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Kentucky UST Field Manual

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Submitted To
PETROLEUM UNDERGROUND STORAGE TANK ENVIRONMENTAL ASSURANCE FUND COMMISSION

BY

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KENTUCKY UST FIELD MANUAL

PREFACE

This study was undertaken to address the removal and closure of defective petroleum underground storage tanks in Kentucky. The authors of this report want it to be known that the recommendations of this study should not be applied to any other environmental contaminants found in Kentucky.

INTRODUCTION

In approaching the disposition of an UST, a systematic approach is required to insure that the health and safety of humans and ecological systems are protected. The procedure defined in this document is based on the best scientific and engineering information available in the current literature and logical development from that literature.

The best approach to reduce the environmental impact from USTs includes the following:

1. Rapid response to replacing defective USTs
   a. Curtailing the loss of free product into the environment
   b. Recovering free product and with petroleum products saturated soil
   c. Remediation of contaminated soil and groundwater
   d. Exposure control measures on those sites not amenable to remediation
   e. Application of in-situ remediation technologies

2. Shift of emphasis to prevention, monitoring and state-of-the-art tank technology.
   a. Double-walled, reinforced fiberglass tanks with pump sumps, fill sumps and fail-safe technology
   b. Groundwater Protection Plans developed for UST installations

Using these concepts as guidance, a classification of sites was developed, procedures for placing each site into a class were outlined, requirements for closing for each class of sites were defined, and a mechanism to inventory site closures was developed. A summary of the study without supporting documents is included for reference. A copy of the full report can be obtained from the Kentucky Water Resources Research Institute, University of Kentucky.

BACKGROUND FOR THE STUDY

This study was commissioned by the Petroleum Storage Tank Environmental Assurance Fund Commission with the following charge:

1. To address standards for levels of contamination requiring corrective action consistent with accepted scientific and technical principles.
2. To recommend a matrix or scoring system to be used for:
   a) ranking sites as to actual or potential harm to human health and the environment caused by a release of petroleum from a petroleum storage tank, and

b) establishing standards and procedures for corrective action that shall adequately protect human health and the environment.

3. To address all compounds individually and collectively known as petroleum.
4. To produce a report that shall be scientifically defensible.

Provisions for reporting, monitoring, and remediating USTs were included under Subtitle 1 of the 1984 Hazardous and Solid Waste Amendment (HSWA) to RCRA. This required the U.S. EPA to develop a comprehensive UST regulatory program (U.S. EPA, 1987). The latter appeared in the Federal Register in September 1988, and became effective December 22 of the same year (U.S. EPA, 1988, 40 CFR parts 280 and 281). Kentucky adopted this action in principle and took further action in 1992 to clarify reporting and cleanup requirements (House Bill 540, amendment to KRS 224.877, now numbered KRS 224.01-400). Guidance on UST removal, soil sampling and analysis, quality assurance and other concerns was addressed by the Natural Resources and Environmental Protection Cabinet in a document dated December 1, 1992 (Natural Resources and Environmental Protection Cabinet, 1992).

The basic assumptions made for the study are:

1. The potential for a given site to be a risk to human health and ecological systems is a function of the quantity of the product present in the soil or groundwater, the proximity of the site to potential human or ecological receptors, and the length of time since the product was released.

2. It is practically impossible to cleanup a petroleum spill to "background" or "zero" concentrations of the constituents found in petroleum products.

3. The cleanup of all contaminated soil and dissolved product in groundwater is not always possible under current technology. It is desirable to cleanup soils and groundwater to the maximum extent practical to reduce any present or future risk.

4. State-wide cleanup levels of contaminated soil and dissolved product are undesirable. Because conditions vary from region to region, a general approach that can be used to quickly establish site-specific levels instead of setting state-wide cleanup levels is desirable.

5. A risk-based contaminant standard should be based on a "reasonable case" set of assumptions rather than a "worst case" approach.

We have assumed that the kinds of problems that occur from a leaking underground storage tank may include:

1. the potential contamination of the soil in the backfill and soil on the sides of the pit wall and the bottom of the pit,

2. contamination of the groundwater,

3. if surface water streams and wetlands or other sensitive ecological systems are close to the site, they may become contaminated as well, and

4. fumes from the leak may move up through the soil to the surface or move in buried trenches that contain conduits to buildings or the surface.

The cost of the cleanup to the citizens of Kentucky is an important consideration. Cost of cleanup will have a large range depending on the degree of contamination at the site. While cost could not be integrated into the study matrix, it remains an issue that must be addressed by the policy makers of the Commonwealth.

STUDY METHODOLOGY

The study was conducted by a multi-disciplinary team of researchers from three Kentucky universities. The study method involved literature search, interviews, both phone and personal, with knowledgeable people working with USTs, development of theoretical considerations, application of mathematical models, and compilation of data and synthesis of the information collected.

An interactive process was developed in the latter part of the study to get feedback on the information developed and the evolving ideas produced by the team.

KENTUCKY PHYSICAL SETTINGS

UST Distribution

The distribution of the tanks in Kentucky and the relationship to the natural conditions is an important component of the study. Information on the USTs was obtained from the Underground Storage Tank Branch and the Commission files. Information on the geology and soils of Kentucky was obtained from the data bases at several agencies.

The distribution of tanks in Kentucky as determined from the data base on permitted tanks is summarized in Appendix II of the report. There may be as many as 14,000 tanks not permitted but the data base analyzed can be considered representative of Kentucky. The USTs are relatively evenly distributed across the state with highest concentrations in eight metropolitan areas (Louisville, Lexington, and Covington with more than 10 million gallons of tank capacity each and Ashland, Elizabethtown, Henderson County, Warren County, and Christian County each with approximately 4 million gallons of tank capacity.)

Twenty-seven counties have more than 1 million gallons tank capacity and 82 have less than 1 million gallons capacity and have less than 200 tanks per county. Twenty-seven percent of the tanks in Kentucky are less than 2000 gallons capacity and 60 percent range between 2000 and 30,000 gallons capacity.

Groundwater Occurrence

The occurrence of groundwater in Kentucky has not been well documented in the literature. The recent availability of a data base of water wells drilled in Kentucky allowed for very preliminary analysis on the depth of water wells and the depth to water in those wells. These two parameters were analyzed, and it was found that the average depth of a water well in Kentucky, based on 10,285 data points, is 145 feet, and the modal depth ranged between 60 and 100 feet. It was also found that the average depth to water in these wells was 65 feet with a modal depth ranging between 20 and 30 feet. The data base was also searched for the depth to bedrock in Kentucky, and it was found to average 15 feet. A more detailed study of the depth to bedrock was conducted by Naugle and discussed later. Probably the most significant conclusion that one can draw from the studies of the data bases is that potable groundwater comes from deeper sources than previously documented and that springs no longer provide the primary source of potable water except in very isolated cases.

Geology of Kentucky

The geology of Kentucky is well documented in the USGS 7.5" Quadrangle maps. The geology has been grouped into regions based on the age and types of rocks found at the surface. Five distinct regions are defined; the Eastern Kentucky Coal Field, the Blue Grass Region, the Mississippian Plateaus, the Western Coal Field, and the Purchase Region. Another geologic region often identified is the Alluvium of the Ohio River.

It is important in site-specific studies that the geology be known, and that the use of the Quadrangle maps is essential. The development of a generalized approach to the utilization of different geologic regions for UST analysis has been incorporated in this study, but the use of geological maps is important in the analysis.

Rock Materials

The state is underlain by different kinds of bed rock materials which influences the occurrence and movement of groundwater. The ability for petroleum products to move through the rock systems is related to the physical properties of the petroleum products and the physical and chemical properties of the rock materials. Because Kentucky is in a humid climate zone, rainfall produces sufficient quantities of water to keep a near surface soil and rock zone saturated to partially saturated most of the time. This water is not generally considered potable groundwater and not used for human consumption, but this water can play a role in supporting sensitive ecological systems if they are present.

There are three broad kinds of geologic materials present in the state that can be related to groundwater occurrence and flow is briefly summarized below.

Geologic Units That Support Porous Flow Of Groundwater (Type A)

Unconsolidated and semi-consolidated rock materials that conduct groundwater through a network of pores between individual grains can be found along the larger streams in the State and the most western physiographic province, the Jackson Purchase. Hydraulic conductivity ranges between 1 and 10^{-3} cm/sec and porosity ranges between 25% and 50%.

Geologic Units That Support Fracture Flow of Groundwater (Type B)

Those areas underlain by granular rocks (shales and sandstones) store water in the pores, but the primary zone for near surface transport of water is the near surface fracture zone. Fractures that are interconnected and large enough to transport water generally occur within 100 feet of the surface. Hydraulic conductivity ranges between 10^{-5} cm/sec to 10^{-9} cm/sec and porosities range between 0% to 30%.

Geologic Units That Support Fracture/Conduit Flow of Groundwater (Type C)

A significant portion of the State is underlain by carbonate rocks. These rocks are also fractured but because of their high susceptibility for dissolution, conduits are developed and large volumes of water move from the surface to these conduits, which eventually discharge the water to the surface through springs. Hydraulic conductivities values will have a very large range. For those limestones that are not well developed in karst features, fracture flow dominates, and the hydraulic conductivities will range between 10^{-4} cm/sec to 10^{-8} cm/sec and porosities will be 0% to 20%. For conduit flow the hydraulic conductivity can vary between 10^{1} cm/sec to 10^{-3} cm/sec. In some cases, the conduits can be large and open channel flow occurs. Porosities for karst limestones ranges between 5% and 50%.

The movement of petroleum products through rocks is based on the literature values for hydraulic conductivities for rocks in general. The domestic and industrial use of groundwater is addressed as a receptor. That receptor may be a water well or a spring.

Soils of Kentucky

The soil thickness and type are important to the holding capacity and attenuation of the petroleum products released. The soil parameters of importance relative to the hydrocarbons found in the petroleum are the soil type, organic matter in the soil, hydraulic properties, porosity and soil thickness.

Soil Type: The soils of the state have been mapped by soil scientists and classified into groups. Those soil parameters important to petroleum spills allow them to be grouped into three main groups. Descriptions of each of these groups are presented below with the important physical parameters assumed for each group.

Sandy Soils

These are course grained sandy soils with fines; sand. These soils have a hydraulic conductivity of 10^{-1} cm/sec, porosity of 25% to 50% (35% average) and a bulk density of 1.72 gm/cm^3.

Silty Soils

These are silty soils with fines; silt. These soils have a hydraulic conductivity of 10^{-3} cm/sec, porosity of 30% to 50% (40% average), and a bulk density of 1.59 gm/cm^3.

Clayey Soils

These are very fine grained clayey soils; clay. These soils have a hydraulic conductivity of 10^{-7} cm/sec, porosity of 35% to 60% (45% average) and a bulk density of 1.46 gm/cm^3.

The soil is important because it is the primary medium that is contaminated by the spill. It is also the medium that retains some of the product and will retard the movement away from the spill source. The rate of movement from the source is dependent on the soil properties. Sandy soils are more porous and associated with Types A and B Geologic Units. Silty soils are less porous with higher clay content and are also associated with Types A and B Geologic Units. Clayey soils are finer grained and contain a significant amount of clay sized particles and clay minerals and are generally associated with Type C Geologic Units.

Soil Thickness: The soil thickness (includes the unconsolidated materials above the bedrock) in Kentucky is generally very thin. More than 50% of the state is covered by soils less than fifteen feet thick. The agronomic soils of Kentucky are well documented in soil survey reports for each county. An analysis of the soils of Kentucky as summarized in these reports and well data is presented in a study by Naugle. It was found that the soil thickness as reported in the county survey reports was 34 inches, 60 inches or 72 inches which reflected the depth to which the soil was studied. An analysis of the water well data base for the depth to rock was also determined for each soil group and has been reported as averages by soil group. It was found in general that the soil thickness varied considerably, but a significant portion (eastern half) of the state has less than 15 feet of soil. Deeper soils are reported in the Purchase Region (greater than 60 feet), but this is thought to be due to the way the information is reported by the drillers and not the depth to bedrock.

Many USTs are either located in or on top of rock with many others located in fill material placed on top of the rock. This has a positive effect in one sense because less soil can be contaminated, but it has a negative effect because there is less soil available for attenuation to take place below a tank where a leak as occurred.

Porosity, Organic Matter, and Hydraulic Conductivity: Soil porosity is important because it will control the amount of petroleum product that can be retained within the soil mass. The amount of organic matter within the soil is important in the biodegradation process of the various petroleum products. Hydraulic conductivity is the property of the soil that controls the rate that fluids and gases move through the soil. The higher the conductivity, the more rapidly the fluid or gas will move through the soil.

Data from the soil survey reports have been summarized and organic carbon varies between 0.1% to 0.8%. Intrinsic permeability data have been collected from these reports and grouped by layers and averaged for the soil column. The organic carbon has also been summarized and the values found in the lower layer range between 0 and 0.3%. Volatilization of some of the petroleum products will occur and move upward through the soil. Degradation will occur if oxygen and/or bacteria can reach the product.

Computer Models of Groundwater Flow

Information developed on the typical settings that can be found in Kentucky for the occurrence of tanks have been utilized to construct a simple model and to use the model SESOIL. The site conditions are typical tank dimensions for conventional installations with 30,000 gallon capacity. The equations developed and the models used to describe the upward movement through volatilization of benzene and the downward movement due to percolating water are described in the report. The results of these calculations have been incorporated in the risk assessment calculations and the resulting matrix.

PETROLEUM PRODUCTS AND HEALTH RISK

The data base on permitted USTs provides information on the distribution of petroleum products in Kentucky. Based on 37,298 tanks permitted, 23,655 (63.4%) contain gasoline, 5,883 (15.8%) contain diesel, 2,279 (6.1%) contain oil, 1,966 (5.3%) contain kerosene, 1,371 (3.7%) are empty, 1,521 (4.1%) contain unknown substances, 365 (1.0%) are CERCLA Hazardous materials, and the remainder 258 (0.7%) contain other materials. This report has focused on gasoline because it represents the largest number of tanks.

Gasoline is generally produced by distillation and catalytic treatment of naturally available petroleum. Commercial gasoline is an extremely complex mixture of organic compounds. An extensive literature summary by the State of California Leaking Underground Fuel Tank Task Force produced a list of 150 compounds in gasoline, each having a distinct molecular structure. Very likely, there are many others present in relatively minor amounts which have not been definitely identified. Diesel fuel is equally or more complex because this material is produced by distillation at a higher temperature and consequently contains higher molecular weight compounds. A detailed discussion of these compounds can be found in the report.

The toxicological properties of many of the compounds present in gasoline and diesel fuels have not been thoroughly studied, making risk assessment for these complex mixtures an uncertain exercise. Fortunately, the toxicological properties of compounds with similar molecular structures are often similar, and in the absence of further testing, we will ge guided by our current understanding of the toxicology of this group of compounds.

Toxicological information has been summarized for gasoline, benzene, toluene, mixed xylenes, lead, diesel fuel, and selected PAHs. Gasoline is not considered highly toxic, but benzene is a class A human carcinogen. It is highly volatile and mobile in water. Toluene is a component of gasoline and diesel fuel of relatively low toxicity. The weight of evidence suggests that toluene is not genotoxic, and none of the available evidence suggests that it is carcinogenic. It also very volatile. The mixed xylenes, which include ortho-, meta-, and para-xylene and ethyl benzene are important fuel components with relatively low toxicity. Biotoxicity studies on mixed xylenes have proved consistently negative and in vivo studies in rats and humans have been negative or unequivocal. No definite conclusions can therefore be drawn regarding the carcinogenicity of mixed xylenes in man and animals. They are also very volatile and can mix with water. Lead, in the form of tetraethyl lead was added to gasoline as an anti-knock agent until recently. Lead is a ubiquitous toxic metal in the environment and in biologic systems. Lead is not destroyed by any biotic or abiotic process, and the major issue is at what concentration lead becomes toxic. It is fortunate that lead is not very mobile in soils.

Diesel fuel is a gas oil fraction from the middle distillate of petroleum. Great variations occur between batches of diesel, depending on the source of the crude, the type of processing, and the climate of the market area. Polycyclic aromatic hydrocarbons (PAHs) are the constituents of concern in diesel fuel. Many PAHs such as benzo(a)pyrene are harmful to human health and a number of PAHs have been shown to be carcinogenic. Because of their carcinogenicity, PAHs are the environmental contaminants in diesel fuel that give rise to the greatest level of concern. A detailed discussion of these compounds can be found in the report.

This study has focused on BTEX compounds for gasoline and will focus on TEX and PAHs for diesel fuels. The data developed to date addresses the BTEX compounds.

The analytical methods used for the measurement of the various petroleum compounds in soil, air and water have been reviewed. The tests selected are considered important to a risk-assessment based approach. These are not too different from those recommended by the UST Branch.

DEGRADATION OF PETROLEUM PRODUCTS

An exhaustive search of the literature was performed to understand the degradation of selected petroleum products in the environment. A review of the half-life data for BTEX compounds leads to the conclusion that benzene half-life ranges from two hours to 20 days in air, 16 days to one year in soil and up to two years in groundwater. Three studies gave benzene half-life values that range in groundwater between 69 days and 700 days. The TEX compounds half-life range from hours to weeks up to one year. In this study, a two-year half-life for benzene seems to be a reasonable number based on the literature available at the present time.

EXPOSURE SCENARIOS, RISK CALCULATIONS AND RISK PLAN

The risk assessment plan has been developed and is presented in the report. The most important component of this plan is the use of a five-year exposure time. Because of the degradation of the petroleum products and the very small amounts of product that could have been released, this assumption is considered to be acceptable for the UST problem in Kentucky. The analysis takes into account the depth of the contaminated soil from the surface, the depth of groundwater and three distances to potential receptors, both surface and groundwater.

The results have been computed on the basis of risk values assessed at the 10^{-6} level. Careful consideration was given to 10^{-5} risk levels as well and risk values calculated. In targeting 10^{-4} to 10^{-6} risk range in reference to CERCLA sites, the U.S. EPA chose a risk level of 10^{-5}. Some states that now use 10^{-5} risk-based factors include California, Maine, Maryland, Massachusetts, Minnesota, Ohio, Virginia and Wisconsin. We have used the 10^{-6} risk level in our final calculations.

The study currently has only addressed gasoline, but the computer programs are in place and will make the application for diesel and other compounds much less time consuming than required for the initial analysis.

ENVIRONMENTAL/ECOLOGICAL RISK ANALYSIS

Not only are humans potentially placed at risk by a leak from an underground storage tank, but other organisms may also be placed at risk. To date, BTEX compounds have been reviewed in the literature to determine the potential impact on ecological systems from a leaking UST. Gasoline (herein represented by BTEX) leaking from a petroleum UST most commonly enters directly into the soil adjacent to the tank. Further migration from the site into surface water, surface soil, groundwater or the atmosphere can become complex and involve many factors. Available data suggests that, given the relatively small soil surface involved, contamination of terrestrial ecosystems beyond a UST site is unlikely. However, the aquatic ecosystems of surface waters and wetlands systems could be at risk under certain conditions. As explained more extensively below, BTEX half-lives in surface waters are short, and small releases of BTEX likely would not significantly impact surface waters and wetlands. However, entry of substantial quantities of BTEX or free-standing petroleum product potentially could have significant environmental impact. Such entry of BTEX into surface waters and wetland systems in large amounts could occur only if the UST were in close proximity(<1000 meters) and some avenue for bulk transport of BTEX existed. Possible avenues of transport could include 1) leaching from soil, 2) karst systems or 3) the presence of man-made conduits (storm sewers, drainage ditches).

Certainly, toxicity is an important consideration when assessing the environmental/ecological effects of a given compound. Toxicity testing by exposing a relevant animal species to incremental concentrations of a compound, under either acute (1-5 days) or chronic (>5 days) exposure conditions, has been used to estimate the environmental toxicity of many compounds. Comparatively few species have been tested with BTEX. Freshwater acute LC_{50} values ranged from 5.3 mg/L to 620 mg/L for benzene. The freshwater acute criterion LOEL values range from 5.3 mg/L for benzene to 32 mg/L for ethylbenzene.

The ratio between the concentration of a substance in tissue lipids of an organism versus the ambient concentration in water surrounding the organism is expressed as the bioconcentration factor (BCF). Theoretical steady-state BCFs have been calculated by the U.S. EPA as follows: 13.2 for benzene, 37.5 for ethylbenzene, 27.1 for toluene, and 45, 105 and 95 for o-, m-, and p- xylene, respectively. These and other BCFs are regarded as low, none of the values is >1000, and bioaccumulation of BTEX is not considered to be important. However, few studies were found assessing bioaccumulation of BTEX.

Because of volatilization, photolysis and biodegradation in surface waters, BTEX half-lives in this medium are short, ranging from hours to weeks. BTEX have comparatively low aquatic toxicity and show little tendency to bioaccumulate or to partition into sediments. It is likely that only substantial quantities of either BTEX or free-standing petroleum product would sufficiently contaminate surface waters to toxic levels.

Cleanup and remediation of gasoline leaks based on the more conservative human health criteria for BTEX should be protective of freshwater biota as well. Such efforts should minimally meet the acute freshwater criteria, which are: benzene, 5.3 mg/L; toluene, 17.5 mg/L; and ethylbenzene, 32 mg/L. Although no criteria exist for xylenes, the acute value of 13.5 mg/L for rainbow trout, a sensitive aquatic species, is suggested as a guideline.

Surface waters and wetlands significantly contaminated by gasoline would likely represent complex situations which should be evaluated on a site-specific basis.

PARAMETERS IN UST REMOVAL ANALYSIS

Several parameters must be considered in the development of risk-managed and risk-based classification and associated standards. These parameters require the measurement various parts of the physical system and the collection of data that requires both scientific and engineering expertise. For this reason, it is important that certified professionals collect the information and make professional judgements. The parameters that must be determined are:

1. Soil Type
2. Soil Thickness
3. Potable Groundwater
4. Depth To Potable Groundwater
5. Geologic Units Present At The Site
6. Volume Of Petroleum In The Pit
7. Potential Receptors
8. Ecologically Sensitive Systems

Soil Type

The soil is important because fluids, gases and liquids, move through soils at different rates depending on the soil type. Likewise the mineralogical structure and the presence of organic carbon play a role in the attenuation and degradation of the petroleum products. The soil type can be determined by standard size analysis.

Soil Thickness

The amount of soil beneath the tank is an important variable. The thicker the soil, the more time required for fluids to move through it and the more opportunity for attenuation and degradation of petroleum products.

Potable Groundwater

The groundwater currently in use and that which can be used in the future must be protected. Knowledge of the potable groundwater occurrence and the geological settings in which the resource occurs is required so that the risk from leaking USTs to the resource can be assessed.

Depth To Potable Groundwater

The depth to the potable groundwater is an important variable because the deeper the groundwater source is, the better is the chance that the petroleum products from a leaking UST will not reach it.

Geologic Units Present At The Site

The geologic units present at the site control the way fugitive product and groundwater occurs. Groundwater moves through different rocks at different rates depending on the permeability of the rock and primary and secondary porosity present. The sensitivity of groundwater to contamination from leaking underground storage tanks will be related to the kind and occurrence of the rocks present at the site.

Volume Of Petroleum In The Pit

The amount of petroleum released by the UST is directly related to the potential contamination that can result. The U.S. Environmental Protection Agency has defined a reportable quantity as 25 gallons released in 24 hours. The reportable quantity has been used as a marker between risk managed sites and risk-based sites.

Potential Receptors

Identification of potential receptors is important in determining the risk that may be present from a leaking UST.

Ecologically Sensitive Systems

Ecological systems that may be sensitive to a leaking UST must be identified and the physical relationships between the site and the system determined.

MULTI-CATEGORY APPROACH TO UST CLASSIFICATION AND STANDARDS

The approach used to develop the classification system evolved from the initial analysis of the variables present at a typical site found in Kentucky and the relationship of these sites to the potential risk caused by a leaking underground storage tank. The distribution of tanks between rural and urban locations within the state, the physical differences between small sites and conventional sites, the variations in the geology and soils of the state, and the relatively small volume of petroleum products that is estimated to have been released into the environment were all factored into the development of the classification. Through discussions with professionals from government, the private sector, and universities, and through the analysis of the regulatory programs of other states, a sense of where the Kentucky conditions fit in this spectrum was developed. Extensive analysis of the scientific and professional trade literature and an understanding of the state of knowledge for the classification, and characterization of sites and remediation technologies was obtained.

A significant conclusion that was developed early in the study was the need to get as many of the defective tanks out of the ground as fast as possible with the concomitant removal of any free product found. A second major policy should be the requirement that "state of the art" tank technology be used to prevent loss of product from the tank and distribution system. A third policy that may be considered should be the development of a Groundwater Protection Plan for each site to protect the groundwater.

CLASSIFICATION OF UST TANK CLOSURES

After taking into account the parameters described above, the data derived from the risk-assessment analysis, and other studies, a classification system that includes three classes of tank closure based on risk managed principles and two classes based on risk-assessment methodology was developed. There are five classes of closures that may occur in Kentucky. They are presented in Figure 1 and described below.

SUMMARY, UST CLASSIFICATION AND CLOSURE GUIDELINES

CLASS I	Small Installations, < 6000 Gallons, Free Product < 25 Gallons. Remove Any Free Product And Specified Amount Of Soil; General Guidance. No Monitoring.
CLASS II	Conventional Installation[1]. Tight System, No Evidence Of Leaks; Empty The Tank, Remove and Close. No Monitoring.
CLASS III	Conventional Installation. Leaks Detected; Free Product < 25 Gallons Meets BTEX Limits Of 2/22/56/20 ppm (mg/kg) If Wells < 300 m; Or 20/230/550/200 (1000 ppm BTEX) If Soil Contamination Only.
CLASS IV	Conventional Installation. Leaks Detected; Free Product > 25 Gallons Actual and Potential Receptors; Remediate According To Risk Level Matrix For Soil/Groundwater Or 1000 ppm BTEX If Soil Only. Monitor Wells < 100 m/Possible G.W. Remediation.
CLASS V (Site Specific)	Major Installation With Unusual Features That May Potentiate Endangerment: Excess Free Product; Special Conduits For Off-Site Petroleum Transport; Unusual Or Particularly Close Proximity Of Sensitive Receptors; Presence Of Surface Water Systems; Further Site Characterization and Risk Assessment As Necessary.

[1] Conventional installations are stations with storage capacity of up to 30,000 gallons or more and that lack unusual features that may potentiate endangerment or complicate risk assessment.

CLASS I CLOSURE (SMALL TANKS)

This class includes tanks found at small installations. The following criteria as determined by a registered professional engineer or geologist should be:

(a) Two tanks or fewer present with a total capacity of less than 6000 gallons.
(b) Tank has been empty for the last five years.
(c) Groundwater surface is below the bottom of the pit.
(d) Potable water well is not [on site or] within 100 meters (328 feet) of the site.
(e) Ecologically sensitive features are more than 150 meters (492 feet) from the site.

Action:

The data must be collected and supportive data presented to demonstrate that the above criteria are met. If they are all met, the site may be closed. Work Sheets are available in Appendix I to gather the important site history relative to product's used and locational information to place the site in the context of surrounding natural and human developments. Upon final closure, the tank pit should be filled with clean soil.

CLASS II CLOSURE (ALL TANKS)

Explanation:

Inspection shows that a tank and pipe system test has been performed according to NREPC standards and a leak is not found. Likewise, upon removal of the tank there is no product found in the pit nor evidence of product having been there. If these two conditions are met, the pit may be closed. The pit inspection must be performed by a certified registered geologist or engineer, who must determine if petroleum products are evident.

Action:

1. Leak test is performed on the tank and piping and no leaks are found.

2. Visual inspection of the tank pit is made by a certified registered engineer or geologist and no evidence of leak is found.

If both of these criteria are met, the tank pit may be closed.

CLASS III CLOSURE (LESS THAN 25 GALLONS REPORTABLE QUANTITY)

Explanation:

The key to this classification is the amount of reportable product found in the pit. The USEPA states that the critical quantity of product that requires action is more than 25 gallons found in a 24-hour period. The manner in which the site will be closed depends on the outfall amount, the relationship of domestic and public water wells to the site, the soil type, and the depth to well water.

Less Than 25 Gallons Product Found In Pit
Water Well Greater Than 300 Meters (984 Feet) Radius Of Site

The following criteria are used for closure under these conditions:

1. Determine that less than 25 gallons of petroleum product is present in pit. Use criteria described in Reportable Quantity Work Sheet to make this determination.

2. Determine that there are no domestic or public wells within a 300-meter radius of the site. Use criteria described in the Groundwater Resource Work Sheet.

3. Determine that there are no ecologically sensitive zones within 150 meters (492 feet) of the site. Use criteria described in the Ecological Sensitivity Work Sheet.

Action:

If the above criteria are met, refer to the **Soil Only Matrix in Table 1** and determine the amount of BTEX that may be left in the soil for closure. Refer to the Measurement of Concentrations of Petroleum Products In Soil and/or Groundwater Work Sheet for methods to be used to collect samples. Close the site with either clean soil or soil that meets the criteria from the matrix.

Less Than 25 Gallons Product Found In Pit
Water Well Less Than 300 Meters (984 Feet) Radius Of The Site

The following criteria are used for closure under these conditions:

1. Determine that less than 25 gallons of petroleum product is present in pit. Use criteria described in Reportable Quantity Work Sheet to make this determination.

2. Locate all of the wells that are less than 300 meters (984 feet) from the site. Use criteria described in Groundwater Resource Work Sheet to assess the groundwater resource. Collect information on the wells.

3. Determine that there are no ecologically sensitive zones within 150 meters (492 feet) of the site. Use criteria described in the Ecological Sensitivity Work Sheet.

Action:

If the information compiled on the site meets the above criteria, refer to **The Soil and Groundwater values in Table 1** for the levels of BTEX that may be left in the soil for closure. If BTEX are found above the allowable limits, a Class IV closure must be made. Refer to the Measurement of Concentrations of Petroleum Products In Soil and/or Groundwater Work Sheet for methods to be used to collect samples. Close the site with either clean soil or soil that meets the criteria from the table.

CLASS IV CLOSURE (GREATER THAN 25 GALLONS REPORTABLE QUANTITY)

Explanation:

It will have been determined that there is more than 25 Gallons of Petroleum Product found in the pit. This is a more serious condition, and the distance to water wells that have been or may be affected is reduced to 100 meters (328 feet). The following procedures and criteria are required to determine the safe level of BETX that may be left in the soil for closure of an UST:

Greater Than 25 Gallons Product Found In Pit
Water Well Greater Than 100 Meters (328 Feet) Radius Of The Site

The following criteria must be met in order to meet closure requirements:

1. The free product is removed from the pit, and more than 25 gallons was found. This will be determined by using the criteria described in Reportable Quantity Work Sheet.

2. Complete site information is collected by a Registered Professional Engineer or Geologist.

3. Soil type is determined according to grain size. Use Soil Classification Work Sheet.

4. Depth to well water. Use Groundwater Resource and Generalized Groundwater Zone Map of Kentucky Work Sheets to make this determination.

5. Determine that there are no ecologically sensitive zones within 150 meters (492 feet) of the site. Use criteria described in the Ecological Sensitivity Work Sheet

Action:

In order to make this determination, additional information is required. To assist the certified professional engineer or geologist in the determination of the cleanup levels required, the following procedure is recommended:

1. Site information must be developed. Work Sheets are provided to assist in the compilation of the required information.

   a. Site History Work Sheet
   b. Characterization of Physical Parameters Work Sheet
   c. Groundwater Resource Determination Work Sheet
   d. Measurement of Concentrations of Petroleum Products In Soil and/or Groundwater
   e. Ecological Sensitivity Work Sheet
   f. Soil Classification Work Sheet

2. Information obtained will be used to select one of three Matrices to make the determination of the level of petroleum products that may be left in the soil.

   The site should be located on the Generalized Groundwater Zone Map of Kentucky to determine the appropriate matrix to be used. Because of the scale of the map, once the site has been generally located, the geologic information developed will be used to verify that the site meets the geological setting criteria for the zone.

   The Zone 1 Matrix applies to the Well Integrated Karst regions of the state.

   The Zone 2 & 3 Matrix applies to Fine Grained Alluvium, Gulf Coastal Plain Sediments, Poorly Integrated Karst, and Fractured Shale geological settings of the state.

   The Zone 4 & 5 Matrix applies to Fractured Sandstone and Shale, Poorly Integrated Karst, and Clay-Mantled Dolomite Karst geological settings of the State.

3. Each Matrix requires the soil type, groundwater resource determination, and depth to water. Once these parameters are known, one may go to the matrix and find the BTEX level that may be left in the soil.

Greater Than 25 Gallons Reportable Product Found In Pit
Water Well Less Than 100 Meters (328 Feet) Radius Of The Site

The same criteria as above are applied with the exception that more detailed site characterization is required to provide information for the risk-based analysis. Soil borings and groundwater monitoring wells may be required, depth to water levels determined, soil samples collected and water samples collected and analyzed for BTEX.

CLASS V CLOSURE (SITE SPECIFIC ANALYSIS)

Explanation:

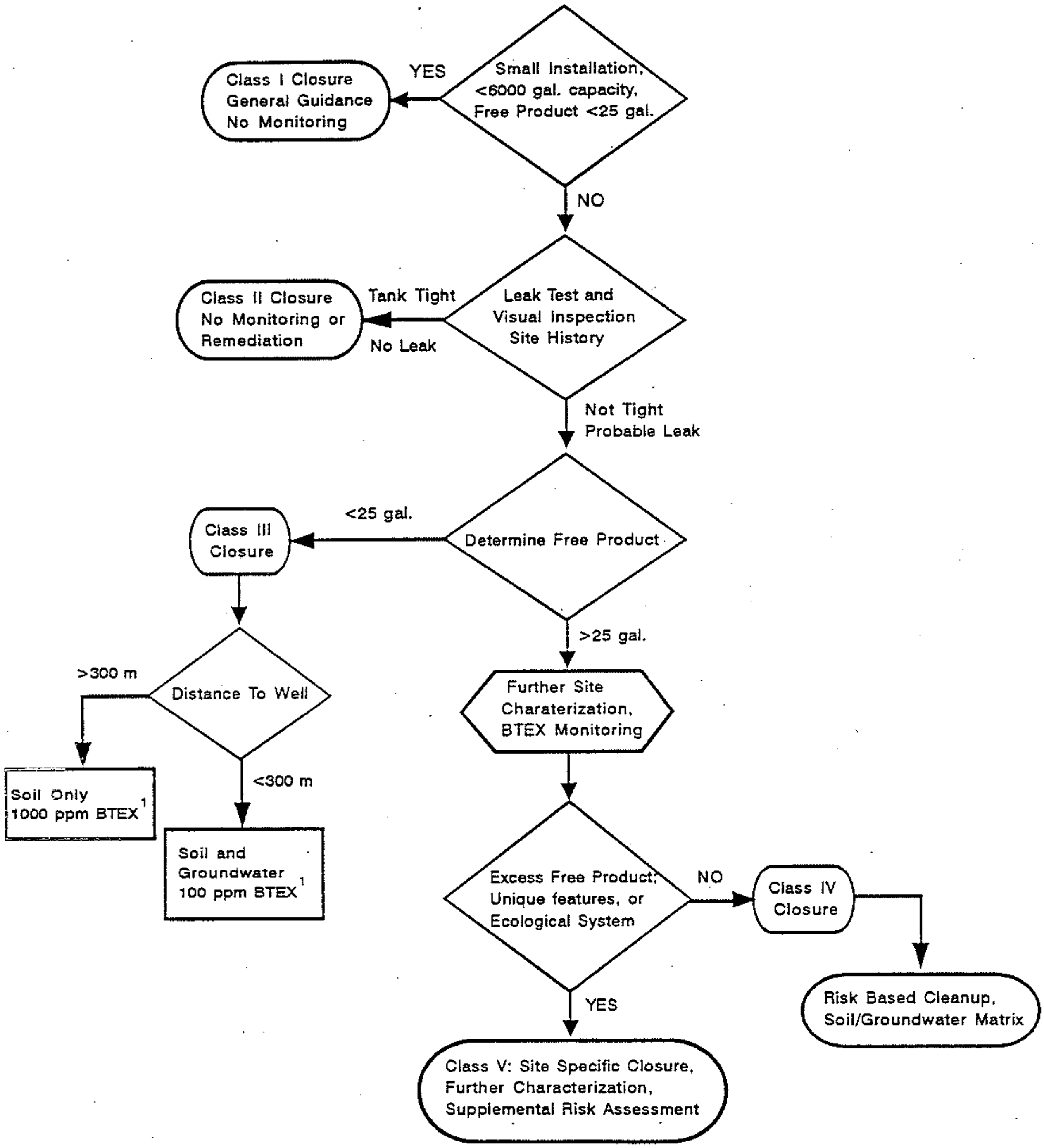
This site has more than 25 gallons reportable free product in pit, and the site is less than 100 meters (328 feet) from an actual or future water well. It is also possible that sensitive receptors are present and that the site has a high potential to impact an ecological system. There may be natural or constructed conduits that could enhance product movement from the site.

Action:

This site will require site-specific information. The thickness of the soil and the depth to groundwater are important risk-based parameters. Collect samples from groundwater monitoring wells and soil borings to determine the extent of free product in the environment.

Complete site characterization will be required to determine the fate and transport of the product from the site. An environmental survey will be required to determine if any ecologically sensitive systems are present and impacted.

STATE OF KENTUCKY
DECISION TREE FOR UST CLASSIFICATION AND CLOSURE GUIDELINES



[1] 100 ppm BTEX: 2/22/56/20; 1000 ppm BTEX: 20/230/550/200

UNDERGROUND STORAGE TANK CLOSURE PROCEDURE

The procedure to close a tank is presented below in a step-by-step format. The Decision Tree presented in Figure 2 summarizes the process.

STEP 1. UST INVESTIGATION

Explanation:

Reasons for initiating an investigation for a leaking underground storage tank usually fall into one of two general categories:

(a) Evidence of a leak

Leaking underground storage tanks are discovered in a variety of ways. Some of the most common are:

(1) Contamination observed or detected during routine field inspection of tank

(2) Contamination observed or detected during routine tank closure or replacement

(3) Confirmed failed precision test and/or inventory discrepancies reported by tank owner/operator

(4) Flammable liquid and/or vapors detected on-site or off-site (e.g., migrating from suspected source into sanitary sewer, utility vault, or open excavation).

(5) Reports of an odor problem or other nuisance conditions from unknown or suspected sources

(b) Routine tank closures where no evidence of a leak exists

Action:

The extent of site history and preliminary field investigations should vary depending upon the reason for initiating the investigation. Also, depending on the tank size and tank integrity, size of outfall, and location of water wells, different approaches can be applied to achieve closure.

STEP 2. PRELIMINARY FIELD INVESTIGATION

Once the investigation has been initiated, the following assessment should be performed by the tank owner, his/her contractor, or by the regulatory agency during the first field visit. Work sheets for Site History and Physical Characteristics of the Site are provided in the Appendix to assist in making the assessment. Some of the questions that should be asked are:

(a) If there is evidence of a leak, has the fire department been consulted to determine whether or not a fire hazard or explosive situation exists?

(b) Safety: An immediate concern at any leaking underground storage tank site is an evaluation of any present or potential threat to public safety. Are vapor exposures significant to workers in neighboring buildings through windows, ventilation system, or subsurface electrical vaults? Is ponded product finding its way into sewer lines and posing a potential explosion hazard? These are a few of the questions regarding site health and safety hazards that should be asked and answered in the earliest stages of problem identification. If they exist, sources of possible hazardous vapors should be identified and eliminated.

(c) If a leak has occurred, has it been abated?

(d) Is this site near sensitive land uses (i.e., next to home or a school)?

(e) Are records and/or information sources available at the site?

(f) Are existing pathways of concern apparent (i.e., sewer laterals, utility conduits, nearby wells, surface runoff)?

(g) Are temporary on-site waste storage procedures being conducted in a safe and secure manner?

(h) Make any other observations which seem pertinent during the initial site survey.

Once the investigation in Step 2 has determined that all safety procedures have been taken and the tank of interest has been placed in context with other potential tanks at the site, a classification of the kind of tank and its relationship to its surroundings must be made. Go to Step 3.

STEP 3. COLLECT INFORMATION ON SITE HISTORY

Explanation:

Once any immediate health or safety issues have been assessed and abated, the field personnel should begin collecting information for site categorization. This phase of the investigation focuses on site history and physical characteristics of the site. The site history includes fact-finding, research, and background review, which field personnel will want to do, in addition to the field work.

Common elements of site history are the review of the permit application and any information obtained pertaining to the site. Specifically, information regarding the following areas may be helpful:

1. Inventory records

2. Precision testing records
3. Repair records
4. Records all water or other pump-outs from the tank(s)
5. Available environmental monitoring information
6. Neighborhood complaints
7. Fire department observations (other Environmental Protection Departments)
8. Previous ownership and description of businesses/uses at the site
9. Current operator/owner data including type of business and associated activities that take place at the site
10. Current equipment installation and maintenance data including number and capacity of operating tanks.
11. Current leak detection system(s) functioning
12. Interviews with employees

Action:

See the Appendix for Site History Work Sheets.

STEP 4. SMALL TANK CLOSURE

Explanation:

Information has been collected to determine if the tank meets the requirements of the Small Tank classification as described above under CLASS I CLOSURE (Small Tank).

Action:

If the tank meets all of the requirements, the tank pit may be closed with clean soil.

STEP 5. TIGHT TANK CLOSURE

Explanation:

Standard tank testing as described by Kentucky Department of Waste Management, Underground Storage Tank Branch should be followed to determine if tank and pipes are tight.

A thorough examination of the tank system should be made. The following points should be considered when conducting the inspection:

1. The tank and associated piping are checked by certified personnel. Inspection and oversight will be conducted by Underground Storage Tank Branch staff (or their designee).

2. A field hydrocarbon vapor analyzer may provide qualitative evidence of fuel hydrocarbons in the excavated material.

Action:

The inspection should include the following:

1. Check the tank and piping for holes

2. Check the tank system for loose or improper connections or other defects

3. Check the backfill or native soil for visible stains or residual odors

4. Determine if there is any free product floating on top of the water or soil surface. If free product is present, a stop-work order should be initiated, and abatement procedures implemented

5. Check to see if there is water in the excavation

6. Check to see if there is a sheen on any water in the excavation

If free product is present in the excavation, it must be removed before any further investigation or analytical work can occur.

In the event that no leak is detected, or contamination found during the inspection of the tank and pit, and no reason for contamination to occur is found in the above inspection, the tank may be removed and the pit closed as described under CLASS II CLOSURE requirements.

If the tank fails the tank tightness test or contamination is found, proceed to Step 6.

STEP 6. REPORTABLE QUANTITY OF PETROLEUM PRODUCTS

Explanation:

The U.S. Environmental Protection Agency has determined that 25 gallons of petroleum products released in a 24-hour period is a reportable quantity. This criterion has been adopted as an indicator of the degree of contamination that may have occurred at a site and the designation has been used in further classifying sites for study.

The amount of free petroleum products found in the pit after tank removal will determine the type of tank closure required.

Action:

This determination can be made by collecting all of the liquids in the pit and measuring the amount of petroleum products present. If the products are mixed with water, they must be separated and the petroleum products measured. If fluid continues to enter the pit as they are removed, the fluid must be collected over a 24-hour period. Refer to the Reportable Quantity Work Sheet in the Appendix. If less than 25 gallons reportable product is found, proceed to Step 7, if more than 25 gallons reportable product is found, proceed to Step 9.

STEP 7. Less Than 25 gallons Reportable Product Found In Pit Water Well Greater Than 300 Meters (984 Feet) Radius Of Site

Explanation:

The criteria used for closure under these conditions are a reportable quantity of less than 25 gallons of reportable product, potable water wells are greater than 300 meters (984 feet) from the site, and there are no ecologically sensitive zones within 150 meters (492 feet) of the site.

Action:

1. Determine that less than 25 gallons reportable product is present in pit. Use criteria described in Reportable Quantity Work Sheet to make this determination.

2. Determine that there are no domestic or public wells within a 300-meter (984 feet) radius of the site. This will require further characterization of the site. Reference should be made to the Characterization of Physical Parameters of the Site Work Sheet in the Appendix. Because an understanding of the potable water supply is needed reference should be made to the Groundwater Resource Work Sheet, also in the Appendix.

3. Determine that there are no ecologically sensitive zones within 150 meters (492 feet) of the site. Use criteria described in the Ecological Sensitivity Work Sheet in the Appendix.

   If the above criteria are met, refer to the **Soil Only Matrix in Table 1** and determine the amount of BTEX that can be left in the soil for closure. Refer to the Measurement of Concentrations of Petroleum Products In Soil and/or Groundwater Work Sheet for methods to be used to collect samples. Close the site with either clean soil or soil that meets the criteria from the table.

STEP 8. Less Than 25 gallons Reportable Product Found In Pit Water Well Less Than 300 Meters (984 Feet) Radius Of The Site

Explanation:

The criteria used for closure under these conditions are a reportable quantity of less than 25 gallons of reportable product, potable water wells less than 300 meters (984 feet) from the site, and there are no ecologically sensitive zones within 150 meters (492 feet) of the site.

TABLE 1
BTEX VALUES FOR CLASS III UST CLOSURE

SOIL ONLY	SOIL AND GROUNDWATER
1000 BTEX 20/ 230/ 550/ 200	100 BTEX 2/ 22/ 56/ 20

Action:

1. Determine that less than 25 gallons reportable product present in pit. Use criteria described in Reportable Quantity Work Sheet to make this determination.

2. Locate all of the wells that are less than 300 meters (328 feet) from the site. This will require further characterization of the site. Reference should be made to the Characterization of Physical Parameters of the Site Work Sheet in the Appendix. Because an understanding of the potable water supply is needed reference should be made to the Groundwater Resource Work Sheet, also in the Appendix.

3. Determine that there are no ecologically sensitive zones within 150 meters (492 feet) of the site. Use criteria described in the Ecological Sensitivity Work Sheet in the Appendix.

   If the information compiled on the site meets the above criteria, refer to **The Soil and Groundwater Values in Table 1** for the levels of BTEX that may be left in the soil for closure. If BTEX are found above the allowable limits, a Class IV closure must be made. Refer to the Measurement of Concentrations of Petroleum Products In Soil and/or Groundwater Work Sheet for methods to be used to collect samples. Close the site with either clean soil or soil that meets the criteria from the table. If the site does not meet the above criteria, proceed to Step 12.

STEP 9. Greater Than 25 gallons Reportable Product Found In Pit Water Well Greater Than 100 Meters (328 Feet) Radius Of The Site

Explanation:

It will have been determined that there is more than 25 gallons reportable product found in the pit. For this determination additional information is required. The soil type and the groundwater zone in which the site occurs. This information is used to find the safe level of BETX that may be left in the soil for closure from the appropriate matrix.

Action:

In order to make this determination, additional information is required. To assist the certified professional engineer or geologist in the determination of the cleanup levels required, the following procedure is recommended:

1. Site information must be developed. Work Sheets are provided to assist in the compilation of the required information.

   a. Site History Work Sheet
   b. Characterization of Physical Parameters Work Sheet
   c. Groundwater Resource Determination Work Sheet
   d. Measurement of Concentrations of Petroleum Products In Soil and/or Groundwater
   e. Ecological Sensitivity Work Sheet
   f. Soil Classification Work Sheet
   g. Generalized Groundwater Zone Criteria Work Sheet

2. After the free product has been removed, complete site information is collected by a Registered Professional Engineer or Geologist, soil type is determined according to grain size, depth to well water as determined from the Generalized Groundwater Zones of Kentucky map and Table A-1, a determination is made to show that there are no ecologically sensitive zones within 150 meters (492 feet) of the site, there are no on site sensitive receptors, and there are no natural or constructed conduits to allow petroleum products to leave the site.

3. Information obtained will be used to select one of three Matrices to make the determination of the level of petroleum products that may be left in the soil.

   The site should be located on the Generalized Groundwater Zone Map to determine the appropriate matrix to be used. Because of the scale of the map, once the site has been generally located, the geologic information developed will be used to verify which zone the meets.

   The Zone 1 Matrix applies to the Well Integrated Karst regions of the State.

   The Zone 2 & 3 Matrix applies to Fine Grained Alluvium, Gulf Coastal Plain Sediments, Poorly Integrated Karst, and Fractured Shale groundwater zones of the State.

   The Zone 4 & 5 Matrix applies to Fractured Sandstone and Shale, Poorly Integrated Karst, and Clay-Mantled Dolomite Karst groundwater

Zone 1 (Karst) Matrix
BTEX Soil Concentration (ppm, mg/kg) to Protect Potable Groundwater

Soil Type	Depth (m) to Groundwater	0-100 meters[1]	100-300 meters[1]	>300 meters[1]
SAND	0	0.065/ 15/ 30/ 18	0.065/ 15/ 30/ 18	0.065/ 15/ 30/ 18
	1	0.25/ 60/ 90/ 65	0.25/ 60/ 90/ 65	0.25/ 60/ 90/ 65
	3	0.44/ 120/ 140/ 105	0.44/ 120/ 140/ 105	0.44/ 120/ 140/ 105
	6	0.65/ 200/ 200/ 155	0.65/ 200/ 200/ 155	0.65/ 200/ 200/ 155
SILT	0	0.065/ 15/ 30/ 18	0.065/ 15/ 30/ 18	0.065/ 15/ 30/ 18
	1	0.25/ 40/ 70/ 50	0.25/ 40/ 70/ 50	0.25/ 40/ 70/ 50
	3	0.35/ 95/ 120/ 100	0.35/ 95/ 120/ 100	0.35/ 95/ 120/ 100
	6	0.70/ 165/ 210/ 150	0.70/ 165/ 210/ 150	0.70/ 165/ 210/ 150
CLAY	0	0.065/ 15/ 30/ 18	0.065/ 15/ 30/ 18	0.065/ 15/ 30/ 18
	1	0.20/ 40/ 50/ 35	0.20/ 40/ 50/ 35	0.20/ 40/ 50/ 35
	3	0.30/ 70/ 90/ 60	0.30/ 70/ 90/ 60	0.30/ 70/ 90/ 60
	6	1.0/ 210/ 400/ 200	1.0/ 210/ 400/ 200	1.0/ 210/ 400/ 200

[1] Distance from UST to receptor(s).

Zones 2 and 3 Matrix
BTEX Soil Concentration (ppm, mg/kg) to Protect Potable Groundwater

Soil Type	Depth (m) to Groundwater	0-100 meters[1]	100-300 meters[1]	>300 meters[1]
SAND	1	0.01/ 2.0/ 2.0/ 15	0.40/ 180/ 450/ 200	20/ 230/ 550/ 200
	3	0.025/ 7/ 4/ 40	1.0/ 230/ 550/ 200	20/ 230/ 550/ 200
	6	0.06/ 19/ 10/ 85	2.0/ 230/ 550/ 200	20/ 230/ 550/ 200
	9	0.135/ 40/ 20/ 190	5.0/ 230/ 550/ 200	20/ 230/ 550/ 200
	19	1.25/ 230/ 215/ 200	20/ 230/ 550/ 200	20/ 230/ 550/ 200
SILT	1	0.035/ 2/ 4/ 40	1.4/ 170/ 550/ 200	20/ 230/ 550/ 200
	3	0.30/ 40/ 25/ 200	10/ 230/ 550/ 200	20/ 230/ 550/ 200
	6	6.0/ 230/ 180/ 200	20/ 230/ 550/ 200	20/ 230/ 550/ 200
	9	7.0/ 230/ 550/ 200	20/ 230/ 550/ 200	20/ 230/ 550/ 200
	19	20/ 230/ 550/ 200	20/ 230/ 550/ 200	20/ 230/ 550/ 200
CLAY	1	0.18/ 45/ 40/ 200	7.0/ 230/ 550/ 200	20/ 230/ 550/ 200
	3	20/ 230/ 550/ 200	20/ 230/ 550/ 200	20/ 230/ 550/ 200
	6	20/ 230/ 550/ 200	20/ 230/ 550/ 200	20/ 230/ 550/ 200
	9	20/ 230/ 550/ 200	20/ 230/ 550/ 200	20/ 230/ 550/ 200
	13	20/ 230/ 550/ 200	20/ 230/ 550/ 200	20/ 230/ 550/ 200

[1] Distance from UST to receptor(s).

Zones 4 and 5 Matrix
BTEX Soil Concentration (ppm, mg/kg) to Protect Potable Groundwater

Soil Type	Depth (m) to Groundwater	0-100 meters[1]	100-300 meters[1]	>300 meters[1]
	1	0.007/ 1.5/ 1.5/ 10	0.05/ 15/ 15/ 110	0.35/ 190/ 475/ 200
	3	0.01/ 3.5/ 2.0/ 20	0.09/ 30/ 25/ 170	0.65/ 230/ 550/ 200
SAND	6	0.02/ 6.0/ 3.0/ 30	0.13/ 50/ 40/ 200	1.0/ 230/ 550/ 200
	9	0.025/ 8.0/ 4.0/ 40	0.15/ 65/ 50/ 200	1.3/ 230/ 550/ 200
	19	0.05/ 14/ 8.0/ 75	0.30/ 120/ 100/ 200	2.5/ 230/ 550/ 200
	1	0.007/ 1.2/ 1.0/ 10	0.05/ 10/ 14/ 90	0.35/ 130/ 360/ 200
	3	0.01/ 3.0/ 2.0/ 20	0.07/ 25/ 20/ 170	0.50/ 230/ 550/ 200
SILT	6	0.02/ 5.0/ 3.5/ 30	0.14/ 40/ 40/ 200	1.0/ 230/ 550/ 200
	9	0.03/ 8.0/ 5.0/ 45	0.20/ 65/ 60/ 200	1.5/ 230/ 550/ 200
	19	1.0/ 25/ 18/ 140	6.0/ 220/ 220/ 200	20/ 230/ 550/ 200
	1	0.006/ 0.70/ 0.35/ 7.0	0.03/ 6.0/ 10/ 60	0.3/ 75/ 280/ 200
	3	0.009/ 2.0/ 1.0/ 10	0.06/ 18/ 15/ 100	0.45/ 230/ 475/ 200
CLAY	6	0.03/ 6.5/ 3.0/ 40	0.20/ 55/ 80/ 200	1.5/ 230/ 550/ 200
	9	0.10/ 20/ 10/ 120	0.60/ 165/ 180/ 200	4.5/ 230/ 550/ 200
	13	0.20/ 50/ 25/ 200	1.5/ 230/ 475/ 200	10/ 230/ 550/ 200

[1] Distance from UST to receptor(s).

zones of the State.

3. Each Matrix requires the soil type, groundwater resource determination, and depth to well water. Once these parameters are known, one may go to the matrix and find the BTEX level that may be left in the soil.

STEP 10. Greater Than 25 Gallon Product Found In Pit Water Well Less Than 100 Meters (328 Feet) Radius Of The Site

Explanation:

It will have been determined that there is more than 25 Gallons of petroleum product found in the pit and that a potable water well is less than 100 meters (328 feet) from the site. Additional information in the form of a groundwater resource analysis and ecological analysis may require a biological field survey and the drilling of monitoring wells.

Action:

Because a water well was found within 100 meters of the site, additional information is required to determine the relationship between the source of the water and the tank site. To assist the registered engineer or geologist in the determination of the cleanup levels required, the following procedure is recommended:

1. Site information must be developed. Work Sheets are provided to assist in the compilation of the required information.

   a. Site History Work Sheet
   b. Characterization of Physical Parameters Work Sheet
   c. Groundwater Resource Determination Work Sheet
   d. Measurement of Concentrations of Petroleum Products In Soil and/or Groundwater
   e. Ecological Sensitivity Work Sheet
   f. Soil Classification Work Sheet

2. After the free product has been removed from the pit, complete site information is collected by a registered engineer or geologist.

3. A groundwater resource analysis is required to determine the relationship between the water wells identified within the 100 meters (328 feet) radius. If this analysis does not provide sufficient information to make the determination that the product has or will impact the water source, monitoring wells may be required to determine if any product has reached the water table. Water samples taken from the monitoring wells should be tested for BTEX. If any of the products are detected proceed to Step 11. If no product is found, continue the investigation.

4. Depth to well water is determined from monitoring wells or the Generalized Groundwater Zone Map and accompanying Table A-1.

5. Determine that there are no ecologically sensitive zones within 150 meters (492 feet) of the site. If there are, proceed to Step 11.

6. Determine that there are no on-site sensitive receptors.

7. Determine that there are no natural or constructed conduits to allow petroleum products to leave the site.

8. All information obtained will be used to select one of three matrices to make the determination of the level of petroleum products that may be left in the soil.

   The site should be located on the Generalized Groundwater Zone Map to determine the appropriate matrix to be used. Because of the scale of the map, once the site has been generally located, the geologic information developed will be used to verify which zone the site meets.

   The Zone 1 Matrix applies to the Well Integrated Karst regions of the State.

   The Zone 2 & 3 Matrix applies to Fine Grained Alluvium, Gulf Coastal Plain Sediments, Poorly Integrated Karst, and Fractured Shale geological settings of the State.

   The Zone 4 & 5 Matrix applies to Fractured Sandstone and Shale, Poorly Integrated Karst, and Clay-Mantled Dolomite Karst geological settings of the State.

9. Each Matrix requires the soil type, groundwater resource determination, and depth to well water. Once these parameters are known, one may go to the appropriate matrix and find the BTEX level that may be left in the soil.

STEP 11. Major Installations With Unusual Features That May Potentiate Endangerment

Explanation:

At this step in the investigation, the tank and piping has been removed and there is evidence of known or suspected groundwater contamination. There is evidence of excess free product on the site. It is also possible that there are underground conduits that could transport the product from the site and their may be unusual or particularity close proximity of sensitive receptors. It is also possible that there is the presence of a surface water system close to the site. Under these conditions, additional information is needed to assess the extent of potential or actual contamination.

Action:

Consult With Underground Storage Tank Branch Staff to Determine Required Actions.

APPENDIX

WORK SHEETS

- A. Site History
- B. Characterization of Physical Parameters Work Sheet
- C. Groundwater Resource Determination Work Sheet
- D. Measurement of Concentrations of Petroleum Products In Soil and/or Groundwater
- E. Ecological Sensitivity Work Sheet
- F. Soil Classification Work Sheet
- G. Generalized Groundwater Zone Criteria Work Sheet
- H. Depth To Well Water Work Sheet

WORK SHEET A
SITE HISTORY WORK SHEET

The work sheets currently used by the UST Branch should be used and perhaps expanded. This will be discussed with UST Board Staff to get the document that will meet other requirements of the Branch.

WORK SHEET B
CHARACTERIZATION OF PHYSICAL PARAMETERS OF THE SITE WORK SHEET

Physical information is required to make an assessment of the impact of the UST on the site. The following data and maps must be compiled.

1. Locational information should be plotted on a USGS topographic quadrangle map. This information allows one to see the relationship of the site to the local topography. Streams and potentially ecologically sensitive areas can be located.

2. A detailed site map is required to locate the tank(s) in relation to site boundaries, other tanks, buildings, buried conduits and any other features that will be important in the analysis.

3. A description of potential receptors and their location relative to the site should be included. Locations must be shown on the topographic map. Potentially ecologically sensitive areas should be identified and noted.

4. Soil samples must be collected and soil types determined. See attached work sheet on Soil Classification.

5. A topographic analysis must be conducted to locate any karst features if this site falls in either the Mississippian Plateaus Region or the Blue Grass Region.

WORK SHEET C
GROUNDWATER RESOURCE DETERMINATION WORK SHEET

This work sheet is designed to assist the registered geologist or engineer in making the determination if potable groundwater occurs at the site and, if possible, to estimate the conditions of the very shallow groundwater in the vicinity of the site. The criteria to make this determination are listed below with a short explanation for each. It is expected that published data will be the source of information to make the determination.

1. Topographic setting

300 meter (984 feet) radius area covered by map

A United State Geological Survey 7.5 minute topographic map can be obtained for the site so that a general topographic setting can be determined. If a larger scale map is available for the site (for example, 1 inch = 600 feet), this map should be utilized for the analysis.

2. Geologic units and setting

A United States Geological Survey 7.5 minute geologic quadrangle map can be obtained for the site to determine the general geological setting of the site. From this map, one can determine the geological units present, the rock type, a general description of physical properties of the rock, approximate thickness of the rock units, the presence of faults and the attitude of the rock units.

For all areas of the Commonwealth, a United State Geological Survey Hydrologic Atlas has been prepared. This document will have maps and descriptions of the groundwater of the region and can be used in the analysis.

The depth of the overburden is important in the geological analysis, and a study by Naugle on the soils is presented in the Appendix. The depth to bedrock is one of the bits of information determined in this study and may be of use in the analysis.

A site visit should include a geologic field inspection to locate out crops of all rocks with a description of the out crops to determine the place in the geologic section where the site is located. A visual description of the rock type can also be made to compare this to the descriptions found in the USGS Quadrangle map.

3. Well inventory

a. KGS repository

10 kilometers (6.21 miles) radius

b. field inventory

300 meters (984 feet) radius

information sought=depth of well, depth to water, yield

A most important indicator of the use of the groundwater in the region and, therefore, the occurrence of a potable water source is the wells located in the area. Two kinds of information can be obtained, which is available from published information in reports and data bases and actual field inventory of wells within the area of the site.

The Kentucky Geological Survey maintains the Kentucky Groundwater Data Repository, a database of water wells drilled in the state since 1987 and other data supplied to the Survey from private and public sources. One can request a list of all well logs for all water wells within the region. A compilation of the well logs for a 10 kilometer radius of the site will provide a general picture of the occurrence of water wells, the depth of well, the depth of the water in the well and very often the well yield.

A field inventory can be performed to determine the location of wells within 300 meters (984 feet) of the site by visiting with all individuals living in residences or owners of places of business. Local well driller may be contacted and information of wells within the region can be obtained.

4. Data analysis

cross sections to show soil bedrock contact, geologic units, depth to wells in area and probable unit of production

draw groundwater table map or predict direction(s) of groundwater flow

define any confined zones or predicted changes in permeability

predict flow rate based on geologic units as well as flow direction in cross section

In this part of the analysis, the data collected should be used to produce the maps and cross sections required to describe the topographic and geologic setting. Other geologic literature should be consulted and professional experience used to produce the information indicated above and to answer the following questions.

5. Answer the following questions

Is a groundwater drinking water source present or is there a potential for a drinking water source within 100 meters of the site?

If yes to the above, what is the depth of the well or producing zone? How deep to the water level. Are there confining layers above the potential producing horizon?

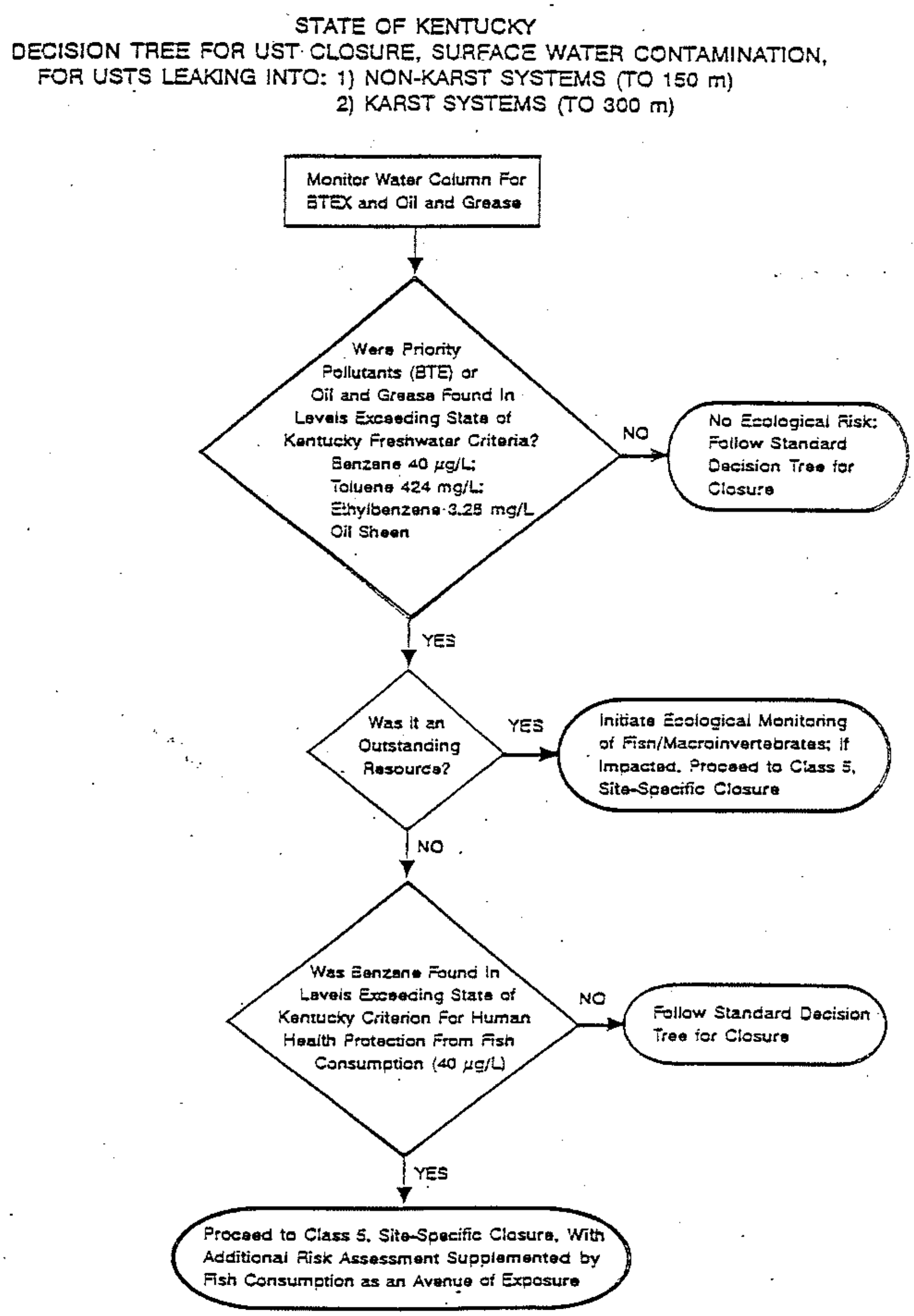
If these questions cannot be answered in full, monitoring wells are required to intersect the groundwater at the site so the groundwater quality can be determined, flow direction determined, and the depth to groundwater can be determined for use in the appropriate matrix for the determination of BTEX concentrations that may be left in the soil.

WORK SHEET D
MEASUREMENT OF CONCENTRATIONS OF PETROLEUM PRODUCTS IN SOIL AND/OR GROUNDWATER

This is the UST Branch document currently being used and entitled Underground Storage Tank System(s) Outline for Collection of Samples and Laboratory Analysis For Underground Storage System(s) in Kentucky. Dated December 1, 1992.

WORK SHEET E
ECOLOGICAL SENSITIVITY WORK SHEET

The decision tree for the ecological sensitivity analysis identifies the procedures as well as the decision points.



WORK SHEET F
SOIL CLASSIFICATION WORK SHEET

Sample Collection

The soil samples to be analyzed for grain size should be collected from the bottom of the pit with three samples collected on the longest straight line that can be drawn across the pit; one at each end of the line and one in the middle of the line.

Soil Classification

The classification of the soil into sand, silt or clay can be determined by a standard grain size analysis. The selection of the grain sizes for each size group is based on the U.S. Standard Sieve Mesh and the Wentworth Size Classes. This classification gives the following grain sizes for each soil.

Sand	2.0 mm to 0.62 mm
Silt	0.062 mm to 0.004 mm
Clay	Less than 0.004 mm

These sizes correspond to the U.S. Standard Sieve Mesh numbers as follows:

Size in mm	Sieve #	
2.00	10	
0.062	230	
0.004	none	measurement by pipette or hydrometer

The gradation for a given soil sample may range from large to small, encompassing all grain sizes. The soil class will be defined by the 50 percent value (D_{50}) as plotted on a grain size distribution curve (a semi-logarithmic plot) with weight percent finer plotted on the arithmetic scale and the grain sizes plotted on the semi-logarithmic scale.

If the two or more of the three soils analyzed fall into one soil size class, that will be the soil type for the site. If the soil types are all different, the sand size will be used as the soil type for the site.

WORK SHEET G
GENERALIZED GROUNDWATER ZONE CRITERIA WORK SHEET

These zones modified after the Generalized Groundwater Sensitivity Regions Of Kentucky as mapped by Ray and O'Dell (1993). They developed a methodology to assess the sensitivity of groundwater based on recharge, flow velocity and groundwater dispersion. Their work identifies potentially sensitive regions of the state to groundwater contamination from surface activities, such as leaking underground storage tanks.

To use the Generalized Groundwater Zone Map of Kentucky, one must locate the zone where their site is located on the Generalized Zone Map, and then determine if the geological and hydrogeological setting of the site fits the descriptions given below. Map 1, Generalized Groundwater Zone Map of Kentucky.

Zone 1

Highly Integrated Karst

These karst aquifers will exhibit highly convergent recharge at the swallets of sinking streams and sinkholes. Conduit flow velocities are high, ranging from 200 m/day at base flow to 100 times faster during flood pulses.

Zone 2

Fine Grained Alluvium

These deposits consist of fine grained sediments such as silt and clay derived from glacial outwash. Lacustrine deposits are also included in this zone due to their small particle size.

Gulf Coastal Plain Sediments

These are found in the Purchase Region of Kentucky. They represent a region where the surface materials are primarily loess or alluvium. The deeper aquifers will be less sensitive to surface activities.

Poorly Integrated Karst

Generally composed of variable proportions of interbedded shale and limestone with limited development of karst features.

Zone 3

Fractured Shale

Those areas underlain by shale will contain a flow system that is mainly in the fractures. The minor amount of groundwater flow that does occur is through these fractures and/or along the soil-bedrock surface.

Gulf Coastal Plain Sediments

These are found in the Purchase Region of Kentucky. They represent a region where the surface materials are primarily loess or alluvium. The deeper aquifers will be less sensitive to surface activities.

Zone 4

Fractured Sandstone and Shale

The fracture flow aquifers of the Eastern and Western Kentucky Coal

Fields are dominated by integrated beds sandstone, siltstone and shale.

Poorly Integrated Karst

Generally composed of variable proportions of interbedded shale and limestone with limited development of karst features.

Clay-Mantled Dolomite Karst

These areas lack rapid infiltration conditions due to a thick, clay-rich mantle and modest development of depressions which are broad and shallow and generally susceptible to ponding of runoff. Open sinkhole drains or valley swallets are rare. Most springs of the area do not indicate a history of flashy conduit flow.

Zone 5

Moderately Integrated Karst

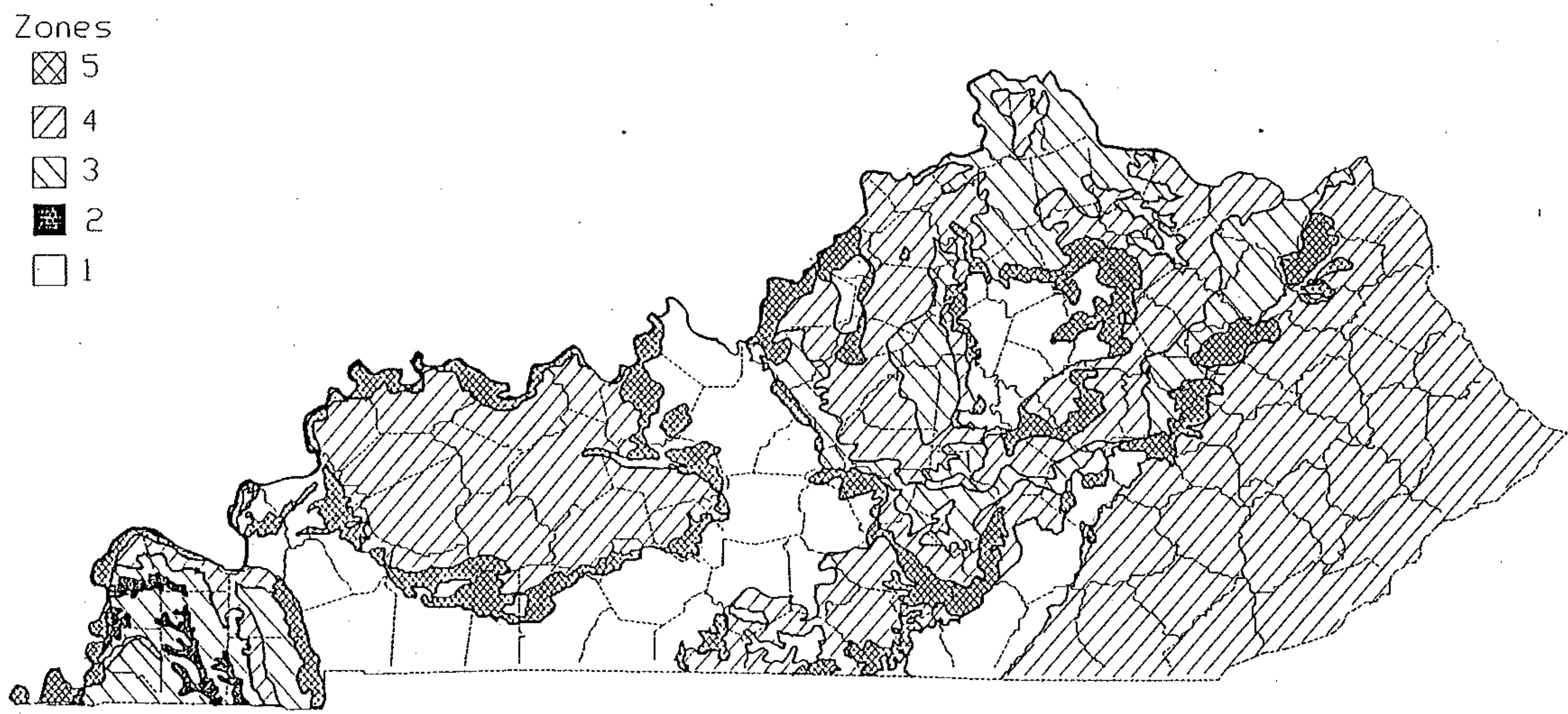
Overall conduits are smaller and less interconnected, and flow velocities are generally slower than in Highly Integrated Karst areas

Alluvium

Alluvium of major streams (third order and larger) can act as unconfined aquifers and will be very susceptible to contamination from leaking USTs.

REFERENCE: **Ray, Joseph A., and Phillip W. O'Dell, 1993, Dispersion/Velocity-rated Groundwater Sensitivity, Applied Karst Geology, William Beck editor, Balkema, Rotterdam.**

Generalized Groundwater Zones of Kentucky



WORK SHEET H
DEPTH TO WELL WATER WORK SHEET

The depth to well water has been determined by Naugle (1993) for the State of Kentucky, and that data has been reorganized by him to fit the Generalized Groundwater Zones included in the Generalized Groundwater Zone Map of Kentucky. Because the depths to water varies within each zone, depending on location within the state, the data have been grouped by physiographic regions. The data are presented below in Table A-1.

TABLE A-1

MEAN DEPTH TO WELL WATER FOR GENERALIZED GROUNDWATER ZONES

ZONE		MEAN DEPTH (FEET/METERS)
PURCHASE REGION	2	20/6.1
	3	46/14
	4	18/5.5
	5	52/15.8
WESTERN COAL FIELD	2	20/6.1
	4	50/15.2
	5	50/15.2
EASTERN COAL FIELD	4	25/7.6
MISSISSIPPIAN PLAT.	1	52/15.8
	5	30/9.1
	4	30/9.1
BLUE GRASS REGION	1	24.5/7.5
	5	20/6.1
	4	20/6.1
	3	20/6.1

ACKNOWLEDGEMENTS

This was a very unique study in that it was fast moving and, thus, required many individuals to respond rapidly to requests of the Committee members. In trying to recognize everyone, we will probably omit some individuals, but they should know that we did appreciate their help and used the information from every contact we made in the evolutionary process. In addition to the people that are listed below it should be noted that numerous phone calls to: underground storage tank agencies in other states; contacts with personnel at the U.S. EPA; and out of state consulting firms and faculty were made over the course of the project. The following is therefore a partial list of those that gave freely of their knowledge and assistance. For those that we have inadvertently omitted, I apologize and wish to extend a word of appreciation.

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Mark P. Stella
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Super America

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Toni Kittle
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Peg Chandler
BP Oil

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KY Conservation Committee

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