially-saturated zone and one saturated zone. The Site 300 area is divided into 14 hydrogeologic environmental settings (Figure 11.2): General Services Area East, General Services Area West, 834 Area, Building 834 Area Perch, Building 833 Area, Building 833 Area Perch, Pit 6 Area, High Explosives Process Area, High Explosives Process Area Perch 1, High Explosives Process Area Perch 2, Pit-7 Area, Southwest Firing Area, Doall Ravine Area, and East Firing Area. Figures 11.3-11.4 present the environmental settings in stratigraphic columns. Hydrogeologic data for the various settings are presented in Tables 11.1-11.15. A description of the hydrogeology of each environmental setting follows.

11.4.1 Livermore Site

The main Livermore site is modelled as a single environmental setting with one partially-saturated zone and one saturated zone. Although the alluvial sediments of the Livermore formation are quite heterogeneous, this heterogeneity is on too fine a scale to be captured by PEIS modelling methods. The input parameters for the saturated and unsaturated zones were taken from Layton et al. (1990).

11.4.2 General Services Area East

The General Services Area East (GSAE) consists of 6 m (20 ft) of unsaturated alluvium underlain by 43 m (140 ft) of saturated sandstones of either the Cierbo Formation or the Neroly lower sandstone.

11.4.3 General Services Area West

The General Services Area West (GSAW) consists of three partially-saturated zones. The unsaturated zones include 1.5 m (5 ft) of alluvium, 7.6 m (25 ft) of Neroly upper sandstone, and 16.8 m (55 ft) of Neroly middle siltstone. This is underlain by a saturated zone consisting of 91.4 m (300 ft) of Neroly lower sandstone.

11.4.4 Building 834 Area

The Building 834 Area consists of five partially-saturated zones. The unsaturated section consists of 6.1 m (20 ft) of quaternary alluvium, 13.7 m (45 ft) of mudstones including a Pliocene nonmarine unit and the upper mudstone member of the Miocene Neroly Formation, 6.1 m (20 ft) of Neroly upper siltstone, 16.8 m (55 ft) of Neroly upper sandstone, and 15.9 m (52 ft) of Neroly middle siltstone. This is underlain by a saturated zone consisting of 61 m (200 ft) of Neroly lower sandstone. The Pliocene nonmarine unit and Neroly upper mudstones locally serve as an aquitard and perches groundwater in the alluvium. We have therefore included an additional environmental setting to represent the perched groundwater.

11.4.5 Building 833 Area

The Building 833 Area consists of four partially-saturated zones. The unsaturated section consists of 4.6 m (15 ft) of quaternary alluvium, 16.8 m (55 ft) of siltstones including a Pliocene nonmarine unit and the Upper siltstone and claystone member of the Miocene Neroly Formation, 12.5 m (41 ft) of Neroly upper blue sandstone, and 19.8 m (65 ft) of Neroly middle siltstone/claystone. This is underlain by a saturated zone consisting of 61 m (200 ft) of Neroly lower sandstone. The lower sandstone has not been penetrated in the Building 833 area, and the 61 m (200 ft) estimate for the thickness has been taken from the Building 834 area. The Pliocene nonmarine unit locally serves as an aquitard and perches groundwater in the alluvium. We have therefore included an additional environmental setting to represent the perched groundwater.

11.4.6 Pit 6 Area

The Pit 6 Area is modeled using one partially-saturated zone consisting of approximately 7 m (23 ft) of alluvial sandy gravel dominantly of Franciscan origin. Underlying this is a sandstone. To the north, the sandstone unit is the Miocene Neroly lower blue sandstone, and to the south the sandstone is the Miocene Cierbo Formation. Both sandstones have similar lithology with layers of claystone and siltstone.

11.4.7 High Explosives Process Area

There are four partially-saturated zones in the High Explosives Process Area (HEPA). The unsaturated section consists of 7.3 m (24 ft) of alluvium, 18.3 m (60 ft) of Pliocene nonmarine plus Neroly upper siltstone, 16.8 m (55 ft) of Neroly upper sandstone, 29 m (95 ft) of Neroly lower siltstone, and 61 m (200 ft) of Neroly lower sandstone. There is extensive perched groundwater with saturated zones in both the Neroly upper sandstone and the Pliocene nonmarine formation. We have therefore included two additional environmental settings with saturated zones in the Neroly upper sandstone and the Pliocene nonmarine/Neroly upper siltstone to represent the perched groundwater.

11.4.8 Pit 7 Area

The Pit 7 Area is modeled with 8.2 m (27 ft) of unsaturated alluvium underlain by 3.7 m (12 ft) of saturated Neroly lower sandstone. A claystone layer capping the Cierbo Formation generally restricts groundwater to the Neroly lower sandstone, although laterally discontinuous groundwater appears to exist at a depth of 21.3 to 27.4 m (70 to 90 ft) within the Cierbo Formation. Because of the sparse understanding of the extent of this groundwater, we do not include it in the model.

11.4.9 Southwest Firing Area

The unsaturated zone appears to be very thick in the Southwest Firing Area (SWFA) with 55 m (180 ft) of unsaturated alluvium underlain by 3 m (10 ft) of saturated sandstone. Because little information is available about the unsaturated zone in this region, it is simply assumed that the unsaturated zone is similar to that of the surrounding areas.

11.4.10 Doall Ravine Area

The Doall Ravine Area (DRA) is modeled with 12.2 m (40 ft) of unsaturated alluvium underlain by 3 m (10 ft) of saturated Neroly lower sandstone. As in the Pit 7 Area, a claystone layer capping the Cierbo Formation serves as an aquitard. In the Doall Ravine Area, however, there appears to be more extensive groundwater at depth within the Cierbo Formation. Again, because of the lateral extent of these deeper confined water bearing layers, we have chosen to model the Doall Ravine area with a single saturated zone.

11.4.11 East Firing Area

The East Firing Area (EFA) has one partially-saturated zone consisting of 15.2 m (50 ft) of alluvium overlying 3 m (10 ft) of saturated Neroly lower sandstone.

11.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the LLNL are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for LLNL. Frank Gouveia supplied input into the development of the meteorologic environmental settings. Preliminary data for the hydrogeologic environmental settings was obtained from Bryn et al. 1990, Layton et al. 1990, and Webster-Scholten 1993. Michael Taffet of the LLNL will coordinate the onsite review and fine tuning of the settings data for Site 300 and David Layton of the LLNL will coordinate onsite review of the Main Site settings data.

11.6 REFERENCES

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Figure 11.1. Location and Environmental Settings for Lawrence Livermore National Laboratory's (LLNL) Livermore Site. For PEIS modeling purposes, the Livermore Site is characterized by a single environmental setting.

S9405048.15

Figure 11.2. Location and Environmental Settings for Lawrence Livermore National Laboratory's (LLNL) Site 300. For PEIS modeling purposes, Site 300 is divided into 14 environmental settings: General Services Area East (GSAE), General Services Area West (GSAW), 834 Area, 834 Area Perch, 833 Area, 833 Area Perch, Pit 6 Area, High Explosives Process Area (HEPA), HEPA Perch 1, HEPA Perch 2, Pit 7 Area, Southwest Firing Area (SWFA), Doall Ravine Area (DRA), and East Firing Area (EFA). Perched and non-perched zones cover the same region.

Figure 11.3. Stratigraphic Column for Lawrence Livermore National Laboratory (LLNL) Main Site Environmental Setting

Figure 11.4. Lawrence Livermore National Laboratory (LLNL) Site 300 Environmental Settings

M bls = Meters below ground surface

Figure 11.4. (continued)

Figure 11.4. (continued)

EXHIBIT 11.1

Lawrence Livermore National Laboratory (LLNL) Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite and at the Stockton Metropolitan Airport.

Station Name: Stockton Metropolitan Airport, Stockton, California	Elevation: 7 m	Latitude: 37.90°N
Lawrence Livermore National Laboratory, Livermore, California	Elevation: 174 m	Latitude: 37.69°N

Annual Mean Air Temp:	57.3 °F	(LLNL) Reference (B)	
Anemometer Height:	6.7 m	(LLNL) Reference (B)	
	6.1 m	(Stoc) Reference (A)	
Mean Annual Wind Speed:	7.4 mph	(LLNL) Reference (B)	
Fastest 1-Min Wind Speed:	46.0 mph	(Stoc) Reference (A)	Based on 23 years of observations.
Annual Precipitation:	14.4 in.	(LLNL) Reference (B)	Based on observations made from 1931-1960.
Precipitation Days:	52 yr ⁻¹	(Stoc) Reference (A)	Based on 44 years of observations.
Thunderstorms Freq:	3 yr ⁻¹	(Stoc) Reference (A)	Based on 32 years of observations.

Avg Morning Mixing Ht:	450 m	Reference (C)	
Avg Afternoon Mixing Ht:	1000 m	Reference (C)	
Top Soil Moisture Capacity:	1.83 cm	Reference (C)	

MEPAS Parameters:	Climatic Region Index:	2	Reference (C)
	Precipitation-Evaporation Index:	44	Reference (C)
	Soil Cons. Serv. Curve Number:	78	Reference (C)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	45	3.0	6.7	7.4	8.9	90	70
Feb	50	2.0	6.9	6.6	8.3	88	61
Mar	54	1.8	7.7	5.7	8.3	83	51
Apr	59	1.4	8.3	4.8	5.5	78	40
May	66	0.3	9.2	3.4	2.3	74	32
Jun	73	0.1	9.2	2.2	0.7	69	28
Jul	78	0.1	8.2	1.2	0.3	65	26
Aug	77	0.1	7.7	1.4	0.4	67	27
Sep	73	0.2	7.1	1.8	1.1	69	30
Oct	65	0.6	6.4	3.3	3.0	75	38
Nov	53	1.8	5.8	5.8	6.8	85	58
Dec	46	2.4	6.2	7.2	6.4	91	72
Reference: ...	(A)	(A)	(A)	(A)	(A)	(A)	(A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part IV Western Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- B: Unpublished technical data provided by correspondence with Frank Gouveia (Lawrence Livermore National Laboratory), December, 1993.
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 11.2.

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Lawrence Livermore National Laboratory. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made from 1988 through 1992.

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
A	NORTH	0.00374	0.00279	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00261	0.00282	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00187	0.00282	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00217	0.00175	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00145	0.00081	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00104	0.00037	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00120	0.00023	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00088	0.00025	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00143	0.00016	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00185	0.00053	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00367	0.00194	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00768	0.00983	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00743	0.00978	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00512	0.00339	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00464	0.00178	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00378	0.00249	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00104	0.00134	0.00161	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00083	0.00242	0.00201	0.00000	0.00000	0.00000
B	NORTHEAST	0.00055	0.00339	0.00129	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00062	0.00129	0.00046	0.00000	0.00000	0.00000
B	EAST	0.00035	0.00018	0.00025	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00048	0.00016	0.00009	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00021	0.00021	0.00000	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00028	0.00007	0.00007	0.00000	0.00000	0.00000
B	SOUTH	0.00039	0.00007	0.00009	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00069	0.00030	0.00002	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00136	0.00261	0.00074	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00198	0.01011	0.00556	0.00000	0.00000	0.00000
B	WEST	0.00175	0.00644	0.00591	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00111	0.00065	0.00065	0.00000	0.00000	0.00000
B	NORTHWEST	0.00122	0.00065	0.00039	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00102	0.00095	0.00125	0.00000	0.00000	0.00000
C	NORTH	0.00099	0.00113	0.00376	0.00164	0.00000	0.00000
C	NORTH-NORTHEAST	0.00051	0.00302	0.00538	0.00102	0.00000	0.00000
C	NORTHEAST	0.00058	0.00459	0.00842	0.00037	0.00000	0.00000
C	EAST-NORTHEAST	0.00025	0.00044	0.00085	0.00009	0.00000	0.00000
C	EAST	0.00030	0.00021	0.00058	0.00000	0.00000	0.00000
C	EAST-SOUTHEAST	0.00018	0.00032	0.00035	0.00002	0.00000	0.00000
C	SOUTHEAST	0.00021	0.00002	0.00014	0.00005	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00023	0.00009	0.00018	0.00002	0.00000	0.00000
C	SOUTH	0.00051	0.00021	0.00025	0.00000	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00083	0.00102	0.00037	0.00005	0.00000	0.00000
C	SOUTHWEST	0.00125	0.00436	0.00851	0.00157	0.00000	0.00000
C	WEST-SOUTHWEST	0.00141	0.00745	0.01950	0.00300	0.00000	0.00000
C	WEST	0.00113	0.00358	0.02310	0.00348	0.00000	0.00000
C	WEST-NORTHWEST	0.00071	0.00074	0.00222	0.00048	0.00000	0.00000
C	NORTHWEST	0.00069	0.00030	0.00074	0.00012	0.00000	0.00000
C	NORTH-NORTHWEST	0.00076	0.00030	0.00129	0.00065	0.00000	0.00000

EXHIBIT 8.2 (continued)

STAB	DIRECTION FROM WHICH THE CLASS WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
D	NORTH	0.00113	0.00060	0.00192	0.00561	0.00192	0.00037
D	NORTH-NORTHEAST	0.00222	0.00311	0.00948	0.00422	0.00041	0.00000
D	NORTHEAST	0.00284	0.00496	0.01004	0.00115	0.00000	0.00000
D	EAST-NORTHEAST	0.00346	0.00083	0.00076	0.00071	0.00021	0.00000
D	EAST	0.00632	0.00048	0.00069	0.00051	0.00012	0.00000
D	EAST-SOUTHEAST	0.00934	0.00074	0.00025	0.00014	0.00000	0.00000
D	SOUTHEAST	0.00575	0.00028	0.00012	0.00000	0.00000	0.00000
D	SOUTH-SOUTHEAST	0.00372	0.00099	0.00074	0.00016	0.00000	0.00000
D	SOUTH	0.00801	0.00432	0.00129	0.00044	0.00000	0.00000
D	SOUTH-SOUTHWEST	0.01080	0.01327	0.00918	0.00754	0.00088	0.00005
D	SOUTHWEST	0.00812	0.02930	0.04338	0.02503	0.00145	0.00002
D	WEST-SOUTHWEST	0.00505	0.02476	0.02808	0.01375	0.00055	0.00000
D	WEST	0.00302	0.01251	0.02997	0.01791	0.00018	0.00000
D	WEST-NORTHWEST	0.00148	0.00272	0.00305	0.00178	0.00000	0.00000
D	NORTHWEST	0.00088	0.00095	0.00088	0.00025	0.00000	0.00000
D	NORTH-NORTHWEST	0.00090	0.00046	0.00104	0.00069	0.00018	0.00002
E	NORTH	0.00148	0.00060	0.00007	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00252	0.00081	0.00055	0.00000	0.00000	0.00000
E	NORTH EAST	0.00494	0.00249	0.00058	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00616	0.00108	0.00000	0.00000	0.00000	0.00000
E	EAST	0.01038	0.00037	0.00002	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.01290	0.00053	0.00002	0.00000	0.00000	0.00000
E	SOUTH EAST	0.00720	0.00060	0.00000	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00563	0.00085	0.00000	0.00000	0.00000	0.00000
E	SOUTH	0.00870	0.00701	0.00039	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00990	0.01527	0.00581	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00641	0.00731	0.00432	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00390	0.00399	0.00085	0.00000	0.00000	0.00000
E	WEST	0.00226	0.00258	0.00106	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00127	0.00122	0.00065	0.00000	0.00000	0.00000
E	NORTHWEST	0.00108	0.00030	0.00005	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00104	0.00035	0.00014	0.00000	0.00000	0.00000
F	NORTH	0.00579	0.00062	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00757	0.00097	0.00000	0.00000	0.00000	0.00000
F	NORTH EAST	0.01064	0.00168	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.01534	0.00192	0.00000	0.00000	0.00000	0.00000
F	EAST	0.01848	0.00113	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTH EAST	0.01904	0.00076	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.01460	0.00092	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.01197	0.00062	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.01105	0.00115	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00840	0.00115	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00817	0.00143	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00600	0.00069	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00498	0.00097	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00399	0.00030	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00413	0.00060	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00429	0.00062	0.00000	0.00000	0.00000	0.00000

Table 11.1. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Main Site Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.07	--
SOILC		4.05	4.05
Thickness	m	10.0	5.0
Bulk_density	g/cm3	1.64	1.64
Total_porosity	%	30	30
Field_capacity	%	10	--
Conductivity	m/day	4.6	--
Longitudinal_disp.	m	0.10	100.0
Transverse_disp.	m	--	20.0
Vertical_disp.	m	--	0.12
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.12
Distance	m	--	1000.0
Textural_class		sand	sand
%_sand	%	80	80
%_silt	%	10	10
%_clay	%	10	10
%_OMC	%	0.1	0.1
%_Fe	%	0	0
pH		7	7.5

Table 11.2. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300/HEPA Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.07	0.07	0.07	0.07	--
SOILC		4.9	5.3	5.3	5.3	5.3
Thickness	m	7.32	18.3	16.8	29.0	61.0
Bulk_density	g/cm3	1.44	2.17	2.25	2.17	2.25
Total_porosity	%	75	35	34	35	34
Field_capacity	%	25	12	27	12	--
Conductivity	m/day	86.7	1.6e-4	2.59	1.6e-0	--
Longitudinal_disp.	m	0.073	0.18	0.17	0.29	100.0
Transverse_disp.	m	--	--	--	--	20.0
Vertical_disp.	m	--	--	--	--	0.12
Effective_porosity	%	--	--	--	--	25.0
Velocity	m/day	--	--	--	--	3.32
Distance	m	--	--	--	--	1000.0
Textural_class		sandy loam	silt	silt loam	silt	silt loam
%_sand	%	75	10	85	10	85
%_silt	%	20	80	5	80	5
%_clay	%	5	10	10	10	10
%_OMC	%	0.1	0.1	0.1	0.1	0.1
%_Fe	%	0	0	0	0	0
pH		7.6	8.45	8	8	8.1

Table 11.3. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300/HEPA Perch 1 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.07	--
SOILC		4.9	4.05
Thickness	m	7.32	1.83
Bulk_density	g/cm ³	1.44	1.75
Total_porosity	%	75	34
Field_capacity	%	25	--
Conductivity	m/day	86.6	--
Longitudinal_disp.	m	0.073	100.0
Transverse_disp.	m	--	20.0
Vertical_disp.	m	--	0.12
Effective_porosity	%	--	25.0
Velocity	m/day	--	3.32
Distance	m	--	1000.0
Textural_class		sandy loam	sand
%_sand	%	75	100
%_silt	%	20	0
%_clay	%	5	0
%_OMC	%	0.1	0.1
%_Fe	%	0	0
pH		7.6	8.2

Table 11.4. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300/HEPA Perch 2 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	SZ
Darcian_velocity	m/yr	0.07	0.07	--
SOILC		5.3	5.3	8.52
Thickness	m	7.32	18.3	10.7
Bulk_density	g/cm3	1.44	2.17	2.25
Total_porosity	%	75	35	34
Field_capacity	%	25	12	--
Conductivity	m/day	86.6	1.6e-4	--
Longitudinal_disp.	m	0.073	0.183	100.0
Transverse_disp.	m	--	--	20.0
Vertical_disp.	m	--	--	0.12
Effective_porosity	%	--	--	25.0
Velocity	m/day	--	--	0.30
Distance	m	--	--	1000.0
Textural_class		silt loam	silt	clay loam
%_sand	%	75	10	85
%_silt	%	20	80	5
%_clay	%	5	10	10
%_OMC	%	0.1	0.1	0.1
%_Fe	%	0	0	0
pH		7.6	8.7	8

Table 11.5. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300/833 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.07	0.07	0.07	0.07	--
SOILC		5.3	5.3	8.52	5.3	8.52
Thickness	m	4.57	16.8	12.5	19.8	61.0
Bulk_density	g/cm3	1.44	2.17	2.25	2.17	2.25
Total_porosity	%	75	35	34	35	34
Field_capacity	%	25	12	27	12	--
Conductivity	m/day	86.6	1.6e-4	0.29	1.6e-4	--
Longitudinal_disp.	m	0.046	0.168	0.125	0.198	50.0
Transverse_disp.	m	--	--	--	--	10.0
Vertical_disp.	m	--	--	--	--	0.06
Effective_porosity	%	--	--	--	--	--
Velocity	m/day	--	--	--	--	0.13
Distance	m	--	--	--	--	500.0
Textural_class		silt loam	silt	clay loam	silt	clay loam
%_sand	%	75	10	85	10	85
%_silt	%	20	80	5	80	5
%_clay	%	5	10	10	10	10
%_OMC	%	0.1	0.1	0.1	0.1	0.1
%_Fe	%	0	0	0	0	0
pH		7	7	8	8	7.5

Table 11.6. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300/833 Perch 1 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.07	--
SOILC		5.3	10.4
Thickness	m	4.57	0.61
Bulk_density	g/cm3	1.44	2.17
Total_porosity	%	75	35
Field_capacity	%	25	--
Conductivity	m/day	86.6	--
Longitudinal_disp.	m	0.046	50.0
Transverse_disp.	m	--	10.0
Vertical_disp.	m	--	0.06
Effective_porosity	%	--	0.13
Velocity	m/day	--	--
Distance	m	--	500.0
Textural_class		silty loam	silty clay
%_sand	%	75	10
%_silt	%	20	80
%_clay	%	5	10
%_OMC	%	0.1	0.1
%_Fe	%	0	0
pH		7	--

Table 11.7. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300/834 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	PZ5	SZ
Darcian_velocity	m/yr	0.07	0.07	0.07	0.07	0.07	--
SOILC		5.3	11.4	5.3	5.3	5.3	4.05
Thickness	m	6.07	13.7	6.10	16.8	15.8	61.0
Bulk_density	g/cm3	1.44	2.17	2.17	2.25	2.17	2.25
Total_porosity	%	75	30	35	34	35	34
Field_capacity	%	25	9	12	27	12	--
Conductivity	m/day	86.6	8.5e-0	1.6e-0	0.29	1.6e-0	--
Longitudinal_disp.	m	0.06	0.137	0.06	0.17	0.158	50.0
Transverse_disp.	m	--	--	--	--	--	10.0
Vertical_disp.	m	--	--	--	--	--	0.06
Effective_porosity	%	--	--	--	--	--	20.0
Velocity	m/day	--	--	--	--	--	0.13
Distance	m	--	--	--	--	--	500.0
Textural_class		silt loam	clay	silt	silt loam	silt	silt loam
%_sand	%	75	35	10	85	10	85
%_silt	%	20	15	80	5	80	5
%_clay	%	5	50	10	10	10	10
%_OMC	%	0.1	0.1	0.1	0.1	0.1	0.1
%_Fe	%	0	0	0	0	0	0
pH		7.8	8.7	8.7	7.8	8.7	7.8

Table 11.8. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300/834 Perch 1 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.07	--
SOILC		5.3	7.75
Thickness	m	6.10	1.5
Bulk_density	g/cm3	1.44	2.17
Total_porosity	%	75	35
Field_capacity	%	25	--
Conductivity	m/day	347.5	--
Longitudinal_disp.	m	0.061	50.0
Transverse_disp.	m	--	10.0
Vertical_disp.	m	--	0.06
Effective_porosity	%	--	20.0
Velocity	m/day	--	0.13
Distance	m	--	500.0
Textural_class		silty loam	silty clay loam
%_sand	%	75	10
%_silt	%	20	80
%_clay	%	5	10
%_OMC	%	0.1	0.1
%_Fe	%	0	0
pH		7.8	7.8

Table 11.9. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300 EFA Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.07	--
SOILC		5.3	8.52
Thickness	m	15.24	3.05
Bulk_density	g/cm3	1.44	2.25
Total_porosity	%	75	34
Field_capacity	%	25	--
Conductivity	m/day	86.6	--
Longitudinal_disp.	m	0.152	469.5
Transverse_disp.	m	--	100.0
Vertical_disp.	m	--	0.60
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.55
Distance	m	--	5000.0
Textural_class		silt loam	clay loam
%_sand	%	75	85
%_silt	%	20	5
%_clay	%	5	10
%_OMC	%	0.1	0.1
%_Fe	%	0	0
pH		7	7

Table 11.10. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300 Pit 7 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.07	--
SOILC		5.3	8.52
Thickness	m	8.23	3.66
Bulk_density	g/cm3	1.44	2.25
Total_porosity	%	75	34
Field_capacity	%	25	--
Conductivity	m/day	86.6	--
Longitudinal_disp.	m	0.082	469.5
Transverse_disp.	m	--	100.0
Vertical_disp.	m	--	0.60
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.23
Distance	m	--	5000.0
Textural_class		silt loam	clay loam
%_sand	%	75	85
%_silt	%	20	5
%_clay	%	5	10
%_OMC	%	0.1	0.1
%_Fe	%	0	0
pH		7	7

Table 11.11. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300 DRA Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.07	--
SOILC		5.3	8.52
Thickness	m	12.2	3.04
Bulk_density	g/cm3	1.44	2.25
Total_porosity	%	75	34
Field_capacity	%	25	--
Conductivity	m/day	86.6	--
Longitudinal_disp.	m	0.122	469.5
Transverse_disp.	m	--	100.0
Vertical_disp.	m	--	0.60
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.12
Distance	m	--	5000.0
Textural_class		silt loam	clay loam
%_sand	%	75	85
%_silt	%	20	5
%_clay	%	5	10
%_OMC	%	0.1	0.1
%_Fe	%	0	0
pH		7	7

Table 11.12. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300 SWFA Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.07	--
SOILC		5.3	8.52
Thickness	m	54.7	3.05
Bulk_density	g/cm3	1.44	2.25
Total_porosity	%	75	34
Field_capacity	%	25	--
Conductivity	m/day	86.6	--
Longitudinal_disp.	m	0.547	469.5
Transverse_disp.	m	--	100.0
Vertical_disp.	m	--	0.60
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.12
Distance	m	--	5000.0
Textural_class		silt loam	clay loam
%_sand	%	75	85
%_silt	%	20	5
%_clay	%	5	10
%_OMC	%	0.1	0.1
%_Fe	%	0	0
pH		7	7

Table 11.13. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300/GSAE Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.07	--
SOILC		5.3	11.4
Thickness	m	6.10	42.7
Bulk_density	g/cm3	1.44	2.06
Total_porosity	%	75	33.5
Field_capacity	%	25	--
Conductivity	m/day	86.7	--
Longitudinal_disp.	m	0.061	20.0
Transverse_disp.	m	--	4.00
Vertical_disp.	m	--	0.02
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.31
Distance	m	--	200.0
Textural_class		silt loam	clay
%_sand	%	75	35
%_silt	%	20	15
%_clay	%	5	50
%_OMC	%	0.1	0.1
%_Fe	%	0	0
pH		7.9	7.9

Table 11.14. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300W Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	SZ
Darcian_velocity	m/yr	0.07	0.07	0.07	--
SOILC		5.3	5.3	5.3	5.3
Thickness	m	1.52	7.62	16.8	91.4
Bulk_density	g/cm3	1.44	2.25	2.17	2.25
Total_porosity	%	75	34	35	34
Field_capacity	%	25	27	12	--
Conductivity	m/day	0.87	0.29	1.6e-4	--
Longitudinal_disp.	m	0.015	0.076	0.168	20.0
Transverse_disp.	m	--	--	--	4.0
Vertical_disp.	m	--	--	--	0.02
Effective_porosity	%	--	--	--	25.0
Velocity	m/day	--	--	--	0.31
Distance	m	--	--	--	200.0
Textural_class		silt loam	silt loam	silt	silt loam
%_sand	%	75	85	10	85
%_silt	%	20	5	80	5
%_clay	%	5	10	10	10
%_OMC	%	0.1	0.1	0.1	0.1
%_Fe	%	0	0	0	0
pH		8.1	8.1	8.1	7.1

Table 11.15. Hydrogeologic Environmental Setting Data for Lawrence Livermore National Laboratory's Site 300 Pit 6 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.07	--
SOILC		5.3	8.52
Thickness	m	3.05	91.4
Bulk_density	g/cm3	1.44	2.25
Total_porosity	%	75	34
Field_capacity	%	28	--
Conductivity	m/day	347.5	--
Longitudinal_disp.	m	0.031	20.0
Transverse_disp.	m	--	4.0
Vertical_disp.	m	--	0.02
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.03
Distance	m	--	200.0
Textural_class		silt loam	clay loam
%_sand	%	75	85
%_silt	%	20	5
%_clay	%	5	10
%_OMC	%	0.1	0.1
%_Fe	%	0	0
pH		8	8

12.0 LOS ALAMOS NATIONAL LABORATORY

Los Alamos National Laboratory (LANL) is administered for the DOE by the University of California. Since its inception in 1943, the principal mission of LANL has been the design, development, and testing of weapons for the nation's nuclear arsenal. In the fall of 1992, the mission of LANL was reoriented to include multidisciplinary capabilities to solve problems in the civilian sector in addition to its special role in defense, particularly nuclear weapons technology (LANL 1992a).

LANL encompasses 110 km² (44 mi²) in north-central New Mexico and is located on long, narrow mesas, whose tops range in elevation from 2400 m (7,800 ft) on the flanks of the Jemez Mountains to approximately 1900 m (6,200 ft) at their eastern termination above the Rio Grande valley. LANL is situated approximately 97 km (60 mi) north-northeast of Albuquerque and 40 km (25 mi) northwest of Santa Fe (Figure 12.1). Ecologically, the predominant vegetative community types at LANL are ponderosa pine woodland in the western third of the reservation, pinon-juniper in the central third, and juniper-grassland in the eastern third. The pronounced east-west canyon and mesa orientations produce a unique interlocking finger effect among ecological zones, resulting in many transitional overlaps of plant and animal communities at LANL over relatively small areas. Currently, understanding the relationships among these ecosystems is limited by the wide diversity of systems present (LANL 1992a).

12.1 CLIMATE

The LANL has a "semiarid, temperate mountain" climate (Bowen 1990). Meteorological data are available from onsite measurements, with the main monitoring site located in the TA-59 area (on a mesa). On average, the maximum daily temperature exceeds 32°C (90°F) on 2 days per year and is below 0°C (32°F) on 19 days per year; the minimum daily temperature is below 0°C (32°F) on 154 days per year and is below -18°C (0°F) on 2 days per year (Bowen 1990). July is the warmest month, with daily maximum and minimum temperatures averaging 27°C (81°F) and 13°C (55°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 4°C (40°F) and -8°C (17°F), respectively (Bowen 1990). Significant temperature differences will frequently occur between the mesa tops and canyons within LANL, with cooler temperatures in the canyons.

Annual precipitation is on the order of 46 cm (18 in.), with about 40% falling in July and August. Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 89 days per year and the area experiences an average of 58 thunderstorm days per year. The average annual snowfall is 130 cm (52 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 14 days per year (Bowen 1990).

Throughout the year, surface winds are strongly influenced by local and regional complex terrain. Mountain-valley circulation patterns often produce significant diurnal variations in the winds. As a result, wind directions and speeds may vary significantly from location to location on the Pajarito Plateau (Bowen 1990). The prevailing wind direction in the western portion of LANL is from the west-northwest (at the TA-50 and TA-59 monitoring stations); while in the eastern portion of the installation it is from the southwest (at the East Gate and Area G monitoring stations). Over the course of a year, wind speeds average about 3 m/s (6 mph) at about 12 m (39 ft) above ground level (Bowen 1990). Average wind speeds are highest in March (3.6 m/s [8 mph]) and lowest in January and December (2.2 m/s [5 mph]) (Bowen 1990).

12.2 GEOLOGY

The Pajarito Plateau forms a topographically high area along the western margin of the Rio Grande depression. Sediments were eroded from highland masses to the east and west to fill the depression with sedimentary rocks of the Santa Fe Group. Sediments of the middle Miocene-Pleistocene aged Santa Fe Group were deposited directly over Precambrian basement material by a southward flowing river (DOE 1979). The Santa Fe Group consists of a thick series of terrestrial conglomerates, sandstones, and mudstones, with minor sandstones, evaporates, volcanic tuffs, and intercalated basalts (LANL 1992a). Formations of the Santa Fe Group exposed in the Los Alamos area include, from oldest to youngest, the Tesuque Formation, the Puye Conglomerate, and Basaltic Rocks of the Chino Mesa (DOE 1979).

The Tesuque Formation is middle to early Pliocene in age and is composed primarily of siltstones and sandstones with lenses of clay. The late Pliocene Puye Conglomerate is composed of well-rounded pebbles, cobbles, and small boulders of quartzite, quartz, and granite with some volcanic debris in a matrix of arkosic sand. It interfingers with the Tschicoma Formation to the west and the Basaltic Rocks of the Chino Mesa to the east beneath the Pajarito Plateau (DOE 1979). The Tschicoma Formation consists of andesites, dacites, rhyodacites, and quartz latites that were erupted from vents in the central to northeastern Jemez Mountains in late Pliocene to early Pleistocene time (DOE 1979; LANL 1992a). Basalts of the Chino Mesa are a sequence of flows erupted from vents in late Pliocene to middle or late Pleistocene time (DOE 1979).

The volcanic rocks of the Jemez Mountains began during the Pliocene with a series of eruptions which culminated with the Bandelier Tuff, a widespread, voluminous ash flow that caps the Pajarito Plateau (LANL 1992a; DOE 1979). The morphology of the Pajarito Plateau is dominated by the gently eastward-sloping surface of the Bandelier Tuff, which is dissected by numerous steep-sided canyons. The Bandelier Tuff is separated into two members, the lower Otowi Member and the overlying Tshirege Member (LANL 1992a). The Otowi Member is primarily a nonwelded ash flow tuff that is composed of multiple flow

units, is highly porous and poorly indurated (LANL 1992b). The Guaje Pumice Bed at the base of the Otowi Member consists of unsorted pumice fragments that average 2 to 4 cm (0.8 to 1.6 in) in size (LANL 1992a; LANL 1992b). The Tshirege Member of the Bandelier Tuff is the most widespread rock unit on the Pajarito Plateau. The Tshirege Member is composed of multiple flow units of ash flow tuff that display significant variations in welding and alteration. The base of the Tshirege Member is often marked by a bedded, unconsolidated pumice-rich ash fall tuff known as the Tsankawi Pumice Bed (LANL 1992a; LANL 1992b).

12.3 HYDROLOGY

Groundwater occurs in three modes in the Los Alamos Area: 1) water in shallow alluvium in some of the larger canyons, 2) perched water, and 3) the main aquifer of the Los Alamos area (LANL 1992a). These three modes of groundwater occurrence have been developed into three of the four environmental settings for the LANL. The fourth environmental setting is canyon bottoms without alluvial or perched aquifers.

Intermittent and ephemeral streamflows in the canyons of the Pajarito Plateau have deposited alluvium that ranges in thickness to as much as 30 m (100 ft). Only canyons that originate in the Sierra de los Valles or that receive significant quantities of industrial effluent have alluvial aquifers. These criteria are met in lower Pueblo, Los Alamos, Mortandad, and Pajarito canyons. Water infiltrates through the alluvium until the downward movement is impeded by the less permeable tuff and sediments (LANL 1992a).

Perched water at LANL occurs in conglomerates and basalts beneath the alluvium in a limited area in the midreach of the Pueblo Canyon, and in a second area near the confluence of lower Pueblo and Los Alamos canyons. The horizontal extent of the aquifer is limited. The perched water in these two locations is not known to be hydrologically connected with the main aquifer (LANL 1992a).

The main aquifer is the only aquifer capable of supplying municipal and industrial water for the LANL area. The upper surface of the main aquifer rises westward from the Rio Grande through the Tesuque Formation and lower Puye Conglomerate beneath the central and western portion of the plateau (LANL 1992a; DOE 1979). The surface water and groundwater in the alluvium are separated from water in the main aquifer by several hundred feet of unsaturated volcanic tuff and sediments (LANL 1992a). The major recharge area for the deep aquifer is in the intermountain basins formed by the Valles Caldera. The saturated sediments and volcanics in the basin are highly permeable and recharge the main aquifer in sediments of the Tesuque Formation and the Puye Conglomerate. The movement of the main aquifer is east-southeast toward the Rio Grande (DOE 1979).

The major surface water feature of the LANL area is the Rio Grande, which flows southward with a drainage area of approximately 37,00 km² (14,300 mi²) in southern

Colorado and northern New Mexico. The eastern margin of the Pajarito Plateau stands approximately 90 to 275 m (300 to 900 ft) above the Rio Grande (LANL 1992a). In the Los Alamos area, there is intermittent stream flow in canyons cut into the Pajarito Plateau. Perennial flow to the Rio Grande occurs in canyons north and south of LANL. Springs on the slopes of the Sierra de los Valles to the west supply base flow throughout the year to the upper reaches of Guaje, Los Alamos, Pajarito, and Water Canyons, and Canyon del Valle. The volume of flow from the springs is insufficient to maintain surface flow within more than the western third of the canyons before it is depleted (DOE 1979). Eleven drainage areas pass through LANL's eastern boundary (LANL 1992a). Stream flow in these canyons is intermittent (DOE 1979). Runoff from heavy thunderstorms and heavy snowmelt reaches the Rio Grande several times a year in some drainages (LANL 1992a). Runoff from summer storms on the Pajarito Plateau reaches a maximum discharge in less than 2 hours and generally lasts less than 24 hours (LANL 1992b).

12.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of LANL for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 12.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 12.2

For PEIS modeling purposes, LANL is characterized using four hydrogeologic environmental settings (Figure 12.1): 1) water in shallow alluvial aquifers, 2) perched water in canyon bottoms, 3) the main aquifer below mesa tops, and 4) the main aquifer below canyon bottoms (LANL 1992a). Figure 12.2 presents stratigraphic columns for each of these settings. Hydrogeologic data for the various settings are presented in Tables 12.1-12.4. A brief description of the hydrogeology of each region follows.

12.4.1 Alluvial Aquifer Setting (Canyon Alluvial)

Alluvial aquifers exist in lower Pueblo, Los Alamos, Mortandad, and Pajarito canyons. A typical alluvium thickness of 6 m (20 ft) was selected for the alluvial aquifer setting based on an average alluvial thicknesses ranging up to 23 m (75 ft) (LANL 1992a). An average saturated alluvium thickness of 3 m (10 ft) was used in the environmental setting based on a saturated thicknesses ranging from 0 to 6 m (0 to 20 ft) (LANL 1992a). The hydraulic conductivity of the alluvial aquifer is based on a average value obtained from nine slug tests conducted on alluvial wells in Los Alamos canyon (LANL 1993). A sandy loam represents the partially-saturated and saturated zone soils based on the average hydraulic conductivity value for the alluvial material. The remaining values for the alluvial aquifer setting are based on standard default parameters.

12.4.2 Perched Aquifer Setting (Canyon Perch)

Perched bodies of water exist in the mid and lower reaches of Pueblo and Los Alamos Canyons and in the lower reach of Sandia Canyon. The depth to perched water ranges from approximately 27 m (90 ft) in the midreach of Pueblo Canyon to about 137 m (450 ft) in lower Sandia Canyon (LANL 1992a). Perched aquifer environmental settings occur below the alluvial aquifer (canyon alluvial) setting, with the upper 15 m (50 ft) of the perched aquifer setting being identical to the setting for alluvial aquifers. Thickness of geologic units underlying the alluvial material are based on lithologic log data for supply well Otowi 4 located below the confluence of DP and Los Alamos canyons, and average alluvial thickness estimates developed for the alluvial aquifer environmental setting (LANL 1993; LANL 1992a). Total thickness of the partially-saturated zone is 77 m (250 ft) based on depth to water measurements in Otowi 4 (LANL 1993). The estimated thickness of the saturated zone (less than 3 m [10 ft]) is based on unpublished data gathered from a recent drilling project at the LANL.

Units encountered in the perched aquifer setting based on the well Otowi 4 lithologic log include alluvium, the Otowi Member of the Bandelier Tuff, the Puye Conglomerate, Basalts of the Chino Mesa, the Tesuque Formation, and interbedded basalts associated with the Tesuque Formation (LANL 1993). Based on similar hydraulic conductivity averages for the Puye Conglomerate, the Tschicoma Formation, the Tesuque Formation, and basalts interbedded with the Tesuque Formation, these units are combined into the same partially-saturated or saturated zones as necessary (DOE 1979). Soil-texture classifications are based on hydraulic conductivity averages for a given unit or combination of units. For the saturated portion of the overlying alluvium (3 m [10 ft]), field capacity is set equal to the sediment porosity. This is based on the assumption that all available pore spaces of the alluvial material are saturated with water. The remaining values for the perched aquifer setting are based on standard default values.

12.4.3 Canyon Bottom Setting (Arroyo)

As previously mentioned, a total of eleven drainage areas pass through LANL's eastern boundary (LANL 1992a). Stream flow in these canyons is intermittent. Dry canyon bottoms either do not have their headwaters located in the Sierra de los Valles or do not receive significant quantities of industrial effluent to keep an alluvial aquifer saturated. Thicknesses for the various geologic units encountered in the canyon bottom environmental setting are based on lithologic log data for supply well Otowi 4 located below the confluence of DP and Los Alamos canyons, and average alluvial thickness estimates developed for the alluvial aquifer environmental setting (LANL 1993; LANL 1992a). Units encountered and the hydrologic properties of these various units were determined as above in the perched aquifer setting. The total thickness of the partially-saturated zone is 240 m (800 ft) based on depth to water measurements in well Otowi 4 (LANL 1993). Based on an estimated

thickness of potable water in the main aquifer (DOE 1979), the thickness of the saturated zone in the canyon bottom setting is about 370 m (1200 ft).

12.4.4 Mesa Top Setting (Mesa Top)

The main aquifer at LANL is encountered at depths either below the previously discussed canyon bottoms or below the various finger-like mesas of the Pajarito Plateau. Mesa tops are capped with the Bandelier Tuff and its two members, the Tshirege and the Otowi. Proceeding west to east across the Pajarito Plateau, the thickness of the Bandelier Tuff ranges from 320 to 80 m (1050 to 260 ft) (DOE 1979). Values for the hydrogeologic parameters used to represent the mesa top environmental setting are primarily based on data from deep well EGH-LA-1, located in the north-central portion of the Pajarito Plateau between Mortandad and Sandia canyons. Thickness of the partially-saturated zone is approximately 400 m (1300 ft) based on depth to water measurements (LANL 1993). Thickness of the saturated zone is about 370 m (1200 ft) based on an estimated thickness of potable water in the main aquifer (DOE 1979). Hydraulic conductivity estimates and soil-texture classifications were performed as above in the alluvial aquifer, perched aquifer, and canyon bottom settings.

12.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for LANL are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Jean Dewart supplied input into the development of the climate and atmospheric dispersion environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings include Bruce Gallaher, Patrick Longmire, and Dave Broxton. Following completion of the environmental settings, Bruce Gallaher coordinated the onsite review and fine tuning of the settings data. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

12.6 REFERENCES

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Figure 12.2. Stratigraphic Columns for Los Alamos National Laboratory (LANL) Environmental Settings

EXHIBIT 12.1

Los Alamos National Lab (LANL) Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite and in Albuquerque, New Mexico.

Station Name: Los Alamos National Laboratory	Elevation: 2260 m	Latitude: 35.53°N
Albuquerque, New Mexico	Elevation: 1619 m	Latitude: 35.05°N

Annual Mean Air Temp:	48.1 °F	(LANL)	Reference (A)	Based on observations made from 1951-1980.
Anemometer Height:	12.0 m	(LANL)	Reference (A)	
	7.0 m	(Albq)	Reference (B)	
Mean Annual Wind Speed:	6 mph	(LANL)	Reference (A)	
Fastest 1-Min Wind Speed:	90 mph	(Albq)	Reference (B)	Based on 44 years of observations.
Annual Precipitation:	17.8 in.	(LANL)	Reference (A)	Based on observations made from 1980-1988.
Precipitation Days:	89 yr ⁻¹	(LANL)	Reference (A)	Based on observations made from 1951-1980.
Thunderstorms Freq:	58 yr ⁻¹	(LANL)	Reference (A)	
	42 yr ⁻¹	(Albq)	Reference (B)	Based on 47 years of observations.

Avg Morning Mixing Ht:	450 m	Reference (C)
Avg Afternoon Mixing Ht:	2600 m	Reference (C)
Top Soil Moisture Capacity:	3.36 cm	Reference (C)

MEPAS Parameters:	Climatic Region Index:	2	Reference (C)
	Precipitation-Evaporation Index:	46	Reference (C)
	Soil Cons. Serv. Curve Number:	38	Reference (C)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED	COVER	DAYS	MAX	MIN
	(°F)	(Inches)	(MPH)	(10ths)	(#)	(%)	(%)
Jan	29	0.9	5.0	4.8	5.4	71	39
Feb	32	0.7	5.5	4.9	6.0	75	37
Mar	38	1.0	7.1	5.1	7.0	70	34
Apr	46	0.9	8.0	4.6	5.5	60	26
May	55	1.1	7.8	4.2	6.9	62	24
Jun	65	1.1	7.3	3.3	6.0	58	22
Jul	68	3.2	6.0	4.5	14.4	69	30
Aug	66	3.9	5.7	4.3	14.5	77	35
Sep	60	1.6	6.3	3.6	7.9	72	32
Oct	50	1.5	6.2	3.5	5.5	70	34
Nov	38	1.0	5.9	4.0	4.3	70	36
Dec	31	1.0	5.0	4.6	5.1	72	40
Reference: ...	(A)	(A)	(A)	(B)	(A)	(A)	(A)

References

- A: Bowen, B.M. 1990. Los Alamos Climatology. LA-11735-MS, Los Alamos National Laboratory Report, Los Alamos, New Mexico.
- B: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part III Central Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 12.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for at Los Alamos National Laboratory's TA50 Monitoring Site. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made from 1990 through 1992.

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
A	NORTH	0.00094	0.00046	0.00004	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00214	0.00063	0.00004	0.00000	0.00000	0.00000
A	NORTHEAST	0.00462	0.00195	0.00002	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00850	0.00227	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00956	0.00303	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00826	0.00440	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00857	0.00727	0.00010	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00674	0.00703	0.00018	0.00000	0.00000	0.00000
A	SOUTH	0.00395	0.00392	0.00026	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00155	0.00129	0.00014	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00100	0.00067	0.00007	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00068	0.00036	0.00001	0.00000	0.00000	0.00000
A	WEST	0.00055	0.00049	0.00005	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00073	0.00032	0.00006	0.00000	0.00000	0.00000
A	NORTHWEST	0.00083	0.00060	0.00012	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00067	0.00056	0.00013	0.00000	0.00000	0.00000
B	NORTH	0.00035	0.00039	0.00011	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00084	0.00115	0.00024	0.00000	0.00000	0.00000
B	NORTHEAST	0.00205	0.00312	0.00033	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00288	0.00307	0.00005	0.00000	0.00000	0.00000
B	EAST	0.00301	0.00333	0.00004	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00203	0.00418	0.00005	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00212	0.00580	0.00055	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00206	0.00813	0.00202	0.00000	0.00000	0.00000
B	SOUTH	0.00145	0.00651	0.00331	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00083	0.00255	0.00186	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00050	0.00104	0.00081	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00018	0.00079	0.00027	0.00000	0.00000	0.00000
B	WEST	0.00025	0.00073	0.00013	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00020	0.00061	0.00013	0.00000	0.00000	0.00000
B	NORTHWEST	0.00015	0.00083	0.00032	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00024	0.00049	0.00024	0.00000	0.00000	0.00000
C	NORTH	0.00068	0.00133	0.00058	0.00000	0.00000	0.00000
C	NORTH-NORTHEAST	0.00179	0.00383	0.00181	0.00000	0.00000	0.00000
C	NORTHEAST	0.00269	0.00601	0.00195	0.00000	0.00000	0.00000
C	EAST-NORTHEAST	0.00372	0.00315	0.00014	0.00000	0.00000	0.00000
C	EAST	0.00438	0.00427	0.00013	0.00000	0.00000	0.00000
C	EAST-SOUTHEAST	0.00228	0.00483	0.00037	0.00000	0.00000	0.00000
C	SOUTHEAST	0.00169	0.00311	0.00077	0.00000	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00196	0.00854	0.00734	0.00000	0.00000	0.00000
C	SOUTH	0.00252	0.01421	0.01632	0.00000	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00144	0.00747	0.00992	0.00000	0.00000	0.00000
C	SOUTHWEST	0.00090	0.00402	0.00486	0.00000	0.00000	0.00000
C	WEST-SOUTHWEST	0.00044	0.00198	0.00344	0.00000	0.00000	0.00000
C	WEST	0.00037	0.00126	0.00218	0.00000	0.00000	0.00000
C	WEST-NORTHWEST	0.00025	0.00123	0.00182	0.00000	0.00000	0.00000
C	NORTHWEST	0.00043	0.00156	0.00265	0.00000	0.00000	0.00000
C	NORTH-NORTHWEST	0.00038	0.00082	0.00064	0.00000	0.00000	0.00000

EXHIBIT 12.2 (continued)

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
D	NORTH	0.00973	0.00859	0.00124	0.00035	0.00000	0.00000
D	NORTH-NORTHEAST	0.00813	0.00829	0.00350	0.00132	0.00000	0.00000
D	NORTHEAST	0.00721	0.00428	0.00065	0.00010	0.00000	0.00000
D	EAST-NORTHEAST	0.00495	0.00112	0.00007	0.00000	0.00000	0.00000
D	EAST	0.00574	0.00207	0.00011	0.00000	0.00000	0.00000
D	EAST-SOUTHEAST	0.00518	0.00255	0.00024	0.00001	0.00000	0.00000
D	SOUTHEAST	0.00408	0.00114	0.00002	0.00001	0.00000	0.00000
D	SOUTH-SOUTHEAST	0.00578	0.00424	0.00212	0.00021	0.00000	0.00000
D	SOUTH	0.00895	0.01183	0.00387	0.00144	0.00000	0.00000
D	SOUTH-SOUTHWEST	0.00938	0.02134	0.00971	0.00307	0.00005	0.00000
D	SOUTHWEST	0.00779	0.01985	0.00765	0.00195	0.00025	0.00001
D	WEST-SOUTHWEST	0.00625	0.01170	0.00737	0.00263	0.00015	0.00000
D	WEST	0.00612	0.00945	0.01205	0.00696	0.00108	0.00018
D	WEST-NORTHWEST	0.00564	0.00866	0.01357	0.00925	0.00220	0.00146
D	NORTHWEST	0.00815	0.01258	0.00995	0.00309	0.00008	0.00000
D	NORTH-NORTHWEST	0.00799	0.00757	0.00120	0.00023	0.00000	0.00000
E	NORTH	0.00536	0.00268	0.00001	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00290	0.00142	0.00000	0.00000	0.00000	0.00000
E	NORTHEAST	0.00169	0.00029	0.00000	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00087	0.00001	0.00000	0.00000	0.00000	0.00000
E	EAST	0.00086	0.00011	0.00000	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00098	0.00015	0.00000	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00089	0.00013	0.00000	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00137	0.00032	0.00000	0.00000	0.00000	0.00000
E	SOUTH	0.00250	0.00104	0.00000	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00450	0.00349	0.00011	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00583	0.00743	0.00008	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00462	0.01521	0.00064	0.00000	0.00000	0.00000
E	WEST	0.00380	0.00908	0.00300	0.00004	0.00000	0.00000
E	WEST-NORTHWEST	0.00372	0.00820	0.00490	0.00042	0.00000	0.00000
E	NORTHWEST	0.00601	0.02219	0.00129	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00594	0.00772	0.00004	0.00000	0.00000	0.00000
F	NORTH	0.00650	0.00123	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00383	0.00064	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00239	0.00007	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00065	0.00000	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00090	0.00000	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00113	0.00007	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00112	0.00008	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00129	0.00002	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00237	0.00015	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00364	0.00044	0.00006	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00649	0.00140	0.00002	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00844	0.00764	0.00005	0.00000	0.00000	0.00000
F	WEST	0.01059	0.03181	0.00270	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.01078	0.03369	0.00395	0.00000	0.00000	0.00000
F	NORTHWEST	0.01150	0.01784	0.00004	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00881	0.00359	0.00002	0.00000	0.00000	0.00000

Table 12.1. Hydrogeologic Environmental Setting Data for Los Alamos National Laboratory's Mesa Top Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	SZ
Darcian_velocity	m/yr	0.09	0.09	0.09	--
SOILC		11.4	5.39	5.3	5.3
Thickness	m	82.3	142	174	365
Bulk_density	g/cm3	1.39	1.42	1.42	1.42
Total_porosity	%	43	50	46.3	46.3
Field_capacity	%	40	23.5	27.5	--
Conductivity	m/day	0.003	3.36	1.0	--
Longitudinal_disp.	m	.82	1.42	1.74	9662.2
Transverse_disp.	m	--	--	--	1929.4
Vertical_disp.	m	--	--	--	11.2
Effective_porosity	%	--	--	--	18.0
Velocity	m/day	--	--	--	0.30
Distance	m	--	--	--	96622
Textural_class		clay	loam	silt loam	silt loam
%_sand	%	35	45	25	25
%_silt	%	15	40	63	63
%_clay	%	50	15	12	12
%_OMC	%	0	0	0	0
%_Fe	%	0	0	0	0
pH		7	7	7	7

Table 12.2. Hydrogeologic Environmental Setting Data for Los Alamos National Laboratory's Canyon Alluvial Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.09	--
SOILC		4.9	4.9
Thickness	m	12.2	3.05
Bulk_density	g/cm3	1.48	1.48
Total_porosity	%	44.2	44.2
Field_capacity	%	17.5	--
Conductivity	m/day	12.5	--
Longitudinal_disp.	m	0.12	844.3
Transverse_disp.	m	--	169.0
Vertical_disp.	m	--	0.98
Effective_porosity	%	--	22.0
Velocity	m/day	--	0.96
Distance	m	--	8443
Textural_class		sandy loam	sandy loam
%_sand	%	65	65
%_silt	%	25	25
%_clay	%	10	10
%_OMC	%	0	0
%_Fe	%	0	0
pH		7	7

Table 12.3. Hydrogeologic Environmental Setting Data for Los Alamos National Laboratory's Canyon Perch Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.09	0.09	0.09	0.09	--
SOILC		4.9	4.9	5.39	5.3	5.3
Thickness	m	12.2	3.05	45.7	16.2	3.05
Bulk_density	g/cm3	1.48	1.48	1.42	1.42	1.42
Total_porosity	%	44.2	44.2	50	46.3	46.3
Field_capacity	%	17.5	17.5	23.5	27.5	--
Conductivity	m/day	12.5	12.5	3.36	1.0	--
Longitudinal_disp.	m	0.12	.031	0.46	0.16	402.0
Transverse_disp.	m	--	--	--	--	80.4
Vertical_disp.	m	--	--	--	--	0.47
Effective_porosity	%	--	--	--	--	18.0
Velocity	m/day	--	--	--	--	18.3
Distance	m	--	--	--	--	4020
Textural_class		sandy loam	sandy loam	loam	silt loam	silt loam
%_sand	%	65	65	45	25	25
%_silt	%	25	25	40	63	63
%_clay	%	10	10	15	12	12
%_OMC	%	0	0	0	0	0
%_Fe	%	0	0	0	0	0
pH		7	7	7	7	7

Table 12.4. Hydrogeologic Environmental Setting Data for Los Alamos National Laboratory's Arroyo Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	SZ
Darcian_velocity	m/yr	0.09	0.09	0.09	--
SOILC		4.9	5.39	5.3	5.3
Thickness	m	15.2	45.7	183	365
Bulk_density	g/cm3	1.48	1.42	1.42	1.42
Total_porosity	%	44.2	50	46.3	46.3
Field_capacity	%	17.5	23.5	27.5	--
Conductivity	m/day	12.5	3.36	1.0	--
Longitudinal_disp.	m	0.15	0.46	1.83	8050.0
Transverse_disp.	m	--	--	--	1610.0
Vertical_disp.	m	--	--	--	9.33
Effective_porosity	%	--	--	--	18.0
Velocity	m/day	--	--	--	0.30
Distance	m	--	--	--	80500
Textural_class		sandy loam	loam	silt loam	silt loam
%_sand	%	65	45	25	25
%_silt	%	25	40	63	63
%_clay	%	10	15	12	12
%_OMC	%	0	0	0	0
%_Fe	%	0	0	0	0
pH		7	7	7	7

13.0 MAYWOOD SITE

The Maywood Chemical Works processed monazite sands from 1916 through 1956 to extract thorium and rare earth elements. The Maywood Site, one of the DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP) Sites, is located in northern New Jersey, approximately 20 km (12 mi) north-northwest of New York City (Figure 13.1). The installation occupies 5 ha (12 acres) and consists of various commercial buildings and the associated property. Over the years, contaminants have spread from the original production sites to offsite areas through a variety of natural processes and human activities. Although the installation is located in Bergen County, remediation activities span across portions of the boroughs of Maywood and Lodi and the township of Rochelle Park. Ecologically, Maywood lies within the glaciated portion of the Appalachian Oak Forest section of the Eastern Deciduous Forest province; however, no forest is left in this well-developed area (Bailey 1978).

13.1 CLIMATE

The Maywood Site has a "humid continental warm summer" climate (Critchfield 1974). Meteorological data are available from measurements at Newark Airport, located about 25 km (16 mi) south-southwest of Maywood. On average, the maximum daily temperature exceeds 32°C (90°F) on 21 days per year and is below 0°C (32°F) on 22 days per year; the minimum daily temperature is below 0°C (32°F) on 85 days per year and is below -18°C (0°F) on 1 day per year (DOC 1987a). July is the warmest month, with daily maximum and minimum temperatures averaging 30°C (86°F) and 20°C (68°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 3°C (38°F) and -4°C (24°F), respectively (DOC 1987a).

Annual precipitation is on the order of 107 cm (42 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 122 days per year and the area experiences an average of 26 thunderstorm days per year. The average annual snowfall is 56 cm (22 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 7 days per year (DOC 1987a).

Winds at the installation will be affected by its urban setting. The prevailing wind direction at Newark Airport is from the southwest (DOC 1987a). Wind speeds at the airport average about 4.5 m/s (10 mph) at about 6 m (20 ft) above ground level (DOC 1987a). Average wind speeds are highest in March (5.4 m/s [12 mph]) and lowest in August (3.9 m/s [8.7 mph]) (DOC 1987a).

13.2 GEOLOGY

The Maywood Site is located in the Newark Basin, a southeastern extension of the Hudson River Valley Basin. This Triassic-Jurassic aged basin was produced by continental rifting, and is characterized by numerous high-angle, northerly-trending normal faults. Most of the faults exhibit "en echelon" characteristics, with the tilted blocks dipping south (Carswell and Rooney 1976). Sediments in the basin were deposited during or after the rifting event and display the red color common to rocks deposited during that period. Basalts, also a product of rifting, are interbedded within the basin sediments.

Unconsolidated Pleistocene glacial deposits overlie the Mesozoic-aged bedrock. Much of the glacial sediment consists of drift deposited by glaciers as they retreated. Within the portion of the basin occupied by the Maywood Site, the finer clastics are remnants of Lake Hackensack, a large glacial lake that deposited up to 30 m (100 ft) of varved clays and stratified sand bodies. These deposits have resulted in a fairly flat topography in the vicinity of Maywood, with relief being generally less than 9 m (30 ft). As a whole, this portion of the basin slopes gently to the west and drains to the Passaic, Saddle, and Hackensack Rivers.

The unconsolidated sediments near the surface of the Maywood Site can be separated into three units. The uppermost unit consists of floodplain deposits (gravels, sands, and silts) from the Saddle River basin. These deposits have been reworked both by natural processes and by human activities. The middle unit is a darker, clayey deposit with localized paleosols and sand channels. These represent the final stages of Lake Hackensack and its transition to a shallow, swampy environment. The lowermost unit is a group of well-sorted, fine-grained sands and silts; they are commonly stratified, and represent relict deposits of Lake Hackensack. Underlying the sediments is the Passaic Formation, a thick sequence of sandstones and, less commonly, siltstones.

13.3 HYDROLOGY

Groundwater in the Maywood area occurs in both the bedrock of the Passaic Formation and within unconsolidated glacial deposits. The Passaic Formation is a productive aquifer that is a major source of water for public and industrial use (Carswell and Rooney 1976). The top of the Passaic is weathered and fractured, providing a conduit for groundwater flow. The unconsolidated glacial deposits provide a more variable source of groundwater reflecting the variability in sediment permeability. Depth to water is shallow and ranges from approximately 0.6 to 4.6 m (2 to 15 ft) below ground surface. Groundwater flow is generally to the west and southwest toward the Saddle River where groundwater is discharged. Recharge to groundwater is primarily through percolation of precipitation.

The Saddle River is located approximately 0.8 km (0.5 mi) west of Maywood and is the major body of water into which the site drains. Long-term average flow for the Saddle

River at Lodi is 2.8 m³/s (100 ft³/s) (USGS 1991). Two perennial streams, Westerly and Lodi Brooks, empty into the Saddle River via Maywood. The original stream channel for Lodi Brook has been replaced by a subsurface storm drain system. Westerly Brook begins as a natural channel and flows south for about a kilometer before entering a culvert beneath Maywood.

13.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of Maywood for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 13.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 13.2

For PEIS modeling purposes, the Maywood Site is characterized by a single hydrogeologic environmental setting (Figure 13.1). Figure 13.2 presents a stratigraphic column for this setting. The setting has two partially-saturated zones; an upper unit consisting of top soil and fill and a lower unit consisting of glacial deposits. The saturated zone at Maywood is also divided into two units; the upper unit consists of unconsolidated glacial deposits and the lower unit consists of fractured Passaic Formation material. The average depth to groundwater at the Maywood Site is only about 2 m (6 ft). Surface water data for the environmental setting are detailed in Table 13.1 and hydrogeologic data are detailed in Table 13.2.

13.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic data for Maywood was obtained from publicly available documents that are referenced below. The hydrogeologic descriptions for Maywood are based on unpublished and draft remedial action reports written for DOE's FUSRAP environmental programs. In all cases, site experts were not available to assist in the collation and interpretation of data used to develop environmental settings for this installation. The primary contacts and sources of information for this report were obtained from the Oak Ridge National Laboratory, FUSRAP Office. Users of the data are cautioned that much of the data presented in this report is based on preliminary site data that have not gone through final reviews and default values based on soil types. While the data presented here is appropriate for intended PEIS modeling purposes, more accurate and detailed characterizations of the Maywood Site should be sought if the application is for more computationally intensive studies.

13.6 REFERENCES

Bailey, R.G. 1978. *Descriptions of the Ecoregions of the United States*. U.S. Forest Service, Intermountain Region, Ogden, Utah.

Carswell, L.D., and J.G. Rooney. 1976. *Summary of Geology and Ground-Water Responses of Passaic County, New Jersey*. U.S. Geological Survey Water Resources Investigations 75-76 (June).

Critchfield, H.J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

U.S. Department of Commerce (DOC). 1987a. *Local Climatological Data Annual Summaries for 1986 Part I Eastern Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

U.S. Geological Survey (USGS). 1991. *Water Resources Data - New Jersey Water Year 1990: Volume 1. Surface Water Data*. USGS-WDR-NJ-90-1, U.S. Department of the Interior, West Trenton, New Jersey.

S9405048.16

Figure 13.1. Location and Environmental Settings for the Maywood Site, one of DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP) Sites. For PEIS modeling purposes, the Maywood Site is characterized by a single environmental setting.

Figure 13.2. Stratigraphic Column for Maywood Environmental Setting

EXHIBIT 13.1

Maywood Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at the Newark Airport.

Station Name: Newark Airport, Maywood, New Jersey Elevation: 2 m Latitude: 40.70°N

Annual Mean Air Temp: 54.2 °F Reference (A) Based on observations made from 1951-1980.
 Anemometer Height: 6.1 m Reference (A)
 Mean Annual Wind Speed: 10 mph Reference (A) Based on 42 years of observations.
 Fastest Mile: 91 mph Reference (A) Based on 38 years of observations.
 Annual Precipitation: 42.3 in. Reference (A) Based on observations made from 1951-1980.
 Precipitation Days: 122 yr⁻¹ Reference (A) Based on 45 years of observations.
 Thunderstorms Freq: 26 yr⁻¹ Reference (A) Based on 45 years of observations.

Avg Morning Mixing Ht: 800 m Reference (B)
 Avg Afternoon Mixing Ht: 1300 m Reference (B)
 Top Soil Moisture Capacity: 5.8 cm Reference (B)

MEPAS Parameters: Climatic Region Index: 7 Reference (B)
 Precipitation-Evaporation Index: 138 Reference (B)
 Soil Cons. Serv. Curve Number: 60 Reference (B)

MONTHLY AVERAGES							
	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
MONTH	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	31	3.1	11.3	6.4	11.1	74	58
Feb	33	3.1	11.6	6.4	9.6	73	55
Mar	41	4.2	12.1	6.3	11.4	69	51
Apr	52	3.6	11.4	6.3	10.8	65	47
May	62	3.6	10.1	6.5	12.0	71	51
Jun	72	2.9	9.5	6.1	10.2	73	52
Jul	77	3.9	8.9	6.2	9.9	72	51
Aug	76	4.3	8.7	6.0	9.2	76	53
Sep	68	3.7	9.0	5.7	8.3	78	55
Oct	57	3.1	9.4	5.5	7.8	78	54
Nov	47	3.6	10.2	6.4	10.3	77	57
Dec	36	3.4	10.8	6.4	11.1	75	59
Reference: ...	(A)	(A)	(A)	(A)	(A)	(A)	(A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part I Eastern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- B: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 13.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Maywood. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made at Newark International Airport at 6.1 m (20 ft) above ground level. Data are based on measurements made from 1960 through 1964.

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	>25
A	NORTH	0.00003	0.00009	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00004	0.00016	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00006	0.00011	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00003	0.00011	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00003	0.00005	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00006	0.00016	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00001	0.00011	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00007	0.00023	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00003	0.00005	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00004	0.00016	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00003	0.00007	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00001	0.00007	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00003	0.00007	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00005	0.00005	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00003	0.00011	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00003	0.00005	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00024	0.00075	0.00034	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00024	0.00087	0.00066	0.00000	0.00000	0.00000
B	NORTHEAST	0.00049	0.00062	0.00057	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00059	0.00085	0.00059	0.00000	0.00000	0.00000
B	EAST	0.00057	0.00089	0.00046	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00053	0.00153	0.00119	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00049	0.00071	0.00087	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00034	0.00123	0.00119	0.00000	0.00000	0.00000
B	SOUTH	0.00043	0.00112	0.00091	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00057	0.00148	0.00089	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00096	0.00135	0.00151	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00039	0.00137	0.00094	0.00000	0.00000	0.00000
B	WEST	0.00040	0.00071	0.00107	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00036	0.00105	0.00119	0.00000	0.00000	0.00000
B	NORTHWEST	0.00026	0.00064	0.00080	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00031	0.00075	0.00094	0.00000	0.00000	0.00000
C	NORTH	0.00010	0.00075	0.00249	0.00050	0.00002	0.00000
C	NORTH-NORTHEAST	0.00040	0.00164	0.00436	0.00050	0.00000	0.00000
C	NORTHEAST	0.00019	0.00178	0.00347	0.00039	0.00000	0.00000
C	EAST-NORTHEAST	0.00014	0.00085	0.00224	0.00050	0.00000	0.00000
C	EAST	0.00042	0.00096	0.00162	0.00011	0.00005	0.00000
C	EAST-SOUTHEAST	0.00019	0.00110	0.00420	0.00048	0.00002	0.00000
C	SOUTHEAST	0.00007	0.00069	0.00274	0.00050	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00031	0.00123	0.00457	0.00094	0.00002	0.00000
C	SOUTH	0.00031	0.00135	0.00237	0.00027	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00042	0.00194	0.00336	0.00059	0.00007	0.00007
C	SOUTHWEST	0.00078	0.00354	0.00685	0.00153	0.00014	0.00000
C	WEST-SOUTHWEST	0.00024	0.00201	0.00582	0.00130	0.00005	0.00000
C	WEST	0.00024	0.00116	0.00477	0.00139	0.00005	0.00002
C	WEST-NORTHWEST	0.00010	0.00091	0.00518	0.00153	0.00043	0.00007
C	NORTHWEST	0.00019	0.00078	0.00438	0.00153	0.00018	0.00002
C	NORTH-NORTHWEST	0.00005	0.00105	0.00379	0.00110	0.00027	0.00002
D	NORTH	0.00012	0.00107	0.00292	0.00505	0.00071	0.00009
D	NORTH-NORTHEAST	0.00031	0.00320	0.00888	0.00970	0.00082	0.00021
D	NORTHEAST	0.00027	0.00390	0.00840	0.00776	0.00073	0.00027
D	EAST-NORTHEAST	0.00028	0.00206	0.00448	0.00507	0.00096	0.00023
D	EAST	0.00058	0.00272	0.00395	0.00274	0.00032	0.00000
D	EAST-SOUTHEAST	0.00047	0.00356	0.00632	0.00402	0.00037	0.00005

EXHIBIT 13.2 (continued)

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
D	SOUTHEAST	0.00024	0.00148	0.00322	0.00224	0.00002	0.00000
D	SOUTH-SOUTHEAST	0.00040	0.00281	0.00550	0.00498	0.00025	0.00000
D	SOUTH	0.00033	0.00217	0.00400	0.00237	0.00032	0.00005
D	SOUTH-SOUTHWEST	0.00047	0.00299	0.00470	0.00639	0.00130	0.00021
D	SOUTHWEST	0.00041	0.00502	0.00669	0.00936	0.00091	0.00037
D	WEST-SOUTHWEST	0.00024	0.00285	0.00589	0.00817	0.00087	0.00011
D	WEST	0.00014	0.00167	0.00527	0.01034	0.00217	0.00037
D	WEST-NORTHWEST	0.00024	0.00148	0.00482	0.01733	0.00532	0.00110
D	NORTHWEST	0.00017	0.00116	0.00368	0.01637	0.00628	0.00219
D	NORTH-NORTHWEST	0.00003	0.00123	0.00404	0.01327	0.00352	0.00073
E	NORTH	0.00033	0.00144	0.00507	0.00694	0.00055	0.00025
E	NORTH-NORTHEAST	0.00049	0.00333	0.01174	0.01121	0.00094	0.00014
E	NORTHEAST	0.00066	0.00368	0.01073	0.00868	0.00114	0.00030
E	EAST-NORTHEAST	0.00061	0.00251	0.00500	0.00482	0.00116	0.00053
E	EAST	0.00085	0.00386	0.00480	0.00249	0.00027	0.00005
E	EAST-SOUTHEAST	0.00076	0.00311	0.00559	0.00199	0.00018	0.00014
E	SOUTHEAST	0.00049	0.00116	0.00178	0.00030	0.00005	0.00000
E	SOUTH-SOUTHEAST	0.00040	0.00222	0.00493	0.00144	0.00009	0.00002
E	SOUTH	0.00081	0.00297	0.00525	0.00194	0.00007	0.00002
E	SOUTH-SOUTHWEST	0.00122	0.00388	0.00989	0.00637	0.00078	0.00039
E	SOUTHWEST	0.00124	0.00500	0.01208	0.00525	0.00025	0.00005
E	WEST-SOUTHWEST	0.00071	0.00297	0.00582	0.00395	0.00043	0.00005
E	WEST	0.00065	0.00208	0.00687	0.00984	0.00121	0.00011
E	WEST-NORTHWEST	0.00047	0.00130	0.00582	0.01566	0.00235	0.00075
E	NORTHWEST	0.00032	0.00087	0.00493	0.01945	0.00452	0.00132
E	NORTH-NORTHWEST	0.00013	0.00071	0.00468	0.01612	0.00269	0.00069
F	NORTH	0.00149	0.00480	0.00639	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00182	0.00932	0.00856	0.00000	0.00000	0.00000
F	NORTHEAST	0.00238	0.00811	0.00343	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00146	0.00313	0.00075	0.00000	0.00000	0.00000
F	EAST	0.00240	0.00358	0.00066	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00152	0.00354	0.00105	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00089	0.00183	0.00053	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00109	0.00461	0.00231	0.00000	0.00000	0.00000
F	SOUTH	0.00254	0.00662	0.00279	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00405	0.01571	0.00747	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00825	0.03386	0.01258	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00372	0.01806	0.00735	0.00000	0.00000	0.00000
F	WEST	0.00304	0.01480	0.01094	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00202	0.00900	0.01062	0.00000	0.00000	0.00000
F	NORTHWEST	0.00138	0.00532	0.01075	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00087	0.00386	0.00970	0.00000	0.00000	0.00000

Table 13.1. Surface Water Environmental Safety Data for FUSRAP, Maywood, NJ

<u>Parameter</u>	<u>Units</u>	<u>Maywood</u>
Velocity	m/s	0.076
Depth	m	1.22
Width	m	30.5
Discharge	cms	2.86

Table 13.2. Hydrogeologic Environmental Setting Data for Maywood Base Flow Zone.
Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zones (SZ).

Parameter	Units	PZ1	PZ2	SZ1	SZ2
Darcian_velocity	m/yr	0.21	0.21	--	--
SOILC		7.12	4.9	4.9	5.39
Thickness	m	0.91	0.91	2.13	2.44
Bulk_density	g/cm3	1.6	1.48	1.48	1.42
Total_porosity	%	40	20	20	47
Field_capacity	%	22	17.5	--	--
Conductivity	m/day	0.18	25.1	--	--
Longitudinal_disp.	m	0.01	0.01	83.8	83.8
Transverse_disp.	m	--	--	16.8	16.8
Vertical_disp.	m	--	--	0.10	0.10
Effective_porosity	%	--	--	10.0	1.0
Velocity	m/day	--	--	2.51	3.81
Distance	m	--	--	838	838
Textural_class		sandy clay loam	sandy loam	sandy loam	loam
%_sand	%	60	65	65	45
%_silt	%	14	25	25	40
%_clay	%	26	10	10	15
%_OMC	%	0	0	0	0
%_Fe	%	2.2	0	0	0
pH		7	7	7	7

14.0 MOUND PLANT

The Mound Plant originated as part of the Manhattan Engineering District in 1943 for the purpose of determining the chemical and metallurgical properties of polonium (DOE 1992b). In 1956, Mound was assigned to develop and produce detonators for military applications. Mound is currently an integrated research, development, and production facility that operates in support of the DOE weapons and energy programs. Mound manufactures nonnuclear components and tritium-containing components for nuclear weapons (DOE 1992b).

The Mound Plant is located in west-central Ohio, within the city limits of Miamisburg, Ohio (Figure 14.1). The Mound Plant occupies about 1.2 km² (0.5 mi²) and is situated on the highlands overlooking the Great Miami River. The topography consists of generally flat-lying uplands, river valleys, and surficial glacial features such as kames and moraines. The dominant geomorphic features of the plant are two adjoining hills: Main Hill and SM/PP Hill. The two hills are separated by a tributary valley to the Great Miami River and the topographic relief is on the order of 60 m (200 ft). Land use within the vicinity of the site is primarily residential and woodland. Ecologically, the installation is located in the Eastern Deciduous Forest Province in the transition zone between the beech-maple forest and the oak-hickory forest (Bailey 1978). Much of the installation has been altered through construction and use; however, heavily wooded areas do remain on and near the Mound Plant.

14.1 CLIMATE

The Mound Plant has a "humid continental warm summer" climate (Critchfield 1974). Meteorological data are available from measurements at Dayton International Airport, located about 16 km [10 mi] north-northeast of the installation, and limited onsite measurements. On average, the maximum daily temperature exceeds 32°C (90°F) on 16 days per year and is below 0°C (32°F) on 36 days per year; the minimum daily temperature is below 0°C (32°F) on 117 days per year and is below -18°C (0°F) on 7 days per year (DOC 1987a). July is the warmest month, with daily maximum and minimum temperatures averaging 29°C (85°F) and 18°C (64°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 2°C (35°F) and -7°C (19°F), respectively (DOC 1987a).

Annual precipitation is on the order of 107 cm (35 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 132 days per year and the area experiences an average of 41 thunderstorm days per year. The average annual snowfall is 74 cm (29 in.) (DOC 1992a) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 9 days per year (DOC 1987a).

Winds will vary across the installation because of the complex hill-valley topography. The prevailing wind direction at Dayton International Airport is from the south-southwest (DOC 1987a). Wind speeds at the airport average about 4.5 m/s (10 mph) at about 7 m (22 ft) above ground level (DOC 1987a). Average wind speeds are highest in March (5.4 m/s [12 mph]) and lowest in August (3.3 m/s [7.5 mph]) (DOC 1987a).

14.2 GEOLOGY

The general stratigraphy in the Mound Plant region consists of Cambrian through Upper Ordovician sedimentary rocks and Quaternary glacial and alluvial deposits. Bedrock beneath the Mound Plant is composed of thin, nearly flat-lying alternating beds of shale and limestone. The limestone beds range from 5 to 15 cm (2 to 6 in.) in thickness and the shale layers are commonly 1.5 to 2.5 m (5 to 8 ft) thick. Physiographically, the Mound highland areas (Main Hill and SM/PP Hill) are bedrock remnants with a thin veneer of fine-grained glacial till. The glacial till is generally less than 1.5 m (5 ft) thick and primarily consists of clay, silt, and some fine gravel (SAIC 1993a).

The major portion of the Mound Plant is covered by Quaternary deposits ranging in thickness from non-existent where bedrock is exposed to 60 m (195 ft) on the western edge of the site. Along the western boundary, channels were eroded into the bedrock by interglacial streams. These channels generally follow the present course of the Great Miami River and contain coarse-grained glacial outwash material reaching up to approximately 46 m (150 ft) thick. Overlying the glacial outwash in the valley area are fine-grained deposits of silt and clay (SAIC 1993a).

14.3 HYDROLOGY

Glacial outwash deposits in the lower elevation portions of the installation form the major aquifer in the area, the Buried Valley Aquifer (also called the Great Miami Aquifer). The aquifer is a major source for potable water in the area. Typically, groundwater occurs 6 to 8 m (20 to 25 ft) below ground surface in the valley. Within the vicinity of the plant, clay layers within the sands and gravels of outwash deposits create local barriers to groundwater movement.

Groundwater flow in the bedrock beneath the Mound Plant is strongly controlled by differences in physical properties within the shale and limestone beds, and by the frequency, orientation, and size of fractures and parting along bedding planes. The upper levels of the shales at the Mound Plant (on the order of 10 m [33 ft] thick) are fractured and allow for the percolation of some waters into the shales. When water reaches the unfractured materials, it migrates laterally to minor springs that form seeps at several locations on the Main hill. It is assumed that a similar sequence of shale and limestone beds is present beneath the SM/PP

Hill, although only one seep has been mapped on the SM/PP Hill and no flow data are available (SAIC 1993a). Although the bedrock does contain groundwater, there isn't enough fracture permeability to provide a reliable source of groundwater. The glacial tills overlying the bedrock may also contain perched water zones, but are generally too thin to act as a water supply.

Natural groundwater recharge at the Mound Plant occurs primarily in three ways: groundwater flow across the northeastern boundary, infiltration from the Great Miami River to the Buried Valley Aquifer, and infiltration of precipitation. Artificial recharge occurs as a result of runoff ditches, ponds, and leaks from onsite water and sewer lines. Groundwater flow is primarily west into the Buried Valley Aquifer. Additional flow occurs as seeps along the margins of the Main Hill and SM/PP Hill (SAIC 1993a).

The surface-water body of concern at Mound is the Great Miami River, located approximately 450 to 600 m [1500 to 2000 ft] west of the installation. Average flow for the Great Miami River in Miamisburg is $69 \text{ m}^3/\text{s}$ ($2400 \text{ ft}^3/\text{s}$) (USGS 1983). A tributary valley to the Great Miami River is located between the Main Hill and SM/PP Hill. This tributary valley contains the plant drainage ditch, the only perennial stream within the Mound Plant boundaries (SAIC 1993a).

14.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of Mound for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 14.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 14.2.

For PEIS modeling purposes, the Mound Plant is characterized using two hydrogeologic environmental settings (Figure 14.1): the Hilltop and Buried Valley Aquifer. Figure 14.2 presents stratigraphic columns for each of these settings. The Hilltop Setting includes the majority of the physical facilities located on the property. The Buried Valley Aquifer Setting consists of the lowlands adjacent to the Great Miami River. To the extent possible, descriptions for each of the individual settings, and the values for their physical/chemical characteristics were drawn from Mercer et al. (1982) and the DOE (1992b). Surface water data are presented in Table 14.1. Hydrogeologic data are presented in Tables 14.2 and 14.3. A brief description of the hydrogeology of each environmental setting follows.

14.4.1 Hilltop Setting

The areas within the Mound Plant property included in the Hilltop Setting are, for the most part, on uplands. The bedrock underlying these uplands consists of remnant Ordovician shales and interbedded limestones, as already described. A thin veneer of glacial till constitutes the surficial materials in these areas. The Hilltop Setting is modeled as having two partially-saturated zones overlying a relatively thin saturated zone. The uppermost partially-saturated zone is described as a clay-rich till with a low permeability. It is about 3 m (10 ft) thick and limits the amount of precipitation infiltrating to the deeper zones. The second zone is described as a sandy loam with a much higher permeability than the surface tills. In actuality, this is a zone of fractured shales and limestone beds that allow for the relatively rapid vertical migration of waters. At a depth of about 12 m (40 ft), the fracturing in the shales becomes minimal, and effectively creates a lower impermeable boundary. This permits a saturated zone to develop within the shales. This groundwater migrates laterally to springs and seeps around the margins of the hills, as described above, and then, either migrates by shallow subsurface flow toward the river, or infiltrates to the Buried Valley Aquifer. The saturated zone created within the shales is not considered to be a potable aquifer, although it does provide a mechanism for contaminants released to the soils in the area to eventually migrate toward the local surface water resources.

14.4.2 Buried Valley Aquifer Setting

The southwestern quadrant of the Mound property, along with the lower stretch of the tributary valley that originates in the north central portion of the property are included in the Buried Valley Aquifer Setting. The setting is modeled as having a single partially-saturated zone overlying the saturated Buried Valley Aquifer (this is essentially the same unit described as the Great Miami Aquifer in the vicinity of Fernald). Surficial sediments within this setting are composed of clays, silts and sands. These are derived from the reworking of glacial deposits in the area. The underlying Buried Valley Aquifer is a coarse, sandy, gravelly unit that is highly transmissive. Recharge to the aquifer is derived from local infiltration of precipitation, from recharge areas located east and north of the installation, and from some local seepage of waters held in ponds and other drainages on the property. Discharge of waters in the Buried Valley Aquifer are presumably to the Great Miami River, although information regarding the exact flow paths of the groundwater were not obtained for this study. For PEIS modeling purposes, we assume that the flow paths are from the setting toward the southwest where the waters intercept the river.

14.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for Mound are based on publicly available documents written for DOE environmental programs. Site experts were contacted and

participated in the development and review of environmental settings for this installation. Larry Roush supplied input into the development of the climate and atmospheric dispersion environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings include Daniel Carfagno, EG&G-Mound; Brent E. Huntsman, Terran Corp.; and C. William Criswell, Roy F. Weston, Inc. (Albuquerque Office). Data compilation and review was completed during a meeting between the site representatives and the PNL staff on 13 April, 1993. Art Kleinrath, DOE/Mound, coordinated the onsite review and fine tuning of the settings data. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

14.6 REFERENCES

Bailey, R.G. 1978. *Descriptions of the Ecoregions of the United States*. U.S. Forest Service, Intermountain Region, Ogden, Utah.

Critchfield, H.J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Mercer, J.W., S.D. Thomas, and B. Ross. 1982. *Parameter and Variables Appearing in Repository Siting Models*. NUREG/CR-3066, U.S. Nuclear Regulatory commission, Washington, D.C.

Science Applications International Corporation (SAIC). 1993a. *Operable Unit 5: Radioactively Contaminated Soils Remedial Investigation/Feasibility Study Work Plan, Mound Plant, Miamisburg, Ohio (Draft Plan)*. Prepared for EG&G Mound Applied Technologies and the U.S. Department of Energy by Science Applications International Corporation, Dayton, Ohio.

U.S. Department of Commerce (DOC). 1987a. *Local Climatological Data Annual Summaries for 1986 Part I Eastern Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

U.S. Department of Energy (DOE). 1992b. *Remedial Investigation/Feasibility Study: Operable Unit 9, Site-Wide Work Plan, The Mound Plant, Miamisburg, Ohio*. Prepared by the Los Alamos National Laboratory Environmental Restoration Program for the Department of Energy Albuquerque Field Office, Albuquerque, New Mexico.

U.S. Geological Survey (USGS). 1983. *Water Resources Data, Ohio, Water Year 1982: Volume 1, Ohio River Basin*. OH-820-1, Reston, Virginia.

Figure 14.1. Location and Environmental Settings for the Mound Plant. For PEIS modeling purposes, the Mound Plant is divided into two environmental settings: Hilltop and Buried Valley Aquifer (BVA).

Figure 14.2. Stratigraphic Columns for Mound Environmental Settings

EXHIBIT 14.1

Mound Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at Dayton International Airport.

Station Name: Dayton International Airport, Dayton, Ohio Elevation: 303 m Latitude: 39.9°N

Annual Mean Air Temp: 51.9 °F Reference (A) Based on observations made from 1951-1980.
 Anemometer Height: 6.7 m Reference (A)
 Mean Annual Wind Speed: 10 mph Reference (A) Based on 43 years of observations.
 Fastest Mile Wind Speed: 78 mph Reference (A) Based on 41 years of observations.
 Annual Precipitation: 34.7 in. Reference (A) Based on observations made from 1951-1980.
 Precipitation Days: 132 yr⁻¹ Reference (A) Based on 47 years of observations.
 Thunderstorms Freq: 41 yr⁻¹ Reference (A) Based on 47 years of observations.

Avg Morning Mixing Ht: 500 m Reference (B)
 Avg Afternoon Mixing Ht: 1400 m Reference (B)
 Top Soil Moisture Capacity: 4.85 cm Reference (B)

MEPAS Parameters: Climatic Region Index: 4 Reference (B)
 Precipitation-Evaporation Index: 103 Reference (B)
 Soil Cons. Serv. Curve Number: 58 Reference (B)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	27	2.6	11.6	7.6	13.0	77	68
Feb	30	2.1	11.6	7.3	11.0	77	66
Mar	40	3.1	12.1	7.4	13.0	78	62
Apr	52	3.4	11.6	7.0	12.8	75	55
May	62	3.7	9.8	6.7	12.1	76	54
Jun	71	3.8	9.0	6.2	10.4	79	54
Jul	75	3.4	8.0	5.8	10.1	81	55
Aug	73	3.1	7.5	5.7	9.4	86	57
Sep	66	2.4	8.2	5.6	8.1	86	57
Oct	55	2.0	9.0	5.6	8.7	81	57
Nov	42	2.6	11.1	7.3	11.3	81	66
Dec	32	2.5	11.3	7.6	12.1	79	71
Reference: ...	↓ (A)	↓ (A)	↓ (A)	↓ (A)	↓ (A)	↓ (A)	↓ (A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part I Eastern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- B: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 14.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Mound. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 50 m (164 ft) above ground level. Data are based on measurements made from 1989 through 1993.

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (M/S)					
		0.3-1.7	1.8-3.3	3.4-5.3	5.4-8.4	8.5-10.8	< 10.8
A	NORTH	0.00156	0.00362	0.00216	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00147	0.00222	0.00056	0.00000	0.00000	0.00000
A	NORTHEAST	0.00145	0.00154	0.00036	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00116	0.00141	0.00028	0.00000	0.00000	0.00000
A	EAST	0.00113	0.00129	0.00027	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00100	0.00146	0.00033	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00095	0.00149	0.00032	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00094	0.00107	0.00020	0.00000	0.00000	0.00000
A	SOUTH	0.00123	0.00134	0.00035	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00141	0.00132	0.00032	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00154	0.00156	0.00029	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00145	0.00160	0.00029	0.00000	0.00000	0.00000
A	WEST	0.00142	0.00140	0.00025	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00137	0.00160	0.00022	0.00000	0.00000	0.00000
A	NORTHWEST	0.00142	0.00219	0.00053	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00134	0.00284	0.00112	0.00000	0.00000	0.00000
B	NORTH	0.00043	0.00190	0.00492	0.00191	0.00000	0.00000
B	NORTH-NORTHEAST	0.00054	0.00145	0.00221	0.00043	0.00000	0.00000
B	NORTHEAST	0.00040	0.00137	0.00143	0.00014	0.00000	0.00000
B	EAST-NORTHEAST	0.00028	0.00107	0.00121	0.00018	0.00000	0.00000
B	EAST	0.00044	0.00130	0.00127	0.00011	0.00000	0.00000
B	EAST-SOUTHEAST	0.00049	0.00146	0.00119	0.00003	0.00000	0.00000
B	SOUTHEAST	0.00024	0.00130	0.00100	0.00003	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00022	0.00089	0.00068	0.00008	0.00000	0.00000
B	SOUTH	0.00051	0.00145	0.00167	0.00026	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00059	0.00190	0.00142	0.00020	0.00000	0.00000
B	SOUTHWEST	0.00051	0.00177	0.00167	0.00030	0.00000	0.00000
B	WEST-SOUTHWEST	0.00048	0.00138	0.00154	0.00034	0.00000	0.00000
B	WEST	0.00037	0.00133	0.00181	0.00037	0.00000	0.00000
B	WEST-NORTHWEST	0.00048	0.00148	0.00164	0.00028	0.00000	0.00000
B	NORTHWEST	0.00039	0.00149	0.00198	0.00060	0.00000	0.00000
B	NORTH-NORTHWEST	0.00034	0.00136	0.00364	0.00140	0.00000	0.00000
C	NORTH	0.00015	0.00045	0.00028	0.00390	0.00074	0.00000
C	NORTH-NORTHEAST	0.00027	0.00169	0.00281	0.00248	0.00040	0.00000
C	NORTHEAST	0.00022	0.00165	0.00291	0.00159	0.00003	0.00000
C	EAST-NORTHEAST	0.00015	0.00138	0.00243	0.00101	0.00001	0.00000
C	EAST	0.00041	0.00182	0.00296	0.00098	0.00001	0.00000
C	EAST-SOUTHEAST	0.00028	0.00198	0.00251	0.00039	0.00002	0.00000
C	SOUTHEAST	0.00024	0.00168	0.00190	0.00043	0.00001	0.00000
C	SOUTH-SOUTHEAST	0.00029	0.00122	0.00196	0.00070	0.00010	0.00000
C	SOUTH	0.00045	0.00211	0.00401	0.00338	0.00041	0.00000
C	SOUTH-SOUTHWEST	0.00070	0.00317	0.00421	0.00299	0.00046	0.00000
C	SOUTHWEST	0.00048	0.00255	0.00442	0.00429	0.00077	0.00000
C	WEST-SOUTHWEST	0.00027	0.00150	0.00335	0.00377	0.00048	0.00000
C	WEST	0.00032	0.00164	0.00332	0.00378	0.00074	0.00000
C	WEST-NORTHWEST	0.00026	0.00171	0.00354	0.00443	0.00078	0.00000
C	NORTHWEST	0.00032	0.00130	0.00304	0.00350	0.00026	0.00000
C	NORTH-NORTHWEST	0.00014	0.00068	0.00183	0.00386	0.00054	0.00000
D	NORTH	0.00017	0.00119	0.00292	0.00587	0.00124	0.00045
D	NORTH-NORTHEAST	0.00063	0.00541	0.01108	0.00871	0.00144	0.00024
D	NORTHEAST	0.00063	0.00554	0.01275	0.01043	0.00095	0.00006

EXHIBIT 14.2 (continued)

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (M/S)					
		0.3-1.7	1.8-3.3	3.4-5.3	5.4-8.4	8.5-10.8	< 10.8
D	EAST-NORTHEAST	0.00070	0.00465	0.01100	0.00599	0.00035	0.00004
D	EAST	0.00073	0.00472	0.00821	0.00371	0.00033	0.00003
D	EAST-SOUTHEAST	0.00066	0.00305	0.00556	0.00258	0.00047	0.00002
D	SOUTHEAST	0.00054	0.00286	0.00457	0.00281	0.00047	0.00003
D	SOUTH-SOUTHEAST	0.00088	0.00320	0.00708	0.00498	0.00134	0.00020
D	SOUTH	0.00104	0.00446	0.01241	0.01838	0.00748	0.00161
D	SOUTH-SOUTHWEST	0.00139	0.00817	0.01651	0.02548	0.01877	0.00641
D	SOUTHWEST	0.00102	0.00741	0.01380	0.02313	0.01403	0.00441
D	WEST-SOUTHWEST	0.00073	0.00395	0.00877	0.01179	0.00472	0.00213
D	WEST	0.00047	0.00316	0.00908	0.01310	0.00582	0.00279
D	WEST-NORTHWEST	0.00043	0.00222	0.00848	0.01271	0.00450	0.00221
D	NORTHWEST	0.00059	0.00295	0.00817	0.00853	0.00169	0.00047
D	NORTH-NORTHWEST	0.00032	0.00161	0.00480	0.00594	0.00097	0.00026
E	NORTH	0.00055	0.00207	0.00510	0.00181	0.00000	0.00000
E	NORTH-NORTHEAST	0.00093	0.00364	0.00481	0.00086	0.00000	0.00000
E	NORTHEAST	0.00092	0.00442	0.00559	0.00086	0.00000	0.00000
E	EAST-NORTHEAST	0.00066	0.00332	0.00492	0.00101	0.00000	0.00000
E	EAST	0.00070	0.00312	0.00342	0.00085	0.00000	0.00000
E	EAST-SOUTHEAST	0.00048	0.00242	0.00245	0.00261	0.00000	0.00000
E	SOUTHEAST	0.00046	0.00213	0.00294	0.00301	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00065	0.00241	0.00459	0.00306	0.00000	0.00000
E	SOUTH	0.00086	0.00332	0.01086	0.01617	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00084	0.00441	0.01465	0.03001	0.00000	0.00000
E	SOUTHWEST	0.00086	0.00357	0.00790	0.01515	0.00000	0.00000
E	WEST-SOUTHWEST	0.00074	0.00244	0.00263	0.00185	0.00000	0.00000
E	WEST	0.00069	0.00238	0.00239	0.00086	0.00000	0.00000
E	WEST-NORTHWEST	0.00067	0.00295	0.00231	0.00076	0.00000	0.00000
E	NORTHWEST	0.00108	0.00341	0.00211	0.00028	0.00000	0.00000
E	NORTH-NORTHWEST	0.00057	0.00320	0.00307	0.00034	0.00000	0.00000
F	NORTH	0.00169	0.00534	0.00689	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00130	0.00127	0.00058	0.00000	0.00000	0.00000
F	NORTHEAST	0.00155	0.00135	0.00067	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00116	0.00106	0.00062	0.00000	0.00000	0.00000
F	EAST	0.00077	0.00077	0.00051	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00076	0.00087	0.00071	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00084	0.00090	0.00062	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00069	0.00067	0.00094	0.00000	0.00000	0.00000
F	SOUTH	0.00070	0.00084	0.00216	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00062	0.00096	0.00312	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00080	0.00095	0.00124	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00086	0.00067	0.00022	0.00000	0.00000	0.00000
F	WEST	0.00095	0.00068	0.00034	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00131	0.00084	0.00028	0.00000	0.00000	0.00000
F	NORTHWEST	0.00149	0.00096	0.00029	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00147	0.00317	0.00171	0.00000	0.00000	0.00000

Table 14.1. Surface Water Environmental Safety Data for the Mound Plant,
Miamisburg, Ohio

<u>Parameter</u>	<u>Units</u>	<u>Station 1</u>	<u>Station 2</u>	<u>SDE</u>
Velocity	m/s	0.244	0.229	0.122
Depth	m	0.228	0.061	0.122
Width	m	0.101	1.52	0.229
Discharge	cms	5.31e-03	0.022	3.54e-03

Table 14.2. Hydrogeologic Environmental Setting Data for Mound Plant's BVA Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.17	--
SOILC		5.3	4.9
Thickness	m	7.62	22.9
Bulk_density	g/cm ³	2.10	2.10
Total_porosity	%	21.3	44.2
Field_capacity	%	15	--
Conductivity	m/day	1.04	--
Longitudinal_disp.	m	0.15	32.0
Transverse_disp.	m	--	6.4
Vertical_disp.	m	--	0.04
Effective_porosity	%	--	32.0
Velocity	m/day	--	36.6
Distance	m	--	320.0
Textural_class		silt loam	sandy loam
%_sand	%	15	70
%_silt	%	25	25
%_clay	%	60	5
%_OMC	%	1.7	1.7
%_Fe	%	1.2	1.2
pH		7.2	7.2

Table 14.3. Hydrogeologic Environmental Setting Data for Mound Plant's Hill Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	SZ
Darcian_velocity	m/yr	0.17	0.17	--
SOILC		11.4	4.9	4.9
Thickness	m	3.05	9.14	7.62
Bulk_density	g/cm3	2.09	1.48	1.48
Total_porosity	%	30	44.2	44.2
Field_capacity	%	15	12	--
Conductivity	m/day	1.05	30.5	--
Longitudinal_disp.	m	0.06	0.18	58.7
Transverse_disp.	m	--	--	11.7
Vertical_disp.	m	--	--	0.07
Effective_porosity	%	--	--	25.0
Velocity	m/day	--	--	30.5
Distance	m	--	--	586.7
extural_class		clay	sandy loam	sandy loam
%_sand	%	10	65	65
%_silt	%	10	25	25
%_clay	%	80	10	10
%_OMC	%	1.73	0.5	0.5
%_Fe	%	1.9	1	1
pH		6.8	7.4	7.4

15.0 NEVADA TEST SITE

The Nevada Test Site (NTS) was established in 1950 for the purpose of conducting nuclear weapons tests. It is currently used to conduct all United States nuclear weapons tests. These tests are conducted underground for containment of detonation products. Other energy-related projects, such as development of a nuclear-powered rocket and ramjets, have also been carried out on the NTS.

The NTS is approximately 105 km (65 mi) northwest of Las Vegas, Nevada (Figure 15.1). The facility is located on a 3,497-km² (1,350-mi²) portion of restricted-access, federally owned land. NTS is bordered on its west, north, and east sides by the Nellis Air Force Base Range Complex. The southern portion of NTS is bounded by public access land. The topography of NTS is typical of much of the Basin and Range physiographic province of Nevada, Arizona, and Utah. It consists basically of three large valleys (Yucca Flat, Frenchman Flat, and Jackass Flats) surrounded by hills and mountains. The northern and northwestern portions are dominated by two large mesas, Rainier Mesa and Pahute Mesa. Elevations range from 914 m (3,000 ft) on Frenchman Flat to 2,316 m (7,600 ft) on Rainier Mesa. The slopes on the upland surface are steep and dissected, whereas the slopes on the lower surfaces are gentle and alluviated with rock debris from the adjacent highlands (DOE 1992e). The principal effect upon the terrain from nuclear testing has been the creation of numerous dish-shaped surface subsidence craters, particularly in Yucca Flat (DOE 1992e).

Throughout the year, there is not enough water in the area surrounding NTS to support the growth of food crops without irrigation. Variations in precipitation and temperature cause marked differences in plant life. Creosote bush, burro bush, and a variety of yuccas dominate in the bajadas below 1,220 m (4,000 ft), giving way to blackbrush and Joshua trees at slightly higher elevations. Juniper, pinon pine, and sagebrush dominate between 1,830 and 2,290 m (6,000 and 7,500 ft), being replaced by white fir and yellow pine above 2,290 m (7,500 ft) (Winograd and Thordarson 1975).

15.1 CLIMATE

The NTS area is on the boundary of the "mid-latitude arid" and "tropical arid" climate (Critchfield 1974). Meteorological data are available from onsite measurements at Desert Rock Airport and Yucca Flats and from measurements taken in the city of Las Vegas, Nevada. On average the maximum daily temperature in Las Vegas exceeds 32°C (90°F) on 131 days per year and is below 0°C (32°F) once every five years; the minimum daily temperature is below 0°C (32°F) on 33 days per year and a temperature below -18°C (0°F) has not been recorded (DOC 1987c). July is the warmest month, with daily maximum and minimum temperatures averaging 40°C (104°F) and 24°C (76°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 13°C (56°F)

and 1°C (33°F), respectively (DOC 1987c). At higher elevations on the NTS, near-surface air temperatures may be significantly cooler than at Las Vegas.

Annual precipitation at Las Vegas is on the order of 11 cm (4 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 26 days per year and the area experiences an average of 14 thunderstorm days per year. The average annual snowfall is 2.5 cm (1 in.) (DOC 1992a) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of twice every 5 years (DOC 1987c). Data from Desert Rock and Yucca Flats indicate annual precipitation levels between 15 cm (6 in.) and 17 cm (7 in.) with measurable precipitation being recorded on an average of 35 days per year. Even greater levels of precipitation and snowfall occur at higher elevations on the installation.

The winds at the NTS site are strongly influenced by the local and regional complex terrain. At Las Vegas, the prevailing wind direction is from the southwest. Wind speeds average about 4 m/s (9 mph) at about 6 m (20 ft). Average wind speeds are highest in April (5 m/s [11 mph]) and lowest in December (3 m/s [7 mph]) (DOC 1987d).

15.2 GEOLOGY

In general, the geology of the NTS consists of three major rock units. These include 1) complexly folded and faulted sedimentary rocks of Precambrian and Paleozoic age which are overlain in many places by 2) volcanic tuffs and lava of Tertiary age, which (in the valleys) are covered by 3) alluvium of late Tertiary and Quaternary age (DOE 1992e). The following is a brief description of the various rock units.

During Precambrian and Paleozoic time, the region was part of the Cordilleran geosyncline, in which 11,300 m (37,000 ft) of marine sediments accumulated (Winograd and Thordarson 1975). Precambrian and Paleozoic sedimentation was marked by two major sequences of clastic and carbonate sedimentation with clastic sediments composed primarily of shale and quartzite, and carbonate sediments dominated by limestone and dolomite (DOE 1992e). Minor clastic rocks occur within the lower carbonate sequence. No major unconformities occur within the Precambrian and Paleozoic sediments (Winograd and Thordarson 1975). No Mesozoic rocks are known to underlie the NTS or its immediate surrounding area.

Cenozoic volcanic and sedimentary rocks are widely distributed in the region. Tertiary volcanic and associated sedimentary rocks locally reach thicknesses as much as 1,830 m (6,000 ft) in Yucca Flat, 2,590 m (8,500 ft) in western Frenchman Flat and eastern Jackass Flats, 1,525 m (5,000 ft) in western Jackass Flats, and greater than 4,115 (13,500 ft) beneath Pahute Mesa (Winograd and Thordarson 1975). The volcanic rocks are of both pyroclastic and lava-flow origin and include several rock types. Common rock types consist of ash-flow and ash-fall tuffs, and lava flows ranging in composition from rhyolite to basalt.

Associated sedimentary rocks include conglomerates, tuffaceous sandstones and siltstones, calcareous lacustrine tuffs, claystone, and fresh-water limestone (Winograd and Thordarson 1975). Quaternary strata consist primarily of valley fill with minor basalt flows (Winograd and Thordarson 1975). These sediments attain thicknesses of 600 to 900 m (2,000 to 3,000 ft) in the central portions of the valleys (DOE 1992e).

Two major periods of deformation affected the region (Winograd and Thordarson 1975). The first period of deformation occurred in late Mesozoic and possibly early Tertiary time and resulted in folding and thrust faulting of the Precambrian and Paleozoic rocks. During middle to late Cenozoic time the region underwent normal block faulting, producing the Basin and Range topography. Displacements along major strike-slip faults, measured in kilometers, occurred during both periods of deformation. Alluvium is rarely faulted. Compared to the Paleozoic rocks, the Tertiary rocks are relatively undeformed and dips are generally gentle (DOE 1992e).

15.3 HYDROLOGY

Depths to groundwater beneath the NTS vary from about 157 m (515 ft) beneath the Frenchman Flat playa (Winograd and Thordarson 1975) in the southern portion of the NTS to greater than 610 m (2,000 ft) beneath the Pahute Mesa (DOE 1992e). In the eastern portions of the NTS, the water table generally occurs in the alluvium and volcanic rocks above the regional carbonate aquifer. Shallower groundwater flow is generally toward major valleys (Yucca and Frenchman Flats) where it is then deflected downward and joins the regional drainage to the southwest (DOE 1992e).

Two major hydrologic systems exist on the NTS. Groundwater in the northwestern part of the NTS (Pahute Mesa area) flows to the south and southwest toward the Ash Meadows Discharge Area, Oasis Valley near Beatty, Nevada, and Death Valley. Groundwater to the east of the NTS moves from north to south. In the extreme southern portion of the NTS at Mercury Valley, the eastern groundwater flow shifts southwest toward the Ash Meadows Discharge Area. Recharge for the hydrologic systems most likely occurs by precipitation at higher elevations and infiltration along intermittent stream channels and in playas (DOE 1992e). Perched groundwater at the NTS occurs principally within widespread tuff and lava-flow aquitards underlying ridges (Winograd and Thordarson 1975). Perched water is not known to occur within the aquifers or aquitards beneath Yucca Flat, Frenchman Flat, or Jackass Flats.

No natural surface-water bodies are present on the NTS. Water used at the NTS comes from local wells. The Amargosa River which lies to the southwest along the Nevada-California border is an ephemeral stream. Lake Mead is the closest major body of surface water, located approximately 160 km (100 mi) southeast of the NTS.

15.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and two joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of NTS for BEMR modeling purposes. Meteorological data for the installation are presented in Exhibit 15.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibits 15.2 and 15.3.

Hydrogeologic settings for the NTS are based on both physiographic and groundwater considerations, with the boundaries for the individual settings being drawn along current operational unit boundaries. This was done for the convenience of assigning waste units to specific hydrogeologic settings. Six different settings were developed for the site and are shown in Figure 15.2. Three of the hydrogeologic settings consist of intermontane basins including Yucca Flat, Frenchman Flat, and Jackass Flats. The higher elevation areas at the Site are collapsed into the Rainier Meas, Pahute Meas, and Timber Mountain settings. A brief description of the hydrogeology of each setting follows. Hydrogeologic data for the NTS environmental settings are presented in Tables 15.1 through 15.6.

Yucca and Frenchman Flats are hydrologically closed basins that lie along the eastern edge of the NTS. Water captured by the higher elevation areas surrounding these basins is transported to and percolates into the alluvium. Water flow in the shallow subsurface is generally downward until it intersects the tuffaceous material, at which point it migrates laterally toward the vicinity of the playas within each basin. In the areas underlying the playas, water migrates downward through the volcanics and is eventually captured by the regional carbonate aquifer.

Jackass Flats has many similarities with the other two basins. Thick alluvium overlying tertiary volcanics and pre-Mesozoic sediments determine the migration of both water and contaminants in the subsurface. Unlike Yucca or Frenchman Flats, Jackass Flats has surface drainage capable of transporting materials off site. Forty Mile Creek bisects the setting along its western third.

The three higher elevation hydrogeologic settings, Pahute Mesa, Rainier Mesa, and Timber Mountain all lack the highly permeable surface alluvium that is a major characteristic of the other three settings. Dominated by uplifted Tertiary volcanics and Paleozoic sediments, these settings offer distinctly different contaminant transport pathways than occur in the basins. The primary feature distinguishing the three higher elevation settings is the flow path of the regional aquifers underlying each. In the vicinity of Pahute Mesa, the regional groundwater flow is toward the southwest, entering Nellis Air Force Base directly. Water from this aquifer eventually emerges in springs and seeps in the Oasis Valley. Regional groundwater flow associated with Rainier Mesa is complex. Components of flow from the central and western portions of the setting converge and migrate into the Yucca Flat area. In the more eastern portions of this setting, regional groundwater flow is toward the southeast. For the purposes of the BEMR project, this setting is modeled as having a

dominant groundwater flow component toward the south, into Yucca Flat. As with Rainier Mesa, groundwater underlying the Timber Mountain setting is controlled to a large degree by topography and is complex. In general, it is assumed that the dominant component of the flow is toward the south and into the Jackass Flats area.

15.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the NTS are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Charles Steadman supplied input into the development of the meteorologic environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings included Frank Maxwell, Environmental Restoration Division, DOE, Nevada Field Office, and Doug Trudeau and James Cole of the U.S.G.S. It should be noted that because of the size of NTS, the hydrogeologic settings described above necessarily contain a great deal of composited data. Use of the data should be strictly limited to broad scale assessments and generalized descriptions. Users are cautioned that more accurate and detailed characterizations are available for more computationally intensive studies.

15.6 REFERENCES

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Figure 15.1. Location and Environmental Settings for the Nevada Test Site.

Figure 15.2. Stratigraphic Columns for Nevada Test Site Environmental Settings.

EXHIBIT 15.1

Nevada Test Site Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at Desert Rock Airport and at Yucca Flat.

Station Name: Desert Rock Airport, Desert Rock, Nevada
Yucca Flat, Yucca Flat, Nevada

Elevation: 1007 m Latitude: 36.63°N
Elevation: 1196 m Latitude: 36.95°N

Annual Mean Air Temp:	62.4 °F (DRA) Reference (a)	Based on observations made from 1978-1991
	54.9 °F (UCC) Reference (b)	Based on observations made from 1962-1978
Anemometer Height:	9.1 m (DRA) Reference (a)	Based on observations made from 1978-1991
	8.8 m (UCC) Reference (b)	Based on observations made from 1962-1978
Mean Annual Wind Speed:	9.2 mph (DRA) Reference (a)	Based on observations made from 1978-1991
	7.2 mph (UCC) Reference (b)	Based on observations made from 1962-1978
Fastest 1-Min Wind Speed:	67.0 mph (DRA) Reference (a)	Based on observations made from 1978-1991
	60.0 mph (UCC) Reference (b)	Based on observations made from 1962-1978.
	Actual fastest wind speed is 60+ mph	
Annual Precipitation:	5.9 in (DRA) Reference (a)	Based on observations made from 1978-1991
	6.7 in (UCC) Reference (b)	Based on observations made from 1962-1978
Precipitation Days:	35 yr ⁻¹ (DRA) Reference (a)	Based on observations made from 1978-1991
	34 yr ⁻¹ (UCC) Reference (b)	Based on observations made from 1962-1978
Thunderstorms Freq:	14 yr ⁻¹ (DRA) Reference (a)	Based on observations made from 1978-1991
	15 yr ⁻¹ (UCC) Reference (b)	Based on observations made from 1962-1978
Avg Morning Mixing Ht:	380 m	Reference (a) Based on observations made from 1978-1991
	200 m	Reference (b) Based on observations made from 1962-1978
Avg Afternoon Mixing Ht:	2200 m	Reference (a) Based on observations made from 1978-1991
	2100 m	Reference (b) Based on observations made from 1962-1978
Top Soil Moisture Capacity:	1.37 cm	Reference (c)

MEPAS Parameters:	Climatic Region Index:	2	Reference (c)
	Precipitation-Evaporation Index:	13	Reference (c)
	Soil Cons. Serv. Curve Number:	21	Reference (c)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	43.5	0.64	8.9	4.9	4	58	35
Feb	47.5	0.68	9.4	5.4	3	55	28
Mar	51.8	0.72	9.5	5.1	5	57	30
Apr	60.3	0.32	10.2	4.5	2	43	20
May	68.3	0.36	10.3	3.8	3	39	17
Jun	79.0	0.10	10.3	2.4	1	26	12
Jul	84.2	0.57	9.8	2.3	3	33	16
Aug	81.9	0.79	8.9	2.4	4	40	19
Sep	74.5	0.34	9.0	2.6	2	39	19
Oct	63.7	0.32	8.1	3.0	2	45	22
Nov	50.8	0.56	8.5	4.2	3	54	29
Dec	43.4	0.54	8.0	4.6	3	61	36
Reference: ...	(a)	(a)	(a)	(a)	(a)	(a)	(a)

References

- A: Unpublished technical data provided by correspondence with Charles Steadman (National Weather Service Western Region, Weather Service Nuclear Support Office), April, 1993.
- B: Unpublished technical data provided by correspondence with Charles Steadman (National Weather Service Western Region, Weather Service Nuclear Support Office), April, 1993.
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 15.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Las Vegas. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made on-site at 6.1 m (20 ft) above ground level. Data are based on measurements made from 1960 through 1964.

STAB CLASS	WIND DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
A	NORTH*	0.00144	0.00064	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00118	0.00068	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00193	0.00132	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00179	0.00114	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00205	0.00114	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00119	0.00073	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00145	0.00084	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00089	0.00055	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00087	0.00057	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00042	0.00027	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00058	0.00027	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00033	0.00021	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00036	0.00023	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00053	0.00016	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00059	0.00032	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00056	0.00034	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00349	0.00349	0.00103	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00394	0.00402	0.00110	0.00000	0.00000	0.00000
B	NORTHEAST	0.00726	0.00735	0.00203	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00676	0.00831	0.00324	0.00000	0.00000	0.00000
B	EAST	0.00574	0.00680	0.00265	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00349	0.00395	0.00160	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00233	0.00233	0.00094	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00180	0.00137	0.00094	0.00000	0.00000	0.00000
B	SOUTH	0.00170	0.00167	0.00087	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00113	0.00084	0.00071	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00199	0.00114	0.00064	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00139	0.00078	0.00043	0.00000	0.00000	0.00000
B	WEST	0.00109	0.00059	0.00023	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00134	0.00089	0.00030	0.00000	0.00000	0.00000
B	NORTHWEST	0.00185	0.00142	0.00041	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00150	0.00128	0.00034	0.00000	0.00000	0.00000
C	NORTH	0.00087	0.00356	0.00231	0.00034	0.00011	0.00005
C	NORTH-NORTHEAST	0.00084	0.00349	0.00322	0.00034	0.00000	0.00000
C	NORTHEAST	0.00151	0.00637	0.00514	0.00053	0.00002	0.00000
C	EAST-NORTHEAST	0.00142	0.00580	0.00573	0.00053	0.00005	0.00000
C	EAST	0.00142	0.00564	0.00450	0.00037	0.00002	0.00000
C	EAST-SOUTHEAST	0.00074	0.00308	0.00290	0.00048	0.00000	0.00000
C	SOUTHEAST	0.00056	0.00235	0.00167	0.00064	0.00005	0.00005
C	SOUTH-SOUTHEAST	0.00039	0.00167	0.00210	0.00105	0.00039	0.00011
C	SOUTH	0.00071	0.00276	0.00340	0.00247	0.00091	0.00025
C	SOUTH-SOUTHWEST	0.00072	0.00217	0.00315	0.00274	0.00244	0.00087
C	SOUTHWEST	0.00095	0.00320	0.00288	0.00164	0.00190	0.00098
C	WEST-SOUTHWEST	0.00076	0.00304	0.00187	0.00053	0.00025	0.00009
C	WEST	0.00086	0.00253	0.00121	0.00016	0.00009	0.00007
C	WEST-NORTHWEST	0.00080	0.00279	0.00078	0.00005	0.00002	0.00000
C	NORTHWEST	0.00059	0.00205	0.00112	0.00016	0.00005	0.00005
C	NORTH-NORTHWEST	0.00046	0.00192	0.00139	0.00037	0.00011	0.00002

EXHIBIT 15.2 (continued)

STAB CLASS	WIND DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
D	NORTH	0.00005	0.00096	0.00116	0.00354	0.00288	0.00126
D	NORTH-NORTHEAST	0.00005	0.00098	0.00066	0.00253	0.00114	0.00025
D	NORTHEAST	0.00005	0.00162	0.00203	0.00322	0.00091	0.00014
D	EAST-NORTHEAST	0.00007	0.00158	0.00180	0.00224	0.00048	0.00005
D	EAST	0.00007	0.00162	0.00167	0.00142	0.00014	0.00000
D	EAST-SOUTHEAST	0.00002	0.00082	0.00094	0.00089	0.00014	0.00000
D	SOUTHEAST	0.00002	0.00075	0.00057	0.00142	0.00041	0.00016
D	SOUTH-SOUTHEAST	0.00002	0.00064	0.00094	0.00256	0.00167	0.00039
D	SOUTH	0.00006	0.00107	0.00217	0.01007	0.00484	0.00105
D	SOUTH-SOUTHWEST	0.00003	0.00105	0.00217	0.00922	0.00874	0.00390
D	SOUTHWEST	0.00007	0.00240	0.00210	0.00929	0.01100	0.00543
D	WEST-SOUTHWEST	0.00012	0.00244	0.00100	0.00473	0.00315	0.00094
D	WEST	0.00012	0.00311	0.00114	0.00087	0.00071	0.00023
D	WEST-NORTHWEST	0.00006	0.00187	0.00048	0.00050	0.00011	0.00011
D	NORTHWEST	0.00004	0.00132	0.00082	0.00119	0.00107	0.00114
D	NORTH-NORTHWEST	0.00005	0.00089	0.00073	0.00233	0.00386	0.00212
E	NORTH	0.00017	0.00032	0.00142	0.00498	0.00233	0.00073
E	NORTH-NORTHEAST	0.00010	0.00021	0.00100	0.00242	0.00046	0.00016
E	NORTHEAST	0.00019	0.00021	0.00096	0.00251	0.00071	0.00011
E	EAST-NORTHEAST	0.00006	0.00018	0.00128	0.00114	0.00027	0.00002
E	EAST	0.00016	0.00021	0.00078	0.00043	0.00000	0.00000
E	EAST-SOUTHEAST	0.00004	0.00011	0.00050	0.00021	0.00002	0.00002
E	SOUTHEAST	0.00015	0.00018	0.00046	0.00050	0.00023	0.00007
E	SOUTH-SOUTHEAST	0.00005	0.00014	0.00135	0.00292	0.00116	0.00032
E	SOUTH	0.00016	0.00039	0.00580	0.01580	0.00384	0.00068
E	SOUTH-SOUTHWEST	0.00009	0.00027	0.00637	0.02105	0.00692	0.00226
E	SOUTHWEST	0.00014	0.00032	0.00886	0.02128	0.00881	0.00290
E	WEST-SOUTHWEST	0.00016	0.00039	0.00884	0.00742	0.00171	0.00055
E	WEST	0.00019	0.00030	0.00548	0.00171	0.00027	0.00000
E	WEST-NORTHWEST	0.00017	0.00041	0.00226	0.00112	0.00032	0.00007
E	NORTHWEST	0.00018	0.00027	0.00137	0.00292	0.00139	0.00073
E	NORTH-NORTHWEST	0.00015	0.00016	0.00105	0.00452	0.00317	0.00142
F	NORTH	0.00161	0.00452	0.00342	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00107	0.00306	0.00336	0.00000	0.00000	0.00000
F	NORTHEAST	0.00129	0.00397	0.00336	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00134	0.00336	0.00194	0.00000	0.00000	0.00000
F	EAST	0.00130	0.00372	0.00185	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00121	0.00279	0.00082	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00118	0.00276	0.00082	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00100	0.00354	0.00208	0.00000	0.00000	0.00000
F	SOUTH	0.00216	0.00797	0.01400	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00282	0.00982	0.02317	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00637	0.02557	0.04315	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00883	0.03664	0.04856	0.00000	0.00000	0.00000
F	WEST	0.00797	0.03226	0.02082	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00358	0.01411	0.00537	0.00000	0.00000	0.00000
F	NORTHWEST	0.00189	0.00621	0.00345	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00134	0.00393	0.00247	0.00000	0.00000	0.00000

EXHIBIT 15.3

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Las Vegas-Nellis Air Base. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made on-site at 2.0 m (7 ft) above ground level. Data are based on measurements made from 1958 through 1967.

STAB CLASS	WIND DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
A	NORTH	0.00158	0.00035	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00143	0.00025	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00276	0.00063	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00187	0.00035	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00411	0.00103	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00354	0.00087	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00438	0.00098	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00227	0.00054	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00583	0.00146	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00388	0.00082	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00283	0.00067	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00133	0.00024	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00178	0.00026	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00142	0.00022	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00112	0.00019	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00076	0.00008	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00325	0.00081	0.00034	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00441	0.00126	0.00047	0.00000	0.00000	0.00000
B	NORTHEAST	0.00654	0.00268	0.00102	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00447	0.00171	0.00078	0.00000	0.00000	0.00000
B	EAST	0.00921	0.00370	0.00153	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00604	0.00250	0.00093	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00651	0.00300	0.00135	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00330	0.00142	0.00085	0.00000	0.00000	0.00000
B	SOUTH	0.01067	0.00420	0.00215	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.01215	0.00375	0.00111	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00826	0.00227	0.00090	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00368	0.00091	0.00031	0.00000	0.00000	0.00000
B	WEST	0.00498	0.00128	0.00027	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00386	0.00070	0.00011	0.00000	0.00000	0.00000
B	NORTHWEST	0.00293	0.00065	0.00015	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00189	0.00039	0.00005	0.00000	0.00000	0.00000
C	NORTH	0.00105	0.00082	0.00126	0.00026	0.00003	0.00001
C	NORTH-NORTHEAST	0.00169	0.00097	0.00175	0.00039	0.00011	0.00000
C	NORTHEAST	0.00324	0.00252	0.00464	0.00072	0.00008	0.00000
C	EAST-NORTHEAST	0.00215	0.00185	0.00337	0.00059	0.00001	0.00001
C	EAST	0.00354	0.00312	0.00450	0.00066	0.00003	0.00000
C	EAST-SOUTHEAST	0.00213	0.00191	0.00257	0.00050	0.00000	0.00000
C	SOUTHEAST	0.00219	0.00200	0.00326	0.00080	0.00008	0.00001
C	SOUTH-SOUTHEAST	0.00117	0.00109	0.00203	0.00099	0.00016	0.00006
C	SOUTH	0.00363	0.00322	0.00543	0.00242	0.00090	0.00016
C	SOUTH-SOUTHWEST	0.00374	0.00296	0.00334	0.00185	0.00109	0.00057
C	SOUTHWEST	0.00313	0.00222	0.00218	0.00085	0.00030	0.00007
C	WEST-SOUTHWEST	0.00145	0.00093	0.00059	0.00017	0.00008	0.00000
C	WEST	0.00179	0.00126	0.00087	0.00016	0.00001	0.00002
C	WEST-NORTHWEST	0.00121	0.00072	0.00057	0.00021	0.00005	0.00003
C	NORTHWEST	0.00141	0.00089	0.00046	0.00008	0.00003	0.00001
C	NORTH-NORTHWEST	0.00065	0.00042	0.00029	0.00000	0.00000	0.00000
D	NORTH	0.00029	0.00077	0.00167	0.00483	0.00135	0.00039

EXHIBIT 15.3 (continued)

STAB CLASS	WIND DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
D	NORTH-NORTHEAST	0.00035	0.00091	0.00326	0.00965	0.00380	0.00142
D	NORTHEAST	0.00056	0.00200	0.00669	0.01290	0.00268	0.00072
D	EAST-NORTHEAST	0.00050	0.00182	0.00527	0.00497	0.00038	0.00005
D	EAST	0.00060	0.00222	0.00468	0.00310	0.00035	0.00005
D	EAST-SOUTHEAST	0.00029	0.00121	0.00240	0.00272	0.00029	0.00011
D	SOUTHEAST	0.00017	0.00065	0.00265	0.00500	0.00069	0.00017
D	SOUTH-SOUTHEAST	0.00018	0.00041	0.00215	0.00798	0.00233	0.00054
D	SOUTH	0.00060	0.00163	0.00962	0.02850	0.00843	0.00236
D	SOUTH-SOUTHWEST	0.00036	0.00123	0.00419	0.01545	0.00734	0.00332
D	SOUTHWEST	0.00027	0.00089	0.00263	0.00949	0.00387	0.00188
D	WEST-SOUTHWEST	0.00010	0.00040	0.00077	0.00244	0.00072	0.00034
D	WEST	0.00026	0.00073	0.00120	0.00227	0.00059	0.00015
D	WEST-NORTHWEST	0.00018	0.00048	0.00131	0.00411	0.00178	0.00077
D	NORTHWEST	0.00028	0.00077	0.00117	0.00417	0.00188	0.00069
D	NORTH-NORTHWEST	0.00006	0.00027	0.00058	0.00109	0.00026	0.00013
E	NORTH	0.00000	0.00206	0.00320	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00000	0.00368	0.00370	0.00000	0.00000	0.00000
E	NORTHEAST	0.00000	0.00477	0.00659	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00000	0.00279	0.00459	0.00000	0.00000	0.00000
E	EAST	0.00000	0.00238	0.00247	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00000	0.00122	0.00129	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00000	0.00125	0.00147	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00000	0.00113	0.00187	0.00000	0.00000	0.00000
E	SOUTH	0.00000	0.00379	0.01446	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00000	0.00234	0.00602	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00000	0.00183	0.00283	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00000	0.00082	0.00081	0.00000	0.00000	0.00000
E	WEST	0.00000	0.00112	0.00088	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00000	0.00110	0.00107	0.00000	0.00000	0.00000
E	NORTHWEST	0.00000	0.00163	0.00152	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00000	0.00077	0.00093	0.00000	0.00000	0.00000
F	NORTH	0.02298	0.00707	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.03131	0.00986	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.03872	0.01223	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.01919	0.00587	0.00000	0.00000	0.00000	0.00000
F	EAST	0.01901	0.00489	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00986	0.00227	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00802	0.00227	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00552	0.00170	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.02452	0.01086	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.02112	0.00748	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.02032	0.00632	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.01047	0.00278	0.00000	0.00000	0.00000	0.00000
F	WEST	0.01324	0.00311	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.01465	0.00327	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.01898	0.00471	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00998	0.00259	0.00000	0.00000	0.00000	0.00000

Table 15.1. Hydrogeologic setting data summary of the Yucca Flat setting, Nevada Test Site. MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

Parameter	Units	PZ1	PZ2	SZ
Darcian_velocity	m/yr	0.024	0.024	--
SOILC	--	4.38	10.4	10.4
Thickness	m	427	183	610
Bulk_Density	gm/cm3	1.49	2.3	2.4
Total_Porosity	%	43.7	10	5.4
Field_Capacity	%	12	9.9	--
Conductivity	m/day	320	1.00E-05	--
Longitudinal_Displacement	m	4.3	0.2	305**
Transverse_Displacement	m	--	--	61**
Vertical_Displacement	m	--	--	30**
Effective_Porosity	%	--	--	2.3
Velocity	m/day	--	--	0.03
Distance	m	--	--	3050
Textural_Class	--	loamy sand	sandy clay	silt clay
%_sand	%	84	50	8
%_silt	%	12	8	47
%_clay	%	4	42	45
%_OMC	%	0	0	0
%_Fe	%	2.1	1.43	0.13
pH	--	7.2	7.5	7.3

Notes: The Welded Tuff unit is an aquifer, but is treated as a PZ here because the receptor for the aquifer is the Lower Carbonate Aquifer.

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

Table 15.2. Hydrogeologic setting data summary of the Frenchman Flat setting, Nevada Test Site. MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

Parameter	Units	PZ1	PZ2	SZ
Darcian_velocity	m/yr	0.024	0.024	--
SOILC	--	4.38	10.4	10.4
Thickness	m	305	183	610
Bulk_Density	gm/cm3	1.49	2.3	2.4
Total_Porosity	%	43.7	10	5.4
Field_Capacity	%	12	9.96	--
Conductivity	m/day	320	1.00E-05	--
Longitudinal_Displacement	m	3	0.2	305**
Transverse_Displacement	m	--	--	61**
Vertical_Displacement	m	--	--	30**
Effective_Porosity	%	--	--	2.3
Velocity	m/day	--	--	0.03
Distance	m	--	--	3050
Textural_Class	--	loamy sand	sandy clay	silt clay
%_sand	%	84	50	8
%_silt	%	12	8	47
%_clay	%	4	42	45
%_OMC	%	0	0	0
%_Fe	%	2.1	1.43	0.13
pH	--	7.2	7.5	7.3

Notes: The Welded Tuff unit is an aquifer, but is treated as a PZ here because the receptor for the aquifer is the Lower Carbonate Aquifer.

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

Table 15.3. Hydrogeologic setting data summary of the Jackass Flat setting, Nevada Test Site. MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.017	--
SOILC	--	4.38	10.4
Thickness	m	366	152
Bulk_Density	gm/cm3	1.49	2.3
Total_Porosity	%	43.7	10
Field_Capacity	%	12	--
Conductivity	m/day	320	--
Longitudinal_Displacement	m	4	305**
Transverse_Displacement	m	--	61**
Vertical_Displacement	m	--	30**
Effective_Porosity	%	--	2
Velocity	m/day	--	0.03
Distance	m	--	3050
Textural_Class	--	loamy sand	sandy clay
%_sand	%	84	50
%_silt	%	12	8
%_clay	%	4	42
%_OMC	%	0	0%
%_Fe	%	2.1	1.43
pH	--	7.2	7.5

Notes:

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

Table 15.4. Hydrogeologic setting data summary of the Pahute Mesa setting, Nevada Test Site. MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.046	--
SOILC	--	10.4	7.12
Thickness	m	640	1067
Bulk_Density	gm/cm3	1.62	1.6
Total_Porosity	%	37.7	40
Field_Capacity	%	9	--
Conductivity	m/day	2.00E-03	--
Longitudinal_Displacement	m	6	305**
Transverse_Displacement	m	--	61**
Vertical_Displacement	m	--	61**
Effective_Porosity	%	--	3
Velocity	m/day	--	8
Distance	m	--	3050
Textural_Class	--	sandy clay	sandy clay loam
%_sand	%	50	60
%_silt	%	8	14
%_clay	%	42	26
%_OMC	%	0	0
%_Fe	%	1.43	1.5
pH	--	7.5	7.5

Notes:

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

Table 15.5. Hydrogeologic setting data summary of the Timber Mountain setting, Nevada Test Site. MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.31	--
SOILC	--	7.12	7.12
Thickness	m	488	914
Bulk_Density	gm/cm3	1.6	1.6
Total_Porosity	%	40	40
Field_Capacity	%	24	--
Conductivity	m/day	8.00E-04	--
Longitudinal_Displacement	m	5	305**
Transverse_Displacement	m	--	61**
Vertical_Displacement	m	--	61**
Effective_Porosity	%	--	11
Velocity	m/day	--	0.03
Distance	m	--	8
Textural_Class	--	sandy clay loam	sandy clay loam
%_sand	%	60	60
%_silt	%	14	14
%_clay	%	26	26
%_OMC	%	0	0
%_Fe	%	1.5	1.5
pH	--	7.5	7.5

Notes:

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

Table 15.6. Hydrogeologic setting data summary of the Rainier Mesa setting, Nevada Test Site. MEPAS parameters are listed for both the partially saturated zones (PZ) and the saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.56	0.56	0.56	0.56	--
SOILC	--	10.4	7.12	10.4	10.4	10.4
Thickness	m	183	183	366	335	610
Bulk_Density	gm/cm3	2.3	1.6	2.4	2.5	2.5
Total_Porosity	%	10	40	3.8	5.4	5.4
Field_Capacity	%	6	24	2	2	--
Conductivity	m/day	1.0E-05	8.0E-04	4.0E-07	4.0E-04	--
Longitudnal_Displacement	m	1.8	1.8	3.7	3.4	305*
Transverse_Displacement	m	--	--	--	--	61**
Vertical_Displacement	m	--	--	--	--	61**
Effective_Porosity	%	--	--	--	--	2.3
Velocity	m/day	--	--	--	--	0.03
Distance	m	--	--	--	--	3050
Textural_Class	--	sandy clay	sandy clay loam	silt clay	silt clay	silt clay
%_sand	%	50	60	8	8	8
%_silt	%	8	14	47	47	47
%_clay	%	42	26	45	45	45
%_OMC	%	0	0	0	0	0
%_Fe	%	1.43	1.5	1.5	0	0
pH	--	7.5	7.5	7.5	7.6	7.6

Notes:

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

16.0 OAK RIDGE GASEOUS DIFFUSION PLANT/K-25 INSTALLATION

Until the summer of 1985, the primary mission of the Oak Ridge Gaseous Diffusion Plant (ORGDP), also known as the K-25 installation, was enrichment of uranium hexafluoride (UF_{16}) in the ^{235}U isotope for use as a fuel in nuclear reactors. In August 1985, the gaseous diffusion process at the ORGDP was placed in a "ready standby" mode because of declining demands for enriched uranium. Remaining missions at the ORGDP include advanced enrichment technology research and development, analytical laboratory programs, and waste treatment services (Martin Marietta, Inc. 1989).

The K-25 installation is located on a 6.9 km^2 (1700 acre) complex in the western-most part of the 140 km^2 (55 mi^2) Oak Ridge Reservation (ORR) (Figure 16.1). The ORR is located about 32 km (20 mi) west of Knoxville, Tennessee, in the rolling terrain between the Cumberland and Great Smoky Mountains. The land surrounding the ORR is primarily rural, with agricultural and residential land use dominating. About 40% of the K-25 installation has been developed to support ORGDP operations. Ecologically, about 70% of the ORR is forested with plant communities characteristic of the those found in the intermountain regions of Appalachia. The dominant oak-hickory association of this area is typified by extensive stands of mixed yellow pine, hardwoods, oak, and hickory.

16.1 CLIMATE

The ORR is located near the boundary between a "humid subtropic" and a "humid continental warm summer" climate (Critchfield 1974). Meteorological data are available from onsite measurements and from measurements in the city of Oak Ridge, Tennessee. On average, the maximum daily temperature exceeds 32°C (90°F) on 30 days per year and is below 0°C (32°F) on 6 days per year; the minimum daily temperature is below 0°C (32°F) on 87 days per year and is below -18°C (0°F) about once every 2 years (DOC 1987b). July is the warmest month, with daily maximum and minimum temperatures averaging 31°C (87°F) and 19°C (66°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 8°C (46°F) and -2°C (28°F), respectively (DOC 1987b).

Annual precipitation is on the order of 140 cm (55 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 128 days per year and the area experiences an average of 51 thunderstorm days per year. The average annual snowfall is 33 cm (13 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 4 days per year (DOC 1987b).

Winds on the ORR are influenced by the local topography. Mountain ridges and valleys tend to channel winds and mountain valley circulation often produce significant

diurnal variations in the winds. As a result, wind directions and speeds may vary significantly from location to location across the ORR. The prevailing wind direction in the ORR's northeast-trending valleys and in the city of Oak Ridge is from the southwest. There is also a high incidence of winds from neighboring sectors and in the opposite direction. Wind speeds in the city of Oak Ridge average about 2 m/s (4 mph) at about 9 m (30 ft) above ground level (DOC 1987b). Average wind speeds are highest in April (2.5 m/s [6 mph]) and lowest in October (1.5 m/s [3.5 mph]) (DOC 1987b).

16.2 GEOLOGY

The ORR is located in the Bethel and Melton Valleys, part of the Tennessee Valley and Ridge Province of the Southern Appalachian fold and thrust belt. The area is characterized by a succession of northeast-trending thrust faults that stack and repeat the Paleozoic section. As a result of thrusting and subsequent differential erosion, a series of ridges consisting of relatively resistant rocks (e.g., sandstone, shale, and dolomite) and valleys developed in more easily eroded material (e.g., less resistant carbonate and shale). Most of the units dip steeply toward the south-southeast. This structure has a major role in regulating groundwater movement in the area. Fracturing is pervasive throughout all rock units at the ORR and also occurs in zones that are associated with faults. Although the rock units are highly fractured, most fractures have been filled with mineral precipitates (predominantly calcite) and do not contribute to a secondary permeability. Karstification, or solution enlargement of existing fractures, is common in the more carbonate-rich units and has been reported from the Knox Group and Chickamauga Group (Martin Marietta, Inc. 1989). The bedrock at the K-25 installation is composed of three separate formations; from youngest to oldest, these are the Chickamauga Limestone, Knox Group, and Rome Formation. Soils of various thickness mantle the irregular bedrock surface at the K-25 installation. These soils consist of the weathered products (residuum, alluvium, and fill) of the underlying bedrock (Moore and Toran 1992).

16.3 HYDROLOGY

In the Valley and Ridge Province of Tennessee, groundwater occurs in bedrock formations, residual soil accumulations near the bedrock surface, and in a few alluvial aquifers along the largest rivers (Martin Marietta, Inc. 1989). Groundwater flow in the shales and carbonate rocks that dominate the region's bedrock is attributed to fractures and solution cavities. The ORR has three major hydrologic units. The first unit is a near-surface stormflow zone. The stormflow zone transmits 90% of the incoming precipitation laterally to surface water. The remaining 10% infiltrates to underlying aquifers. Because of its proximity to the surface, no clearly defined partially-saturated zones overlie the stormflow zone. The second hydrologic unit is the Knox aquifer, which includes areas underlain by the Knox Group and the Maynardville Limestone member of the Conasauga Group. The third

hydrologic unit is the ORR Aquitards consisting of areas underlain by all other geologic formations. "Vertical" movement of these waters tends to occur along contact zones between major lithologic units. Therefore, soil waters generally move down dip until reaching a zone of saturation where it then tends to migrate along strike until reaching an area of discharge (Moore and Toran 1992).

The Clinch River is the major surface water source that receives discharges from the Oak Ridge installations. Four Tennessee Valley Authority reservoirs influence the flow and/or water levels of the lower Clinch River: Norris and Melton Hill on the Clinch River and Watts Bar and Fort Loudon on the Tennessee River. The ORR is bounded on the south and west by a 63-km (39-mi) stretch of the Clinch River. Melton Hill Dam is located at Clinch River kilometer 37.2 (river mile 23), forming the Melton Hill Reservoir and several major embayments which bound the ORR. Both groundwater and surface water are drained from the ORR by a network of small tributaries of the Clinch River. The K-25 installation is located at the confluence of the Poplar Creek stream system and the Clinch River and drains predominantly into Poplar Creek and Mitchell Branch (Martin Marietta 1989).

16.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the K-25 installation for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 16.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 16.2.

For PEIS modeling purposes, the K-25 installation is modeled using one hydrogeologic environmental setting (Figure 16.1). This setting, designated as the K-25 setting, has two subsettings: a base flow and storm flow zone. The K-25 base flow zone consists of two partially-saturated zones (designated as Inceptisol 1 and 2) and one saturated zone (designated as Fill). Inceptisol 1 is classified as a silty loam with a thickness of 0.5 m (1.6 ft). Its porosity and conductivity are much higher than Inceptisol 2 which is 3.5 m (11.4 ft) thick and is classified as a sandy loam. The Fill saturated zone has a thickness of 6 m (20 ft), consists of 85% clay, and is characterized by very low groundwater velocities of 0.03 m/day (0.1 ft/day). The storm flow subsetting consists of a single saturated zone designated as the Karst zone. The Karst zone is approximately 4.6 m (15 ft) thick and has much higher groundwater velocity and effective porosity than the Fill. Figure 16.2 presents stratigraphic columns for both the base and storm flow zone subsettings. Surface water data are presented in Table 16.1. Hydrogeologic data for the environmental setting are presented in Tables 16.2 and 16.3.

16.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the K-25 installation are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Ron Sharp supplied data used in the development of the climate and atmospheric dispersion environmental settings. Laura Toran supplied input into the development of the meteorologic environmental settings. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

16.6 REFERENCES

Critchfield, H.J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

U.S. Department of Commerce (DOC). 1987b. *Local Climatological Data Annual Summaries for 1986 Part II Southern Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

Martin Marietta Energy Systems, Inc. 1989. *Oak Ridge Reservation Environmental Report for 1988, Vol. 1: Narrative, Summary, and Conclusions*. ES/ESH-8/V1, Environmental and Safety Activities, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

Moore, G.K., and L.E. Toran. 1992. *Supplement to a Hydrologic Framework for the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/TM-12191, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

S9405048.2

Figure 16.1. Location and Environmental Settings for the ORNL, K-25, and Y-12 installations at Oak Ridge. For PEIS modeling purposes, the K-25 installation is characterized by a single environmental setting; the ORNL is divided into three environmental settings (the Stormflow Zone, Knox, and Aquitard settings), and the Y-12 installation is divided into seven environmental settings: the Bear Creek Aquitard, Bear Creek Stormflow, East Fork Poplar Creek (EFPC) Aquitard, EFPC Stormflow, Y-12 Knox, Clinch River Aquitard, and Clinch River Stormflow settings. Stormflow zones and other installation zones cover the same area.

Figure 16.2. Stratigraphic Columns for K-25 Environmental Settings

EXHIBIT 16.1

K-25 (ORGP) Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at the X-10 meteorological tower and in the city of Oak Ridge, Tennessee.

Station Name: Oak Ridge, Tennessee	Elevation: 268 m	Latitude: 36.10°N
MT2 Monitoring Location at X-10 facility, Oak Ridge, Tennessee	Elevation: 289 m	Latitude: 35.93°N

Annual Mean Air Temp:	57.4 °F	(Oak Ridge) Reference (A)	Based on observations made from 1951-1980.
Anemometer Height:	12.0 m	(Oak Ridge) Reference (A)	Based on average of 3 heights used during observations.
	10.0 m	(MT2/X-10) Reference (B)	
Mean Annual Wind Speed:	4 mph	(Oak Ridge) Reference (A)	Based on 16 years of observations.
	4 mph	(MT2/X-10) Reference (B)	
Fastest 1-Min Wind Speed:	59 mph	(Oak Ridge) Reference (A)	Based on 22 years of observations.
Annual Precipitation:	54.8 in.	(Oak Ridge) Reference (A)	Based on observations made from 1951-1980.
Precipitation Days:	128 yr ⁻¹	(Oak Ridge) Reference (A)	Based on 38 years of observations.
Thunderstorms Freq:	51 yr ⁻¹	(Oak Ridge) Reference (A)	Based on 17 years of observations.

Avg Morning Mixing Ht:	450 m	Reference (C)
Avg Afternoon Mixing Ht:	1600 m	Reference (C)
Top Soil Moisture Capacity:	7.1 cm	Reference (C)

MEPAS Parameters:	Climatic Region Index:	6	Reference (C)
	Precipitation-Evaporation Index:	116	Reference (C)
	Soil Cons. Serv. Curve Number:	77	Reference (C)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	36	5.3	3.8	6.7	12.4	75	55
Feb	42	4.6	4.0	6.5	11.4	73	48
Mar	50	6.2	4.3	6.5	12.6	68	47
Apr	58	4.4	4.3	5.9	10.8	72	47
May	65	4.2	3.8	5.9	10.7	76	52
Jun	73	4.3	3.3	5.5	10.3	77	53
Jul	77	5.2	3.1	5.8	11.9	74	50
Aug	75	3.8	2.9	5.5	10.4	81	55
Sep	69	3.8	2.9	5.6	8.3	77	56
Oct	57	2.9	3.0	5.0	7.9	71	47
Nov	48	4.5	3.4	6.1	10.1	71	48
Dec	39	5.7	3.5	6.5	10.9	72	55
Reference: ...	↓ (B)	↓ (A)	↓ (B)	↓ (A)	↓ (A)	↓ (B)	↓ (B)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part II Southern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- B: Unpublished technical data provided by meteorologist Ron Sharp (ORNL Office of Environmental Compliance and Documentation). Data were provided using the Oak Ridge Meteorological Data Analysis Program (OMDRAP). The program reads archived hourly meteorological data and generates tables of climatological averages, input files for atmospheric dispersion models, and other meteorological support products. Technical information on the ORNL meteorological data acquisition system is described in detail in: "Oak Ridge National Laboratory Meteorological Tower Data Acquisition System", Environmental Systems Corporation, TIN 82-1844, August, 1982.
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 16.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for the Oak Ridge Reservation's K-25 Area. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made in 1986, 1987, and 1989 through 1992.

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	>25
A	NORTH	0.00446	0.00258	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00382	0.00291	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00367	0.00334	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00299	0.00367	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00210	0.00291	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00175	0.00147	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00154	0.00180	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00175	0.00246	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00170	0.00360	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00334	0.00701	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00481	0.01023	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00539	0.00891	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00334	0.00476	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00251	0.00261	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00304	0.00208	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00382	0.00208	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00104	0.00129	0.00041	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00127	0.00132	0.00018	0.00000	0.00000	0.00000
B	NORTHEAST	0.00116	0.00205	0.00038	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00170	0.00243	0.00035	0.00000	0.00000	0.00000
B	EAST	0.00076	0.00101	0.00010	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00041	0.00073	0.00003	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00030	0.00078	0.00010	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00018	0.00104	0.00020	0.00000	0.00000	0.00000
B	SOUTH	0.00058	0.00157	0.00025	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00066	0.00408	0.00089	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00152	0.00590	0.00094	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00106	0.00468	0.00084	0.00000	0.00000	0.00000
B	WEST	0.00071	0.00210	0.00058	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00048	0.00119	0.00073	0.00000	0.00000	0.00000
B	NORTHWEST	0.00091	0.00122	0.00056	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00068	0.00104	0.00038	0.00000	0.00000	0.00000
C	NORTH	0.00157	0.00152	0.00056	0.00008	0.00000	0.00000
C	NORTH-NORTHEAST	0.00122	0.00144	0.00025	0.00003	0.00000	0.00000
C	NORTHEAST	0.00182	0.00370	0.00078	0.00005	0.00000	0.00000
C	EAST-NORTHEAST	0.00203	0.00408	0.00104	0.00005	0.00000	0.00000
C	EAST	0.00063	0.00099	0.00035	0.00000	0.00000	0.00000
C	EAST-SOUTHEAST	0.00048	0.00051	0.00005	0.00000	0.00000	0.00000
C	SOUTHEAST	0.00041	0.00086	0.00003	0.00000	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00048	0.00089	0.00041	0.00000	0.00000	0.00000
C	SOUTH	0.00051	0.00129	0.00132	0.00003	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00101	0.00377	0.00423	0.00028	0.00000	0.00000
C	SOUTHWEST	0.00129	0.00686	0.00529	0.00023	0.00000	0.00000
C	WEST-SOUTHWEST	0.00134	0.00352	0.00266	0.00018	0.00000	0.00000
C	WEST	0.00076	0.00268	0.00220	0.00033	0.00000	0.00000
C	WEST-NORTHWEST	0.00030	0.00159	0.00311	0.00035	0.00000	0.00000
C	NORTHWEST	0.00048	0.00165	0.00337	0.00048	0.00000	0.00000
C	NORTH-NORTHWEST	0.00099	0.00124	0.00106	0.00028	0.00000	0.00000

EXHIBIT 16.2 (continued)

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	>25
D	NORTH	0.00904	0.00453	0.00357	0.00066	0.00030	0.00010
D	NORTH-NORTHEAST	0.00894	0.00547	0.00127	0.00046	0.00030	0.00020
D	NORTHEAST	0.01443	0.01711	0.00233	0.00066	0.00068	0.00013
D	EAST-NORTHEAST	0.01127	0.01663	0.00223	0.00041	0.00089	0.00053
D	EAST	0.00471	0.00306	0.00023	0.00025	0.00013	0.00008
D	EAST-SOUTHEAST	0.00296	0.00142	0.00048	0.00025	0.00015	0.00008
D	SOUTHEAST	0.00289	0.00180	0.00030	0.00013	0.00008	0.00008
D	SOUTH-SOUTHEAST	0.00230	0.00200	0.00053	0.00048	0.00008	0.00000
D	SOUTH	0.00471	0.00430	0.00311	0.00127	0.00025	0.00005
D	SOUTH-SOUTHWEST	0.00922	0.01172	0.01246	0.00613	0.00104	0.00018
D	SOUTHWEST	0.01175	0.01957	0.01468	0.00481	0.00119	0.00041
D	WEST-SOUTHWEST	0.00830	0.00957	0.00711	0.00208	0.00076	0.00033
D	WEST	0.00582	0.00620	0.00582	0.00329	0.00053	0.00046
D	WEST-NORTHWEST	0.00400	0.00709	0.01144	0.00560	0.00109	0.00023
D	NORTHWEST	0.00484	0.00625	0.01785	0.00800	0.00134	0.00030
D	NORTH-NORTHWEST	0.00544	0.00691	0.00656	0.00192	0.00043	0.00028
E	NORTH	0.00972	0.00332	0.00041	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.01000	0.00266	0.00010	0.00000	0.00000	0.00000
E	NORTHEAST	0.01673	0.00537	0.00043	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.01342	0.00797	0.00028	0.00000	0.00000	0.00000
E	EAST	0.00499	0.00203	0.00015	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00334	0.00122	0.00005	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00289	0.00109	0.00000	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00316	0.00089	0.00003	0.00000	0.00000	0.00000
E	SOUTH	0.00501	0.00192	0.00023	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00949	0.00595	0.00119	0.00000	0.00000	0.00000
E	SOUTHWEST	0.01195	0.00886	0.00170	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00985	0.00446	0.00066	0.00000	0.00000	0.00000
E	WEST	0.00623	0.00256	0.00035	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00575	0.00241	0.00043	0.00000	0.00000	0.00000
E	NORTHWEST	0.00534	0.00301	0.00119	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00625	0.00309	0.00048	0.00000	0.00000	0.00000
F	NORTH	0.01499	0.00342	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.01360	0.00200	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.01398	0.00309	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.01190	0.00387	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00696	0.00205	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00486	0.00149	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00415	0.00127	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00448	0.00139	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00501	0.00175	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00904	0.00354	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.01073	0.00494	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00985	0.00400	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00886	0.00276	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00719	0.00208	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00765	0.00187	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00975	0.00175	0.00000	0.00000	0.00000	0.00000
G	NORTH	0.00041	0.00010	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHEAST	0.00066	0.00008	0.00000	0.00000	0.00000	0.00000
G	NORTHEAST	0.00071	0.00020	0.00000	0.00000	0.00000	0.00000
G	EAST-NORTHEAST	0.00051	0.00043	0.00000	0.00000	0.00000	0.00000
G	EAST	0.00023	0.00020	0.00000	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.00020	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHEAST	0.00020	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00023	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH	0.00015	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHWEST	0.00046	0.00003	0.00000	0.00000	0.00000	0.00000
G	SOUTHWEST	0.00063	0.00020	0.00000	0.00000	0.00000	0.00000
G	WEST-SOUTHWEST	0.00053	0.00008	0.00000	0.00000	0.00000	0.00000
G	WEST	0.00038	0.00003	0.00000	0.00000	0.00000	0.00000
G	WEST-NORTHWEST	0.00023	0.00003	0.00000	0.00000	0.00000	0.00000
G	NORTHWEST	0.00025	0.00003	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHWEST	0.00041	0.00005	0.00000	0.00000	0.00000	0.00000

Table 16.1. Surface Water Environmental Safety Data for Oak Ridge Reservation K-25 Installation

<u>Parameter</u>	<u>Units</u>	<u>Clinch River</u>
Velocity	m/s	0.124
Depth	m	9.14
Width	m	124
Discharge	cms	143

Table 16.2. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's K-25 Installation Incept_1 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ1</u>	<u>PZ2</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.27	0.27	--
SOILC	--	5.3	4.9	11.4
Thickness	m	0.49	3.47	6.10
Bulk_density	g/cm3	1.3	1.7	1.5
Total_porosity	%	50	37	40
Field_capacity	%	42	33	--
Conductivity	m/day	11.6	4.0	--
Longitudinal_disp.	m	304.8	304.8	3.05
Transverse_disp.	m	--	--	0.31
Vertical_disp.	m	--	--	0.31
Effective_porosity	%	--	--	10.0
Velocity	m/day	--	--	0.03
Distance	m	--	--	30.5
Textural_class		silt loam	sandy loam	clay
%_sand	%	30	60	5
%_silt	%	50	25	10
%_clay	%	20	15	85
%_OMC	%	1.5	0.3	0.1
%_Fe	%	1	2	1
pH		5.5	5	7

Table 16.3. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's K-25 Installation Karst Storm Flow Zone. Parameters are characterized the settings saturated zone (SZ).

Parameter	Units	SZ
Darcian_velocity	m/yr	--
SOILC		5.39
Thickness	m	4.57
Bulk_density	g/cm3	2.7
Total_porosity	%	50
Field_capacity	%	--
Conductivity	m/day	--
Longitudinal_disp.	m	3.05
Transverse_disp.	m	0.31
Vertical_disp.	m	0.31
Effective_porosity	%	50.0
Velocity	m/day	182.9
Distance	m	30.5
Textural_class		loam
%_sand	%	45
%_silt	%	40
%_clay	%	15
%_OMC	%	0.1
%_Fe	%	1
pH		7

17.0 OAK RIDGE NATIONAL LABORATORY

The Oak Ridge National Laboratory (ORNL) is a large, multipurpose research laboratory whose basic mission has been the commercial development of radioisotopes and research and development related to nuclear energy, non-nuclear energy alternatives, and other areas of scientific research. To accomplish this mission, the ORNL conducts research in fields of modern science and technology (Martin Marietta, Inc. 1989).

ORNL is located on 36 km² (17 mi²) in the southcentral portion of the 140 km² (55 mi²) Oak Ridge Reservation (ORR) (Figure 17.1). The ORR is located about 32 km (20 mi) west of Knoxville, Tennessee, in the rolling terrain between the Cumberland and Great Smoky Mountains. The land surrounding the ORR is primarily rural, dominated by agricultural and residential land. The ORNL's main laboratory area (designated as the X-10 facility) takes up only about 15% of the ORNL grounds. Ecologically, about 70% of the ORR is forested with plant communities characteristic of the those found in the intermountain regions of Appalachia. The dominant oak-hickory association of this area is typified by extensive stands of mixed yellow pine and hardwoods as well as oak and hickory.

17.1 CLIMATE

The ORR is located near the boundary between a "humid subtropic" and a "humid continental warm summer" climate (Critchfield 1974). Meteorological data are available from onsite measurements and from measurements in the city of Oak Ridge, Tennessee. On average, the maximum daily temperature exceeds 32°C (90°F) on 30 days per year and is below 0°C (32°F) on 6 days per year; the minimum daily temperature is below 0°C (32°F) on 87 days per year and is below -18°C (0°F) about once every 2 years (DOC 1987b). July is the warmest month, with daily maximum and minimum temperatures averaging 31°C (87°F) and 19°C (66°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 8°C (46°F) and -2°C (28°F), respectively (DOC 1987b).

Annual precipitation is on the order of 140 cm (55 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 128 days per year and the area experiences an average of 51 thunderstorm days per year. The average annual snowfall is 33 cm (17 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of four days per year (DOC 1987b).

Winds on the ORR are influenced by the local topography. Mountain ridges and valleys tend to channel winds and mountain valley circulation often produces significant diurnal variations in the winds. As a result, wind directions and speeds may vary significantly from location to location across the ORR. The prevailing wind direction in the

ORR's northeast-trending valleys and in the city of Oak Ridge is from the southwest. There is also a high incidence of winds from neighboring sectors and in the opposite direction. Wind speeds in the city of Oak Ridge average about 2 m/s (4 mph) at about 9 m (30 ft) above ground level (DOC 1987b). Average wind speeds are highest in April (2.5 m/s [6 mph]) and lowest in October (1.5 m/s [3.5 mph]) (DOC 1987b).

17.2 GEOLOGY

The ORR is located in the Bethel and Melton Valleys, part of the Tennessee Valley and Ridge Province of the Southern Appalachian fold and thrust belt. The area is characterized by a succession of northeast-trending thrust faults that stack and repeat the Paleozoic section. As a result of thrusting and subsequent differential erosion, a series of ridges consisting of relatively resistant rocks (e.g., sandstone, shale, and dolomite) and valleys developed in more easily eroded material (e.g., less resistant carbonate and shale). Most of the units dip steeply toward the south-southeast. This structure has a major role in regulating groundwater movement in the area. The main plant area of the ORNL is situated in the Bethel Valley; Chestnut Ridge lies to the north of the installation and Haw Ridge lies to the south. Chestnut ridge is formed from the Knox Group, which is a deeply weathered cherty dolomite. The Bethel Valley is underlain by the Chickamauga Limestone, which consists of silty limestones and calcareous siltstones. Haw Ridge is formed from Rome Formation, consisting of sandstones, siltstones and shales. The Melton Valley, located south of Haw Ridge, is underlain by the Conasauga Group, which consists of calcareous shales interlayered with limestone and siltstone. The Copper Creek Fault lies south of the main plant area of Haw Ridge. Fracturing is pervasive throughout all rock units at the ORNL and also occurs in zones that are associated with faults. Although the rock units are highly fractured, most fractures have been filled with mineral precipitates (predominantly calcite) and do not contribute to a secondary permeability. Karstification, or solution enlargement of existing fractures, is common in the more carbonate-rich units and has been reported from the Knox Group and Chickamauga Group (Martin Marietta, Inc. 1989).

17.3 HYDROLOGY

In the Valley and Ridge Province of Tennessee, groundwater occurs in bedrock formations, residual soil accumulations near the bedrock surface, and a few alluvial aquifers along the largest rivers (Martin Marietta, Inc. 1989). Groundwater flow in the shales and carbonate rocks that dominate the region's bedrock is attributed to fractures and solution cavities. Although groundwater occurs in all formations that outcrop at the ORNL, three major hydrologic units are present. Mechanisms and rates of flow appear to be controlled by topography, structure, and lithology. The first hydrologic unit is a near-surface stormflow zone that extends across all of the ORNL (as well as other ORR areas). Because of its proximity to the surface, there are no clearly defined partially-saturated zones that overlie the

stormflow zone. The stormflow transmits 90% of the incoming precipitation laterally to surface water. The remaining 10% infiltrates to underlying aquifers. The second hydrologic unit is the Knox aquifer, which includes areas underlain by the Knox Group and the Maynardville Limestone member of the Conasauga Group. The third hydrologic unit is the ORR Aquitards consisting of areas underlain by all other geologic formations. Vertical movement of these waters tends to occur along contact zones between major lithologic units. Therefore, soil waters generally move down dip until reaching a zone of saturation where they then tend to migrate along strike until reaching an area of discharge.

The Clinch River is the major surface water source that receives discharges from the Oak Ridge installations. Four Tennessee Valley Authority reservoirs influence the flow and/or water levels of the lower Clinch: Norris and Melton Hill on the Clinch River and Watts Bar and Fort Loudon on the Tennessee River. The ORR is bounded on the south and west by a 63-km (39-mi) stretch of the Clinch River. Melton Hill Dam is located at Clinch River kilometer 37.2 (river mile 23), forming the Melton Hill Reservoir and several major embayments which bound the ORR. Both groundwater and surface water are drained from the ORR by a network of small tributaries of the Clinch River. The ORNL site drains into White Oak Creek and the Melton Branch which both drain into the Clinch River (Martin Marietta, Inc. 1989).

17.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the ORNL for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 17.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 17.2.

For PEIS modeling purposes, the ORNL is divided into three hydrogeologic environmental settings (Figure 17.1): the Stormflow Zone, Knox, and Aquitard settings. Figure 17.2 presents stratigraphic columns for each of these settings. The Stormflow zone has no partially-saturated zones associated with it. The Knox and Aquitard groundwater settings share a series of four partially-saturated zones named inceptisol 1 (silt loam), inceptisol 2 (sandy loam), ultisol 1 (silt loam), and ultisol 2 (clay loam). The combined thickness of the four partially-saturated zones is 8 m (26 ft). The following is a brief description of the characteristics of the saturated zones for each of the settings. Surface water data are presented in Table 17.1. Hydrogeologic data for the various settings are presented in Tables 17.2-17.4.

17.4.1 Stormflow Zone

The Stormflow Zone approximately corresponds to the root zone of vegetation. For PEIS modelling, the Stormflow Zone covers the entire site zone of vegetation, although it may be missing in urbanized areas and tends to be thicker in forested than in grassy areas. In vegetated areas the vertical permeability of the Stormflow Zone is larger than the 1 hour precipitation intensity, thus nearly all rainfall is absorbed. The permeability of the Stormflow Zone is much larger than the underlying vadose zone and large precipitation fluxes tend to result in transient perched water in the Stormflow Zone which is then transmitted downslope to streams. The physical characteristics of the Stormflow Zone are summarized in Moore and Toran (1992).

Infiltration rates into the Stormflow Zone were measured in one large-area test for grassland and in over 60 double-ring infiltrometer tests for forest. Total porosity was measured in multiple samples at two locations near the ORNL. Macropore porosity was measured during some infiltration tests. Specific yield, hydraulic conductivity, and discharge rate were determined by hydrograph analysis for Ish Creek and the headwaters of Melton Branch. Storage capacity was calculated from specific yield and average thickness. Average hydraulic gradient was measured on topographic maps.

17.4.2 Knox and Aquitard Groundwater Zones

In the general hydrologic framework developed by hydrogeologists at Oak Ridge, there are two hydrostratigraphic units controlling groundwater flow. These are designated as the Knox aquifer and the ORR aquitards. The Knox aquifer consists of the Knox Group and the underlying Maynardville Limestone of the Conasauga Group. The Aquitard zone includes all rock formations other than those comprising the Knox Group. For the PEIS, we include an environmental setting for each of these zones, designated as the Knox Setting and the Aquitard Setting. Measurements of thicknesses, total porosities, fracture porosities, and matrix conductivities are discussed in Moore and Toran (1992). Specific yields were computed from hydrograph analysis for Ish Creek and the headwaters of the Melton Branch. Storage capacity was calculated from specific yield and the average water table fluctuation. Conductivity was calculated from the average transmissivity as measured from slug tests, and the thickness of each unit. Hydraulic gradient was measured on water table maps. The hydraulic gradient and the conductivity were used to estimate groundwater velocities.

17.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the ORNL are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation.

Ron Sharp supplied input into the development of the climate and atmospheric dispersion environmental settings. Laura Toran supplied input into the development of the meteorologic environmental settings. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

17.6 REFERENCES

Critchfield, H.J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Martin Marietta Energy Systems., Inc. 1989. *Oak Ridge Reservation Environmental Report for 1988, Vol. 1: Narrative, Summary, and Conclusions*. ES/ESH-8/V1, Environmental and Safety Activities, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

Moore, G.K. 1988. *Concepts of Groundwater Occurrence and Flow Near Oak Ridge National Laboratory, Tennessee*. ORNL/TM-10969, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Moore, G.K., and L.E. Toran. 1992. *Supplement to a Hydrologic Framework for the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/TM-12191, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

U.S. Department of Commerce (DOC). 1987b. *Local Climatological Data Annual Summaries for 1986 Part II Southern Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.

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Figure 17.1. Location and Environmental Settings for the ORNL, K-25, and Y-12 installations at Oak Ridge. For PEIS modeling purposes, the K-25 installation is characterized by a single environmental setting; the ORNL is divided into three environmental settings (the Stormflow Zone, Knox, and Aquitard settings), and the Y-12 installation is divided into seven environmental settings: the Bear Creek Aquitard, Bear Creek Stormflow, East Fork Poplar Creek (EFPC) Aquitard, EFPC Stormflow, Y-12 Knox, Clinch River Aquitard, and Clinch River Stormflow settings. Stormflow zones and other installation zones cover the same area.

M bls = Meters below land surface

Figure 17.2. Stratigraphic Columns for X-10 Environmental Settings

EXHIBIT 17.1

Oak Ridge National Laboratory Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at the X-10 meteorological tower and in the city of Oak Ridge, Tennessee.

Station Name: Oak Ridge, Tennessee	Elevation: 268 m	Latitude: 36.10°N
MT2 Monitoring Location at X-10 facility, Oak Ridge, Tennessee	Elevation: 289 m	Latitude: 35.93°N

Annual Mean Air Temp:	57.4 °F	(Oak Ridge) Reference (A)	Based on observations made from 1951-1980.
Anemometer Height:	12.0 m	(Oak Ridge) Reference (A)	Based on average of 3 heights used during observations.
	10.0 m	(MT2/X-10) Reference (B)	
Mean Annual Wind Speed:	4 mph	(Oak Ridge) Reference (A)	Based on 16 years of observations.
	4 mph	(MT2/X-10) Reference (B)	
Fastest 1-Min Wind Speed:	59 mph	(Oak Ridge) Reference (A)	Based on 22 years of observations.
Annual Precipitation:	54.8 in.	(Oak Ridge) Reference (A)	Based on observations made from 1951-1980.
Precipitation Days:	128 yr ⁻¹	(Oak Ridge) Reference (A)	Based on 38 years of observations.
Thunderstorms Freq:	51 yr ⁻¹	(Oak Ridge) Reference (A)	Based on 17 years of observations.

Avg Morning Mixing Ht:	450 m	Reference (C)	
Avg Afternoon Mixing Ht:	1600 m	Reference (C)	
Top Soil Moisture Capacity:	7.1 cm	Reference (C)	

MEPAS Parameters:	Climatic Region Index:	6	Reference (C)
	Precipitation-Evaporation Index:	116	Reference (C)
	Soil Cons. Serv. Curve Number:	77	Reference (C)

MONTHLY AVERAGES

MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED	COVER	DAYS	MAX	MIN
	(°F)	(Inches)	(MPH)	(10ths)	(#)	(%)	(%)
Jan	36	5.3	3.8	6.7	12.4	75	55
Feb	42	4.6	4.0	6.5	11.4	73	48
Mar	50	6.2	4.3	6.5	12.6	68	47
Apr	58	4.4	4.3	5.9	10.8	72	47
May	65	4.2	3.8	5.9	10.7	76	52
Jun	73	4.3	3.3	5.5	10.3	77	53
Jul	77	5.2	3.1	5.8	11.9	74	50
Aug	75	3.8	2.9	5.5	10.4	81	55
Sep	69	3.8	2.9	5.6	8.3	77	56
Oct	57	2.9	3.0	5.0	7.9	71	47
Nov	48	4.5	3.4	6.1	10.1	71	48
Dec	39	5.7	3.5	6.5	10.9	72	55

	↓	↓	↓	↓	↓	↓	↓
Reference: ...	(B)	(A)	(B)	(A)	(A)	(B)	(B)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part II Southern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- B: Unpublished technical data provided by meteorologist Ron Sharp (ORNL Office of Environmental Compliance and Documentation). Data were provided using the Oak Ridge Meteorological Data Analysis Program (OMDRAP). The program reads archived hourly meteorological data and generates tables of climatological averages, input files for atmospheric dispersion models, and other meteorological support products. Technical information on the ORNL meteorological data acquisition system is described in detail in: "Oak Ridge National Laboratory Meteorological Tower Data Acquisition System", Environmental Systems Corporation, TIN 82-1844, August, 1982.
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 17.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for the Oak Ridge Reservation's X-10 Area. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made from 1983 through 1992.

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	>25
A	NORTH	0.00179	0.00201	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00179	0.00211	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00207	0.00243	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00286	0.00396	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00334	0.00704	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00428	0.00533	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00347	0.00384	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00308	0.00404	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00355	0.00579	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00413	0.00922	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00336	0.01116	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00261	0.00737	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00226	0.00522	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00158	0.00353	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00139	0.00189	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00128	0.00199	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00104	0.00132	0.00012	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00105	0.00116	0.00004	0.00000	0.00000	0.00000
B	NORTHEAST	0.00137	0.00153	0.00003	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00168	0.00386	0.00028	0.00000	0.00000	0.00000
B	EAST 0.00138	0.00586	0.00036	0.00000	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00139	0.00161	0.00007	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00067	0.00076	0.00005	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00072	0.00054	0.00005	0.00000	0.00000	0.00000
B	SOUTH	0.00084	0.00166	0.00013	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00162	0.00576	0.00082	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00183	0.00857	0.00171	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00153	0.00634	0.00114	0.00000	0.00000	0.00000
B	WEST	0.00111	0.00503	0.00176	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00097	0.00299	0.00216	0.00000	0.00000	0.00000
B	NORTHWEST	0.00054	0.00111	0.00047	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00084	0.00103	0.00008	0.00000	0.00000	0.00000
C	NORTH	0.00126	0.00097	0.00018	0.00000	0.00000	0.00000
C	NORTH-NORTHEAST	0.00180	0.00124	0.00037	0.00004	0.00000	0.00000
C	NORTHEAST	0.00258	0.00324	0.00024	0.00000	0.00000	0.00000
C	EAST-NORTHEAST	0.00318	0.01124	0.00171	0.00000	0.00000	0.00000
C	EAST 0.00133	0.00903	0.00151	0.00000	0.00000	0.00000	0.00000
C	EAST-SOUTHEAST	0.00118	0.00118	0.00011	0.00000	0.00000	0.00000
C	SOUTHEAST	0.00086	0.00026	0.00004	0.00000	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00092	0.00020	0.00005	0.00000	0.00000	0.00000
C	SOUTH	0.00118	0.00082	0.00036	0.00001	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00213	0.00409	0.00292	0.00013	0.00000	0.00000
C	SOUTHWEST	0.00292	0.01073	0.01011	0.00062	0.00000	0.00000
C	WEST-SOUTHWEST	0.00274	0.00805	0.00492	0.00017	0.00000	0.00000
C	WEST	0.00183	0.00583	0.00558	0.00016	0.00000	0.00000
C	WEST-NORTHWEST	0.00130	0.00272	0.00325	0.00008	0.00000	0.00000
C	NORTHWEST	0.00104	0.00050	0.00007	0.00000	0.00000	0.00000
C	NORTH-NORTHWEST	0.00103	0.00050	0.00018	0.00000	0.00000	0.00000
D	NORTH	0.01617	0.00125	0.00020	0.00000	0.00000	0.00000
D	NORTH-NORTHEAST	0.01694	0.00255	0.00033	0.00008	0.00000	0.00000
D	NORTHEAST	0.02357	0.00416	0.00003	0.00000	0.00000	0.00000
D	EAST-NORTHEAST	0.01848	0.02019	0.00132	0.00000	0.00000	0.00000
D	EAST 0.00474	0.00740	0.00158	0.00003	0.00000	0.00000	0.00000
D	EAST-SOUTHEAST	0.00321	0.00158	0.00004	0.00001	0.00000	0.00000
D	SOUTHEAST	0.00238	0.00091	0.00004	0.00001	0.00000	0.00000

EXHIBIT 17.2 (continued)

STAB.	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
D	SOUTH-SOUTHEAST	0.00211	0.00066	0.00001	0.00000	0.00000	0.00000
D	SOUTH	0.00291	0.00121	0.00016	0.00000	0.00000	0.00000
D	SOUTH-SOUTHWEST	0.00597	0.00358	0.00101	0.00016	0.00000	0.00000
D	SOUTHWEST	0.01608	0.01870	0.00738	0.00095	0.00000	0.00000
D	WEST-SOUTHWEST	0.02456	0.02313	0.00474	0.00037	0.00000	0.00000
D	WEST	0.02177	0.01379	0.00522	0.00028	0.00000	0.00000
D	WEST-NORTHWEST	0.01595	0.00424	0.00229	0.00007	0.00000	0.00000
D	NORTHWEST	0.01573	0.00082	0.00005	0.00000	0.00000	0.00000
D	NORTH-NORTHWEST	0.01465	0.00096	0.00008	0.00000	0.00000	0.00000
E	NORTH	0.02128	0.00064	0.00000	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.02396	0.00132	0.00000	0.00000	0.00000	0.00000
E	NORTHEAST	0.02842	0.00262	0.00000	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.01699	0.00661	0.00004	0.00000	0.00000	0.00000
E	EAST	0.00237	0.00072	0.00000	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00108	0.00029	0.00000	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00080	0.00014	0.00000	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00080	0.00013	0.00000	0.00000	0.00000	0.00000
E	SOUTH	0.00118	0.00028	0.00000	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00200	0.00108	0.00000	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00911	0.00387	0.00003	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.02550	0.01104	0.00004	0.00000	0.00000	0.00000
E	WEST	0.02782	0.00580	0.00013	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.02431	0.00255	0.00003	0.00000	0.00000	0.00000
E	NORTHWEST	0.02257	0.00087	0.00003	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.02109	0.00091	0.00000	0.00000	0.00000	0.00000
F	NORTH	0.00558	0.00036	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00563	0.00029	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00640	0.00029	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00537	0.00058	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00147	0.00028	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00063	0.00020	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00039	0.00022	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00058	0.00022	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00064	0.00030	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00112	0.00046	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00247	0.00067	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00740	0.00204	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00851	0.00178	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00751	0.00164	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00604	0.00058	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00496	0.00041	0.00000	0.00000	0.00000	0.00000
G	NORTH	0.00009	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHEAST	0.00017	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTHEAST	0.00033	0.00001	0.00000	0.00000	0.00000	0.00000
G	EAST-NORTHEAST	0.00046	0.00004	0.00000	0.00000	0.00000	0.00000
G	EAST	0.00013	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHEAST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHWEST	0.00003	0.00001	0.00000	0.00000	0.00000	0.00000
G	WEST-SOUTHWEST	0.00024	0.00007	0.00000	0.00000	0.00000	0.00000
G	WEST	0.00028	0.00003	0.00000	0.00000	0.00000	0.00000
G	WEST-NORTHWEST	0.00017	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTHWEST	0.00013	0.00001	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHWEST	0.00012	0.00000	0.00000	0.00000	0.00000	0.00000

Table 17.1. Surface Water Environmental Safety Data for Oak Ridge Reservation, X-10, Oak Ridge, Tennessee

<u>Parameter</u>	<u>Units</u>	<u>Clinch River</u>
Velocity	m/s	0.124
Depth	m	9.14
Width	m	124
Discharge	cms	143

Table 17.2. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's X-10 Installation KNOX Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.27	0.27	0.27	0.27	--
SOILC		5.3	4.9	5.3	8.52	5.39
Thickness	m	0.49	3.47	0.49	3.51	3.05
Bulk_density	g/cm3	1.3	1.7	1.3	1.6	2.7
Total_porosity	%	50	37	42	45	1
Field_capacity	%	42	33	30	40	--
Conductivity	m/day	11.6	3.96	16.5	3.05	--
Longitudinal_disp.	m	304.8	304.8	304.8	304.8	609.6
Transverse_disp.	m	--	--	--	--	61.0
Vertical_disp.	m	--	--	--	--	61.0
Effective_porosity	%	--	--	--	--	1.0
Velocity	m/day	--	--	--	--	3.05
Distance	m	--	--	--	--	6096
Textural_class		silt loam	sandy loam	silt loam	clay loam	loam
%_sand	%	30	60	35	30	45
%_silt	%	50	25	50	40	40
%_clay	%	20	15	15	30	15
%_OMC	%	1.5	0.3	2	0.1	0.1
%_Fe	%	1	2	1	3	1
pH	--	5.5	5	6	5	7

Table 17.3. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's X-10 Installation AQUI Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.27	0.27	0.27	0.27	--
SOILC		5.3	4.9	5.3	8.52	8.52
Thickness	m	0.49	3.47	0.49	3.51	1.52
Bulk_density	g/cm3	1.3	1.7	1.3	1.6	2.6
Total_porosity	%	50	37	42	45	20
Field_capacity	%	42	33	30	40	--
Conductivity	m/day	11.6	3.96	16.5	3.05	--
Longitudinal_disp.	m	304.8	304.8	304.8	304.8	304.8
Transverse_disp.	m	--	--	--	--	30.5
Vertical_disp.	m	--	--	--	--	30.5
Effective_porosity	%	--	--	--	--	20.0
Velocity	m/day	--	--	--	--	0.31
Distance	m	--	--	--	--	3048
Textural_class		silt loam	sandy loam	silt loam	clay loam	clay loam
%_sand	%	30	60	35	30	30
%_silt	%	50	25	50	40	40
%_clay	%	20	15	15	30	30
%_OMC	%	1.5	0.3	2	0.1	0.1
%_Fe	%	1	2	1	3	1
pH		5.5	5	6	5	7

Table 17.4. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's X-10 Installation SFZ Storm Flow Zone. Parameters are characterized for the setting's saturated zone (SZ).

Parameter	Units	SZ
Darcian_velocity	m/yr	--
SOILC	--	8.52
Thickness	m	0.46
Bulk_density	g/cm3	1.3
Total_porosity	%	40
Field_capacity	%	--
Conductivity	m/day	--
Longitudinal_disp.	m	304.8
Transverse_disp.	m	30.5
Vertical_disp.	m	30.5
Effective_porosity	%	20.0
Velocity	m/day	3.05
Distance	m	3048
Textural_class		clay loam
%_sand	%	30
%_silt	%	40
%_clay	%	30
%_OMC	%	0.1
%_Fe	%	1
pH	--	7

18.0 OAK RIDGE Y-12 INSTALLATION

The mission of the Y-12 plant includes fabricating nuclear weapons components, processing source and special nuclear material, providing support to the weapons design laboratories, and supporting Martin Marietta Energy Systems, Inc. and other government agencies (Martin Marietta, Inc. 1989).

The Y-12 installation is located on 3.3 km² (811 acres) in the eastern end of the 140 km² (35,000 acres) ORR (Figure 18.1), immediately adjacent to the city of Oak Ridge, Tennessee. The ORR is located about 32 km (20 mi) west of Knoxville, Tennessee, in the rolling terrain between the Cumberland and Great Smoky Mountains. The land surrounding the ORR is primarily rural and is used largely for agricultural and residential purposes. The Y-12 installation is in the Bear Creek Valley, sandwiched between Pine and Chestnut Ridges, about 16 km (10 mi) southeast of the Cumberland Mountains. Ecologically, about 70% of the ORR is forested with plant communities characteristic of the those found in the intermountain regions of Appalachia. The dominant oak-hickory association of this area is typified by extensive stands of mixed yellow pine and hardwoods as well as oak and hickory.

18.1 CLIMATE

The ORR is located near the boundary between a "humid subtropic" and a "humid continental warm summer" climate (Critchfield 1974). Meteorological data are available from onsite measurements and from measurements in the city of Oak Ridge, Tennessee. On average, the maximum daily temperature exceeds 32°C (90°F) on 30 days per year and is below 0°C (32°F) on 6 days per year; the minimum daily temperature is below 0°C (32°F) on 87 days per year and is below -18°C (0°F) about once every 2 years (DOC 1987b). July is the warmest month, with daily maximum and minimum temperatures averaging 31°C (87°F) and 19°C (66°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 8°C (46°F) and -2°C (28°F), respectively (DOC 1987b).

Annual precipitation is on the order of 140 cm (55 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 128 days per year and the area experiences an average of 51 thunderstorm days per year. The average annual snowfall is 33 cm (13 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 4 days per year (DOC 1987b).

Winds on the ORR are influenced by the local topography. Mountain ridges and valleys tend to channel winds and mountain valley circulation often produce significant diurnal variations in the winds. As a result, wind directions and speeds may vary significantly from location to location across the ORR. The prevailing wind direction in the

ORR's northeast-trending valleys and in the city of Oak Ridge is from the southwest. There is also a high incidence of winds from neighboring sectors and in the opposite direction. Wind speeds in the city of Oak Ridge average about 2 m/s (4 mph) at about 9 m (30 ft) above ground level (DOC 1987b). Average wind speeds are highest in April (2.5 m/s [6 mph]) and lowest in October (1.5 m/s [3.5 mph]) (DOC 1987b).

18.2 GEOLOGY

The ORR is located in the Bethel and Melton Valleys, part of the Tennessee Valley and Ridge Province of the Southern Appalachian fold and thrust belt. The area is characterized by a succession of northeast-trending thrust faults that stack and repeat the Paleozoic section. As a result of thrusting and subsequent differential erosion, a series of ridges consisting of relatively resistant rocks (e.g., sandstone, shale, and dolomite) and valleys developed in more easily eroded material (e.g., less resistant carbonate and shale). Most of the units dip steeply toward the south-southeast. This structure has a major role in regulating groundwater movement in the area. Fracturing is pervasive throughout all rock units at the ORR and also occurs in zones that are associated with faults. Although the rock units are highly fractured, most fractures have been filled with mineral precipitates (predominantly calcite) and do not contribute to a secondary permeability. Karstification, or solution enlargement of existing fractures, is common in the more carbonate-rich units and has been reported from the Knox Group and Chickamauga Group (Martin Marietta, Inc. 1989). The bedrock at Y-12 is composed of four separate formations which are, in order from youngest to oldest, the Chickamauga Limestone, Knox Group, Conasauga Group, and Rome Formation. Pine Ridge, the northwest border of the installation, is formed by the Rome Formation. Most of the installation is in Bear Creek Valley, which is underlain by the shale, siltstone, and limestone of the Conasauga Group. The soils in Bear Creek Valley are a mixture of clays, silts and weathered shale fragments. Chestnut Ridge, the southeast border of the installation, is formed by the Knox Group (Moore and Toran 1992).

18.3 HYDROLOGY

In the Valley and Ridge Province of Tennessee, groundwater occurs in bedrock formations, residual soil accumulations near the bedrock surface, and a few alluvial aquifers along the largest rivers (Martin Marietta, Inc. 1989). Groundwater flow in the shales and carbonate rocks that dominate the region's bedrock is attributed to fractures and solution cavities. There are three major hydrologic units at the ORR. The first unit is a near-surface Stormflow Zone. The Stormflow Zone transmits 90% of the incoming precipitation laterally to surface water. The remaining 10% infiltrates to underlying aquifers. Because of its proximity to the surface, there are no clearly defined partially-saturated zones that overlie the Stormflow Zone. The second hydrologic unit is the Knox aquifer, which includes areas underlain by the Knox Group and the Maynardville Limestone member of the Conasauga

Group. The third hydrologic unit is the ORR Aquitards consisting of areas underlain by all other geologic formations. "Vertical" movement of these waters tends to occur along contact zones between major lithologic units. Therefore, soil water generally moves down dip until reaching a zone of saturation where it then tends to migrate along strike until reaching an area of discharge.

The Clinch River is the major surface water source that receives discharges from the Oak Ridge installations. Four Tennessee Valley Authority reservoirs influence the flow and/or water levels of the lower Clinch: Norris and Melton Hill on the Clinch River and Watts Bar and Fort Loudon on the Tennessee River. The ORR is bounded on the south and west by a 63-km (39 mi) stretch of the Clinch River. Melton Hill Dam is located at Clinch River kilometer 37.2 (river mile 23), forming the Melton Hill Reservoir and several major embayments which bound the ORR. Both groundwater and surface water are drained from the ORR by a network of small tributaries of the Clinch River. Surface water at Y-12 is dominated by three major drainages: Bear Creek, East Fork Poplar Creek, and the Clinch River. The main part of Y-12 lies in the East Fork Poplar Creek drainage. Water in this region flows into East Fork Poplar Creek through the town of Oak Ridge. The Bear Creek drainage flows westward and connects with East Fork Poplar Creek about 1.5 km (1 mi) east of the K-25 site. Outside these regions water is transmitted into the Clinch river through a complex network of minor streams.

18.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and two joint frequency distribution exhibits are sufficient to address the climate and atmospheric dispersion characteristics of Y-12 for PEIS modeling purposes. Data from the Y-12 West monitoring site is representative of the atmospheric dispersion conditions in the western half of the Y-12 installation and data from the Y-12 East monitoring site are representative of atmospheric dispersion conditions in the eastern half of the installation. Meteorological data for the installation are presented in Exhibit 18.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibits 18.2 and 18.3.

For PEIS modeling purposes, Y-12 is divided into seven hydrogeologic environmental settings (Figure 18.1): the Bear Creek Aquitard, Bear Creek Stormflow, East Fork Poplar Creek Aquitard, East Fork Poplar Creek Stormflow, Clinch River Aquitard setting, Clinch River Knox, and Clinch River stormflow settings. Figure 18.2 presents the stratigraphic columns for these environmental settings. The settings represent significant combinations of groundwater and surface water pathways. The regional names correspond to major drainages identified in the Y-12 area. The Stormflow, Aquitard, and Knox designators are lithological and follow the framework described in Moore and Toran (1992).

Each of the Aquitard and Knox settings have four partially-saturated zones known as Inceptisol 1 (silt loam), Inceptisol 2 (sandy loam), Ultisol 1 (silt loam), and Ultisol 2 (clay loam). The stormflow zone has no partially-saturated zones associated with it. The following is a brief description of the characteristics of the saturated zones for each of the settings. Surface water data are presented in Table 18.1. Hydrogeologic data for the various settings are presented in Tables 18.2-18.7.

18.4.1 Stormflow Zone

The Stormflow Zone approximately corresponds to the root zone of vegetation. For PEIS modelling, the Stormflow Zone covers the entire site zone of vegetation, although it may be missing in urbanized areas and tends to be thicker in forested areas than in grassy areas. In vegetated areas the vertical permeability of the stormflow zone is larger than the 1-hour precipitation intensity, thus nearly all rainfall is absorbed. The permeability of the Stormflow Zone is much larger than the underlying vadose zone and large precipitation fluxes tend to result in transient perched water in the stormflow zone which is then transmitted downslope to streams (Moore and Toran 1992).

Infiltration rates into the Stormflow Zone were measured in one large-area test for grassland and in over 60 double-ring infiltrometer tests for forest. Total porosity was measured in multiple samples at two locations near the ORNL. Macropore porosity was measured during some infiltration tests. Specific yield, hydraulic conductivity, and discharge rate were determined by hydrograph analysis for Ish Creek and the headwaters of Melton Branch. Storage capacity was calculated from specific yield and average thickness. Average hydraulic gradient was measured on topographic maps.

18.4.2 Base Groundwater Zones

In the general hydrologic framework developed by hydrogeologists at Oak Ridge, there are two hydrostratigraphic units controlling groundwater flow. These are designated as the Knox aquifer and the ORR aquitards. The Knox aquifer consists of the Knox Group and the underlying Maynardville Limestone of the Conasauga Group. The Aquitard zone includes all rock formations other than those comprising the Knox zone. For the PEIS we include an environmental setting for each of these zones, designated as the Knox setting and the Aquitard Setting. Measurements of thicknesses, total porosities, fracture porosities, and matrix conductivities are discussed in Moore and Toran (1992). Specific yields were computed from hydrograph analysis for Ish Creek and the headwaters of the Melton Branch. Storage capacity was calculated from specific yield and the average water table fluctuation. Conductivity was calculated from the average transmissivity as measured from slug tests, and the thickness of each unit. Hydraulic gradient was measured on water table maps. The hydraulic gradient and the conductivity were used to estimate groundwater velocities.

18.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for ORNL are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Ron Sharp supplied input into the development of the climate and atmospheric dispersion environmental settings. Laura Toran supplied input into the development of the meteorologic environmental settings. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

18.6 REFERENCES

Critchfield, H.J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Martin Marietta Energy Systems, Inc. 1989. *Oak Ridge Reservation Environmental Report for 1988, Vol. 1: Narrative, Summary, and Conclusions*. ES/ESH-8/V1, Environmental and Safety Activities, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

Moore, G.K., and L.E. Toran. 1992. *Supplement to a Hydrologic Framework for the Oak Ridge Reservation, Oak Ridge, Tennessee*. ORNL/TM-12191, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

U.S. Department of Commerce (DOC). 1987b. *Local Climatological Data Annual Summaries for 1986 Part II Southern Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

S9405048.2

Figure 18.1. Location and Environmental Settings for the ORNL, K-25, and Y-12 installations at Oak Ridge. For PEIS modeling purposes, the K-25 installation is characterized by a single environmental setting; the ORNL is divided into three environmental settings (the Stormflow Zone, Knox, and Aquitard settings), and the Y-12 installation is divided into seven environmental settings: the Bear Creek Aquitard, Bear Creek Stormflow, East Fork Poplar Creek (EFPC) Aquitard, EFPC Stormflow, Y-12 Knox, Clinch River Aquitard, and Clinch River Stormflow settings. Stormflow zones and other installation zones cover the same area.

Figure 18.2. Stratigraphic Columns for Y-12 Environmental Settings

EXHIBIT 18.1

Y-12 Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at the X-10 meteorological tower and in the city of Oak Ridge, Tennessee.

Station Name: Oak Ridge, Tennessee	Elevation: 268 m	Latitude: 36.10°N
MT2 Monitoring Location at X-10 facility, Oak Ridge, Tennessee	Elevation: 289 m	Latitude: 35.93°N

Annual Mean Air Temp:	57.4 °F	(Oak Ridge) Reference (A)	Based on observations made from 1951-1980.
Anemometer Height:	12.0 m	(Oak Ridge) Reference (A)	Based on average of 3 heights used during observations.
	10.0 m	(MT2/X-10) Reference (B)	
Mean Annual Wind Speed:	4 mph	(Oak Ridge) Reference (A)	Based on 16 years of observations.
	4 mph	(MT2/X-10) Reference (B)	
Fastest 1-Min Wind Speed:	59 mph	(Oak Ridge) Reference (A)	Based on 22 years of observations.
Annual Precipitation:	54.8 in.	(Oak Ridge) Reference (A)	Based on observations made from 1951-1980.
Precipitation Days:	128 yr ⁻¹	(Oak Ridge) Reference (A)	Based on 38 years of observations.
Thunderstorms Freq:	51 yr ⁻¹	(Oak Ridge) Reference (A)	Based on 17 years of observations.

Avg Morning Mixing Ht:	450 m	Reference (C)
Avg Afternoon Mixing Ht:	1600 m	Reference (C)
Top Soil Moisture Capacity:	7.1 cm	Reference (C)

MEPAS Parameters:	Climatic Region Index:	6	Reference (C)
	Precipitation-Evaporation Index:	116	Reference (C)
	Soil Cons. Serv. Curve Number:	77	Reference (C)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	36	5.3	3.8	6.7	12.4	75	55
Feb	42	4.6	4.0	6.5	11.4	73	48
Mar	50	6.2	4.3	6.5	12.6	68	47
Apr	58	4.4	4.3	5.9	10.8	72	47
May	65	4.2	3.8	5.9	10.7	76	52
Jun	73	4.3	3.3	5.5	10.3	77	53
Jul	77	5.2	3.1	5.8	11.9	74	50
Aug	75	3.8	2.9	5.5	10.4	81	55
Sep	69	3.8	2.9	5.6	8.3	77	56
Oct	57	2.9	3.0	5.0	7.9	71	47
Nov	48	4.5	3.4	6.1	10.1	71	48
Dec	39	5.7	3.5	6.5	10.9	72	55
Reference: ...	(B)	(A)	(B)	(A)	(A)	(B)	(B)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part II Southern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- B: Unpublished technical data provided by meteorologist Ron Sharp (ORNL Office of Environmental Compliance and Documentation). Data were provided using the Oak Ridge Meteorological Data Analysis Program (OMDRAP). The program reads archived hourly meteorological data and generates tables of climatological averages, input files for atmospheric dispersion models, and other meteorological support products. Technical information on the ORNL meteorological data acquisition system is described in detail in: "Oak Ridge National Laboratory Meteorological Tower Data Acquisition System", Environmental Systems Corporation, TIN 82-1844, August, 1982.
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 18.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for the eastern half of the Oak Ridge Reservation's Y-12 Area. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at the MT/East tower at 10 m (33 ft) above ground level. Data are based on measurements made from July, 1986 through June, 1993.

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	>25
A	NORTH	0.00495	0.00176	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00511	0.00215	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00587	0.00416	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00708	0.00402	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00680	0.00318	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00802	0.00214	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00790	0.00158	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00685	0.00169	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00683	0.00267	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00628	0.00468	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00576	0.00457	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00420	0.00351	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00409	0.00238	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00358	0.00164	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00374	0.00089	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00507	0.00137	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00100	0.00093	0.00000	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00151	0.00107	0.00012	0.00000	0.00000	0.00000
B	NORTHEAST	0.00160	0.00415	0.00098	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00206	0.00402	0.00082	0.00000	0.00000	0.00000
B	EAST	0.00199	0.00221	0.00021	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00180	0.00094	0.00002	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00126	0.00100	0.00000	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00119	0.00109	0.00004	0.00000	0.00000	0.00000
B	SOUTH	0.00101	0.00192	0.00004	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00094	0.00457	0.00032	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00080	0.00582	0.00071	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00094	0.00468	0.00057	0.00000	0.00000	0.00000
B	WEST	0.00116	0.00399	0.00060	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00096	0.00237	0.00018	0.00000	0.00000	0.00000
B	NORTHWEST	0.00096	0.00078	0.00011	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00130	0.00085	0.00012	0.00000	0.00000	0.00000
C	NORTH	0.00160	0.00060	0.00004	0.00000	0.00000	0.00000
C	NORTH-NORTHEAST	0.00153	0.00139	0.00025	0.00000	0.00000	0.00000
C	NORTHEAST	0.00148	0.00690	0.00386	0.00004	0.00000	0.00000
C	EAST-NORTHEAST	0.00306	0.00676	0.00336	0.00007	0.00000	0.00000
C	EAST	0.00240	0.00406	0.00055	0.00000	0.00000	0.00000
C	EAST-SOUTHEAST	0.00141	0.00144	0.00007	0.00002	0.00000	0.00000
C	SOUTHEAST	0.00089	0.00089	0.00002	0.00000	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00078	0.00078	0.00002	0.00000	0.00000	0.00000
C	SOUTH	0.00121	0.00205	0.00005	0.00000	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00110	0.00568	0.00137	0.00002	0.00000	0.00000
C	SOUTHWEST	0.00084	0.00920	0.00575	0.00014	0.00000	0.00000
C	WEST-SOUTHWEST	0.00078	0.00856	0.00536	0.00012	0.00000	0.00000
C	WEST	0.00192	0.00797	0.00470	0.00018	0.00000	0.00000
C	WEST-NORTHWEST	0.00174	0.00222	0.00068	0.00004	0.00000	0.00000
C	NORTHWEST	0.00123	0.00084	0.00016	0.00000	0.00000	0.00000
C	NORTH-NORTHWEST	0.00135	0.00085	0.00018	0.00000	0.00000	0.00000
D	NORTH	0.01117	0.00087	0.00005	0.00000	0.00000	0.00000
D	NORTH-NORTHEAST	0.01763	0.00311	0.00055	0.00000	0.00000	0.00000
D	NORTHEAST	0.02612	0.02379	0.00971	0.00005	0.00000	0.00000
D	EAST-NORTHEAST	0.03612	0.02085	0.00653	0.00009	0.00000	0.00000

EXHIBIT 18.2 (continued)

STAB.	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	>25
D	EAST	0.01692	0.01144	0.00101	0.00002	0.00000	0.00000
D	EAST-SOUTHEAST	0.00436	0.00212	0.00020	0.00000	0.00000	0.00000
D	SOUTHEAST	0.00208	0.00044	0.00002	0.00000	0.00000	0.00000
D	SOUTH-SOUTHEAST	0.00203	0.00071	0.00005	0.00000	0.00000	0.00000
D	SOUTH	0.00279	0.00174	0.00009	0.00000	0.00000	0.00000
D	SOUTH-SOUTHWEST	0.00377	0.00788	0.00084	0.00004	0.00000	0.00000
D	SOUTHWEST	0.00375	0.01753	0.01260	0.00203	0.00000	0.00000
D	WEST-SOUTHWEST	0.00459	0.02292	0.01792	0.00238	0.00011	0.00000
D	WEST	0.00813	0.02573	0.00909	0.00082	0.00002	0.00000
D	WEST-NORTHWEST	0.00881	0.00657	0.00093	0.00004	0.00000	0.00000
D	NORTHWEST	0.00591	0.00059	0.00002	0.00005	0.00000	0.00000
D	NORTH-NORTHWEST	0.00891	0.00110	0.00009	0.00000	0.00000	0.00000
E	NORTH	0.01288	0.00071	0.00000	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.02035	0.00199	0.00002	0.00000	0.00000	0.00000
E	NORTHEAST	0.03560	0.00724	0.00068	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.04307	0.00783	0.00036	0.00000	0.00000	0.00000
E	EAST	0.01557	0.00498	0.00005	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00340	0.00060	0.00004	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00192	0.00021	0.00002	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00153	0.00023	0.00000	0.00000	0.00000	0.00000
E	SOUTH	0.00194	0.00052	0.00000	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00263	0.00285	0.00012	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00253	0.00495	0.00100	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00377	0.00486	0.00121	0.00000	0.00000	0.00000
E	WEST	0.00594	0.00817	0.00055	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00562	0.00210	0.00002	0.00000	0.00000	0.00000
E	NORTHWEST	0.00416	0.00023	0.00000	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00738	0.00037	0.00000	0.00000	0.00000	0.00000
F	NORTH	0.00568	0.00032	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00987	0.00093	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.01521	0.00169	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.01959	0.00149	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00792	0.00069	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00165	0.00016	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00162	0.00007	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00109	0.00023	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00098	0.00014	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00098	0.00052	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00085	0.00032	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00082	0.00052	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00125	0.00121	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00169	0.00053	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00224	0.00021	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00372	0.00021	0.00000	0.00000	0.00000	0.00000
G	NORTH	0.00044	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHEAST	0.00105	0.00004	0.00000	0.00000	0.00000	0.00000
G	NORTHEAST	0.00171	0.00027	0.00000	0.00000	0.00000	0.00000
G	EAST-NORTHEAST	0.00215	0.00027	0.00000	0.00000	0.00000	0.00000
G	EAST	0.00073	0.00012	0.00000	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.00007	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHEAST	0.00007	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00002	0.00002	0.00000	0.00000	0.00000	0.00000
G	SOUTH	0.00007	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHWEST	0.00000	0.00014	0.00000	0.00000	0.00000	0.00000
G	SOUTHWEST	0.00002	0.00021	0.00000	0.00000	0.00000	0.00000
G	WEST-SOUTHWEST	0.00012	0.00016	0.00000	0.00000	0.00000	0.00000
G	WEST	0.00012	0.00034	0.00000	0.00000	0.00000	0.00000
G	WEST-NORTHWEST	0.00018	0.00004	0.00000	0.00000	0.00000	0.00000
G	NORTHWEST	0.00012	0.00002	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHWEST	0.00027	0.00002	0.00000	0.00000	0.00000	0.00000

EXHIBIT 18.3

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for the western half of the Oak Ridge Reservation's Y-12 Area. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at the MT/West tower at 10 m (33 ft) above ground level. Data are based on measurements made from July, 1986 through June, 1993.

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	>25
A	NORTH	0.00432	0.00104	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00447	0.00192	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00568	0.00489	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00522	0.00439	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00473	0.00317	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00370	0.00245	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00407	0.00230	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00468	0.00306	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00522	0.00330	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00553	0.00556	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00771	0.01241	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00802	0.01350	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00704	0.00698	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00628	0.00419	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00500	0.00223	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00422	0.00132	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00072	0.00017	0.00002	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00091	0.00077	0.00011	0.00000	0.00000	0.00000
B	NORTHEAST	0.00157	0.00392	0.00070	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00106	0.00338	0.00132	0.00000	0.00000	0.00000
B	EAST	0.00079	0.00230	0.00036	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00075	0.00124	0.00004	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00064	0.00134	0.00004	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00072	0.00183	0.00032	0.00000	0.00000	0.00000
B	SOUTH	0.00121	0.00332	0.00032	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00128	0.00458	0.00062	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00204	0.00936	0.00251	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00192	0.01052	0.00394	0.00000	0.00000	0.00000
B	WEST	0.00185	0.00426	0.00096	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00096	0.00192	0.00045	0.00000	0.00000	0.00000
B	NORTHWEST	0.00075	0.00032	0.00004	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00060	0.00017	0.00000	0.00000	0.00000	0.00000
C	NORTH	0.00070	0.00030	0.00000	0.00000	0.00000	0.00000
C	NORTH-NORTHEAST	0.00066	0.00155	0.00023	0.00000	0.00000	0.00000
C	NORTHEAST	0.00192	0.00692	0.00283	0.00000	0.00000	0.00000
C	EAST-NORTHEAST	0.00145	0.00573	0.00413	0.00008	0.00000	0.00000
C	EAST	0.00094	0.00224	0.00147	0.00004	0.00000	0.00000
C	EAST-SOUTHEAST	0.00053	0.00160	0.00023	0.00002	0.00000	0.00000
C	SOUTHEAST	0.00045	0.00134	0.00015	0.00000	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00051	0.00140	0.00034	0.00000	0.00000	0.00000
C	SOUTH	0.00087	0.00294	0.00085	0.00008	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00134	0.00634	0.00370	0.00013	0.00000	0.00000
C	SOUTHWEST	0.00270	0.01026	0.00783	0.00030	0.00000	0.00000
C	WEST-SOUTHWEST	0.00243	0.01126	0.00588	0.00019	0.00000	0.00000
C	WEST	0.00192	0.00321	0.00121	0.00004	0.00000	0.00000
C	WEST-NORTHWEST	0.00102	0.00121	0.00021	0.00000	0.00000	0.00000
C	NORTHWEST	0.00064	0.00028	0.00004	0.00000	0.00000	0.00000
C	NORTH-NORTHWEST	0.00060	0.00017	0.00008	0.00000	0.00000	0.00000

EXHIBIT 18.3 (continued)

STAB.	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
D	NORTH	0.00500	0.00119	0.00000	0.00000	0.00000	0.00000
D	NORTH-NORTHEAST	0.00862	0.00866	0.00106	0.00006	0.00000	0.00000
D	NORTHEAST	0.01096	0.03393	0.01790	0.00038	0.00000	0.00000
D	EAST-NORTHEAST	0.00590	0.01822	0.01188	0.00041	0.00000	0.00000
D	EAST	0.00317	0.00600	0.00211	0.00015	0.00002	0.00000
D	EAST-SOUTHEAST	0.00140	0.00240	0.00040	0.00002	0.00002	0.00000
D	SOUTHEAST	0.00075	0.00109	0.00017	0.00004	0.00000	0.00000
D	SOUTH-SOUTHEAST	0.00081	0.00117	0.00011	0.00000	0.00000	0.00000
D	SOUTH	0.00149	0.00304	0.00085	0.00015	0.00000	0.00000
D	SOUTH-SOUTHWEST	0.00443	0.00724	0.00428	0.00075	0.00002	0.00000
D	SOUTHWEST	0.01462	0.01820	0.00447	0.00043	0.00000	0.00000
D	WEST-SOUTHWEST	0.01914	0.02748	0.00513	0.00041	0.00002	0.00000
D	WEST	0.01284	0.00885	0.00111	0.00011	0.00000	0.00000
D	WEST-NORTHWEST	0.00794	0.00257	0.00023	0.00002	0.00000	0.00000
D	NORTHWEST	0.00445	0.00092	0.00006	0.00000	0.00000	0.00000
D	NORTH-NORTHWEST	0.00338	0.00021	0.00000	0.00000	0.00000	0.00000
E	NORTH	0.00619	0.00109	0.00000	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.01215	0.00768	0.00026	0.00000	0.00000	0.00000
E	NORTHEAST	0.01409	0.02252	0.00556	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00573	0.00717	0.00111	0.00000	0.00000	0.00000
E	EAST	0.00179	0.00153	0.00028	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00092	0.00051	0.00000	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00057	0.00036	0.00000	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00072	0.00028	0.00000	0.00000	0.00000	0.00000
E	SOUTH	0.00115	0.00062	0.00000	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00315	0.00141	0.00002	0.00000	0.00000	0.00000
E	SOUTHWEST	0.01373	0.00903	0.00013	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.02197	0.01656	0.00015	0.00000	0.00000	0.00000
E	WEST	0.01505	0.00562	0.00011	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00960	0.00230	0.00004	0.00000	0.00000	0.00000
E	NORTHWEST	0.00521	0.00057	0.00000	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00398	0.00026	0.00000	0.00000	0.00000	0.00000
F	NORTH	0.00528	0.00068	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00654	0.00158	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00936	0.00383	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00671	0.00179	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00319	0.00041	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00183	0.00019	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00166	0.00019	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00158	0.00032	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00296	0.00034	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00502	0.00153	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.01085	0.00824	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.01384	0.00783	0.00000	0.00000	0.00000	0.00000
F	WEST	0.01251	0.00485	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00905	0.00300	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00664	0.00092	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00470	0.00045	0.00000	0.00000	0.00000	0.00000
G	NORTH	0.00028	0.00013	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHEAST	0.00070	0.00009	0.00000	0.00000	0.00000	0.00000
G	NORTHEAST	0.00157	0.00247	0.00000	0.00000	0.00000	0.00000
G	EAST-NORTHEAST	0.00136	0.00200	0.00000	0.00000	0.00000	0.00000
G	EAST	0.00045	0.00040	0.00000	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.00030	0.00009	0.00000	0.00000	0.00000	0.00000
G	SOUTHEAST	0.00019	0.00006	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00008	0.00002	0.00000	0.00000	0.00000	0.00000
G	SOUTH	0.00013	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHWEST	0.00026	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHWEST	0.00094	0.00017	0.00000	0.00000	0.00000	0.00000
G	WEST-SOUTHWEST	0.00204	0.00123	0.00000	0.00000	0.00000	0.00000
G	WEST	0.00181	0.00008	0.00000	0.00000	0.00000	0.00000
G	WEST-NORTHWEST	0.00115	0.00008	0.00000	0.00000	0.00000	0.00000
G	NORTHWEST	0.00055	0.00002	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHWEST	0.00040	0.00004	0.00000	0.00000	0.00000	0.00000

Table 18.1. Surface Water Environmental Safety Data for Oak Ridge Reservation, Y-12, Oak Ridge, Tennessee

<u>Parameter</u>	<u>Units</u>	<u>East Fork Popular Creek</u>	<u>Bear Creek</u>	<u>Clinch River</u>
Velocity	m/s	0.152	0.914	0.124
Depth	m	0.304	0.061	9.14
Width	m	4.57	1.07	124
Discharge	cms	0.22	0.057	143

Table 18.2. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's Y-12 Installation EFPC_AQUI Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.27	0.27	0.27	0.27	--
SOILC		5.3	4.9	5.3	8.52	8.52
Thickness	m	0.49	3.47	0.49	3.51	1.52
Bulk_density	g/cm3	1.3	1.7	1.3	1.6	2.6
Total_porosity	%	50	37	42	45	20
Field_capacity	%	42	33	30	40	--
Conductivity	m/day	11.6	4.0	16.5	3.05	--
Longitudinal_disp.	m	304.8	304.8	304.8	304.8	304.8
Transverse_disp.	m	--	--	--	--	30.5
Vertical_disp.	m	--	--	--	--	30.5
Effective_porosity	%	--	--	--	--	20.0
Velocity	m/day	--	--	--	--	0.31
Distance	m	--	--	--	--	3048
Textural_class		silt loam	sandy loam	silt loam	clay loam	clay loam
%_sand	%	30	60	35	30	30
%_silt	%	50	25	50	40	40
%_clay	%	20	15	15	30	30
%_OMC	%	1.5	0.3	2	0.1	0.1
%_Fe	%	1	2	1	3	1
pH		5.5	5	6	5	7

Table 18.3. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's Y-12 Installation EFPC_SFC Storm Flow Zone. Parameters are characterized for the setting's saturated zone (SZ).

Parameter	Units	SZ
Darcian_velocity	m/yr	--
SOILC		8.52
Thickness	m	0.46
Bulk_density	g/cm3	1.3
Total_porosity	%	40
Field_capacity	%	--
Conductivity	m/day	--
Longitudinal_disp.	m	304.8
Transverse_disp.	m	30.5
Vertical_disp.	m	30.5
Effective_porosity	%	20.0
Velocity	m/day	3.05
Distance	m	3048
Textural_class		clay loam
%_sand	%	30
%_silt	%	40
%_clay	%	30
%_OMC	%	0.1
%_Fe	%	1
pH		7

Table 18.4. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's Y-12 Installation BC_AQUI Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.27	0.27	0.27	0.27	--
SOILC		5.3	4.9	5.3	8.52	8.52
Thickness	m	0.49	3.47	0.49	3.51	1.52
Bulk_density	g/cm3	1.3	1.7	1.3	1.6	2.6
Total_porosity	%	50	37	42	45	20
Field_capacity	%	42	33	30	40	--
Conductivity	m/day	11.6	3.96	16.5	3.05	--
Longitudinal_disp.	m	304.8	304.8	304.8	304.8	304.8
Transverse_disp.	m	--	--	--	--	30.5
Vertical_disp.	m	--	--	--	--	30.5
Effective_porosity	%	--	--	--	--	20.0
Velocity	m/day	--	--	--	--	0.31
Distance	m	--	--	--	--	3048
Textural_class		silt loam	sandy loam	silt loam	clay loam	clay loam
%_sand	%	30	60	35	30	30
%_silt	%	50	25	50	40	40
%_clay	%	20	15	15	30	30
%_OMC	%	1.5	0.3	2	0.1	0.1
%_Fe	%	1	2	1	3	1
pH		5.5	5	6	5	7

Table 18.5. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's Y-12 Installation BC_SFZ Storm Flow Zone. Parameters are characterized for the setting's saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>SZ</u>
Darcian_velocity	m/yr	--
SOILC		8.52
Thickness	m	0.46
Bulk_density	g/cm3	1.3
Total_porosity	%	40
Field_capacity	%	--
Conductivity	m/day	--
Longitudinal_disp.	m	304.8
Transverse_disp.	m	30.5
Vertical_disp.	m	30.5
Effective_porosity	%	20.0
Velocity	m/day	3.05
Distance	m	3048
Textural_class		clay loam
%_sand	%	30
%_silt	%	40
%_clay	%	30
%_OMC	%	0.1
%_Fe	%	1
pH		7

Table 18.6. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's Y-12 Installation CR_KNOX Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.27	0.27	0.27	0.27	--
SOILC		5.3	4.9	5.3	8.52	5.39
Thickness	m	0.49	3.47	0.49	3.50	3.05
Bulk_density	g/cm3	1.3	1.7	1.3	1.6	2.7
Total_porosity	%	50	37	42	45	1
Field_capacity	%	42	33	30	40	--
Conductivity	m/day	11.6	3.96	16.5	3.05	--
Longitudinal_disp.	m	304.8	304.8	304.8	304.8	609.6
Transverse_disp.	m	--	--	--	--	61.0
Vertical_disp.	m	--	--	--	--	70.0
Effective_porosity	%	--	--	--	--	1.0
Velocity	m/day	--	--	--	--	3.05
Distance	m	--	--	--	--	6096
Textural_class		silt loam	sandy loam	silt loam	clay loam	loam
%_sand	%	30	60	35	30	45
%_silt	%	50	25	50	40	40
%_clay	%	20	15	15	30	15
%_OMC	%	1.5	0.3	2	0.1	0.1
%_Fe	%	1	2	1	3	1
pH		5.5	5	6	5	7

Table 18.7. Hydrogeologic Environmental Setting Data for Oak Ridge Reservation's Y-12 Installation CR_AQUI Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.27	0.27	0.27	0.27	--
SOILC		5.3	4.9	5.3	8.52	8.52
Thickness	m	0.49	3.47	0.49	3.51	1.52
Bulk_density	g/cm3	1.3	1.7	1.3	1.6	2.6
Total_porosity	%	50	37	42	45	20
Field_capacity	%	42	33	30	40	--
Conductivity	m/day	11.6	3.96	16.5	3.05	--
Longitudinal_disp.	m	304.8	304.8	304.8	304.8	304.8
Transverse_disp.	m	--	--	--	--	30.5
Vertical_disp.	m	--	--	--	--	30.5
Effective_porosity	%	--	--	--	--	20.0
Velocity	m/day	--	--	--	--	0.31
Distance	m	--	--	--	--	3048
Textural_class		silt loam	sandy loam	silt loam	clay loam	clay loam
%_sand	%	30	60	35	30	30
%_silt	%	50	25	50	40	40
%_clay	%	20	15	15	30	30
%_OMC	%	1.5	0.3	2	0.1	0.1
%_Fe	%	1	2	1	3	1
pH		5.5	5	6	5	7

19.0 PADUCAH GASEOUS DIFFUSION PLANT

The mission of the Paducah Gaseous Diffusion Plant (PGDP) has been the production of ^{235}U in conjunction with operations at the ORGDP (K-25 installation) to provide feed material to the Portsmouth Gaseous Diffusion Plant for commercial operations. The PGDP has been in operation for the DOE since 1952 (Clausen et al. 1992).

The PGDP is located in the Jackson Purchase region of western Kentucky, about 6 km (4 mi) south of the Ohio River and 16 km (10 mi) west of Paducah, Kentucky (Figure 19.1). The PGDP occupies about 14 km² (5.3 mi²). Slightly over 20% of the site is fenced off for PGDP activities, with most of the remaining installation consisting largely of areas of open grassland with some wooded areas (Kornegay et al. 1993). About 60% of the installation's total acreage is managed by the Kentucky Wildlife Department. The terrain surrounding the PGDP is gently rolling with large areas of open grassland and farmland. Areas with steep slopes are generally forested. Ecologically, the terrestrial ecosystem at the PGDP is typical of western Kentucky. Mature hardwood forests dominate the riparian communities on stream banks and upland hardwoods (predominately oak-hickory forest) are present in numerous small woodlots. Grasslands are maintained by strip mowing every other year. The site is typified by diverse animal populations indigenous to several habitat types (i.e., grasslands, fields, riparian and upland forest ecosystems) (Kornegay et al. 1993).

19.1 CLIMATE

The PGDP has a "humid continental warm summer" climate (Critchfield 1974). Meteorological data are available from onsite measurements and from the Barkley Regional Airport, Paducah, Kentucky. On average, the maximum daily temperature exceeds 32°C (90°F) on 53 days per year and is below 0°C (32°F) on 13 days per year; the minimum daily temperature is below 0°C (32°F) on 85 days per year and is below -18°C (0°F) on 2 days per year (DOC 1992b). July is the warmest month, with daily maximum and minimum temperatures averaging 32°C (89°F) and 21°C (69°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 6°C (42°F) and -4°C (24°F), respectively (DOC 1992b).

Annual precipitation is on the order of 119 cm (47 in.), with over 40% of this total occurring from March through June. Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 110 days per year and the area experiences an average of 60 thunderstorm days per year. The average annual snowfall is 17 cm (6.5 in.) (DOC 1992a) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 4 days per year (DOC 1992b).

The prevailing wind direction onsite is from the south-southwest. Wind speeds at the airport average about 3.5 m/s (8 mph) at about 10 m (33 ft) above ground level (DOC 1992b). Average wind speeds are highest in March (4.5 m/s [10 mph]) and lowest in August (2.5 m/s [5.5 mph]) (DOC 1992b).

19.2 GEOLOGY

The PGDP lies within the northern tip of the Mississippi Embayment portion of the Gulf Coastal Plain Province, a large sedimentary trough oriented nearly north-south (Clausen et al. 1992). The stratigraphic sequence in the region consists of Cretaceous, Tertiary and Quaternary sediments that unconformably overly Paleozoic bedrock. In the PGDP area, bedrock is overlain by the Upper Cretaceous McNairy Formation, which consists of interbedded lenses of sand, silt, and clay. The thickness of the McNairy Formation is approximately 70 m (225 ft). In the southern portions of the PGDP, the Paleocene-aged Porters Creek Clay lies above the McNairy Formation. Porters Creek Clay consists of a dark gray to black clay with varying amounts of silt and fine-grained, micaceous, commonly glauconitic sand. Thickness of the Porters Creek Clay ranges from 0 to 26 m (0 to 85 ft), increasing southward. This unit is occasionally exposed in stream beds south of the PGDP. In the extreme southern end of the installation, Eocene-aged sediments consisting of interbedded and interlensing sand, silt, and clay overlay the Porters Creek Clay. Thickness of the Eocene sediments ranges from 0 to 9 m (0 to 30 ft) with an average thickness of less than 3 m (10 ft) at the PGDP.

Unconformable Miocene(?), Pliocene, and Pleistocene continental deposits overlie Cretaceous through Eocene strata at the PGDP. The continental deposits are informally divided into a lower unit (gravel facies) and an upper unit (clay facies). Deposits of the lower unit consist of chert gravel in a matrix of poorly sorted sand and silt and range in thickness from 9 to 15 m (30 to 50 ft). Upper continental deposits consist primarily of clayey silt with lenses of sand and some gravel and vary in thickness from 5 to 17 m (15 to 55 ft). Approximately 1.5 to 8 m (5 to 25 ft) of unstratified loess composed of yellowish-brown silt and clayey silt overlies the continental deposits (Clausen et al. 1992).

19.3 HYDROLOGY

Major aquifers that are dependable sources of groundwater exist within the Jackson Purchase region. The principal water bearing units include the Wilcox Formation, the Claiborne Group, and the McNairy Formations. Additionally, quaternary alluvial deposits along the Tennessee, Ohio, and Mississippi Rivers, and the Pliocene(?) gravel deposits yield appreciable amounts of water. The regional aquifers of the Claiborne Group do not occur at the PGDP either due to nondeposition or removal by erosion. Only the Paleozoic bedrock,

the McNairy Formation, the Wilcox Formation, and the Pliocene(?) and Quaternary sand and gravel deposits are locally significant (Clausen et al. 1992).

Limestone believed to be Mississippian-aged occurs approximately 90 to 120 m (300 to 400 ft) below ground surface at the PGDP. Groundwater production from the bedrock aquifer comes from fissures and fractures and from a weathered rubble zone near the top of the bedrock. The McNairy Formation ranges in depth from 21 to 30 m (70 to 100 ft) below ground surface at the PGDP. Regionally, the McNairy Formation is an excellent aquifer in the southeastern part of the Jackson Purchase region. The McNairy Formation grades from predominantly sand in these areas to predominantly clay near the PGDP where it is described as a poor aquifer. The Porters Creek Clay directly overlies the McNairy Formation and consists primarily of clay with minor amounts of fine-grained sand. The Porters Creek Clay acts as an aquitard between the McNairy and overlying aquifer except where eroded, such as near the southern part of the PGDP. The Eocene Wilcox Formation overlies the Porters Creek Clay. Sands within the Wilcox are difficult to distinguish from sands in the overlying Claiborne Group and are often combined as the Lower Wilcox aquifer. Regionally, recharge to the Lower Wilcox aquifer occurs in areas of outcrop through the Jackson Purchase region. Discharge occurs along the larger tributaries of the Mississippi River. Locally, an area of apparent recharge has resulted in a groundwater mound near the PGDP. Pliocene gravel deposits unconformably overlie Paleozoic to Eocene sediments in most areas of the Jackson Purchase. The Pliocene(?) gravel forms the shallow zone of saturation to the south of the PGDP. Thicker Quaternary gravels form the main zone of saturation in and around PGDP (Clausen et al. 1992).

Surface drainage of the PGDP is by two small tributaries of the Ohio River, the Big Bayou Creek on the west side of the installation and the Little Bayou Creek on the east side of the installation. The two streams merge north of the installation and discharge into the Ohio River at a point about 55 km (34 mi) upstream from the confluence of the Ohio and Mississippi Rivers (Kornegay et al. 1993).

19.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the PGDP for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 19.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 19.2

For PEIS modeling purposes, Paducah can be characterized using one hydrogeologic environmental setting (Figure 19.1). Figure 19.2 presents a stratigraphic column for this setting. The hydrogeological setting consists of three partially-saturated zones and one saturated zone. These zones comprise the late Tertiary and Quaternary gravels, sands, silts,

and clays designated as the Continental Deposits. The first partially-saturated zone consists of overlying loess which blankets the entire site, and consists of silt and clayey silt. The average thickness of this unit is 4.6 m (15 ft). Partially-saturated zone 2 consists of fine to coarse sand and gravel, with an average thickness of 4.9 m (16 ft). The third partially-saturated zone consists of clay and silt, with an average thickness of 5.5 m (18 ft). The saturated zone consists of a regional gravel aquifer overlain by discontinuous sand, sand, and cobbly gravel. The total thickness of the saturated zone is 12.2 m (40 ft). All groundwater flows north into the Ohio River. There are no groundwater divides. Surface water data are presented in Table 19.1. Hydrogeologic data for the environmental setting are presented in Table 19.2.

19.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the PGDP are based on publicly available documents written for DOE environmental programs. Ron Sharp of the ORNL supplied input into the development of the meteorologic and atmospheric dispersion environmental settings. Eric Morti supplied input into the development of the meteorologic environmental settings. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

19.6 REFERENCES

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Figure 19.1. Location and Environmental Settings for the Paducah Gaseous Diffusion Plant (PGDP). For PEIS modeling purposes, the installation is characterized by a single environmental setting.

Figure 19.2. Stratigraphic Column for Paducah Environmental Setting

EXHIBIT 19.1

Paducah Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite and at the Barkley Regional Airport.

Station Name: Barkley Regional Airport, Paducah, Kentucky	Elevation: 123 m	Latitude: 37.07°N
Paducah Meteorology Tower, Paducah, Kentucky	Elevation: 100 m	Latitude: 37.07°N

Annual Mean Air Temp:	57.2 °F	(airport)	Reference (A)	Based on observations made from 1984-1991.
Anemometer Height:	10.0 m	(airport)	Reference (A)	
	10.0 m	(Paducah)	Reference (B)	
Mean Annual Wind Speed:	8 mph	(airport)	Reference (A)	Based on 7 years of observations.
	7 mph	(Paducah)	Reference (B)	
Fastest 1-Min Wind Speed:	44 mph	(airport)	Reference (A)	Based on 7 years of airport observations.
Annual Precipitation:	46.9 in.	(airport)	Reference (A)	Based on 8 years of observations.
Precipitation Days:	110 yr ⁻¹	(airport)	Reference (A)	Based on 8 years of observations.
Thunderstorms Freq:	60 yr ⁻¹	(airport)	Reference (A)	Based on 8 years of observations.

Avg Morning Mixing Ht:	450 m	Reference (C)
Avg Afternoon Mixing Ht:	1400 m	Reference (C)
Top Soil Moisture Capacity:	2.1 cm	Reference (C)

MEPAS Parameters:	Climatic Region Index:	4	Reference (C)
	Precipitation-Evaporation Index:	113	Reference (C)
	Soil Cons. Serv. Curve Number:	78	Reference (C)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	34	3.7	7.1	6.9	8.4	81	65
Feb	38	3.4	7.7	6.9	10.4	83	65
Mar	47	5.0	7.9	6.7	10.0	78	57
Apr	59	4.6	7.3	5.9	10.8	83	51
May	67	4.7	6.4	6.2	11.0	87	57
Jun	76	4.5	5.6	5.7	8.1	88	55
Jul	79	3.7	5.2	5.1	7.9	91	57
Aug	78	3.2	4.7	5.0	7.3	94	57
Sep	71	3.5	5.5	5.3	7.1	93	56
Oct	60	2.6	6.2	5.6	9.0	88	55
Nov	48	4.0	7.6	6.3	9.9	83	61
Dec	38	4.2	7.5	6.4	9.8	82	63
Reference: ...	(B)	(A)	(B)	(A)	(A)	(A)	(A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part III Central Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- B: Private communication (a FAX dated 9/03/93) from Ron Sharp with Oak Ridge National Laboratory (ORNL processes meteorological data from the Paducah meteorological tower).
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 19.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Paducah. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made in 1988, 1989, and 1992.

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	>25
A	NORTH	0.00041	0.00669	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00043	0.00295	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00025	0.00221	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00010	0.00360	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00025	0.00407	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00031	0.00203	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00056	0.00239	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00069	0.00280	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00122	0.00443	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00125	0.00478	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00132	0.00427	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00155	0.00361	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00125	0.00354	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00183	0.00392	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00181	0.00735	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00142	0.00725	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00008	0.00318	0.00323	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00003	0.00168	0.00191	0.00000	0.00000	0.00000
B	NORTHEAST	0.00010	0.00114	0.00071	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00005	0.00265	0.00104	0.00000	0.00000	0.00000
B	EAST	0.00013	0.00285	0.00071	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00008	0.00132	0.00033	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00015	0.00127	0.00074	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00033	0.00160	0.00079	0.00000	0.00000	0.00000
B	SOUTH	0.00033	0.00231	0.00170	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00041	0.00326	0.00277	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00053	0.00425	0.00285	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00046	0.00277	0.00135	0.00000	0.00000	0.00000
B	WEST	0.00018	0.00181	0.00066	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00059	0.00203	0.00117	0.00000	0.00000	0.00000
B	NORTHWEST	0.00036	0.00343	0.00242	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00023	0.00287	0.00298	0.00000	0.00000	0.00000
C	NORTH	0.00018	0.00153	0.00684	0.00107	0.00000	0.00000
C	NORTH-NORTHEAST	0.00013	0.00158	0.00354	0.00046	0.00000	0.00000
C	NORTHEAST	0.00000	0.00130	0.00196	0.00015	0.00000	0.00000
C	EAST-NORTHEAST	0.00000	0.00270	0.00198	0.00005	0.00000	0.00000
C	EAST	0.00010	0.00272	0.00135	0.00000	0.00000	0.00000
C	EAST-SOUTHEAST	0.00008	0.00137	0.00120	0.00000	0.00000	0.00000
C	SOUTHEAST	0.00005	0.00176	0.00114	0.00005	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00036	0.00193	0.00287	0.00023	0.00000	0.00000
C	SOUTH	0.00028	0.00200	0.00549	0.00074	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00051	0.00389	0.01173	0.00137	0.00000	0.00000
C	SOUTHWEST	0.00020	0.00491	0.00845	0.00076	0.00000	0.00000
C	WEST-SOUTHWEST	0.00033	0.00298	0.00333	0.00010	0.00000	0.00000
C	WEST	0.00028	0.00206	0.00242	0.00033	0.00000	0.00000
C	WEST-NORTHWEST	0.00043	0.00186	0.00326	0.00008	0.00000	0.00000
C	NORTHWEST	0.00025	0.00216	0.00394	0.00033	0.00000	0.00000
C	NORTH-NORTHWEST	0.00068	0.00183	0.00539	0.00048	0.00000	0.00000
D	NORTH	0.00066	0.00730	0.01473	0.00679	0.00025	0.00030
D	NORTH-NORTHEAST	0.00043	0.00865	0.01379	0.00544	0.00015	0.00000
D	NORTHEAST	0.00025	0.00565	0.00781	0.00092	0.00000	0.00003

EXHIBIT 19.2 (continued)

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
D	EAST-NORTHEAST	0.00031	0.01043	0.01137	0.00066	0.00003	0.00000
D	EAST	0.00041	0.00806	0.00226	0.00003	0.00003	0.00003
D	EAST-SOUTHEAST	0.00048	0.00562	0.00359	0.00013	0.00000	0.00000
D	SOUTHEAST	0.00112	0.00956	0.00616	0.00066	0.00013	0.00000
D	SOUTH-SOUTHEAST	0.00453	0.01226	0.00875	0.00376	0.00033	0.00000
D	SOUTH	0.00481	0.01424	0.01750	0.01012	0.00148	0.00000
D	SOUTH-SOUTHWEST	0.00445	0.01597	0.02447	0.01686	0.00140	0.00000
D	SOUTHWEST	0.00422	0.01165	0.01063	0.00394	0.00048	0.00000
D	WEST-SOUTHWEST	0.00465	0.00743	0.00448	0.00127	0.00005	0.00000
D	WEST	0.00382	0.00486	0.00285	0.00066	0.00000	0.00000
D	WEST-NORTHWEST	0.00468	0.00654	0.00366	0.00064	0.00000	0.00000
D	NORTHWEST	0.00527	0.00845	0.00595	0.00168	0.00005	0.00003
D	NORTH-NORTHWEST	0.00374	0.00885	0.01104	0.00364	0.00008	0.00006
E	NORTH	0.00061	0.00753	0.00328	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00025	0.00402	0.00422	0.00000	0.00000	0.00000
E	NORTHEAST	0.00010	0.00150	0.00112	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00008	0.00346	0.00310	0.00000	0.00000	0.00000
E	EAST	0.00020	0.00191	0.00013	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00018	0.00298	0.00059	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00066	0.00707	0.00262	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00333	0.01178	0.00417	0.00000	0.00000	0.00000
E	SOUTH	0.00552	0.01505	0.00532	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00555	0.01496	0.00631	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00588	0.00649	0.00076	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00473	0.00394	0.00059	0.00000	0.00000	0.00000
E	WEST	0.00336	0.00315	0.00010	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00455	0.00244	0.00028	0.00000	0.00000	0.00000
E	NORTHWEST	0.00539	0.00458	0.00081	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00356	0.00697	0.00163	0.00000	0.00000	0.00000
F	NORTH	0.00059	0.00348	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00005	0.00094	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00010	0.00025	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00013	0.00056	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00015	0.00061	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00028	0.00053	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00046	0.00333	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00371	0.00962	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00633	0.01150	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00636	0.00989	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00577	0.00440	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00463	0.00176	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00432	0.00132	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00537	0.00170	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00638	0.00196	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00455	0.00460	0.00000	0.00000	0.00000	0.00000
G	NORTH	0.00036	0.00036	0.00000	0.00000	0.00000	0.00021
G	NORTH-NORTHEAST	0.00018	0.00008	0.00000	0.00000	0.00000	0.00000
G	NORTHEAST	0.00003	0.00013	0.00000	0.00000	0.00000	0.00000
G	EAST-NORTHEAST	0.00003	0.00010	0.00000	0.00000	0.00000	0.00000
G	EAST	0.00028	0.00023	0.00000	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.00005	0.00010	0.00000	0.00000	0.00000	0.00000
G	SOUTHEAST	0.00043	0.00117	0.00003	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00387	0.00488	0.00003	0.00000	0.00000	0.00000
G	SOUTH	0.00593	0.00443	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00529	0.00555	0.00000	0.00000	0.00000	0.00000
G	SOUTHWEST	0.00369	0.00163	0.00000	0.00000	0.00000	0.00000
G	WEST-SOUTHWEST	0.00242	0.00046	0.00000	0.00000	0.00000	0.00000
G	WEST	0.00282	0.00036	0.00000	0.00000	0.00000	0.00000
G	WEST-NORTHWEST	0.00338	0.00008	0.00000	0.00000	0.00000	0.00000
G	NORTHWEST	0.00420	0.00010	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHWEST	0.00224	0.00056	0.00000	0.00000	0.00000	0.00000

Table 19.1. Surface Water Environmental Safety Data for Paducah Gaseous Diffusion Plant, Paducah, Kentucky

<u>Parameter</u>	<u>Units</u>	<u>Ohio River</u>
Velocity	m/s	1.07
Depth	m	9.14
Width	m	1,520
Discharge	cms	14,940

Table 19.2. Hydrogeologic Environmental Setting Data for Paducah Gaseous Diffusion Plant's PGDP Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	SZ
Darcian_velocity	m/yr	0.24	0.24	0.24	--
SOILC		5.3	4.05	11.4	4.38
Thickness	m	4.57	4.88	5.49	12.19
Bulk_density	g/cm3	1.4	1.77	1.6	1.77
Total_porosity	%	40	30	40	30
Field_capacity	%	28	9	40	--
Conductivity	m/day	8.5e-4	0.01	8.5e-5	--
Longitudinal_disp.	m	0.05	0.05	0.06	518.2
Transverse_disp.	m	--	--	--	103.6
Vertical_disp.	m	--	--	--	0.61
Effective_porosity	%	--	--	--	25.0
Velocity	m/day	--	--	--	0.31
Distance	m	--	--	--	5182
Textural_class		silt	sand	clay	loamy sand
%_sand	%	15	75	15	80
%_silt	%	55	15	35	15
%_clay	%	30	10	50	5
%_OMC	%	0.05	0.05	0.05	0.05
%_Fe	%	0	0	0	0
pH		6.7	6.6	6.6	6.5

20.0 PANTEX PLANT

The Pantex Plant was established in the early 1940s for loading conventional ammunition shells and bombs. Currently, the principal operations performed at Pantex are the assembly of nuclear weapons from components received from other DOE plants and from chemical high explosive components fabricated at Pantex. The Pantex Plant has been used since 1951 by the DOE and its predecessor agencies (Battelle Pantex 1992).

The Pantex Plant lies on the Llano Estacado (staked plains) portion of the Great Plains, and is approximately 27 km (17 mi) northeast of downtown Amarillo, Texas (Figure 20.1). The installation occupies 42 km² (16 mi²). Topography at the Pantex Plant is relatively flat, characterized by rolling grassy plains and numerous natural playa basins. The term "playa" refers to the more than 17,000 ephemeral lakes generally less than 1200 m (4000 ft) in diameter in the Texas Panhandle that receive water run-off from the surrounding area. Outside the boundaries of the installation, the land is generally undeveloped and is used for livestock grazing. Ecologically, the installation is characterized as being a mixed prairie with native and introduced grasses (Battelle Pantex 1992).

20.1 CLIMATE

Pantex is located near the boundary between a "mid-latitude semiarid" and a "tropical semiarid" climate (Critchfield 1974). Meteorological data are available from measurements at the Amarillo International Airport and from limited onsite monitoring. On average, the maximum daily temperature exceeds 32°C (90°F) on 65 days per year and is below 0°C (32°F) on 13 days per year; the minimum daily temperature is below 0°C (32°F) on 110 days per year and is below -18°C (0°F) on 2 days per year (DOC 1987b). July is the warmest month, with daily maximum and minimum temperatures averaging 33°C (91°F) and 19°C (66°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 9.5°C (49°F) and -6°C (22°F), respectively (DOC 1987b).

Annual precipitation is on the order of 48 cm (19 in.), with over 60% of this total occurring from May through August. Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 69 days per year and the area experiences an average of 49 thunderstorm days per year. The average annual snowfall is 38 cm (15 in.) (DOC 1992a) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 5 days per year (DOC 1987b).

The prevailing wind direction is from the southwest. Wind speeds at the airport average about 6 m/s (14 mph) at about 7 m (23 ft) above ground level (DOC 1987b). Average wind speeds are highest in March and April (6.9 m/s [15.5 mph]) and lowest in August (5.4 m/s [12 mph]) (DOC 1992b).

20.2 GEOLOGY

The Pantex facility lies on the Southern High Plains, which consists of uniform, deep, moderately fine-textured, fertile soils. The soils are gently sloping, forming localized closed basins at the Pantex Plant. The primary surface deposits at Pantex are Pleistocene-aged windblown sands and playa deposits of the Pullman and Randall soil series (Battelle Pantex 1992; Purtymun and Becker 1982). Surface deposits grade downward into the Blackwater Draw Formation, a sequence of buried soils with an upper unit of clay loam with caliche and a lower unit of sandy clay loam with caliche (Battelle Pantex 1992).

The Tertiary Ogallala Formation underlies the Blackwater Draw Formation and contains deposits of both fluvial and aeolian origin (Battelle Pantex 1992; Nativ 1988). Deposition of the basal fluvial sequence of the Ogallala Formation was controlled by an irregular surface that represents the pre-Ogallala topography. As a result, the depth of the Ogallala Formation varies from less than 122 m (400 ft) at the southwest section of the plant to over 198 m (650 ft) near the northeast boundary (Battelle Pantex 1992). Paleovalley-fill deposits consist of gravelly and sandy braided-stream deposits interbedded with and overlain by aeolian sediments that were deposited as sand sheets and loess (Gustavson and Winkler 1988). A resistant caliche caprock lies at or near the top of the Ogallala Formation. Calcium-carbonate and silica-cemented sandstone have also been recorded locally at the base of the Ogallala Formation (Nativ 1988).

Underlying much of the Ogallala Formation are sedimentary rocks of the Triassic Dockum Group. These rocks consist primarily of shales, clayey siltstones, and sandstones that accumulated in a variety of continental depositional settings, including braided and meandering streams, alluvial fan deltas, lacustrine deltas, lacustrine systems, and mud flats (Nativ 1988).

20.3 HYDROLOGY

The two principal aquifers beneath the Pantex Plant are the Ogallala aquifer and the underlying Dockum Group aquifer. Within the Ogallala Formation there are two water-bearing units present at Pantex. A discontinuous perched zone is present in the middle of the Ogallala Formation and the main zone of saturation is in the lower fluvial facies of the Ogallala. The lateral extent of this perched water zone has not yet been defined (Battelle Pantex 1992).

The main Ogallala aquifer lies below the perched water zone and is the primary water supply on the High Plains (Battelle Pantex 1992). Water occurs in the lower part of the formation perched on the relatively impermeable Triassic red beds of the Dockum Group (Purtymun and Becker 1982). At the Pantex Plant, the saturated zone of the Ogallala is

thickest to the northeast, ranging from 12 m (40 ft) in the southwest corner of the plant to 98 m (320 ft) in the northeast (Battelle Pantex 1992).

Groundwater in the Ogallala Formation generally occurs under water table conditions. Slight artesian pressures may exist locally where water is confined beneath lenticular bodies of silt and clay (Purtymun and Becker 1982). Due to extensive pumping at the City of Amarillo's well field northeast of the Pantex Plant, groundwater flow trends to the northeast across the plant toward the city's well field with an average hydraulic gradient of 0.0058 (Battelle Pantex 1992). Localized recharge to the Ogallala occurs in conjunction with the hydrology of the playas (Mullican et al. 1994). Based on regional studies, Knowles et al. (1984) reported an annual natural recharge rate of 0.5 cm (0.2 in) over the entire Ogallala aquifer. As a result of small recharge rates relative to groundwater withdrawal rates, the water table level of the Ogallala aquifer in the vicinity of Pantex is declining at a rate of approximately 0.6 to 1.5 m (2 to 5 ft) per year (Purtymun and Becker 1982; Battelle Pantex 1992).

The Dockum Group aquifer is contained within sandstone layers of the Lower Dockum Group. Water contained within the Lower Dockum Group sediments supplies domestic and livestock wells south and southeast of Pantex (Battelle Pantex 1992). The Triassic rocks should be expected to yield only small quantities of water and water quality may be saline (Purtymun and Becker 1982). While no detailed information is available on the potentiometric surface of the Dockum aquifer for the Pantex area, groundwater flow directions are estimated toward the southwest along the dip of Triassic beds (Battelle Pantex 1992).

The major surface water feature of the Pantex area is the Canadian River located approximately 40 km (25 mi) north of the Pantex Plant. The river flows eastward into Lake Meredith, a manmade reservoir. To the east of the plant, the eastern edge of the Southern High Plains is drained by Sweetwater Creek and a little farther to the south by the Salt Fork of the Red River. Local drainage in the plains area covered by windblown sand goes into the playa basins. At the Pantex Plant and adjacent area, there is no drainage into any streams (Purtymun and Becker 1982).

20.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of Pantex for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 20.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 20.2.

For PEIS modeling purposes, Pantex is characterized using four hydrogeologic environmental settings (Figure 20.1): a shallow Ogallala alluvial aquifer, a deep Ogallala alluvial aquifer, perched water in the northeast corner of the installation, and Playas 1 and 2. Figure 20.2 presents stratigraphic columns for each of these settings. Division of the Pantex Plant into these four hydrogeologic regions is based on groundwater occurrences and guidance provided by onsite experts. A brief description of the hydrogeology of each region follows. Hydrogeologic data for the Pantex environmental settings are presented in Tables 20.1-20.4.

20.4.1 Shallow and Deep Ogallala Alluvial Aquifer Settings

Sediments overlying the Ogallala Formation at the Pantex Plant consist primarily of the Blackwater Draw Formation, the upper 12 m (40 ft) of which are composed of clay loam and the lower 6 m (20 ft) which consist of a sandy clay loam. The two units of the Blackwater Draw Formation comprise partially-saturated zones 1 and 2 for both the shallow and deep Ogallala settings. Underlying the Blackwater Draw Formation is the caliche caprock of the upper Ogallala Formation. Thickness of the caprock ranges from 0 to 3 m (0 to 10 ft), with an average thickness of 1.5 m (5 ft). Although caliche is commonly regarded as a barrier to recharge due to its low permeability, the calcrete layer at the Pantex Plant is partially dissolved and fractured. As a consequence, the caliche caprock is more permeable than an undisturbed layer of calcrete (Nativ 1988). Below the caliche caprock is 58 m (190 ft) of aeolian material, primarily very fine sand with some silt. For both the shallow and deep Ogallala settings, the caliche caprock was combined with the underlying aeolian unit for partially-saturated zone 3 and classified as a loamy sand.

Directly below the aeolian unit is 0 to 24 m (0 to 80 ft) of clay loam. The depositional history of this unit is not yet fully understood, precluding explanation or prediction of the discontinuous nature of this zone. This unit is commonly referred to as the "fine-grained zone" and is the confining unit for the perched aquifer and playa environmental settings. The "fine-grained zone" is not impermeable, but rather a lithologic discontinuity which retards flow and causes a perched layer of groundwater to occur. Based on the discontinuous nature of this fine-grained unit, thickness values were not assigned for these two environmental settings in order to represent a worst case scenario.

Underlying the "fine-grained zone" is the fluvial facies of the lower Ogallala Formation. Although composition of the lower Ogallala is dominated by gravelly sand, this soil-texture classification is not among the choices allowed as MEPAS model input (Droppo et al. 1989). Default values assigned in Table 20.3 for the lower Ogallala Formation are based on a sandy soil, the coarsest soil-texture classification available for PEIS modeling (Droppo et al. 1989). The fluvial facies can be divided into three zones: an unsaturated zone, a zone of former saturation which has been dewatered due to the declining regional water table, and a saturated zone ranging in thickness from 12 m (40 ft) in the southwestern portion of the plant to 98 m (320 ft) in the northeastern portion. Based on a contour map of

the saturated thickness of the Ogallala Formation (Bowers and McReynolds 1980), the plant is divided into two settings: the shallow aquifer setting in the southern half of the plant and the deep aquifer setting in the northern half of the plant.

The deep aquifer setting contains all three of the zones found in the lower Ogallala, including partially-saturated zone 4 which is composed of 27 m (90 ft) of unsaturated fluvial material, partially-saturated zone 5 which consists of 9 m (30 ft) of formerly saturated material, and the saturated zone with an average thickness of 67 m (220 ft). All three zones are composed of gravelly sands. The shallow aquifer setting consists of two of the fluvial facies zones, partially-saturated zone 4 and the underlying saturated zone. Partially-saturated zone 4 is composed of approximately 20 m (65 ft) of unsaturated fluvial material which directly overlies the saturated zone with an estimated thickness of 12 m (40 ft). The formerly-saturated zone is not present in the shallow aquifer setting.

20.4.2 Perched Aquifer and Playa Settings

As previously mentioned, a discontinuous zone of perched water is present in the northeastern corner of the Pantex Plant above the main zone of saturation in the Ogallala Formation. The perched water zone is above a 12 m (40 ft) thick layer of clay loam referred to as the "fine-grained zone" (Battelle Pantex 1992). Although the lateral extent of this perched water zone is currently uncertain, a potentiometric-surface map for the perched aquifer suggests that the area covers approximately two-thirds of the northern portion of the plant centered around playas 1 and 2 (Battelle Pantex 1992; Fryar and Mullican 1993). Based on estimated recharge rates, this area has been divided into two settings: the upland area of no recharge surrounding playas 1 and 2 (the perched aquifer setting), and the area of recharge directly under playas 1 and 2 (the playa setting). According to recent estimates, recharge rates to the perched aquifer in conjunction with the playas range from 13 to 62 cm/yr (5 to 24 in./yr), with a suggested average value of 37.5 cm/yr (14.8 in./yr). Recharge rates are recorded in Table 20.3 as darcy velocity.

Partially-saturated zones 1 and 2 for the perched aquifer and playa settings are of the same thickness and description as zones 1 and 2 for the deep and shallow aquifer environmental settings. Partially-saturated zone 3 is identical in composition as the similarly named zone in the deep and shallow settings with an average thickness of 53 m (175 ft), 6 m (20 ft) less than the average thickness assigned to the deep and shallow aquifer settings. Thickness of the perched aquifer ranges from 0.3 to 30 m (1 to 100 ft) with an average thickness of 15 m (50 ft) used for partially-saturated zone 4 in both the perched and playa environmental settings. Since both of these hydrogeologic environmental settings are extended down to the saturated portion of the Ogallala Formation, the saturated nature of the perched zone is represented by setting the field capacity of partially-saturated zone 4 in Table 20.3 equal to the total porosity of the representative soil classification. Partially-saturated zone 5 for both settings consists of 12 m (40 ft) of clay loam referred to as the "fine-grained zone." Partially-saturated zones 6 and 7, and the saturated zone for the

perched and playa settings correlate to partially-saturated zones 5 and 6 and the saturated zone in the deep aquifer setting.

20.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for Pantex are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Dan McGrath supplied input into the development of the meteorologic environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings included Dan McGrath, Ray Brady, and Joe Honea. Following completion of the environmental settings, Dan McGrath coordinated the onsite review and fine tuning of the settings data. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

20.6 REFERENCES

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Figure 20.1. Location and Environmental Settings for Pantex. For PEIS modeling purposes, Pantex is divided into four environmental settings: the Shallow Ogallala, Deep Ogallala, Perched, and Playas 1 and 2 zones. Note that Playas 1 and 2 are located within the boundaries of the Perched zone.

Figure 20.2. Stratigraphic Columns for Pantex Environmental Settings

EXHIBIT 20.1

Pantex Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at the Amarillo International Airport.

Station Name: Amarillo International Airport, Amarillo, Texas

Elevation: 1098 m

Latitude: 33.37°N

Annual Mean Air Temp: 57.2 °F Reference (A) Based on observations made from 1951-1980.
 Anemometer Height: 7.0 m Reference (A)
 Mean Annual Wind Speed: 13.6 mph Reference (A) Based on 45 years of observations.
 Fastest 1-Min Wind Speed: 58.0 mph Reference (A) Based on 12 years of observations.
 Annual Precipitation: 19.1 in. Reference (A) Based on observations made from 1951-1980.
 Precipitation Days: 69 yr⁻¹ Reference (A) Based on 45 years of observations.
 Thunderstorms Freq: 49 yr⁻¹ Reference (A) Based on 45 years of observations.

Avg Morning Mixing Ht: 350 m Reference (C)
 Avg Afternoon Mixing Ht: 2100 m Reference (C)
 Top Soil Moisture Capacity: 3.53 cm Reference (C)

MEPAS Parameters: Climatic Region Index: 3 Reference (C)
 Precipitation-Evaporation Index: 40 Reference (C)
 Soil Cons. Serv. Curve Number: 41 Reference (C)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	35	0.5	13.0	5.1	4.0	70	50
Feb	40	0.6	14.1	5.2	4.4	72	49
Mar	46	0.9	15.5	5.3	4.6	68	42
Apr	57	1.1	15.5	5.0	5.0	67	38
May	66	2.8	14.6	5.1	8.3	73	42
Jun	75	3.5	14.3	4.4	8.3	76	44
Jul	79	2.7	12.6	4.5	8.2	72	41
Aug	77	3.0	12.0	4.3	8.4	77	46
Sep	70	1.7	13.0	4.2	5.9	79	49
Oct	59	1.4	13.0	4.0	5.0	73	44
Nov	45	0.6	13.1	4.4	3.3	73	48
Dec	38	0.5	12.9	4.9	3.9	70	49
Reference: ...	(A)	(A)	(A)	(A)	(A)	(A)	(A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part II Southern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- B: Unpublished technical data provided by correspondence with Sandi Synder (Pacific Northwest Lab), March, 1993.
- C: Droppo, J.G., Jr., D.L. Streng, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 20.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Pantex. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made from 1990 through 1992.

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (m/s)					
		≥0-<1.8	≥1.8-<3.3	≥3.3-<5.4	≥5.4-<8.5	≥8.5-<11.1	≥ 11.1
A	NORTH	0.0007	0.0008	0.0000	0.0000	0.0000	0.0000
A	NORTH-NORTHEAST	0.0007	0.0010	0.0000	0.0000	0.0000	0.0000
A	NORTHEAST	0.0007	0.0010	0.0000	0.0000	0.0000	0.0000
A	EAST-NORTHEAST	0.0007	0.0016	0.0000	0.0000	0.0000	0.0000
A	EAST	0.0008	0.0012	0.0000	0.0000	0.0000	0.0000
A	EAST-SOUTHEAST	0.0008	0.0010	0.0000	0.0000	0.0000	0.0000
A	SOUTHEAST	0.0007	0.0006	0.0000	0.0000	0.0000	0.0000
A	SOUTH-SOUTHEAST	0.0009	0.0011	0.0000	0.0000	0.0000	0.0000
A	SOUTH	0.0007	0.0008	0.0000	0.0000	0.0000	0.0000
A	SOUTH-SOUTHWEST	0.0009	0.0012	0.0000	0.0000	0.0000	0.0000
A	SOUTHWEST	0.0008	0.0012	0.0000	0.0000	0.0000	0.0000
A	WEST-SOUTHWEST	0.0011	0.0010	0.0000	0.0000	0.0000	0.0000
A	WEST	0.0006	0.0012	0.0000	0.0000	0.0000	0.0000
A	WEST-NORTHWEST	0.0009	0.0011	0.0000	0.0000	0.0000	0.0000
A	NORTHWEST	0.0007	0.0010	0.0000	0.0000	0.0000	0.0000
A	NORTH-NORTHWEST	0.0005	0.0008	0.0000	0.0000	0.0000	0.0000
B	NORTH	0.0000	0.0006	0.0007	0.0000	0.0000	0.0000
B	NORTH-NORTHEAST	0.0001	0.0009	0.0004	0.0000	0.0000	0.0000
B	NORTHEAST	0.0001	0.0010	0.0010	0.0001	0.0000	0.0000
B	EAST-NORTHEAST	0.0001	0.0011	0.0008	0.0001	0.0000	0.0000
B	EAST	0.0001	0.0005	0.0008	0.0001	0.0000	0.0000
B	EAST-SOUTHEAST	0.0002	0.0002	0.0006	0.0000	0.0000	0.0000
B	SOUTHEAST	0.0000	0.0004	0.0007	0.0000	0.0000	0.0000
B	SOUTH-SOUTHEAST	0.0002	0.0006	0.0009	0.0001	0.0000	0.0000
B	SOUTH	0.0001	0.0007	0.0008	0.0002	0.0000	0.0000
B	SOUTH-SOUTHWEST	0.0000	0.0010	0.0012	0.0001	0.0000	0.0000
B	SOUTHWEST	0.0002	0.0013	0.0009	0.0000	0.0000	0.0000
B	WEST-SOUTHWEST	0.0003	0.0006	0.0005	0.0000	0.0000	0.0000
B	WEST	0.0000	0.0012	0.0006	0.0000	0.0000	0.0000
B	WEST-NORTHWEST	0.0003	0.0009	0.0006	0.0000	0.0000	0.0000
B	NORTHWEST	0.0001	0.0008	0.0005	0.0000	0.0000	0.0000
B	NORTH-NORTHWEST	0.0001	0.0009	0.0005	0.0000	0.0000	0.0000
C	NORTH	0.0001	0.0004	0.0024	0.0007	0.0000	0.0000
C	NORTH-NORTHEAST	0.0000	0.0007	0.0029	0.0006	0.0000	0.0000
C	NORTHEAST	0.0002	0.0008	0.0025	0.0004	0.0000	0.0000
C	EAST-NORTHEAST	0.0001	0.0008	0.0016	0.0003	0.0000	0.0000
C	EAST	0.0000	0.0004	0.0014	0.0003	0.0000	0.0000
C	EAST-SOUTHEAST	0.0001	0.0004	0.0010	0.0002	0.0000	0.0000
C	SOUTHEAST	0.0000	0.0004	0.0016	0.0006	0.0000	0.0000
C	SOUTH-SOUTHEAST	0.0002	0.0004	0.0022	0.0010	0.0000	0.0000
C	SOUTH	0.0002	0.0007	0.0041	0.0014	0.0000	0.0000
C	SOUTH-SOUTHWEST	0.0001	0.0008	0.0042	0.0018	0.0000	0.0000
C	SOUTHWEST	0.0000	0.0010	0.0036	0.0012	0.0000	0.0000
C	WEST-SOUTHWEST	0.0001	0.0005	0.0022	0.0004	0.0000	0.0000
C	WEST	0.0002	0.0005	0.0018	0.0003	0.0000	0.0000
C	WEST-NORTHWEST	0.0002	0.0004	0.0018	0.0004	0.0000	0.0000
C	NORTHWEST	0.0004	0.0004	0.0016	0.0002	0.0000	0.0000
C	NORTH-NORTHWEST	0.0001	0.0004	0.0018	0.0004	0.0000	0.0000

EXHIBIT 20.2 (continued)

STAB	DIRECTION FROM WHICH THE CLASS WIND IS BLOWING	WIND SPEED CLASS (m/s)					
		≥0-<1.8	≥1.8-<3.3	≥3.3-<5.4	≥5.4-<8.5	≥8.5-<11.1	≥ 11.1
D	NORTH	0.0010	0.0030	0.0105	0.0182	0.0093	0.0034
D	NORTH-NORTHEAST	0.0010	0.0026	0.0074	0.0220	0.0102	0.0028
D	NORTHEAST	0.0012	0.0019	0.0075	0.0146	0.0039	0.0008
D	EAST-NORTHEAST	0.0011	0.0017	0.0039	0.0039	0.0003	0.0000
D	EAST	0.0008	0.0012	0.0034	0.0021	0.0004	0.0002
D	EAST-SOUTHEAST	0.0004	0.0019	0.0038	0.0044	0.0007	0.0004
D	SOUTHEAST	0.0005	0.0015	0.0065	0.0156	0.0045	0.0006
D	SOUTH-SOUTHEAST	0.0007	0.0024	0.0126	0.0362	0.0106	0.0026
D	SOUTH	0.0011	0.0029	0.0148	0.0459	0.0132	0.0020
D	SOUTH-SOUTHWEST	0.0011	0.0033	0.0171	0.0542	0.0209	0.0042
D	SOUTHWEST	0.0011	0.0034	0.0116	0.0355	0.0149	0.0042
D	WEST-SOUTHWEST	0.0011	0.0027	0.0071	0.0118	0.0046	0.0039
D	WEST	0.0010	0.0018	0.0048	0.0071	0.0015	0.0024
D	WEST-NORTHWEST	0.0016	0.0030	0.0052	0.0085	0.0012	0.0012
D	NORTHWEST	0.0014	0.0037	0.0041	0.0060	0.0014	0.0006
D	NORTH-NORTHWEST	0.0016	0.0027	0.0046	0.0095	0.0036	0.0032
E	NORTH	0.0015	0.0029	0.0032	0.0002	0.0000	0.0000
E	NORTH-NORTHEAST	0.0015	0.0030	0.0059	0.0002	0.0000	0.0000
E	NORTHEAST	0.0014	0.0030	0.0061	0.0002	0.0000	0.0000
E	EAST-NORTHEAST	0.0011	0.0044	0.0030	0.0002	0.0000	0.0000
E	EAST	0.0004	0.0022	0.0024	0.0001	0.0000	0.0000
E	EAST-SOUTHEAST	0.0008	0.0022	0.0044	0.0000	0.0000	0.0000
E	SOUTHEAST	0.0008	0.0028	0.0094	0.0003	0.0000	0.0000
E	SOUTH-SOUTHEAST	0.0008	0.0035	0.0130	0.0004	0.0000	0.0000
E	SOUTH	0.0012	0.0061	0.0280	0.0007	0.0000	0.0000
E	SOUTH-SOUTHWEST	0.0016	0.0089	0.0282	0.0012	0.0000	0.0000
E	SOUTHWEST	0.0018	0.0061	0.0152	0.0011	0.0000	0.0000
E	WEST-SOUTHWEST	0.0014	0.0036	0.0054	0.0002	0.0000	0.0000
E	WEST	0.0010	0.0035	0.0049	0.0002	0.0000	0.0000
E	WEST-NORTHWEST	0.0015	0.0037	0.0067	0.0007	0.0000	0.0000
E	NORTHWEST	0.0021	0.0047	0.0048	0.0002	0.0000	0.0000
E	NORTH-NORTHWEST	0.0019	0.0041	0.0049	0.0002	0.0000	0.0000
F	NORTH	0.0015	0.0008	0.0000	0.0000	0.0000	0.0000
F	NORTH-NORTHEAST	0.0016	0.0006	0.0000	0.0000	0.0000	0.0000
F	NORTHEAST	0.0014	0.0018	0.0000	0.0000	0.0000	0.0000
F	EAST-NORTHEAST	0.0024	0.0018	0.0000	0.0000	0.0000	0.0000
F	EAST	0.0008	0.0009	0.0000	0.0000	0.0000	0.0000
F	EAST-SOUTHEAST	0.0006	0.0008	0.0000	0.0000	0.0000	0.0000
F	SOUTHEAST	0.0010	0.0009	0.0000	0.0000	0.0000	0.0000
F	SOUTH-SOUTHEAST	0.0008	0.0012	0.0000	0.0000	0.0000	0.0000
F	SOUTH	0.0010	0.0021	0.0001	0.0000	0.0000	0.0000
F	SOUTH-SOUTHWEST	0.0016	0.0021	0.0000	0.0000	0.0000	0.0000
F	SOUTHWEST	0.0014	0.0016	0.0000	0.0000	0.0000	0.0000
F	WEST-SOUTHWEST	0.0010	0.0010	0.0000	0.0000	0.0000	0.0000
F	WEST	0.0014	0.0008	0.0000	0.0000	0.0000	0.0000
F	WEST-NORTHWEST	0.0011	0.0007	0.0000	0.0000	0.0000	0.0000
F	NORTHWEST	0.0017	0.0006	0.0000	0.0000	0.0000	0.0000
F	NORTH-NORTHWEST	0.0016	0.0010	0.0000	0.0000	0.0000	0.0000

Table 20.1. Hydrogeologic Environmental Setting Data for Pantex Plant's Shallow Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.00	0.00	0.00	0.00	--
SOILC		8.52	7.12	4.38	4.05	4.05
Thickness	m	12.2	6.10	59.4	19.8	12.2
Bulk_density	g/cm3	1.39	1.6	1.49	1.64	1.64
Total_porosity	%	47.7	39.8	43.7	38.0	38.0
Field_capacity	%	34	24	12	9	--
Conductivity	m/day	0.15	0.49	98.1	883.9	--
Longitudinal_disp.	m	0.12	0.06	0.59	0.20	723.9
Transverse_disp.	m	--	--	--	--	144.8
Vertical_disp.	m	--	--	--	--	0.84
Effective_porosity	%	--	--	--	--	25.0
Velocity	m/day	--	--	--	--	20.9
Distance	m	--	--	--	--	7239
Textural_class		clay loam	sandy clay loam	loamy sand	sand	sand
%_sand	%	31	60	84	95	95
%_silt	%	36	14	12	3	3
%_clay	%	33	26	4	2	2
%_OMC	%	0	0	0	0	0
%_Fe	%	0	0	0	0	0
pH		8.2	8.2	8.2	7	7

Table 20.2. Hydrogeologic Environmental Setting Data for Pantex Plant's Perched Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	PZ5	PZ6	PZ7	SZ
Darcian_velocity	m/yr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
SOILC		8.52	7.12	4.38	4.38	11.4	4.05	4.05	4.05
Thickness	m	12.19	6.10	53.34	15.24	12.19	27.4	9.14	67.1
Bulk_density	g/cm3	1.39	1.6	1.49	1.49	1.39	1.64	1.64	1.64
Total_porosity	%	47.7	39.8	43.7	43.7	47.5	43.7	38	38
Field_capacity	%	34	24	12	12	40	9	27.7	--
Conductivity	m/day	0.15	0.49	98.1	98.1	2.4e-3	880.9	880.9	--
Longitudinal_disp.	m	0.12	0.06	0.53	0.15	0.12	0.27	321.9	321.9
Transverse_disp.	m	--	--	--	--	--	--	--	64.3
Vertical_disp.	m	--	--	--	--	--	--	--	0.38
Effective_porosity	%	--	--	--	--	--	--	--	25.0
Velocity	m/day	--	--	--	--	--	--	--	21.3
Distance	m	--	--	--	--	--	--	--	3219
Textural_class		clay loam	sandy clay loam	loamy sand	loamy sand	clay	sand	sand	sand
%_sand	%	31	60	84	84	35	95	95	95
%_silt	%	36	14	12	12	15	3	3	3
%_clay	%	33	26	4	4	50	2	2	2
%_OMC	%	0	0	0	0	0	0	0	0
%_Fe	%	0	0	0	0	0	0	0	0
pH		8.2	8.2	8.2	8.2	8.2	7	7	7

Table 20.3. Hydrogeologic Environmental Setting Data for Pantex Plant's Playas Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	PZ5	PZ6	PZ7	SZ
Darcian_velocity	m/yr	0.38	0.38	0.38	0.38	0.38	0.38	0.38	--
SOILC		8.52	7.12	4.38	4.38	11.4	4.05	4.05	4.05
Thickness	m	12.2	6.10	53.3	15.2	12.2	27.4	9.1	67.1
Bulk_density	g/cm3	1.39	1.6	1.49	1.49	1.39	1.64	1.64	1.64
Total_porosity	%	47.7	39.8	43.7	43.7	47.5	38	38	38
Field_capacity	%	34	24	12	12	40	9	27.7	--
Conductivity	m/day	0.15	0.50	98.1	98.1	2.4e-3	880.9	880.9	--
Longitudinal_disp.	m	0.12	0.06	0.53	0.15	0.12	0.27	321.7	321.9
Transverse_disp.	m	--	--	--	--	--	--	--	64.3
Vertical_disp.	m	--	--	--	--	--	--	--	0.38
Effective_porosity	%	--	--	--	--	--	--	--	25.0
Velocity	m/day	--	--	--	--	--	--	--	21.3
Distance	m	--	--	--	--	--	--	--	3219
Textural_class		clay loam	sandy clay loam	loamy sand	loamy sand	clay	sand	sand	sand
%_sand	%	31	60	84	84	35	95	95	95
%_silt	%	36	14	12	12	15	3	3	3
%_clay	%	33	26	4	4	50	2	2	2
%_OMC	%	0	0	0	0	0	0	0	0
%_Fe	%	0	0	0	0	0	0	0	0
pH		8.2	8.2	8.2	8.2	8.2	7	7	7

Table 20.4. Hydrogeologic Environmental Setting Data for Pantex Plant's Deep Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	PZ5	PZ6
Darcian_velocity	m/yr	0.00	0.00	0.00	0.00	0.00	--
SOILC		8.52	7.12	4.38	4.05	4.05	4.05
Thickness	m	12.2	6.0	59.4	27.4	9.1	67.1
Bulk_density	g/cm3	1.4	1.6	1.5	1.6	1.6	1.6
Total_porosity	%	47.7	39.8	43.7	38	38	38
Field_capacity	%	34	24	12	9	9	--
Conductivity	m/day	0.15	0.50	98.1	883.9	883.9	--
Longitudinal_disp.	m	0.12	0.06	0.59	0.27	321.9	321.9
Transverse_disp.	m	--	--	--	--	--	64.3
Vertical_disp.	m	--	--	--	--	--	0.38
Effective_porosity	%	--	--	--	--	--	25.0
Velocity	m/day	--	--	--	--	--	20.4
Distance	m	--	--	--	--	--	3219
Textural_class		clay loam	sandy clay loam	loamy sand	sand	sand	sand
%_sand	%	31	60	84	95	95	95
%_silt	%	36	14	12	3	3	3
%_clay	%	33	26	4	2	2	2
%_OMC	%	0	0	0	0	0	0
%_Fe	%	0	0	0	0	0	0
pH		8.2	8.2	8.2	7	7	7

21.0 PINELLAS PLANT

The Pinellas Plant was constructed in the mid-1950s as part of the DOE's nuclear weapons research and development program. The plant was originally built to manufacture neutron generators for use in nuclear weapons. While neutron generators remain the principal product of the Pinellas Plant, additional products have been introduced over the years which include radioisotopically powered thermoelectric generators, thermal batteries, specialty capacitors, neutron detectors, and other special mechanical and electronic components (DOE 1991b).

The Pinellas Plant is located in Pinellas County approximately 48 km (30 mi) east of Tampa, Florida (Figure 21.1). The facility is located on a 40-ha (99-acre) portion of federally owned land along the westcentral coastline of Florida on a peninsula separating Tampa Bay from the Gulf of Mexico. Topography at the Pinellas Plant is generally flat with a total elevation variation of less than 1 m (2 ft) (DOE 1991b). Average elevation of the Pinellas Plant is 5.5 m (18 ft). Ecologically, the Pinellas Plant is located in a pine flatwoods habitat area (DOE 1991b). Pine flatwoods are found on relatively level areas with poorly drained sandy soils. The vegetation is two-layered with the overstory composed primarily of slab and longleaf pines and the understory composed of saw palmetto grasses and various herbs. The Pinellas Plant site was previously a dairy farm with improved pasture areas. Approximately 55% of the site is currently occupied by structures and paved areas (DOE 1990); the remaining 45% is open space.

21.1 CLIMATE

The Pinellas area has a "humid subtropic" climate (Critchfield 1974). Meteorological data are available from measurements at the Tampa International Airport in Tampa, Florida. On average the maximum daily temperature exceeds 32°C (90°F) on 79 days per year and a maximum temperature below 0°C (32°F) has not been recorded; the minimum daily temperature is below 0°C (32°F) on 4 days per year and a temperature below -18°C (0°F) has not been recorded (DOC 1987b). July is the warmest month, with daily maximum and minimum temperatures averaging 32°C (90°F) and 23°C (74°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 21°C (70°F) and 10°C (50°F), respectively (DOC 1987b).

Annual precipitation at Tampa is on the order of 119 cm (47 in.), with about 60% falling during the summer months (DOC 1987b). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 107 days per year and the area experiences an average of 87 thunderstorm days per year. The average annual snowfall is less than 1.3 cm (0.5 in.) (DOC 1992a) and a daily snowfall accumulation of 2.5 cm (1 in.) or greater has never been recorded at the monitoring station (DOC 1987b).

At the Tampa International Airport, the prevailing wind direction is from the east. Wind speeds at the Tampa airport average about 4 m/s (9 mph) at about 7 m (22 ft). Average wind speeds are highest in March (4 m/s [10 mph]) and lowest in August (3 m/s [7 mph]) (DOC 1987b). The local sea-breeze effect can impact the wind direction and speed at the installation.

21.2 GEOLOGY

The Pinellas Plant is located on a flat coastal plain known as the Floridan Plateau, a broad, partially submerged shelf in the Gulf of Mexico composed of alternating layers of terrigenous clastics and carbonates (DOE 1993c). From the early Cretaceous Period to the Oligocene Age, several hundred meters of limestones were deposited in a setting similar to today's Bahamas Bank region (DOE 1990). From the late Oligocene Age throughout most of the Miocene Age, a sandy limestone referred to as the Tampa Formation was deposited across the carbonate shelf. The Tampa Formation reached up to 46 m (150 ft) in thickness and marked the last period of carbonate deposition in the region. During the late Miocene Age through the Pliocene Age, regional deposition occurred primarily as a clastic unit known as the Hawthorne Formation (DOE 1990). The Hawthorne Formation is described as a sandy gray clay with regional thicknesses ranging from 15 to 27 m (50 to 90 ft). Surficial deposits in the region are primarily sands and shelly sands ranging in thickness from 2 to 15 m (5 to 50 ft) (DOE 1990). The surficial deposits are believed to be of Pleistocene age.

Sinkhole formation is common in Florida with sinkholes tending to recur along previous pathways (DOE 1991b). According to the Florida Sinkhole Research Institute, six sinkholes have been reported within a five-mile radius of the Pinellas Plant. Since no sinkholes have been found at the plant, the probability of a sinkhole occurring is considered to be very small with an estimated probability of one sinkhole developing every 1,340 years (DOE 1991b).

21.3 HYDROLOGY

The regional groundwater system in Pinellas County is composed of three primary units (DOE 1991b). These include the lower regional aquifer unit, the middle confining unit, and the upper surficial aquifer.

The lower regional aquifer, known as the Upper Floridan Aquifer, is an extensive water-bearing unit that is of primary economic importance as the main source of water for the Pinellas Plant and surrounding counties (DOE 1994b). The Upper Floridan Aquifer is greater than 370 m (1200 ft) in thickness and occurs within the Tampa Limestone (DOE 1990). Groundwater flow in the regional aquifer at the Pinellas Plant is primarily east-northeast toward Tampa Bay. Estimates of recharge to the Upper Floridan Aquifer at the Pinellas Plant range from no recharge to less than 5 cm (2 in.) per year (DOE 1991b).

Locations where recharge rates are known to be very low correspond to areas where the Floridan is overlain by thick, impermeable units. This unit corresponds to the clay-rich Hawthorne Formation, which is generally considered an aquitard at the Pinellas Plant (DOE 1991b). Average clay content in the Hawthorn Formation is 21%, resulting in an estimated vertical travel time of 629 years for groundwater movement through the unit (DOE 1994b). Additional evidence of a lack of communication between the surficial aquifer and the Upper Floridan Aquifer is the absence of contaminants in wells monitoring the Tampa Limestone and a high upward gradient in the upper portion of the Floridan Aquifer (DOE 1994b).

The surficial aquifer unit is associated with the upper 8 to 11 m (25 to 35 ft) of undifferentiated sands from the Pleistocene Age. Groundwater in the surficial aquifer is not used as a water supply at the Pinellas Plant due to its poor quality and limited availability (DOE 1991b, 1994b). However, due to its unconfined nature, shallowness, and susceptibility to contamination, it is the aquifer of primary interest for this review. Currently, the surficial aquifer is the only hydrogeologic unit determined to have been impacted by past plant activities (DOE 1994b). The water table in the surficial aquifer is reported to fluctuate seasonally from 0.5 to 1.2 m (1.7 to 3.9 ft) below ground surface (DOE 1993c). Data indicates that the West Pond at the Pinellas Plant acts as a point of recharge for the surficial aquifer, with groundwater flow corresponding to surface water drainage patterns (DOE 1990, 1993c).

No natural surface waters exist at the Pinellas Plant (DOE 1990). Surface waters consist of storm water runoff into drainage swales, culverts, and onsite storm water ponds (East, West, and South Ponds) (DOE 1993c). Surface water drainage from the site is influenced by the topography of the site (DOE 1990). In general, a surface water divide trends north to south through the Pinellas Plant. Three plant outfalls discharge storm waters to offsite surface waters. Based on the very large size of these lakes and bays (Seminole Lake, Tampa Bay, and Boca Ciega Bay) relative to the probable input of contaminants from the site, a surface water setting is considered unnecessary for BEMR modeling purposes.

21.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of Pinellas Plant for BEMR modeling purposes. Meteorological data for the installation are presented in Exhibit 21.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 21.2.

Environmental settings for the Pinellas Plant are based on groundwater occurrences and are shown in Figure 21.2. Two groundwater settings were developed for the plant based on surface water drainage patterns, a Northwest Flow Setting and an East Flow Setting. The characteristics of the settings are essentially identical with the exception of the flow direction.

A brief description of the environmental settings follows. Hydrogeologic data for the Pinellas environmental settings are presented in Tables 21.1 and 21.2.

The average depth to groundwater beneath the Pinellas Plant is 0.85 m (2.8 ft) with approximately 0.9 m (3 ft) of water table fluctuation throughout the year (DOE 1993c). A single partially saturated zone (PZ1) with a thickness of 0.85 m (2.8 ft) is considered adequate to describe the vadose zone for both the Northwest and East Flow settings. Based on site descriptions and particle size estimates, the composition of vadose zone sediment is sand (DOE 1993c). Additional PZ1 parameters are MEPAS default values with the exception of bulk density, hydraulic conductivity, and pH values which were obtained from Corrective Measures Study Reports for the Northeast Site and Building 100 Area (DOE 1993c, 1994b).

The saturated zone (SZ1) for both the Northwest and East Flow settings is a single zone composed of sand (DOE 1993c). This zone consists of material similar to PZ1 with an average thickness of 8.3 m (27 ft) based on the thickness of PZ1 (0.85 m) and the average thickness of the surficial aquifer (9.1 m) (DOE 1993c). Bulk density and effective porosity values were obtained from the Corrective Measures Study Report for the Building 100 Area (DOE 1994b). Groundwater pH and organic matter content values were averaged from a RCRA Facility Investigation Report (DOE 1991b). All other data parameters are MEPAS default values.

21.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the Pinellas Plant are based on publicly available documents written for DOE environmental programs. Site experts were contacted and chose not to participate in the development and review of environmental settings for this installation. These simplified environmental settings are considered adequate for BEMR modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

21.6 REFERENCES

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U.S. Department of Commerce (DOC). 1987b. *Local Climatological Data Annual Summaries for 1986 Part II Southern Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

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U.S. Department of Energy (DOE). 1990. *RCRA Facility Investigation - Pinellas Plant, Task 4, Miscellaneous Sites Work Plan (DRAFT)*. U.S. Department of Energy, Environmental Restoration Program, Albuquerque Operations Office, Albuquerque, New Mexico.

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Figure 21.1. Location and Environmental Settings for the Pinellas Plant.

M bls = Meters below land surface

Figure 21.2. Stratigraphic Columns for Pinellas Plant Environmental Settings.

EXHIBIT 21.1

Pinellas Plant Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at Tampa International Airport.

Station Name: Tampa International Airport, Florida (TPA)

Elevation:

6 m

Latitude: 27.97°N

Annual Mean Air Temp: 72.0 °F (TPA) Reference (a) Based on observations made from 1946-1986
 Anemometer Height: 22.0 ft (TPA) Reference (a) Based on observations made from 1965-1986
 Mean Annual Wind Speed: 8.5 mph (TPA) Reference (a) Based on observations made from 1946-1986
 Fastest 1-Min Wind Speed: 67.0 mph (TPA) Reference (a) Based on observations made from 1952-1986
 Annual Precipitation: 46.7 in (TPA) Reference (a) Based on observations made from 1946-1986
 Precipitation Days: 107 yr⁻¹ (TPA) Reference (a) Based on observations made from 1946-1986
 Thunderstorms Freq: 87 yr⁻¹ (TPA) Reference (a) Based on observations made from 1946-1986

Avg Morning Mixing Ht: 700 m Reference (b)

Avg Afternoon Mixing Ht: 1300 m Reference (b)

Top Soil Moisture Capacity: 2.92 cm Reference (b)

MEPAS Parameters: Climatic Region Index: 5 Reference (b)
 Precipitation-Evaporation Index: 95 Reference (b)
 Soil Cons. Serv. Curve Number: 50 Reference (b)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	59.8	2.17	8.7	5.6	6	86	59
Feb	60.7	3.04	9.3	5.5	7	85	56
Mar	66.2	3.46	9.6	5.4	7	86	55
Apr	71.5	1.82	9.4	4.9	5	87	51
May	77.2	3.38	8.8	5.2	6	86	52
Jun	80.9	5.29	8.1	6.1	12	87	60
Jul	82.1	7.35	7.3	6.7	16	88	63
Aug	82.3	7.64	7.1	6.6	17	91	64
Sep	80.8	6.23	7.9	6.4	13	91	62
Oct	74.4	2.34	8.6	5.2	7	89	57
Nov	66.7	1.87	8.5	5.0	5	88	57
Dec	61.3	2.14	8.6	5.6	6	87	59
Reference: ...	(a)	(a)	(a)	(a)	(a)	(a)	(a)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Par II - Southern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- B: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 21.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Tampa. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made on-site at 6.7 m (22 ft) above ground level. Data are based on measurements made from 1989 through 1993.

STAB CLASS	WIND DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
A	NORTH	0.00110	0.00064	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00187	0.00078	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00294	0.00162	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00526	0.00304	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00582	0.00322	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00508	0.00274	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00341	0.00219	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00255	0.00158	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00290	0.00158	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00057	0.00043	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00084	0.00055	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00093	0.00055	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00085	0.00046	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00078	0.00057	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00089	0.00055	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00068	0.00023	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00217	0.00317	0.00135	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00259	0.00400	0.00110	0.00000	0.00000	0.00000
B	NORTHEAST	0.00526	0.00783	0.00231	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00669	0.00989	0.00299	0.00000	0.00000	0.00000
B	EAST	0.00642	0.00868	0.00247	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00394	0.00685	0.00256	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00316	0.00578	0.00317	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00188	0.00436	0.00228	0.00000	0.00000	0.00000
B	SOUTH	0.00217	0.00420	0.00169	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00081	0.00196	0.00087	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00086	0.00178	0.00096	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00087	0.00201	0.00119	0.00000	0.00000	0.00000
B	WEST	0.00110	0.00210	0.00137	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00078	0.00142	0.00057	0.00000	0.00000	0.00000
B	NORTHWEST	0.00083	0.00121	0.00050	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00070	0.00078	0.00048	0.00000	0.00000	0.00000
C	NORTH	0.00050	0.00258	0.00434	0.00057	0.00000	0.00000
C	NORTH-NORTHEAST	0.00053	0.00326	0.00450	0.00050	0.00000	0.00000
C	NORTHEAST	0.00086	0.00559	0.00626	0.00059	0.00000	0.00000
C	EAST-NORTHEAST	0.00117	0.00744	0.00623	0.00053	0.00000	0.00000
C	EAST	0.00114	0.00548	0.00521	0.00043	0.00000	0.00000
C	EAST-SOUTHEAST	0.00077	0.00486	0.00418	0.00041	0.00000	0.00000
C	SOUTHEAST	0.00051	0.00388	0.00653	0.00059	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00047	0.00313	0.00416	0.00027	0.00000	0.00000
C	SOUTH	0.00062	0.00285	0.00390	0.00011	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00029	0.00139	0.00219	0.00002	0.00000	0.00000
C	SOUTHWEST	0.00021	0.00190	0.00274	0.00000	0.00000	0.00000
C	WEST-SOUTHWEST	0.00029	0.00162	0.00370	0.00009	0.00000	0.00000
C	WEST	0.00035	0.00123	0.00459	0.00030	0.00000	0.00000
C	WEST-NORTHWEST	0.00022	0.00105	0.00121	0.00021	0.00000	0.00000
C	NORTHWEST	0.00020	0.00121	0.00073	0.00018	0.00000	0.00000
C	NORTH-NORTHWEST	0.00015	0.00091	0.00098	0.00007	0.00000	0.00000
D	NORTH	0.00069	0.00368	0.01267	0.00751	0.00043	0.00005
D	NORTH-NORTHEAST	0.00064	0.00363	0.00909	0.00477	0.00016	0.00000
D	NORTHEAST	0.00077	0.00516	0.01477	0.00642	0.00009	0.00000
D	EAST-NORTHEAST	0.00074	0.00518	0.01477	0.00639	0.00014	0.00000
D	EAST	0.00075	0.00495	0.01386	0.00753	0.00016	0.00000
D	EAST-SOUTHEAST	0.00055	0.00374	0.01030	0.00349	0.00005	0.00005
D	SOUTHEAST	0.00062	0.00338	0.00943	0.00420	0.00016	0.00002

EXHIBIT 21.2 (continued)

STAB CLASS	WIND DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
D	SOUTH-SOUTHEAST	0.00040	0.00297	0.00712	0.00201	0.00002	0.00000
D	SOUTH	0.00070	0.00413	0.01082	0.00582	0.00023	0.00005
D	SOUTH-SOUTHWEST	0.00025	0.00194	0.00781	0.00518	0.00027	0.00002
D	SOUTHWEST	0.00025	0.00155	0.00683	0.00276	0.00000	0.00005
D	WEST-SOUTHWEST	0.00020	0.00153	0.00868	0.00297	0.00011	0.00002
D	WEST	0.00018	0.00160	0.01491	0.01368	0.00023	0.00018
D	WEST-NORTHWEST	0.00022	0.00146	0.00694	0.00717	0.00080	0.00021
D	NORTHWEST	0.00016	0.00128	0.00831	0.00785	0.00078	0.00002
D	NORTH-NORTHWEST	0.00019	0.00139	0.00710	0.00619	0.00050	0.00000
E	NORTH	0.00000	0.00626	0.00728	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00000	0.00463	0.00441	0.00000	0.00000	0.00000
E	NORTHEAST	0.00000	0.00856	0.00658	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00000	0.00961	0.00849	0.00000	0.00000	0.00000
E	EAST	0.00000	0.00966	0.00952	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00000	0.00760	0.00479	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00000	0.00537	0.00349	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00000	0.00345	0.00263	0.00000	0.00000	0.00000
E	SOUTH	0.00000	0.00630	0.00402	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00000	0.00349	0.00402	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00000	0.00425	0.00447	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00000	0.00427	0.00626	0.00000	0.00000	0.00000
E	WEST	0.00000	0.00525	0.01388	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00000	0.00372	0.00655	0.00000	0.00000	0.00000
E	NORTHWEST	0.00000	0.00498	0.00651	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00000	0.00361	0.00498	0.00000	0.00000	0.00000
F	NORTH	0.00323	0.00961	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00232	0.00669	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00373	0.00957	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00425	0.01201	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00473	0.01000	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00300	0.00632	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00159	0.00365	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00105	0.00228	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00206	0.00475	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00131	0.00402	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00144	0.00352	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00136	0.00338	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00163	0.00489	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00157	0.00569	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00257	0.01059	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00187	0.00575	0.00000	0.00000	0.00000	0.00000
G	NORTH	0.00411	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHEAST	0.00354	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTHEAST	0.00484	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST-NORTHEAST	0.00609	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST	0.00494	0.00000	0.00000	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.00281	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHEAST	0.00135	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00120	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH	0.00198	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTH-SOUTHWEST	0.00088	0.00000	0.00000	0.00000	0.00000	0.00000
G	SOUTHWEST	0.00130	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST-SOUTHWEST	0.00088	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST	0.00114	0.00000	0.00000	0.00000	0.00000	0.00000
G	WEST-NORTHWEST	0.00161	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTHWEST	0.00245	0.00000	0.00000	0.00000	0.00000	0.00000
G	NORTH-NORTHWEST	0.00224	0.00000	0.00000	0.00000	0.00000	0.00000

Table 21.1. Hydrogeologic setting data summary of the Pinellas Plant, Northwest Setting. MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.24	--
SOILC		4.05	4.05
Thickness	m	0.85	8.3
Bulk_Density	gm/cm3	1.6	1.6
Total_Porosity	%	38	38
Field_Capacity	%	9	--
Conductivity	m/day	0.2	--
Longitudinal_Displacement	m	0.01	21.3**
Transverse_Displacement	m	--	4.27**
Vertical_Displacement	m	--	2.48e-02**
Effective_Porosity	%	--	20
Velocity	m/yr	--	3.4
Distance	m	--	213
Textural_Class		sand	sand
%_sand	%	95	95
%_silt	%	0	0
%_clay	%	5	5
%_OMC	%	2.2	2.2
%_Fe	%	0	0
pH		7.7	7.7

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

Table 21.2. Hydrogeologic setting data summary of the Pinellas Plant, East Setting.
MEPAS parameters are listed for both the partially saturated (PZ) and saturated zones (SZ).

Parameter	Units	PZ1	SZ
Darcian_velocity	m/yr	0.24	--
SOILC		4.05	4.05
Thickness	m	0.85	8.3
Bulk_Density	gm/cm3	1.6	1.6
Total_Porosity	%	38	38
Field_Capacity	%	9	--
Conductivity	m/day	0.2	--
Longitudinal_Displacement	m	0.01	24.4**
Transverse_Displacement	m	--	4.87**
Vertical_Displacement	m	--	2.83e-02**
Effective_Porosity	%	--	20
Velocity	m/yr	--	3.4
Distance	m	--	244
Textural_Class		sand	sand
%_sand	%	95	95
%_silt	%	0	0
%_clay	%	5	5
%_OMC	%	2.2	2.2
%_Fe	%	0	0
pH		7.7	7.7

** It is recommended that default values be substituted for the values listed once the distances to the receptors have been determined.

22.0 PORTSMOUTH URANIUM ENRICHMENT COMPLEX

The principal onsite process at the Portsmouth Uranium Enrichment Complex (PUEC) is the separation of uranium isotopes through gaseous diffusion and centrifuge technologies. This process produces enriched uranium which is used for nuclear fuel in commercial power plants and for military purposes. The PUEC is located in an upland area of southcentral Ohio, about 8 km (5 mi) south of the town of Piketon. The PUEC occupies 16 km² (4,000 acres) in a former river valley situated 40 m (130 ft) above the level of the nearby Scioto River (Figure 22.1). The average elevation of the installation is 200 m (670 ft) above sea level. The area around the PUEC consists of farmland and wooded hills, generally with less than 30 m (100 ft) of relief. The central operations area is fully developed; grounds surrounding the buildings are maintained as lawns. Outside the operations area, the installation's ecology is dominated by second growth forest. Three types of forest types are found on the installation: upland hardwoods, oak-hickory, and bottomland hardwoods (Geraghty & Miller, Inc. 1992).

22.1 CLIMATE

The PUEC has a "humid continental warm summer" climate (Critchfield 1974). Meteorological data are available from onsite measurements and from measurements at the Greater Cincinnati Airport. On average, the maximum daily temperature exceeds 32°C (90°F) on 19 days per year and is below 0°C (32°F) on 30 days per year; the minimum daily temperature is below 0°C (32°F) on 109 days per year and is below -18°C (0°F) on 7 days per year (DOC 1987a). July is the warmest month, with daily maximum and minimum temperatures averaging 30°C (86°F) and 18°C (65°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 3°C (37°F) and -7°C (20°F), respectively (DOC 1987a).

Annual precipitation is on the order of 100 cm (40 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 129 days per year and the area experiences an average of 43 thunderstorm days per year. The average annual snowfall is 58 cm (23 in.) (DOC 1992a) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 7 days per year (DOC 1987a).

The prevailing wind direction at the Cincinnati airport is from the south-southwest (DOC 1987a). Wind speeds average about 4.5 m/s (10 mph) at about 6 m (20 ft) above ground level (DOC 1987a). Average wind speeds at the airport are highest in March (5 m/s [11 mph]) and lowest in August (3 m/s [7 mph]) (DOC 1987a).

22.2 GEOLOGY

Five key geologic units underlie the Portsmouth Site. The upper two units were deposited during the Quaternary Period prior to and during glaciation. The youngest of the units is the Minford Member of the Teays Formation. The Gallia Member of the Teays Formation lies beneath the Minford and on top of bedrock. The Minford Member can be divided into an upper reddish-brown silty clay with traces of sand and a lower yellow-brown silt unit which also contains traces of sand. Average thickness of the Minford Member at the PUEC is 7.6 m (25 ft), 4.6 m (15 ft) for the upper clay unit, and 3 m (10 ft) for the lower silt unit. The Gallia unit consists of loosely consolidated reddish-brown silt, clayey sand, and gravel with an average thickness of 0.9 to 1.5 m (3 to 5 ft). Average clay content of the Gallia is 30%. Underlying the Minford and Gallia units are three bedrock units: the Cuyahoga Shale, Sunbury Shale, and Berea Sandstone/Bedford Shale. The Cuyahoga Shale is the uppermost bedrock unit at the site and consists of gray, thinly bedded shale with scattered lenses of sandstone. Thickness of the Cuyahoga locally reaches 50 m (160 ft). The Sunbury Shale ranges in thickness from 0 to 6 m (0 to 20 ft) with an average thickness of 3 m (10 ft) across most of the site. The Sunbury is a black, carbonaceous, fissile shale. The Berea Sandstone is a light-gray, hard, thickly-bedded, fine-grained sandstone and siltstone with an average thickness of 30 m (100 ft). The geologic structure of the area is quite simple, with the bedrock units gently dipping to the east at about 0.3°. There are no significant geologic faults in or around the PUEC; however, distinct joint sets and bedding plane fractures are present in the bedrock formations (Geraghty and Miller, Inc. 1992).

22.3 HYDROLOGY

Groundwater flow at Portsmouth can be divided into four major quadrants which form the basis for the division of hydrogeologic settings for the PEIS. Quadrants II and IV both drain into Little Beaver Creek. Quadrant III drains into the westward flowing drainage ditch, and Quadrant I drains south into Big Run Creek. In effect, all groundwater is assumed to discharge into local surface water drainages. In areas where the Sunbury Shale confining layer is present between the Gallia and Berea, the groundwater flow systems in these two units are independent. In areas where the Sunbury is absent, the Gallia and Berea are hydraulically connected (Geraghty and Miller, Inc. 1992).

Three major drainages control surface water flowing out of the PUEC. The eastern and northern portion of the PUEC are drained by ditches which flow into Little Beaver Creek. This creek connects to Big Beaver Creek, which in turn flows into the Scioto River about 5 km (3 mi) from the installation. The western portion of the installation is drained by ditches which flow directly into the Scioto River just over 3 km (2 mi) west of the PUEC. The southeastern portion of the installation is drained by Big Run Creek which flows into the Scioto River just over 6 km (4 mi) southwest of the PUEC.

22.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the PUEC for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 22.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 22.2.

For PEIS modeling purposes, the PUEC is represented by one hydrogeologic environmental setting (Figure 22.1) with three different groundwater flow directions (as defined by groundwater flow in Quadrants II/IV, Quadrant I, and Quadrant III). Figure 22.2 presents stratigraphic columns for each of these settings. The setting is characterized by two partially-saturated zones. The first partially-saturated zone corresponds to the clay layer of the Minford formation. This layer is 5 m (16 ft) thick and is approximately 5% sand, 45% silt, and 50% clay. The second partially-saturated zone is 2.4 m (8 ft) of silty clay loam composed of approximately 10% sand, 50% silt, and 40% clay, with nearly 20 times the hydraulic conductivity of the overlying clay unit. The saturated zone in the Gallia sand averages 1 m (3.5 ft) in thickness, and consists of 85% sand, 10% silt and 5% clay. The base of the Gallia is effectively sealed by the underlying Sunbury Shale. Surface water data are presented in Table 22.1. Hydrogeologic data for the environmental setting are presented in Table 22.2.

22.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the PUEC are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Robert Blythe supplied input into the development of the climate and atmospheric dispersion environmental settings. Jim Campbell supplied input into the development of the hydrogeologic environmental settings.

22.6 REFERENCES

Critchfield, H.J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Geraghty and Miller, Inc. 1992. *Quadrant I RFI Draft Final Report, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio*. Prepared for Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee.

U.S. Department of Commerce (DOC). 1987a. *Local Climatological Data Annual Summaries for 1986 Part I Eastern Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

U.S. Department of Commerce (DOC). 1992a. *International Station Meteorological Climate Summary Version 2*. Compact Disc. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

S9405048.6

Figure 22.1. Location and Environmental Settings for the Portsmouth Uranium Enrichment Complex (PUEC). For PEIS modeling purposes, the installation is characterized by a single environmental setting.

M bls = Meters below land surface

Figure 22.2. Stratigraphic Column for Portsmouth Uranium Enrichment Complex (PUEC) Environmental Setting

EXHIBIT 22.1

Portsmouth Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite and at the Greater Cincinnati Airport.

Station Name: Greater Cincinnati Airport, Cincinnati, Ohio	Elevation: 265 m	Latitude: 39.05°N
Portsmouth Meteorology Tower, Piketon, Ohio	Elevation: 204 m	Latitude: 39.01°N

Annual Mean Air Temp:	53.3 °F (airport)	Reference (A)	Based on observations made from 1951-1980.
Anemometer Height:	6.1 m (airport)	Reference (A)	
	10.0 m (Portsmouth)	Reference (B)	
Mean Annual Wind Speed:	9 mph (airport)	Reference (A)	Based on 39 years of observations.
	4 mph (Portsmouth)	Reference (B)	
Fastest 1-Min Wind Speed:	46 mph (airport)	Reference (A)	Based on 23 years of airport observations.
Annual Precipitation:	40.1 in. (airport)	Reference (A)	Based on observations made from 1951-1980.
Precipitation Days:	129 yr ⁻¹ (airport)	Reference (A)	Based on 39 years of observations.
Thunderstorms Freq:	43 yr ⁻¹ (airport)	Reference (A)	Based on 39 years of observations.

Avg Morning Mixing Ht:	500 m	Reference (C)
Avg Afternoon Mixing Ht:	1450 m	Reference (C)
Top Soil Moisture Capacity:	7.1 cm	Reference (C)

MEPAS Parameters:	Climatic Region Index:	4	Reference (C)
	Precipitation-Evaporation Index:	107	Reference (C)
	Soil Cons. Serv. Curve Number:	76	Reference (C)

MONTHLY AVERAGES							
MONTH	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	29	3.1	10.7	7.5	12.0	78	68
Feb	32	2.7	10.4	7.3	11.1	78	64
Mar	42	4.0	11.1	7.3	13.2	77	60
Apr	54	3.6	10.7	6.9	12.5	76	54
May	63	3.8	8.7	6.7	11.5	80	55
Jun	71	4.1	8.0	6.2	10.6	82	56
Jul	75	4.3	7.2	6.0	10.0	85	57
Aug	74	3.0	6.8	5.8	9.0	88	58
Sep	68	2.9	7.5	5.6	7.8	88	57
Oct	55	2.5	8.2	5.7	8.3	83	56
Nov	43	3.1	9.6	7.1	10.9	80	64
Dec	34	3.0	10.2	7.5	12.1	79	69
Reference: ...	↓ (A)	↓ (A)	↓ (A)	↓ (A)	↓ (A)	↓ (A)	↓ (A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part I Eastern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- B: Private communication (a FAX dated 6/25/93) from Robert Blythe with the Portsmouth Gaseous Diffusion Plant (Martin Marietta Energy Systems).
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 22.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Portsmouth Gaseous Diffusion Plant. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made from 1983 through 1997.

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 24
A	NORTH	0.00173	0.00013	0.00005	0.00003	0.00000	0.00000
A	NORTH-NORTHEAST	0.00068	0.00118	0.00010	0.00000	0.00000	0.00000
A	NORTHEAST	0.00155	0.00288	0.00008	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00198	0.00393	0.00035	0.00000	0.00000	0.00000
A	EAST	0.00298	0.00488	0.00005	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00436	0.00403	0.00020	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00511	0.00418	0.00025	0.00003	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00658	0.00418	0.00023	0.00000	0.00000	0.00000
A	SOUTH	0.00901	0.00803	0.00035	0.00000	0.00000	0.00003
A	SOUTH-SOUTHWEST	0.01019	0.00783	0.00028	0.00003	0.00000	0.00000
A	SOUTHWEST	0.01036	0.01264	0.00115	0.00005	0.00000	0.00000
A	WEST-SOUTHWEST	0.00929	0.01071	0.00055	0.00003	0.00000	0.00005
A	WEST	0.00666	0.00926	0.00063	0.00000	0.00003	0.00000
A	WEST-NORTHWEST	0.00415	0.00713	0.00065	0.00000	0.00000	0.00000
A	NORTHWEST	0.00203	0.00348	0.00053	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00050	0.00093	0.00013	0.00000	0.00000	0.00000
B	NORTH	0.00368	0.00028	0.00023	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00080	0.00173	0.00088	0.00000	0.00000	0.00000
B	NORTHEAST	0.00160	0.00335	0.00043	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00225	0.00463	0.00088	0.00000	0.00000	0.00000
B	EAST	0.00313	0.00400	0.00078	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00395	0.00390	0.00078	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00636	0.00410	0.00108	0.00003	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00776	0.00328	0.00060	0.00008	0.00000	0.00000
B	SOUTH	0.01171	0.01046	0.00208	0.00000	0.00003	0.00000
B	SOUTH-SOUTHWEST	0.01029	0.01276	0.00273	0.00010	0.00003	0.00010
B	SOUTHWEST	0.00788	0.00944	0.00496	0.00043	0.00005	0.00003
B	WEST-SOUTHWEST	0.00611	0.00781	0.00443	0.00008	0.00003	0.00000
B	WEST	0.00368	0.00385	0.00200	0.00013	0.00008	0.00000
B	WEST-NORTHWEST	0.00223	0.00375	0.00185	0.00008	0.00000	0.00000
B	NORTHWEST	0.00120	0.00328	0.00233	0.00010	0.00000	0.00000
B	NORTH-NORTHWEST	0.00043	0.00140	0.00100	0.00000	0.00000	0.00000
C	NORTH	0.00000	0.00040	0.00175	0.00033	0.00000	0.00000
C	NORTH-NORTHEAST	0.00118	0.00403	0.00340	0.00013	0.00000	0.00000
C	NORTHEAST	0.00415	0.01024	0.00108	0.00000	0.00000	0.00000
C	EAST-NORTHEAST	0.00293	0.00916	0.00343	0.00005	0.00000	0.00000
C	EAST	0.00238	0.00588	0.00175	0.00015	0.00000	0.00000
C	EAST-SOUTHEAST	0.00298	0.00473	0.00203	0.00010	0.00003	0.00000
C	SOUTHEAST	0.00353	0.00398	0.00175	0.00013	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00586	0.00456	0.00140	0.00013	0.00000	0.00000
C	SOUTH	0.00966	0.01887	0.00603	0.00078	0.00003	0.00000
C	SOUTH-SOUTHWEST	0.00854	0.02165	0.00691	0.00075	0.00010	0.00000
C	SOUTHWEST	0.00365	0.01156	0.01086	0.00373	0.00028	0.00005
C	WEST-SOUTHWEST	0.00358	0.00866	0.01372	0.00418	0.00073	0.00000
C	WEST	0.00205	0.00956	0.01332	0.00298	0.00023	0.00000
C	WEST-NORTHWEST	0.00160	0.00996	0.01091	0.00153	0.00005	0.00000
C	NORTHWEST	0.00095	0.00778	0.00979	0.00210	0.00005	0.00000
C	NORTH-NORTHWEST	0.00033	0.00548	0.00621	0.00095	0.00000	0.00000
D	NORTH	0.00501	0.00030	0.00263	0.00065	0.00000	0.00000
D	NORTH-NORTHEAST	0.00198	0.00708	0.00636	0.00035	0.00000	0.00000
D	NORTHEAST	0.00516	0.00944	0.00163	0.00005	0.00000	0.00000
D	EAST-NORTHEAST	0.00353	0.00250	0.00148	0.00000	0.00000	0.00000
D	EAST	0.00488	0.00173	0.00063	0.00005	0.00000	0.00000
D	EAST-SOUTHEAST	0.00801	0.00070	0.00048	0.00005	0.00003	0.00000

EXHIBIT 22.2 (continued)

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, MPH					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	>24
D	SOUTHEAST	0.01339	0.00035	0.00013	0.00000	0.00000	0.00000
D	SOUTH-SOUTHEAST	0.02125	0.00053	0.00000	0.00000	0.00003	0.00000
D	SOUTH	0.03824	0.00651	0.00150	0.00015	0.00013	0.00003
D	SOUTH-SOUTHWEST	0.01682	0.00355	0.00028	0.00003	0.00005	0.00000
D	SOUTHWEST	0.00851	0.00173	0.00048	0.00005	0.00000	0.00000
D	WEST-SOUTHWEST	0.00663	0.00348	0.00175	0.00045	0.00005	0.00003
D	WEST	0.00436	0.00215	0.00068	0.00003	0.00003	0.00000
D	WEST-NORTHWEST	0.00188	0.00260	0.00100	0.00010	0.00000	0.00000
D	NORTHWEST	0.00058	0.00451	0.00250	0.00028	0.00000	0.00000
D	NORTH-NORTHWEST	0.00015	0.00576	0.00380	0.00060	0.00000	0.00000
E	NORTH	0.00003	0.00000	0.00000	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00010	0.00023	0.00005	0.00000	0.00000	0.00000
E	NORTHEAST	0.00025	0.00043	0.00013	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00013	0.00003	0.00000	0.00000	0.00000	0.00000
E	EAST	0.00023	0.00005	0.00000	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00030	0.00000	0.00000	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00035	0.00000	0.00000	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00165	0.00000	0.00000	0.00000	0.00003	0.00000
E	SOUTH	0.00143	0.00033	0.00000	0.00000	0.00008	0.00000
E	SOUTH-SOUTHWEST	0.00035	0.00008	0.00000	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00013	0.00000	0.00000	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00013	0.00010	0.00000	0.00000	0.00000	0.00000
E	WEST	0.00015	0.00005	0.00000	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00008	0.00005	0.00000	0.00003	0.00000	0.00000
E	NORTHWEST	0.00000	0.00005	0.00000	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00000	0.00005	0.00000	0.00000	0.00000	0.00000
F	NORTH	0.00481	0.00170	0.00040	0.00003	0.00000	0.00000
F	NORTH-NORTHEAST	0.00100	0.00008	0.00008	0.00000	0.00000	0.00000
F	NORTHEAST	0.00133	0.00003	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00205	0.00000	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00398	0.00000	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00916	0.00000	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.02158	0.00000	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.02275	0.00000	0.00003	0.00000	0.00000	0.00000
F	SOUTH	0.02355	0.00000	0.00038	0.00008	0.00000	0.00003
F	SOUTH-SOUTHWEST	0.00894	0.00008	0.00000	0.00000	0.00000	0.00003
F	SOUTHWEST	0.00581	0.00000	0.00000	0.00000	0.00000	0.00003
F	WEST-SOUTHWEST	0.00375	0.00003	0.00000	0.00000	0.00005	0.00000
F	WEST	0.00178	0.00010	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00093	0.00180	0.00115	0.00030	0.00000	0.00000
F	NORTHWEST	0.00028	0.00013	0.00013	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00008	0.00053	0.00083	0.00000	0.00000	0.00000

Table 22.1. Surface Water Environmental Safety Data for the Portsmouth Uranium Enrichment Compaex, Portsmouth, Ohio

<u>Parameter</u>	<u>Units</u>	<u>Little Bear Creek</u>	<u>Big Run</u>	<u>West Drainage</u>
Velocity	m/s	0.244	0.229	0.122
Depth	m	0.228	0.061	0.122
Width	m	0.101	1.52	0.229
Discharge	cms	5.31e-03	0.022	3.54e-03

Table 22.2. Hydrogeologic Environmental Setting Data for Portsmouth Uranium Enrichment Complex's PUEC Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	SZ
Darcian_velocity	m/yr	0.20	0.20	--
SOILC		10.4	7.75	4.38
Thickness	m	5.00	2.32	1.04
Bulk_density	g/cm3	1.67	1.35	1.68
Total_porosity	%	48.6	39	42
Field_capacity	%	42	37.5	--
Conductivity	m/day	7.0e-5	0.001	--
Longitudinal_disp.	m	0.05	0.05	213.4
Transverse_disp.	m	--	--	42.7
Vertical_disp.	m	--	--	0.25
Effective_porosity	%	--	--	35.0
Velocity	m/day	--	--	0.09
Distance	m	--	--	2133.6
Textural_class		silt clay	silt clay loam	loamy sand
%_sand	%	8	12	84
%_silt	%	44	50	12
%_clay	%	48	38	4
%_OMC	%	2.5	1.13	0
%_Fe	%	7.6	8.9	8.9
pH		5.7	6	6.2

23.0 ROCKY FLATS PLANT

The primary mission of the Rocky Flats Plant (RFP) was to produce components for nuclear weapons from materials such as plutonium, uranium, beryllium, and various alloys of stainless steel. Additional plant missions included plutonium recovery and reprocessing and waste management. The RFP's historical mission was officially ended in 1992 with the end of the Cold War and the administration's decision not to resume weapons production at the plant (Cirrincione et al. 1993).

The RFP is located east of the foothills of the Rocky Mountains approximately 26 km (16 mi) northwest of Denver, Colorado (Figure 23.1). The RFP is situated in a generally rural area outside the Denver metropolitan area with some ranches and industrial facilities located nearby. The installation occupies 27 km² (10 mi²), with its facilities centrally located on only about 6% of the property. The topography of the RFP is relatively flat. Ecologically, the RFP is a plains grassland/montane ecotome and is in a transition zone between the Great Plains and the foothills of the Rocky Mountains.

23.1 CLIMATE

The RFP has a "semiarid" climate (Critchfield 1974). Meteorological data are available from onsite measurements and from measurements at Stapleton International Airport in Denver. On average, the maximum daily temperature exceeds 32°C (90°F) on 33 days per year and is below 0°C (32°F) on 22 days per year; the minimum daily temperature is below 0°C (32°F) on 158 days per year and is below -18°C (0°F) on 9 days per year (DOC 1987c). July is the warmest month, with daily maximum and minimum temperatures averaging 31°C (88°F) and 15°C (59°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 6°C (43°F) and -9°C (16°F), respectively (DOC 1987c).

Annual precipitation is on the order of 39 cm (15 in.), with about 80% falling from April through September. Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 88 days per year and the area experiences an average of 41 thunderstorm days per year. The average annual snowfall is 160 cm (63 in.) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 18 days per year (DOC 1987c).

Wind directions are strongly influenced by the RFP's proximity to the Front Range of the Rocky Mountains. The prevailing wind direction onsite is from the west-northwest (Cirrincione et al. 1993). At Denver's Stapleton Airport, about 50 km (30 mi) to the east-southeast of the RFP (farther away from the mountains), the prevailing wind direction is from the south. At the RFP during the day, thermally-driven circulations often result in

upvalley winds from the northeast and upslope winds from the southeast. During the night, drainage conditions often produce winds from the opposite directions. Over the course of a year, wind speeds average about 4 m/s (9 mph) at about 10 m (33 ft) above ground level (Cirrincione et al. 1993; DOC 1987c). There is little seasonal variation in wind speeds; average speeds tend to be no more than about 0.5 m/s (1 mph) above the annual average in the winter and spring, and about 0.5 m/s (1 mph) below the annual average in the summer and fall.

23.2 GEOLOGY

The RFP is located on Quaternary-aged alluvial and fluvial deposits. The Rocky Flats Alluvium is the dominant unit associated with the broad flat-lying areas on the western half of the site. The thickness of the alluvium varies across the site. Near the western boundary, the alluvium can exceed 15 m (50 ft), but gradually pinches out toward the middle of the site. Surficial deposits in the central portions of the plant are primary colluvium. These deposits are generally thin, and tend to cover the slopes and floors of ravines located north and south of the main facility. Valley fill, which is essentially fluvially-reworked Rocky Flats alluvium, is found in the eastern portion of the site. Bedrock in the vicinity of the plant is of Cretaceous age, and dips gently toward the east. The uppermost unit is the Arapahoe Formation, a light to medium olive-gray sequence of claystones, siltstones and sandstones. In general, the Arapahoe has a low permeability, and hence has a major influence on the hydrology in the area. Directly beneath the Arapahoe Formation is the Laramie Formation, a thick sequence consisting predominantly of claystones with a few water-bearing sand lenses. The Fox Hills Sandstone (a confined aquifer) underlies the Laramie Formation.

23.3 HYDROLOGY

Groundwater of concern is primarily the shallow aquifer overlying the Arapahoe Formation, and found within the Rocky Flats Alluvium and valley fill. This unconfined aquifer is recharged directly by deposition in the vicinity of the RFP and from areas west of the installation, but east of the Front Range. Groundwaters discharge to surface waters at seeps and springs along both the Woman's and Walnut Creeks.

The RFP has two major surface drainages. The northern half of the installation drains into Walnut Creek, a low flow stream that flows through a series of small ponds on the plant property before eventually discharging into the Great Western Reservoir several kilometers east of the RFP. Flow in the creek is primarily storm flow. Natural drainage on the southern half of the property feeds into Woman's Creek. Much of the storm flow and runoff from the facilities area is diverted to a drainage ditch which parallels Woman's Creek.

Waters from the southern half of the property discharge to Standley Lake, a major surface water body located south and east of the installation.

23.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the RFP for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 23.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 23.2

For PEIS modeling purposes, RFP is characterized using five hydrogeologic environmental settings (Figure 23.1): Woman's Creek with Surficial Alluvium, Woman's Creek with Surficial Colluvium, Walnut Creek with Surficial Alluvium, Walnut Creek with Surficial Colluvium, and Operable Unit 3. Figure 23.2 presents stratigraphic columns for each of these settings. As previously described, the RFP is built on alluvial materials derived from the Colorado Front Range. The bedrock in the area is gently dipping Cretaceous clay and silt stones, the uppermost of which is the Arapahoe Formation. Due to the impervious nature of these units, contaminant migration has been limited to the upper area divided into two separate settings, one in which Rocky Flats Alluvium is modeled as the surficial material and one in which the more permeable colluvium is modeled at the surface. Because colluvium is generally found in side slopes and floors of the ravines, the thickness of the partially-saturated zones associated with the colluvium are thinner than those modeled for the Rocky Flat Alluvium. The fifth environmental setting was developed for an operable unit (OU3) located east of the installation, adjacent to the Great Western Reservoir and Standley Lake. This setting describes what is essentially the reworked Rocky Flats Alluvium and is distinct because of the relatively shorter distances involved to drinking water supplies. Surface water data are presented in Table 23.1. Hydrogeologic data for the various settings are presented in Table 23.2-23.5.

23.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the RFP are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Brent Bowen supplied input into the development of the climate and atmospheric dispersion environmental settings. Tim Lovseth, Brent Bowen, and Trish Powell supplied input into the development of the hydrogeologic environmental settings.

23.6 REFERENCES

Cirrincione, D.A., N.L. Erdmann, P.J. Etchart, K. Headrick, N.R. Stallcup, and D.R. Stanton. 1993. *Rocky Flats Plant Site Environmental Report for 1992*. EG&G Rocky Flats, Golden, Colorado.

Critchfield, H.J. 1974. *General Climatology*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

U.S. Department of Commerce (DOC). 1987c. *Local Climatological Data Annual Summaries for 1986 Part III Central Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

S9405048.10

Figure 23.1. Location and Environmental Settings for the Rocky Flats Plant (RFP). For PEIS modeling purposes, the RFP is divided into five environmental settings: Woman's Creek with Surficial Rocky Flats Alluvium (RFA), Woman's Creek with Surficial Colluvium (COLL), Walnut Creek with Surficial RFA, Walnut Creek with Surficial COLL, and Operable Unit 3 (not shown).

Figure 23.2. Stratigraphic Columns for Rocky Flats Plant (RFP) Environmental Settings

EXHIBIT 23.1

Rocky Flats Plant Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite and at Stapleton International Airport.

Station Name: Stapleton International Airport, Denver, Colorado Elevation: 1610 m Latitude: 39.77°N
 Rocky Flats Plant, Northwest Buffer Zone's monitoring location Elevation: 1800 m Latitude: 40°N

Annual Mean Air Temp: 50.3 °F (Stapleton) Reference (A) Based on observations made from 1951-1980.
 Anemometer Height: 8.0 m (Stapleton) Reference (A) Based on average of 2 heights used during observations.
 10.0 m (RFP/NBZ) Reference (B)
 Mean Annual Wind Speed: 9 mph (Stapleton) Reference (A) Based on 38 years of observations.
 10 mph (RFP/NBZ) Reference (B) Based on an analysis of 7 years of joint frequency data.
 Fastest 1-Min Wind Speed: 44 mph (Stapleton) Reference (A) Based on 3 years of observations. A climatologically representative value for RFP should be somewhat greater.
 Annual Precipitation: 15.3 in. (Stapleton) Reference (A) Based on observations made from 1951-1990.
 15.4 in. (RFP/NBZ) Reference (B) Based on observations made from 1953-1992.
 Precipitation Days: 88 yr⁻¹ (Stapleton) Reference (A) Based on 52 years of observations.
 Thunderstorms Freq: 41 yr⁻¹ (Stapleton) Reference (A) Based on 52 years of observations.

Avg Morning Mixing Ht: 300 m Reference (C)
 Avg Afternoon Mixing Ht: 2600 m Reference (C)
 Top Soil Moisture Capacity: 0.3 cm Reference (C)

MEPAS Parameters: Climatic Region Index: 3 Reference (C)
 Precipitation-Evaporation Index: 43 Reference (C)
 Soil Cons. Serv. Curve Number: 86 Reference (C)

MONTHLY AVERAGES							
	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
MONTH	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	30	0.5	8.7	5.6	5.8	63	49
Feb	34	0.5	9.0	5.9	5.8	66	43
Mar	38	1.2	9.8	6.1	8.6	67	40
Apr	47	1.8	10.2	6.0	8.8	67	35
May	57	2.7	9.4	6.2	10.6	70	38
Jun	67	1.9	8.9	5.1	8.8	69	35
Jul	73	1.5	8.3	5.0	9.2	68	34
Aug	71	1.5	8.1	5.0	8.7	68	35
Sep	63	1.5	8.0	4.4	6.2	68	34
Oct	52	0.9	7.9	4.5	5.4	65	36
Nov	39	0.8	8.3	5.4	5.3	68	44
Dec	33	0.6	8.6	5.3	5.1	65	45
Reference: ...	(A)	(B)	(A)	(A)	(A)	(A)	(A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part III Central Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- B: Unpublished technical data provided by Steve Pamp and meteorologist Brent Bowen.
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 23.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Rocky Flats Plant. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made from 1986 through 1993.

DIRECTION		WIND SPEED CLASS, KNOTS					
STAB.	FROM WHICH THE						
CLASS	WIND IS BLOWING	<3	3 - <6	6 - <10	10 - <16	16 - <21	>21
A	NORTH	0.00081	0.00036	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00101	0.00148	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00104	0.00240	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00137	0.00233	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00152	0.00294	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00147	0.00295	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00097	0.00180	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00064	0.00051	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00037	0.00032	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00007	0.00013	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00018	0.00006	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00006	0.00008	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00014	0.00008	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00016	0.00006	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00015	0.00011	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00037	0.00017	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00016	0.00044	0.00002	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00028	0.00127	0.00000	0.00000	0.00000	0.00000
B	NORTHEAST	0.00027	0.00201	0.00002	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00021	0.00176	0.00004	0.00000	0.00000	0.00000
B	EAST	0.00039	0.00218	0.00004	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00024	0.00261	0.00002	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00031	0.00187	0.00002	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00020	0.00045	0.00004	0.00000	0.00000	0.00000
B	SOUTH	0.00019	0.00019	0.00004	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00000	0.00009	0.00002	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00012	0.00011	0.00002	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00012	0.00004	0.00002	0.00000	0.00000	0.00000
B	WEST	0.00008	0.00004	0.00004	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00002	0.00004	0.00000	0.00000	0.00000	0.00000
B	NORTHWEST	0.00006	0.00008	0.00002	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00018	0.00030	0.00002	0.00000	0.00000	0.00000
C	NORTH	0.00030	0.00170	0.00027	0.00002	0.00000	0.00000
C	NORTH-NORTHEAST	0.00047	0.00280	0.00076	0.00000	0.00000	0.00000
C	NORTHEAST	0.00045	0.00305	0.00097	0.00000	0.00000	0.00000
C	EAST-NORTHEAST	0.00046	0.00248	0.00057	0.00000	0.00000	0.00000
C	EAST	0.00036	0.00322	0.00051	0.00000	0.00000	0.00000
C	EAST-SOUTHEAST	0.00048	0.00439	0.00136	0.00000	0.00000	0.00000
C	SOUTHEAST	0.00020	0.00420	0.00093	0.00000	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00030	0.00170	0.00028	0.00002	0.00000	0.00000
C	SOUTH	0.00012	0.00038	0.00008	0.00000	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00008	0.00032	0.00011	0.00000	0.00000	0.00000
C	SOUTHWEST	0.00004	0.00038	0.00013	0.00000	0.00000	0.00000
C	WEST-SOUTHWEST	0.00006	0.00019	0.00006	0.00000	0.00000	0.00000
C	WEST	0.00012	0.00006	0.00011	0.00000	0.00000	0.00000
C	WEST-NORTHWEST	0.00018	0.00028	0.00013	0.00002	0.00000	0.00000
C	NORTHWEST	0.00023	0.00030	0.00023	0.00004	0.00000	0.00000
C	NORTH-NORTHWEST	0.00023	0.00053	0.00021	0.00000	0.00000	0.00000

EXHIBIT 23.2 (continued)

STAB.	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, KNOTS					
		<3	3 - <6	6 - <10	10 - <16	16 - <21	>21
D	NORTH	0.00188	0.00958	0.01742	0.01843	0.00367	0.00131
D	NORTH-NORTHEAST	0.00234	0.00826	0.01428	0.01144	0.00140	0.00062
D	NORTHEAST	0.00193	0.00680	0.00981	0.00470	0.00038	0.00004
D	EAST-NORTHEAST	0.00197	0.00515	0.00642	0.00244	0.00002	0.00000
D	EAST	0.00139	0.00521	0.00598	0.00176	0.00006	0.00000
D	EAST-SOUTHEAST	0.00104	0.00595	0.00900	0.00259	0.00006	0.00000
D	SOUTHEAST	0.00150	0.00801	0.01409	0.00606	0.00027	0.00004
D	SOUTH-SOUTHEAST	0.00153	0.00913	0.01415	0.01004	0.00087	0.00027
D	SOUTH	0.00167	0.00739	0.00924	0.01083	0.00108	0.00025
D	SOUTH-SOUTHWEST	0.00217	0.00568	0.00706	0.00894	0.00114	0.00042
D	SOUTHWEST	0.00161	0.00462	0.00530	0.01011	0.00136	0.00027
D	WEST-SOUTHWEST	0.00164	0.00456	0.00699	0.01820	0.00354	0.00117
D	WEST	0.00195	0.00498	0.00651	0.01875	0.00894	0.00816
D	WEST-NORTHWEST	0.00195	0.00559	0.00786	0.03250	0.01915	0.02040
D	NORTHWEST	0.00238	0.00680	0.00896	0.02244	0.00898	0.00472
D	NORTH-NORTHWEST	0.00202	0.00801	0.01326	0.01693	0.00316	0.00064
E	NORTH	0.00147	0.00619	0.00951	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00092	0.00350	0.00470	0.00000	0.00000	0.00000
E	NORTHEAST	0.00068	0.00286	0.00265	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00051	0.00157	0.00146	0.00000	0.00000	0.00000
E	EAST	0.00053	0.00197	0.00161	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00051	0.00163	0.00138	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00056	0.00227	0.00239	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00091	0.00400	0.00479	0.00000	0.00000	0.00000
E	SOUTH	0.00110	0.00454	0.00953	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00090	0.00464	0.01216	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00123	0.00655	0.01880	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00176	0.00761	0.02485	0.00000	0.00000	0.00000
E	WEST	0.00181	0.00905	0.01807	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00218	0.00856	0.01843	0.00000	0.00000	0.00000
E	NORTHWEST	0.00162	0.00841	0.01922	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00178	0.00739	0.01735	0.00000	0.00000	0.00000
F	NORTH	0.00050	0.00223	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00030	0.00106	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00018	0.00068	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00014	0.00055	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00021	0.00047	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00013	0.00032	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00019	0.00076	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00034	0.00165	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00042	0.00371	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00096	0.00608	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00088	0.00759	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00128	0.00812	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00153	0.01059	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00153	0.00956	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00088	0.00697	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00051	0.00407	0.00000	0.00000	0.00000	0.00000

Table 23.1. Surface Water Environmental Safety Data for the Rocky Flats Plant, Denver, Colorado

<u>Parameter</u>	<u>Units</u>	<u>Woman's Creek</u>	<u>Walnut Creek</u>
Velocity	m/s	0.041	0.077
Depth	m	0.304	0.304
Width	m	1.22	1.22
Discharge	cms	0.015	0.029

Table 23.2. Hydrogeologic Environmental Setting Data for Rocky Flats Plant's Coll_WmF Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.08	--
SOILC		10.4	4.05
Thickness	m	2.27	1.90
Bulk_density	g/cm3	1.84	1.84
Total_porosity	%	30	30
Field_capacity	%	10	--
Conductivity	m/day	0.22	--
Longitudinal_disp.	m	0.02	0.19
Transverse_disp.	m	--	0.04
Vertical_disp.	m	--	4.4e-5
Effective_porosity	%	--	10.0
Velocity	m/day	--	0.55
Distance	m	--	1.9
Textural_class		sandy clay	sand
%_sand	%	50	95
%_silt	%	8	3
%_clay	%	42	2
%_OMC	%	0	0
%_Fe	%	0	0
pH		7	7

Table 23.3. Hydrogeologic Environmental Setting Data for Rocky Flats Plant's RFA_WmF Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.08	--
SOILC		10.4	10.4
Thickness	m	5.36	2.90
Bulk_density	g/cm3	1.84	1.84
Total_porosity	%	30	30
Field_capacity	%	10	--
Conductivity	m/day	5.18e-2	--
Longitudinal_disp.	m	0.06	0.29
Transverse_disp.	m	--	0.06
Vertical_disp.	m	--	6.7e-5
Effective_porosity	%	--	10.0
Velocity	m/day	--	0.05
Distance	m	--	2.9
Textural_class		sandy clay	sandy clay
%_sand	%	50	50
%_silt	%	8	8
%_clay	%	42	42
%_OMC	%	0	0
%_Fe	%	0	0
pH		7	7

Table 23.4. Hydrogeologic Environmental Setting Data for Rocky Flats Plant's Coll_WIF Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.08	--
SOILC		10.4	4.05
Thickness	m	2.27	1.90
Bulk_density	g/cm3	1.84	1.84
Total_porosity	%	30	30
Field_capacity	%	10	--
Conductivity	m/day	0.22	--
Longitudinal_disp.	m	0.02	0.19
Transverse_disp.	m	--	0.04
Vertical_disp.	m	--	4.4e-5
Effective_porosity	%	--	10.0
Velocity	m/day	--	0.55
Distance	m	--	1.9
Textural_class		sandy clay	sand
%_sand	%	50	95
%_silt	%	8	3
%_clay	%	42	2
%_OMC	%	0	0
%_Fe	%	0	0
pH		7	7

Table 23.5. Hydrogeologic Environmental Setting Data for Rocky Flats Plant's OU 3 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.08	--
SOILC		10.4	4.05
Thickness	m	5.36	3.66
Bulk_density	g/cm3	1.84	1.84
Total_porosity	%	30	30
Field_capacity	%	10	--
Conductivity	m/day	5.18e-2	--
Longitudinal_disp.	m	0.06	0.37
Transverse_disp.	m	--	0.07
Vertical_disp.	m	--	8.5e-5
Effective_porosity	%	--	10.0
Velocity	m/day	--	0.07
Distance	m	--	3.7
Textural_class		sandy clay	sand
%_sand	%	50	95
%_silt	%	8	3
%_clay	%	42	2
%_OMC	%	0	0
%_Fe	%	0	0
pH		7	7

Table 23.6. Hydrogeologic Environmental Setting Data for Rocky Flats Plant RFA_WIF Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.08	--
SOILC	n/a	10.4	10.4
Thickness	m	5.4	2.9
Bulk_density	g/cm3	1.84	1.84
Total_porosity	%	30	30
Field_capacity	%	10	--
Conductivity	m/day	5.18e-2	--
Longitudinal_disp.	m	.055	0.290
Transverse_disp.	m	--	0.058
Vertical_disp.	m	--	6.74e-05
Effective_porosity	%	--	10.0
Velocity	m/day	--	0.046
Distance	m	--	2.9
Textural_class		sandy clay	sandy clay
%_sand	%	50	50
%_silt	%	8	8
%_clay	%	42	42
%_OMC	%	0	0
%_Fe	%	0	0
pH		7	7

24.0 SANDIA NATIONAL LABORATORIES, ALBUQUERQUE

Sandia National Laboratories at Albuquerque (SNLA) was established in 1945 to develop the nonnuclear portions of nuclear weapons. Current activities at the SNLA include process development, environmental testing, radiation research, combustion research, computing, and microelectronic research and development (SNLA/DOE 1993a; McCord et al. 1993).

The SNLA is contained entirely within the boundaries of the Kirtland Air Force Base (KAFB), immediately south of Albuquerque, New Mexico. The SNLA/KAFB encompasses 210 km² (82 mi²) and is located on the eastern edge of the Albuquerque-Belen Basin, one of the largest of a series of north-south aligned basins in the Rio Grande trough (Figure 24.1) (SNLA/DOE 1993a; McCord et al. 1993). Elevations range from about 1,500 m (4,900 ft) at the Rio Grande to 2,400 m (8,000 ft) at the Manzano Lookout Tower in the Manzano Mountains (McCord et al. 1993). The western two-thirds of the area is relatively flat, sloping gently westward toward the Rio Grande. Ecologically, the SNLA has four biome groups: riparian scrublands, grasslands, woodlands, and riparian woodlands (McCord et al. 1993).

24.1 CLIMATE

The SNLA is located near the boundary between a "mid-latitude semiarid" and a "tropical semiarid" climate (Critchfield 1974). Meteorological data are available from measurements at the Albuquerque International Airport, located immediately west of the KAFB, and some meteorological monitoring conducted within the KAFB. On average, the maximum daily temperature exceeds 32°C (90°F) on 64 days per year and is below 0°C (32°F) on 5 days per year; the minimum daily temperature is below 0°C (32°F) on 120 days per year and is below -18°C (0°F) about once every 2 years (DOC 1987b). July is the warmest month, with daily maximum and minimum temperatures averaging 34°C (93°F) and 18°C (65°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 8°C (47°F) and -5°C (22°F), respectively (DOC 1987b).

Annual precipitation is on the order of 21 cm (8 in.), with about 55% falling from July through October. Precipitation is about double in the Manzano mountains to the east (McCord et al. 1993). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 60 days per year and the area experiences an average of 42 thunderstorm days per year. The average annual snowfall is 28 cm (11 in) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 4 days per year (DOC 1987b).

Winds across the SNLA are modified by the Manzano Mountains and other terrain features. The prevailing wind direction at the Albuquerque International Airport is from the southeast. Wind speeds average about 4 m/s (9 mph) at about 7 m (23 ft) above ground level. Average wind speeds are highest in April (5 m/s [11 mph]) and lowest in December (3.5 m/s [8 mph]) (DOC 1987b).

24.2 GEOLOGY

The Albuquerque-Belen Basin is a complex graben bordered by uplifted fault blocks (McCord et al. 1993). These fault blocks comprise the Sandia, Manzanita, and Manzano Mountains to the east and the Lucero uplift to the west (SNLA 1990). The fault blocks and the bedrock underlying the basin are composed of massive Precambrian crystalline basement rocks similar to those that compose the Sandia and Manzano Uplifts. Overlying the crystalline basement material is a sequence of Paleozoic limestones, sandstones, and shales which extend to a depth of 4,600 m (13,000 ft) below land surface (SNLA/DOE 1993a). The basin fill consists of up to 4,400 m (14,500 ft) of Miocene-Pliocene aged Santa Fe Group, composed primarily of alluvial fan material from nearby mountains and fluvial material transported by rivers flowing through the Albuquerque-Belen Basin. Post Santa Fe Group units include fan, pediment, inset-terrace, eolian, and floodplain deposits (McCord et al. 1993).

The Albuquerque-Belen Basin is bounded on the east and west by complex fault zones consisting of four major fault systems. These fault systems include the Manzano, Hubbell Spring, Sandia, and Tijeras Faults. The Manzano Fault is located on the eastern edge of the SNLA/KAFB where the uplift of the Manzanita and Manzano Mountains occurred. The Sandia Fault lies at the front of the Sandia Mountains east of Albuquerque, and intersects the Tijeras Fault south of Thunder Range. The Hubbell Spring Fault runs parallel to the Manzano Fault along the eastern side of the Albuquerque Basin and is responsible for creating the Hubble Bench, a natural bedrock bench where groundwater is 30 to 107 m (200 to 350 ft) lower on the west side of the fault than on the east side (SNLA/DOE 1993a; McCord et al. 1993). The Tijeras Fault is a major fault in the Tijeras rift zone that trends northeast with continuous exposure for approximately 50 km (30 mi). The Tijeras Fault is a left lateral wrench fault that exhibits scissor rotation of its blocks (SNLA/DOE 1993b).

24.3 HYDROLOGY

The structural regime at the SNLA/KAFB is a major factor in depths to groundwater and regional groundwater flow patterns. Waste sites east of major north trending fault systems lie on thinner alluvial sections with shallow depths to bedrock compared to sites west of the fault system (SNLA/DOE 1993b). The hydrogeology east of the faults is poorly understood because there are few wells and the geology between the faults and the canyons

of the Manzanita Mountains is complex. Valley fill is the principal aquifer in the region. The valley fill consists of unconsolidated and semi-consolidated sands, gravels, silts, and clays of the Santa Fe Formation. On the east side of the SNLA/KAFB the valley fill is composed of heterogeneous alluvial fan deposits. West of the SNLA/KAFB alluvial fan materials interfinger with predominantly finer-grained Rio Grande sediments. The aquifer is generally unconfined, with localized confining conditions created by discontinuous lenses of silt and clay. Pre-development groundwater flow in the Albuquerque-Belen Basin was to the southwest, away from the Manzano Mountains following the gradient of the Rio Grande. Heavy pumping of municipal wells by the City of Albuquerque has shifted groundwater flow to the northwest (SNLA/DOE 1993a).

The major surface water feature of the Albuquerque area is the Rio Grande, which flows southward with an annual average flow of $9.0 \times 10^9 \text{ m}^3$ (730,000 acre-feet) (SNLA/DOE 1993a). The Rio Grande is located approximately 11 km (7 mi) west of the SNLA/KAFB (SNLA/DOE 1993a). The surface water system within the SNLA/KAFB consists primarily of ephemeral drainages. The major surface area drainage feature is the Tijeras Arroyo, which flows westward from the Sandia and Manzano Mountains to the Rio Grande. Tijeras Arroyo downstream of the KAFB drains a 330 km^2 (130 mi^2) area that includes some urban run-off, Tijeras Canyon, and the Arroyo del Coyote drainage. The Arroyo del Coyote drainage drains a 100 km^2 (40 mi^2) area that includes Lurance Canyon, Madera Canyon, and much of the Manzano Base area. Arroyo del Coyote, Tijeras Arroyo, and all surface water features in the SNLA/KAFB are ephemeral streams, with the exception of small portions of Arroyo del Coyote near Coyote Springs and G Spring which are intermittent. Tijeras Arroyo is also intermittent approximately 3 km (2 mi) upstream of the KAFB boundary (McCord et al. 1993). Most of the floods in the Albuquerque area occur between May and October, during high-intensity thunderstorms. Floods in Tijeras Arroyo and Arroyo del Coyote are characterized by high peak flows, small volumes, and short durations (SNLA/DOE 1993a).

24.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the SNLA for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 24.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 24.2.

For PEIS modeling purposes, SNLA is characterized using three hydrogeologic environmental settings (Figure 24.1): Hydrogeologic Region (HR) 1, HR2, and HR3. Figure 24.2 presents stratigraphic columns for each of these settings. Hydrogeologic environmental settings for the SNLA are based on divisions developed in McCord et al. (1993); HR1 occupies the western part of the SNLA/KAFB and is characterized by thick

basin fill, HR2 is situated between the Sandia fault-Tijeras fault complex, and HR3 occurs east of the fault complex on the Hubbell Bench and is characterized by shallow bedrock. Physical characteristics of the hydrogeologic regions are defined by the location of environmental restoration sites within each setting. For example, although the area east of the Hubbell fault zone exhibits complex depth to bedrock relationships with both Paleozoic limestone and crystalline Precambrian material outcropping at the surface, waste sites within the HR3 are predominantly located on alluvium with shallow depths to water. Environmental settings were developed that best describe the hydrogeologic characteristics of environmental restoration sites in a given region. Hydrogeologic data for the various settings are presented in Tables 24.1-24.3. A brief description of the hydrogeology of each environmental setting follows.

24.4.1 HR1 Setting

The HR1 is the largest hydrogeologic region on the SNLA. Sediments in the HR1 are composed of piedmont-slope alluvium, including coalescing alluvial fan deposits and surficial deposits reaching thicknesses up to 46 m (150 ft) across the SNLA/KAFB. Underlying the piedmont alluvium are sediments of the Santa Fe Group. Included within the HR1 are coarse-grained sand, gravel, silt, and clay of the Upper and Middle Santa Fe Group. Total thickness of Upper and Middle Santa Fe Group sediments is based on Santa Fe Group isopach maps in the Albuquerque Area (McCord et al. 1993). Isopach maps of Upper and Middle Santa Fe Group sediments suggest a combined thickness of approximately 650 m (2,100 ft), plus an additional estimated 23 m (75 ft) of overlying piedmont-slope alluvium. The partially-saturated zone at the HR1 is estimated to be 120 m (400 ft) thick based on a depth to water map of the SNLA/KAFB (SNLA/DOE 1993a). Additional parameters are based on soil properties.

24.4.2 HR2 Setting

The HR2 is the most structurally complex area on the SNLA/KAFB. The depth to bedrock is quite variable across the region resulting from the numerous, intersecting faults that occur in this area. The relationship between faulting and groundwater within this region is complex and poorly resolved; currently, little is known about the saturated zone flow across the fault complex. Environmental Restoration (ER) sites in the HR2 are predominantly located in the southern half of the region over piedmont alluvium and away from bedrock outcrops in the north and east. The environmental setting developed for the HR2 reflects the location of these ER sites and is not intended to summarize the geology of the entire hydrogeologic region. Piedmont alluvium occurs at the surface across most of the region, with an estimated depth of 23 m (75 ft) based on a maximum depth of 46 m (150 ft) across the SNLA/KAFB. Piedmont alluvium is underlain by coarse gravels, sand, silt, and clay of the Upper Santa Fe Group in the west and Paleozoic/Precambrian bedrock in the east (McCord et al. 1993). Total thickness of Upper Santa Fe Group sediments in the HR2 is based on Santa Fe Group isopach maps in the Albuquerque Area (McCord et al. 1993).

Isopach maps of Upper Santa Fe Group sediments in the northwestern portion of the HR2 suggest a thickness of less than 150 m (500 ft) for sediments in the Sandia Fault Zone, plus an additional estimated 23 m (75 ft) of overlying piedmont-slope alluvium. Thickness of the partially-saturated zone was based on an average depth to water of 70 m (200 ft) for the HR2 (SNLA/DOE 1993a). Additional parameters are based on soil properties.

24.4.3 HR3 Setting

The HR3 is located on the Hubbell Bench and is characterized by an irregular, shallow depth to bedrock (from 15 to 45 m [50 to 150 ft]). Piedmont-slope alluvium is the only hydrostratigraphic unit present in this region, although bedrock material is also considered a potential aquifer system due to its fractured nature. Based on a summary table of wells located in the HR3, the average depth to water within the alluvial fill/paleozoic sandstone is 28 m (94 ft) below ground surface. The aquifer appears to be locally confined and unconfined within this material, but lack of information on the distribution and interrelationship of the bedrock with the overlying alluvium precludes distinction between these two aquifer systems. The thickness of the saturated zone within the alluvium/paleozoic sandstone is 16 m (53 ft) based on the maximum producing interval thickness for boreholes located in the HR3 (McCord et al. 1993). Waste sites within this setting are predominantly located on piedmont alluvium with shallow depths to water.

24.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the SNLA are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Su Hwang and Gina Deola supplied input into the development of the climate and atmospheric dispersion environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings include Warren Cox, Franz Lauffer, Jim Krumhansl, and Jonathan Helper. Following completion of the environmental settings, Franz Lauffer coordinated the onsite review and fine tuning of the settings data. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

24.6 REFERENCES

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S9405048.12

Figure 24.1. Location and Environmental Settings for the Sandia National Laboratory Albuquerque (SNLA) and Inhalation Toxicology Research Institute (ITRI). For PEIS modeling purposes, the SNLA is divided into three environmental settings: HR1, HR2, and HR3. The ITRI is characterized by a single environmental setting (HR2).

Figure 24.2. Stratigraphic Columns for Sandia National Laboratory Albuquerque (SNLA) Environmental Settings

EXHIBIT 24.1

Sandia National Laboratory Albuquerque Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at Albuquerque International Airport.

Station Name: Albuquerque International Airport, Albuquerque, New Mexico Elevation: 1619 m Latitude: 35.05°N

Annual Mean Air Temp: 56.2 °F Reference (A) Based on observations made from 1951-1980.
 Anemometer Height: 7.0 m Reference (A)
 Mean Annual Wind Speed: 9 mph Reference (A) Based on 47 years of observations.
 Fastest 1-Min Wind Speed: 90 mph Reference (A) Based on 44 years of observations.
 Annual Precipitation: 8.1 in. Reference (A) Based on observations made from 1951-1980.
 Precipitation Days: 60 yr⁻¹ Reference (A) Based on 47 years of observations.
 Thunderstorms Freq: 42 yr⁻¹ Reference (A) Based on 47 years of observations.

Avg Morning Mixing Ht: 450 m Reference (B)
 Avg Afternoon Mixing Ht: 2600 m Reference (B)
 Top Soil Moisture Capacity: 2.8 cm Reference (B)

MEPAS Parameters: Climatic Region Index: 2 Reference (B)
 Precipitation-Evaporation Index: 46 Reference (B)
 Soil Cons. Serv. Curve Number: 41 Reference (B)

MONTHLY AVERAGES							
	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
MONTH	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	35	0.4	8.0	4.8	3.9	71	40
Feb	39	0.4	8.8	4.9	4.1	65	32
Mar	46	0.5	10.1	5.1	4.6	56	24
Apr	55	0.4	11.0	4.6	3.3	49	18
May	64	0.5	10.5	4.2	4.3	48	18
Jun	75	0.5	10.0	3.3	3.8	46	17
Jul	79	1.3	9.1	4.5	8.9	60	27
Aug	76	1.5	8.2	4.3	9.2	66	30
Sep	69	0.9	8.6	3.6	5.7	62	31
Oct	57	0.9	8.3	3.5	4.9	62	30
Nov	44	0.4	7.9	4.0	3.5	66	36
Dec	36	0.5	7.7	4.6	4.1	71	43
Reference: ...	(A)	(A)	(A)	(A)	(A)	(A)	(A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part II Southern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- B: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 24.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Sandia National Laboratory Albuquerque. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made at the Albuquerque International Airport at 15 m (48 ft) above ground level. Data are based on measurements made from 1960 through 1964.

DIRECTION		WIND SPEED CLASS (KNOTS)					
STAB FROM WHICH	CLASS WIND IS BLOWING	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
A	NORTH	0.00102	0.00103	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00018	0.00025	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00073	0.00030	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00042	0.00018	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00033	0.00016	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00056	0.00041	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00084	0.00041	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00042	0.00053	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00101	0.00142	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00079	0.00089	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00107	0.00158	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00104	0.00132	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00126	0.00128	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00097	0.00128	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00077	0.00105	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00043	0.00057	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00636	0.00379	0.00130	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00274	0.00201	0.00055	0.00000	0.00000	0.00000
B	NORTHEAST	0.00296	0.00144	0.00032	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00171	0.00087	0.00025	0.00000	0.00000	0.00000
B	EAST	0.00158	0.00073	0.00011	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00228	0.00082	0.00030	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00346	0.00180	0.00066	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00271	0.00203	0.00082	0.00000	0.00000	0.00000
B	SOUTH	0.00576	0.00521	0.00299	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00291	0.00464	0.00260	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00545	0.00598	0.00377	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00378	0.00532	0.00299	0.00000	0.00000	0.00000
B	WEST	0.00448	0.00491	0.00212	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00476	0.00464	0.00180	0.00000	0.00000	0.00000
B	NORTHWEST	0.00509	0.00393	0.00139	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00415	0.00374	0.00069	0.00000	0.00000	0.00000
C	NORTH	0.00168	0.00662	0.00683	0.00034	0.00002	0.00000
C	NORTH-NORTHEAST	0.00076	0.00253	0.00151	0.00005	0.00000	0.00000
C	NORTHEAST	0.00064	0.00132	0.00110	0.00000	0.00000	0.00000
C	EAST-NORTHEAST	0.00054	0.00057	0.00048	0.00009	0.00000	0.00000
C	EAST	0.00037	0.00048	0.00085	0.00023	0.00002	0.00000
C	EAST-SOUTHEAST	0.00081	0.00142	0.00089	0.00037	0.00009	0.00000
C	SOUTHEAST	0.00145	0.00279	0.00151	0.00027	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00101	0.00265	0.00212	0.00037	0.00002	0.00000
C	SOUTH	0.00192	0.00623	0.00623	0.00132	0.00034	0.00005
C	SOUTH-SOUTHWEST	0.00080	0.00358	0.00541	0.00128	0.00032	0.00005
C	SOUTHWEST	0.00110	0.00427	0.00594	0.00171	0.00018	0.00005
C	WEST-SOUTHWEST	0.00067	0.00308	0.00416	0.00114	0.00014	0.00005
C	WEST	0.00096	0.00313	0.00295	0.00091	0.00018	0.00005
C	WEST-NORTHWEST	0.00084	0.00311	0.00299	0.00062	0.00023	0.00000
C	NORTHWEST	0.00113	0.00390	0.00292	0.00037	0.00023	0.00000
C	NORTH-NORTHWEST	0.00095	0.00502	0.00395	0.00041	0.00005	0.00000
D	NORTH	0.00147	0.00495	0.01372	0.01541	0.00199	0.00016
D	NORTH-NORTHEAST	0.00058	0.00192	0.00352	0.00215	0.00011	0.00002
D	NORTHEAST	0.00058	0.00194	0.00281	0.00116	0.00014	0.00002
D	EAST-NORTHEAST	0.00049	0.00064	0.00210	0.00361	0.00091	0.00021

EXHIBIT 24.2 (continued)

DIRECTION		WIND SPEED CLASS (KNOTS)					
STAB FROM WHICH	CLASS WIND IS BLOWING	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
D	EAST	0.00050	0.00116	0.00349	0.01306	0.00827	0.00400
D	EAST-SOUTHEAST	0.00060	0.00212	0.00573	0.01400	0.00808	0.00260
D	SOUTHEAST	0.00103	0.00301	0.00509	0.00413	0.00162	0.00027
D	SOUTH-SOUTHEAST	0.00065	0.00228	0.00450	0.00265	0.00039	0.00005
D	SOUTH	0.00118	0.00365	0.00911	0.00856	0.00313	0.00112
D	SOUTH-SOUTHWEST	0.00022	0.00183	0.00539	0.00824	0.00240	0.00032
D	SOUTHWEST	0.00088	0.00251	0.00573	0.00671	0.00210	0.00050
D	WEST-SOUTHWEST	0.00050	0.00171	0.00548	0.00669	0.00203	0.00078
D	WEST	0.00035	0.00167	0.00374	0.00553	0.00260	0.00066
D	WEST-NORTHWEST	0.00069	0.00164	0.00336	0.00742	0.00320	0.00096
D	NORTHWEST	0.00089	0.00217	0.00324	0.00810	0.00322	0.00073
D	NORTH-NORTHWEST	0.00067	0.00267	0.00553	0.00838	0.00142	0.00018
E	NORTH	0.00000	0.00589	0.02183	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00000	0.00333	0.00820	0.00000	0.00000	0.00000
E	NORTHEAST	0.00000	0.00251	0.00297	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00000	0.00171	0.00183	0.00000	0.00000	0.00000
E	EAST	0.00000	0.00194	0.00263	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00000	0.00553	0.00543	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00000	0.00877	0.00587	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00000	0.00493	0.00390	0.00000	0.00000	0.00000
E	SOUTH	0.00000	0.00511	0.00553	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00000	0.00263	0.00324	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00000	0.00274	0.00301	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00000	0.00231	0.00244	0.00000	0.00000	0.00000
E	WEST	0.00000	0.00206	0.00190	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00000	0.00222	0.00253	0.00000	0.00000	0.00000
E	NORTHWEST	0.00000	0.00201	0.00361	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00000	0.00311	0.00619	0.00000	0.00000	0.00000
F	NORTH	0.01361	0.02073	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00773	0.00998	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00986	0.00925	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00640	0.00441	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00723	0.00555	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.01348	0.01534	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.01779	0.02267	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00993	0.01228	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.01167	0.00963	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00382	0.00333	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00527	0.00370	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00416	0.00354	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00416	0.00313	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00534	0.00422	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00570	0.00557	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00660	0.00954	0.00000	0.00000	0.00000	0.00000

Table 24.1. Hydrogeologic Environmental Setting Data for Sandia National Laboratory Albuquerque's HR1 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.04	--
SOILC		4.38	4.38
Thickness	m	122	551
Bulk_density	g/cm3	1.49	1.49
Total_porosity	%	43.7	43.7
Field_capacity	%	12	--
Conductivity	m/day	0.03	--
Longitudinal_disp.	m	1.22	323.1
Transverse_disp.	m	--	64.6
Vertical_disp.	m	--	0.38
Effective_porosity	%	--	23.0
Velocity	m/day	--	0.02
Distance	m	--	3231
Textural_class		loamy sand	loamy sand
%_sand	%	84	84
%_silt	%	12	12
%_clay	%	4	4
%_OMC	%	0	0
%_Fe	%	0	0
pH		6.8	6.8

Table 24.2. Hydrogeologic Environmental Setting Data for Sandia National Laboratory Albuquerque's HR2 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.04	--
SOILC		4.38	4.38
Thickness	m	61	114
Bulk_density	g/cm3	1.49	1.49
Total_porosity	%	43.7	43.7
Field_capacity	%	12	--
Conductivity	m/day	0.03	--
Longitudinal_disp.	m	0.61	563.9
Transverse_disp.	m	--	112.8
Vertical_disp.	m	--	0.66
Effective_porosity	%	--	23.0
Velocity	m/day	--	0.02
Distance	m	--	5639
Textural_class		loamy sand	loamy sand
%_sand	%	84	84
%_silt	%	12	12
%_clay	%	4	4
%_OMC	%	0	0
%_Fe	%	0	0
pH		6.8	6.8

Table 24.3. Hydrogeologic Environmental Setting Data for Sandia National Laboratory Albuquerque's HR3 Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.04	--
SOILC		4.38	4.38
Thickness	m	28.7	16.2
Bulk_density	g/cm3	1.49	1.49
Total_porosity	%	43.7	43.7
Field_capacity	%	12	--
Conductivity	m/day	0.03	--
Longitudinal_disp.	m	0.29	1.3e+4
Transverse_disp.	m	--	2578.6
Vertical_disp.	m	--	14.9
Effective_porosity	%	--	23.0
Velocity	m/day	--	0.02
Distance	m	--	1.3e+5
Textural_class		loamy sand	loamy sand
%_sand	%	84	84
%_silt	%	12	12
%_clay	%	4	4
%_OMC	%	0	0
%_Fe	%	0	0
pH		6.8	6.8

25.0 SAVANNAH RIVER SITE

The Savannah River Site (SRS) was established by the U.S. Atomic Energy Commission in 1950 to produce plutonium and tritium for national defense and additional special nuclear material for other government and civilian purposes. The SRS's main activities now involve waste management and environmental restoration.

The SRS is located in the southwest portion of South Carolina, approximately 20 km (12 mi) south of Aiken, South Carolina, and 40 km (25 mi) southeast of Augusta, Georgia (Figure 25.1). The installation occupies 800 km² (310 mi²), with about 10% of the property being used to support facilities and operations (Arnett et al. 1993). Except for timber harvesting, about 90% of the installation has remained virtually untouched. Approximately 40% of the site is forested with longleaf and loblolly pines and sweet gum, maple, birch, and various oak-hickory hardwood trees. Major plant communities include cypress-gum and lowland hardwood swamps, sandhills, and old agricultural fields, as well as aquatic and semiaquatic areas (Arnett et al. 1993).

25.1 CLIMATE

The SRS has a "humid subtropic climate" (Critchfield 1974). Meteorological data are available from onsite measurements (Parker et al. 1992) and from measurements at Bush Field in Augusta, Georgia. On average, the maximum daily temperature exceeds 32°C (90°F) on 69 days per year and is below 0°C (32°F) about twice every 3 years; the minimum daily temperature is below 0°C (32°F) on 58 days per year and is below -18°C (0°F) about once every 20 years (DOC 1987b). July is the warmest month, with daily maximum and minimum temperatures averaging 33°C (92°F) and 21°C (70°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging 12°C (53°F) and 1°C (33°F), respectively (DOC 1987b).

Annual precipitation is on the order of 110 cm (43 in.). Measurable precipitation (0.025 cm [0.01 in.] or greater) is recorded on an average of 107 days per year and the area experiences an average of 54 thunderstorm days per year. The average annual snowfall is 3 cm (1 in.) (DOC 1987b).

Winds are relatively uniform across the SRS. There is no strongly prevailing wind direction at the SRS. At the H-Area monitoring station (located near the center of the installation) the most common wind direction is from the southwest; although winds are from both neighboring sectors and opposing sectors with almost the same frequency. This broad distribution of wind directions is characteristic of the lower midlands of South Carolina (Arnett et al. 1993). Wind speeds average about 4 m/s (9 mph) at about 61 m (200 ft) above ground level at the H-Area Station and about 3 m/s (7 mph) at about 6 m (20 ft) above

ground level at Bush Field (DOC 1987b). At Bush Field, average wind speeds are highest in March (3.5 m/s [8 mph]) and lowest in August (2.5 m/s [5.5 mph]) (DOC 1987b).

25.2 GEOLOGY

The SRS is located on the Upper Atlantic Coastal Plain, approximately 32 km (20 mi) southeast of the Fall Line, which separates the Piedmont and Coastal Plain provinces. The site is located on the Aiken Plateau, a relatively flat area that slopes southeastward and is dissected by several tributaries of the Savannah River. The SRS is underlain by a 210 to 370 m (700 to 1200 ft) thick seaward-thickening wedge of Coastal Plain sediments composed of Cretaceous to Post Eocene-aged unconsolidated sands, clayey sands, sandy clays, and lesser amounts of calcareous sediment. The sediments at the SRS constitute a multilayer hydrogeologic system in which there are clay-rich confining units partially or totally isolating transmissive zones of interbedded sand and sandy clay. The sandier units of the Coastal Plain contain the productive aquifers (Christensen and Gordon 1983). Sediments of the Coastal Plain wedge are underlain by dense crystalline igneous and metamorphic rock or younger consolidated sediments of the Triassic Period. The Triassic formations and older igneous and metamorphic rocks are hydrologically isolated from the overlying Coastal Plain sediments (Arnett et al. 1993).

25.3 HYDROLOGY

There are three major water-bearing zones in the Coastal Plain sediments divided by regional aquitards. In ascending order, these are the Cretaceous zone, the lower Eocene Congaree-Fourmile zone, and the middle to post-Eocene upper saturated zone (Arnett et al. 1993). The deepest aquifer monitored at the SRS occurs in Cretaceous-aged sediments. Overlying and separating the deepest zone from the intermediate Congaree-Fourmile aquifer is a Paleocene-aged regional aquitard. The intermediate aquifer is an important local source of groundwater. A local aquitard referred to as the "Green Clay" overlies the intermediate aquifer, separating it from the upper saturated zone. Sediments of the upper saturated zone generally yield low amounts of water, occurring predominantly in sandy clays and calcareous sediments of middle to late Eocene and post Eocene age. Numerous discontinuous clay-rich layers act as local aquitards, creating groundwater flow patterns at the SRS which are locally complex. Few of these aquitards are continuous across the SRS (Arnett et al. 1993).

The primary sources of recharge to the aquifers are precipitation and leakage from overlying or underlying aquifers. Valleys of the smaller streams and swamps allow for the discharge of groundwater from saturated formations higher in the section, while more significant streams drain aquifers of intermediate depth and the Savannah River drains deeper formations (Arnett et al. 1993). Artificial recharge to the unconfined aquifers at the SRS occurs from liquid-waste disposal operations. There currently is no indication that activities

at the SRS have impacted the lower two aquifers; therefore, environmental settings for the SRS focus on the upper unconfined aquifer.

The saturated zone extends from the ground surface to the water table with depths ranging from about 40 m (130 ft) in the extreme north end of the SRS to about 15 m (50 ft) in the upland areas in the south. In lowland areas and valley bottoms, the saturated zone is extremely shallow. Texturally, the saturated zone is heterogeneous, composed of clayey sand or silt, silty sand or sand. These low permeability materials provide a major pathway for water to recharge underlying aquifers.

Groundwater flow direction at the SRS is typically controlled by the streams on the Aiken Plateau. Groundwater in the deep Cretaceous zone flows toward and discharges into the Savannah River. Groundwater in the intermediate Congaree-Fourmile aquifer flows toward and discharges into either Upper Three Runs Creek or the Savannah River, with the closer channel having the greatest influence. Groundwater in the upper saturated zone flows toward and discharges into the nearest perennial stream, swamp, or river. Local flow patterns may be very complex; nevertheless, all groundwater in these zones eventually exits the subsurface and flows from springs or streams into the Savannah River (Arnett et al. 1993).

The SRS is bounded on its southwestern boundary by the Savannah River for about 32 km (20 mi), approximately 260 km (160 mi) upriver from the Atlantic Ocean. Five major streams at the SRS feed into the Savannah River: Upper Three Runs Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek. Other surface water bodies at the site which feed into the five streams include PAR Pond, L Lake, Tims Branch, Tinker Creek, and Meyers Branch (Arnett et al. 1993). In all but one of the environmental settings developed for the SRS (the P-R Area setting), surface and subsurface drainage from both upland and lowland areas flows into creeks flowing southward into the Savannah River.

25.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of the SRS for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 25.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 25.2.

For PEIS modeling purposes, SRS is characterized using five hydrogeologic environmental settings (Figure 25.1): A-M Area, P-R Area, GS-TNX-D Area, K-C Area and L Area. The five hydrogeological environmental settings have been identified based on the locations of potential release sites and on a number of distinctive transport characteristics associated with the installation's hydrologic systems. In four of the environmental settings,

two distinct physiographic subregions exist: the Pleistocene coastal terraces and the Aiken Plateau. A brief description of each environmental setting follows. Figure 25.2 presents stratigraphic columns for each of these settings. Surface water data are presented in Table 25.1. Hydrogeologic data for the various settings are presented in Tables 25.2-25.6.

25.4.1 A-M Area Setting

More than a fourth of the SRS falls within the A-M Area setting with the Pleistocene terraces occupying the southwestern quarter of the setting's area. Shallow groundwaters in this setting discharge to the Upper Three Runs and Tinker Creeks at springs and seeps along their margins.

The units of interest for the PEIS are limited to the saturated zone and uppermost aquifer. The thickness of the saturated zone averages 34 m (110 ft), with maximum thicknesses reaching more than 46 m (150 ft) at higher elevations. The upper aquifer averages 15 m (50 ft) in the A-M area, but may be as thick as 46 m (150 ft). A total porosity value of 40%, and an effective porosity of 25% were used for the A-M Area setting. The vertical hydraulic conductivity of the saturated zone is estimated at 1.0×10^{-4} cm/s (2.8×10^{-2} ft/day). Hydraulic gradient ranges from 0.016 to 0.002 are based on measurements from a 1993 water table map. The effective porosity value, hydraulic conductivity, and hydraulic gradient were used to calculate the groundwater flow velocity which ranged from 3.0×10^{-5} to 3.3×10^{-6} m/day (1.0×10^{-4} to 1.1×10^{-5} ft/day). The remaining values for the A-M Area setting are based on default values for the soil types.

25.4.2 GS-TNX-D, K-C, and L Area Settings

Setting descriptions for GS-TNX-D, K-C, and L Area settings are nearly identical to the A-M Area Setting with the exception of groundwater flow direction and discharge within each specific area. This setting description will focus on items unique to the individual areas as well as information pertaining to all three areas.

Pleistocene terraces occupy the southwestern third of the GS-TNX-D Area and the Aiken Plateau occupies the upland two thirds of this setting. Water in the shallow aquifer flows northward from all three operation units and discharges to Upper Three Runs Creek. There is also a component of southward flow to Fourmile Branch. Discharge is at springs and seeps along the creek margins.

In the K-C Area, Pleistocene terraces occupy the southwestern third of this setting while the Aiken Plateau occupies the upland two thirds of this setting. The shallow aquifer flows to the north, southwest, south, and east from the K and C operational Areas and discharges to Fourmile Branch along the northern boundary of this setting. The southward

flow from these three facilities is to the creek call Pen Branch, which flows into the Savannah River. Discharge is at springs and seeps along the creek margins.

Only a tenth of the SRS falls within the L Area setting. The Pleistocene terraces occupy the southwestern third of the L Area with the Aiken Plateau occupying the remaining two thirds. The shallow aquifer flows to the southwest, south, and east from the L Operational Area and discharges to P Branch, which forms the northern boundary of this setting. The southward flow from the facility is to Steel Creek, which flows into the Savannah River. Discharge is at springs and seeps along their margins.

The units of interest for the PEIS are limited to the saturated zone and uppermost aquifer. The saturated zone averages 15 m (50 ft) in thickness, but presumably reaches thicknesses greater than 30 m (100 ft) in areas of higher elevation. The upper aquifer averages about 15 m (50 ft) in the GS-TNX-D area. A total porosity value of 40% and an effective porosity of 25% were used for the environmental setting. The vertical hydraulic conductivity of the saturated zone was estimated at 1.0×10^{-4} cm/s (2.8×10^{-2} ft/day). The hydraulic gradient ranged from 0.06 to 0.002 based on measurements from a 1993 water table map. The effective porosity, hydraulic conductivity, and the hydraulic gradient were used to calculate the groundwater flow velocities which ranged from 1.2×10^{-4} to 3.1×10^{-6} m/day (4.0×10^{-4} to 1.0×10^{-5} ft/day). The remaining values are based on default values for the soil types.

25.4.3 P-R Area Setting

The P-R setting consists of both upland areas that recharge Par Pond and lowland areas in the southeastern portion of the installation. Nearly a third of the SRS falls within the P-R Area setting. The Pleistocene terraces occupy the southern half of the P-R Area and the Aiken Plateau occupies the remainder of the setting. The shallow aquifer and other deeper aquifers discharge primarily to Par Pond which drains into the Lower Three Runs Creek and Steel Creek at springs and seeps along their margins.

The units of interest for the PEIS are limited to the saturated zone and uppermost aquifer. The saturated zone averages 18 m (60 ft) in thickness, but may reach thicknesses greater than 30 m (100 ft) at higher elevations. The upper aquifer averages 15 m (50 ft) in the P-R area. A total porosity value of 40% and an effective porosity of 25% were used in the setting. The vertical hydraulic conductivity of the saturated zone is estimated at 1.0×10^{-4} cm/s (2.8×10^{-2} ft/day). The hydraulic gradient ranged from 0.03 to 0.002 based on measurements from a 1993 water table map. The effective porosity value, hydraulic conductivity, and the hydraulic gradient were used to calculate the groundwater flow velocities ranging from 6.1×10^{-5} to 3.4×10^{-4} m/day (2.0×10^{-4} to 1.1×10^{-5} ft/day). Soil texture classification for the partially-saturated and saturated zones is estimated as sand based on geologic descriptions for the Upper Pleistocene material as clayey sands with little silt. The remaining values for the P-R Area setting are based on default values for the soil type.

25.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for the SRS are based on publicly available documents written for DOE environmental programs. Site experts were contacted and participated in the development and review of environmental settings for this installation. Alan Weber supplied input into the development of the climate and atmospheric dispersion environmental settings. Individuals supplying input into the development of the hydrogeologic environmental settings include John Haselow and Brian Looney. Following completion of the environmental settings, Barry Shedrow coordinated the onsite review and fine tuning of the settings data. Settings were accepted by installation experts as appropriate for intended PEIS modeling purposes; however, more accurate and detailed characterizations are available for more computationally intensive studies.

25.6 REFERENCES

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U.S. Department of Commerce (DOC). 1987b. *Local Climatological Data Annual Summaries for 1986 Part II Southern Region*. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.

Figure 25.1. Location and Environmental Settings for the Savannah River Site (SRS). For PEIS modeling purposes, the SRS is divided into five environmental settings: A-M Area, P-R Area, GS-TNX-D Area, K-C Area, and L Area.

Figure 25.2. Stratigraphic Columns for Savannah River Site (SRS) Environmental Settings

EXHIBIT 25.1

Savannah River Site Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made onsite and at Bush Field Airport.

Station Name: Bush Field Airport, Augusta, Georgia
Savannah River Technology Center

Elevation: 44 m Latitude: 33.37°N
Elevation: 85 m Latitude: 33.28°N

Annual Mean Air Temp: 64.3 °F (Bush) Reference (A) Based on observations made from 1957-1986.
Anemometer Height: 61.0 m (SavR) Reference (B)
6.1 m (Bush) Reference (A)
Mean Annual Wind Speed: 8.5 mph (SavR) Reference (B)
6.5 mph (Bush) Reference (A) Based on 36 years of observations.
Fastest 1-Min Wind Speed: 62 mph (Bush) Reference (A) Based on 36 years of observations.
Annual Precipitation: 43.1 in. (Bush) Reference (A) Based on observations made from 1951-1980.
Precipitation Days: 107 yr⁻¹ (Bush) Reference (A) Based on 36 years of observations.
Thunderstorms/Freq: 54 yr⁻¹ (Bush) Reference (A) Based on 36 years of observations.

Avg Morning Mixing Ht: 375 m Reference (c)
Avg Afternoon Mixing Ht: 1450 m Reference (c)
Top Soil Moisture Capacity: 0.5 cm Reference (c)

MEPAS Parameters: Climatic Region Index: 7 Reference (c)
Precipitation-Evaporation Index: 92 Reference (c)
Soil Cons. Serv. Curve Number: 84 Reference (c)

MONTHLY AVERAGES							
	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
MONTH	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	45	4.1	9.0	6.2	10.2	81	49
Feb	49	4.5	9.6	5.9	9.0	80	43
Mar	56	4.9	9.7	6.0	10.2	83	38
Apr	65	3.5	9.4	5.4	8.0	87	36
May	72	4.1	8.2	5.8	9.3	92	39
Jun	78	4.4	8.0	5.8	9.4	95	41
Jul	81	5.2	7.6	6.2	11.4	97	45
Aug	80	4.9	7.0	5.8	10.2	98	46
Sep	75	3.7	7.7	5.7	7.4	96	45
Oct	66	3.0	8.7	4.7	5.8	92	41
Nov	56	2.6	8.8	5.2	7.0	89	42
Dec	49	3.6	8.8	5.9	9.2	85	49
Reference: ...	↓ (B)	↓ (B)	↓ (B)	↓ (A)	↓ (A)	↓ (B)	↓ (B)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part II Southern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, North Carolina.
- B: Unpublished technical data provided by correspondence with meteorologist Allen H. Weber (Savannah River Technology Center), March, 1993.
- C: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 25.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for the Savannah River Site. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made in the H-Area at 61 m (200 ft) above ground level. Data are based on measurements made from 1987 through 1991.

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, M/S					
		0 - 2	2 - 4	4 - 6	6 - 8	8 - 12	>12
A	NORTH	0.00374	0.00872	0.00573	0.00089	0.00005	0.00000
A	NORTH-NORTHEAST	0.00406	0.00735	0.00260	0.00052	0.00000	0.00000
A	NORTHEAST	0.00372	0.00876	0.00157	0.00007	0.00002	0.00000
A	EAST-NORTHEAST	0.00422	0.00995	0.00187	0.00011	0.00002	0.00000
A	EAST	0.00402	0.00942	0.00148	0.00007	0.00000	0.00000
A	EAST-SOUTHEAST	0.00374	0.00942	0.00073	0.00002	0.00000	0.00000
A	SOUTHEAST	0.00404	0.00648	0.00066	0.00005	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00356	0.00618	0.00094	0.00011	0.00000	0.00000
A	SOUTH	0.00358	0.00739	0.00139	0.00021	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00347	0.00721	0.00139	0.00018	0.00007	0.00000
A	SOUTHWEST	0.00450	0.0100	0.00208	0.00016	0.00009	0.00000
A	WEST-SOUTHWEST	0.00392	0.01282	0.00242	0.00037	0.00009	0.00000
A	WEST	0.00454	0.01294	0.00274	0.00032	0.00002	0.00000
A	WEST-NORTHWEST	0.00434	0.00942	0.00235	0.00021	0.00007	0.00000
A	NORTHWEST	0.00370	0.00534	0.00141	0.00014	0.00002	0.00000
A	NORTH-NORTHWEST	0.00413	0.00602	0.00240	0.00055	0.00009	0.00000
B	NORTH	0.00075	0.00267	0.00139	0.00007	0.00000	0.00000
B	NORTH-NORTHEAST	0.00078	0.00411	0.00388	0.00082	0.00007	0.00000
B	NORTHEAST	0.00087	0.00577	0.00377	0.00027	0.00002	0.00000
B	EAST-NORTHEAST	0.00098	0.00621	0.00313	0.00007	0.00000	0.00000
B	EAST	0.00052	0.00429	0.00164	0.00005	0.00000	0.00000
B	EAST-SOUTHEAST	0.00055	0.00342	0.00105	0.00011	0.00000	0.00000
B	SOUTHEAST	0.00057	0.00244	0.00071	0.00002	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00048	0.00217	0.00084	0.00009	0.00002	0.00000
B	SOUTH	0.00078	0.00324	0.00187	0.00050	0.00002	0.00000
B	SOUTH-SOUTHWEST	0.00071	0.00329	0.00212	0.00037	0.00002	0.00000
B	SOUTHWEST	0.00046	0.00477	0.00317	0.00052	0.00007	0.00000
B	WEST-SOUTHWEST	0.00050	0.00671	0.00507	0.00103	0.00007	0.00000
B	WEST	0.00046	0.00559	0.00511	0.00171	0.00064	0.00000
B	WEST-NORTHWEST	0.00075	0.00372	0.00356	0.00214	0.00064	0.00000
B	NORTHWEST	0.00052	0.00251	0.00126	0.00059	0.00007	0.00000
B	NORTH-NORTHWEST	0.00071	0.00210	0.00089	0.00014	0.00002	0.00000
C	NORTH	0.00032	0.00173	0.00116	0.00014	0.00002	0.00000
C	NORTH-NORTHEAST	0.00057	0.00573	0.00539	0.00098	0.00011	0.00000
C	NORTHEAST	0.00091	0.01125	0.01303	0.00196	0.00000	0.00000
C	EAST-NORTHEAST	0.00071	0.01031	0.00742	0.00082	0.00002	0.00000
C	EAST	0.00059	0.00600	0.00354	0.00018	0.00002	0.00000
C	EAST-SOUTHEAST	0.00046	0.00408	0.00192	0.00032	0.00005	0.00000
C	SOUTHEAST	0.00055	0.00411	0.00217	0.00032	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00048	0.00370	0.00253	0.00059	0.00027	0.00000
C	SOUTH	0.00068	0.00479	0.00470	0.00155	0.00043	0.00000
C	SOUTH-SOUTHWEST	0.00048	0.00516	0.00461	0.00164	0.00041	0.00000
C	SOUTHWEST	0.00055	0.00589	0.00561	0.00208	0.00046	0.00000
C	WEST-SOUTHWEST	0.00050	0.00794	0.00687	0.00258	0.00059	0.00002
C	WEST	0.00075	0.00527	0.00643	0.00445	0.00155	0.00000
C	WEST-NORTHWEST	0.00046	0.00445	0.00564	0.00429	0.00167	0.00002
C	NORTHWEST	0.00050	0.00301	0.00212	0.00096	0.00018	0.00000
C	NORTH-NORTHWEST	0.00052	0.00237	0.00119	0.00018	0.00007	0.00000
D	NORTH	0.00018	0.00103	0.00123	0.00011	0.00000	0.00000
D	NORTH-NORTHEAST	0.00048	0.00436	0.00434	0.00052	0.00023	0.00000
D	NORTHEAST	0.00055	0.01072	0.00853	0.00098	0.00023	0.00000
D	EAST-NORTHEAST	0.00037	0.00888	0.00584	0.00023	0.00000	0.00000
D	EAST	0.00055	0.00552	0.00395	0.00005	0.00002	0.00000
D	EAST-SOUTHEAST	0.00030	0.00504	0.00440	0.00011	0.00000	0.00000

EXHIBIT 25.2

STAB. CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS, M/S					
		0 - 2	2 - 4	4 - 6	6 - 8	8 - 12	>12
D	SOUTHEAST	0.00055	0.00705	0.00653	0.00046	0.00000	0.00000
D	SOUTH-SOUTHEAST	0.00068	0.00691	0.01164	0.00180	0.00007	0.00000
D	SOUTH	0.00055	0.00924	0.01451	0.00219	0.00016	0.00000
D	SOUTH-SOUTHWEST	0.00032	0.00910	0.00778	0.00146	0.00037	0.00000
D	SOUTHWEST	0.00071	0.00803	0.00901	0.00098	0.00002	0.00000
D	WEST-SOUTHWEST	0.00048	0.00808	0.00769	0.00087	0.00002	0.00000
D	WEST	0.00037	0.00723	0.00776	0.00030	0.00007	0.00000
D	WEST-NORTHWEST	0.00034	0.00570	0.00648	0.00052	0.00002	0.00000
D	NORTHWEST	0.00050	0.00427	0.00317	0.00030	0.00000	0.00000
D	NORTH-NORTHWEST	0.00041	0.00272	0.00089	0.00002	0.00000	0.00000
E	NORTH	0.00011	0.00062	0.00071	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00021	0.00274	0.00527	0.00050	0.00002	0.00000
E	NORTHEAST	0.00039	0.00687	0.00689	0.00032	0.00002	0.00000
E	EAST-NORTHEAST	0.00007	0.00477	0.00705	0.00037	0.00000	0.00000
E	EAST	0.00009	0.00297	0.00600	0.00011	0.00000	0.00000
E	EAST-SOUTHEAST	0.00025	0.00333	0.00454	0.00011	0.00000	0.00000
E	SOUTHEAST	0.00030	0.00456	0.00650	0.00002	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00030	0.00701	0.01006	0.00027	0.00000	0.00000
E	SOUTH	0.00016	0.00673	0.01184	0.00043	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00016	0.00573	0.00940	0.00018	0.00000	0.00000
E	SOUTHWEST	0.00011	0.00543	0.00910	0.00043	0.00000	0.00000
E	WEST-SOUTHWEST	0.00011	0.00472	0.00894	0.00009	0.00000	0.00000
E	WEST	0.00021	0.00431	0.00484	0.00005	0.00000	0.00000
E	WEST-NORTHWEST	0.00014	0.00427	0.00402	0.00002	0.00000	0.00000
E	NORTHWEST	0.00023	0.00333	0.00187	0.00002	0.00000	0.00000
E	NORTH-NORTHWEST	0.00021	0.00301	0.00141	0.00000	0.00000	0.00000
F	NORTH	0.00000	0.00018	0.00014	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00005	0.00052	0.00256	0.00027	0.00000	0.00000
F	NORTHEAST	0.00007	0.00087	0.00212	0.00021	0.00000	0.00000
F	EAST-NORTHEAST	0.00011	0.00039	0.00144	0.00021	0.00000	0.00000
F	EAST	0.00007	0.00023	0.00144	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00005	0.00075	0.00187	0.00011	0.00000	0.00000
F	SOUTHEAST	0.00002	0.00089	0.00132	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00005	0.00091	0.00162	0.00007	0.00000	0.00000
F	SOUTH	0.00007	0.00107	0.00221	0.00018	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00014	0.00080	0.00214	0.00014	0.00000	0.00000
F	SOUTHWEST	0.00018	0.00119	0.00235	0.00018	0.00000	0.00000
F	WEST-SOUTHWEST	0.00007	0.00091	0.00228	0.00007	0.00000	0.00000
F	WEST	0.00007	0.00030	0.00068	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00005	0.00050	0.00039	0.00000	0.00000	0.00000
F	NORTHWEST	0.00011	0.00050	0.00023	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00005	0.00073	0.00041	0.00000	0.00000	0.00000
G	NORTH	0.00000	0.00002	0.00005	0.00000	0.00000	0.00000
G	NORTH-NORTHEAST	0.00000	0.00000	0.00023	0.00002	0.00000	0.00000
G	NORTHEAST	0.00002	0.00000	0.00009	0.00000	0.00000	0.00000
G	EAST-NORTHEAST	0.00000	0.00000	0.00002	0.00000	0.00000	0.00000
G	EAST	0.00000	0.00000	0.00007	0.00000	0.00000	0.00000
G	EAST-SOUTHEAST	0.00002	0.00002	0.00037	0.00002	0.00000	0.00000
G	SOUTHEAST	0.00000	0.00009	0.00025	0.00002	0.00000	0.00000
G	SOUTH-SOUTHEAST	0.00005	0.00002	0.00016	0.00000	0.00000	0.00000
G	SOUTH	0.00007	0.00007	0.00021	0.00000	0.00000	0.00000
G	SOUTH-SOUTHWEST	0.00009	0.00007	0.00014	0.00002	0.00000	0.00000
G	SOUTHWEST	0.00007	0.00027	0.00011	0.00000	0.00000	0.00000
G	WEST-SOUTHWEST	0.00002	0.00009	0.00027	0.00000	0.00000	0.00000
G	WEST	0.00002	0.00005	0.00002	0.00000	0.00000	0.00000
G	WEST-NORTHWEST	0.00000	0.00002	0.00007	0.00000	0.00000	0.00000
G	NORTHWEST	0.00000	0.00002	0.00002	0.00000	0.00000	0.00000
G	NORTH-NORTHWEST	0.00002	0.00000	0.00005	0.00000	0.00000	0.00000

Table 25.1. Surface Water Environmental Safety Data for the Savannah River Site, Aiken, South Carolina

<u>Parameter</u>	<u>Units</u>	<u>Upper 3 Runs Creek</u>	<u>Fourmile Branch</u>	<u>Pens Branch</u>
Velocity	m/s	0.27	0.09	1.24
Depth	m	1.35	1.47	0.9
Width	m	18.3	5.88	7.62
Discharge	cms	6.8	5.88	7.71

<u>Parameter</u>	<u>Units</u>	<u>Steel Creek</u>	<u>Lower 3 Runs Creek</u>	<u>Savannah River</u>
Velocity	m/s	0.304	0.304	0.86
Depth	m	3.05	1.52	3.05
Width	m	5.49	5.18	100.6
Discharge	cms	5.2	2.4	265.1

Table 25.2. Hydrogeologic Environmental Setting Data for Savannah River Site's A-M Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

<u>Parameter</u>	<u>Units</u>	<u>PZ</u>	<u>SZ</u>
Darcian_velocity	m/yr	0.22	--
SOILC		4.38	--
Thickness	m	33.5	15.2
Bulk_density	g/cm3	1.6	2
Total_porosity	%	40	40
Field_capacity	%	10	--
Conductivity	m/day	0.09	--
Longitudinal_disp.	m	0.03	0.03
Transverse_disp.	m	--	0.003
Vertical_disp.	m	--	0.003
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.10
Distance	m	--	0.30
Textural_class		sandy clay	sand
%_sand	%	80	80
%_silt	%	10	10
%_clay	%	10	10
%_OMC	%	0.0001	0.0001
%_Fe	%	1.3	1.3
pH		5	5

Table 25.3. Hydrogeologic Environmental Setting Data for Savannah River Site's GS-TNX-D Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.22	--
SOILC		4.38	--
Thickness	m	15.24	15.24
Bulk_density	g/cm3	1.6	2
Total_porosity	%	40	40
Field_capacity	%	10	--
Conductivity	m/day	0.09	--
Longitudinal_disp.	m	0.03	0.03
Transverse_disp.	m	--	0.003
Vertical_disp.	m	--	0.003
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.10
Distance	m	--	0.30
Textural_class		sandy	sandy
		clay	clay
%_sand	%	80	80
%_silt	%	10	10
%_clay	%	10	10
%_OMC	%	0.0001	0.0001
%_Fe	%	1.3	1.3
pH		5	5

Table 25.4. Hydrogeologic Environmental Setting Data for Savannah River Site's K-C Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.22	--
SOILC		4.38	--
Thickness	m	15.2	15.2
Bulk_density	g/cm3	1.6	2
Total_porosity	%	40	40
Field_capacity	%	10	--
Conductivity	m/day	0.09	--
Longitudinal_disp.	m	0.03	0.03
Transverse_disp.	m	--	0.003
Vertical_disp.	m	--	0.003
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.101
Distance	m	--	0.30
Textural_class		sandy	sandy
		clay	clay
%_sand	%	80	80
%_silt	%	10	10
%_clay	%	10	10
%_OMC	%	0.0001	0.0001
%_Fe	%	1.3	1.3
pH		5	5

Table 25.5. Hydrogeologic Environmental Setting Data for Savannah River Site's L Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.22	--
SOILC		4.38	--
Thickness	m	15.2	15.2
Bulk_density	g/cm3	1.6	2
Total_porosity	%	40	40
Field_capacity	%	10	--
Conductivity	m/day	0.09	--
Longitudinal_disp.	m	0.03	0.03
Transverse_disp.	m	--	0.003
Vertical_disp.	m	--	0.003
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.101
Distance	m	--	0.30
Textural_class		sandy	sandy
		clay	clay
%_sand	%	80	80
%_silt	%	10	10
%_clay	%	10	10
%_OMC	%	0.0001	0.0001
%_Fe	%	1.3	1.3
pH		5	5

Table 25.6. Hydrogeologic Environmental Setting Data for Savannah River Site's P-R Base Flow Zone. Parameters are characterized for the setting's partially-saturated zone (PZ) and saturated zone (SZ).

Parameter	Units	PZ	SZ
Darcian_velocity	m/yr	0.22	--
SOILC		4.38	--
Thickness	m	18.3	15.2
Bulk_density	g/cm3	1.6	2
Total_porosity	%	40	40
Field_capacity	%	10	--
Conductivity	m/day	0.09	--
Longitudinal_disp.	m	0.03	0.03
Transverse_disp.	m	--	0.003
Vertical_disp.	m	--	0.003
Effective_porosity	%	--	25.0
Velocity	m/day	--	0.101
Distance	m	--	0.30
Textural_class		sandy clay	sandy clay
%_sand	%	80	80
%_silt	%	10	10
%_clay	%	10	10
%_OMC	%	0.0001	0.0001
%_Fe	%	1.3	1.3
pH		5	5

26.0 TONAWANDA SITE

From 1942 to 1946, portions of the Linde Center property and buildings in the Town of Tonawanda, Erie County, New York, were used for separation of uranium ores. These processing activities, conducted under contract with the Manhattan Engineering District, resulted in radioactive contamination of portions of the property and buildings. Subsequent disposal and relocation of processing wastes from the Linde property resulted in radioactive contamination of three nearby properties in the Town of Tonawanda: Ashland 1, Ashland 2, and the Seaway Industrial Park. Together these properties cover a total of 143 ha (354 acres) and are referred to as the Tonawanda Site (Figure 26.1) (Bechtel 1993). The DOE is currently conducting a cleanup of the Tonawanda site under the Formerly Utilized Sites Remedial Action Program (FUSRAP).

The Town of Tonawanda is located immediately north of Buffalo, New York, and is bounded on the west by the Niagara River, which flows northwest toward Lake Ontario. Lake Erie is less than 16 km (10 mi) to the southwest, and Lake Ontario is 34 km (21 mi) to the north (DOE 1993d). Ecologically, Tonawanda lies within the Beech-Maple Forest section of the Eastern Deciduous Forest division. The predominant forest cover type in the Tonawanda area is elm-ash-cottonwood (locally exhibited as ash-elm-maple) surrounded by a maple-beech-birch cover type (DOE 1993d).

26.1 CLIMATE

Tonawanda is located near the boundary between a "humid continental warm summer" and a "humid continental cool summer" climate (Critchfield 1974). Meteorological data are available from measurements at the Greater Buffalo International Airport, located about 16 km (10 mi) west-southwest of Tonawanda. On average, the maximum daily temperature exceeds 32°C (90°F) on 2 days per year and is below 0°C (32°F) on 57 days per year; the minimum daily temperature is below 0°C (32°F) on 134 days per year and is below -18°C (0°F) on 5 days per year (DOC 1987a). July is the warmest month, with daily maximum and minimum temperatures averaging 27°C (80°F) and 16°C (68°F), respectively. January is the coolest month, with daily maximum and minimum temperatures averaging -1°C (30°F) and -8°C (17°F), respectively (DOC 1987a).

Annual precipitation is on the order of 96 cm (38 in.). Measurable precipitation (defined as 0.025 cm [0.01 in.] or greater) is recorded on an average of 169 days per year and the area experiences an average of 31 thunderstorm days per year. The average annual snowfall is 230 cm (90 in.) (DOC 1992a) and daily snowfall accumulations of 2.5 cm (1 in.) or greater occur an average of 27 days per year (DOC 1987a).

Winds at the installation will be affected by its urban setting. The prevailing wind direction at Buffalo Airport is from the southwest (DOC 1987a). Wind speeds at the airport average about 5.4 m/s (12 mph) at about 10 m (33 ft) above ground level (DOC 1987a). Average wind speeds are highest in January (6.4 m/s [14 mph]) and lowest in August (4.5 m/s [10 mph]) (DOC 1987a).

26.2 GEOLOGY

The Tonawanda site is located within the Erie-Ontario Lowland Physiographic Unit of New York. The Erie-Ontario Lowland has significant relief characterized by two major escarpments, the Niagara and the Onondaga. The Niagara escarpment separates the Erie-Ontario Lowland into two segments, a northern, topographically lower segment and a southern, topographically higher segment. The Onondaga escarpment is a north-facing, east-northeast trending rise that extends parallel to and immediately north of the Allegheny plateau. The Tonawanda site is located between the Niagara and Onondaga escarpments with ground surface elevations ranging from 180 m (590 ft) above mean sea level at the Ashland properties and 183 m (600 ft) at the Linde property (DOE 1993d).

The bedrock underlying the Tonawanda properties belongs to the upper Salina Group and consists of shale, dolomite with layers of gypsum, and occasionally halite of the Akron, Bertie, Camillus, Syracuse, and Vernon Formations. Locally, the carbonate portions of these formations are a massive, fine-grained limy shale with solution channelling through vertical joints and horizontal bedding planes. Massive gypsum layers (up to 1.5 m [5 ft] thick) are interbedded within the shales and dolomite (DOE 1993d). Shales of the Salina Group occur at depths of 17 to 29 m (55 to 95 ft) and constitute an irregular floor for the overlying glacial deposits. The upper portion of the bedrock is slightly to moderately fractured and exhibits some weathering. Core samples retrieved from greater than 3 m (10 ft) below the bedrock surface are only slightly fractured and exhibit less weathering (DOE 1993d).

Surficial deposits in the Tonawanda area were primarily derived from late Wisconsin glaciation. Glaciers advancing and retreating through this region deposited till and coarse-grained glacial outwash/ice-contact deposits. Relatively thick deposits of silt and clay were deposited in glacial lakes (DOE 1993d).

The uppermost deposits are a glacial till composed of a massive silty clay with various amounts of embedded sand and gravel (Bechtel 1993). The till is compact with desiccation cracks extending to a depth of 4.5 m (15 ft) below ground surface (DOE 1993d). The fine-grained nature of the material and lack of structure does not readily allow fluids to be transmitted except through areas where fractures occur. A zone of varved lacustrine clays and silts occur beneath the uppermost till (Bechtel 1993; DOE 1993d). Immediately below are sediments resulting from a variety of glacial depositional processes. Sediments include homogeneous, massive silty clays, massive to bedded sandy silts and clays, and silty/clayey

sands. Some of the silty and clayey sands in this interval are likely to be of glaciofluvial origin. The coarse grained basal zone is generally thick and well sorted in paleovalleys and channels, thinning over bedrock knolls and ridges. Composition of the basal zone ranges from clean sand and gravelly sand in the bedrock lows to clay and other fine-grained sediments over bedrock highs (Bechtel 1993).

26.3 HYDROLOGY

Groundwater at the Tonawanda site has been observed in three distinct hydrogeologic systems: a perched system, a shallow semi-confined system, and a contact-zone aquifer which occurs within unconsolidated basal zone sediments and weathered bedrock (DOE 1993d). The perched system occurs in fill material, alluvial fill in surface water drainage depressions, and the upper portion of the till where desiccation cracks are present (DOE 1993d; Bechtel 1993). The perched zone is conceptualized as a short flowpath system, representing subsurface movement of water from precipitation events to local drainages (Bechtel 1993). Due to the shallow position of this perched zone, transpiration can have a significant impact on the amount of groundwater in this system (DOE 1993d).

The shallow semi-confined system occurs in sand lenses surrounded by material of lower hydraulic conductivity approximately 5 to 12 m (16 to 40 ft) below ground surface in the glaciolacustrine deposits (Bechtel 1993; DOE 1993d). Groundwater in the shallow system may be conceptualized as flowing through a series of hydraulically interconnected sand lenses, with recharge to and discharge from the system through the uppermost sand lenses. The surrounding material of lower hydraulic conductivity decreases the shallow system's response to recharge from the perched aquifer system (DOE 1993d). The system discharges to Rattlesnake Creek downstream of the Site (Bechtel 1993).

Groundwater in the contact-zone aquifer occurs under confined conditions within the coarse-grained basal material and the fractured, weathered upper portion of the Salina Group bedrock (Bechtel 1993; DOE 1993d). Recharge to the contact-zone aquifer probably occurs at several locations, including carbonate rocks southeast of the Linde property and coarse-grained alluvial deposits east of Linde. Regional groundwater flow patterns suggest that the discharge area for the contact-zone aquifer is the Niagara River, north-northwest of the site (DOE 1993d). At the Linde site, contaminated effluent was injected directly into the contact-zone aquifer (Bechtel 1993).

The Tonawanda Channel of the Niagara River is the major surface water feature near the Tonawanda site, receiving site drainage from Rattlesnake and Twomile Creeks. The Tonawanda Channel is approximately 500 m (1,600 ft) wide and 8 m (26 ft) deep where it passes by the Town of Tonawanda. The average flow of the Niagara River is 6,200 m³/s (220,000 ft³/s), with an estimated 42% of the flow through the Tonawanda Channel; the remaining 58% flows through the Chippawa Channel during normal flow conditions (Bechtel

1993). Rattlesnake Creek is a natural channel formed from surface drainage received from Ashland 1, Ashland 2, and Seaway. The channel is approximately 3 m (10 ft) wide and 1 m (3 ft) deep at bank-full capacity. Rattlesnake Creek is 2,300 m (7,600 ft) in length and drains a total of 138 ha (340 acres) before joining Twomile Creek. Twomile Creek originates south of the Linde site and flows roughly north approximately 3 km (2 mi) before emptying into the Tonawanda Channel of the Niagara River (DOE 1993d). Twomile Creek drains an area of approximately 1,550 ha (3,830 acres) (Bechtel 1993).

26.4 ENVIRONMENTAL SETTINGS

One meteorological exhibit and one joint frequency distribution exhibit are sufficient to address the climate and atmospheric dispersion characteristics of Tonawanda for PEIS modeling purposes. Meteorological data for the installation are presented in Exhibit 26.1. Atmospheric dispersion data in the form of a joint frequency distribution of wind direction, wind speed, and atmospheric stability are presented in Exhibit 26.2.

For PEIS modeling purposes, Tonawanda is characterized using four hydrogeologic environmental settings (Figure 26.1): Stormflow Aquifer, Shallow Aquifer, Linde Deep Aquifer, and Ashland Deep Aquifer. Figure 26.2 presents stratigraphic columns for each of these settings. A brief description of the hydrogeology of each environmental setting follows. Surface water data are presented in Table 26.1. Hydrogeologic data for the various settings are presented in Tables 26.2-26.6.

26.4.1 Stormflow Setting

For the purpose of the PEIS, the perched system is considered a stormflow zone in which water migrates laterally and is discharged to surface waters throughout the site. Thickness of the stormflow zone is based on an average depth to groundwater of approximately 2 m (7 ft) (Bechtel 1993) and a saturated zone with an average thickness of 0.6 m (2 ft) (Bechtel 1993). Partially-saturated zone 1 (PZ1) is composed of fill material which is present on all properties and ranges in thickness from 0.3 to 1.2 m (1 to 4 ft), with an average thickness of 0.75 m (2.5 ft). Geologic drill logs indicate that the composition of the fill material ranges from a well sorted gravel-sand mixture with a sandy clay loam binder to a clay fill (Bechtel 1993). Based on the variety of compositions, the soil classification chosen to represent the fill is a sandy clay loam. The remaining values for PZ1 are based on default values for this soil type.

A sandy clay soil classification was chosen for the uppermost till of partially-saturated zone 2 (PZ2) and the saturated zone (SZ) based on descriptions of the till as sandy and gravelly clay. Average total porosity values for the till, varved lacustrine clay, and glaciolacustrine deposits are listed as 37% with an estimated effective porosity of 8%. The average hydraulic conductivity listed for the uppermost fractured portion of the till is

1×10^{-3} cm/s, or 86.4 cm/day. Groundwater velocity for the saturated zone is based on the previously mentioned values for hydraulic conductivity and effective porosity, and an average hydraulic gradient of 0.0003 (Bechtel 1993). The hydraulic gradient value is defined for the contact-zone aquifer (deep setting) and assumed to be representative of the stormflow and shallow aquifer settings. Based on distances to surface water discharge points defined for the Linde, Seaway, and Ashland properties, the saturated portion of the stormflow setting is divided into two areas: Seaway/Ashland 2 and Linde/Ashland 1. Average discharge distances defined for Seaway/Ashland 2 are 155 m (500 ft) and 31 m (100 ft) for Linde/Ashland 1 (Bechtel 1993). Default values for longitudinal dispersivity, transverse dispersivity, and vertical dispersivity were calculated based on the average discharge distances listed for the various properties. Parameter values remaining for PZ2 and the SZ are based on standard default values for their soil types.

26.4.2 Shallow Aquifer Setting

The semiconfined shallow system occurs principally in sand lenses 5 to 12 m (16 to 39 ft) below ground surface under the Ashland properties (Bechtel 1993). Due to the lack of a well-defined groundwater table at Linde, the shallow aquifer setting applies only to the Seaway and Ashland properties (Bechtel 1993). Within the shallow aquifer setting, there are four partially-saturated zones. Zones PZ1 through PZ3 are of the same thickness and description as the partially-saturated zones in the stormflow setting. In the PZ3 zone, the field capacity is set equal to the total porosity to represent saturation. The PZ4 zone is composed of the uppermost glacial till described in PZ2 and PZ3. The thickness of the PZ4 zone is 2.5 m (8 ft) based on the depth of the saturated zone below ground surface. Hydraulic conductivity for the till in the PZ4 zone is 1×10^{-6} cm/s (3.38×10^{-8} ft/s) or 8.64×10^{-2} cm/day (2.83×10^{-3} ft/day), three orders of magnitude less than the value for the overlying uppermost portion of the glacial till. The higher conductivity values for the uppermost glacial material is attributed to jointing and fracturing (Bechtel 1993). Total porosity and field capacity for the PZ4 zone are the same as values defined for the PZ2 and PZ3 zones. Values for the saturated zone are identical to those of the Ashland 2/Seaway Stormflow setting with the exception of thickness. As previously mentioned, the shallow aquifer occurs between 5 and 12 m (16 to 39 ft) below ground surface, giving the saturated zone a thickness of 7 m (23 ft). Default values for longitudinal dispersivity, transverse dispersivity, and vertical dispersivity were calculated based on the 155 m (510 ft) discharge distance average from the Ashland 2 watershed divide to Rattlesnake Creek (Bechtel 1993). Remaining parameter values are based on standard default values for the soil type.

26.4.3 Deep Aquifer Settings

The contact-zone aquifer consists of the coarser-grained basal zone and the fractured, weathered portion of the shale bedrock. Width of the saturated portion of the deep aquifer ranges from 3 to 4.5 m (10 to 15 ft), with an average thickness of 4 m (12 ft) (Bechtel 1993). The aquifer is confined with an average hydraulic gradient of 0.0003 (Bechtel 1993). Within the deep aquifer setting, there are two subsettings: the setting at Seaway and the Ashland properties and the setting at Linde. As previously mentioned, Linde lacks a well-defined shallow aquifer system. This creates a deep setting at Linde with unsaturated glacial sediments extending from the stormflow zone down to the contact-zone aquifer.

The deep aquifer setting at Seaway and the Ashland properties consists of six partially-saturated zones and a single saturated zone. Zones PZ1 through PZ5 correspond to the zones described in the shallow aquifer setting. In the PZ5 zone, field capacity is set equal to total porosity to represent saturation. The PZ6 zone has the same characteristics as the till material in the PZ5 zone, but lacks saturation. Thickness of the PZ6 zone is based on the average thickness of the various glacial units overlying bedrock minus the total thickness of zones PZ1 through PZ5. The underlying coarse-grained basal material is not included in average thickness estimates as it is included in the saturated portion of the deep aquifer setting. A clay loam soil classification was chosen for the Ashland/Seaway saturated zone based on a mean hydraulic conductivity of 22.5 cm/day (0.74 ft/day). The effective porosity value for the bedrock ranges from 0.1 to 0.01%. A value of 0.1% was selected for groundwater velocity calculations performed for the Tonawanda site due to the highly fractured nature of the upper portion of the bedrock. The average linear groundwater velocity in the upper bedrock at Ashland/Seaway is estimated to be 25 m/yr (82 ft/yr). Groundwater velocity for the saturated zone is based on the previously mentioned values for hydraulic conductivity and effective porosity, and an average hydraulic gradient of 0.0003 (Bechtel 1993). Discharge area for the contact-zone aquifer is presumed to be the Niagara River, north-northwest of the site (DOE 1993d). Default values for longitudinal dispersivity, transverse dispersivity, and vertical dispersivity were calculated based on a distance estimate measured from the center of Seaway north-northwest to Niagara River (see Figure 3.1 of Bechtel 1993). Remaining parameters are based on standard default values for the soil type.

The Linde deep aquifer setting consists of four partially-saturated zones and a saturated zone. Zones PZ1 through PZ3 are identical to the zones described in the stormflow setting. In the PZ3 zone, field capacity is set equal to total porosity to represent saturation. The PZ4 zone is identical to the glacial till in the PZ2 and PZ3 zones with the exception of hydraulic conductivity. As in the shallow aquifer setting, the till in the PZ4 zone has a hydraulic conductivity three orders of magnitude less than the overlying uppermost portion of the glacial till due to jointing and fracturing. Total porosity and field capacity for the PZ4 zone are the same as values defined for the PZ2 and PZ3 zones. The saturated interval of the Linde deep aquifer setting is classified as a sandy clay based on a mean hydraulic conductivity of 6.74 cm/day (0.22 ft/day). Average linear groundwater velocity in the

saturated zone is estimated at 7 m/yr (23 ft/yr) (Bechtel 1993). Default values for longitudinal dispersivity, transverse dispersivity, and vertical dispersivity were calculated based on a distance estimate measured from the center of Linde north-northwest to Niagara River (see Figure 3.1 of Bechtel 1993). Remaining parameters are standard default values for the soil type.

26.5 INSTALLATION PARTICIPATION IN THE DEVELOPMENT OF ENVIRONMENTAL SETTINGS

The climatic and hydrogeologic descriptions for Tonawanda are based on publicly available documents written for DOE environmental programs. Ron Kirk of DOE supplied the documents used to develop the Tonawanda environmental settings.

26.6 REFERENCES

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Figure 26.1. Location and Environmental Settings for the Tonawanda Site, one of DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP) Sites. For PEIS modeling purposes, the Tonawanda Site is characterized by a single environmental setting.

Figure 26.2. Stratigraphic Columns for Tonawanda Environmental Settings

EXHIBIT 26.1

Tonawanda Average Local Climatology. Meteorological parameters are presented using the units with which they are routinely measured (e.g., temperature: °F, wind speed: mph). Data are from measurements made at the Greater Buffalo International Airport, Buffalo, New York.

Station Name: Greater Buffalo International Airport, Buffalo, New York Elevation: 215 m Latitude: 42.93°N

Annual Mean Air Temp: 47.6 °F Reference (A) Based on observations made from 1951-1980.
 Anemometer Height: 10.0 m Reference (A)
 Mean Annual Wind Speed: 12 mph Reference (A) Based on 47 years of observations.
 Fastest Mile: 91 mph Reference (A) Based on 40 years of observations.
 Annual Precipitation: 37.5 in. Reference (A) Based on observations made from 1951-1980.
 Precipitation Days: 169 yr⁻¹ Reference (A) Based on 43 years of observations.
 Thunderstorms Freq: 31 yr⁻¹ Reference (A) Based on 43 years of observations.

Avg Morning Mixing Ht: 600 m Reference (B)
 Avg Afternoon Mixing Ht: 1300 m Reference (B)
 Top Soil Moisture Capacity: 0.35 cm Reference (B)

MEPAS Parameters: Climatic Region Index: 4 Reference (B)
 Precipitation-Evaporation Index: 110 Reference (B)
 Soil Cons. Serv. Curve Number: 76 Reference (B)

MONTHLY AVERAGES							
	TEMP.	PRECIP.	WIND	CLOUD	PRECIP.	DAILY RH	
MONTH	(°F)	(Inches)	SPEED (MPH)	COVER (10ths)	DAYS (#)	MAX (%)	MIN (%)
Jan	24	3.0	14.3	8.4	20.2	79	73
Feb	25	2.4	13.7	8.2	17.0	80	71
Mar	33	3.0	13.5	7.6	16.2	80	66
Apr	45	3.1	12.8	7.1	14.3	76	58
May	56	2.9	11.5	6.8	12.4	75	56
Jun	66	2.7	11.0	6.2	10.4	77	57
Jul	71	3.0	10.4	6.0	9.9	78	55
Aug	69	4.2	9.8	6.2	10.6	83	58
Sep	62	3.4	10.4	6.4	10.9	84	60
Oct	52	2.9	11.1	6.7	11.4	82	61
Nov	40	3.6	12.7	8.3	16.0	81	70
Dec	29	3.4	13.4	8.6	19.7	81	74
Reference: ...	(A)	(A)	(A)	(A)	(A)	(A)	(A)

References

- A: U.S. Department of Commerce. 1987. Local Climatological Data Annual Summaries for 1986 Part I Eastern Region. National Oceanic and Atmospheric Administration, National Climatic Data Center, Ashville, North Carolina.
- B: Droppo, J.G., Jr., D.L. Strenge, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter, and G. Whelan. 1989. Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance. Volume 2 - Guidelines for Evaluating MEPAS Input Parameters. PNL-7216, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 26.2

Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed for Tonawanda. Atmospheric stability is determined using the Pasquill-Gifford method. Wind measurements were made at the Buffalo International Airport at 10 m (33 ft) above ground level. Data are based on measurements made from 1967 through 1971.

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
A	NORTH	0.00040	0.00021	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHEAST	0.00004	0.00014	0.00000	0.00000	0.00000	0.00000
A	NORTHEAST	0.00004	0.00014	0.00000	0.00000	0.00000	0.00000
A	EAST-NORTHEAST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
A	EAST	0.00010	0.00007	0.00000	0.00000	0.00000	0.00000
A	EAST-SOUTHEAST	0.00005	0.00021	0.00000	0.00000	0.00000	0.00000
A	SOUTHEAST	0.00002	0.00007	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHEAST	0.00004	0.00014	0.00000	0.00000	0.00000	0.00000
A	SOUTH	0.00004	0.00014	0.00000	0.00000	0.00000	0.00000
A	SOUTH-SOUTHWEST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
A	SOUTHWEST	0.00005	0.00021	0.00000	0.00000	0.00000	0.00000
A	WEST-SOUTHWEST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
A	WEST	0.00009	0.00000	0.00000	0.00000	0.00000	0.00000
A	WEST-NORTHWEST	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
A	NORTHWEST	0.00012	0.00014	0.00000	0.00000	0.00000	0.00000
A	NORTH-NORTHWEST	0.00012	0.00014	0.00000	0.00000	0.00000	0.00000
B	NORTH	0.00075	0.00096	0.00055	0.00000	0.00000	0.00000
B	NORTH-NORTHEAST	0.00025	0.00096	0.00041	0.00000	0.00000	0.00000
B	NORTHEAST	0.00039	0.00082	0.00069	0.00000	0.00000	0.00000
B	EAST-NORTHEAST	0.00046	0.00075	0.00014	0.00000	0.00000	0.00000
B	EAST	0.00061	0.00096	0.00041	0.00000	0.00000	0.00000
B	EAST-SOUTHEAST	0.00052	0.00055	0.00034	0.00000	0.00000	0.00000
B	SOUTHEAST	0.00044	0.00027	0.00027	0.00000	0.00000	0.00000
B	SOUTH-SOUTHEAST	0.00024	0.00055	0.00021	0.00000	0.00000	0.00000
B	SOUTH	0.00088	0.00048	0.00021	0.00000	0.00000	0.00000
B	SOUTH-SOUTHWEST	0.00083	0.00103	0.00062	0.00000	0.00000	0.00000
B	SOUTHWEST	0.00068	0.00082	0.00082	0.00000	0.00000	0.00000
B	WEST-SOUTHWEST	0.00050	0.00178	0.00137	0.00000	0.00000	0.00000
B	WEST	0.00024	0.00069	0.00144	0.00000	0.00000	0.00000
B	WEST-NORTHWEST	0.00026	0.00110	0.00055	0.00000	0.00000	0.00000
B	NORTHWEST	0.00052	0.00055	0.00007	0.00000	0.00000	0.00000
B	NORTH-NORTHWEST	0.00016	0.00041	0.00027	0.00000	0.00000	0.00000
C	NORTH	0.00033	0.00110	0.00212	0.00069	0.00000	0.00000
C	NORTH-NORTHEAST	0.00016	0.00034	0.00151	0.00014	0.00000	0.00000
C	NORTHEAST	0.00026	0.00137	0.00226	0.00034	0.00000	0.00000
C	EAST-NORTHEAST	0.00019	0.00123	0.00192	0.00034	0.00014	0.00000
C	EAST	0.00011	0.00116	0.00206	0.00027	0.00000	0.00000
C	EAST-SOUTHEAST	0.00017	0.00082	0.00164	0.00027	0.00000	0.00000
C	SOUTHEAST	0.00009	0.00048	0.00144	0.00021	0.00000	0.00000
C	SOUTH-SOUTHEAST	0.00011	0.00096	0.00158	0.00007	0.00000	0.00000
C	SOUTH	0.00027	0.00329	0.00363	0.00007	0.00000	0.00000
C	SOUTH-SOUTHWEST	0.00040	0.00308	0.00377	0.00055	0.00000	0.00000
C	SOUTHWEST	0.00042	0.00171	0.00473	0.00219	0.00048	0.00000
C	WEST-SOUTHWEST	0.00032	0.00096	0.00692	0.00356	0.00130	0.00041
C	WEST	0.00027	0.00144	0.00411	0.00130	0.00027	0.00000
C	WEST-NORTHWEST	0.00008	0.00034	0.00178	0.00014	0.00000	0.00000
C	NORTHWEST	0.00001	0.00034	0.00151	0.00027	0.00000	0.00007
C	NORTH-NORTHWEST	0.00030	0.00055	0.00178	0.00027	0.00007	0.00000

EXHIBIT 26.1 (continued)

STAB CLASS	DIRECTION FROM WHICH THE WIND IS BLOWING	WIND SPEED CLASS (KNOTS)					
		0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	> 21
D	NORTH	0.00111	0.00726	0.01398	0.00911	0.00116	0.00007
D	NORTH-NORTHEAST	0.00087	0.00445	0.00760	0.00466	0.00034	0.00007
D	NORTHEAST	0.00134	0.00582	0.00987	0.00493	0.00069	0.00000
D	EAST-NORTHEAST	0.00124	0.00500	0.01041	0.00822	0.00089	0.00021
D	EAST	0.00091	0.00569	0.01596	0.01178	0.00178	0.00007
D	EAST-SOUTHEAST	0.00035	0.00384	0.00870	0.00301	0.00027	0.00000
D	SOUTHEAST	0.00038	0.00267	0.00733	0.00233	0.00007	0.00000
D	SOUTH-SOUTHEAST	0.00076	0.00336	0.01384	0.00363	0.00014	0.00000
D	SOUTH	0.00170	0.01000	0.02302	0.00897	0.00219	0.00034
D	SOUTH-SOUTHWEST	0.00112	0.00541	0.01980	0.02069	0.00432	0.00144
D	SOUTHWEST	0.00152	0.00473	0.01822	0.02994	0.01034	0.00315
D	WEST-SOUTHWEST	0.00101	0.00459	0.02206	0.05378	0.02583	0.01062
D	WEST	0.00126	0.00555	0.02302	0.04748	0.01966	0.00623
D	WEST-NORTHWEST	0.00054	0.00315	0.01329	0.02103	0.00623	0.00075
D	NORTHWEST	0.00069	0.00336	0.00925	0.01055	0.00274	0.00027
D	NORTH-NORTHWEST	0.00055	0.00343	0.00918	0.01082	0.00274	0.00007
E	NORTH	0.00000	0.00308	0.00151	0.00000	0.00000	0.00000
E	NORTH-NORTHEAST	0.00000	0.00137	0.00144	0.00000	0.00000	0.00000
E	NORTHEAST	0.00000	0.00253	0.00089	0.00000	0.00000	0.00000
E	EAST-NORTHEAST	0.00000	0.00247	0.00199	0.00000	0.00000	0.00000
E	EAST	0.00000	0.00363	0.00315	0.00000	0.00000	0.00000
E	EAST-SOUTHEAST	0.00000	0.00288	0.00295	0.00000	0.00000	0.00000
E	SOUTHEAST	0.00000	0.00185	0.00349	0.00000	0.00000	0.00000
E	SOUTH-SOUTHEAST	0.00000	0.00343	0.00480	0.00000	0.00000	0.00000
E	SOUTH	0.00000	0.00939	0.00952	0.00000	0.00000	0.00000
E	SOUTH-SOUTHWEST	0.00000	0.00665	0.00617	0.00000	0.00000	0.00000
E	SOUTHWEST	0.00000	0.00397	0.00760	0.00000	0.00000	0.00000
E	WEST-SOUTHWEST	0.00000	0.00281	0.00863	0.00000	0.00000	0.00000
E	WEST	0.00000	0.00384	0.00617	0.00000	0.00000	0.00000
E	WEST-NORTHWEST	0.00000	0.00123	0.00336	0.00000	0.00000	0.00000
E	NORTHWEST	0.00000	0.00171	0.00206	0.00000	0.00000	0.00000
E	NORTH-NORTHWEST	0.00000	0.00178	0.00219	0.00000	0.00000	0.00000
F	NORTH	0.00181	0.00233	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHEAST	0.00195	0.00151	0.00000	0.00000	0.00000	0.00000
F	NORTHEAST	0.00255	0.00301	0.00000	0.00000	0.00000	0.00000
F	EAST-NORTHEAST	0.00193	0.00356	0.00000	0.00000	0.00000	0.00000
F	EAST	0.00140	0.00356	0.00000	0.00000	0.00000	0.00000
F	EAST-SOUTHEAST	0.00109	0.00349	0.00000	0.00000	0.00000	0.00000
F	SOUTHEAST	0.00187	0.00301	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHEAST	0.00113	0.00308	0.00000	0.00000	0.00000	0.00000
F	SOUTH	0.00398	0.01685	0.00000	0.00000	0.00000	0.00000
F	SOUTH-SOUTHWEST	0.00235	0.00788	0.00000	0.00000	0.00000	0.00000
F	SOUTHWEST	0.00132	0.00582	0.00000	0.00000	0.00000	0.00000
F	WEST-SOUTHWEST	0.00158	0.00459	0.00000	0.00000	0.00000	0.00000
F	WEST	0.00115	0.00411	0.00000	0.00000	0.00000	0.00000
F	WEST-NORTHWEST	0.00073	0.00281	0.00000	0.00000	0.00000	0.00000
F	NORTHWEST	0.00086	0.00343	0.00000	0.00000	0.00000	0.00000
F	NORTH-NORTHWEST	0.00114	0.00247	0.00000	0.00000	0.00000	0.00000

Table 26.1. Surface Water Environmental Safety Data
for FUSRAP - Tonawanda, New YORK

<u>Parameter</u>	<u>Units</u>	<u>Rattlesnake Creek</u>	<u>Twomile Creek</u>	<u>Niagara River</u>
Velocity	m/s	0.5	0.03	0.801
Depth	m	0.201	0.9	7.62
Width	m	1.52	6.1	488
Discharge	cms	0.015	0.169	2620

Table 26.2. Hydrogeologic Environmental Setting Data for Tonawanda Site's Storm_LA1 Storm Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	SZ
Darcian_velocity	m/yr	0.19	0.19	--
SOILC		7.12	10.4	10.4
Thickness	m	0.75	1.1	0.62
Bulk_density	g/cm3	1.6	1.51	1.51
Total_porosity	%	39.8	37	37
Field_capacity	%	24	32	--
Conductivity	m/day	0.49	0.86	--
Longitudinal_disp.	m	0.01	0.01	15.5
Transverse_disp.	m	--	--	3.10
Vertical_disp.	m	--	--	0.02
Effective_porosity	%	--	--	8.0
Velocity	m/day	--	--	0.003
Distance	m	--	--	155
Textural_class		sandy clay loam	sandy clay	sandy clay
%_sand	%	60	50	50
%_silt	%	14	8	8
%_clay	%	26	42	42
%_OMC	%	0	0	0
%_Fe	%	0	0	0
pH		7	7	7

Table 26.3. Hydrogeologic Environmental Setting Data for Tonawanda Site's Storm_SeaA2 Storm Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	SZ
Darcian_velocity	m/yr	0.19	0.19	--
SOILC		7.12	10.4	10.4
Thickness	m	0.75	1.1	0.62
Bulk_density	g/cm3	1.6	1.51	1.51
Total_porosity	%	39.8	37	37
Field_capacity	%	24	32	--
Conductivity	m/day	0.49	0.86	--
Longitudinal_disp.	m	0.01	0.01	15.5
Transverse_disp.	m	--	--	3.10
Vertical_disp.	m	--	--	0.02
Effective_porosity	%	--	--	8.0
Velocity	m/day	--	--	0.003
Distance	m	--	--	155
Textural_class		sandy clay loam	sandy clay	sandy clay
%_sand	%	60	50	50
%_silt	%	14	8	8
%_clay	%	26	42	42
%_OMC	%	0	0	0
%_Fe	%	0	0	0
pH		7	7	7

Table 26.4. Hydrogeologic Environmental Setting Data for Tonawanda Site's Tona_Shallow Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.19	0.19	0.19	0.19	--
SOILC		7.12	10.4	10.4	10.4	10.4
Thickness	m	0.75	1.1	0.62	2.52	7
Bulk_density	g/cm3	1.6	1.51	1.51	1.51	1.51
Total_porosity	%	39.8	37	37	37	37
Field_capacity	%	24	32	32	32	--
Conductivity	m/day	0.49	0.86	0.86	8.6e-4	--
Longitudinal_disp.	m	0.01	0.01	0.01	0.03	15.5
Transverse_disp.	m	--	--	--	--	3.10
Vertical_disp.	m	--	--	--	--	0.02
Effective_porosity	%	--	--	--	--	8.0
Velocity	m/day	--	--	--	--	3.2e-6
Distance	m	--	--	--	--	155
Textural_class		sandy clay loam	sandy clay	sandy clay	sandy clay	sandy clay
%_sand	%	60	50	50	50	50
%_silt	%	14	8	8	8	8
%_clay	%	26	42	42	42	42
%_OMC	%	0	0	0	0	0
%_Fe	%	0	0	0	0	0
pH		7	7	7	7	7

Table 26.5. Hydrogeologic Environmental Setting Data for Tonawanda Site's A1A2Sea_Deep Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	PZ5	PZ6	SZ
Darcian_velocity	m/yr	0.19	0.19	0.19	0.19	0.19	0.19	--
SOILC		7.12	10.4	10.4	10.4	10.4	10.4	8.52
Thickness	m	0.75	1.1	0.62	2.52	7	9.85	3.75
Bulk_density	g/cm3	1.6	1.51	1.51	1.51	1.51	1.51	1.39
Total_porosity	%	39.8	37	37	37	37	37	47.7
Field_capacity	%	24	32	32	32	32	32	--
Conductivity	m/day	0.49	0.86	0.86	8.6e-4	8.6e-4	8.6e-4	--
Longitudinal_disp.	m	0.01	0.01	0.01	0.03	0.07	0.10	106.0
Transverse_disp.	m	--	--	--	--	--	--	21.2
Vertical_disp.	m	--	--	--	--	--	--	0.12
Effective_porosity	%	--	--	--	--	--	--	0.10
Velocity	m/day	--	--	--	--	--	--	0.07
Distance	m	--	--	--	--	--	--	1060
Textural_class		sandy clay loam	sandy clay	sandy clay	sandy clay	sandy clay	sandy clay	clay loam
%_sand	%	60	50	50	50	50	50	31
%_silt	%	14	8	8	8	8	8	36
%_clay	%	26	42	42	42	42	42	33
%_OMC	%	0	0	0	0	0	0	0
%_Fe	%	0	0	0	0	0	0	0
pH		7	7	7	7	7	7	9

Table 26.6. Hydrogeologic Environmental Setting Data for Tonawanda Site's Linde_Deep Base Flow Zone. Parameters are characterized for the setting's partially-saturated zones (PZ) and saturated zone (SZ).

Parameter	Units	PZ1	PZ2	PZ3	PZ4	SZ
Darcian_velocity	m/yr	0.19	0.19	0.19	0.19	--
SOILC		7.12	10.4	10.4	10.4	10.4
Thickness	m	0.75	1.1	0.62	19.4	3.75
Bulk_density	g/cm3	1.6	1.51	1.51	1.51	1.51
Total_porosity	%	39.8	37	37	37	43
Field_capacity	%	24	32	32	32	--
Conductivity	m/day	0.49	0.86	0.86	8.6e-4	--
Longitudinal_disp.	m	0.01	0.01	0.01	0.19	402.0
Transverse_disp.	m	--	--	--	--	80.4
Vertical_disp.	m	--	--	--	--	0.47
Effective_porosity	%	--	--	--	--	0.10
Velocity	m/day	--	--	--	--	0.02
Distance	m	--	--	--	--	4020
Textural_class		sandy clay loam	sandy clay	sandy clay	sandy clay	sandy clay
%_sand	%	60	50	50	50	50
%_silt	%	14	8	8	8	8
%_clay	%	26	42	42	42	42
%_OMC	%	0	0	0	0	0
%_Fe	%	0	0	0	0	0
pH		7	7	7	7	9

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APPENDIX

DESCRIPTION OF ENVIRONMENTAL SETTING PARAMETERS

APPENDIX

DESCRIPTION OF ENVIRONMENTAL SETTING PARAMETERS

The following pages present a description of the hydrogeologic, surface water, climatic, and atmospheric dispersion environmental setting parameters required by the MEPAS model. The material presented here is excerpted from Sections 2 and 3 of *Multimedia Environmental Pollutant Assessment System Application Guidance, Volume 2 -- Guidelines for Evaluating MEPAS Input Parameters* (Droppo et al. 1989b).

The material in this appendix is provided as a courtesy to the reader so more detailed information on key environmental setting parameters can be obtained without consulting a separate reference. However, if more detailed information is required, the reader is urged to refer to Droppo et al. (1989b) for the following information:

- examples on how to generate parameter values
- information on the MEPAS model's other environmental data input requirements
- information on source term characterizations
- guidance on how to perform initial problem definition
- guidance on how to establish exposure pathways.

The reader is cautioned that some of the material presented in this appendix will refer to sections of Droppo et al. (1989b) that are not reproduced in this appendix.

The reader who intends to modify PEIS environmental setting data or requires additional information should study Droppo et al. (1989b) before proceeding. Other pertinent MEPAS documents include: Buck et al. (1989), Doctor et al. (1990), Droppo et al. (1989a), Droppo et al. (1989c), Strenge and Peterson (1989), and Whelan et al. (1987).

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2.4 PARTIALLY SATURATED ZONE

Partially Saturated Zone (PSZ) Soil Composition Data

- 2.4a **WP-CLASS** -- partially saturated zone textural classification (if more than one PSZ are specified, only one can be designated as top soil)

Units: none

See Section 2.2a for instructions for determining soil textural classification.

- 2.4b **WP-SAND** -- percent sand of partially saturated zone

Units: percent (%)

Model input range: 0 to 100

See Section 2.2b for instructions for determining percent sand.

- 2.4c **WP-SILT** -- percent silt of partially saturated zone

Units: percent (%)

Model input range: 0 to 100

See Section 2.2c for instructions for determining percent silt.

- 2.4d **WP-CLAY** -- percent clay of partially saturated zone

Units: percent (%)

Model input range: 0 to 100

See Section 2.2d for instructions on determining percent clay.

- 2.4e **WP-OMC** -- percent organic matter content of partially saturated zone

Units: percent (%)

Model input range: 0.00 to 9.99

See Section 2.2e for instructions on determining percent organic matter.

- 2.4f **WP-IRON** -- percent iron and aluminum in partially saturated zone

Units: percent (%)

Model input range: 0 to 99

Typical environmental range: 0 to 10

See Section 2.2f for instructions on determining percent iron and aluminum.

- 2.4g **WP-PH** -- pH of pore water in the partially saturated zone

Units: none

Model input range: 0.1 to 14.0

See Section 2.2g for instructions on determining pH.

Properties of Partially Saturated Zone

2.4h WP-THICK -- thickness of partially saturated zone

Units: feet (ft)

Model input range: 0.1 to 9999.9

Determine the number of distinct geologic layers in the unsaturated zone beneath the waste site. Minimize the number of layers by requiring each layer to have very distinct or different characteristics (percent sand, silt, and clay). If you are uncertain about distinguishing between one or two layers, make one and use the more conservative parameters (i.e., use the parameters yielding the fastest travel time for contaminant passing through the zone). Layers must be continuous beneath the site as the model does not simulate partial layers.

2.4i WP-BULKD -- bulk density of partially saturated zone

Units: grams per cubic centimeter (g/cm³)

Model input range: 1.00 to 3.00

Typical environmental range: See Table 2.1

If bulk density values are not available from site documents for the layers in the partially saturated zone, typical values may be selected from Table 2.1 for the appropriate soil-textural classification. If you are uncertain which of two values to choose, use the smallest value to be conservative. This value should correspond with the total porosity identified in Section 2.4j.

2.4j WP-TOTPOR -- total porosity of partially saturated zone

Units: percent (%)

Model input range: 0.1 to 99.9

If total porosities are not available for the partially saturated zone, use the values from Table 2.1 for the appropriate soil-textural classification. If you must choose between two categories, choose an average value. This value should correspond with the bulk density identified in Sections 2.4i and 2.1h.

2.4k WP-FIELDC -- field capacity of partially saturated zone

Units: percent (%)

Model input range: 0.1 to 99.9

If field capacities are not available for the partially saturated zone, use the typical value from Table 2.1 for the appropriate textural classification. Field capacity must be less than or equal to WP-TOTPOR.

2.4l **WP-LDISP** -- longitudinal dispersivity of partially saturated zone

Units: feet (ft)

Model input range: greater than 0.0 and less than WP-THICK

Enter the longitudinal dispersivity for each layer. If values are not available for the partially saturated zone, estimate the value as

$$D_L = 0.01 (Th)$$

where D_L is the longitudinal dispersivity in feet and Th is the thickness of the partially saturated layer in feet (see Section 2.4h).

2.4m **WP-CONDOC** -- saturated hydraulic conductivity

Units: feet per day (ft/day)

Model input range: greater than 0.0

If values are not available for layers in the partially saturated zone, select a value from Table 2.1 for the appropriate soil-textural classification. Choose the largest value for a given class.

2.5 SATURATED ZONE

Saturated Zone Soil Composition Data

2.5a **WZ-CLASS** -- subsurface soil textural classification

Units: none

See Section 2.2a for instructions on determining soil textural classification.

2.5b **WZ-SAND** -- percent sand of saturated zone soil

Units: percent (%)

Model input range: 0 to 100

See Section 2.2b for instructions for determining percent sand.

2.5c **WZ-SILT** -- percent silt of saturated zone soil

Units: percent (%)

Model input range: 0 to 100

See Section 2.2c for instructions for determining percent silt.

2.5d **WZ-CLAY** -- percent clay of saturated zone soil

Units: percent (%)

Model input range: 0 to 100

See Section 2.2d for instructions on determining percent clay.

2.5e **WZ-OMC** -- percent organic matter content of saturated zone soil

Units: percent (%)

Model input range: 0.00 to 9.99

See Section 2.2e for instructions on determining percent organic matter.

2.5f **WZ-IRON** -- percent iron and aluminum in saturated zone soil

Units: percent (%)

Model input range: 0 to 99

Typical environmental range: 0 to 10

See Section 2.2f for instruction on determining percent iron and aluminum.

2.5g **WZ-PH** -- pH of the pore water in the saturated zone

Units: none

Model input range: 0.1 to 14.0

See Section 2.2g for instructions on determining pH.

Properties of Saturated Zone

2.5h **WZ-TOTPOR** -- total porosity of saturated zone is based on total pore space in the soil

Units: percent (%)

Model input range: 0.1 to 99.9

If total porosity is not available for the saturated zone, use typical values from Table 2.1 for the appropriate textural classification. If you are trying to choose between two categories, choose an average value. Be sure the value chosen is consistent with the value used in Section 2.5j (pore-water velocity) and corresponds with the bulk density identified in Section 2.5l.

2.5i **WZ-EFFPOR** -- effective porosity of saturated zone

Units: percent (%)

Model input range: 0.1 to WZ-TOTPOR

The effective porosity is based on the pore space that contributes to advective flow. If effective porosity is not available for the saturated zone, interpolate using the following: sand = 25%, silt = 15%; and clay = 10%. The value used must be less than the value for total porosity given in Section 2.5h and Table 2.1.

2.5j **WZ-PVELOC** -- contaminant velocity in the saturated zone

Units: feet per day (ft/day)

Model input range: greater than 0.0

If no value is available from the site data, pore water velocity (V_p) can be estimated as the Darcy or bulk velocity divided by the effective porosity in decimal form (see Section 2.5i):

$$V_p = [K (H_1 - H_2)/d]/N_e$$

where K = saturated hydraulic conductivity, (ft/day)
(see Section 2.4m).

$(H_1 - H_2)/d$ = hydraulic gradient, defined as the difference in head or hydraulic potential at two points in the aquifer, divided by the distance (d) between the two points. This can be obtained from water table or potentiometric surface maps or from well logs.

N_e = effective porosity in decimal form (see Section 2.5i).

If no value is available for saturated hydraulic conductivity, additional values can be obtained from Table 2.1. Use the largest value in the range given.

If sampling indicates that contaminants have moved from the waste unit, check that the calculated pore water velocity is consistent with the speed at which the contaminant plume is traveling in the aquifer. The contaminant cannot be moving faster than the water (except by diffusion) but it can move significantly slower, depending on its retardation (equilibrium coefficient, Section 2.7a). If the calculated pore water velocity is less than the apparent speed of the contaminant plume (due to retardation), then adjust the pore water velocity so it is equal to the speed of the plume.

2.5k **WZ-THICK** -- thickness of saturated zone

Units: feet (ft)

Model input range: 0.1 to 9999.9

This thickness is defined as the distance from the water table to the bottom of (the vertical extent of) the contaminant plume. The saturated thickness should be obtained from the site data. If in doubt, choose a conservative estimate such as the total thickness of the aquifer.

2.5l WZ-BULKD -- bulk density of saturated zone

Units: grams per cubic centimeter (g/cm³)
Model input range: 1.00 to 3.00
Typical environmental range: see Table 2.1

If the bulk density is not available for the saturated zone, take the value from Table 2.1 for the appropriate textural classification. To be conservative, choose the smallest value of bulk density when trying to decide between two categories. This value should correspond to the total porosity identified in Section 2.5h.

2.5m WZ-DIST -- travel distance in saturated zone

Units: feet (ft)
Model input range: greater than 0.0

WZ-DIST must be determined for each downgradient receptor. This distance is measured from the center of the ranking unit to each downgradient receptor, defined as a well or a river into which the ground-water discharges. This distance can be determined from the site documents and maps or from 7.5-min USGS topographic maps. Carefully determine the downgradient direction. It will correspond to the direction used to determine the hydraulic head in Section 2.5h.

2.5n WZ-LDISP -- longitudinal dispersivity

Units: feet (ft)
Model input range: greater than 0.0

Enter the value for longitudinal dispersivity in feet. If no value is available from the site data, estimate it for the saturated zone as

$$D_L = 0.1 (Tr)$$

where Tr is the length of the travel path (plan view) from the center of the waste site to the receptor point, e.g., river or well (ft).

2.5o WZ-TDISP -- transverse dispersivity

Units: feet (ft)
Model input range: greater than 0.0

Enter the value for transverse dispersivity in feet. If no value is available from the site data, estimate it for the saturated zone as:

$$D_T = 0.2 (D_L)$$

where D_L is the longitudinal dispersivity as defined in Section 2.5o above (ft).

2.5p **WZ-VDISP** -- vertical dispersivity

Units: feet (ft)

Model input range: greater than 0.0

Enter the value for vertical dispersivity in feet. If value is available from the site data, estimate it for the saturated zone as

$$D_v = 1.16 \times 10^{-3} (D_L)$$

where D_L is the longitudinal dispersivity as defined in Section 2.5o above (ft).

2.6 **SURFACE WATER**

2.6a **WW-VELOC** -- river flow velocity

Units: feet per second (ft/s)

Model input range: greater than 0.0

The river flow velocity should be for the river where it is closest to the ranking unit and where contaminants from the ranking unit will have reached it. The river flow velocity is based on the average annual stream discharge.

2.6b **WW-DEPTH** -- river depth

Units: feet (ft)

Model input range: 1 to 500

Estimate the flow depth (for the same location as that used in determining the river flow velocity) in an analogous procedure as that outlined in Section 2.6a. In step 2, use flow depth from Form 9-207 and plot flow depth versus discharge.

2.6c **WW-WIDTH** -- river width

Units: feet (ft)

Model input range: 1 to 9999

Estimate the river width (for the same location as that used in determining the river flow velocity) in an analogous procedure as that

2.6d **WW-DIST** -- distance to closest receptor

Units: feet (ft)

Model input range: 1 to 792,000 (150 miles)

Identify the distance from the surface-water source to the downstream receptor from the USGS topographic maps. Identify the distance from the center of the source entering the surface water to the downstream receptors and the "activity types" of all downstream receptors (e.g., swimming, irrigation, municipal water supply) within 50 mi downstream from the source center. An example is illustrated in Figure 2.22. Finally, at each receptor, identify the activity associated with the usage location (e.g., recreational; intake structure for irrigation, drinking water, or stock/feed water; fishing; etc.).

2.6e **WW-DISCHG** -- average annual discharge at each receptor location

Units: cubic feet per second (ft³/s)

Model input range: greater than 0.0

Discharge is a function of distance and may change from one usage location to the next. To determine the average annual discharge, follow the guidelines outlined in 2.6a. If a receptor location lies between two gaging stations, interpolate linearly to estimate the discharge at the receptor. Note that the discharge is not necessarily associated with the flow velocity, river depth, or river width determined in Sections 2.6a, b, or c.

2.6f **WW-ORDER** -- relative order of receptors

Units: none

Model input range: number of receptors

Rank the receptor locations in order of increasing distance from the ranking unit. For example the nearest location is location 1 with the locations farther downstream being ranked 2, 3, 4, etc.

2.8 **CLIMATOLOGY**

2.8a **WC-ALT** -- altitude of ranking unit

Units: feet (ft)

Model input range: -50 to 9999

Altitude refers to the altitude of the waste site in feet above mean sea level. This may be taken from a reference or determined from a topographic map. In either case, indicate the reference used.

2.8b WC-LCDREF -- reference weather station name and state

Units: none

An annual summary of the Local Climatological Data (LCD) for the nearest representative national weather service station should be obtained. They are published by the Environmental Data Service, NOAA, National Climatic Center (NCC) in Asheville, North Carolina.

2.8c WC-ELEV -- elevation of weather station

Units: feet (ft)

Model input range: -50 to 9999

Elevation refers to the elevation of the reference weather station from which the LCD summary was obtained. This information is available in the LCD summary's narrative discussion of the station, in the LCD section titled "Normals, Means, and Extremes," or in facility descriptions.

2.8d WC-LAT -- latitude of weather station

Units: decimal degrees

Model input range: 0.0 to 180.0

Latitude refers to the latitude of the facility in decimal form. This value can be taken from a site description or determined from a map.

2.8e WC-WINDHT -- height of weather station's wind measurement

Units: feet (ft)

Model input range: 1 to 500

Wind height refers to the height of the wind measurement (2.8h WC-WINDV) listed in the selected LCD summary or from other documentation. Enter the most recent height when multiple heights are listed. This height may or may not be the same value as 3.2b AJ-ANEMT depending on whether the climatic data and the joint frequency summaries are based on measurements from the same location and sensor (see also 3.1i AV-WINDHT).

Monthly Climatological Data

Enter the mean monthly and average-annual values for designated parameters. For LCD from NCC, these are given in the table labeled "Normals, Means, and Extremes" table (see Figure 2.24). In particular, enter the following:

2.8f WC-TEMP -- mean monthly temperature

Units: degrees Fahrenheit (°F)

Model input range: -50 to 90

2.8g **WC-RAIN** -- mean monthly precipitation

Units: inches (in.)

Model input range: greater than or equal to 0.0

2.8h **WC-WINDV** -- mean monthly wind speed

Units: miles per hour (mph)

Model input range: greater than or equal to 0.0

2.8i **WC-CLOUD** -- average cloudiness or mean sky cover

Units: tenths

Model input range: greater than or equal to 0.0

2.8j **WC-PRENUM** -- mean number of days in the month where precipitation is 0.01 in. or more.

Units: number of days (#)

Model input range: 0 to 31

If the smallest measured value is more than 0.01 in., use the mean number of days in the month where the precipitation has the smallest unit of measurement.

2.8k **WC-RHMAX** -- maximum relative humidity for the month

Units: percent (%)

Model input range: 0 to 100

Use the larger value if two are given.

2.8l **WC-RHMIN** -- minimum relative humidity for the month

Units: percent (%)

Model input range: 0 to 100

Use the smaller value if two are given.

Map-Derived Climatological Data

3.1a **AC-MIXAM** -- morning mixing height for the site

Units: meters (m)

Model input range: 300 to 900

Source of this information is in Figure 3.1 of this document. Multiply the average morning mixing height for the facility from Figure 3.1 by 100 and enter the value on the worksheet. A common range of values is from 300 to 900 m.

FIGURE 3.1. Mean Annual Morning Mixing Heights ($m \times 10^2$)

3.1b AC-MIXPM -- afternoon mixing height for the site

Units: meters (m)
Model input range: 800 to 2600

Source of this information is in Figure 3.2 of this document. Multiply the average afternoon mixing height for the facility from Figure 3.2 by 100 and enter the value on the worksheet. A common range of values is from 1000 to 2600 m.

3.1c AC-REGION -- suspension potential index defined in terms of a climate region

Units: none
Model input range: 1 to 7

Source of this information is in Figure 3.3 of this document. Find the climatic region index (1 through 7) by locating the facility on the map given in Figure 3.3.

3.1d AC-PEI -- precipitation-evaporation index

Units: none
Model input range: 6 to 318

Enter the precipitation-evaporation index from Figure 3.4 of this document.

LCD DATA:

3.1e AC-LCDREF -- name of the station referenced for LCD data

Units: none

Prior to entering data, the nearby stations with LCD summaries will need to be identified. From these stations, select the station which is most representative of the climatology of the site. Usually this will be the station located closest to the site. Enter the name of the selected station, and use the data from this station to complete the entries below.

3.1f AC-NUMTS -- number of thunderstorm days per year

Units: number per year (#/yr)
Model input range: 1 to 150

Source of these data is the LCD summary (see 3.1e AC-LCDREF). Enter the number of days with thunderstorms per year as listed in the LCD. This parameter is defined as the number of days that thunder was heard at the station in 1 year.

FIGURE 3.2. Mean Annual Afternoon Mixing Heights ($m \times 10^2$)

FIGURE 3.3. Climatic Region Index

FIGURE 3.4. Precipitation-Evaporation Index

3.1g AC-FASTV -- fastest wind speed

Units: miles per hour (mph)
Model input range: 1 to 150

Source of these data is the LCD summary (see 3.1e AC-LCDREF).
Enter the value of wind speed listed for the "YEAR" entry under
"WIND/FASTEST MILE."

3.1h AC-WINDV -- mean annual wind speed

Units: miles per hour (mph)
Model input range: 1 to 50

Source of these data is the LCD summary (see 3.1e AC-LCDREF).
Enter the mean annual wind speed from onsite monitoring data, or
use the climatologic value listed in the LCD summary under the
wind category for "Normals, Means and Extremes."

3.1i AC-WINDHT -- height of annual average wind speed measurement

Units: meters (m)
Model input range: 1 to 500
Typical environmental range: 3 to 15

Enter the height at which the annual average wind speed (3.1h AC-WINDV)
measurements were taken.

3.1j AC-PRESS -- annual average atmospheric pressure

Units: atmospheres (atm)
Model input range: 0.10 to 9.99
Typical environmental range: 0.8 to 1.2

Source of these data is the LCD summary (see 3.1e AC-LCDREF). The
pressure value normally occurs in the LCD summary in the "Year" row of
the last column under "Normals, Means, and Extremes." This number is
the average station pressure in millibars. If this value is not given
in the LCD summary, enter the typical value of 1.000 atm.

The worksheets requires a value in atmospheres; conversion of millibars
to atmospheres is done by multiplying the millibar value by
 9.86923×10^{-4} atm/mb.

3.1k AC-TEMP -- annual atmospheric temperature

Units: degrees Fahrenheit (°F)
Model input range: 10 to 90

Source of these data is the LCD summary (see 3.1e AC-LCDREF).
Enter the annual atmospheric temperature, which is listed in the
LCD summary.

3.11 AC-RAIN -- annual precipitation

Units: inches (in.)

Model input range: 0.1 to 130.0

Source of these data is the LCD summary (see 3.1e AC-LCDREF). Obtain the annual amount of precipitation from the LCD summary table.

3.1m AC-PRENUM -- number of precipitation days per year

Units: number per year (#/yr)

Model input range: 0 to 365

Source of these data is the LCD summary (see 3.1e AC-LCDREF). The precipitation day is defined as having at least 0.01 inch of precipitation for that day. Obtain the annual number of precipitation days for the LCD summary table (see Figure 2.24). This value is found under the heading of Mean number of days: Precipitation 0.01 inch or more. The annual value is the bottom number; for example, in Figure 2.24, the value is 89/yr.

3.2a AJ-STATNM -- joint frequency summary station name and state

Units: none

Enter a name that describes the location at which the data were taken. Use a descriptive name to designate the location where onsite data were taken. For the NCC data, enter the name of the climatic station (normally the name of a nearby city). Also enter the name of the state in which the station is located. Document the source of the joint frequency summary data. If it was obtained from a document, give the reference and pages. If it was obtained from another source, such as NCC, identify the source in a reference note.

3.2b AJ-ANEMHT -- joint frequency summary anemometer height

Units: meters (m)

Model input range: 0.1 to 999.9

Typical environmental range: 3 to 15

The height at which the winds were measured can normally be obtained either from the source of the joint frequency data (i.e., facility documentation for onsite data or from the last page of the LCD summary for NCC data). The typical value for joint frequency anemometer height is 3 m. This parameter is critical only for data sets obtained from towers; 3 m will be adequate for most near-surface data.

3.2c AJ-RLEN -- joint frequency summary roughness length

Units: centimeters (cm)
Model input range: 0.0 to 999.9
Typical environmental range: 0 to 150

Using the guidelines given for variable AJ-RLEN in 3.2c, estimate an average roughness length for the area surrounding the weather station used for the wind joint frequency summary. The typical value for roughness length is 10 cm.

3.2d AJ-WINDS(6) -- joint frequency summary wind speed group midpoints

Units: meters per second (m/s)
Model input range: 0.00 to 99.99
Typical environmental range: 1.0 to 10.0

Enter the data from the joint frequency summaries. Combination of the values in the data tables is required if the number of wind speed groups is greater than six. If combination is required, combine the wind-speed categories so that the coverage of the range of wind-speed conditions is as even as possible. The frequency of occurrence of conditions within wind-speed groups will provide some guidance as to which adjacent groups to combine -- groups already having high frequencies are generally left separate and groups with relatively low frequencies combined.

Midpoints of the six wind-speed categories are needed. If ranges of wind speeds are given in the summaries, enter the ranges in the template and compute the midpoint by averaging the two range values. If the midpoints are given in the summary, enter these in the "Reported Midpoint" column (and ignore the "Range" columns). Convert the midpoints to meters per second and enter them in the "Converted Midpoint" column. (Conversion factors are 1 knot = 0.5148 m/s and 1 mph = 0.4470 m/s.)

3.2e AJ-UNIT -- indicates units or source of wind joint frequency summary data

Units: none

3.2f AJ-MODE -- mode of joint frequency summary data input

Units: none
Model input range: 1 or 2

Defines method of data input to shell; select between screen entry or file read modes. Screen entry is made in the format defined by AJ-FDATA (in 3.2g).

3.2g AJ-FDATA -- wind joint frequency summary data

Units: number, percent or fraction of observations

Input the data in the joint frequency table according to the following guidelines:

1. Although entries may be expressed in a number of forms, a single consistent form must be used within the table. Entries are limited to five significant digits including the decimal point. The use and placement of the decimal point depends on the form of the data:
 - Fractions of total time (table sum will equal 1.0) are entered as thousandths; e.g., 0.0013, 0.0232, 0.0000
 - Percentages of total time (table sum will equal 100.) are entered as hundredths of percent; e.g., 00.13, 02.32, and 00.00
 - Number of occurrences [table sum is 8760 for one non-leap year of hourly observations (24 x 365)] are expressed as whole numbers; e.g., 11., 2., 0., and so on.
2. If frequencies are reported for an "unknown" or other undefined category, the entries may be ignored. The model will automatically adjust the input table account for missing values. Data sets from which more than 15% is missing should normally not be used.
3. The table allows seven stability categories to be input. If only the first six stability categories are provided, enter the available data along with zeros for the seventh stability class. If some other combination of six or fewer stability categories are encountered, enter the data in the appropriate sections of the table with zeros entered for missing data. If only wind direction and wind-speed information are available, enter those data in the fourth stability category (D).
4. The table has room for up to six wind-speed groups, as defined in 3.2d. If fewer than six groups are encountered, enter zeros for the frequencies in the undefined groups.
5. Do not record summary, total, and average values in the table.

3.2h AJ-CALMS -- wind joint frequency calms

Units: number, percent, or fraction

Enter total frequencies of calm conditions using the same units (as noted in 3.2e) for the table in 3.2f. If no value is given for calms, enter a value of zero.

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