Appendix A

Remedial Investigation Project Background

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A1.0 Project Background

This section includes a site description and history, summary of existing analytical data, and a table of Applicable or Relevant and Appropriate Requirements (ARAR). The following information was obtained from the Remedial Investigation (RI) and in the Record of Decision (ROD) by Ebasco (1989), other referenced reports, and updated/expanded appropriately to describe the current conditions.

A1.1 Site, Location, and Description

The MFDS is an inactive low-level radioactive waste site, owned by the Commonwealth and located in Fleming County, Kentucky, approximately 10 miles northwest of the city of Morehead, Kentucky. The location of the MFDS is shown in Figure A-1. The MFDS property covers approximately 720 acres of land, including a buffer zone consisting of approximately 440 acres, which was purchased to prevent deforestation and erosion of hillslopes at MFDS. The waste is buried in a fenced area of about 45 acres, designated as the Restricted Area for radiation protection purposes, as shown in Figure A-3. About 27 of the 45 acres within the Restricted Area have been used for the construction of 52 disposal trenches and a "hot well" area. The Restricted Area also contains a Radiation Control Building, Garage, storage and warehouse buildings, three liquid storage tank buildings, a building enclosing an evaporator, gravel driveways, and parking areas. An office/laboratory building is located outside the Restricted Area. The ground surface over the trench disposal area is covered with about 30 acres of scrim-reinforced polypropylene cover to prevent the infiltration of precipitation into the trenches.

A1.2 Site History

In 1962 the Commonwealth was given Agreement State status by the U.S. Atomic Energy Commission [now the Nuclear Regulatory Commission (NRC)] to assume regulatory powers for the management of radioactive materials. The Commonwealth then issued a license to Nuclear Engineering Company (NECO), effective January 8, 1963, for the disposal of low-level radioactive waste at MFDS.

From 1963 to 1977 approximately 4.5 to 6.0 million cubic feet of low-level radioactive waste was received and buried at the MFDS. Disposal records for non-radiological chemicals associated with the radiological waste were not required during this time period. However, some organic and inorganic materials are known to exist in the trench leachate. The radiological waste has been estimated to contain about 2.4 million curies of by-product material, about 533,000 pounds (241,769 kilograms) of source material, about 950 pounds (431 kilograms) of special

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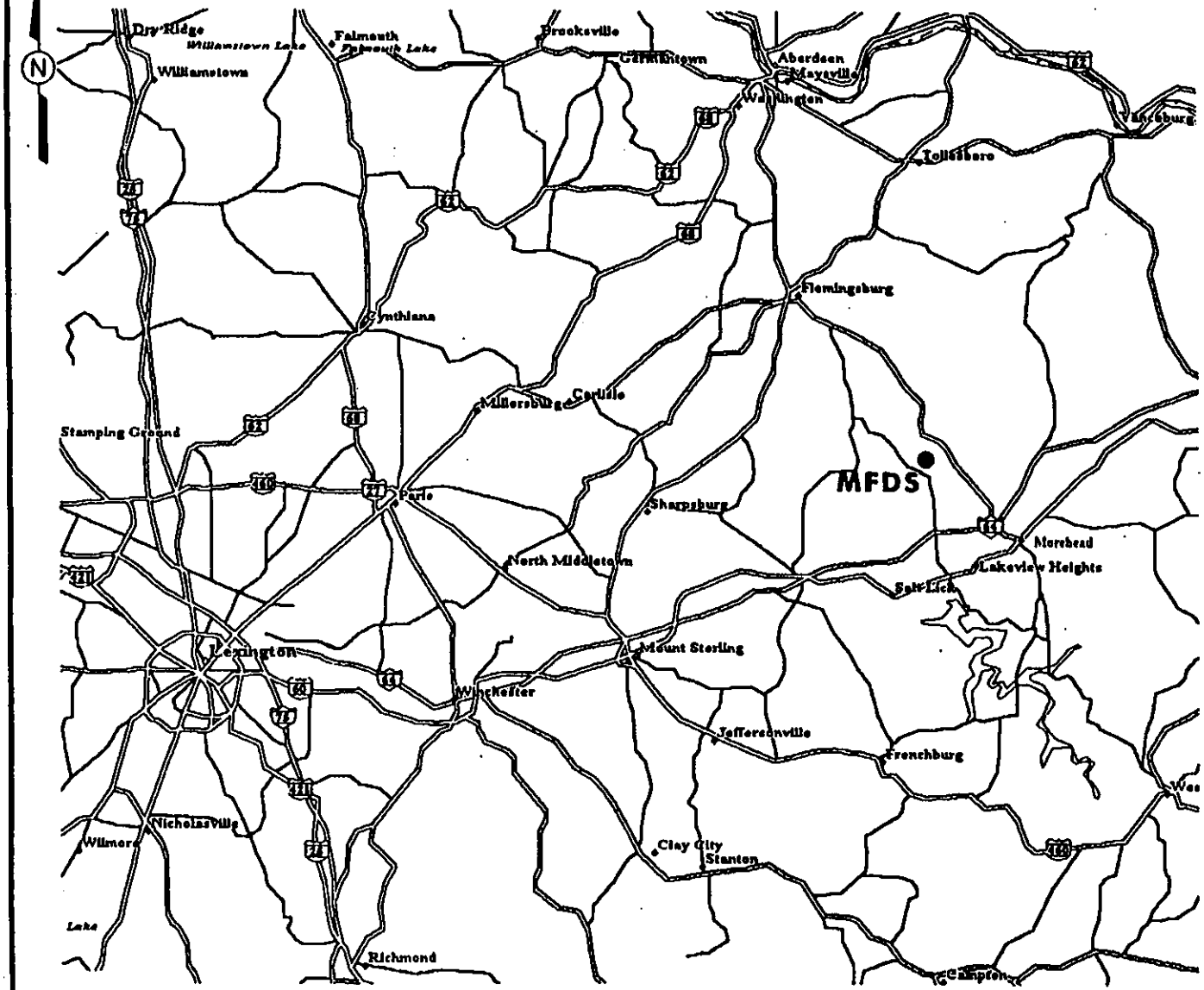

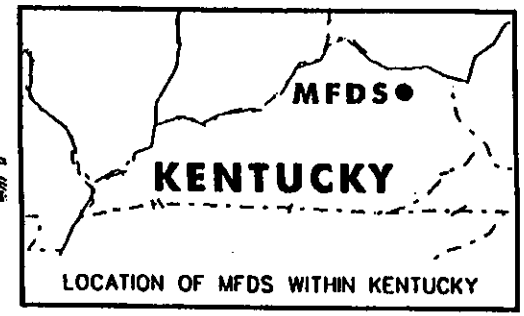

FIGURE A-1
LOCATION MAP

MAXEY FLATS DISPOSAL SITE
MOREHEAD, KENTUCKY

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nuclear material, and more than 140 pounds (63 kilograms) of plutonium (Pu). This waste was placed in 46 disposal trenches, except for waste designated as high specific activity, which was placed in "hot wells". Since 1977, seven trenches have been added for the disposal of waste derived from site operation activities, bringing the total number of trenches at MFDS to 53. (The number 1 has been assigned to two trenches: No. 1 and No. 1S).

A1.3 Trench Designations and Chronological Events

Most of the waste transported to MFDS was deposited in the trenches in solid form (clothing, paper, glassware, shielding material, animal carcasses) in containers constructed of various materials including cardboard, wooden boxes, and steel drums. Liquid wastes were accepted from 1963 to 1972 and were placed in special "liquids" trenches after being solidified with papier-mâche', urea-formaldehyde compounds, and/or cement. They are identified as trenches 4L, 6L, 8L, 9L, 12L, 13L, 14L, 16L, 17L, 21L, and 33L. Trench 33L consists of several adjacent slit trenches, which were lined with plastic into which slurries of various compositions were pumped and allowed to solidify. Trench 21L originally contained seven buried tanks used for the temporary storage of liquid wastes. The liquid wastes were removed, and all tanks except one were stabilized by removing the top section and backfilling with solid waste and soil.

The trenches are divided into four areas, which are referred to as the Western Trench Area, Central Trench Area, 40 Series Trench Area, and the southeast Trench Area. The majority of the trenches were called common trenches and their dimensions typically ranged from 300 to 650 feet long, 30 to 70 feet wide, and 15 to 30 feet deep. The common trenches typically contained solid wastes, emplaced randomly in the rectangular trenches. Trenches were excavated in weathered and unweathered shales with thin sandstone interbeds. The walls of the trenches were vertical or nearly vertical, and adjacent trenches were typically 5 to 10 feet apart. When the trenches were filled, the waste was typically covered with 3 to 10 feet of clay and crushed shale. However, in some cases the above-burial specifications were not met and trenches were filled over capacity and covered with unknown depths of clay and crushed shale.

The "S" trenches, 1S, 5S, 11S, and 19S, were used for the burial of "special" wastes typically containing radionuclides, such as Strontium-90 (Sr-90), and Pu isotopes, which have longer half-lives than most of the wastes buried in the Restricted Area. Zehner reported that the S trenches were constructed and filled in a manner similar to the common trenches.

As each trench was filled, it was covered with a soil cap. Consequently, the trench caps are supported only by the trench contents. Subsidence of the trench contents, due in part to the decomposition of cardboard, wood, and metal containers in the trenches, has caused and continues to cause cracking, dropouts, and other subsidence damage to the trench caps. Infiltration of rainwater and surface water through the trench caps resulted in the accumulation of leachate in the trenches. To prevent the trenches from filling, leachate was pumped from the trenches beginning in 1972.

In mid-1973, an evaporator was placed in operation to reduce the volume of liquids which had accumulated from leachate pumping and site operations. The evaporator frequently operated 24 hours per day, 5 days per week until May 1986.

In 1977, during construction of Trench 46, it was determined that leachate was migrating through the subsurface geology. The MFDS was closed to commercial use in December 1977. In May 1978 the Commonwealth purchased NECO's leasehold estate and rights to MFDS. Since that time, custodial and stabilization activities have been performed by contractors for the Commonwealth. These contractors have included U.S. Ecology (formerly NECO), National Waste Management Service, Dames and Moore, Hittman Nuclear and Development Corporation, and Westinghouse Electric Corporation. The Commonwealth currently maintains and monitors MFDS.

The custodial care that was performed by MFDS operations contractors included pumping leachate from the trenches, storing leachate in on-site tanks, and reducing leachate volume with the evaporator facility. Custodial care also included efforts to reduce the amount of water infiltrating the trenches by grading and recontouring, eliminating on-site liquid holding ponds, installing dewatering sumps into the trenches, and installing and maintaining polyvinyl chloride (PVC) covers over the trench areas. Three water control structures (two detention basins and a weir) were constructed to help prevent hillslope erosion due to surface runoff. Environmental monitoring of the facility has included sampling and analysis of air, surface water, stream sediments, vegetation, and subsurface water.

In November 1981, a low-permeability PVC membrane cover was placed over several trenches to limit infiltration and accumulation of water in trenches. By September 1984, about 3/4 of the Restricted Area was covered, but several trenches, gravel roads, and parking lots remained uncovered. In 1990/1991, a PVC cover was placed over the existing membrane cover and expanded to cover the area shown in Figure A-3. Holes were cut in this PVC membrane to

expose the sump tops. PVC deterioration in sunlight necessitated the installation of a new, more durable cover. At direction of the Committee in 1995, a new polypropelyne cover was installed by IT over the existing PVC cover. New boots were installed around the sump tops to prevent precipitation infiltration.

The U.S. Geological Survey has installed more than 100 monitoring wells and performed hydrogeologic studies at the facility since the mid-1970s to obtain geologic and hydrogeologic data on important strata and to determine the extent of radionuclide migration. Monitoring wells were also installed by Walker in 1962, Emcon Associates in 1972 and 1973, and Ebasco (1987 and 1988).

The results of the trench sampling and chemical characterization by Brookhaven National Laboratory (BNL) revealed that most trench leachates were anoxic, had pH values ranging from 6 to 8.5, negative redox potentials, and high conductivities. Twelve generalized classes of organic compounds were found to have been present in the trenches sampled at MFDS during the BNL study from 1976 to 1981. Chemical compounds and concentrations present within each class varied greatly among the trenches sampled.

In 1986, MFDS was placed on the EPA National Priorities List (NPL) of sites to be evaluated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In 1987, an Administrative Order by consent was entered between EPA and the Committee, a committee of 82 potentially responsible parties. Under this consent order, the Committee performed an RI/feasibility study (FS). The RI was completed in 1989, and the FS was completed in 1991. Reports were submitted to EPA. Tritium is discussed frequently in the reports because it is the most widespread radionuclide at MFDS. Tritium is an isotope of hydrogen and exchanges with stable hydrogen in molecules of water. Tritium has migrated from the trenches due to its mobility, and is the most widely distributed radionuclide in soil and water outside the Restricted Area. Tritium migration from the trenches is indicated by the movement of water and is the key radionuclide used to evaluate migration pathways. Tritium has a relatively short half-life of approximately 12 years and decays by emitting a beta particle. Surface water and stream sediment samples contain low concentrations of some radionuclides. The highest concentrations of these radionuclides in the surface water and sediment were detected in the sampling stations adjacent to the Restricted Area.

Leachate was sampled from 15 trench sumps during the program to determine radionuclide and chemical concentrations. Parameters measured during the RI program are normally associated

with nuclear power operations and non-power operations for low-level radioactive waste. These parameters are similar to the historical data available for MFDS. Concentrations of specific chemicals were highly varied among the trench sump samples. This variability of chemical concentrations, as with radionuclide concentrations, was related to the heterogeneous nature and placement of waste deposited within the trenches. Trench leachate appeared to be highly buffered, principally by chelating agents, carbonates and bicarbonates, and typically exhibits near-neutral pH values despite the presence of numerous acidic compounds, such as phenols and organic acids.

In September and October 1989, EPA initiated a response action to solidify leachate that was stored in aboveground tanks. An EPA-approved vendor solidified the leachate into large concrete blocks. The blocks and solidification equipment were disposed in a newly-constructed trench in September and October 1991. This trench, No. 52, is the last trench constructed on the MFDS.

A1.4 Physical Characteristics of the Study Area

A1.4.1 Topography

MFDS is located in the Appalachian Plateau, in the Knobs physiographic region of northeast Kentucky, an area characterized by relatively flat-topped ridges (flats) and hills (knobs). The MFDS is located on a spur of Maxey Flats, one of the larger flat-topped ridges in the region. The MFDS is bounded by steep slopes to the west, east, and south and is approximately 350 feet above the adjacent valley bottoms.

A1.4.2 Geology, Hydrology, and Hydrogeology

Numerous studies have reported on the geology of MFDS. The following text is a summary of the geology, hydrology, and hydrogeology from the RI report and the ROD.

The MFDS lies in a tectonically stable region of North America with few exposed faults and relatively infrequent earthquakes. The rock units exposed in the area surrounding MFDS consist of shale, siltstone, and sandstone ranging in age from the Silurian to Mississippian (320 to 430 million years old). In the MFDS area, the rock units dip 25 feet per mile (0.3 degrees); regionally they dip to the east at 30 to 50 feet per mile.

As shown in Figure A-4, the Nancy Member of the Borden Formation is exposed on the hilltop at MFDS and is 27 to 60 feet thick. The unit is mostly shale with two laterally extensive

siltstone beds, the LMB and Upper Marker Bed. These beds were up to 2.8 feet thick at locations encountered during drilling operations at MFDS.

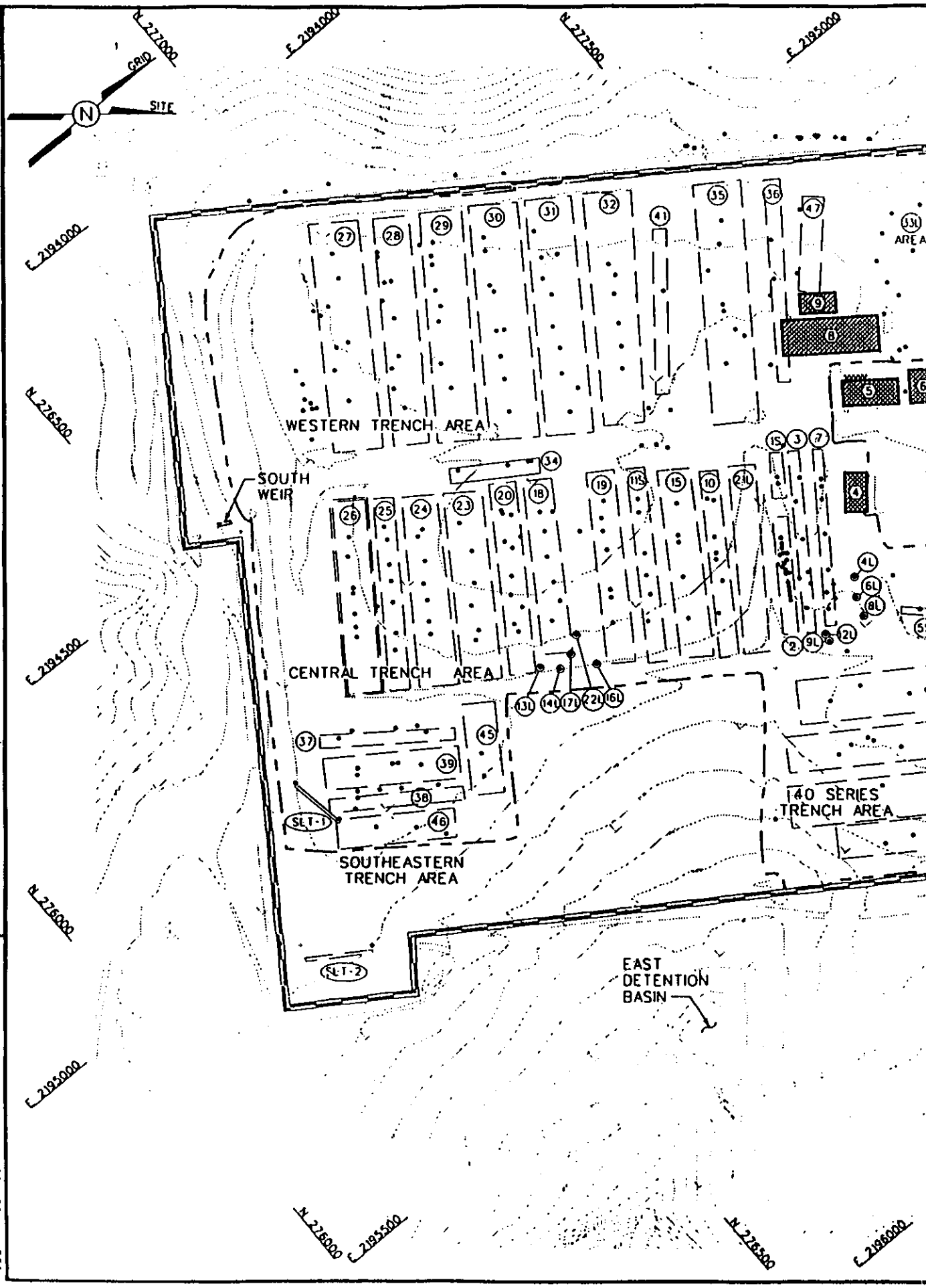
Underlying the Nancy Member, the Farmers Member of the Borden Formation is characterized as an interbedded siltstone and shale, approximately 29 to 42 feet thick. Underlying the Farmers Member is the 4 to 7 feet thick shale of the Henley Bed, 17 to 18 feet thick Sunbury Shale, and 21 feet thick Bedford Shale.

Fractures are present in all rock units at MFDS, with fracture sets oriented in descending order, northeast-southwest, northwest-southeast, and north-south. The fracture sets are generally within 20 degrees of vertical. The weathered shale of the Nancy Member is the most highly fractured.

The distinguishing feature of the Nancy Member, and perhaps that of MFDS geology, is the LMB of the Nancy Member. The LMB is a thin siltstone layer that is generally flat-lying (some local undulations of the bed are present), fractured and weathered, and lies approximately 15 to 25 feet below ground surface. The LMB is the principal leachate flow pathway at MFDS and underlies or intersects the majority of disposal trenches. Consequently, the LMB is a highly-contaminated geologic unit at MFDS. Another distinguishing characteristic of the LMB is that underlying units are hydraulically connected to the LMB. However, as shown in Figure A-5, rates and quantities of flow to the underlying units are, most likely, low.

Vertical migration between geological strata is limited by shale layers of low permeability, which act as aquitards. On the east side of the site, the 40 series trenches, which commonly bottom bear the top of the Farmers Member (approximately 40 feet below ground surface), leach tritium and other contamination to the Farmers Member. Because MFDS is bounded on the three sides by steep slopes, the contaminated leachate migrating horizontally through the fractured siltstone layers generally moves into the bottom of the soil layer on these hillslopes. However, as evidenced by the occurrence of seeps on the east hillside, not all leachate migrates to the bottom of the soil layer on the hillslopes.

Hydrogeologic evaluations of MFDS indicate that groundwater movement through the rock strata to the disposal trenches may be negligible. However, a potential pathway for groundwater flow into the trenches would be through the narrow neck at the north side of MFDS where the trench area is connected to the main portion of the Maxey Plateau. Because of present water mounding (i.e., there is a higher potentiometric surface at the center of MFDS than at the edges), the tendency is for water/leachate to migrate outwardly from MFDS rather than toward the site.



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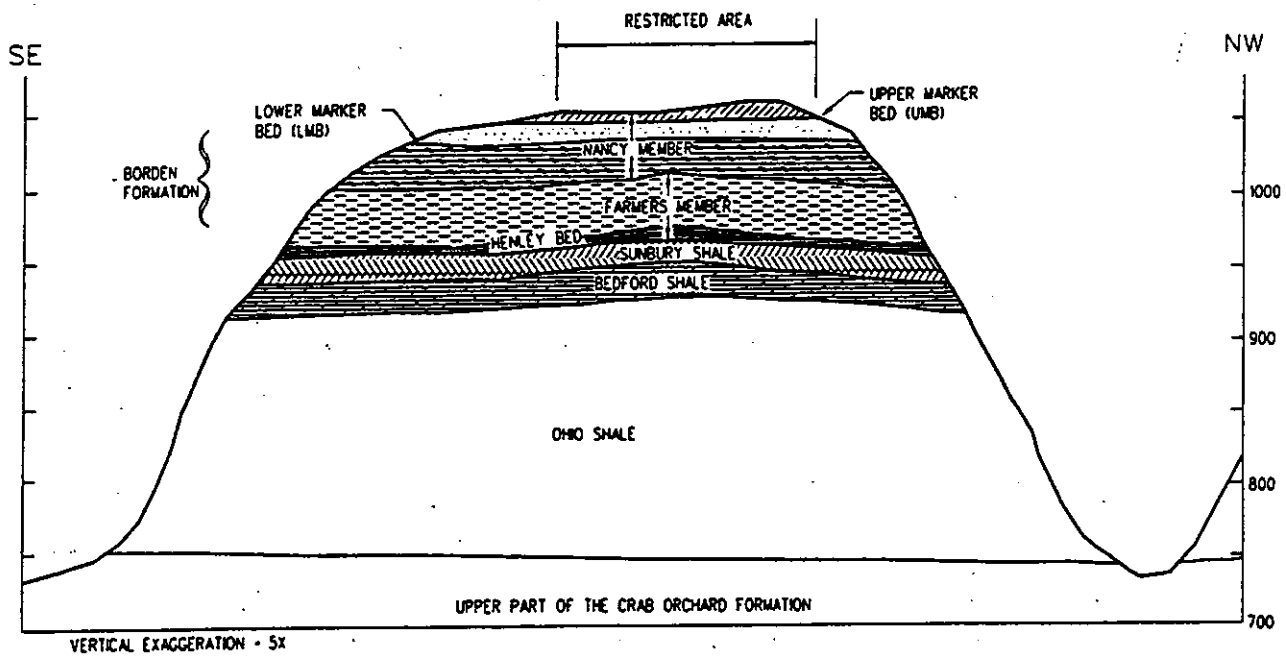

FIGURE A-4
SCHEMATIC GEOLOGIC CROSS-SECTION

MAXEY FLATS DISPOSAL SITE
MOREHEAD, KENTUCKY

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FIGURE ADAPTED FROM FIGURE 4-2 OF EBASCO (1989)

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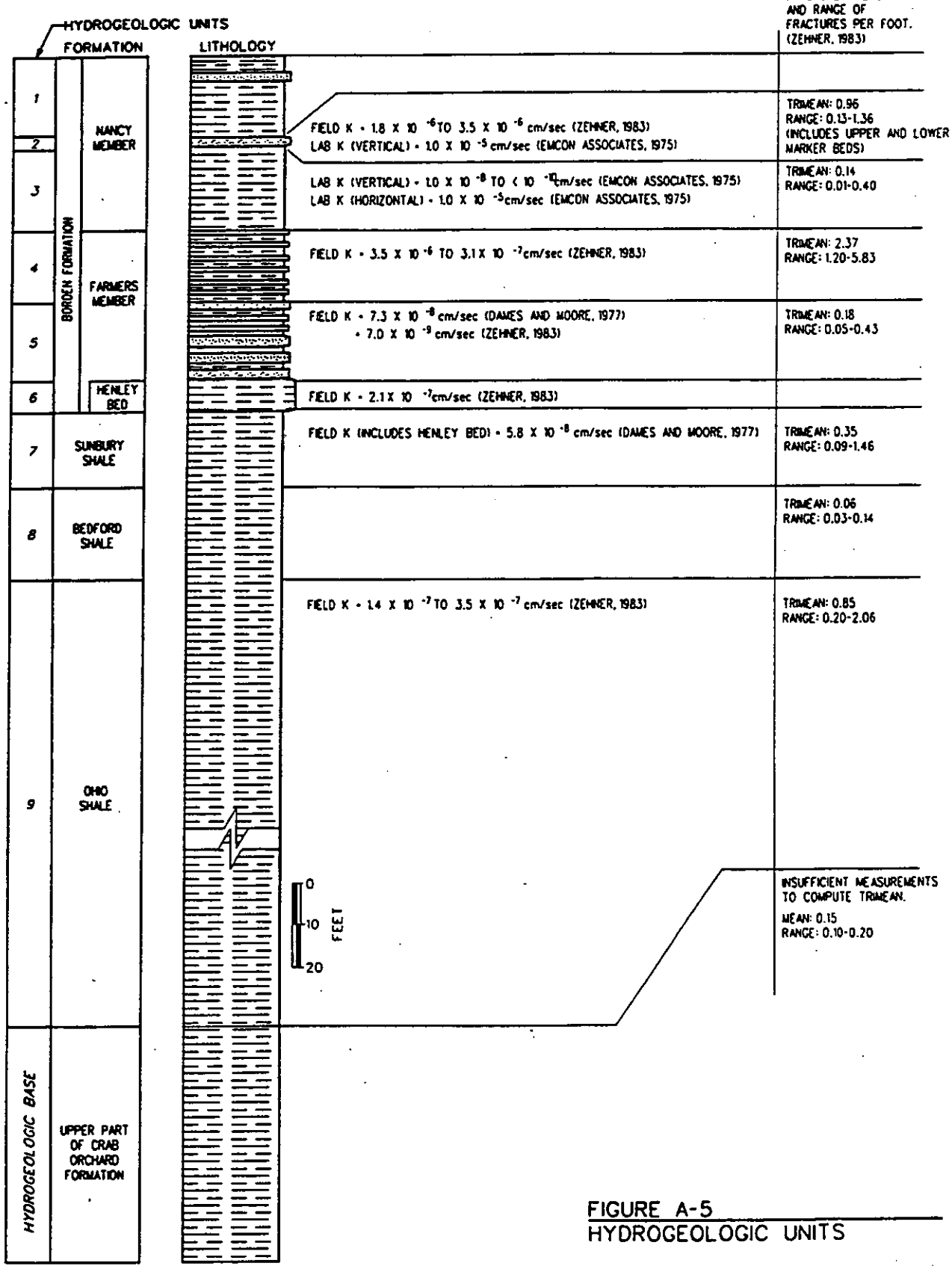

FIGURE A-5
HYDROGEOLOGIC UNITS

MAXEY FLATS DISPOSAL SITE
MOREHEAD, KENTUCKY

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The LMB and the Farmers Member are the two principal geological formations at MFDS by which leachate migrates to the hillslopes.

Soil cover on the hillslopes in MFDS area averages 5 feet thick, but ranges from 0.5 to greater than 18 feet thick. The soil types are generally an upper soil unit of clayey silt, and a lower soil unit of silty clay.

Hillslope runoff at MFDS typically travels in narrow, high gradient, steep walled channels that connect to the perennial streams that flow along the base of the plateau at the periphery of the MFDS area. As shown in Figure A-6, Drip Springs, No Name, and Rock Lick creeks flow through relatively level valleys bordered by steep hillslopes. Drip Springs Creek, located on the west side of MFDS, and No Name Creek, located on the east side of MFDS, flow into Rock Lick Creek to the southwest of MFDS. Rock Lick Creek flows into Fox Creek approximately 2 miles southwest of MFDS. Fox Creek flows into the Licking River, approximately 6.5 miles west of MFDS, which empties into the Ohio River near Cincinnati, Ohio, approximately 100 miles from MFDS.

A1.4.3 Demography

The MFDS is located approximately 16 miles south-southeast of Flemingsburg in Fleming County. In 1980, Fleming County had a total population of 12,575. Within a one-half mile radius of MFDS, there existed approximately 11 residences. The actual population of this area was 25 people, 14 male and 11 female. Of the 11 females, 7 were of childbearing age. Only 2 children were present in the population. It has been estimated that approximately 152 persons resided within a 1-mile radius of the facility. An estimated 663 people lived within 2.5 miles of MFDS, of which an estimated 148 were women of childbearing age and an estimated 148 were children (under the age of 14). The MFDS study area population represented approximately 5.3 percent of the total Fleming County population.

Nine residences were purchased within the Buffer Zone. Occupants still remaining in these residences will relocate prior to the start of IRP construction activities.

A1.4.4 Meteorology

A brief discussion of meteorology in the MFDS area is presented here.

The climate of the MFDS area is classified as Temperate Continental. The summers are generally warm with temperatures above 90 degrees Fahrenheit (°F) occurring approximately 30

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days per year. The winters are cold but not extreme, as temperatures below 0°F generally occur only a few times per year.

Average annual precipitation in the MFDS area is approximately 44 inches. A 100-year rainstorm occurred in 1988. A maximum 24-hour precipitation total of 5.8 inches would be expected for a 100-year return period ("100-year flood") in the area. Snowfall in the area averages approximately 18 inches per year with the highest monthly average occurring during January.

Wind distribution data for the MFDS area reveals a fairly even annual distribution of wind direction, with the greatest frequency from the south and southwest directions. The average wind speed observed over a 10-year period was 9.7 miles per hour. Average wind speeds are greater during the spring and winter seasons and the greatest percentage of calm wind conditions occur during the summer months. A maximum wind speed of 90 miles per hour associated with a return period of 100 years is estimated for the MFDS area.

A1.4.5 Biota

The hillslopes adjacent to MFDS are primarily deciduous and include hickories, oak, ash, maple, black gum, tulip poplar, and beech.

Wildlife species common to the MFDS area are those associated with the oak-hickory forest of the ridge slopes, the adjacent farmlands, or a mix of these two habitats. This mix benefits such game species as white-tailed deer, woodchuck, opossum, fox squirrel, and migrating woodcock, and furbearers such as red fox, gray fox, long-tailed weasel, raccoon, and striped skunk. Rough grouse and gray squirrel are also hunted in the more extensively wooded areas. During late autumn and winter, numerous Canada geese and mallards, wood ducks, green-winged teal, and other game waterfowl feed on open crop lands of the region. The acorn and hickory mast (nuts accumulated on the forest floor) produced on the hillslopes of MFDS probably constitutes an important part of the diet for white-footed mice, deer, squirrel, and turkey.

Several species of fish that are native to the Licking River drainage have been collected from Fox Creek including muskellunge, channel catfish, rockbass, spotted bass, largemouth bass, white crappie, various sunfish, and sauger.

There are no federal threatened or endangered species (animal or plant) known to exist within the vicinity of MFDS. Blazing Star, a plant species listed as being of special concern by the

Kentucky Preserves Commission, does occur within a 2.5 mile radius of MFDS, but would not be threatened by any physical activities at MFDS due to its distance (approximately 1.5 miles) from MFDS.

A1.4.6 Natural Resources

A1.4.6.1 Water Resources

The perennial streams at the base of the plateau and a few ponds fed by surface water runoff are used as freshwater supplies for livestock raised in the valleys. Fox Creek is also used for light recreational fishing. The Licking River serves a variety of uses including recreational fishing and boating. The Licking River also serves as an important source of public drinking water for municipal water systems upstream and downstream of MFDS. The nearest municipal water intake downstream of MFDS is the West Fleming Water District intake on the Licking River near the town of Blue Licks Spring, about 54 river miles downstream of MFDS.

A1.4.6.2 Geological Resources

The area of Fleming County around MFDS has limited potential geological resources that could have public or economic value. Potential geological resources include building stone, clay and shale, petroleum, oil shale, and groundwater. Building stone was once extensively quarried in the area for dimension construction stone, but is uneconomical at this time because of the lower cost of concrete and imported stone. Quarries were typically located in areas with little or no overburden on the lower Farmers Member, with the larger quarries located on relatively extensive flats or benches, and the smaller quarries often located on spurs or noses of ridges.

The shale of the Nancy Member may be suitable for lightweight aggregate production, for brick or other heavy clay products, and for low-permeability layers for construction of farm ponds, landfill linings, and earthen dam cores. Some minor oil and gas production is known from the area but the producing geologic unit (Bisher Limestone) is not present beneath MFDS. Local gas fields are now abandoned.

Groundwater resources in the area are very limited, with adequate residential supplies (100 to 500 gpd) generally available only in the valley bottoms. In wells drilled on the tops of hills, the wells completed in the Borden Formation yield little water (less than 100 gpd), and almost no water is produced from wells completed in shale. Wells completed in the Ohio shale can provide up to 500 gpd but locally can be of poor quality.

The residents of the Maxey Flats area have been on a public water supply since about 1985. Before this date, water was typically obtained by the residents on top of the plateau from willow wells located in the soil or weathered shale of the Nancy Member, which supplied approximately 25 to 50 gpd. Most investigators have considered the water in these willow wells to be from a perched water table. The source of this water was apparently from secondary porosity in the soil or weathered rock, and also from roof downspouts routed into the wells. These willow wells were unreliable sources of water and may have acted more as water storage cisterns than as wells. Prior to the installation of the public water supply system, some residents at the base of the plateau obtained water from hand-dug wells in the alluvium or colluvium.

A1.4.6.3 Timber Resources

The wooded areas within a 2.5-mile radius of MFDS are classified as evergreen, deciduous, or mixed forest lands. The hillslopes in the area are mostly classified as deciduous forest land, except the hillslope to the northeast of the Restricted Area which is classified as mixed deciduous and evergreen forest. The timber on the hillslopes was harvested about 50 to 60 years ago and two abandoned logging roads are present on the hillslopes. Trees present on the hillslopes include hickory, oak, ash, maple, black gum, tulip poplar, and beech.

A1.5 Summary of Existing Analytical Data

Numerous investigations have been completed to identify contamination at MFDS and to determine the potential for contaminant migration. The number of published papers and reports on MFDS is in the hundreds. The RI Report is particularly important, it is the most comprehensive description of the nature and extent of contamination and the physical characteristics of MFDS. The RI and FS form the basis for the ROD, Consent Decree and SOW. This RI Report concentrated on the potentially contaminated area adjacent to the Restricted Area. The environmental media sampled outside the MFDS boundary included soil, soil water, surface water, stream sediment, soil and rock core from boreholes, groundwater, stream sediment, selected food crop samples, and selected background samples. Leachate was the only medium sampled from within the Restricted Area.

A brief summary for each of the above environmental media follows, including data ranges of the sampling events. For more specific information of data collected refer to the corresponding section within the RI Report.

- ***Leachate.*** Leachate samples from trenches in the Restricted Area were analyzed for radiological characteristics by a number of investigators during the history of the MFDS. The most extensive study, which also summarizes previous work, was performed by BNL.

During 1977, BNL performed a reconnaissance study of trenches in the Restricted Area to determine the spatial variation of radionuclide concentrations. Leachate samples were obtained from trench sumps that had sufficient leachate for sample collection. These samples were analyzed for tritium and gamma-emitting radionuclides. The reconnaissance study demonstrated that tritium was present in all sampled trenches and had concentrations ranging from 250 picocuries per milliliter (pCi/ml) to 7,400,000 pCi/ml. The gamma-emitting radionuclide cobalt-60 (Co-60) had concentrations ranging from below the detection limit to 840 pCi/ml. Cesium-137 (Cs-137) was detected in about half of the samples and had a maximum concentration of 170 pCi/ml. Cs-137 and americium-241 (Am-241) concentrations were below the detection level in most trenches, having maximum concentrations of 22 pCi/ml and 9.3 pCi/ml, respectively.

Based on the results of the radiological reconnaissance study completed in 1977, BNL chose 15 trenches for additional sampling. This sampling included analyses for additional radionuclide concentrations with time. The long-term sampling showed that tritium and Sr-90 were present in all the trenches that were sampled. From 1976 to 1981, the tritium concentrations in the selected trench sumps ranged from 1,000 to 4,600,000 pCi/ml and Sr-90 concentrations ranged from 0.44 to 1,800 pCi/ml. Most of the trenches sampled contained Co-60 and Cs-137. Concentrations of Cs-137 ranged from 0.023 to 71 pCi/ml. Less than half the samples had detectable Cs-134, with a maximum observed concentration of 1.2 pCi/ml. Slightly more than half the samples had detectable Am-241, with the maximum detected concentration being 45 pCi/ml. Samples analyzed for Pu-238 had concentrations ranging from 0.0048 to 350 pCi/ml. The Pu-239 and Pu-240 isotopes are not detected individually, and were reported as combined concentrations ranging from 0.0012 to 21 pCi/ml.

Numerous organic compounds, inorganics, cyanide, and total phenolics were detected in the trench leachates sampled from the Restricted Area during the RI. Parameters measured during the RI program were normally associated with fuel and non-fuel cycle low-level waste and were similar to the historical data available for the MFDS. Concentrations of specific chemicals were highly variable among the trench sumps sampled. This variability is caused by the heterogeneous nature and differential placement of waste deposited within the trenches, and the restricted hydrologic mixing between different parts of the trench. Trench leachate appeared to be highly buffered, principally by chelating agents, carbonates and bicarbonates, and typically exhibited near-neutral pH values despite the presence of numerous acidic compounds, such as phenols and organic acids. The Resource Conservation and Recover Act (RCRA) sulfide and ignitability screen tests for trench leachate samples yielded negative results. Additionally, organic and inorganic analyses performed on the trench leachate samples indicated that EP Toxicity test results would also be negative.

- ***Soil.*** Soil samples collected during the RI were analyzed for tritium. Samples were collected on the hillslopes at the background soil sample locations and at the food crop study areas. Tritium concentrations in the soils collected at the back-

ground locations and food crop areas were less than 10 pCi/ml in all but one instance. A background sample was reported to contain 200 pCi/ml of tritium. This sample was mistakenly analyzed with extremely contaminated trench leachate samples at the contract laboratory and the result was considered suspect. Results of tritium analyses for the soils collected during the two sampling rounds varied widely from less than 10 to 560,000 pCi/ml.

Soil samples collected during Round 2 and the background and food crop study areas, were analyzed for gamma-emitting radionuclides in addition to tritium. Radionuclides detected in the soils included potassium-40 (K-40), Cs-137, Radium-226 (Ra-226), Thorium-232 (Th-232), Uranium-238 (U-238), and Co-60. Of these radionuclides, K-40, Ra-226, Th-232, and U-238 are naturally-occurring. The concentrations of the naturally-occurring radionuclides in soil samples were within the range common in soils of this area, particularly for areas with shale bedrock.

Cobalt-60 was detected in one soil sample at a low concentration. This was probably derived from the MFDS waste because there was no other likely source for this radionuclide.

Cesium-137 concentrations in soil samples collected ranged from less than 0.1 picocuries per gram (pCi/g) to 0.8 pCi/g. Because low concentrations of Cs-137 occur in shallow soils worldwide from fallout from nuclear weapons testing, it was impossible to differentiate the source of Cs-137 in many of the soil samples.

Selected soil samples were analyzed for the EPA Region IV Target Compound List (TCL) chemicals, which includes volatile organics, base-neutral and acid extractable organics, pesticides, and polychlorinated biphenyls (PCBs). The only volatile organic chemical detected in significant concentrations in the soil samples was toluene. Fourteen of the 16 soil samples collected from the site area contained toluene in concentrations ranging from 40 to 250 parts per billion (ppb). It is possible that toluene in soil samples from the area could have been related to contamination originating from the Restricted Area, since toluene was a component of the volatile organic fraction of the trench leachate. However, toluene concentrations displayed no statistical correlation with tritium and no geographic correlation could be discerned between the sample locations with elevated toluene concentrations and the areas with elevated tritium concentrations. Samples collected for the RI may have been contaminated by the tape used to seal the sample containers.

Other volatile organic chemicals present above detection levels in the soil samples were acetone and methylene chloride. The presence of these volatile organics chemicals was probably due to laboratory contamination since they were present in relatively low concentrations, and are common intralaboratory contaminants. Semi-volatile organic compounds were not found above detection limits in any of the soil samples.

Pesticides were not detected in the soil samples from the area. However, dieldrin was detected in a food crop sample at a concentration of 290 ppb. This pesticide was probably related to routine agricultural practices within the food crop study area. PCBs were not detected in any of the soil samples.

The soil samples analyzed for the EPA TCL organic chemicals were also analyzed for the EPA Target Analyte List (TAL) inorganic chemicals. In addition, the soils were tested for the following RCRA parameters: pH, sulfide, ignitability, acid reactivity, base reactivity, and water reactivity. Twenty inorganics were found at concentrations above detection limits in the hillslope soils, background soils, and food crop study area soils.

Typical inorganic concentrations were reviewed in several references, including one study where analyses included soils and rocks similar to those found in the area. All the soil samples, including the background and food crop study area samples, displayed inorganic concentrations within ranges considered normal for soils, with one exception. Two soil samples contained arsenic in concentrations of 60 and 106 parts per million (ppm).

The concentrations of cyanide and total phenolics were less than 2 ppm for soil samples. Negative results were reported for RCRA parameters. Organic and inorganic analyses performed on soil samples indicated that EP Toxicity test results would also have been negative.

- ***Soil Water.*** Soil water (dissolved solids) were sampled. Well Point 1 (WP-1) was the only well point that produced sufficient water for sampling purposes. The soil water samples were analyzed for tritium, isotopic gamma, carbon-14 (C-14), Sr-90, and gross alpha. If gross alpha specific activity exceeded 0.015 pCi/ml, then Ra-226 and isotopic Pu and U were included in the analyses. Soil water samples were also tested for TCL organic chemicals, and the TAL inorganic chemicals. The following RCRA parameters were also analyzed: pH, sulfide screen, and ignitability screen.

  Results of the soil water analyses indicated that the soil water near the northeastern corner had low concentrations of some radionuclides. Tritium concentrations ranged from less than 10 to 50 pCi/ml. The only other radionuclide above the detection limit was Sr-90, which was detected in only one sampling round at a concentration of 0.011 pCi/ml. Toluene was detected in the Round 2 sample at the detection limit of 5 ppb. The concentrations of inorganic chemicals detected in the soil water samples were generally lower than results obtained from the groundwater monitoring wells. The concentrations of cyanide and total phenolics were less than 10 ppb. Results of the RCRA parameter analyses were negative. The Round 2 analyses for major anions, cations, and other geochemical parameters, such as alkalinity and dissolved solids, resulted in lower values than for groundwater samples obtained from the monitoring wells. The results of the dissolved solids analysis were an order of magnitude lower than the groundwater samples. Thus, indications were that the water in this well point was mainly derived from surface

water infiltration. The tritium detected in the Round 1 well point water sample was probably from evaporator discharge or from surface water runoff from contaminated soils.

- ***Groundwater.*** Groundwater samples obtained during the RI were analyzed for radionuclides, TCL organic chemicals, and TAL inorganic chemicals. A limited number of soil samples were tested in the laboratory for permeability values. Groundwater samples were analyzed for tritium, C-14, Sr-90, and gross alpha. If gross alpha activity exceeded 0.015 pCi/ml, then Ra-226, and isotopic Pu and U were included in the analyses. Supplemental tritium data were obtained from pore water distilled from samples of rock and soil core collected during the drilling program. Groundwater samples were also tested for the TCL organic chemicals, TAL inorganic chemicals, and RCRA parameters. Groundwater samples collected during the second round of sampling were analyzed for selected major anions and cations.

  Tritium was found in concentrations ranging from 98 to 2,000,000 pCi/ml in those wells where it was detected. Other radionuclides detected in the wells included Co-60, Sr-90, Ra-226, U-233/234, U-235, U-238, Pu-238, and Pu-239/240. Co-60 was found in the wells outside the west boundary of the Restricted Area below the detection limit in the other sampled wells. Sr-90 was detected in all samples in Round 1 and in three samples in Round 2. The highest Sr-90 detected concentrations in Round 1 were in samples from the monitoring wells completed in the LMB outside the southeast corner of the Restricted Area, but Sr-90 was not detected in these wells in Round 2. Ra-226 was reported at concentrations from below the detection limit to 0.42 pCi/ml. The sample with the highest Ra-226 level in both sampling rounds was from a well screened in the Ohio shale. The Ohio shale is known to be enriched in naturally-occurring uranium, and the Ra-226 values were probably due to the natural decay of this uranium. U-233/234 was reported at concentrations ranging from 0.0014 to 0.105 pCi/ml. U-238 concentrations ranged from 0.0005 to 0.0051 pCi/ml. U-235 concentrations were above the detection limits in three wells.

  Pu-238 concentrations ranged from 0.00005 to 0.36 pCi/ml. Pu-239/240 concentrations ranged from 0.0004 to 0.005 pCi/ml.

  Because of unsaturated conditions in stratigraphic units at the MFDS, supplemental tritium contamination data were obtained from pore water in samples of rock and soil core taken from the boreholes. Tritium concentrations in the groundwater collected from the monitoring wells and in the pore water were compared to determine the relationship between the water that travels through fractures and the water that moves more slowly through, or is trapped within, the primary porosity. The results of this comparison are presented in the RI.

  Data show that some organic chemicals were present in monitoring wells. The wells with several organic contaminants are located outside of the west central part of the Restricted Area and had the highest levels of radiological contamination.

Benzene was the major non-chlorinated organic contaminant in the wells. Benzene ranged in concentration from less than 5 to 96 ppb. Toluene was present in four wells samples and ranged from 6 to 9 ppb. Naphthalene was detected in one sample at a concentration of 10 ppb.

Chlorinated volatile organic compounds represent a major fraction of the chemical contamination in the four wells from the west side. The phenol and carbon disulfide detected in the wells could be naturally-occurring chemicals from the organic-rich Ohio Shale. Toluene and benzene were present close to analytical detection limits and could have been naturally-occurring products of the organic-rich shale or could have been from intralaboratory contamination. Acetone appeared to be an isolated contaminant because it was detected in only two groundwater samples during the RI program. The concentrations of acetone exceeded concentrations normally associated with intralaboratory contamination. The acetone could have been introduced into the well during previous well monitoring activities.

No pesticides or PCBs were detected in the groundwater samples from the MFDS. The natural inorganic composition of groundwater is dependent upon the chemical composition of the rock through which it flows and the residence time in the rock. In addition to major anion and cation analyses, groundwater was analyzed for the TAL inorganic chemicals.

Arsenic, sodium, manganese, cyanide, and total phenolics were present above background concentrations in some wells. Concentrations of arsenic were high in wells on the west side, ranging from 25 to 90 ppb as compared to background concentrations of less than 10 ppb. However, several of the detected arsenic values were rejected or listed as estimated values during the data validation process because of a poor spike recovery.

Concentrations of sodium were high in the west side wells and ranged from 272,000 to 466,000 ppb, as compared to background concentrations of 222,000 and 268,000 ppb. Concentrations of sodium in all other wells were close to the background concentrations except for the more saline waters of the Ohio shale which had concentrations as high as 12,900,000 ppb.

In three of the west side wells, and a south side well, manganese concentrations ranged from 3470 to 4870 ppb, an order of magnitude higher than values in the background well. Concentrations of cyanide were present in samples ranging in concentration from 10 to 55 ppb as compared to background levels less than 10 ppb. Concentrations of total phenolics were present with concentrations ranging from less than 10 to 1,020 ppb, as compared to less than 10 ppb for the background well. Such naturally-occurring high concentrations of total phenolics in the Ohio shale could have been due to the high organic content of the shale.

Though present in the groundwater, concentrations of aluminum, cadmium, calcium, chromium, potassium, nickel, iron, lead, magnesium, and vanadium were generally in the same range as concentrations present in the background well. The inorganics barium, cobalt, copper, selenium, and thallium were above detection limits only in monitoring wells completed in the Ohio Shale (UB-2 and UA-4). The inorganics, antimony, beryllium, and silver were below detection limits in the monitoring wells.

RCRA groundwater tests had negative results.

- ***Surface Water and Sediment.*** Surface water and sediment samples were analyzed for tritium and other radionuclides, volatile organic chemicals, and TAL inorganic chemicals.

  Tritium was present in higher concentrations in the Round 2 surface water and sediment samples than in the samples collected during Round 1. The main differences between these sampling periods were the cooler seasonal temperatures and the increased amount of precipitation that occurred in Round 2. Cooler ambient air temperatures are known to increase the transport of tritiated gases and vapors from the trench dewatering sumps by natural convection. Precipitation may also have increased the amount of tritium leaving the Restricted Area due to larger surface water flows and associated flushing of tritium from contaminated soil.

  Tritium concentrations were highest at the South Weir and the West Pond, and lower in the East Pond. Most of the surface water flowing from these structures is surface runoff from the PVC trench covers and the exposed soils within the Restricted Area. The higher tritium concentrations at the South Weir and the West Pond could have been due to the fact that drainage systems of these structures included trenches with some of the highest tritium concentrations. Other possible sources of tritium detected at the weir and ponds could have been subsurface flow of tritiated water to the ground surface through fractures.

  Surface water and sediment samples were analyzed for radionuclides. Ra-226 was the only radionuclide other than tritium found in concentrations above detection limits in the surface water samples. Potassium-40, Ra-226, and Th-232 are naturally-occurring radionuclides and were present above the detection limit in all of the sediment samples. Cesium-137 was present above the detection limit in some of the sediment samples. Cesium-137 is not a naturally-occurring radionuclide, but has been widely distributed in the environment by worldwide fallout from nuclear weapons testing. Co-60 concentrations were below the detection limit in all of the samples.

  The concentrations of radionuclides detected in the vicinity of the MFDS, other than tritium, were not above background radioactivity levels. The concentrations of these radionuclides were generally higher in the sediments collected from the stream sampling stations than in the sediments collected from the South Weir and the East and West ponds. Most samples with detectable radionuclide concentra-

tions, other than tritium, were sediment samples. Only two surface water samples contained detectable concentrations of Ra-226. The concentrations in these samples reflected natural radioactivity or fallout from atmospheric testing of nuclear weapons, and did not indicate any movement of radionuclides other than tritium and, possibly, Cs-137 away from the Restricted Area in the surface water or sediment.

The volatile organic chemicals, acetone, 2-butanone, toluene, methylene chloride, and chloroform, were detected in some surface water and sediment samples. Volatile organic chemicals were also present in some of the background samples collected in Daniel Boone National Forest and at stream sampling Station A, located upstream of drainages that lead from the Restricted Area. Toluene and acetone were detected in background samples in surface water and in sediment. Volatile organic chemicals were also present in the field blanks and the associated trip blanks.

The above volatile organic chemicals, which are common intralaboratory contaminants, appeared throughout the surface water, sediment, background, field blanks and trip blanks. These volatile organics were not present in the surface water and sediment analyzed for the Site Operations Contractor's Environmental Monitoring Program in 1987. Probable sources of these chemicals were introduction during sample collection and preparation and/or intralaboratory contamination.

Analyses were performed for semivolatile organic chemicals detected phthalate esters in both the surface water and sediment samples at the South Weir and the East and West Ponds. Phthalate esters were present, but below detection limits, in the surface water and sediment samples collected at some of the stream sampling stations. Phthalate esters were not found in the background surface water and sediment samples, or in the associated field and trip blanks. Since phthalate esters are common plasticizers, a possible source of this contaminant could have been the PVC plastic trench cover in the Restricted Area. This was supported by the relatively high concentrations of phthalate esters detected at the weir and ponds that received surface water drainage from the plastic covers.

HCB is a pesticide γHBC "Lindane"

In addition to phthalates, other semivolatile organics were detected in surface water and sediment samples. Hexachlorobenzene was detected in the surface water in Round 2. A possible source of hexachlorobenzene was the breakdown of chlorinated pesticide compounds. Phenol was present in a Round 1 sediment sample. Also, three polyaromatic hydrocarbons were present in a sediment sample collected from the West Pond during Round 2: phenanthrene, fluoranthene, and pyrene. These compounds are typically associated with petroleum-based lubricants and/or fuel and were probably derived from maintenance machinery.

Pesticides were also detected in the surface water at the West Pond and at Station B. The pesticides were found in low concentrations and are probably associated with routine pest control practices.

Although the MFDS may have contributed some of the inorganic chemical content of the surface water and sediment samples, data indicated that any inorganic contamination in the surface water and sediment attributable to the MFDS was insignificant.

- ***Air.*** The operations contractor performed continuous, routine air monitoring at MFDS and addressed these studies in the annual MFDS operations contractor reports. No air quality investigation was conducted during the RI program at MFDS. This section reviews the atmospheric monitoring data presented in the MFDS operations contractor annual reports for 1983 to 1987. The primary source of airborne radiation prior to 1987 was the evaporator system. Other potential sources of airborne radiation were tritium transpiration by trees, diffusion of tritium vapor directly through the trench cap, and the ascension of tritium-bearing gases escaping from trench sumps.

  The average gross alpha concentration measured at the air monitoring stations around the perimeter of the Restricted Area ranged from 0.012 to 0.018 picocuries per cubic meter (pCi/m^3) of air during the years 1983 to 1987. For comparative purposes, these gross alpha average concentrations were less than one-third of the maximum concentration permitted outside of the Restricted Area by the Commonwealth for an individual alpha-emitting radionuclide such as Pu-239 (0.07 pCi/m^3). Gamma-emitting radionuclides detected in samples collected from 1983 to 1987 were consistently reported as equal to or less than the minimum detection limits of the procedure (Westinghouse Electric Corporation, 1988). The average gross beta concentration ranged from 0.038 to 0.06 pCi/m^3 during the years 1983 to 1987. For comparative purpose, this average was three orders of magnitude lower than the maximum concentration permitted outside the Restricted Area by the Commonwealth for Sr-90 (30 pCi/m^3). Strontium-90 was used for this comparison because it had the most restrictive regulatory limits for the beta-emitting radionuclides that could be released into the air from MFDS.

  The tritium activity measured at the air monitoring stations ranged from 240 to 3,000 pCi/m^3 during the years 1983 to 1986, and averaged 275 pCi/m^3 in 1987. For comparative purposes, the average tritium activity for 1987 was less than 0.2 percent of the maximum permissible concentration (200,000 pCi/m^3) for areas outside of the Restricted Area. The highest average of measured airborne tritium concentrations at a single location during 1987 was 1,260 pCi/m^3. This was 0.6 percent of the average annual maximum permissible concentration of airborne tritium (200,000 pCi/m^3) allowed outside of the Restricted Area by the Commonwealth regulations.

  The trend of airborne tritium concentrations closely followed the release of tritium by the evaporator system. Tritium concentrations measured at the air monitoring stations markedly decreased during 1983 and 1987 when the evaporator was not operating, and again in 1986 when the evaporator was operating at lower capacities. An air monitoring station located at the perimeter of the Restricted Area next to the western trenches also showed a decline in tritium concentrations during the times of

low evaporator output, but to a lesser extent than the other perimeter air monitoring stations. Possible sources of the tritium detected at this station were transpiration of tritium from the trees located on the western hillslope, tritiated water vapor rising from the trench sumps, and/or tritiated water vapor diffusing directly through the trench caps. The leachate in the western trenches contained some of the highest levels of tritium at MFDS and many of these trenches had unsealed sump openings that could have facilitated the escape of tritiated water vapor.