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Bioremediation Field Performance Evaluation of the Prepared Bed Land Treatment System

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Champion International Superfund Site, Libby, Montana: Bioremediation Field Performance Evaluation of the Prepared Bed Land Treatment System

Volume I - TEXT

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Notice

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Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet these mandates, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and ground water; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

The performance evaluation of the land treatment units at the Champion International Superfund Site in Libby, Montana, was made possible by the Bioremediation Field Initiative established in 1990. Two objectives of the Initiative were to (1) more fully document the performance of full-scale bioremediation field applications in terms of treatment effectiveness, operational reliability, and cost; and (2) to disseminate this information to the public and private sectors. This project represents a significant cooperative effort between industry (Champion International), academia (Utah State University), and the Environmental Protection Agency. Results from this study provide valuable insight to the biodegradation of soil contaminants associated with wood preserving wastes and to the operation of land treatment systems.

This report is published in two volumes. Volume I contains the text and several tables and figures. Volume II contains numerous Tables which represent a compilation of contaminant concentrations in the field and laboratory studies and Figures which identify the sample locations in the land treatment units.

Clinton W. Hall

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EXECUTIVE SUMMARY

The Champion International Superfund Site, a former wood preserving facility in Libby, Montana (referred to as the Libby Site), was nominated by the Robert S. Kerr Environmental Research Laboratory (RSKERL), Ada, OK, as a candidate site for bioremediation performance evaluation under the Bioremediation Field Initiative (BFI) sponsored by the U.S. Environmental Protection Agency (U.S. EPA). Target chemicals for bioremediation at the Libby Site include the polycyclic aromatic hydrocarbons (PAH), naphthalene, phenanthrene, and pyrene, total carcinogenic PAH compounds, and pentachlorophenol (PCP). The potentially responsible party (PRP), Champion International, agreed to cooperate with the RSKERL and Utah State University (USU) in conducting the proposed bioremediation performance evaluation studies for biological treatment processes in operation at the Libby Site. Results of the evaluation of bioremediation in a prepared bed system for treating creosote and PCP contaminated unsaturated soil are presented in this report.

Objectives of the evaluation of bioremediation in the prepared bed, lined land treatment unit were to: (1) describe and summarize previous and current remediation activities; (2) develop an approach to the evaluation of the prepared bed; (3) conduct a comprehensive field evaluation to assess performance of the unit in terms of treatment effectiveness, treatment rate, and detoxification of contaminated soil; and (4) perform a laboratory evaluation using field samples to determine indigenous soil microbial potential for accomplishing bioremediation of target chemicals in the soil matrix under site conditions of temperature and soil moisture.

Previous and current remediation activities involve the treatment of lifts of contaminated soil in prepared bed land treatment units. After a lift of contaminated soil is treated to target remediation levels, another lift of contaminated soil is added and treated until target remediation levels are obtained. Management of the prepared bed includes: (1) periodic addition of nutrients and moisture, and (2) tilling of the soil to increase oxygen transfer into the prepared bed to accomplish aerobic degradation. Land treatment operations began in 1989. At that point in time, it was projected by Champion International that it would take 10 years to treat the stockpile of contaminated soil. At the time of this report, land treatment remedial activities were in full operation, and the projected time of completion was still 10 years from 1989. This projection assumed that weather conditions did not prevent normal operations and that no additional land treatment units were constructed. There is currently no U.S. EPA or other U.S. government guidance manual that provides standard procedures for the use, evaluation, and monitoring of prepared bed systems for the treatment of organic-contaminated soils.

An approach to evaluation of the prepared bed was developed based upon a chemical mass balance conceptual model that was used to design sampling and analysis procedures and to interpret results of field and laboratory analyses.

A comprehensive field evaluation was conducted to assess performance of the prepared bed unit. Three-dimensional sampling of the prepared bed system, consisting of two full-scale land treatment unit (LTU) cells with liner and leachate collection, was conducted over a two-year period. Design of the performance evaluation was based on analysis of discrete soil samples collected using a random systematic sampling technique to minimize statistical bias and increase coverage of the contaminated area. This design allowed identification of areas within the LTU cells where individual soil samples exceeded the target remediation level, even though the mean value for a sampling event was less than the target remediation level. In addition, statistical analysis of the results provided information concerning variation in chemical concentrations both horizontally and vertically and also with time.

Analyses of over 300 soil samples were performed, from which greater than 5,000 individual chemical concentrations were determined for the 16 U.S. EPA priority pollutant PAH compounds using gas chromatography/mass spectrometry (GC/MS) and for pentachlorophenol (PCP) using gas chromatography/ electron capture detector (GC/ECD). The field performance evaluation was based upon results obtained with regard to: (1) soil chemical concentrations compared with target remediation levels for target chemicals; (2) evaluation of downward migration of target chemicals as a result of the application of additional lifts; (3)

detoxification of contaminated as indicated soil using bioassays; and (4) a laboratory evaluation for confirmation of indigenous soil microbial metabolic potential to biodegrade the target chemicals.

Results of chemical analyses indicated that target remediation levels were generally achieved, based on mean values at each depth evaluated. Target remediation levels for chemicals in the contaminated soils in the prepared bed system are: naphthalene, 8.0 mg/kg; phenanthrene, 8.0 mg/kg; pyrene, 7.3 mg/kg, total carcinogenic PAH, 88 mg/kg; and pentachlorophenol (PCP), 37 mg/kg, as specified in the Record of Decision (ROD). Statistical analysis of the results provided information concerning variation in chemical concentrations both spatially and temporally. Calculation of rates of apparent degradation of target chemicals indicated a 50 percent decrease in pyrene and PCP concentrations in 100 to 200 days and 200 to 300 days, respectively, under field conditions at the site.

Downward migration of target PAH compounds and PCP through the LTU cells was evaluated by determining if chemical concentrations were observed to increase in lower layers due to downward migration from upper layers containing greater chemical concentrations. Results of chemical analyses indicated a trend of decreasing chemical concentrations through time at each sampling depth. Based on the information obtained, downward migration of target chemicals through the LTU cells was not observed.

Soil within the LTU cells was detoxified to background soil levels, based upon results of using both the Microtox™ assay to measure soil water extract toxicity and the Ames Salmonella typhimurium mammalian microsome mutagenicity assay (Ames assay) to measure mutagenicity of soil solvent extracts. Detoxification was evident in all samples evaluated.

Laboratory analyses were conducted using radiolabeled target chemicals to evaluate the role of microbial processes in field observations of the disappearance of target chemicals. Results of the laboratory evaluation demonstrate that PCP and phenanthrene can be metabolized to carbon dioxide and water (mineralized) by indigenous microorganisms in the contaminated soil matrix at temperatures and moisture contents representative of site conditions. Incorporation of radiolabeled carbon into the soil solid phase was also a significant treatment process. Significant volatilization of PCP or phenanthrene at the full-scale field site is unlikely based upon the laboratory evaluation of chemical volatilization. The information obtained in the laboratory evaluation of LTU soil corroborates the interpretation that the majority of the apparent decrease in the target chemical concentration in field samples is due to biological processes rather than physical/chemical processes.

Results of field sampling indicated that the method of management of the lifts may be changed to decrease the total time required for treatment of all of the contaminated soil. Chemical concentrations for pyrene and PCP continued to decrease with time in buried lifts. If biodegradation continues in buried lifts, then a new lift may be placed on top of a lower lift after some significant treatment has been accomplished, but before the lower lift reaches target remediation levels for individual chemicals. This method of management of the LTU has not been practiced at the Libby Superfund Site; however, further investigation of this approach with regard to technical issues and optimization of time of placement of subsequent lifts should be evaluated in an effort to decrease the total time required for active soil placement and management at Superfund sites utilizing land treatment in prepared bed reactors.

Results of the field performance of the land treatment units at the Champion International Superfund Site in Libby, Montana, indicated that bioremediation using indigenous microorganisms was the process that accomplished soil treatment. Soil treatment included degradation of target PAH compounds and PCP in contaminated soil to target remediation levels as well as detoxification of contaminated soil.

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Chapter 1

Introduction

1.0 Introduction

The Office of Solid Waste and Emergency Response (OSWER) and the Office of Research and Development (ORD) of the U.S. Environmental Protection Agency (U.S. EPA) jointly established the Bioremediation Field Initiative (BFI) in 1990 as part of a strategy to develop bioremediation as an effective alternative remediation technology. The Initiative was designed to address the need for additional field experience concerning the implementation of bioremediation techniques, including the collection and dissemination of performance data from field experiences.

Specifically, the Bioremediation Field Initiative has three primary objectives: (1) to document more fully the performance of full-scale bioremediation field applications in terms of treatment effectiveness and operational reliability; (2) to provide technical assistance to U.S. EPA and State remediation managers responsible for overseeing or considering use of bioremediation as a remedial alternative for hazardous waste sites; and (3) to develop biotreatability data bases, which are available through the U.S. EPA Alternative Treatment Technology Information Center (ATTIC). This report focuses on Objective 1 by providing an evaluation of a full-scale field application of bioremediation at a specific site, the Champion International Superfund Site in Libby, Montana. The field performance evaluation was designed and conducted by Utah State University with support from the U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, to provide information on the effectiveness of bioremediation in addition to the information that is being generated by Champion International personnel as part of regulatory monitoring requirements.

The Champion International Superfund Site, a former wood preserving facility in Libby, Montana (referred to as the Libby Site) (Figures 1.1), was nominated by the Robert S. Kerr Environmental Research Laboratory (RSKERL), Ada, Oklahoma, as a candidate site for bioremediation performance evaluation. The potentially responsible party (PRP), Champion International, agreed to cooperate with the RSKERL and Utah State University (USU) in conducting the proposed bioremediation performance evaluation studies for biological treatment processes in operation at the Libby Site.

The Libby Site uses three distinct biological processes in the site remediation scenario: (1) surface soil biological treatment in a prepared bed system consisting of two lined land treatment units and a leachate system; (2) extraction of ground water, followed by aqueous phase treatment in an above-grade, fixed-film bioreactor; and (3) in situ bioremediation of the Upper Aquifer (Figure 1.2). Results of the evaluation of bioremediation in the prepared bed system are presented in this report.

Objectives of the evaluation of bioremediation in the prepared bed system were to: (1) describe and summarize previous and current remediation activities; (2) develop an approach to the evaluation of the prepared bed; (3) conduct a comprehensive field evaluation to assess performance of the unit in terms of treatment effectiveness, treatment rate, and detoxification of contaminated soil; and (4) perform a laboratory evaluation using field samples to determine indigenous soil microbial potential to accomplish bioremediation of target chemicals in the soil matrix under site conditions of temperature and soil moisture.

After a lift of contaminated soil is treated to target remediation levels in the prepared bed system, another lift of contaminated soil is added and treated until target remediation levels are obtained. Target chemicals for bioremediation at the Libby Site include three polycyclic aromatic hydrocarbon (PAH) compounds, naphthalene, phenanthrene, and pyrene, total carcinogenic PAH compounds (TCPAH), and pentachlorophenol (PCP). Target remediation levels for soil treated in the two LTU cells at the site are: naphthalene, 8.0 mg/kg; phenanthrene, 8.0 mg/kg; pyrene, 7.3 mg/kg, total carcinogenic PAH compounds, 88 mg/kg; and PCP, 37 mg/kg as specified in the Record of Decision (ROD).

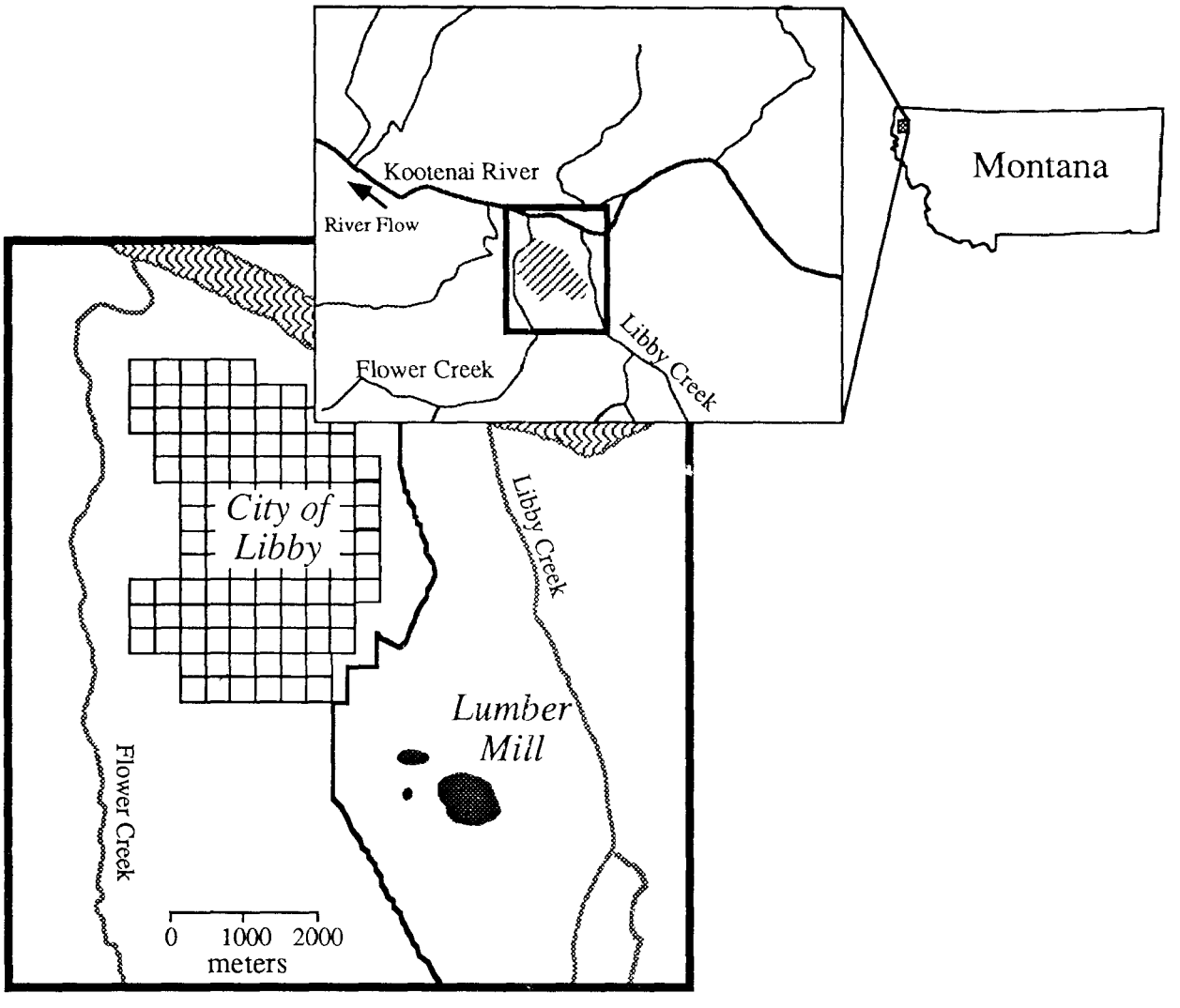


Figure 1.1 Location of the Libby Site.

Three-dimensional sampling of the two full-scale LTU cells was conducted over a two-year period. Analyses of over 300 soil samples were conducted, from which greater than 4,000 individual chemical concentrations were determined for 16 U.S. EPA priority pollutant PAH compounds using gas chromatography/mass spectrometry (GC/MS) and for PCP using gas chromatography/electron capture detector (GC/ECD). The field performance evaluation was based upon results obtained with regard to: (1) soil chemical concentrations compared with target remediation levels for target chemicals; (2) evaluation of downward migration of target chemicals as a result of the application of additional lifts; (3) detoxification of contaminated soil using bioassays; and (4) a laboratory evaluation for confirmation of indigenous soil microbial metabolic potential to biodegrade the target chemicals.

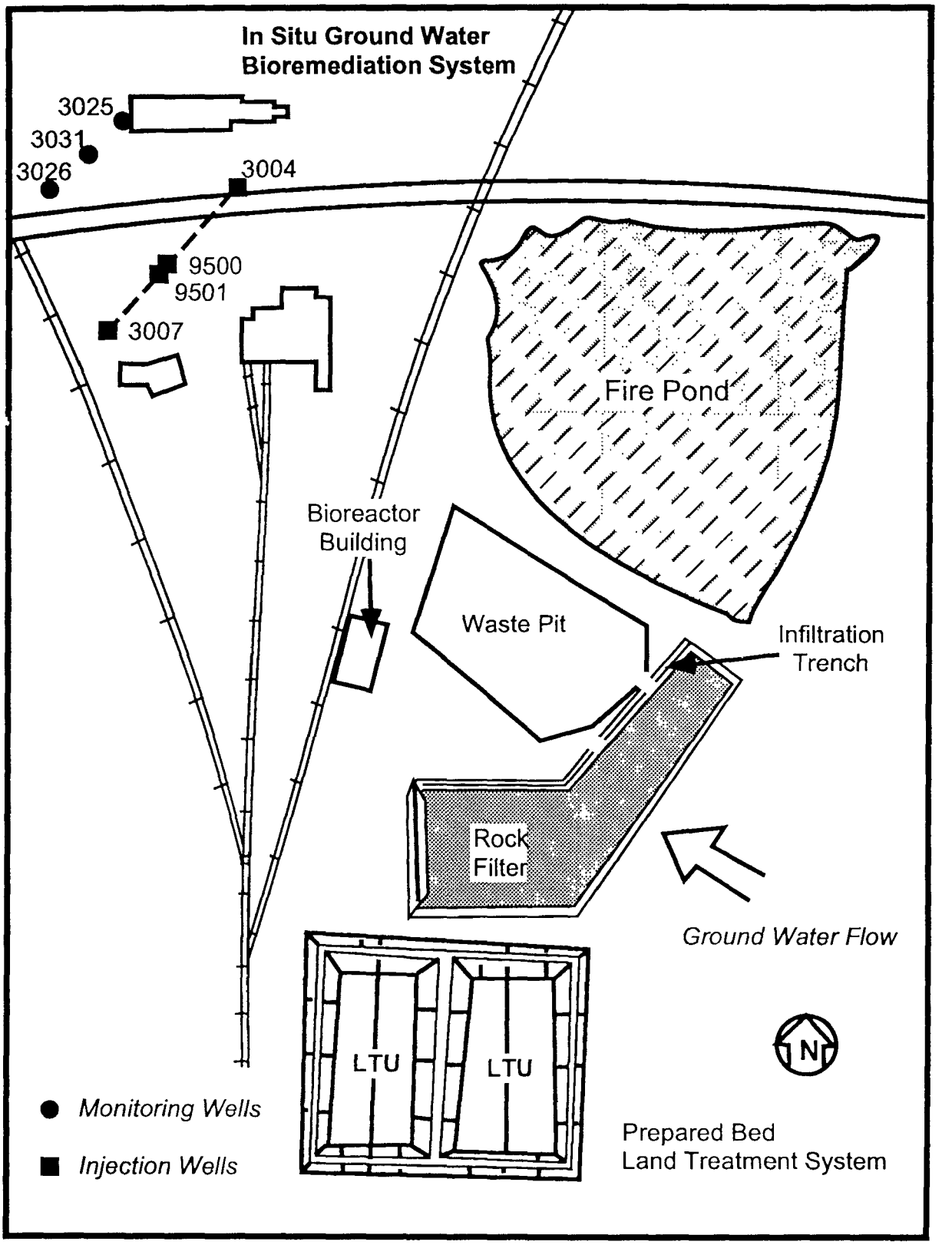


Figure 1.2 Bioremediation processes at the Libby Site.

Chapter 2

Conclusions

2.0 Conclusions

The field performance evaluation of a prepared bed bioremediation system at the Libby, Montana Superfund Site indicated that biodegradation of wood preservative chemicals in a prepared bed system was effective and resulted in the treated soil meeting target remediation levels for target contaminants, as specified in the Record of Decision (ROD). Downward migration of target chemicals as a result of the application of additional lifts was not observed. The contaminated soil was detoxified to background levels as a result of the treatment, based upon results of toxicity and mutagenicity assays.

Design of the performance evaluation was based on analysis of discrete soil samples collected using a random systematic sampling technique to minimize statistical bias and provide adequate coverage of the contaminated area. This design allowed identification of areas within the LTU cells where individual soil samples exceeded the target remediation level, even though the mean value for a sampling event was less than the target remediation level. In addition, statistical analysis of the results provided information concerning variation in chemical concentrations both horizontally and vertically and with time.

Based on the results of the field evaluation, a possible management tool may be to place a new lift on top of a lift after some significant treatment has been accomplished, but before the lower lift reaches target remediation levels for individual chemicals. This conclusion is based on limited field results that demonstrated that concentrations of pyrene and PCP appeared to continue to decrease with time after subsequent lifts had been placed on the first lift in the LTU cells.

Results of the laboratory evaluation using spiked radiolabeled target compounds demonstrated that PCP and phenanthrene could be metabolized to carbon dioxide and water (mineralized) by indigenous soil microorganisms at temperatures and moisture contents representative of site conditions. Incorporation of radiolabeled carbon into the soil solid phase was also a significant treatment process. In addition, significant volatilization of PCP or phenanthrene at the full-scale field site is unlikely based upon results of the laboratory evaluation of chemical volatilization. The information obtained in the laboratory evaluation of LTU soil corroborates the interpretation that the majority of the apparent decrease in the target chemical concentration is due to biological processes rather than physical/chemical processes.

Results of the field performance of the land treatment units at the Champion International Superfund Site in Libby, Montana, indicated that bioremediation using indigenous microorganisms was the process that accomplished soil treatment. Soil treatment in the lifts evaluated included degradation of target PAH compounds and PCP in contaminated soil to target remediation levels and detoxification of contaminated soil.

Chapter 3

Recommendations

3.0 Recommendations

The following recommendations are made concerning the approach to a comprehensive evaluation of field performance of bioremediation in full-scale prepared bed systems, and are not made for the purposes of routine sampling and testing for regulatory compliance or for management of prepared bed systems.

A chemical mass balance conceptual approach for evaluation of bioremediation is recommended that includes a field component and a laboratory component. The field component involves developing information that can be used to identify important phases (air, water, oil, and solid) that contain target chemicals, and identifying potential pathways of chemical escape from the prepared bed system that may be misinterpreted as biodegradation, for example, volatilization. The use of gas chromatography/mass spectroscopy is recommended for identification of target chemicals to ensure accurate analysis of target chemicals present in the soil phases sampled within the prepared bed system.

The field component also includes the development of a statistical sampling strategy for obtaining soil samples. Analysis of discrete soil samples collected using a random systematic sampling technique, designed to minimize statistical bias and provide adequate coverage of the contaminated area, is recommended. Individual soil samples may exceed target remediation levels even though mean values for a sampling event may be less than the target remediation levels. Discrete soil sampling and analysis allows identification of areas with elevated toxicity or elevated concentrations of contaminants as well as areas that may be oxygen deficient within the LTU cells. Statistical analysis of results of discrete sampling provides information concerning variation in chemical concentrations both spatially and temporally and with time that may influence biodegradation rate and extent.

The laboratory component involves providing direct evidence of microbial degradation (mineralization) of target compounds in site soil under environmental and management conditions representative of the site. Laboratory evaluations using radiolabeled target chemicals should be conducted as part of a field-scale evaluation of bioremediation to confirm soil microbial metabolic potential and to demonstrate that target chemicals can be metabolized to carbon dioxide and water in the contaminated soil matrix present at the site at temperatures and moisture contents representative of site conditions. The potential for a target chemical to become incorporated into soil humic material and to become non-solvent extractable can also be determined. In addition, the laboratory phase of the field-scale evaluation should measure potential abiotic losses, including volatilization of target chemicals. The information obtained in the laboratory phase of the field-scale bioremediation should corroborate the interpretation of apparent decrease in target chemical concentration as due to biological processes rather than physical/chemical processes. The laboratory phase provides a chemical mass balance confirmation of the effectiveness of bioremediation at field-scale.

Information obtained through field and laboratory evaluations based upon a chemical mass balance approach provide the necessary confidence that results observed through analysis of field samples are due to bioremediation and not due to interphase transfer or escape pathways for the target chemicals.

The following recommendation is made concerning management of prepared bed systems based upon results obtained in this performance evaluation. Because concentrations of both pyrene and PCP appeared to continue to decrease with time after subsequent lifts had been placed on the first lift, it may be possible to place a new lift on top of a lift after some significant treatment has been accomplished, but before the lower lift reaches target remediation levels for individual chemicals. This method of management of the LTU cells has not been practiced at the Libby Site. However, this approach should be further evaluated with regard to optimization of time of placement of subsequent lifts in an effort to decrease the total time required for active soil placement and management at Superfund sites utilizing land treatment in prepared bed reactors.

Chapter 4

Methodology

4.0 Methodology

4.1 Chemical mass balance approach

A chemical mass balance approach (Sims, 1990) was used to focus the evaluation of bioremediation at the Libby Site. Field-scale sampling and analysis were used in conjunction with a laboratory evaluation to provide complementary information for assessing the extent and rate of bioremediation and therefore, the effectiveness of bioremediation at the site. Specifically, a field scale mass balance evaluation approach was used to develop information that could be used to eliminate the possibility of escape of target chemicals in air, water, and soil phases as a cause of disappearance of PAH compounds and PCP from the LTU cells. This was accomplished by evaluating the tendency of target chemicals to be associated with each phase and by identifying the containment of each phase within an LTU. The laboratory-scale mass balance approach was used to provide direct information concerning the biological degradation (mineralization) of target chemicals in the site soil, and the influence of site environmental and management factors on the extent and rate of bioremediation.

4.2 Field-scale evaluation

The methodology developed by Sims (1990) for data collection and evaluation of soil remediation, based upon a chemical mass balance approach, was used for the field-scale evaluation. The methodology consisted of four activities: (1) site characterization, (2) assessment of the problem, (3) evaluation of the treatment (train) selected, and (4) monitoring treatment performance.

The first step involved characterizing the chemical/soil/site interactions to address the question "Where is the contamination and in what form(s) does it exist?" The target contaminants, PAH compounds and PCP, originally contaminated the soil as part of an oily matrix currently present in a residual saturation phase. The target chemicals are strongly associated with the soil (sorbed and residual saturation of total petroleum hydrocarbons and soil solid phase), with the exception of naphthalene. Naphthalene was present in low concentrations in contaminated soil applied to the LTU cells, generally below the target remediation level (8.0 mg/kg), and therefore did not present a problem with regard to volatilization. The remaining target PAH compounds and PCP are only slightly soluble in water, are non-volatile, and are strongly associated with the soil/oil matrix (log Kow and log Kd values greater than 4.0) (Sims and Overcash, 1983). Therefore, the focus of this investigation was on the soil/oil matrix.

The second step addressed the question "Where is the contamination going under the influence of natural processes?" The target PAH compounds and PCP will remain associated with the residual oily saturation in the soil and with the soil solid phases within each LTU cell. Each lift of contaminated soil was applied on the top of each LTU cell, thus providing potential for downward migration of PAH compounds in an oily/water phase (leachate) within the LTU cells. This downward migration was identified as a potential escape process from the top lift that could be misinterpreted as bioremediation. Therefore, to determine if downward migration of target chemicals was occurring, the soil was sampled through depth at each sampling event in order to determine if the concentration of PAH compounds within previously treated and buried soil increased with time.

The third step was the evaluation of the treatment train used for remediation of the contaminated soil at the Libby Site. This treatment train consists of containment of contaminated soil in the lined LTU cells, with provisions for leachate collection, and followed by long-term bioremediation of sorbed contaminants.

Berms provide effective containment of the soil phase, and the leachate collection system provides effective containment of the water phase within the LTU cells. Therefore, changes in concentrations of target chemicals within the LTU could be attributed to changes occurring within the LTU cells and the possibility of escape of target chemicals from the system through phase transport, including air, water, and soil phases, could be eliminated.

Finally, a monitoring strategy for determining the extent and rate of degradation was developed for the soil solid phase that consisted of taking discrete samples through depth and through time. With regard to interpretation of results in the context of bioremediation, this monitoring strategy was supported with a laboratory mass balance evaluation using site soil spiked with radiolabeled PCP and phenanthrene. Results of three-dimensional field sampling for determination of the decrease in target chemical concentration within each LTU cell and laboratory determination of biological mineralization were used to evaluate the effectiveness of bioremediation.

4.3 Soil sampling strategy for soil monitoring

The objective of the methodology for the location of sample site collection points was to develop a systematic, random sampling technique to minimize statistical bias and provide adequate coverage of the contaminated area. To gain confidence that target remediation levels have been reached, the amount of data is increased by collecting and analyzing discrete samples rather than composited samples so that the variance of the concentration of contaminant(s) across the treatment site is accurately estimated (i.e., the information available is maximized). Since the goal of treatment is to protect public health and the environment, extremes in concentrations and not their central tendency (i.e., mean concentration) are of concern. Compositing of samples, in effect, averages the concentration in the composited samples, which only tends to indicate the central tendency of the concentrations. No estimate of the variance of the mean and thus the precision with which the mean is estimated can be obtained from a composite of samples (Peterson and Calvin, 1986). In addition, compositing does not provide information about the likelihood of the existence of relatively high concentrations (i.e., above the target remediation levels) within the soil being treated. Concentrations of compounds in soils, both natural and contaminant-related, are typically highly variable over small distances, both horizontally and vertically (Mason, 1983; Wilding, 1985; Peterson and Calvin, 1986).

Compositing is often used, however, to reduce handling and analytical costs. When compositing is used, at least four different samples taken in the vicinity of each selected sampling site should be composited into a single sample. A discrete sample that is not composited should be collected for comparison with the composited sample (Barth and Mason, 1984). Care must be taken in mixing the samples to ensure homogeneity and representativeness of the composited sample prior to collecting subsamples for analytical measurements (Barth et al., 1989). In general, compositing should not be used if high concentrations from specific areas will be reduced by being averaged with samples with lower levels of concentrations (Barth and Mason, 1984).

The boundaries of the LTU beds at the Libby Site are well-defined, which allowed the design of a systematic sampling protocol that maximized coverage of the soil materials, provided sufficient samples to indicate the variance of the contaminants of concern, and increased the probability that more highly contaminated soils were sampled. The systematic approach used a sample selection grid to assure that sample locations were not close to one another, which resulted in the distribution of samples over essentially all of the treatment bed. Samples taken at locations that are close together tend to result in redundant information (Barth et al., 1989).

4.4 Laboratory -scale evaluation

The chemical mass balance approach using the laboratory evaluation of bioremediation using the Libby soil is described in detail in section 6.7. The laboratory evaluation was undertaken to determine a chemical mass balance for radiolabeled phenanthrene and PCP and the influence of soil microbial metabolic

potential on the chemical mass balance for these chemicals in the LTU soil at the Libby Site. The objectives of the mass balance evaluation were to (1) determine the fate of 14C-phenanthrene and 14C-PCP in the soil system, including an evaluation of mineralization and volatilization, and (2) determine the rate and extent of biological mineralization of 14C-phenanthrene and 14C-PCP in contaminated soil as affected by management factors including soil moisture and temperature.

Chapter 5

Overview of Site and Remediation Activities

5. 0 Overview of site and remediation activities

The activities described in this report are based on operation and management of the site at the time of this study (1991-1992). The prepared bed reactor system at the Libby Site has been operated in a dynamic manner, i.e., as opportunities arise to improve or optimize the system, modifications to system operations are implemented. Therefore, several of the operational systems described in this chapter have been changed to improve the effectiveness of the system.

5.1 Site history

The two types of wood preserving chemicals that were used at the Libby Site during its period of operation (1946 to 1969) were creosote and pentachlorophenol (PCP). Though wood treatment operations have not taken place at the site since 1969, residual contamination of soils and ground water remain. Contaminants of most concern at the site include: (1) polycyclic aromatic hydrocarbons (PAH compounds), which are the primary components of creosote (PAH compounds are associated primarily with the soil solid phase by adsorption); (2) PCP (PCP is somewhat volatile and, in the ionized form, is soluble in water); and (3) dioxins, an impurity in technical grade PCP (dioxins are nonvolatile, highly insoluble in water and are closely associated with the soil solid phase). PAH compounds and PCP were also detected in some Libby city wells.

In 1983, the U.S. EPA placed the Libby Site on the National Priorities List of Superfund sites. In 1985, the PRP provided an alternative water supply to people whose wells were contaminated and conducted studies of the contamination problems, which included bench and pilot-scale testing of remedial technologies. In 1988, the U.S EPA and the Montana Department of Health and Environmental Sciences signed a Record of Decision (ROD) that designated biological treatment as the remedial method for both soil and ground-water remediation. During the summer of 1989, a land treatment demonstration was conducted to collect information on contaminant degradation rates, to evaluate potential for contaminants to migrate downward during treatment, and to demonstrate biodegradation was the major mechanism of contaminant loss. A consent decree that required the PRP to utilize bioremediation as the selected remedial technology was entered in Federal District Court in October, 1989.

However, although the U.S. EPA had formally approved the plan for the site, land disposal restrictions promulgated under the Resource and Recovery Act (RCRA) restricted application of the soils to land after August 8, 1990. Therefore, a "No Migration Petition" (Woodward-Clyde Consultants, 1990b) was filed with the U.S. EPA in February, 1990, which included data from the land treatment demonstration conducted in 1989 that showed that no migration of contaminants would occur during treatment. The U.S. EPA formally approved the petition in October 1990, and full-scale soil remedial activities commenced in 1991.

5.2 Assessment of the problem

Contaminated surface soils at the Libby Site present a potential public health threat via direct contact and ingestion. The soils also pose potential environmental and public health threats because they serve as source materials for release of contaminants to the ground water. The purpose of the soil remediation program is to reduce organic contaminant concentrations to levels considered acceptable from a regulatory perspective and to minimize risks to public health and the environment.

5.3 Target remediation levels

Target remediation levels (clean-up goals) for the contaminated soils (on a dry-weight basis), as specified in the Record of Decision (ROD) (U.S. Environmental Protection Agency, 1988), are:

(1) 88 mg/kg total carcinogenic PAHs (sum of fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, and indeno(1,2,3-cd)pyrene);

(2) 8 mg/kg naphthalene;

(3) 8 mg/kg phenanthrene;

(4) 7.3 mg/kg pyrene;

(5) 37 mg/kg PCP; and

(6) < 0.001 mg/kg dioxin equivalency (sum of 2,3,7,8-tetrachloro-dibenzo-p dioxin (TCDD) - equivalent concentrations of polychlorinated dibenzo-p-dioxins and dibenzofurans).

Additional lifts may be placed on the LTU when the total carcinogenic PAH and PCP concentrations in the treatment zone for the preceding lift are at or below target remediation levels.

5.4 Soil remediation

Contaminated soils were located in three primary source areas at the Libby Site: a former tank farm, an unlined butt dip area, and an unlined waste pit (Figure 5.1). In 1989, contaminated soils from these three areas (approximately 75,000 cubic yards of materials) were excavated down to the water table. Before the tank farm and butt dip areas were filled with clean soil, samples were collected and analyzed to verify that contamination had been removed.

Since the major contaminants of concern were expected to be associated with finer-grained materials, the soils excavated from the tank farm and butt dip areas and any previously excavated contaminated materials from the waste pit area were physically screened to remove rocks larger than one inch in diameter (referred as de-rocking). The screened soils from all three areas (approximately 45,000 cubic yards) were placed

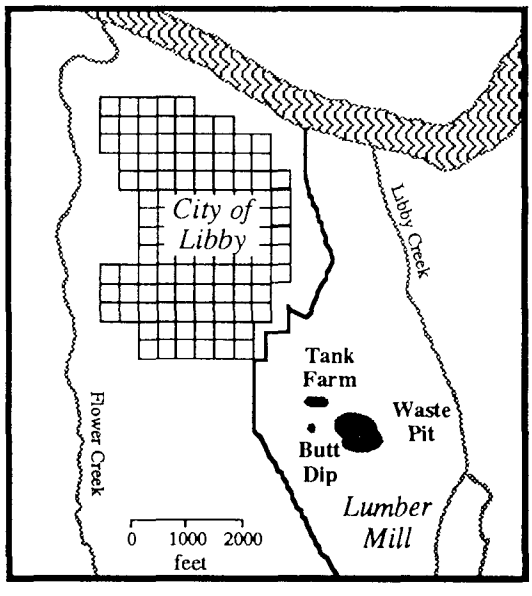


Figure 5.1. Contamination source areas at the Libby Site.

in the excavated waste pit area. The separated rocks were placed upgradient to the waste pit area to construct sub-grade infiltration galleries. This rock percolation bed is used for biological treatment of the contaminated rocks using effluents from the above grade, fixed-film bioreactor.

Initial soil concentrations of contaminants of concern, expressed as the geometric mean, in the contaminated soils from all three areas were calculated as: 189 mg/kg total carcinogenic PAH compounds; 29 mg/kg PCP; and 0.9 x 10-3 mg/kg 2,3,7,8-TCDD (tetrachloro-dibenzo-p-dioxin) equivalency. However, the soils are variable in concentration from sample to sample, with the maximum concentrations for individual carcinogenic PAH compounds, PCP, and 2,3,7,8-TCDD equivalency greater by factors from 6 to 90 than the geometric mean concentrations.

The screened soils in the waste pit area undergo remediation using a two-step enhanced biodegradation treatment process. The first step involves stimulation of biodegradation within the waste pit area by (1) adding nutrients (approximately 5 times during a summer operational season); (2) tilling twice weekly; and (3) adding bioreactor effluent, fire pond water or LTU leachate periodically to maintain a soil moisture level in the tilling zone of 8.5 percent. This pretreatment is used to reduce initial contaminant levels for subsequent treatment in the prepared bed, lined land treatment unit. Soil samples are collected and analyzed periodically to monitor moisture levels in the waste pit area and to estimate moisture requirements for the LTU.

The second step in the treatment process involves placement and management of the soils from the waste pit area in the two LTU treatment cells, which also act as the final disposal location for the soils (Figures 5.2 and 5.3) (Woodward - Clyde Consultants, 1990a). Each one-acre LTU cell is lined with low permeability materials to minimize leachate infiltration from the treatment unit. Contaminated soils are placed in the LTU cells in 6 to 12 inch lifts for treatment during the summer period. Moisture is applied to the LTU to maintain adequate moisture levels (approximately 40 to 70 percent of field capacity) in the treatment zone as well as for dust control.

Field capacity is measured in the field at least once per lift to provide data on the moisture holding capacity of the soils and to estimate and define the target moisture levels corresponding to the desired 40 to 70 percent field capacity range. Field capacity is determined by wetting a small area (approximately 5 ft. by 5 ft.) with fire pond water. The area is then covered with a plastic sheet and left for 48 hours. A sample is then collected to determine the percent moisture content. For example, if the field capacity as measured in the field is about 13 percent, the soil moisture content in the LTU should be maintained at target levels of about 5 to 9 percent. Weekly laboratory moisture measurements are conducted to calculate the amount of water to be applied to the LTU to reach the target level. In between weekly laboratory measurements, field observations consisting of (1) daily visual observations of the moisture content of the surface soils, (2) the soil moisture profile with depth, and (3) the amount of dust generated from the LTU operations, are used to estimate moisture needs. Additional moisture applied to the LTU is usually added immediately prior to tilling to control the generation of dust during the tilling operations. Active management of the LTU cells is conducted from approximately March to October each year.

Water sources for irrigation include fire pond water, effluent from the bioreactor, or leachate collected from LTU sumps. The water is applied manually to the LTU using a fire hose connected to irrigation piping that is located around the perimeter of the LTU. The application of water to the LTU depends on soil moisture levels in the treatment zone. Water application is limited during high moisture periods to minimize the volume of leachate produced in the LTU sump.

Nutrients (inorganic forms of nitrogen and phosphorus, usually ammonium sulfate and ammonium phosphate) are added to the LTU by dissolving them in water applied to the unit or by fertilizers applied directly to the LTU. The amounts of nutrients added are dependent on nutrient requirements for optimizing biodegradation and the total amount of total organic carbon (TOC), nitrogen, and phosphorus already existing in the soil. The nutrient requirement used for bioremediation optimization was selected as a carbon:nitrogen ratio in the soils of approximately 12-30:1 and a nitrogen:phosphorus ratio of approximately 10:1. The soil in the treatment zone is monitored periodically for TOC, total Kjeldahl nitrogen (TKN), and total phosphorus to

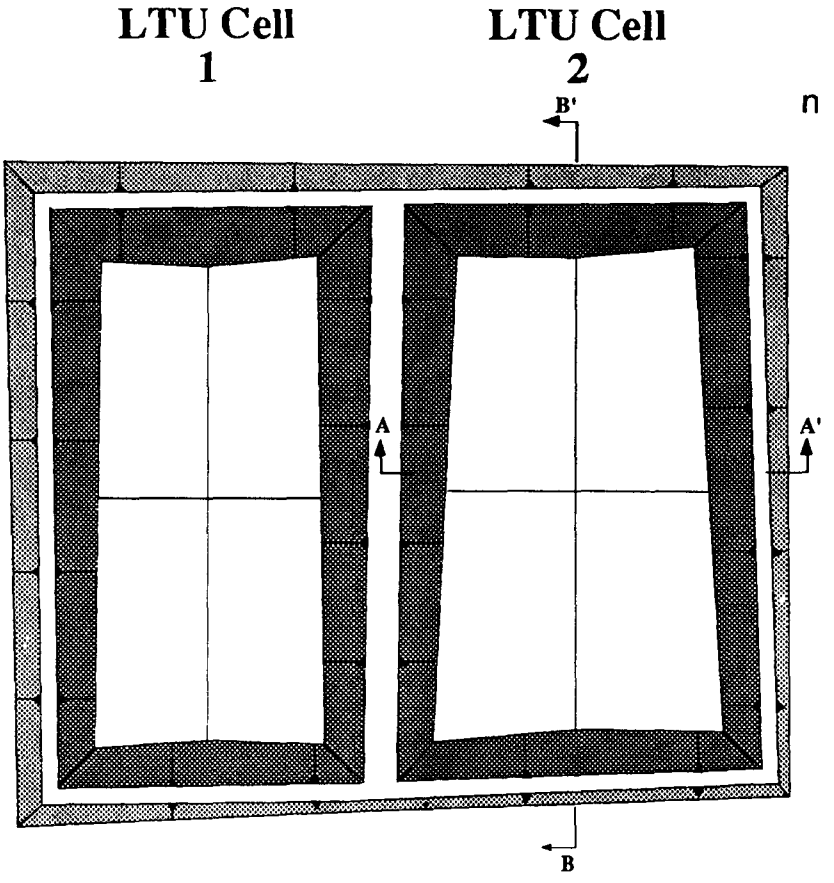


Figure 5.2 LTU treatment cells

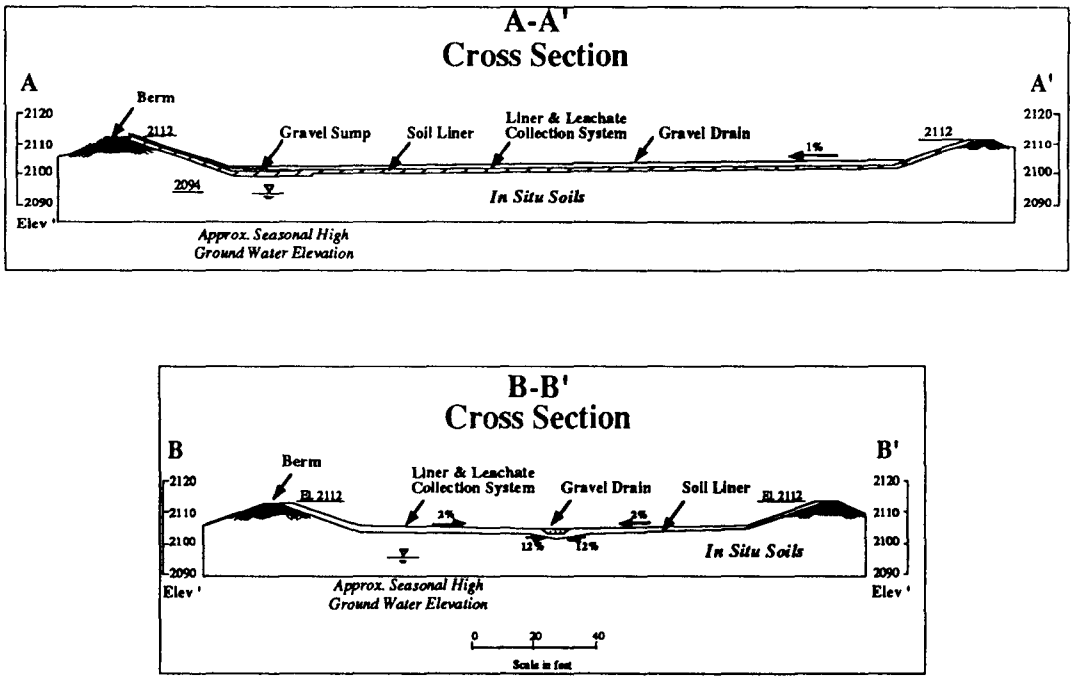


Figure 5.3 Cross section of LTU treatment cells

estimate concentrations already existing in the soils. The amount of nitrogen and phosphorus to be added is estimated by subtracting the amounts of nitrogen and phosphorus already existing in the soil from the nutrient requirement, and multiplying the remaining concentration by the estimated weight of the lift being treated. Because a significant percent of carbon measured by the TOC analysis may exist as ash or other non-available forms of carbon, the use of TOC to estimate the amount of carbon in the soil should result in a larger amount of nutrients being applied to the LTU than that needed to enhance degradation. Nutrients are added as frequently as every other day, depending on soil moisture and nutrient needs.

To enhance microbial activity by oxygenating the soils, tilling of the entire LTU is performed frequently (at least weekly, if possible, but dependent on weather conditions) using a tractor-mounted rototiller or similar type equipment. If the LTU contains ponded water after storms, tilling is suspended until the soil dries sufficiently for tilling. Deep tilling to promote biodegradation may be used occasionally in the LTU if deeper soils with contaminant concentrations above the target remediation levels are detected. Deep tilling will be continued until the lower zone has contaminant levels at or below the target remediation levels specified in the ROD. If contaminants are found to consistently migrate into underlying lifts, operation procedures will be modified. Such modifications may include (1) loading of smaller lifts on the LTU; (2) an increase in tilling frequency; or (3) reduction in moisture applied to the LTU.

Operation of the LTU, including the loading of soil lifts, is discontinued during the winter months. New lifts are not loaded near the end of the treatment year if contaminant levels are not expected to decrease substantially before the operation of the LTU is discontinued for the winter.

After all contaminated soils have been treated in the LTU unit to achieve reduction of contaminant concentrations to acceptable levels, a protective cover will be installed and maintained over the total two-acre treatment unit to minimize surface infiltration, erosion, and direct contact.

5.5 LTU design: process overview

Selection of the location for LTU construction was based on previously existing site factors as well as possible future influences resulting from operation of the facility. Previously existing site factors that influenced selection of the LTU location included: (1) proximity to the contaminated soils to be treated; (2) company on-site operational constraints; and (3) soil and water quality analyses that indicated low level contamination of surface soil and subsurface environments.

Contaminated soils are treated in lifts (approximately six to twelve inches in thickness) in the designated LTU cell until target soil contaminant levels are achieved for a given lift. Degradation rates, amount (volume) of soil to be treated, initial contaminant concentration, duration of summer operational period, and LTU size determine the time requirements for remediation of a given lift of contaminated soil. Based on an estimated 45-day time frame for remediation of each applied lift of contaminated soil to acceptable contaminant levels, an estimated volume of 45,000 cubic yards of contaminated soil requiring remediation, and a two-acre total LTU surface area, the time for completion of soil remediation was estimated to be approximately 8 to 10 years.

Design criteria for each LTU cell include provisions for total containment of contaminated soils, water, and leachate, with ultimate treatment and disposal of all contaminated soils within the LTU treatment unit.

5.5.1 Facility design components

- treatment unit with two-acre final surface area (two one-acre LTU cells)
- treatment zone with 30-inch depth (18 inches sandy-material supporting 12 inches silty-material)
- liner system (60 ml high density polyethylene (HDPE), compacted clay, geotextile filter fabric, geonet)

- leachate collection system (perforated PVC piping/gravel drains/sumps)
- rainfall runoff/leachate storage unit (two 50,000-gallon tanks)
- passive moisture control system (perforated HDPE piping system)

5.5.2 Details of system components

5.5.2.1 Size

The lined, prepared bed land treatment unit is comprised of two cells with a final surface area of one acre each. The surface area required was based on the estimated total quantity of material excavated from the source areas minus the quantity of materials greater than one inch in diameter removed during de-rocking, since contaminants were expected to be associated with finer soil materials.

Each LTU cell is surrounded by a berm constructed with low permeability soils that were compacted with a dozer. Incremental berm construction design allows modification of the LTU height to increase storage capacity as needed, in order to maintain at least two feet of elevation difference between the top of the treatment zone and the top of the berms. The use of berms allows for containment, treatment and ultimate disposal of additional contaminated soils if required. The berm was designed to control run-on and runoff associated with a 25-year, 24-hour storm event.

The LTU cells are each sloped to a central gravel drain (2 percent slope) to accomplish water control within the unit. The gravel drain also is sloped to a gravel sump (1 percent slope).

5.5.2.2 Treatment zone

The treatment zone consists of the contaminated soil that is tilled and amended with moisture and nutrients. Beneath the first layer of contaminated soil (lift) is a layer of sandy material (18 inches) supporting a top layer (12 inches) of silty material. The sandy material was collected on-site and consists of uncontaminated material meeting the Unified Soil Classification System (USCS) definition of SP SM (poorly graded sands or gravelly sands and silty sands) or SM (silty sands). Maximum size is 1/2 inch. The silty material consists of silts and/or clays collected from an on-site area and meets the Unified Soil Classification System definition of ML (silts and very fine sands, silty or clayey fine sands, or clayey silts of low plasticity), ML-CL (silts and very fine sands, silty or clayey fine sands, or clayey silts of low plasticity with clays of low to medium plasticity or gravelly, sandy, or silty clays) or CL-ML (clays of low to medium plasticity or gravelly, sandy, or silty clays with silts and very fine sands, silty or clayey fine sands, or clayey silts of low plasticity). Standard filter criteria were used for material sizing between the treatment zone silty layer and sandy layer with regard to reducing clogging potential.

5.5.2.3 Liner system

A liner system was designed to minimize migration of leachate that may be generated from treatment operations and that might otherwise continue downward through unsaturated zone soils into ground water.

The underlying liner system for each LTU cell consists of a 60-mil synthetic flexible geomembrane liner placed on top of a compacted soil liner (18 inches thick) constructed from low permeability (5 x 10-5 cm/sec) soils (Glacial lake sediments) collected on-site. The compacted soil beneath the HDPE liner was compacted to accomplish a maximum permeability of 5 X 10-7 cm/sec. High density polyethylene (HDPE) materials were chosen for the geomembrane liner due to its documented compatibility with most common wastes and waste by-products. Leakage testing of the geomembrane liner was performed utilizing electrical resistivity. This method involves flooding the lined facility and installing an electrical source in the water within the contained area and an electrode outside the unit to complete the electrical circuit. The intact geomembrane liner acts as a resistance to the imposed current, and any leaks can be detected using voltmeters

to locate areas of high current flows. Additional analysis of leakage through the liner under different scenarios of liner rupture was accomplished using the hydrological evaluation of leachate performance (HELP) model.

5.5.2.4 Leachate collection system

The purpose of the leachate collection system is to prevent leachate from accumulating within the LTU and to monitor contaminant concentrations. The leachate collection system, including surface water pumping, subsurface drainage net, gravel drains, and collection pipes, is designed to collect leachate generated from two sources of water: (1) water applied during operation of the LTU, and (2) water from precipitation events. Leachate collected in the bottom of each cell is removed to minimize buildup of leachate (hydraulic head) on the liner system, thus reducing potential for leakage, and to prevent free water buildup in the LTU that could eventually lead to horizontal migration if the water levels were to exceed the top of the flexible membrane liner.

A drainage net (Tensar DN-3) covered by a geotextile filter fabric (Typar 3601) was placed over the geomembrane/soil liner system (Figures 5.4 and 5.5) (Woodward - Clyde Consultants, 1990a). Water filtration criteria were used to select the geotextile filter fabric in order to minimize migration of treatment zone sands from above into the drainage net, which could result in the clogging of the leachate collection system.

A gravel drain (12-inch thickness) was constructed along the entire length of the floor in each LTU cell. River gravels, which contain non-angular materials, were used in the drainage system to reduce puncture potential and maintain liner integrity. A collection sump and sloping riser was constructed at the lowest point of the gravel drain (at the north end of each LTU cell, centered in the east-west direction). Two four-inch diameter HDPE pipes slotted and wrapped in geotextile filter fabric were placed in the gravel drain and sloped to the collection sump. The drain and sump were back-filled with gravel and completely enclosed in geotextile filter fabric. A single slotted six-inch diameter pipe was located along the base of each sump and was connected to a solid six-inch diameter HDPE pipe that rises upward along the interior slope of the north berm of each cell. This pipe provides access to the sump area for leachate removal.

Plan View of Top of HDPE Liner in Leachate Collection Sump

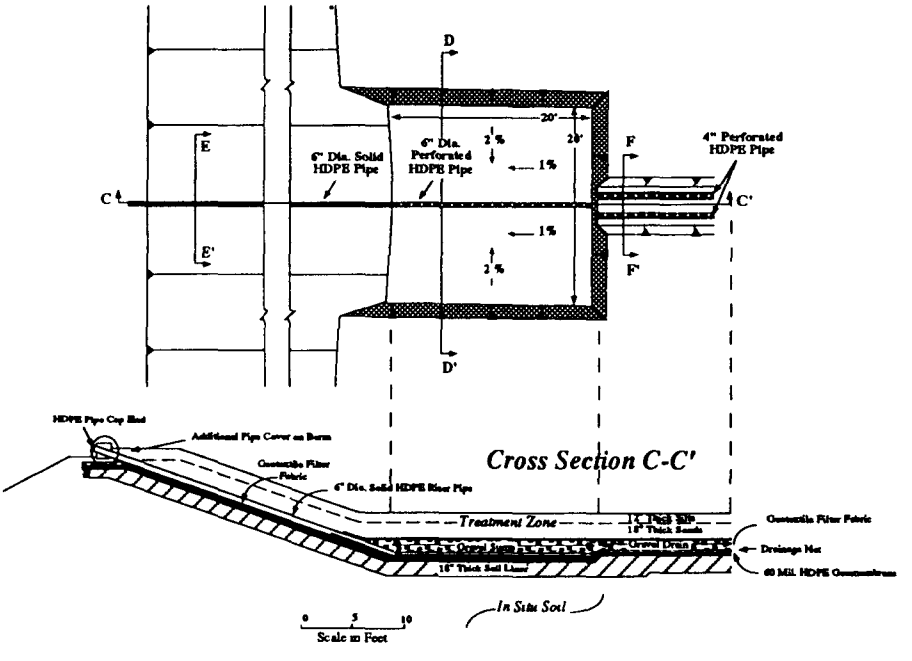
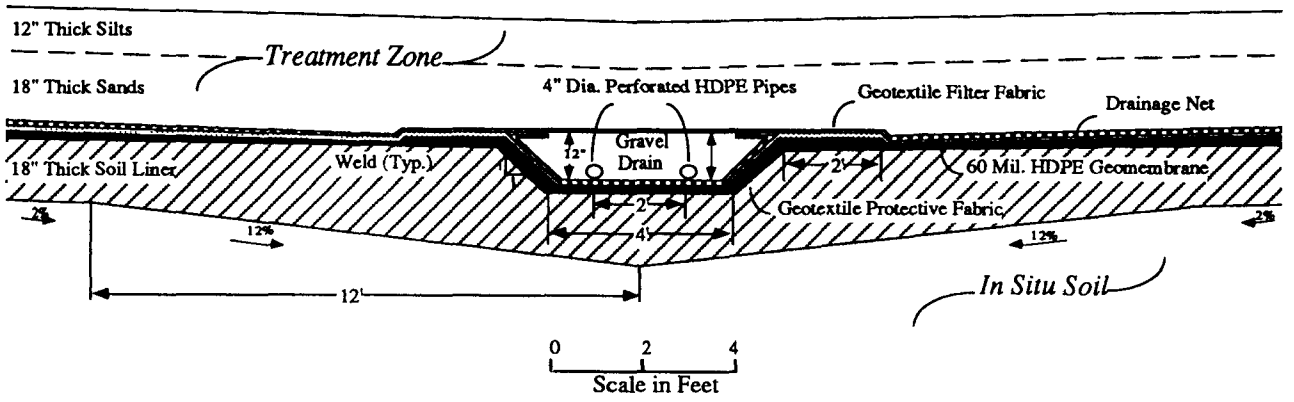
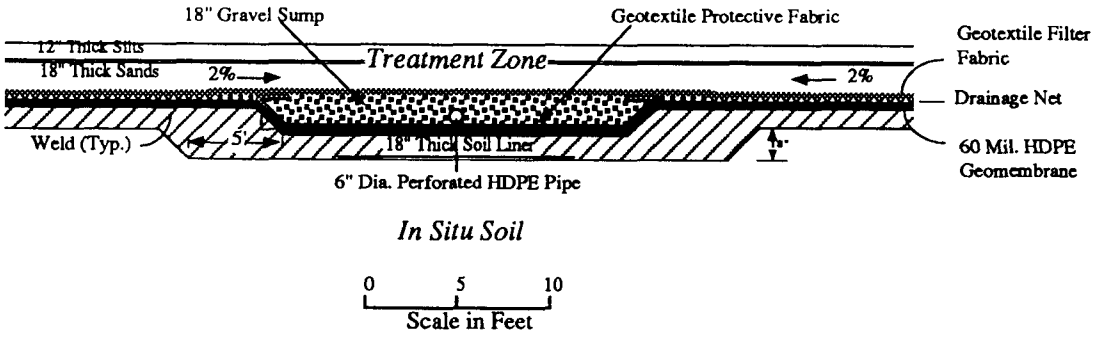


Figure 5.4 Geomembrane / soil liner system for leachate collection

Cross Section F-F'
Typical Gravel Drain Section



Cross Section D-D'



Cross-Section E-E'

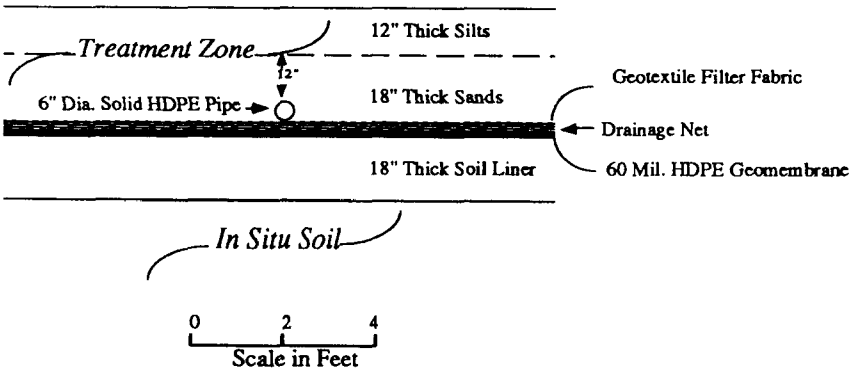


Figure 5.5 Cross sections in leachate collection system

Leachate is removed from the leachate collection system sump area by means of an automated leachate collection pump and piping system (which can be overridden for manual control). The automated system ensures that a significant level of water will not collect in the sump area. Self-priming pumps located in a heated pump house are used for leachate removal. High and low level automatic pump activation switches were installed near the base of the HDPE pipe located in the sump for each cell. The level controls are usually set so that 300 to 600 gallons are pumped when the system is activated. The flow rate is monitored using a flow meter located within the pump house. Discharge pipes installed below the frost depth can carry effluent to two 50,000 gallon storage tanks or to the bioreactor. These pipes are insulated and heat-taped where exposed.

Daily inspections of the pump removal system are made on regular work days. If failure should occur in the pumps or piping system, the system will be repaired within one week to ensure continued removal of leachate from the LTU.

Surface water is managed by daily monitoring of the LTU during regular work days to see if significant amounts of water have collected on the surface of the LTU. The surfaces of the LTU cells are sloped so that surface water collects at the low point of the cells above the leachate collection sumps. If water collects to a sufficient depth to be pumped by a submersible pump, then the water is promptly removed until the submersible pump is unable to continue pumping.

The recovered water is sprayed directly on the rock pad or injected into closed or open trenches. These disposal areas were selected because they should be able to handle the maximum design storm event, which is the 24-hour, 25-year storm of 2.4 inches. This maximum design storm event could result in approximately 150,000 gallons over the 24-hour event period being recovered from the two-acre LTU and associated haul roads. The trenches were tested at a 250 gpm injection rate and were able to handle water discharged at this rate. The leachate collection pumps have a pumping rate of only 50 gpm, so the infiltration trenches should be able to handle the water being recovered from the LTU at this lower rate.

5.5.2.5 Leachate storage unit

Effluent in the two 50,000 gallon storage tanks can be directed to (1) the LTU cells for irrigation in the summer months; (2) to the infiltration galleries/infiltration trench, where it can be amended with nutrients for use in the in situ aquifer bioremediation system; (3) to the rock pad; or (4) to open trenches. To prevent freezing of collected liquids in the storage tanks, the design incorporates use of a combination of electric immersion heating and sparging with warm, compressed air. In addition, all exposed piping is insulated.

5.5.2.6 Passive moisture control system

A passive moisture control system is installed within the LTU adjacent to the incremental berms to minimize the potential for soils to become saturated in this area. The system consists of interconnected perforated HDPE pipes, wrapped in filter fabric and placed around the perimeter of the LTU. This drainage system drains water from areas adjacent to the berms and carries it to the treatment zone above the LTU sump, where, when it accumulates in excessive amounts, it is removed by the leachate collection system.

5.6 Process monitoring

The monitoring program involves periodic collection and analyses of leachate, soil, ground water, and air samples both outside and within the treatment cells during operation and closure periods. Post-closure care will include monitoring and inspection following placement of the cap at the end of the closure period.

5.6.1 Monitoring outside the LTU

Monitoring systems in the vicinity of the LTU include ground-water and air sample collection systems. Background samples have been collected and analyzed to establish a baseline for evaluating data collected during the LTU operation.

The ground-water monitoring system includes six wells (three down-gradient, two upgradient, and one midway between the LTU and the waste pit area). Monitoring of the ground water wells around the LTU is performed semi-annually. Ground-water samples collected from each of the monitoring wells are analyzed at an off-site laboratory.

Periodic ambient air monitoring is conducted to: (1) characterize emissions that may be released to the atmosphere as a result of operations at the unit; and (2) quantify ambient concentrations of the compounds in order to protect the health of the workers at the LTU. Dust is expected to be the principal contaminant of concern for the workers at the LTU. Dust control is primarily accomplished by applying to the moisture to the LTU before tilling. If during tilling operations, dust generation becomes visible, additional moisture is applied to the LTU to suppress the dust, and/or tilling operations are discontinued until weather conditions change so that dust generation is reduced.

Analysis parameters for air quality parameters include gaseous and particulate PAH and PCP constituents. Air monitoring is performed shortly after loading during the day that the initial tilling occurs. This initial tilling sampling event for a lift is considered to provide worst-case data for emissions from the LTU, since the highest concentrations should be present in the soils at this time. Two air samples are collected at a height of 1.5 meters above ground level on the berms adjacent to the LTU to monitor for contaminant migration. One sample station is placed directly upwind of the LTU, and a second sample station is placed directly downwind of the LTU so that both downwind and upwind air quality data are obtained. To place the samplers at the appropriate locations, the prevailing wind direction is monitored at a on-site meteorological monitoring station every two hours during the sampling period. If the wind direction changes during any of the 2 hour periods, the sampling stations are rotated so that they continue to monitor the upwind and downwind air quality of the LTU. The total sampling time of each collection period is approximately six hours. One sample is collected for PAH and PCP analysis at two locations (upwind and downwind) around the LTU to provide a total of four samples (2 PAH and 2 PCP) per collection period. A duplicate sample for PAH and PCP is collected from the berm expected to be the downgradient berm prior to tilling. This duplicate sample and one field blank as well as the air samples collected from the monitors during tilling are analyzed by an off-site laboratory for PAH compounds and PCP. Concurrent with ambient air sampling, one hour values for wind speed, wind direction, sigma theta (standard deviation of wind direction), and temperature are recorded at the on-site meteorological monitoring station. These data are used to evaluate air dispersion characteristics (i.e., atmospheric stability) during air monitoring.

Concentrations of PAH compounds and PCP measured in the air samples are compared to concentrations used for modeling in the No Migration Petition (Woodward-Clyde Consultants, 1990b) to determine if acceptable concentrations are present. More frequent samples are collected if the concentrations are unexpectedly high. If after several years of monitoring, consistently low concentrations of PCP and PAH compounds are measured from the LTU, air monitoring will be discontinued after obtaining approval from the regulatory agencies.

5.6.2 Monitoring within the LTU

Monitoring systems within the LTU include systems for collection of soil and leachate samples.

Soil monitoring involves collection, compositing, and analysis of soil samples. Three types of soil samples are collected periodically from the LTU: operational, confirmation, and compliance.

Operational samples are collected periodically to monitor the degradation of PCP and PAH compounds in the soils during the treatment of each contaminated soil lift. These samples are analyzed by the on-site laboratory and are used primarily for making operational decisions for the LTU. The samples consist of composite samples from each quadrant of the two LTU cells. Each sample is composited from four randomly-selected individual samples from within each quadrant. After the initial tilling of a newly-placed lift of contaminated soils in the LTU cells and application of soil moisture, composited soil samples from the

uppermost lift of contaminated soil are collected from the four quadrants of each cell representing the lift and are analyzed for PAH compounds and PCP. Results from this sampling are used to characterize baseline contaminant levels and to identify degradation rates in the LTU cells. After initial placement of a lift, samples are usually collected every two to three weeks. The sampling frequency is increased (up to one sample per week or less) when the soil concentrations in the treatment zone are near target remediation levels. Sample collection and analyses continue until samples from each quadrant are at or below the target remediation levels. After target levels are reached, a new lift may be loaded on the LTU.

After target remediation levels are achieved in the uppermost lift, an additional sample is collected in the next lowest lift to evaluate the potential for vertical migration of contaminants during treatment. The sample is collected under the quadrant of the uppermost lift that contained the highest level of contamination during treatment. The sample consists of a four-point composite sample, collected in the same manner as the other operational samples. The sample is analyzed for PCP and PAH compounds by the on-site laboratory. If PCP and PAH compounds are found to exceed the target remediation levels, then deep tilling of the top two lifts is performed until achievement of target remediation levels is achieved.

Other operational samples collected and analyzed include (1) composited soil samples from the four soil quadrants for the measurement of TOC, TKN and total phosphorus immediately after the placement of a lift to assess nutrient requirements; and (2) weekly soil moisture measurements to determine water application rates.

After the results of the operational samples have indicated that target contaminant remediation levels have been reached, a confirmation sample is collected from each quadrant from each lift treated and are submitted to an off-site laboratory for confirmation analyses. These samples may be split samples from the last operational sample analyzed or samples collected separately. Each confirmation sample is a composite sample. Confirmation sampling results are used to demonstrate that target remediation levels have been achieved and to establish the validity of operational sampling data. These sampling data are provided to the regulatory agency after receipt from the off-site laboratory.

Compliance samples are used to demonstrate that target remediation levels have been met. These samples consist of previously collected confirmation samples (if the concentrations are at or below target remediation levels), or additional samples may be collected, if required. There are two types of compliance samples. The first type is a single-lift compliance sample. A minimum of four single lift compliance samples (one from each quadrant) is obtained from each treated soil lift to demonstrate that target remediation levels established in the ROD for PCP, carcinogenic PAH compounds, naphthalene, phenanthrene, and pyrene have been met. These samples typically consist of previously collected confirmation samples. The second type of compliance sample is a three-lift sample for dioxin analysis. Four three-lift dioxin compliance samples are collected from each LTU cell, with one sample collected from each quadrant. The samples consist of soils collected from the full vertical interval of the three lifts applied during that treatment interval. One duplicate split sample is collected for every four samples collected, for QA/QC purposes. The dioxin analysis is performed by an off-site laboratory. If dioxin is detected above the target remediation level in the three-lift compliance samples, an evaluation will be made to determine how to best address remedial goals. The results of the evaluation will be presented to the regulatory agency for approval.

The compliance samples analyzed by the off-site laboratory that meet the quality requirements outlined in the Quality Assurance Project Plan (QAPP) (Woodward-Clyde Consultants, 1989c) are used to evaluate the achievement of target remediation levels. Contaminant concentrations measured in each of the four samples (one from each quadrant) for each lift are compared to the target remediation levels specified in the ROD. Only when the contaminant concentrations for all four samples (not just the mean of the four samples) are at or below the target remediation levels for total carcinogenic PAH compounds, naphthalene, phenanthrene, pyrene, and PCP is that lift considered remediated.

At the end of each treatment year, additional composite samples from each lift placed in the unit during that year are collected and analyzed. If target contamination remediation levels are not met by the end

of a given year for the composite samples of all lifts placed in an LTU cell that year, LTU operations are continued in the spring of the next year. No additional lift placement in that LTU cell are made until such levels are achieved.

Leachate monitoring involves collection of samples from LTU sumps on a quarterly basis and whenever leachate is produced during rainfall events. Samples are analyzed for PCP and PAH compounds by the on-site laboratory. If a visible oil phase is present in the sample, the sample is sent to an off-site laboratory for dioxin analysis. One duplicate sample is sent to the off-site laboratory annually for PAH and PCP analyses as a quality assurance/quality control (QA/QC) measure for the on-site laboratory. If concentrations of contaminants in the leachate are below U.S. EPA detection limits for a period of one year, leachate monitoring will be reduced to a frequency of twice annually. Sump sampling may not be possible if little or no leachate is recovered from the sump during a quarter. The sumps (one from each cell) are monitored each work day during operation of the LTU to evaluate if the leachate collection system is operating properly.

5.7 Future closure and post-closure activities

Closure of the LTU will commence following completion of standard LTU operations for both cells. Closure activities will be designed to provide long term containment of disposed materials and protection of the environment. The LTU will be closed in a manner that: (1) minimizes the need for further maintenance; and (2) controls, minimizes and eliminates, to the extent necessary to prevent threats to human health and the environment, the post-closure escape of hazardous waste, hazardous waste constituents, leachate, contaminated runoff, or waste decomposition products to the ground water, surface waters or to the atmosphere. The closed facility will be monitored in a manner that will allow detection of any contaminant releases.

Criteria that will be used to initiate closure activities include: (1) little or no evidence of movement of organics beneath the treatment zone; (2) achievement of soil target remediation levels for all constituents; and (3) no detection of regulated contaminants in leachate samples for at least the last two years of operation of the facility. A regular program of tillage, watering, and maintenance of the land treatment area will be conducted until the above criteria are met.

Groundwater monitoring will be continued through the closure period. Upgradient wells (two wells) and down-gradient wells (four wells) will be sampled semi-annually for target constituent.

5.7.1 LTU cover system

Random fill will be placed over the treated soil to prepare a minimum 3 percent grade from the crown of the LTU to the exterior berms (Figure 5.6). A 12-inch thick compacted soil liner will be placed above the random fill. A 30 mil HDPE geomembrane liner will be placed over the soil liner, and a 12-inch thick layer of cover sand in a single lift will be added to protect the geomembrane. A 12-inch thick layer of topsoil will be placed above the cover sand. The topsoil will be used to establish a vegetative cover of native plants in order to prevent erosion of the cover system.

The side-slope of the cover system will consist of a drainage net (Tensar DN-3 geonet) placed between two Typar 3601 filter fabrics placed above the exterior of the incremental and LTU containment berm graded to a 3:1 (horizontal to vertical) slope. A 12-inch thick layer of cover sand will be placed above the drainage net and filter fabrics; a 12-inch thick layer of topsoil will be placed above the cover sand. A vegetative cover will be planted in the topsoil layer.

It has been proposed that if criteria (3) above is met at the end of the LTU operational period, the following actions will be taken: (1) the cover system will be redesigned to exclude the flexible geomembrane liner and drainage net; and (2) the HDPE liner at the bottom of the LTU cells will be punctured in the sump areas, allowing the leachate to gravity drain and thus avoiding any "bathtub" water accumulation in the system.

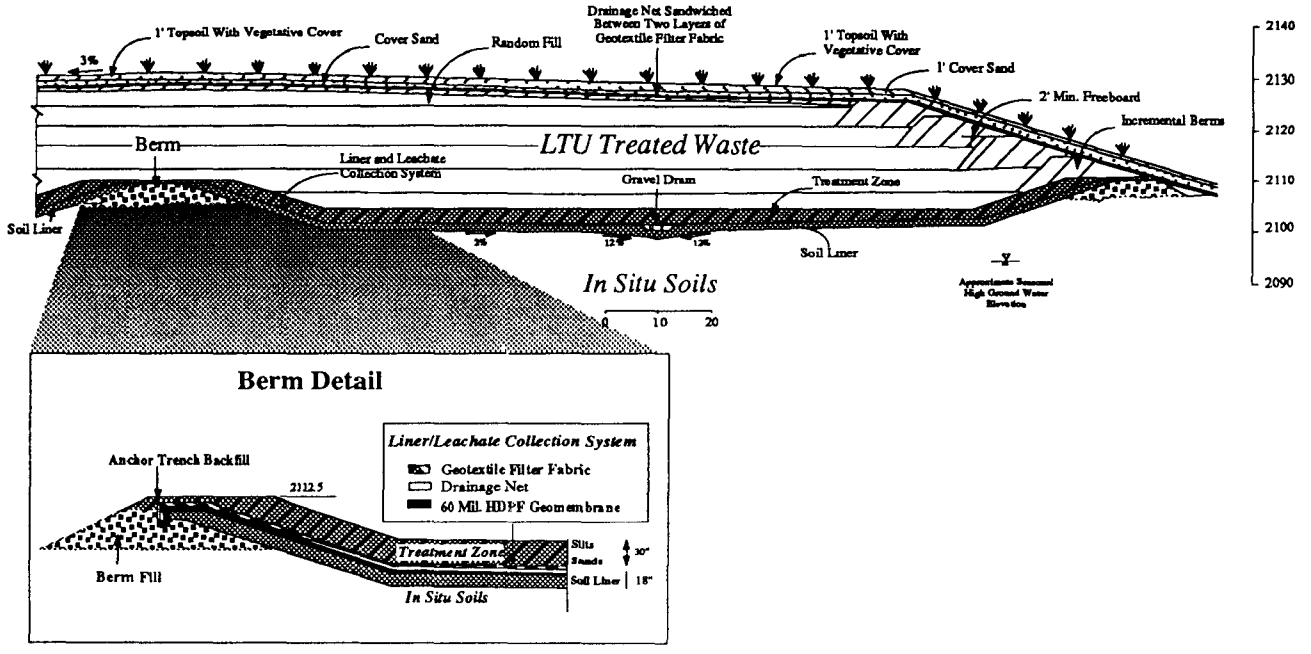


Figure 5.6 LTU waste placement and final cover

Final grading of the facility will maintain the berms surrounding the LTU at a sufficient height to control run-on, runoff, and wind dispersal. The berm will be raised with uncontaminated fill to contain the 25-year, 24-hour storm event.

5.7.2 Post-closure activities

Post-closure care will continue for at least five years. Such care may be terminated after the fifth year if target constituents in the soils, ground water, and leachate are not detected above target remediation levels. The post-closure care period may be extended to thirty years if significant concentrations of target constituents are detected.

Primary activities that will take place during the post-closure period include continued inspection and maintenance of the facility. Inspections of the vegetative cover, run-on/runoff control system, and LTU sumps will be performed on a monthly basis or after any major storm. The vegetative cover will be selected to adapt to the climate at the site; therefore, after the first year of post-closure, irrigation will be discontinued. Access to the facility will be restricted by the company security system and fencing around the site.

5.8 Health and safety plan

Contractors at the site abide by an approved Health and Safety Plan (Woodward-Clyde Consultants, 1989a) prior to working on any activity of a hazardous nature during construction, operation or closure of the LTU.

5.9 Quality assurance program

A quality assurance program was developed for analytical evaluation of soil, leachate, ground water, and air samples and was presented in a Quality Assurance Project Plan (Woodward Clyde Consultants, 1989c). Construction quality control testing was also performed during construction of the LTU cells.

5.10 Periodic reporting requirements

Information summarizing LTU operations and monitoring are submitted to the regulatory agencies in annual reports, as required by the ROD. Annual reports detail operational aspects such as sampling results, amount of soils remediated, monitoring data, problems encountered, and corrective action taken. The reports also contain an assessment of overall progress toward reaching final cleanup, with emphasis on achievement of target remediation levels. Monthly status reports provide updates on the operation of the LTU during the treatment season.

After target remediation levels have been achieved for all the contaminated soils and verified by the regulatory agencies, annual summary reports will be prepared discussing closure maintenance and monitoring.

In addition, every five years during operation, closure, and post-closure, a report summarizing the previous five years of activities and evaluating the effectiveness of land treatment in achieving target remediation levels will be prepared.

5.11 Information sources

Information for Chapter 5 was obtained from the following sources: (1) *LTU 1992 Annual Operational Report: Groundwater Site, Libby, Montana* (Champion International Corporation, 1993); (2) *LTU Operations and Monitoring, Groundwater Site, Libby, Montana* (Woodward Clyde Consultants, 1992); (3) *Pre-Final Design Report, Land Treatment Unit, Ground Water Site, Libby, Montana* (Woodward-Clyde Consultants, 1990a); (4) *No Migration Petition for Land Treatment Unit, Libby Ground Water Site, Libby, Montana* (Woodward-Clyde Consultants, 1990b); (5) *Health and Safety Plan, LTDU and Soil Demonstration, Ground Water Site, Libby, Montana* (Woodward-Clyde Consultants, 1989a); (6) *Land Treatment Demonstration Unit: One Acre LTDU, Ground Water Site, Libby, Montana* (Woodward-Clyde Consultants, 1989b); (7) *Quality Assurance Project Plan, RI/FS/RD/ RA Activities, Ground Water Site, Libby, Montana* (Woodward-Clyde Consultants, 1989c); and (8) *Record of Decision: Libby Ground Water Superfund Site, Lincoln County, Montana* (U.S. Environmental Protection Agency, 1988).

Chapter 6

Materials and Methods

6.0 Materials and Methods

6.1 Field sampling procedures

Sampling points within each LTU were located using a rectangular grid overlay of a map of the LTU beds. The starting point of the grid was randomly chosen by statistically selecting four random numbers. The first two numbers were used to locate a specific grid rectangle on the overlay, while the second two numbers identified a point within that rectangle. The point was fixed on the map, and the grid was shifted so that the lower right corner of the grid rectangle was over this point. Each point of the intersection of the grid within the LTU bed was then designated as a sampling point (Mason, 1983). The selection of the first sample location completely determined all of the other sample locations. The performace evaluation monitoring strategy involved collecting discrete soil samples; unlike the compositing soil sampling strategy described in Section 5.6.2 which was conducted for regulatory performance monitoring.

Specifically, sampling grids of the two land treatment units (LTU 1 and LTU 2) were developed using the following procedure:

Each land treatment unit was scaled according to the dimensions of the units as follows:

Centerline length of LTU (running N-S) = 226 ft, equivalent to 126 mm on map
Center line width of LTU (running E-W) = 106 ft, equivalent to 54 mm on the map
Average scale of the map = 0.535 mm per ft

Initial sampling protocol called for 30 random samples from the site for each lift. Assuming that these 30 sampling points would concur with 30 points of a square grid with intersections, the area of each square was: 23,956/30 = 798.5 ft^2 per square (28.3 ft x 28.3 ft), where 23,956 is the area of the LTU in square feet. Each LTU is one acre (about 43,560 ft^2) in total size, including the berms. The area that is used for treatment is the area that is at the bottom of the berms, which is about 23,956 ft^2. As the soil elevation increases within the LTU cells as more contaminated soil is added, the treatment area will increase.

Based on the scale selected, each square represented a 15.1 mm square grid on the map. A grid of such dimensions was drawn on plain paper, using the Superpaint™ program for the Macintosh computer. The grid was numbered from the left corner (Figure 6.1).

For LTU 1, using a random number table, four random, two digit numbers were randomly selected. The first two numbers located the specific grid square (06, 02 on the grid map), and the second two numbers located the reference point "a" within the grid square (using a mm scale, this was 06 and 05 from the lower left corner of the grid square, as shown in Figure 6.1).

A transparency of the LTU 1 map was overlaid on the grid such that the N-S center line of the LTU map was parallel to the longitudinal grid lines. The reference point "a" was marked "R" on the LTU map transparency. The transparency was then moved so that "R" coincided with the lower right corner of the randomly selected grid square (Figure 6.2). Each point of intersection of the grid within the LTU was then designated as a sampling point. There were a total of 32 sampling points within the LTU. Based on the map, the reference point "R" was located at 37.7 feet from the N-S center line of the plot and 38.4 feet from the top of the northern embankment.

In LTU 2, the reference point for setting up the grid system was randomly located by selecting four random numbers with an HP28C calculator. The first two numbers located the grid square (08, 02) on the grid map) and the second two numbers located reference point "a" within the square (4 mm north and 7 mm west of the southeast corner of the grid square). A transparency of the LTU 2 map was placed on the grid map, and reference point "a" was marked on the transparency in the southeast corner of LTU 2. The transparency was

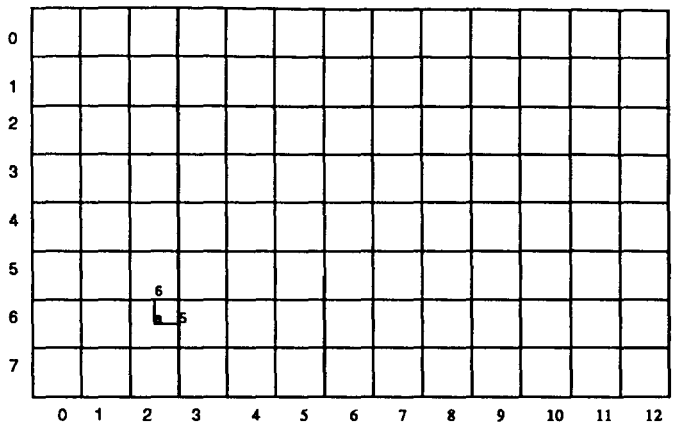


Figure 6.1 Scale of each land treatment unit for the area for one soil sample: 798.5 ft² = 15.1 mm square grid on map.

then moved until point "a" was over the right corner of the grid square (Figure 6.3). Each point of the grid was then designated as a sampling point with point "a" being the reference point "R" for LTU 2.

For both LTU cells, each square in the sampling grid was 28.3 ft. x 28.3 ft. The points of intersection of the grid corresponded to the sampling points. The N-S center line of the LTU was first determined and marked using stakes and twine. Longitudinal lines parallel to the N-S center line and 28.3 feet apart were set up using a surveyor's measuring tape, twine, and stakes. These lines were labelled 1W, 2W, 1E, and 2E. An E-W line perpendicular to the 2W line was set up through the reference point. Each sampling site was located 28.3 feet along the longitudinal lines. There were four N-S rows, with eight sampling sites in each row.

For each sampling trip, the reference point established during the initial sampling trip (May 6-8, 1991 for LTU 1 and July 27, 1992 for LTU 2) was used to establish new reference and sampling points (in the sampling grid) relative to the original sampling point (e.g., for the second sampling trip, the reference point was moved 1 foot north). The sampling grid at the site was marked with twine, and each sampling point was located at an intersection of the N-S and E-W sampling grid lines. Sampling was begun at reference point "R".

The LTU was designated as the "hot zone", where all personnel wore appropriate protective clothing (i.e., Level C). A "cold zone" was designated immediately outside the "hot zone" (i.e., the contaminated area) as the area where sample jars and other uncontaminated equipment were located. All sample jars were labelled with field ID numbers before going to the site. The date and year of sampling were included on the label. Samples from LTU 1 were numbered 1 through 32 (Figure 6.4); samples from LTU 2 were numbered 33 through 64 (Figure 6.5). The depth sampled was identified by naming the depths alphabetically, with the lowest depth having the letter "A."

A Giddings tube soil sampler was marked with the desired sampling depths, based on 6 inches per sampling depth. The Giddings tube sampler was driven into the soil to the lowest depth using a slide hammer. The slide hammer was lubricated with distilled water. The Giddings tube was extracted from the borehole using a tripod and a come-along. If the clay layer below the waste materials was inadvertently sampled, the clay layer was discarded. The clay layer was recognized by differences in color and texture.

The samples in the Giddings tube were taken to an area of the "hot zone" adjacent to the "cold zone." Appropriately labelled, commercially pre-cleaned 500 mL I-CHEM glass jars with teflon-lined caps were obtained from personnel in the "cold zone." A large screwdriver was inserted in the slot in the side of the tube, and samples were forced out of the bottom of the tube. The bottom inch of sample as well as any large rocks present in the sample were discarded into a plastic container. The next several inches of sample were

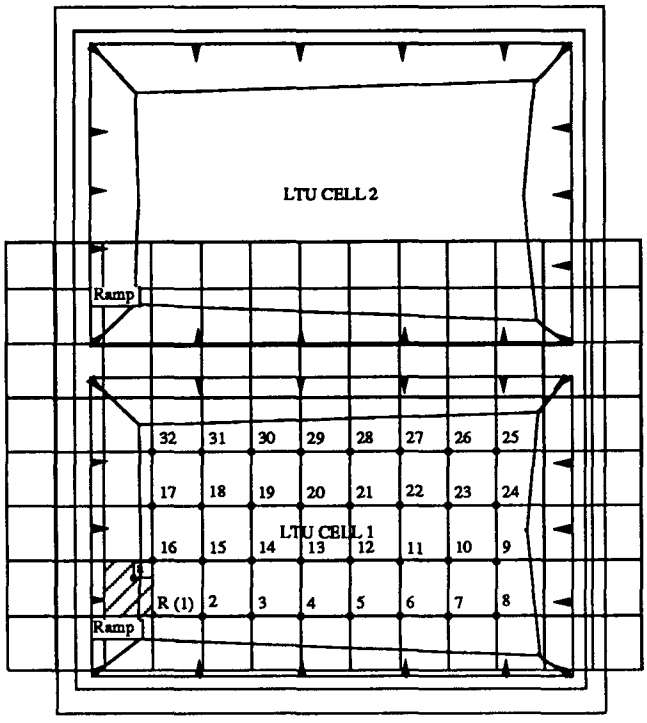


Figure 6.2 Location of the reference point (R) and sampling points in LTU 1.

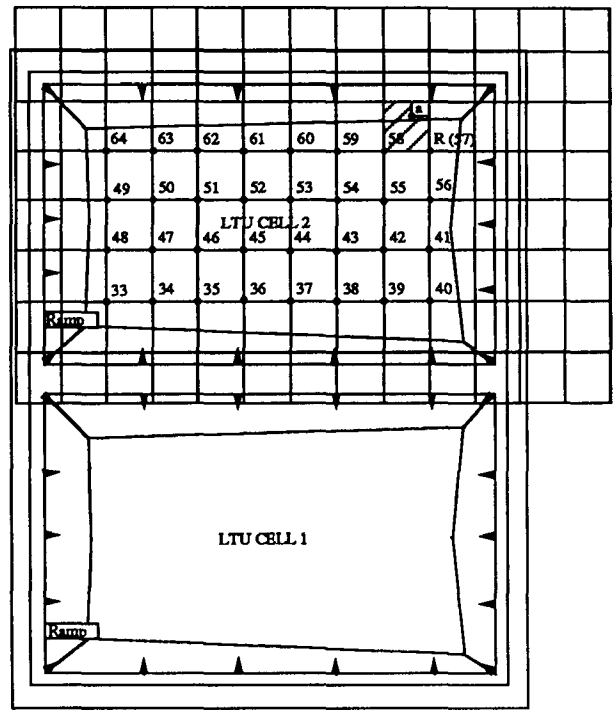


Figure 6.3 Location of the reference point (R) and sampling points in LTU 2.

collected in the I-CHEM jar. The rest of the sample at a particular depth, as defined by the marks on the Giddings tube, was collected in the plastic container. This method of taking samples from the center of each depth was used in order to standardize the collection technique. For surface sampling, samples were collected at a depth of 2-3 inches using trowels.

To prevent cross-contamination between samples, the Giddings tube, screwdriver, and/or trowel were cleaned and decontaminated with soapy water and a large diameter bottle brush after each sample was collected. The equipment was rinsed with tap water, followed by rinsing with distilled water. The plastic container with the unused soil and rocks was emptied at the sampling site, and the sampling borehole was filled with bentonite.

For QA/QC considerations, for each day of sampling, a trip blank was prepared by opening a jar of uncontaminated Kidman sandy loam soil during sampling. The jar was left open to the atmosphere at the LTU for approximately five minutes and then closed. If the sampling trip lasted for two days, a trip blank was collected each day. The trip blanks were prepared in the laboratory before the sampling trip by placing the soil in a labelled, pre-cleaned I-CHEM jar. The trip blanks were transported to and from the Libby Site with the I-CHEM jars containing samples. The trip blanks were extracted and analyzed using the same procedures as used for the LTU samples. An additional blank was prepared in the same manner and left closed in the laboratory. This blank sample was also extracted and analyzed this blank using the same procedures as used for the LTU samples. No PAH compounds or PCP were detected in the trip blanks.

After all samples were collected, all equipment was decontaminated in the "hot zone" with soapy water. The equipment was rinsed with tap water, followed by rinsing with distilled water. All disposable clothing (Tyvek suits, booties, and gloves) and other disposable items such as twine, stakes, etc., were placed in garbage bags and returned to the laboratory for proper disposal. Non-disposable clothing (e.g., boots) was decontaminated with soapy water and rinsed with tap water, followed by rinsing with distilled water. All decontaminated and bagged equipment were handed to personnel in the "cold zone."

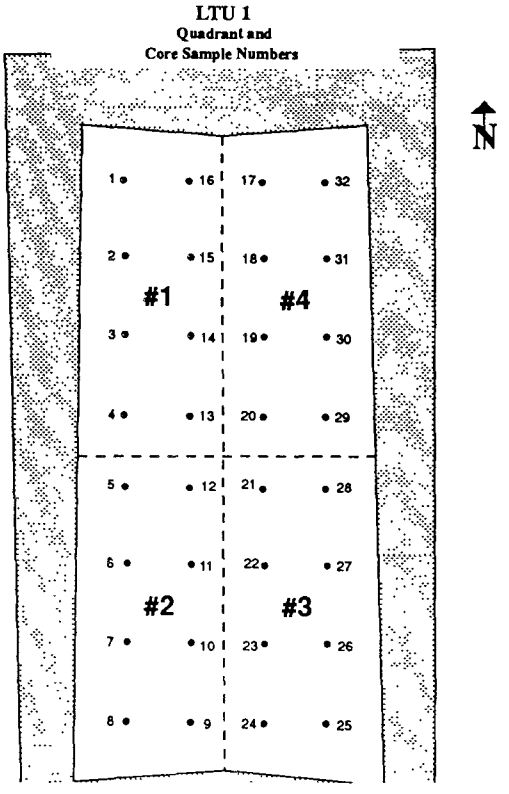


Figure 6.4 Location of sampling cores for obtaining descrete soil samples with depth for LTU 1: Quadrant and coresample numbers.

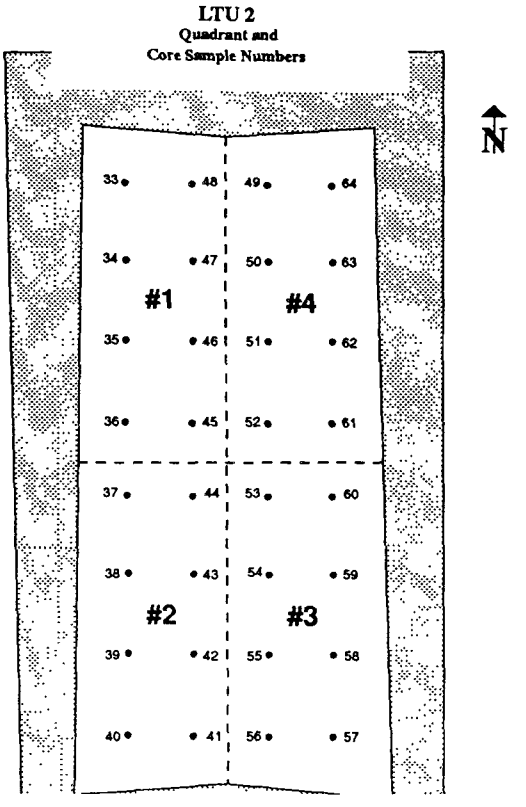


Figure 6.5 Location of sampling cores for obtaining discrete soil sample with depth fro LTU 1: Quadrant and coresample numbers.

After all samples had been collected, the samples in the I-CHEM jars were placed in zip lock bags to contain the samples in case of breakage. The samples were wrapped in newspaper and placed in a cooler, or alternatively, were placed in a cooler with cardboard dividers. "Blue ice" was also placed in the coolers. The coolers were secured with filament tape and shipped by Federal Express to the Utah Water Research Laboratory (UWRL), in Logan, Utah for analysis.

Upon arrival of samples at the UWRL, the condition of samples were checked and noted. All samples were logged in by assigning each sample a UWRL log number and by entering appropriate information in the UWRL log book, including sample type, date sampled, date logged in, field ID, and type of analyses to be performed. All samples were placed in a refrigerated unit at 4° C. During sample extraction and analysis, all containers (extraction, storage, GC vials, LC vials, etc.) were labelled with the UWRL log number. After extraction and analysis, the samples were stored or archived in the 4° refrigerated unit or in a freezer at -70° C. During data management and analysis, UWRL log numbers were re-associated with field ID numbers and the concentrations of the target compounds measured in the samples.

6.2 Sampling events

Sampling was conducted six times during the 1991 and 1992 LTU operating seasons, as shown in Figure 6.6. Approximately 20 samples were analyzed out of 32 samples taken in each depth. The remaining 12 samples were archived. The waste lifts present during each sampling event are also shown. The actual thickness of lifts after initial placement of 9 to 12 inches is unknown due to natural and managed soil compaction. Therefore sampling depths, designated with letters A, B, etc., are only approximately correlated with lifts placed in the units, designated with numbers 1, 2, etc. The first lift in each LTU is well correlated with

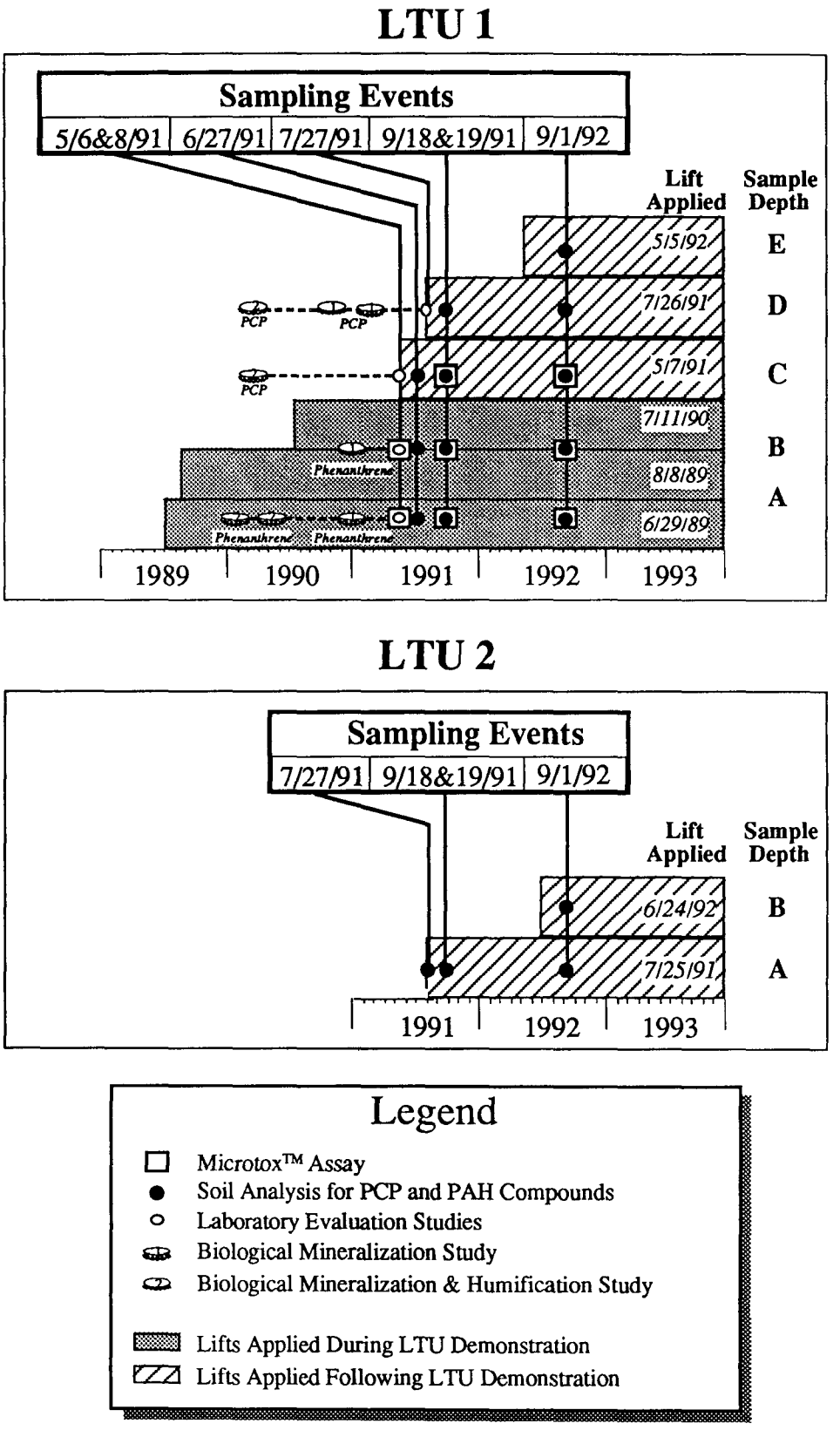


Figure 6.6 Conceptual model of LTU lifts and sampling events.

depth A for each LTU, since the different textures of the underlying sand and contaminated soil above the sand were easily visually recognized. In addition, lift 4 (depth C) of LTU 1 was the top lift for May and June,1991, sampling events, and lift 5 (depth D) of LTU 1 was the top lift for July and September, 1991, sampling events. Therefore, lifts and depths are well correlated for lift 1 in both LTU cells and for lifts 4 and 5 in LTU 1 for two sampling events (until the next lift was added).

Each lift was actively managed, including tilling and moisture control. Nutrient addition was initiated after placement of lift 5 in LTU 1 and lift 1 in LTU 2. During the active management phase, each lift was monitored by Champion International for determining the concentrations of target chemicals in composited soil samples. Following the active management phase and upon reaching the target remediation levels for the compounds of concern, a subsequent lift was placed in the LTU for treatment. Each unit was operated independently with respect to lift placement. The duration of the active management phase for each lift is summarized in Table 6.1.

6.3 Soil characteristics

During the sampling trip conducted September 18-19, 1991, six soil samples were collected from the waste pit area for nutrient analyses. The contaminated soils in the waste pit area serve as the source of soils that are treated in the LTU cells after pretreatment in the waste pit area. The soil samples were analyzed for nutrient content by the Utah State University Soil Testing Laboratory. Results of the analyses are presented in Table 6.2.

Also during the sampling trip in September, 1991, two soil samples were collected from the uncontaminated berms surrounding LTU 1 for characterization of physical properties. These soils were considered to be representative of the original soils that had been used to construct the treatment beds of the LTU cells. The soil samples were analyzed for physical characteristics by the Utah State University Soil Testing Laboratory. Results of the analyses are presented in Table 6.3. One contaminated soil sample collected July 27, 1991 from Depth A was analyzed for physical characteristics and nutrient levels. Results are presented in Table 6.4.

6.4 Sample extraction and analytical methods

The UWRL Environmental Quality Laboratory is certified by the State of Utah Department of Health, Division of Laboratory Services, for analyses pertaining to environmental compliance monitoring applicable to the Resource Conservation and Recovery Act. Sampling extraction and analytical methods (U.S. Environmental Protection Agency, 1982) are described in Appendix A for: (1) extraction of samples (U.S. EPA Method 3550) and soil moisture determinations (A-1); (2) analysis of PCP (U.S. EPA Method 8040) using gas chromatography (A-2); and (3) analysis of PAH compounds by gas chromatography/mass spectrometry (GC/MS) (U.S. EPA Method 8270) (A-3).

Table 6.1. Time that each lift was actively managed before application of the subsequent lift.

Lift	Treatment Time as the Top Lift	
	LTU 1 (days)	LTU 2 (days)
1	40	333
2	336	691
3	299	
4	80	
5	282	
6	119	

1 LTU 2 lift 2 was sampled after 69 days of treatment.

Table 6.2. Soil nutrient analyses of contaminated waste pit area soils.

Sample No.	NH_3-N[1] (mg/kg)	NO_3-N[2] (mg/kg)	TKN[3] (%)	P[4] (mg/kg) ($NaHCO_3$-extractable)	K[5]	Total P[6] (%)	O.C.[7] (%)
1	0.6	2.2	0.03	8.4	64	0.036	1.11
2	0.6	2.9	0.04	8.7	62	0.027	1.43
3	0.5	3.0	0.04	16.0	71	0.034	1.81
4	0.2	3.6	0.05	11.0	69	0.035	2.07
5	nd[8]	3.5	0.03	13.0	68	0.033	1.53
6	nd	2.9	0.04	22.0	92	0.037	1.71

1 NH3-N = ammonia nitrogen
2 NO3-N = nitrate nitrogen
3 TKN = total Kjeldahl nitrogen
4 P = phosphorus
5 K = potassium
6 Total P = total phosphorus
7 O.C. = organic carbon

Table 6.3. Physical characteristics of uncontaminated LTU soils.

Sample No.	O.C. (%)	pH	CEC[1] (meq/100 g)	Texture	Moisture (%)
1	1.17	7.1	7.9	Silt Loam	0.9
2	1.19	6.8	8.5	Silt Loam	1.0

[1] CEC = cation exchange capacity

Table 6.4. Physical characteristics and nutrient analyses for contaminated LTU soil.

Sample Identification (Lift, Date)	O.C. (%)	pH	K (mg/L[1])	NO_3-N ---------- (mg/kg)	$NaHCO_3$-extractable P ---------	Saturation Percent (%)	Texture
A, 7/91	1.62	7.6	16	<1.0	13	36.3	Loam

[1] Concentration of K in saturation paste

6.5 Soil gas analyses for oxygen and carbon dioxide in the LTU cells

Soil gas in LTU 1 at 1 foot and 2 feet depths were analyzed for O_2 and CO_2 concentrations on September 18 and 19, 1991. The composition of the soil atmosphere at depth was accessed with a manually-driven probe. Oxygen and carbon dioxide were measured as indicators of microbial respiratory activity.

A stainless steel probe with holes leading from the outside of the probe to a hollow stem (Soil Gas Sampling Kit, Art's Manufacturing & Supply, American Falls, ID) was driven into the soil to the desired depth with a manual slide hammer device. The holes in the probe were protected from being filled with soil by a screen and a retractable shield. Flexible Teflon tubing, connected to the hollow stem of the probe, extended through the steel pipe that was used as the drive string to the surface. After the desired depth was reached, the drive string was withdrawn approximately 2 cm to open the gas ports. Suction was applied to the plastic tubing with a pump to move gas from the soil into the oxygen/carbon dioxide detector (Gastechtor, Model 32520X, Gastech, Inc., Newark, CA). After measurements of oxygen and carbon dioxide concentrations were obtained, the drive string and probe were removed from the soil using a high-lift mechanical jack.

6.6 Detoxification evaluation using the Microtox™ assay

Detoxification of contaminated soils being treated in the LTUs was analyzed using the Microtox™ assay. The samples were evaluated for relative toxicity compared to a known standard. Soil cores taken from LTU 1 on three sampling dates were analyzed at selected depths (Table 6.5), in addition to evaluation of the Microtox™ toxicity of soil applied to LTU 1 before land treatment.

6.7 Laboratory evaluation of LTU soil for biodegradation of phenanthrene and PCP

The laboratory evaluation consisted of two tests for evaluation of biodegradation potential for target contaminants in site soil under conditions simulating environmental and active phase management factors. The first test, referred to as the biological mineralization study, was designed to evaluate the extent and rate of mineralization of radiolabeled phenanthrene and PCP spiked into site soil. The second test, referred to as the biological mineralization and humification study, was designed to provide additional information including the distribution of radiolabeled carbon among soil, air, and solvent extract phases in order to determine the fate and behavior of parent compounds within the Libby LTU soil.

Soil moisture and temperature are management factors that are expected to affect biodegradation of chemicals in soil within the LTU cells. The influence of these factors on the rate and extent of biological mineralization and abiotic loss through volatilization was evaluated using field soil samples. A temperature of 10° C was selected as representative of soil conditions during extended periods of each year at the site for the first study; temperatures of 10°C and 20°C were used in the second study.

6.7.1 Objectives

In the laboratory evaluation, a chemical mass balance for phenanthrene and PCP in LTU soil and the influence of soil microbial metabolic potential on the chemical mass balance for these chemicals were deter-

Table 6.5. Samples from LTU 1 analyzed with Microtox™ assay.

Sampling Date	Depths Evaluated
September 1-2, 1992	A, B, C
September 18-19, 1991	A, B, C
May 6, 1991	A, B

Additional details addressing the Microtox™ assay organism and procedures are provided in Appendix A (A-4).

mined. The objectives of the mass balance evaluation were to:

(1) determine the rate and extent of biological mineralization of ^{14}C-phenanthrene and ^{14}C-PCP in contaminated soil as affected by management factors including soil moisture and temperature; and (2) determine the fate of ^{14}C-phenanthrene and ^{14}C-PCP in the soil system, including an evaluation of mineralization, volatilization, and humification (represented by the non-solvent extractable fraction).

6.7.2 Experimental approach

A complete factorial design approach, with every factor at two levels (2k design) and with duplicate sets of each treatment, was used in the first laboratory test (the biological mineralization study). Table 6.6 shows the treatments used in the first test. The first laboratory test was conducted at 10° C for 30 days.

This design resulted in the use of 16 microcosms [2 contaminants (PCP and phenanthrene) x 2 soil samples x 2 moisture levels (40 percent and 80 percent FC) x 2 replicates of each soil sample = 16].

For the biological mineralization study, Table 6.7 shows the concentrations of PCP and PAH compounds in soil samples that were randomly selected to be representative of the soils found in the LTU.

A complete factorial design approach, with every factor at two levels (2k design), with duplicate sets of each treatment, was also used in the second laboratory study (the biological mineralization and humification study). Table 6.8 shows the treatments used in the second study. The study was conducted for 45 days.

This design resulted in the use of 32 microcosms [2 contaminants (PCP and phenanthrene) x 2 soil samples x 2 moisture levels (40 percent and 80 percent FC) x 2 temperatures (10°C and 20°C) x 2 replicates = 32).

For the biological mineralization and humification study, Table 6.9 shows the concentrations of PCP and PAH compounds in soil samples that were randomly selected to be representative of the soils found in the LTU.

For both studies, the field capacity of the soil was determined by filling a 250 mL glass graduated cylinder with soil to the 190 mL mark. Approximately 20 mL of deionized, distilled water (DDW) was added to the top of the soil. After 24 hours, three samples were taken at mid-depth of the wetted soil and moisture content was determined. This moisture content was used as the field capacity in subsequent calculations.

Microcosms (Figure 6.7) consisted of 250 mL Erlenmeyer flasks with a two-holed rubber stopper. Glass tubing through the stopper provided an inlet and an outlet. The outlet was connected to a trap for volatile organic chemicals and a CO_2 trap. The outlet of the organic chemical trap was connected to the inlet of the CO_2 trap, as shown in the Figure 6.7. Each microcosm contained 20 grams of contaminated soil. The soil was sieved before use with a 2 mm sieve.

Moisture content of the soil samples was determined by drying the soil in an oven at 103° C for 24 hours and calculating the weight loss. The amount of water required to bring the soil to 40 percent and 80 percent field capacity was calculated.

Table 6.6. Evaluation conditions in the biological mineralization study.

Treatment Variable	Levels of Treatment	Endpoints
Moisture	40% FC[1] and 80% FC	Mineralization Volatilization

[1] FC = Field Capacity

Table 6.7. Contaminant concentrations in the laboratory samples for the biological mineralization study.[1]

	Samples Used to Evaluate Degradation of			
	------ Phenanthrene -------		---------- PCP ----------	
Date Sample Collected	5/6/91	5/6/91	7/27/91	7/27/91
Core Number	16	18	21	39
Depth	B	A	D	A
Naphthalene[1,2]	2.16	1.16	0.73	<0.46
Acenaphthylene	1.08	<0.30	0.50	<0.29
Acenaphthene	1.06	0.16	<0.10	<0.10
Fluorene	1.31	1.73	<0.33	<0.33
Phenanthrene[3]	2.44	1.47	<0.95	<0.95
Anthracene	3.15	14.0	8.37	<1.08
Fluoranthene	3.63	<0.79	2.76	7.32
Pyrene[4]	4.90	<1.04	125	145
Benzo(a)anthracene	3.21	<1.73	8.38	<1.67
Chrysene	3.33	<1.14	6.74	<1.10
Benzo(b)fluoranthene	9.08	2.06	18.0	<1.49
Benzo(k)fluoranthene	5.69	<1.67	14.4	<1.61
Benzo(a)pyrene	10.2	<2.60	6.56	<2.51
Benzo(ghi)perylene	3.82	<3.82	<3.68	<3.69
Dibenzo(ah)anthracene	3.06	<1.63	<1.57	<1.57
Indeno(1,2,3-cd)pyrene	5.45	<3.85	<3.71	<3.72
Total Carcinogenic PAH Compounds[5]	52.4	2.06	182	153
PCP[6]	2.6	17.8	79.6	56.8

[1] All concentrations are given in mg/kg on dry-weight basis.
[2] Target remediation level for naphthalene is 8 mg/kg of soil.
[3] Target remediation level for phenanthrene is 8 mg/kg of soil.
[4] Target remediation level for pyrene is 7.3 mg/kg of soil.
[5] Target remediation level for total carcinogenic PAH compounds is 88 mg/kg of soil.
[6] Target remediation level for PCP is 37 mg/kg of soil.

Table 6.8. Evaluation conditions in the biological mineralization and humification study.

Treatment Variable	Levels of Treatment	Endpoints
Contaminant concentration	High and moderate	Mineralization
Moisture	40% FC[1] and 80% FC	Volatilization
Temperature	10° C and 20° C	Solvent-Extractable
		Humification

[1] FC = Field Capacity

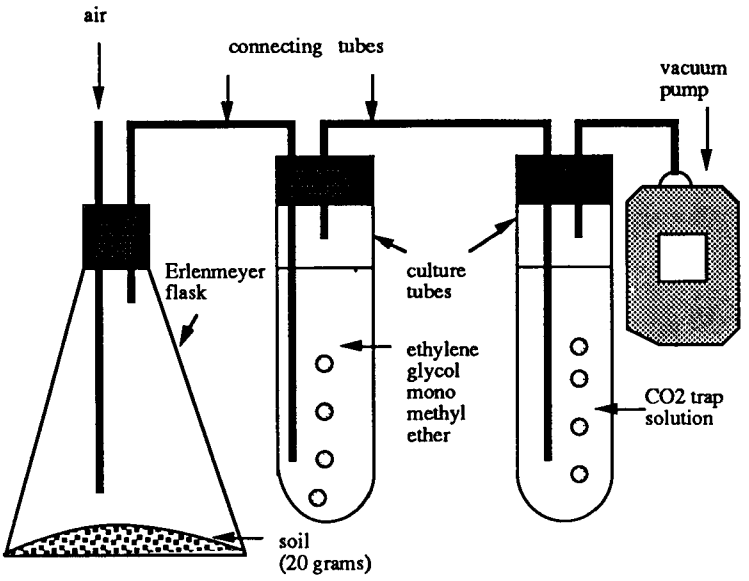


Figure 6.7. Laboratory Microcosms.

The fertilizers used in the land treatment unit (LTU) at the Libby Site are monobasic ammonium phosphate and ammonium sulfate. These salts were used as the nutrient sources in this study, and applied in an aqueous solution to the soil. The soil was amended to have a final concentration of 0.0061 mg P/g and 0.0102 mg N/g.

Gas traps used with the microcosms were made of 12 x 75 mm culture tubes. The first trap contained 15 mL of ethylene glycol monomethyl ether (EGME). The carbon dioxide trap contained 15 mL of trapping solution, prepared using 50 percent Ready Gel™ (Beckman), 40 percent methanol, and 10 percent monoethanolamine.

Uniformly labeled ^{14}C-PCP (9.10 x 105 DPM) or ^{14}C-phenanthrene (9.30 x 10^5 DPM) was spiked into 16 microcosms.

The microcosms were simultaneously purged and aerated once every four days by applying a vacuum at the outlet of the CO_2 trap, thus maintaining a net negative pressure within the microcosm system. The purge rate was slow (<40 mL/min), and air bubbles were small to effect a greater trapping efficiency. Each purge cycle was 15 minutes. A 1 mL sample was collected from each trap, i.e., the CO_2 trap and the volatile trap. Each sample was counted in a liquid scintillation counter after mixing the solution with Ready Gel™. The maximum counting time used was 10 minutes, and the maximum counting error allowed was 10 percent.

At the end of the biological mineralization and humification study, the samples were solvent-extracted according to the extraction procedures given in Appendix A-1, and the radioactivity in the sample extracts was measured. To evaluate humification, the residues of the soil samples after extraction were combusted using a Harvey Biological Oxidizer (Model OX-400, R.J. Harvey Instrument Corporation, Hillsdale, NJ) to determine the amount of radioactivity associated with the soil-bound radiolabeled carbon fraction. Some of the ^{14}C received from combusting the soil represents ^{14}C incorporation into microbial biomass. However, recovery of ^{14}C using the combustion of soil after the extraction process was assumed to provide a relative measure of humification in the reactors.

Statistical analyses were conducted using the JMP® software package (SAS Institute, Inc.) on a Macintosh computer.

Table 6.9. Contaminant concentrations in the laboratory samples for the biological mineralization and humification study.[1]

	Samples Used to Evaluate Degradation of			
	------ Phenanthrene -------		---------- PCP ----------	
Date Sample Collected	5/6/91	5/6/91	7/27/91	5/8/91
Core Number	12	15	9	17
Depth	A	A	D	C
Naphthalene[1]	<0.48	8.2	<0.44	0.74
Acenaphthylene	<0.30	2.60	<0.28	<0.31
Acenaphthene	<0.11	2.30	<0.10	0.14
Fluorene	<0.35	2.10	<0.33	<0.35
Phenanthrene	<1.00	4.60	<0.95	<1.00
Anthracene	<1.13	7.40	2.2	<1.13
Fluoranthene	<0.80	11.3	8.60	1.02
Pyrene	1.75	15.6	54.5	2.82
Benzo(a)anthracene	<1.75	9.50	7.0	<1.75
Chrysene	1.17	7.40	<1.07	1.87
Benzo(b)fluoranthene	2.13	18.2	9.20	2.42
Benzo(k)fluoranthene	<1.69	10.8	5.0	3.38
Benzo(a)pyrene	<2.63	20.2	<2.44	3.58
Benzo(ghi)perylene	<3.86	18.3	<3.61	<3.86
Dibenzo(ah)anthracene	<1.65	8.4	<1.53	<1.65
Indeno(1,2,3-cd)pyrene	<3.88	19.4	<3.59	3.53
Total Carcinogenic PAH Compounds	5.05	139	84.3	18.62
PCP	11.6	17.1	119	87.3

[1] All concentrations are given in mg/kg on dry-weight basis.
[2] Target remediation level for naphthalene is 8 mg/kg of soil.
[3] Target remediation level for phenanthrene is 8 mg/kg of soil.
[4] Target remediation level for pyrene is 7.3 mg/kg of soil.
[5] Target remediation level for total carcinogenic PAH compounds is 88 mg/kg of soil.
[6] Target remediation level for PCP is 37 mg/kg of soil.

Chapter 7

Results and Discussion

7.0 Results and Discussion

7.1 Field scale results for soil physical and chemical analyses

Results of soil nutrient analyses of contaminated soils within the waste pit area are provided in Table 6.2. Contaminated soils within the waste pit area routinely received nutrient additions as a soil pretreatment method for initiating microbial biodegradation before contaminated soils were applied to the LTU cells for treatment. The nutrients nitrogen and phosphorus are required for microbial growth and metabolism of target organic chemicals. Based upon the analyses presented in Table 6.2, the ratio of C:N:P on a weight basis as organic carbon of added waste:total Kjeldahl nitrogen:total phosphorus averaged 13:1.2:1, with little variation from these values. Recommended ratios for microbial activity are 120:10:1 (Sims et al., 1989). The C:N:P ratios for the contaminated soils compared with recommended levels indicate that there is an excess of nitrogen and phosphorus, and therefore nutrients are not limiting the biodegradation process within the waste pit pretreatment area. Recycling of phosphorus and nitrogen under aerobic conditions within the LTU cells should maintain excess levels of nitrogen and phosphorus during active soil bioremediation.

Characterization information for soil considered to be representative of the soil that was used to construct the treatment beds of the LTU cells is presented in Table 6.3. The organic carbon content of this uncontaminated soil was lower than the organic carbon content in contaminated soils (Tables 6.2 and 6.4), as expected. Uncontaminated soil was at neutral pH with a CEC representative of a soil with a silt loam texture. Moisture content was low because the soil samples were taken from the berms surrounding LTU 1.

Characterization information for contaminated soil that had been treated to target remediation levels is provided in Table 6.4. The concentrations of phosphorus and potassium (on a soil dry-weight basis) in treated soil remained similar to the concentrations in the waste pit pretreatment area. Decrease in the concentration of NO_3-N in the treated soil may be due to leaching of NO_3- through the LTU cell and/or denitrification within buried lifts as oxygen diffusion from the atmosphere becomes limiting and residual organic carbon (1.6 percent) depletes soil oxygen within the buried lift.

Results of soil chemical analyses include an evaluation of soil concentrations of specific target chemicals as specified in the Record of Decision. Concentrations of the specific target chemicals as well as other PAH compounds are presented in Appendix B (in Volume II). The detection limit was used to calculate the average concentration where sample concentrations were reported below the detection limit.

7.1.1 Naphthalene and phenanthrene

7.1.1.1 Initial concentrations

Initial concentrations of naphthalene and phenanthrene in contaminated soil applied to the LTU cells are shown in Figures 7.1 through 7.3 (refer to Volume II) and in tabular form in Tables 7.1 through 7.3 (depths C and D were initially equivalent to lifts 4 and 5 for LTU 1 (applied May 7, 1991 and July 26, 1991, respectively), and depth A was initially equivalent to lift 1 for LTU 2 (applied July 25, 1991) (Figure 6.6)). Figures 7.1 through 7.3 indicate the position within each quadrant for each applied lift (initial depth) where each sample was taken and the PAH concentration as greater than or less than the target remediation level. Tables 7.1 through 7.3 provide more specific information concerning concentrations measured for each sample, as well as statistical analyses of the data, including mean and 95 percent confidence interval (CI) values; statistics are also provided for PAH concentrations for each quadrant within an LTU cell. Values given in Tables 7.1 through 7.3 indicate that initial mean concentrations for each LTU cell for naphthalene and phenanthrene were less than 8 mg/kg, the target remediation level for both chemicals, and that all but three

individual values for naphthalene and one individual value for phenanthrene were below the target remediation levels.

7.1.1.2 Concentrations as a function of time and depth

An evaluation of the horizontal and vertical distribution of naphthalene and phenanthrene for LTU cells 1 and 2 was conducted to compare measured soil concentrations with target remediation levels and to evaluate downward migration of PAH compounds with in the LTU cells. Comparisons of horizontal and vertical concentrations of naphthalene and phenanthrene on September 1, 1992 with target remediation levels are presented in graphical form for naphthalene and phenanthrene in Figures 7.4 through 7.8 (LTU 1) and in Figures 7.9 and 7.10 (LTU 2). Results for discrete sampling indicate that naphthalene and phenanthrene were at concentrations less than target remediation levels (8.0 mg/kg) for all samples of soil where a lift was applied on or before 7/23/91 (Depths A, B, C, and D) in LTU 1. Depth E (the top layer for the September 1, 1992 sampling event), where naphthalene concentrations were greater than the target remediation goal for some samples, was undergoing active management for treatment at the time of the sampling. Naphthalene and phenanthrene concentrations were less than target remediation levels for all samples in LTU 2.

Tables 7.4 through 7.6 (LTU cell 1) and 7.7 (LTU 2) provide more specific information for the September, 1992, sampling concerning concentrations of naphthalene and phenanthrene measured for each sample, as well as statistical analyses of the data including mean and 95 percent confidence interval (CI) values; statistics are also provided for PAH concentrations for each quadrant within an LTU. Values given in Tables 7.4 through 7.7 indicate that the mean concentrations for both LTU cells for naphthalene and phenanthrene were all below target remediation levels. In addition, the 95 percent confidence intervals for LTU 1 for depths A, B, C and D and for LTU 2 for depths A and B were all below target remediation levels. Depth E of LTU 1 was undergoing active management for treatment at the time of the sampling, and therefore was not evaluated.

Comparisons of horizontal and vertical concentration distributions of naphthalene and phenanthrene in September, 1991, with target remediation levels are presented in graphical form in Figures 7.11 through 7.14 (LTU 1) and in Figure 7.15 (LTU 2). Results for discrete sampling indicate that naphthalene and phenanthrene were at concentrations less than target remediation level (8.0 mg/kg) in both LTU cells, with the exception of one sample where phenanthrene exceeded 8.0 mg/kg, indicated by "g" at depth B, LTU 1 (Figure 7.12).

Tables 7.8 and 7.9 (LTU 1) and 7.10 (LTU 2) provide more specific information for the September, 1991, sampling concerning concentrations of naphthalene and phenanthrene measured for each sample, as well as statistical analyses of the data. Values given for depths A, B, and C in Tables 7.8 and 7.9 indicate that the mean concentrations for naphthalene and phenanthrene in LTU 1 were all below target remediation levels. In addition, the 95 percent confidence intervals for LTU 1 for depths A, B, and C for target PAH compounds were below target remediation levels. Depth D of LTU 1 and Depth A of LTU 2 were undergoing active management for treatment at the time of the sampling; however, mean and 95 percent confidence limit values for these depths also were below target remediation levels.

Comparisons of horizontal and vertical concentration distributions of naphthalene and phenanthrene for samples obtained in June, 1991, with target remediation levels are presented in graphical form in Figures 7.16 through 7.18 for LTU 1 (LTU 2 was inactive at this sampling time). Results for discrete sampling indicate that naphthalene and phenanthrene were at concentrations less than the target remediation level for over 85 percent of the samples analyzed. Depth C was undergoing active management at the time of sampling and therefore was not evaluated with regard to target remediation levels.

Tables 7.11 and 7.12 provide more specific information for the June, 1991, sampling concerning concentrations of PAH compounds measured for each sample, as well as statistical analyses of the data. Values given for depths A through C in Tables 7.11 and 7.12 indicate that the mean concentrations for naph-

thalene and phenanthrene in LTU 1 were all below target remediation levels. Some 95 percent confidence intervals have values above the target remediation level.

Comparisons of horizontal and vertical concentrations of naphthalene and phenanthrene for samples obtained in May, 1991, with target remediation levels are presented in graphical form in Figures 7.19 (depth A) and 7.20 (depth B) for LTU 1 (depth C was used to indicate initial concentrations; results are presented in Figure 7.1; LTU 2 was inactive at this sampling time). Results for discrete sampling indicate that naphthalene and phenanthrene were at concentrations less than target remediation levels for each PAH, with the exception of one sample where naphthalene exceeded 8.0 mg/kg, indicated by "G" at depth A.

Table 7.13 provides more specific information for the May, 1991, sampling concerning concentrations of PAH compounds measured for each sample, as well as statistical analyses of the data. Values given for depths A and B in Table 7.13 indicate that the mean concentrations for naphthalene and phenanthrene in LTU 1 were all below target remediation levels. In addition, the 95 percent confidence intervals for LTU 1 for depths A and B for target PAH compounds were below target remediation levels. Depth C sampling for May, 1991, was used to indicate initial concentrations; results are included in Table 7.1.

7.1.1.3 Degradation rates

The target chemicals naphthalene and phenanthrene were evaluated with regard to determining field rates of apparent degradation. Determination of rate of treatment through time was based upon samples analyzed from depths that could be correlated with placement of lifts within the LTU cells. The correlation of other depths with specific lifts was not possible due to mixing of subsequent lifts and compaction of applied soil lifts within each LTU.

A summary of mean values for each LTU for concentrations of naphthalene and phenanthrene that were used for describing field apparent degradation kinetics within the LTU cells is provided in Table 7.14. Many of the concentration values for naphthalene and phenanthrene for discrete soil samples at each sampling time were at less than detection levels. Therefore, concentration values and differences in concentrations are based upon values near and below the detection limits of the instrumentation used and below the target

Table 7.14. Field-scale degradation rates for naphthalene and phenanthrene using mean values.

LTU, Lift	Dates	Naphthalene			Phenanthrene		
		Concentration (mg/kg)	k[1] (Day^{-1})	Half-life[1] (Days)	Concentration (mg/kg)	k[1] (Day^{-1})	Half-life[1] (Days)
LTU 1	5/8/91	4.5	-	-	2.5	-	-
Lift 4	6/27/9	4.3			3.2		
LTU 1	7/27/91	1.1	-	-	<0.95	-	-
Lift 5	9/18-19/91	1.0			0.70		
LTU 1	5/6-7/91	3.2	0.01537	44	2.4	0.0105	66
Lift 1	9/18-19/91	0.40			0.60		
	9/1/92	1.0			0.5		
LTU 2	7/27/91	1.4	-	-	4.5	0.0224	31
Lift 1	9/18-9/91	3.4			1.4		
	9/1/92	2.4			1.3		

[1] Degradation rate (k) and half-life values were calculated based upon a first-order kinetic model, using data from the first two dates; a third date indicates the asymptotic nature of apparent degradation, and the concentration values were not used in calculating rates and half-life values.

remediation level. As a result, calculation of kinetic values becomes difficult because they are based on differences between very small numbers (near and below the detection limit) over relatively large time intervals. Because of these limitations, no confidence intervals can be generated, and the results represent worst case (longest half-life) values since concentrations less than detection were truncated to "zero" values. Therefore the average concentration values and calculated kinetic values are the lowest possible values, based on the data obtained.

7.1.1.4 Naphthalene and phenanthrene treatment within the LTU cells

Concentrations for naphthalene and phenanthrene were consistently below the target remediation level of 8.0 mg/kg in contaminated soil applied to the LTU cells for treatment, with the exception of lift 4 applied on May 7, 1991, where discrete sampling indicated naphthalene concentrations as high as 10 mg/kg. Values for both PAH compounds were generally similar and were consistently within the range of 1 to 4 mg/kg in treated soil, with concentrations stabilizing at approximately 1 mg/kg. Due to the consistently low concentrations of naphthalene and phenanthrene in the contaminated soil, accurate calculation of apparent degradation kinetics was not possible.

7.1.2 Pyrene and total carcinogenic PAH (TCPAH)

7.1.2.1 Initial concentrations

Initial concentrations of pyrene and TCPAH in contaminated soil applied to the LTU cells are shown in graphical form in Figures 7.21 through 7.23 and in tabular form in Tables 7.15 through 7.17 (depths C and D were initially equivalent to lifts 4 and 5 for LTU 1 (applied May 7, 1991 and July 26, 1991, respectively), and depth A was initially equivalent to lift 1 for LTU 2 (applied July 25, 1991) (Figure 6.6)). Figures 7.21 through 7.23 indicate the position within each quadrant for each applied lift (initial depth) where each sample was taken and the PAH concentration as greater than or less than the target remediation level. Tables 7.15 through 7.17 provide more specific information concerning concentrations measured for each sample, as well as statistical analyses of the data including mean and 95 percent confidence interval (CI) values; statistics are also provided for PAH concentrations for each quadrant within an LTU. Values given in Tables 7.15 through 7.17 indicate that initial mean concentrations for each LTU for pyrene ranged from 76 to 135 mg/kg, and initial mean concentrations for TCPAH ranged from approximately 200 to 254 mg/kg.

7.1.2.2 Concentrations as a function of time and depth

An evaluation of the horizontal and vertical distribution of pyrene and TCPAH for LTU cells 1 and 2 was conducted for comparison of measured soil concentrations with target remediation levels and for evaluation of downward PAH migration. Comparisons of horizontal and vertical concentrations on September 1, 1992 with target remediation levels are presented in graphical form for pyrene and TCPAHs in Figures 7.24 through 7.28 (LTU 1) and in Figures 7.29 and 7.30 (LTU 2). Tables 7.18 through 7.20 (LTU 1) and 7.21 (LTU 2) provide more specific information concerning concentrations of pyrene and TCPAH measured for each sample, as well as statistical analyses of the data.

Pyrene concentrations in LTU 1 were below the target remediation level (7.3 mg/kg) for over 80 percent (69 out of 75) of the samples. Depth E (the top layer for the September, 1992 sampling event) was undergoing active management for treatment at the time of the sampling, and therefore was not evaluated with regard to target remediation levels for this sampling event. For the approximately 20 percent (6 out of 75) of samples that exceeded the target remediation level, the majority of samples (5 out of 6) were located in quadrants 2 and 3, located on the south side of the LTU. Pyrene concentrations in LTU 2 were below the target remediation level for 85 percent (11 out of 13) of the samples for depth A (lift 1). Depth B (the top layer) was undergoing active management for treatment at the time of sampling, and therefore was not

evaluated with regard to target remediation levels for this sampling event. For the 15% of samples that exceeded the target remediation level (2 out of 13), both samples were located in quadrant 3, located on the south side of the LTU.

TCPAH concentrations in LTU 1 were below the target remediation level (88 mg/kg) for over 90 percent (69 out of 75) of the samples for the September, 1992, sampling. Depth E was undergoing active management for treatment at the time of the sampling, and therefore was not evaluated with regard to target remediation levels for this sampling event. For the approximately 20 percent (6 out of 75) of samples that exceeded the target remediation level, all of the samples (6 out of 6) were located in quadrants 2 and 3, located on the south side of the LTU. TCPAH concentrations in LTU 2 were below the target remediation level for over 90 percent (12 out of 13) of the samples. Depth B (the top layer) was undergoing active management for treatment at the time of sampling, and therefore was not evaluated with regard to target remediation levels for this sampling event. The one sample that exceeded the target remediation level samples was located in quadrant 3, located on the south side of the LTU.

Comparisons of horizontal and vertical concentrations of pyrene and TCPAH in September, 1991, with target remediation levels are presented in graphical form in Figures 7.31 through 7.34 (LTU 1) and in Figure 7.35 (LTU 2). Tables 7.22 and 7.23 (LTU 1) and Table 7.24 (LTU 2) provide more specific information concerning concentrations of pyrene and TCPAH measured for each sample, as well as statistical analyses of the data.

Pyrene concentrations in LTU 1 were below the target remediation level (7.3 mg/kg) for 89 percent of samples that included depths A, B, and C. Depth D (the top layer for the September, 1991, sampling event), was undergoing active management for treatment at the time of the sampling, and therefore was not evaluated with regard to target remediation levels for this sampling event. Depth A in LTU 2 was undergoing active management for treatment at the time of sampling and therefore were not evaluated with regard to target remediation levels for this sampling event.

TCPAH concentrations in LTU 1 were below the target remediation level (88 mg/kg) for over 90 percent of samples that included depths A, B, and C. Depth D in LTU 1 and depth A in LTU 2 were undergoing active management for treatment at the time of the sampling, and therefore were not evaluated with regard to target remediation levels for this sampling event.

Comparisons of horizontal and vertical concentration distributions of pyrene and TCPAH with target remediation levels for samples obtained in June, 1991, are presented in graphical form in Figures 7.36 through 7.38 for LTU 1 (LTU 2 was inactive at this sampling time). Tables 7.25 and 7.26 (LTU 1) provide more specific information concerning concentrations of pyrene and TCPAH measured for each sample, as well as statistical analyses of the data.

Pyrene concentrations in LTU 1 in June, 1991 were below the target remediation level (7.3 mg/kg) for 75 percent of the samples. TCPAH concentrations in LTU 1 were below the target remediation level (88 mg/kg) for 80 percent of the samples that included depths A and B. Depth C was undergoing active management at the time of sampling and therefore was not evaluated with regard to target remediation levels.

Comparisons of horizontal and vertical concentrations of pyrene and TCPAH for samples obtained in May, 1991, with target remediation levels are presented in graphical form in Figures 7.39 and 7.40 for LTU 1 (LTU 2 was inactive at this sampling time). Table 7.27 (LTU 1) provides more specific information concerning concentrations of pyrene and TCPAH measured for each sample, as well as statistical analyses of the data.

Pyrene concentrations in May, 1991, in LTU 1 were below the target remediation level (7.3 mg/kg) for 75 percent of samples. TCPAH concentrations in LTU 1 were below the target remediation level (88 mg/kg) for 80 percent of samples that included depths A and B.

7.1.2.3 Rate of treatment through time

The target contaminants, pyrene and total carcinogenic PAH (TCPAH), were evaluated with regard to determining field rates of apparent degradation. Determination of rate of treatment through time was based upon samples analyzed from depths that could be correlated with placement of lifts within the LTU cells. Lift 4 (depth C) of LTU 1 was sampled in May and June, 1991, before another lift was added. Lift 5 (depth D) of LTU 1 was sampled in July and September, 1991, before another lift was added. Lift 1 of LTU 1 was sampled four times between May, 1991, and September, 1992, (a 16 month period) and represents a buried lift throughout the sampling evaluation. Results of the kinetic analysis for pyrene and TCPAHs are presented in Table 7.28.

Half-life values for pyrene ranged from 27 days to 61 days for lifts 4 and 5, respectively, to 533 days for lift 1. Half-life values for TCPAH ranged from 56 days to 33 days for lifts 4 and 5, respectively, to greater than 1,700 days for lift 1. The major difference between lifts 4 and 5 versus lift 1 is that lifts 4 and 5 were evaluated while each was the top lift, while lift 1 was evaluated while it was buried.

7.1.2.4 Pyrene and TCPAH treatment within the LTU cells

Results of discrete sampling demonstrated that pyrene and TCPAH were treated to target remediation levels within the LTU cells in over 90 percent of samples analyzed. Mean values for each LTU cell for each sampling time indicated that pyrene and TCPAH were below target remediation levels. No downward migration of pyrene or TCPAH through the LTU cells is apparent based upon the results obtained.

Kinetic results indicate faster treatment occurs while a lift is the top lift, and sustained, but slower treatment when the lift becomes buried. Continued treatment of pyrene and TCPAH may be limited by oxygen diffusion into buried lifts. Because concentrations of both pyrene and TCPAH appeared to continue to decrease with time after placement of lift A in LTU 1, it may be possible to place a new lift on top of a lift after some significant treatment has been accomplished, but before the lower lift reaches target remediation

Table 7.28. Field-scale degradation rates and half-lives for pyrene and TCPAH in LTU soil.

LTU, Lift	Dates	Pyrene			TCPAH		
		k[1] (day^{-1}) / Half-life (days)	95% CI[2] on k (day^{-1}) Lower	Upper	k[1] (day^{-1}) / Half-life (days)	95% CI[2] on k (day^{-1}) Lower	Upper
LTU 1	5/8/91	0.0256	0.0504	0.0007	0.0124	0.0325	0.0077
Lift 4	6/27/91	27	14	990	56	21	90
LTU 1	7/27/91	0.0113	0.0202	0.0024	0.0212	0.0283	0.0042
Lift 5	9/18/91	61	34	288	33	24	165
LTU 1	5/8/91	0.0013	0.0053	0.0001	0.0004	0.0006	0.0002
Lift 13	6/29/91	533	131	6,930	1,732	1,155	3,465
	9/18/91						
	9/1/92						

[1] Degradation rate (k) and half-life values were calculated based upon a first-order kinetic model
[2] 95 percent confidence intervals on the first order kinetic rate constant
[3] Buried lift

levels for individual chemicals. Enhancement of treatment in buried lifts may be accomplished by adding oxygen through bioventing systems. This method of management has not been practiced at the Libby, Montana Superfund site; however, further investigation of this approach with regard to technical issues and optimization of time of placement of subsequent lifts should be evaluated in an effort to decrease the total time required for active soil placement and management at Superfund sites utilizing land treatment in prepared bed reactors.

7.1.3 Pentachlorophenol (PCP)

7.1.3.1 Initial concentrations

Initial concentrations of PCP in contaminated soil applied to the LTU cells are shown in graphical form in Figures 7.41 through 7.43 and in tabular form in Tables 7.29 through 7.31 (depths C and D were initially equivalent to lifts 4 and 5 for LTU 1, and depth A was initially equivalent to lift 1 for LTU 2 (Figure 6.6)). Values given in Tables 7.29 through 7.31 indicate that initial mean concentrations for PCP in lifts applied to the LTU cells were between 100 mg/kg and 132 mg/kg.

7.1.3.2 Concentrations as a function of time and depth

An evaluation of the horizontal and vertical distribution of pentachlorophenol (PCP) for LTUs 1 and 2 was conducted for comparison of measured soil concentrations with the target remediation level of 37 mg/kg, and for evaluation of downward migration of PCP through the LTU cells. Comparisons of horizontal and vertical concentrations of PCP on September 1, 1992 with the target remediation level are presented in graphical form in Figures 7.44 through 7.48 (LTU 1) and in Figures 7.49 and 7.50 (LTU 2). Results for discrete sampling indicate that PCP was at concentrations less than target remediation level (37 mg/kg) for 97 percent of samples in LTU 1. Depth E of LTU 1 (the top layer for the September 1, 1992 sampling event) was undergoing active management for treatment at the time of the sampling. PCP concentrations were less than target remediation levels for 95 percent of samples in LTU 2.

Tables 7.32 through 7.38 provide more specific information for the September, 1992, sampling concerning concentrations of PCP measured for each sample, as well as statistical analyses of the data including mean and 95 percent confidence interval (CI) values; statistics are also provided for PCP concentrations for each quadrant within an LTU. Values given in Tables 7.32 through 7.36 for LTU 1 indicate that the mean concentrations for PCP were all below the target remediation level for all depths sampled (A, B, C, D, and E). In addition, the 95 percent confidence intervals for PCP for LTU 1 were all below target remediation levels. Values given in Tables 7.37 and 7.38 for LTU 2 indicate that the mean concentration for PCP were all below the target remediation level for both depths sampled (A and B). In addition, the 95 percent confidence intervals for PCP for LTU 2 were all below target remediation levels. Depth E of LTU 1 was undergoing active management for treatment at the time of the sampling.

Comparisons of horizontal and vertical concentrations of PCP on September 18 and 19, 1991 with the target remediation level are presented in graphical form in Figures 7.51 through 7.54 for LTU 1 and in Figure 7.55 for LTU 2. Results for discrete sampling indicate that PCP was at concentrations less than target remediation level (37 mg/kg) for 95 percent of samples in LTU 1. Depth D of LTU 1 (the top layer for the September 18 and 19, 1991 sampling event) was undergoing active management for treatment at the time of the sampling, and therefore was not included in the comparison. Depth A in LTU 2 was undergoing active management for treatment at the time of the sampling and therefore was not included in the comparison.

Tables 7.39 through 7.43 provide more specific information for the September 18 and 19, 1991 sampling concerning concentrations of PCP measured for each sample, as well as statistical analyses of the data. Values given in Tables 7.39 through 7.41 for depths A, B, and C for LTU 1 indicate that the mean concentrations for PCP were all below the target remediation level. In addition, the 95 percent confidence intervals for PCP for LTU 1 depths A, B, and C were all below target remediation level. Depth D in LTU 1

(the top layer for the September 18 and 19, 1991 sampling event) was undergoing active management for treatment and therefore was not included in the comparison with the target remediation limit. Depth A of LTU 2 (Table 7.43) was undergoing active management for treatment at the time of the September 18 and 19, 1991 sampling, and therefore was not included in the comparison with the target remediation limit.

Comparisons of horizontal and vertical concentrations of PCP for samples obtained on June 27, 1991 with the target remediation level are presented in graphical form in Figures 7.56 through 7.58 for LTU 1. Results for discrete sampling of LTU 1 indicate that PCP was at concentrations less than target remediation level (37 mg/kg) for all samples.

Tables 7.44 through 7.46 provide more specific information for the June, 1991, sampling concerning concentrations of PCP measured for each sample, as well as statistical analyses of the data. Values given in Tables 7.44 through 7.46 for depths A, B, and C indicate that the mean concentrations of PCP for all three depths were below the target remediation level. In addition, the 95 percent confidence intervals for depths A, B, and C were below target remediation level.

Comparisons of horizontal and vertical concentrations of PCP for samples obtained on May 6, 1991 with the target remediation level are presented in graphical form in Figures 7.59 and 7.60 for LTU 1 (LTU 2 was inactive at this sampling time). Results for discrete sampling indicate that PCP was at concentrations less than target remediation level (37 mg/kg) for 85 percent of samples (Depths A and B).

Tables 7.47 and 7.48 provide more specific information for the May 6, 1991 sampling concerning concentrations of PCP measured for each sample, as well as statistical analyses of the data. Values given in Tables 7.47 and 7.48 for depths A and B indicate that the mean concentrations of PCP for both depths were below the target remediation level. In addition, the 95 percent confidence intervals for depths A and B were below the target remediation level. Depth C (lift 4) was applied on the day following sampling.

Table 7.49. Field-scale degradation rates and half-lives for PCP in LTU soil.

LTU, Lift	Dates	PCP		
		k[1] (day^{-1})	95% CI[2] on k (day^{-1})	
			Upper	Lower
		Half-life (days)		
LTU 1	5/8/91	0.0421	0.0535	0.0307
Lift 4	6/27/91	16	13	23
LTU 1	7/27/91	0.0215	0.0281	0.0149
Lift 5	9/18/91	32	25	47
LTU 1	5/8/91	0.0014	0.0025	0.0002
Lift 13	6/29/91	495	277	3,465
	9/18/91			
	9/1/92			

[1] Degradation rate (k) and half-life values were calculated based upon a first-order kinetic model
[2] 95 percent confidence intervals on the first order kinetic rate constant
[3] Buried lift

7.1.3.3 Rate of treatment through time

PCP was evaluated with regard to determining field rates of apparent degradation. Determination of rate of treatment through time was based upon samples analyzed from depths that could be correlated with placement of lifts within the LTU cells. Lift 4 (depth C) of LTU 1 was sampled in May and June, 1991, before another lift was added. Lift 5 (depth D) of LTU 1 was sampled in July and September, 1991, before another lift was added. Lift 1 of LTU 1 was sampled four times between May, 1991, and September, 1992, (a 16 month period) and represents a buried lift throughout the sampling evaluation. Results of the kinetic analysis for PCP are presented in Table 7.49.

Half-life values ranged from 16 days to 32 days for lifts 4 and 5, respectively, to 495 days for lift 1. The major difference between lifts 4 and 5 versus lift 1 is that lifts 4 and 5 were evaluated while each was the top lift, while during all of the sampling events, lift 1 was a buried lift.

7.1.3.4 PCP treatment within the LTU cells

Results of discrete sampling demonstrated that pyrene was treated to target remediation levels within the LTU cells. Mean values for each LTU cell for each sampling time indicated that PCP was below target remediation levels. No downward migration of PCP through the LTU cells was apparent based upon the results obtained.

Kinetic results indicate faster treatment while a lift is the top lift, and sustained, but slower treatment for the buried lift. Continued treatment of PCP may be limited by oxygen diffusion into buried lifts. Because the concentration of PCP continued to decrease with time after placement of lift A in LTU 1, it may be possible to place a new lift on top of a lift after some significant treatment has been accomplished, but before the lower lift reaches target remediation levels for individual chemicals. Enhancement of treatment in buried lifts may be accomplished by adding oxygen through bioventing systems. This method has not been used at the Libby, Montana, Superfund site; however, further investigation of this approach with regard to technical issues and optimization of time of placement of subsequent lifts should be evaluated in an effort to decrease the total time required for active soil placement and management at Superfund sites utilizing land treatment in prepared bed reactors.

7.1.4 Soil gas analyses for oxygen and carbon dioxide

Soil gas in LTU 1 at 1 foot and 2 feet depths were analyzed for O_2 and CO_2 concentrations on September 18 and 19, 1991. Results of the analyses are shown in Figure 7.61 and 7.62. O_2 concentrations were observed to decrease and CO_2 concentrations were observed to increase as depth of sampling increased from 1 to 2 ft. Oxygen at 1 ft depth averaged 19.7 percent ($\pm$ 1.6 percent) and at 2 ft depth averaged 17.3 percent ($\pm$ 4.3 percent). Carbon dioxide averaged 0.9 percent ($\pm$ 1.0 percent) and 2.1 percent ($\pm$ 1.9 percent) at the 1 ft and 2 ft depths, respectively. Regression analysis showed that O_2 and CO_2 concentrations were highly inversely correlated ($r^2 = 0.91$) in the O_2 range of 14 to 21 percent and CO_2 in the range of 0 to 5 percent.

Also, at the 2 ft depth, O_2 concentrations were significantly less and CO2 concentrations were significantly greater in quadrants 1 and 4 compared with quadrants 2 and 3. Oxygen concentrations were recorded as low as 7 percent and 9 percent in quadrant 4. In quadrants 1 and 4 during the September, 1991 sampling event, phenanthrene (Figure 7.12 (depth B)), TCPAH and pyrene (Figures 7.31 (depth A), 7.32 (depth B), 7.33 (depth C), and 7.44 (depth D)), and PCP (Figures 7.53 (depth C) and 7.54 (depth D)) were observed to be above the target remediation levels. Park and Sims (1994) observed that the rate of apparent degradation of PAH compounds in soil was a function of O_2 concentration, and at O_2 concentrations less than 7 percent in uncontaminated soil spiked with PAH compounds, the degradation rate was significantly decreased.

Table 7.50. Soil Microtox™ toxicity (EC50) Values, Discret Soil Samples Collected 7/27/91, and 9/18/91, LTU 2, Lift 1, Day 1 and 53.

7/27/91 - Day 1

Grid No.	EC50 value	Low*	High*	Corr. Coef.
34	3.73	2.54	5.50	0.9950
34	3.03	1.89	4.86	0.9939
43	5.09	3.51	7.37	0.9937
43	7.21	4.42	11.75	0.9840
45	8.44	6.15	11.59	0.9920
45	7.10	6.62	7.63	0.9997
54	7.84	5.70	10.77	0.9926
54	8.89	8.08	9.77	0.9992
57	6.74	3.87	11.74	0.9810
57	7.88	4.82	12.89	0.9822
Mean	6.60			

9/18/91 - Day 53

Grid No.	EC50 value	Low*	High*	Corr. Coef.
34	NDR**			
34	NDR			
43	NDR			
45	NDR			
52	47.5	24.1	93.7	0.9724
52	NDR			
54	NDR			
54	NDR			
58	8.86	6.68	11.76	0.9933
58	9.01	7.85	10.33	0.9984

* 95% CI for EC50
** NDR = No Dose Response

7.1.5 Detoxification of soil in the LTU cells

An evaluation of the toxicity of the water soluble extract of soil samples taken from LTU 2 was measured with the Microtox™ assay. The Microtox™ assay was used to determine whether a reduction in target chemicals would correspond with a reduction in the toxicity status of the treated soil. Microtox™ analyses were performed on discrete soil samples collected from LTU 2, lift 1, on 7/27/91 (day one), two days after lift 1 was applied. The ten samples represented replicates from five locations on the sample grid. An additional ten discrete soil samples were collected from LTU2, lift 1, on 9/18/91 (day 53), and eight of these samples represented replicates from four grid locations. Microtox™ results from day one and day 53 are presented in Table 7.50. These data indicate that toxicity, as measured by Microtox™, decreased significantly from day one (mean EC50 6.6) to day 53 where seven of the ten soil samples had no dose response (NDR), as did background samples. The three values where an EC50 value was measured, reflect the variability of contaminant concentrations in LTU 2 that was observed earlier. For example, while the overall mean PCP concentration decreased (Table 7.31) from day one (101.4 mg/kg, n=20, 95-percent CI 66.1-136.7) to day 53

(Table 7.43) (42.7 mg/kg, n=19, 95-percent CI 9.9-75.5) (excluding one abnormally high value in quadrant 2, core No. 42), there were random high concentrations which may have resulted in measurable EC50 values.

The reduction in Microtox™ EC50 from 7/27/91 to 9/18/91 corresponded with reductions in pyrene, TCPAHs, and PCP concentrations on day 1 (Tables 7.17, 7.31, respectively) to day 53 (Tables 7.24, 7.43, respectively). A similar correspondence between toxicity reduction, as measured by Microtox™, and PCP soil concentration (Loehr, 1989; Dasappa and Loehr, 1991) and PAH soil concentration (Symons and Sims, 1988; Abbott and Sims, 1989; Wang et.al., 1990) has been observed in laboratory microcosms.

The potential for vertical migration of the contaminants being treated or their transformation products is an important concern for LTU performance. The Microtox™ assay represents an indirect measurement of this process, because PCP and its decompostion products, i.e., tetra-, tri-, di-, and chlorophienols (McGinnis et. al., 1991), are very toxic to *P phosphoreum*. The Microtox™ assay is generally more sensitive to the toxicants involved (PCP, PAHs) than are other indicators of soil microbial acativity (Sims et. al., 1986a; Sims et. al., 1986b; Symons and Sims, 1988; and Aprill et. al., 1990). In this study, samples from buried lifts were assayed by Microtox™ to determine whether vertical migration of contaminants occurred from upper lifts. The position within each quadrant for each depth where each sample was taken is identified, and the Microtox™ toxicity indicated as non-toxic (NT, indicating that the EC50 value was greater than 100 or that there was no dose response(NDR) for the sample) or toxic (the value of the EC50 is given).

Depths A, B, and C were assayed on Sept. 1, 1992 (Figure 7.63 - 7.65) and on Sept. 18-19, 1991 (Figures 7.66 - 7.68) and depths A and B were assayed on May 6, 1991 (Figures 7.69 - 7.70). Pyrene, TCPAH, and PCP concentrations (Tables 7.16, 7.30) in lift D (LTU 1), when it was applied onto lift C were greater than values in LTU 2, lift A on day 1 (Tables 7.17, 7.31), which yielded a mean EC50 of 6.6. It was assumed that the EC50 of soil extracts form LTU 1, lift D would have also been high. Indicator compound concentrations in lift D on two later dates (9/18/91, 9/1/92), when lift C soils were sampled for the Microtox™ assay, indicated a significant loss of these compoundsand the Microtox™ EC50 values for the 14 discrete soil samples collected from all the sampling depths were non toxic. These data indicate that loading contaminated lifts onto lifts that had previously reached the clean up goals had no measurable effect on the Microtox™ response in lower lifts in LTU 1. Therefore, the vertical migration of soluble contaminants from such lifts had little effect on the microbial activity in the underlying treated soil.

In Summary, detoxification, as measured by the Microtox™ assay, occurred in the soil; and toxicity reduction corresponded with PCP, pyrene, and TCPAH disappearance. No increase in toxicity in the lower treated soil layer (lifts) of the LTUs was observed with time, while the upper, more recently applied lifts were highly contaminated and toxic. This indicated that vertical migration of soluble contaminants had little effect on microbial activity in lower lifts of treated soil.

An evaluation of the decrease in mutagenic potential of soil extracts from soil samples in LTU 1 was undertaken by Dr. K. C. Donnelly of Texas A&M University (Donnelly et al., 1992). Initial mutagenic potential of soil applied to LTU 1 was estimated to be approximately 330 revertants per gram of soil (weighted activity). Results of mutagenicity testing for lift 1 (Depth A) sampled September, 1989 (3 months after application of lift 1) indicated detoxification to soil background levels (less than 150 revertants per gram of soil). Soil samples taken from lift 1, 5 months after application of lift 2 (November, 1989) showed only three of nine samples with mutagenic activities near or greater than 150 revertants per gram of soil. Results obtained by Donnelly et al. (1992) indicated that biological treatment of contaminated soil in LTU 1 reduced the mutagenic potential of the solvent extracts of soil (measured as weighted activity or revertants per gram of soil) to background levels after approximately three months of treatment.

7.2 Laboratory-scale evaluation of LTU soil for biodegradation of phenanthrene and PCP

Two independent laboratory evaluations of soil microbial metabolic potential were conducted using randomly selected LTU soil samples (Tables 6.7 and 6.9) to add additional information concerning biodegradation versus other behavior mechanisms (e.g., volatilization) for phenanthrene and PCP that could account

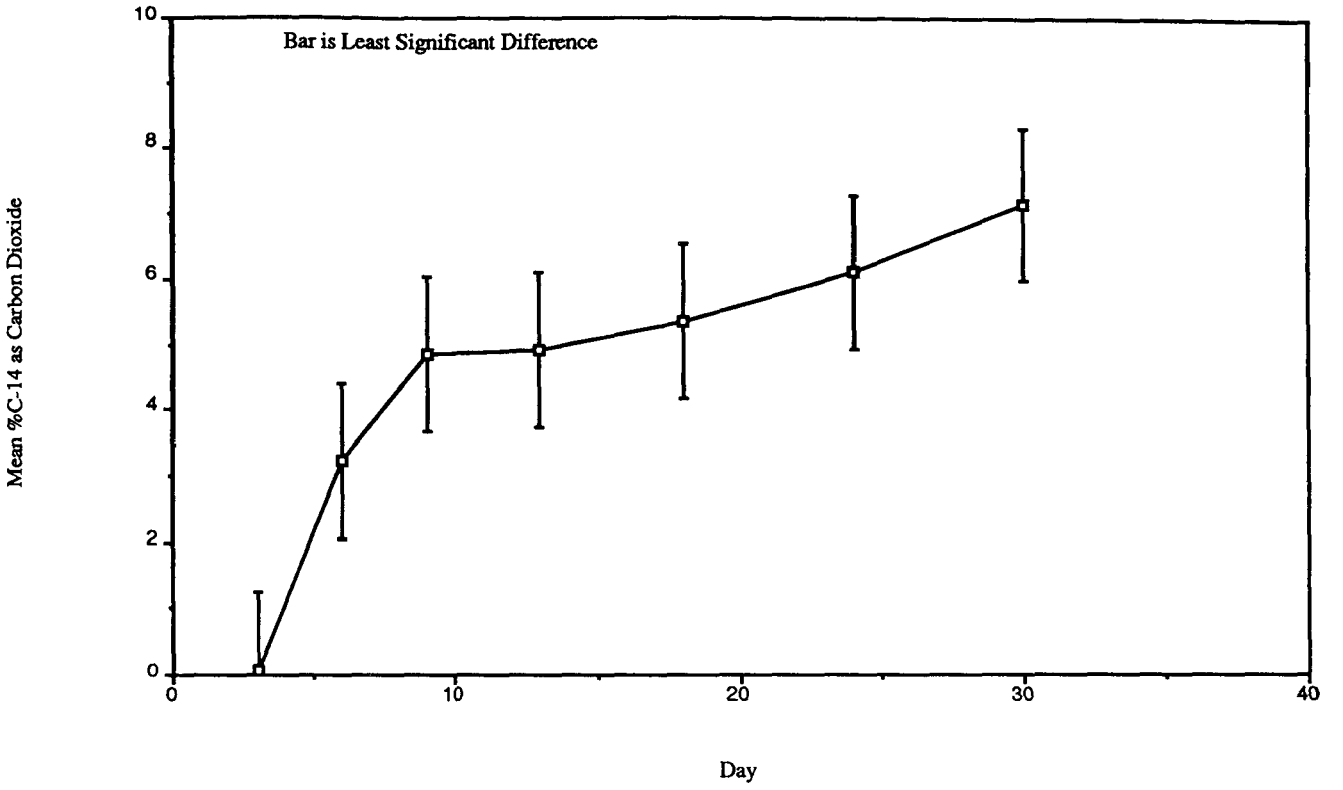


Figure 7.71 Mineralization of PCP with time at 10° C in Libby LTU soil ing th biological mineralization study.

for the apparent degradation observed at field scale. The first laboratory evaluation was designed to determine rates of biological mineralization and volatilization as affected by soil moisture. The second laboratory evaluation was designed to evaluate humification of the chemicals, as determined by the measurement of the non-solvent-extractable radiolabeled carbon. In the second evaluation, the effects of soil moisture and temperature were also evaluated.

7.2.1 Results of laboratory evaluation test for biological mineralization

With regard to the first laboratory evaluation of spiked PCP mineralization, there were no significant effects of soil sample or moisture content (40 percent or 80 percent of field capacity) at 10° C. Statistically significant effects of treatments were evaluated at the 95 percent confidence level. Total volatilization of PCP was less than 1 percent and essentially ceased after the first few days of incubation. Overall, there was 7 percent PCP mineralization over the 30 days of incubation at 10° C (Figure 7.71). The rate of mineralization decreased substantially after 8 days. Based upon mineralization observed in the laboratory evaluation, a laboratory biological mineralization first order rate constant of 0.0024 per day was calculated. Field-scale rates for PCP apparent disappearance were calculated as 0.0421 per day and 0.0215 per day for lifts exposed to the atmosphere and 0.0014 for buried lift 1. The rate based upon laboratory mineralization determination is lower than the rates based upon field scale observation for lifts exposed to the atmosphere. Mineralization is generally not expected to be equivalent to chemical disappearance, as some fraction of carbon is used for microbial cell carbon and for the formation of biochemical intermediates. Also, some carbon may be incorporated into soil organic matter by humification.

Mineralization of spiked phenanthrene was significantly affected by the interaction of incubation time and soil sample. Mineralization accounted for 12 percent of the disappearance of phenanthrene from the soil sample collected from Depth A, 5/6/91, and 5 percent of the disappearance of phenanthrene from the soil sample collected from Depth B, 5/6/91, over the 30 days of incubation at 10° C. The differences in the

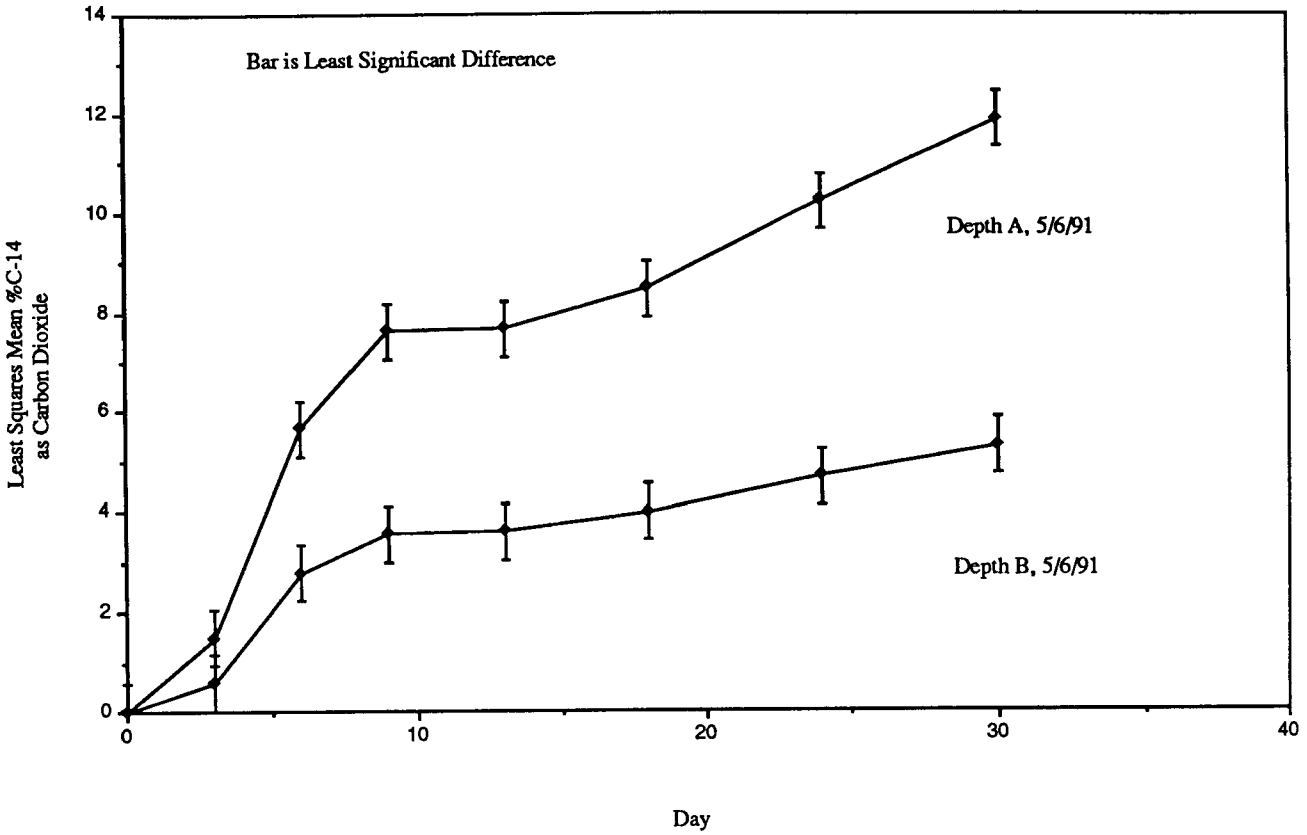


Figure 7.72 The effect of soil sample on the mineralization of phenathrene with time at 10°C in Libby LTU soil in the biological mineralization study.

kinetics of degradation and the total amount of $^{14}CO_2$ evolved over the period of the experiment are shown in Figure 7.72. There was little change in the $^{14}CO_2$ evolved between days 9 and 13 from either sample. However, mineralization was more rapid in the sample taken from Depth A both before and after this period. The more rapid mineralization of phenanthrene in the soil sample from Depth A correlates with lower concentrations of all of the PAHs measured in this sample compared with the soil sample from Depth B (Table 6.7). While only approximately 60 days were required to treat lift 1 (Depth A) to target remediation levels, over one year was required for treatment of lift 2 (Depth B). Therefore, soil present in lift 1 (Depth A) appears to be more microbially active than soil present in lift 2 (Depth B). This could have been due to more aggressive pretreatment of lift 1 soil in the waste pit area through addition of nutrients compared with lift 2 (Depth B). Also, because the first three lifts were applied to the LTU before this study commenced, initial concentrations were not measured in this study, and therefore, the effects of differences in initial concentrations of chemicals in the soil on remediation could not be evaluated. Total volatilization of spiked phenanthrene was less than 1 percent and essentially ceased after the first few days of incubation, similar to results obtained for PCP.

The interaction of soil sample and moisture also had a significant effect on phenanthrene mineralization at 10° C. The Depth A sample and low moisture content (40 percent of field capacity) combination resulted in the highest amount of mineralization. This result was not significantly different from the combination of Depth A sample and the high moisture content (80 percent of field capacity) treatment. The combination of Depth B sample and high moisture content resulted in the lowest mineralization (one percent), and was statistically significantly lower than the lower moisture content (Figure 7.73). Mineralization in the Depth B soil sample was significantly lower than in the Depth A soil at both low and high moisture contents.

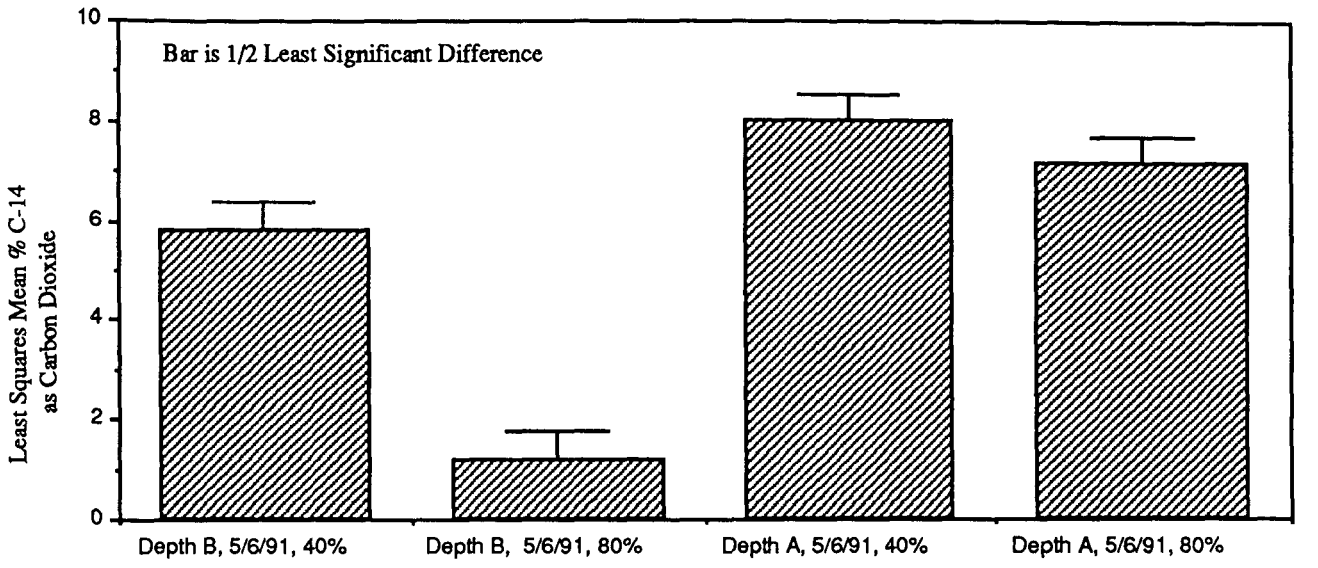


Figure 7.73 The effect of soil sample and moisture content (as percent of field capacity) on mineralization of phenanthrene at 10°C in Libby LTU soil in the biological mineralization study.

Results of the first laboratory evaluation of soil microbial metabolic potential demonstrate that PCP and phenanthrene can be partially metabolized to carbon dioxide in the contaminated soil matrix present at the site. Both PCP and phenanthrene can be mineralized with the indigenous soil microorganisms at temperatures and moisture contents representative of site conditions. In addition, significant volatilization of PCP or phenanthrene at the full-scale field site is unlikely based upon the laboratory evaluation of chemical volatilization. The information obtained in the laboratory evaluation of LTU soil corroborates the interpretation of apparent decrease in target chemical concentration as due to biological processes rather than physical/chemical processes.

7.2.2 Results of laboratory evaluation test for biological mineralization and humification

The second laboratory evaluation of phenanthrene and PCP was conducted in two soil samples (for phenanthrene, two samples collected 5/6/91 from Depth A; for PCP, samples collected one day after application to LTU 1 from Depth C (5/8/91) and Depth D (collected 7/21/91)) at two soil moisture contents (80 percent and 40 percent field capacity) and two temperatures (10°C and 20°C).

7.2.2.1 Mass balance

The mass balance of radioactive carbon added to the microcosms in the laboratory determination of biodegradation potential averaged 83 percent for all microcosms for phenanthrene and 67 percent for all microcosms for PCP (Tables 7.51 and 7.52). The mass balance error may be due to such random sources as undetected gas leaks, undetected spills of soil materials, and/or random error in dispensing the radiolabeled chemicals into the microcosms. Since these errors were as likely to occur in one microcosm as another and would, therefore, not be likely to affect the data from one experimental treatment more than another, it was assumed that the error did not bias the statistical treatment of the data or the interpretation of the results.

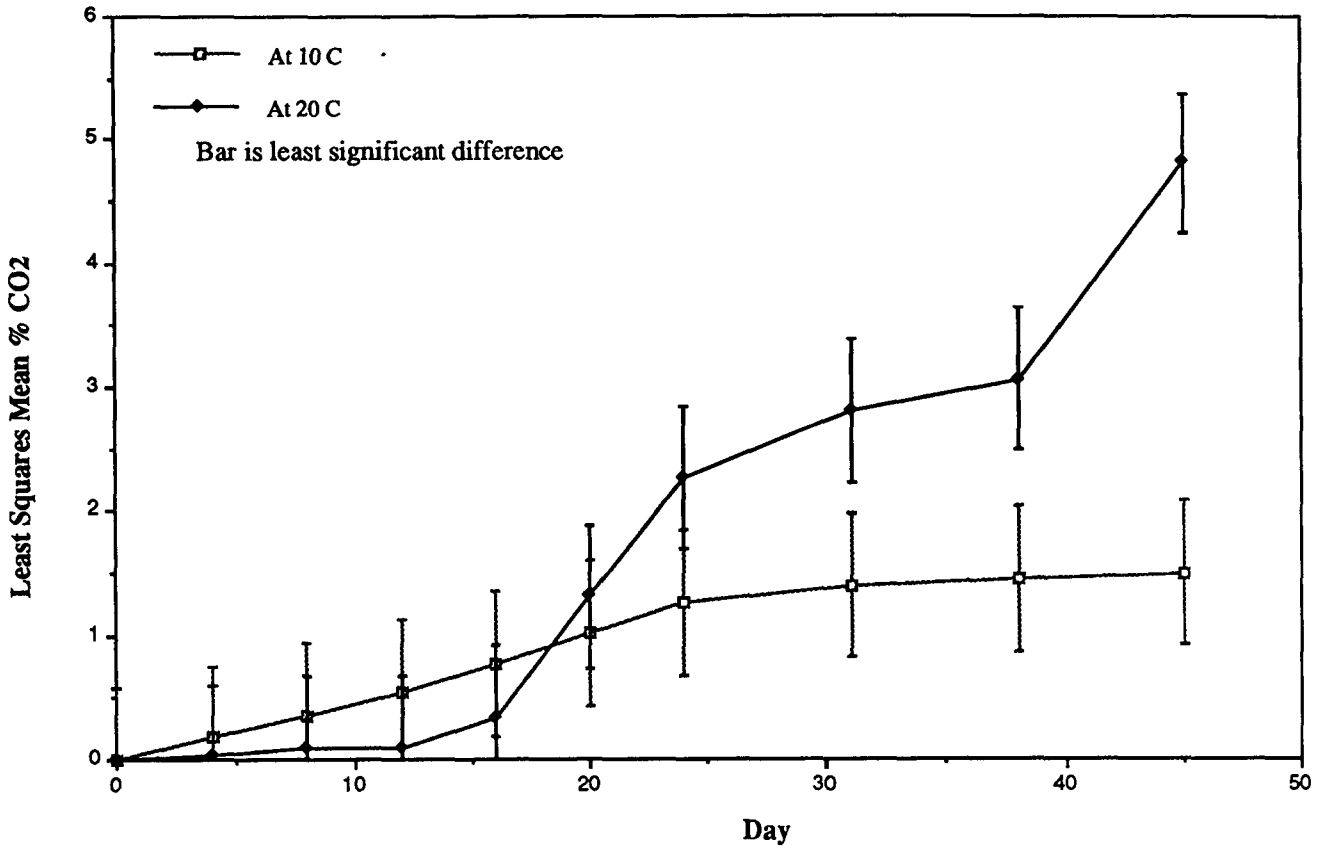


Figure 7.74 The interaction of temperature and incubation time on the mineralization of phenanthrene in Libby LTU soil in the biological mineralization and humification study.

7.2.2.2 Volatilization and mineralization.

The values for average cumulative radioactive volatile ^{14}C- and $^{14}CO_2$- carbon trapped during the second laboratory evaluation are listed in Tables 7.51 and 7.52 for phenanthrene and PCP, respectively. Similar to results obtained for the first laboratory evaluation, the total volatilization of both phenanthrene and PCP over the 45 day evaluation was less than 1 percent. Therefore, volatilization was not considered to be an important route of compound removal from soil based upon the two laboratory evaluations.

No significant differences in mineralization of PCP among the treatments (soil sample, moisture, and temperature) and their two- and three-way interactions were found. Over the incubation period, the average cumulative $^{14}CO_2$ for all of the treatments increased from 0.06 percent at day 4 to 3.0 percent at day 45, but the differences among the means determined for each analysis day over this period were not significant. Assuming first order kinetics for PCP mineralization, the first order rate coefficient was calculated as 0.001 per day from the regression of the natural logarithm of the average radiolabeled carbon remaining over time, resulting in a half life of approximately 2 years.

Phenanthrene mineralization in the second test of the laboratory evaluation was not significantly affected by soil sample, by soil moisture content, or by the interaction of these factors. There was a significant difference, however, in the progress of phenanthrene mineralization depending upon incubation temperature (Figure 7.74). Through the sixteenth day of incubation, cumulative average mineralization at both 10° and 20° C remained below 1 percent and more mineralization had occurred at 10° C. By day 31, mineralization at 20° C was significantly higher than at 10° C. By day 45 mineralization at 20° C was continuing to accelerate, while at 10° C, the rate of mineralization appeared to decrease after 24 days. Near surface summer

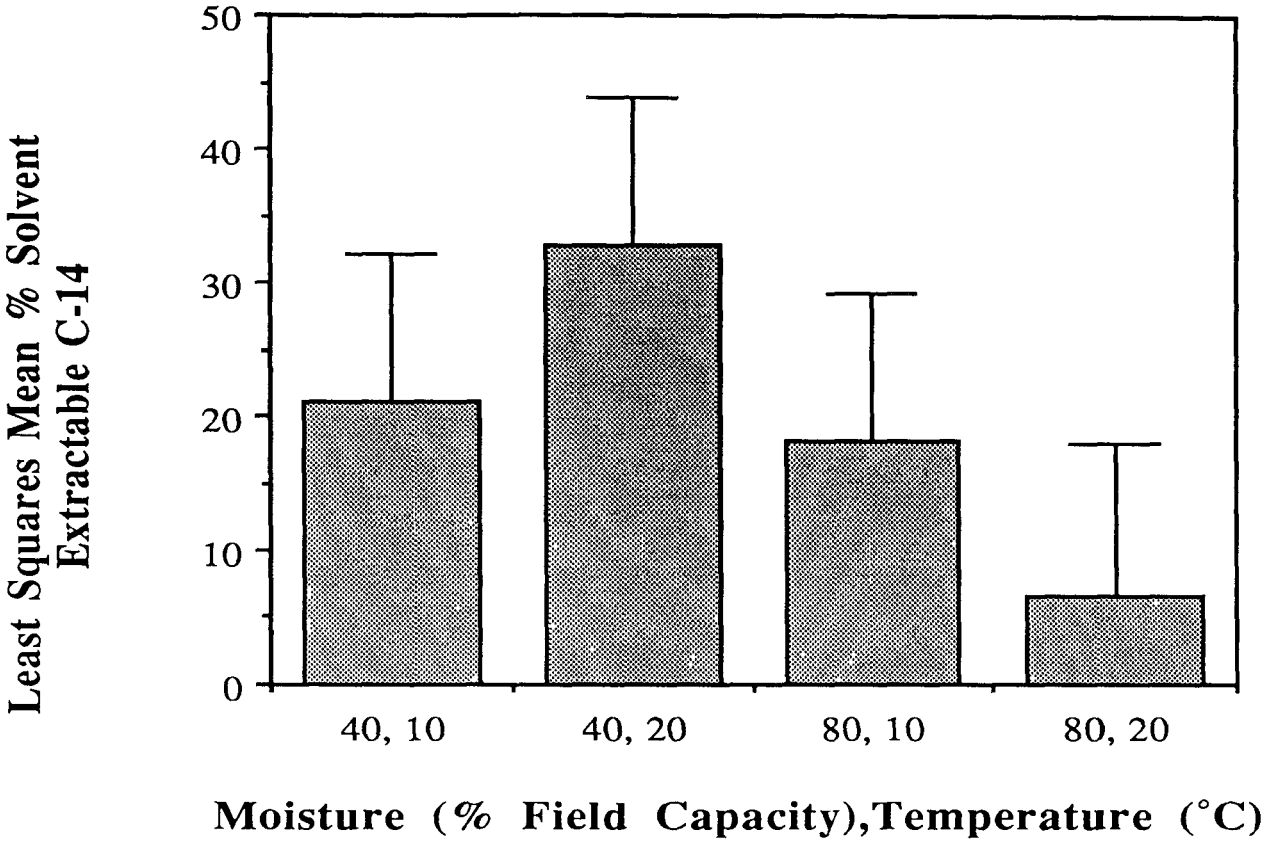


Figure 7.75 Fraction of radiolabeled carbon added as phenanthrene that was solvent- extractable in relation to the interaction of moisture and temperature factors in the biological mineralization and humification study.

daily average soil temperatures at the Libby Site would be approximately 20° C while the annual average temperature for all of the soil in the LTU is anticipated to be about 10° C.

When these results are compared with the results from the first laboratory evaluation, it is clear that phenanthrene mineralization rate is variable among samples from the LTU. It appears that the soil sample can be important in affecting the rate, at least at 10° C, but that within the samples evaluated, this effect is marginal and variable. Similarly, the effect of moisture content appears to be relatively small and quite variable.

7.2.2.3 Solvent-extractable radiolabeled carbon.

Radiolabeled carbon that was extractable from soil with methylene chloride:acetone solvent after 45 days of incubation averaged 34 percent for PCP microcosms and 20 percent for phenanthrene microcosms. There were no significant differences in the amount of ^{14}C extractable among the different soil samples, moisture, and temperature treatments. Neither were any of the interactions of these factors significant in their effect on extractability of PCP or its transformation products.

Radiolabeled carbon extractable from the phenanthrene microcosms averaged 20 percent (± 13 percent) at the end of the incubation period (Table 7.51). Figure 7.75 illustrates the effect of the interaction of moisture content and incubation temperature on radiolabeled carbon extractability for phenanthrene. The microcosms incubated at 20°C with 40 percent field capacity moisture content contained significantly more

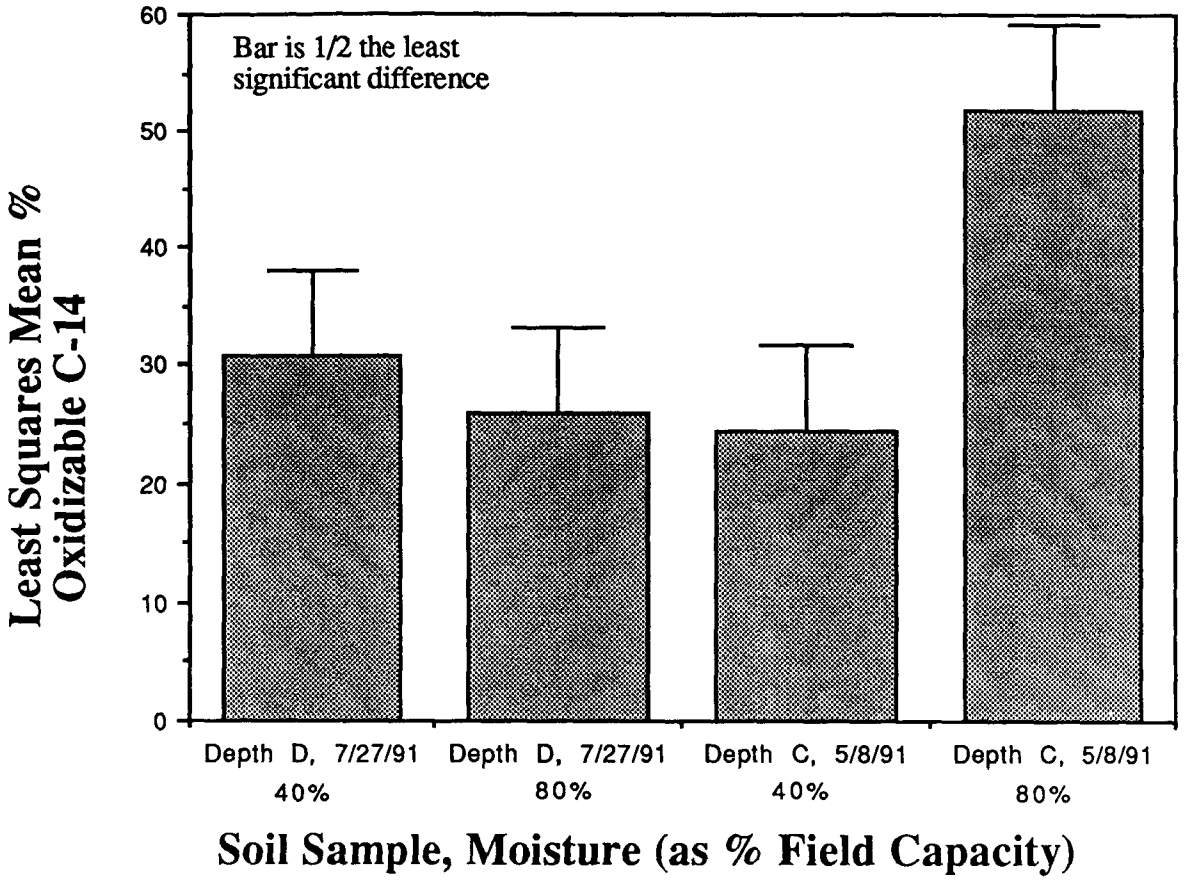


Figure 7.76 Fraction of radiolabeled carbon added as PCP that was recoverable by combustion of soil solids (representing the soil-bound fraction) in relation to the interaction of soil sample and moisture content in the biological mineralization and humification study.

extractable ^{14}C than those with 80 percent field capacity. Since this effect involves the interaction of higher incubation temperature and different moisture contents, and both of these factors are known to be important in affecting soil microbial activity, it seems plausible that biological mechanisms resulting in the increased incorporation of phenanthrene or its degradation products into soil organic matter (humification) at the higher moisture content are important in affecting this result. At the lower temperature, the effect of moisture was not significant.

7.2.2.4 Humified soil-bound radiolabeled carbon

Soil-bound radiolabeled carbon is summarized for phenanthrene in Table 7.51 and for PCP in Table 7.52. Soil-bound ^{14}C from PCP averaged 32 percent (± 13 percent) at the end of the incubation period. The interaction of soil sample and moisture content had a significant effect on the amount of bound ^{14}C from PCP. Figure 7.76 shows that the combination of the sample collected from Depth C on 5/8/91 and high moisture resulted in a significantly higher bound (oxidizable) ^{14}C than did the other three combinations of soil sample and moisture.

Soil-bound ^{14}C from phenanthrene averaged 60 percent (± 20 percent) after the 45 day incubation period (Table 7.51). The interaction of soil sample and moisture content (Figure 7.77) had a significant effect on soil incorporation of radiolabeled carbon. The combination of Depth A sample collected 5/6/91 and high moisture yielded a higher percentage of humification.

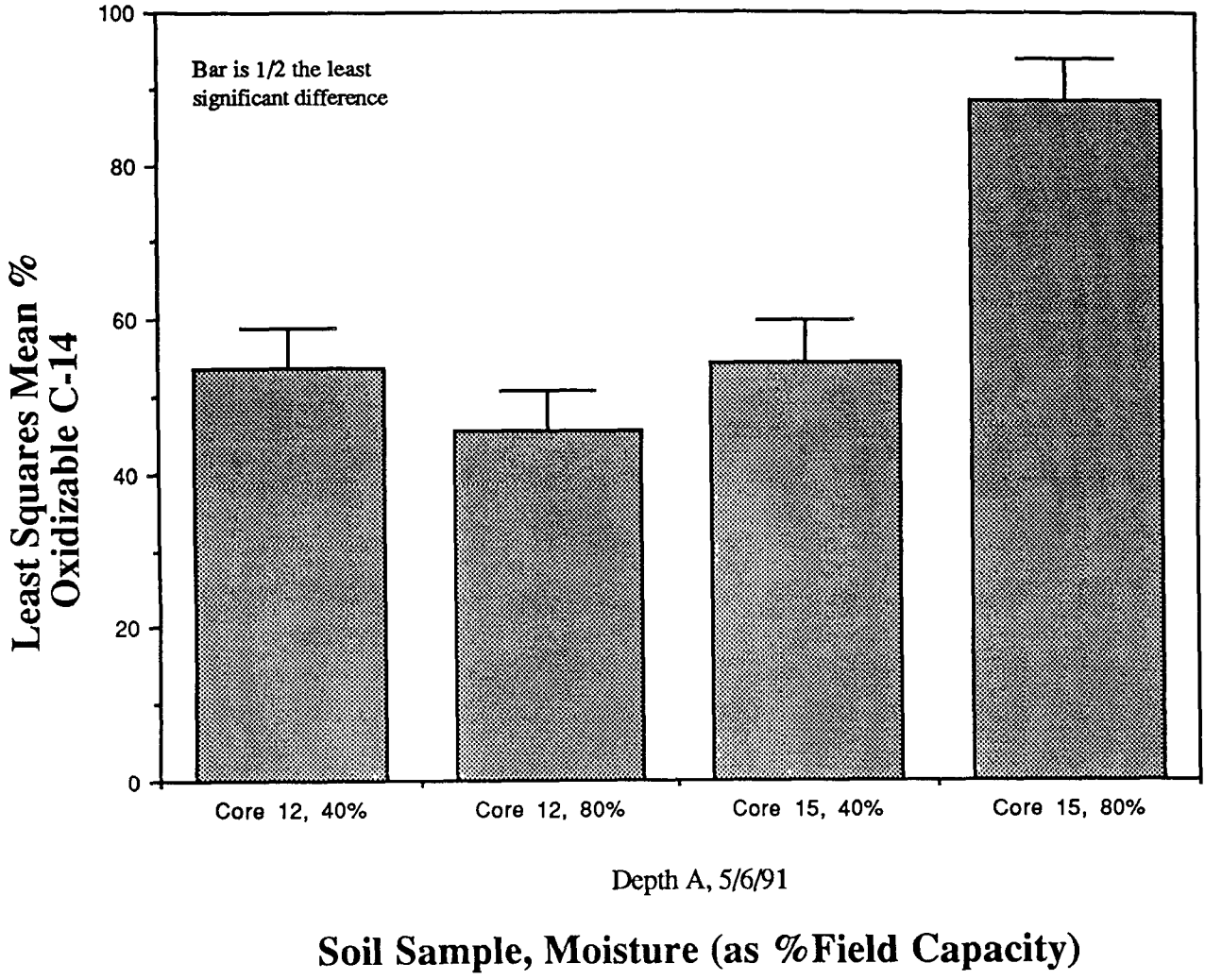


Figure 7.77 Fraction of radiolabeled carbon added as phenanthrene that was recoverable by combustion of soil solids (representing the soil-bound fraction of ^{14}C) in relation to the interaction of soil sample and moisture content in the biological mineralization and humification study.

7.2.3 Discussion of laboratory evaluation

Results of the laboratory evaluations demonstrate that not all of parent compounds are mineralized within a soil system. Rather, carbon in the parent compounds become distributed among air, solvent extract, and soil-bound compartments, as indicated in Tables 7.51 and 7.52. A major pathway for ^{14}C for phenanthrene and PCP is humification (binding to soil), such that the compound is not solvent-extractable from soil. A significant fraction of ^{14}C is solvent-extractable from the soil, either in the form of the parent compound or intermediates. Mineralization represents the third most important fraction for ^{14}C. Volatilization is the least significant as a fate and behavior process for any combination of environmental and management factors.

Results of the laboratory evaluations add additional information to the field-scale observations, i.e., that the loss of PAH compounds and PCP is not due to volatilization of parent compound or of intermediates (with the possible exception of naphthalene), but that the parent compounds are mineralized and humified within the LTU soil system.

7.3 Cost information related to field-scale bioremediation at the Libby Site

Champion International acquired St. Regis Paper Company in 1985. Prior to this time, approximately $100,000 was spent on activities related to site remediation at the Libby Site. The remedial investigation and feasibility study (RI/FS) costs under Champion International ownership was $2.3 million for the Libby Site. Between 1986 and 1993, costs, including engineering planning, construction, and oversight, have totalled $7.7 million. Annual operating costs for the site, including the LTU for treatment of contaminated soils, the above-ground fixed film bioreactor for treatment of ground water, and the in situ treatment system for the Upper Aquifer are estimated to be $1.2 million for 1993, with $700,000 to $800,000 of that total amount for consulting and oversight work. By 1995, consulting work, monitoring, and oversight activities are anticipated to cost $300,000 to $500,000 annually.

Concerning the land treatment units, construction costs for LTU 1 and LTU 2 amounted to $400,000. Monitoring requirements plus annual operations were estimated to cost $117,000 for the year 1992.

Chapter 8

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APPENDIX A

Methods and Quality Assurance/Quality Control Procedures

A-1. Extraction of samples and soil moisture determinations

The procedure used for the extraction of contaminated soils was based on U.S. EPA Method 3550 (U.S. Environmental Protection Agency, 1982) using sonication. Method 3550 is a procedure for extracting nonvolatile and semi-volatile organic compounds from solids such as soils, sludges, and wastes. The sonication process ensures intimate contact of sample matrix with the extraction solvent. A 30 g sample is solvent-extracted with methylene chloride/acetone (in a 1:1 mixture by volume) using sonication. The sample extract is passed through a funnel containing anhydrous sodium sulfate. The sample is concentrated in a Kuderna-Danish apparatus. Final volumes are adjusted, and the sample is then ready for analysis. Specifically, the procedures used included the following steps:

The soil samples were prepared for extraction by removing soil particles above 2 mm. The soil samples were sieved through a 2 mm screen. Each sample was poured onto a clean piece of aluminum foil and mixed thoroughly using a nickel-plated steel spatula. The sample was returned to original sample container. Approximately 30 g of soil sample was weighed using an analytical balance (Sartorius Model B120S) into a tared plastic, disposable weighing dish (4 cm x 4 cm), and the weight was recorded to the nearest 0.01 g. The sample was then transferred to a 125 mL glass jar with a teflon-lined lid (labelled with UWRL sample log number) that had been cleaned with a solvent rinse or by muffling in a muffle furnace at 550° C for 24 hours.

At the same time as the portion used for analytical determination was removed and weighed, 5 to 10 g of the sample were removed and weighed in a tared crucible for moisture determination. The sample was dried overnight at 105° C and allowed to cool in a desiccator before re-weighing. The percent moisture of the sample was calculated using the following relationship:

$$\frac{\text{g of sample (wet weight)} - \text{g of dry sample}}{\text{g of dry sample}} \times 100 = \%\ \text{moisture (dry weight basis)}$$

For the samples used for analytical determination of contaminant concentrations, 1 mL of a tribromophenol spiking solution (5000 mg/L, prepared as pure (99 percent or greater; Aldrich Chemical Co.) tribromophenol in acetonitrile) was added to the soil in each jar. Approximately 100 mL of solvent, 1:1 methylene chloride/acetone (pesticide quality) by volume was then added to the sample in the jar, and the sample and solvent were mixed by swirling.

The sample was then disrupted for 3 minutes with a sonicator (Tekmar Sonic Disrupter Model No. CV 17, with a 3/4 inch probe) with the output control setting at 10, pulse mode switch on "on," and percent duty cycle set at 50 percent.

After sonication, the solids were allowed to settle. The supernatant (sample extract) was poured into a 100-mm funnel filled with 2-2.5 inches of anhydrous sodium sulfate and glass wool for removal of water. The anhydrous sodium sulfate (reagent grade) was prepared by drying in an oven at 105° C for 12 hours in 600 mL beaker covered with triple layer of aluminum foil, followed by storage in a desiccator until use. The dried extract was collected in a 500 mL Kuderna-Danish (K-D) flask with a 10 mL graduated concentrator tube attached (the flask was labelled with UWRL sample log number). One hundred mL of solvent were added to the sample two more times, with sonication of the sample and separation of supernatant performed after each addition of solvent. After the sample had been sonicated three times, 5-10 mL of additional solvent were added to the sample, and the sample was swirled. The solids were allowed to settle and the supernatant was poured through the funnel containing anhydrous sodium sulfate. This washing procedure of the sample was conducted four more times.

After the sample extract had drained from the funnel, the funnel was rinsed three times with 2-4 mL of solvent. After all the rinses had drained, the funnel was removed from the K-D flask/concentrator, and the tip of the column was rinsed with solvent into the K-D flask.

A small boiling chip (Teflon Boilezers) was added to the K-D flask, and a 3-ball macro Snyder column was attached. The Snyder column was prewet by adding about 1 mL of methylene chloride to the top of the column. The K-D apparatus was placed on the steam table (80-90° C) (concentric ring electric steaming bath, Precision Model No. 66738) so that the concentrator tube was partially immersed in the hot water, and the entire lower rounded surface of the flask was bathed with hot vapor. The vertical position of the apparatus and the water temperature, as required, were adjusted to complete the concentration in 10-15 min. At the proper rate of distillation, the balls of the column actively chattered, but the chambers did not flood with condensed solvent. When the volume of the liquid reached approximately 5 mL, the K-D apparatus was removed from the steam table and allowed to drain and cool for at least 10 minutes.

To accomplish solvent exchange, the Snyder column was removed and 15 - 20 mL of acetonitrile were added to the flask. The Snyder column was re-attached and the K-D apparatus was placed back on the steam table. The extract was concentrated to approximately 5 mL. The temperature of the steam table was raised as necessary to maintain the proper rate of distillation. The K-D apparatus was removed from the steam table and allowed to cool. The Snyder column was removed, and the flask and its lower joints were rinsed into the concentrator tube with 1-2 mL acetonitrile.

The final volume was adjusted to 10 mL by transferring the sample to a 10 mL volumetric flask using a clean disposable Pasteur pipette. The flask was brought to volume with acetonitrile.

Two mL of the extract were transferred to a GC vial (12 x 32 mm (OD x H)) (labelled with UWRL log number) for PCP analysis using gas chromatography (GC). One mL was transferred to a 10 mL volumetric flask and brought to volume with acetonitrile. This sample extract was filtered through a 0.2 micron filter. Two mL of this extract were transferred to a GC vial (labelled with UWRL log number) for analysis for PAH analysis using gas chromatography/mass spectrometry. The samples were stored in the dark at 4° C until analysis.

Quality control procedures utilized during the extraction procedure included:

1. Duplicate extractions: every fifteenth to seventeenth sample was extracted in duplicate to check for reproducibility of the extraction procedure. Each duplicate sample was analyzed for PCP and PAH compounds.

2. Procedural blanks: With each set of extractions (i.e., every 9 - 10 samples), a solvent sample (containing no soil) was run through the extraction procedure to detect contamination associated with the extraction procedure. The procedural blanks were analyzed with the set of samples with which they were extracted.

3. Spikes: With every set of extractions (i.e., every 9 - 10 samples), duplicate samples were spiked with PCP and tribromophenol. Thirty g aliquots of a sample were weighed into two containers. Before adding the solvent to the two containers, 250 uL of the PCP spiking solution, and 1 mL of the tribromophenol spiking solution were added directly to the soil. Samples in both containers were extracted. The spiked samples were analyzed and the results were recorded, including percent recovery of the spiking solutions.

Stock solutions of the compounds used for spiking the samples were prepared in the following manner:

a) PCP spiking solution: The spiking solution was prepared by dissolving 0.200 g PCP (reagent grade) into 100 mL of methanol (pesticide quality).

b) Tribromophenol spiking solution: The spiking solution was prepared at a concentration of 5000 mg/L by dissolving the appropriate amount of pure (99 percent or greater; Aldrich) tribromophenol in acetonitrile (pesticide quality).

After preparation, the stock spiking solutions were stored at -20° C in the dark until use.

As part of the quality assurance/quality control program, a technician certification procedure was used. Before a laboratory technician was allowed to perform extractions, he/she was required to extract duplicate spiked, clean sand samples. Recovery efficiencies of the spiked samples had to be greater than or equal to 95 percent and equal to or less than 105 percent before the technician was allowed to extract project samples.

A-2. Analysis of PCP using gas chromatography

An adaptation of U.S. EPA Method 8040 (U.S. Environmental Protection Agency, 1982) was used to determine the concentration of pentachlorophenol (PCP) in the soil extracts. Gas chromatography with an electron capture detector was used to detect PCP in the sample extracts. Prior to use of this method, samples were extracted using sonication as the extraction technique.

Samples were analyzed using a Shimadzu Gas Chromatograph 14A-GC with a Shimadzu Automatic Sample Injector AOC-1400, an RTX-5 column, and a Shimadzu C-R501 Chromatopac integrator.

Before every analysis run, the GC column was brought to its highest allowable operating temperature for five hours. During this time, a solvent was injected every hour in order to achieve better conditioning of the column. After conditioning, without any injection, the GC was operated for twice the length of time of a normal run. If a steady baseline was not achieved, the column was re-conditioned.

The temperature program for the analysis was: initial column temperature set at 110° C, held for 2 minutes, followed by 2.5°/min temperature rise to 240° C, held for 6 minutes, a 4° C/min temperature rise to 185° C, and a 20° C/min temperature rise to 325° C, held for 4 minutes. The injector and detector temperatures were set at 270° C. Nitrogen was used as the carrier gas.

For each GC run, a log sheet was prepared containing sample identification, name(s) of persons performing the analyses, type of samples being analyzed, instrument set-up parameters, and identification of standard solutions. Also recorded on the log sheet were the date the samples were analyzed, the file name that data were stored in, and any comments specific to the samples and/or data. Also recorded were instrument operating conditions and changes (e.g., if N_2 cylinder was changed, column was reconditioned, or any changes were made in operating conditions).

Once a week, seven PCP and four tribromophenol (TBP) calibration standards were injected to prepare the linear range of the analytical system for PCP. TBP was analyzed because it had been added as an internal standard to each sample during the extraction procedure. The standard curves generated were compared to previous standard curves. During each daily run, three PCP standards and one TBP calibration standard were injected. Results had to agree within 10 percent of values calculated from the weekly standard curve.

To develop the standard curves for PCP and TBP, peak areas, retention times, and corresponding calibration concentrations were transferred from the chromatograms to a computer spreadsheet. Regression equations were calculated based on peak areas and corresponding concentrations. Control charts were maintained for slope, y-intercept, and R^2 for PCP. A standard curve was rejected if the R2 was less than 0.993.

For preparation of the PCP standard calibration curve, a PCP stock standard solution was prepared at a concentration of 1000 mg/l by dissolving the appropriate amount of pure (99.5 percent or greater) solid PCP (Sigma) in methanol. The stock standard solution was stored at 4° C in an amber bottle to protect the solution from light. A new stock standard solution was prepared at least every four months. The PCP calibration standards (at a minimum of seven concentration levels) were prepared by dilution of the stock standard solution with acetonitrile. Concentration levels corresponded to the range of concentrations expected in samples. The calibration standards were stored at 4° C and were protected from light. New calibration standards were prepared weekly.

For preparation of the TBP standard calibration curve, a TBP stock solution was prepared at a concentration of 5000 mg/L by dissolving the appropriate amount of pure (99 percent or greater; Aldrich) TBP in acetonitrile. The stock solution was stored at -20° C in the dark until use. A new stock standard solution was prepared at least every four months. TBP calibration standards (at a minimum of 4 concentration levels) were prepared by dilution of stock standard solution with acetonitrile. Concentration levels corresponded to the range of concentrations expected in the samples. The calibration standards were stored at 4° C and were protected from light. New calibration standards were prepared weekly.

For each run, a solvent blank was injected, followed by the injection of 10 - 12 samples; the run was completed with the injection of another solvent blank. A typical injection volume was 1 uL. After each run, the GC glass injection sleeve was replaced with a clean sleeve. Before starting the next run, the sleeve in the injector port was heated to the maximum injection temperature allowable for one hour. The used glass sleeve was cleaned according to a procedure that utilized sulfuric acid and methanol as cleaning solutions, followed by immersion in a silonizing solution and methanol.

PCP and TBP in samples were identified by matching their respective retention times with retention times of PCP and TBP obtained using calibration standards. If the peak area exceeded the linear calibration range of the system for a sample, the extract was diluted or concentrated and re-analyzed. Using an EXCEL spreadsheet, the peak area of PCP or TBP in a sample was converted to concentration by using the slope and y-intercept of the corresponding calibration standard curve for the specific run of samples. The formula used was:

concentration (mg/L) = (peak area - y intercept)/slope

The concentration was converted to mg/kg (wet weight) by dividing the concentration in mg/L by the weight of the soil extracted and then multiplying by the dilution factor. The concentration was converted to dry weight concentration by dividing the wet weight concentration by the percent dry weight x 100.

Quality control samples analyzed included:

(1) analysis of duplicate extraction samples to check reproducibility of extraction procedure (every twentieth sample was extracted in duplicate);
(2) analysis of procedural blanks to determine if any contamination was associated with the extraction procedure (procedural blanks were run through the extraction procedure every 9-10 samples);
(3) analysis of TBP in every sample to determine recovery of TBP (TBP was added to every sample before extraction);
(4) analysis of samples spiked with PCP to determine recovery of PCP in the spiked samples (duplicate samples were spiked every 9-10 samples); and
(5) analysis of solvent blanks to determine if carryover of PCP was occurring during an analytical run.

A-3. Analysis of PAH compounds by GC/MS

An adaptation of U.S. EPA Method 8270 (U.S. Environmental Protection Agency,1982) was used to determine the concentration of PAH compounds in the soil extracts using gas chromatography/mass spectrometry (GC/MS). Analyses were conducted for sixteen specific PAH compounds, including (in order of retention time): 1) naphthalene; 2) acenaphthylene; 3) acenaphthene; 4) fluorene; 5) phenanthrene; 6) anthracene; 7) fluoranthene; 8) pyrene; 9) benzo(a)anthracene; 10) chrysene; 11) benzo(b)fluoranthene; 12) benzo(k)fluoranthene; 13) benzo(a)pyrene; 14) indeno(1,2,3-cd)pyrene; 15) dibenzo(a,h)anthracene; and 16) benzo(g,h,i)perylene. Prior to analysis by GC/MS, soil samples were extracted using sonication as the extraction technique.

The GC system was comprised of a Varian 3400 GC, with a Varian splitless 2 mm ID standard deactivated glass insert (catalog # 03-949437-00). The GC was operated in splitless mode. The GC column was an XTI-5 (30 meter by .25 mm ID) column, with 0.25 µm coating (catalog #12223) from RESTEK Corporation. The column was directly attached with a butt-connector to a 1 meter by .25 mm ID piece of deactivated capillary column that ran through the transfer line that connects the GC to the source of the mass spectrometer.

The injection port temperature was set at 285° C. The transfer line between the GC and mass spectrometer was set at 295° C. The carrier gas was ultra pure helium (99.99+ percent). Carrier gas flow was 1.0 milliliters per minute at 50° C. The temperature program for the GC oven was as follows: 50° C for 2 minutes; then the temperature was ramped at 10° C/min to a temperature of 300° C and held for 10 minutes. The total run time was 37 minutes.

The mass detector was a Finnigan MAT Ion Trap 700 Detector. The inlet to the mass spectrometer from the gas chromatograph was configured for direct injection. The ion trap was operated in multiple ion detection mode (MID), which results in an improved signal-to-noise ratio and more reproducible peaks for quantitation.

The data system consisted of an IBM AT computer with Finnigan MAT ITDS software version 3.1. The computer was used for direct data acquisition during a run.

Perfluorotributylamine (FC-43) was used as the standard for instrument calibration to achieve acceptable tuning performance. Table A-1 list the criteria for tuning. The instrument was auto tuned by using the Ion Trap Setup program in the ITDS system software. The mass spectrometer was routinely calibrated/auto tuned approximately every ten days. The instrument was also calibrated/auto tuned when daily calibration check standards (containing all sixteen PAH compounds) did not meet the performance check test. To evaluate the performance check of the daily standard, the percent difference was determined by calculating:

$$\% \text{ Difference} = \frac{(RFI - RFC) \times 100}{RFI}$$

where:

RFI = average response factor from initial calibration; and
RFC = response factor from current daily standard verification check standard.

If the percent difference was greater than 50 percent, corrective action was taken. If the corrective action did not solve the problem,the instrument was calibrated/auto tuned, and a new standard curve was run. The mass spectrometer was also calibrated/auto tuned when routine maintenance was required.

Table A-1. FC-43 key ions and ion abundance criteria.

Mass (m/z)	Ion Abundance Criteria
69	Base peak, 100% relative abundance
70	1% of mass 69
131	20 to 50% of mass 69
132	3% of mass 131
264	20 to 50% of mass 131
265	6% of mass 264
502	20 to 50% of mass 264
503	10% of mass 502

During sample analysis, a 1.0 µl portion of sample was drawn into a 10 µl syringe, with approximately a 2 µl volume of ambient air separating the sample from the syringe plunger. The sample was manually injected. At the time of injection, the data acquisition system and the GC were simultaneously triggered via a switch on top of the injection port.

The masses selected for quantitation were the molecular ion of each of the sixteen PAH compounds. Table A-2 lists the retention time and quantitation ion for each PAH compound.

Table A-2. Characteristic ions for PAH compounds.

Compound	Retention Time (Sec)	Primary Ion
Naphthalene	614	128
Acenaphthylene	844	152
Acenaphthene	872	154
Fluorene	956	166
Phenanthrene	1093	178
Anthracene	1101	178
Fluoranthene	1275	202
Pyrene	1307	202
Benzo(a)anthracene	1494	228
Chrysene	1499	228
Benzo(b)fluoranthene	1650	252
Benzo(k)fluoranthene	1652	252
Benzo(a)pyrene	1699	252
Indeno(1,2,3-cd)pyrene	1906	276
Dibenzo(a,h),anthracene	1912	278
Benzo(g,h,i)perylene	1963	276

The ten masses were scanned once every 1.000 seconds and each recorded scan was comprised of the average of two micro scans. The acquire time was 37 minutes. The filament delay at the start of the run was 400 seconds. The peak threshold was set to 1, and the mass defect was 1 millimass unit per atomic mass unit.

A set of five standards and a blank were prepared in methylene chloride. The standards were prepared by diluting a certified stock solution purchased from Supelco Incorporated (cat #4-8905). The stock solution contained all sixteen PAH compounds at 2000 µg/mL. Each standard contained the sixteen PAH compounds in the following concentrations: 50, 40, 20, 10, and 4 µg/mL. The standards were stored at 4° C in glass vials sealed with Teflon lids. The standards were replaced every 60 days. External standard curves were generated using the ITDS software and r2 values of greater than 0.988 were obtained for each compound. Samples were quantified in the semi-automatic external standard calibration mode of the quantitation software to insure proper peak identification.

The standard curves were produced by plotting the area (y-axis) versus the concentration in mg/L (x-axis). The concentration of a sample extract was calculated by entering the area of the extracted sample for each of the PAH compounds present into the linear regression line equation for that particular compound. Thus, the concentration of the soil extract was calculated with the quantitation software provided in the ITDS software.

The concentration values for each compound in the extract were manually entered into a Macintosh EXCEL spread sheet, where the final concentration of each compound was calculated using:

$$\text{PAH concentration in soil (mg/kg)} = \frac{COE \times VOE}{DWF \times SWW}$$

where:

COE = concentration of PAH in extract in mg per liter;
VOE = volume of extract in liters (0.01 for all samples);
DWF = dry weight fraction; and
SWW = sample wet weight in kg.

The Method Quantitation Limit (MQL) was determined for each compound by making ten replicate injections of sample 2592. Sample 2592 was chosen for the determination of MQL since all sixteen PAH compounds in the sample were detectable at less than 4 mg/L. The lowest standard in the external calibration curve for each PAH compound was 4 mg per liter. The MQL was calculated as five times the standard deviation of the ten replicates. When the concentration in soil for a particular PAH compound was below the MQL, the value was reported as "less than the MQL value." Any value less than the MQL value was considered zero when tabulating the total carcinogenic PAH concentration.

Anthracene-d_{10} was used as a deuterated check standard. A stock solution of anthracene was prepared from neat compound in methylene chloride. The concentration of the stock solution was 2840 mg/L. A 14 µl portion of the stock solution was spiked into 986 µl of sample extract. A 40 mg/L standard solution was also prepared by spiking 14 µl of the stock solution into 986 µl of methylene chloride. Three different samples were spiked. The concentration of anthracene-d10 was 40 mg/L in the spiked sample and the retention time of the deuterated compound (molecular weight 188) was very close to that of anthracene (molecular weight 178). The results for the deuterated spikes are shown in Table A-3. The concentration of anthracene-d10 found in the spiked samples was calculated by:

$$\text{Concentration of anthracene-d10 in sample} = \frac{EA \times 40\ mg/L}{SSA}$$

where:

EA = extract area quantified for molecular mass 188; and
SSA = standard solution area for molecular mass 188 (318355 units)

Table A-3. Results of anthracene-d10 spiked in soil extracts at 40 mg/L.

Core No. & Depth	Date	Retention Time: Anthracene (sec)	Retention Time: Anthracene-d10 (sec)	Amount Spiked (mg/L)	Area Measured: Mass 188	Concentration: Anthracene-d10 (mg/L)
15 B	9/2/92	1080	1078	40.00	379765	47.71
16 C	9/2/92	1080	1083	40.00	291059	36.57
31 D	9/19/91	1080	1082	40.00	413398	52.31
Standard	--	----	1086	40.00	318355	40.00

A stock solution was prepared containing four PAH compounds: naphthalene, phenanthrene, pyrene and benzo(a)pyrene. The stock solution was prepared with neat PAH compounds dissolved in methylene chloride. The concentration of the spiking solution was 100 mg/L for each of the four compounds. Six samples were individually spiked by adding 1.000 mL of the stock solution to 1.000 mL of sample extract. The expected concentration of each of the four PAH compounds is the concentration previously determined for the extract divided by 2 plus 50 mg/L.

A-4. Detoxification evaluation using the Microtox™ assay

The Microtox™ assay utilizes the light output of a marine bacterium, Photobacterium phosphorium, to evaluate relative toxicity of an aqueous test sample. This photoluminescent organism is subjected to several dilutions of a test sample. The light output of the organism is monitored under defined conditions of exposure time (t) and test temperature (T). The degree of light loss indicates the degree of toxicity. A dose-response curve is generated and used to determine the effective concentration (EC50) of the test sample that is required to cause a 50 percent reduction in light output after 5 min.

Aqueous samples to utilize in the testing procedure were obtained by extracting approximately 25 g of each soil sample with 100 mL of distilled, deionized water (DDW) in glass jars with screw-cap lids. The samples were extracted for approximately 24 hours in a rotating box at 30 rpm. Approximately 50 mL of supernatant from each sample was transferred to separate Nalgene centrifuge tubes. Suspended solids were then removed from the extracts by centrifugation for 20 minutes at 5000 rpm. The osmotic pressure of the extracts was adjusted using 2 percent sodium chloride, as required for the Microtox™ assay. Dilutions of 6.25, 12.5, 25.0, and 50.0 percent were prepared for each aqueous extract. The marine bacterium, Photobacterium phosphorium, was then challenged at each sample concentration, and the light output was recorded at time(t) = 0 and (t) = 5 minutes. A positive reagent control (blank) was tested concurrently with each test sample. This control blank consisted of DDW adjusted to 2 percent NaCl and 10 µl of the Microtox™ reagent (Photobacterium phosphorium). Light loss for the control blank and the test samples were compared with the light loss caused by a known toxic standard (sodium pentachlorophenate at 10 mg/L). One toxic control standard was run for every ten samples.

EC50 was determined using the following calculations:

Blank ratio:

$$R(t) = \frac{L(t)b}{L(0)b}$$

Normalized light loss (gamma):

$$\text{gamma}(t,T) = \frac{\text{Light Lost}}{\text{Light Remaining}} = \frac{R(t)L(0) - L(t)}{L(t)}$$

$$\text{gamma}(t,T) = \frac{R(t)L(0)}{L(t)} \quad 1$$

where:

L(0) = initial light reading (b=blank);
L(t) = final light reading at time (t);
R(t) = mean blank ratio for time (t); and
gamma (t,T) = gamma effect for exposure time (t) and test temperature T (15° C)

Plot ln(gamma) vs ln(concentration):

EC50 = concentration where gamma =1
EC50 concentration = e^intercept since (ln[1]=0)

If the value of the EC50 was found to be greater than 100 or no dose-response (NDR) was observed, then the sample was considered non-toxic (NT). An NDR indicates that with increasing sample concentration, no significant light loss was observed.

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Champion International Superfund Site, Libby, Montana: Bioremediation Field Performance Evaluation of the Prepared Bed Land Treatment System Volume II - FIGURES AND TABLES

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Initial naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth C samples collected 5/6&8/91

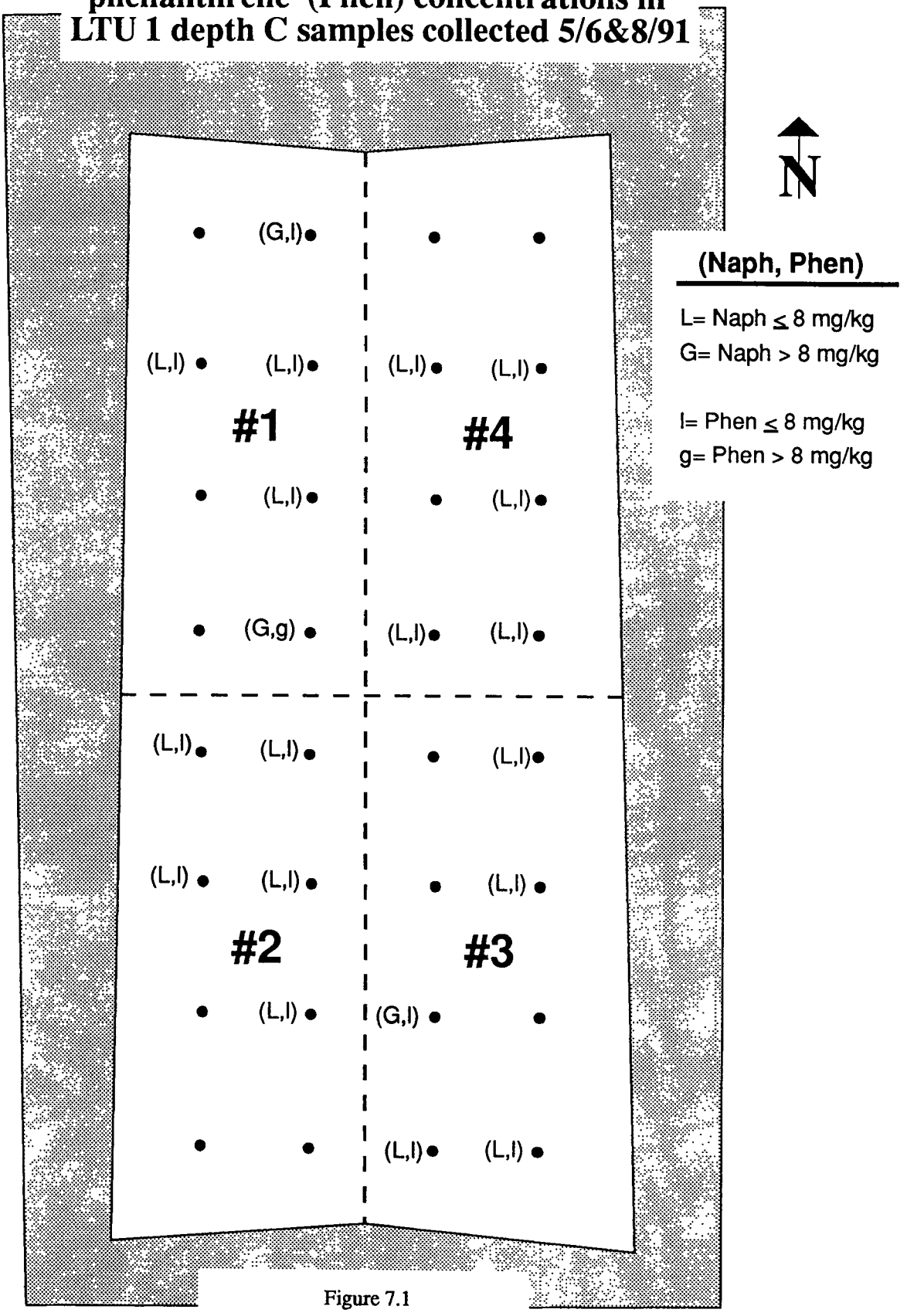

Figure 7.1

Initial naphthalene (Naph) and phenanthrene (Phen) concentrations in

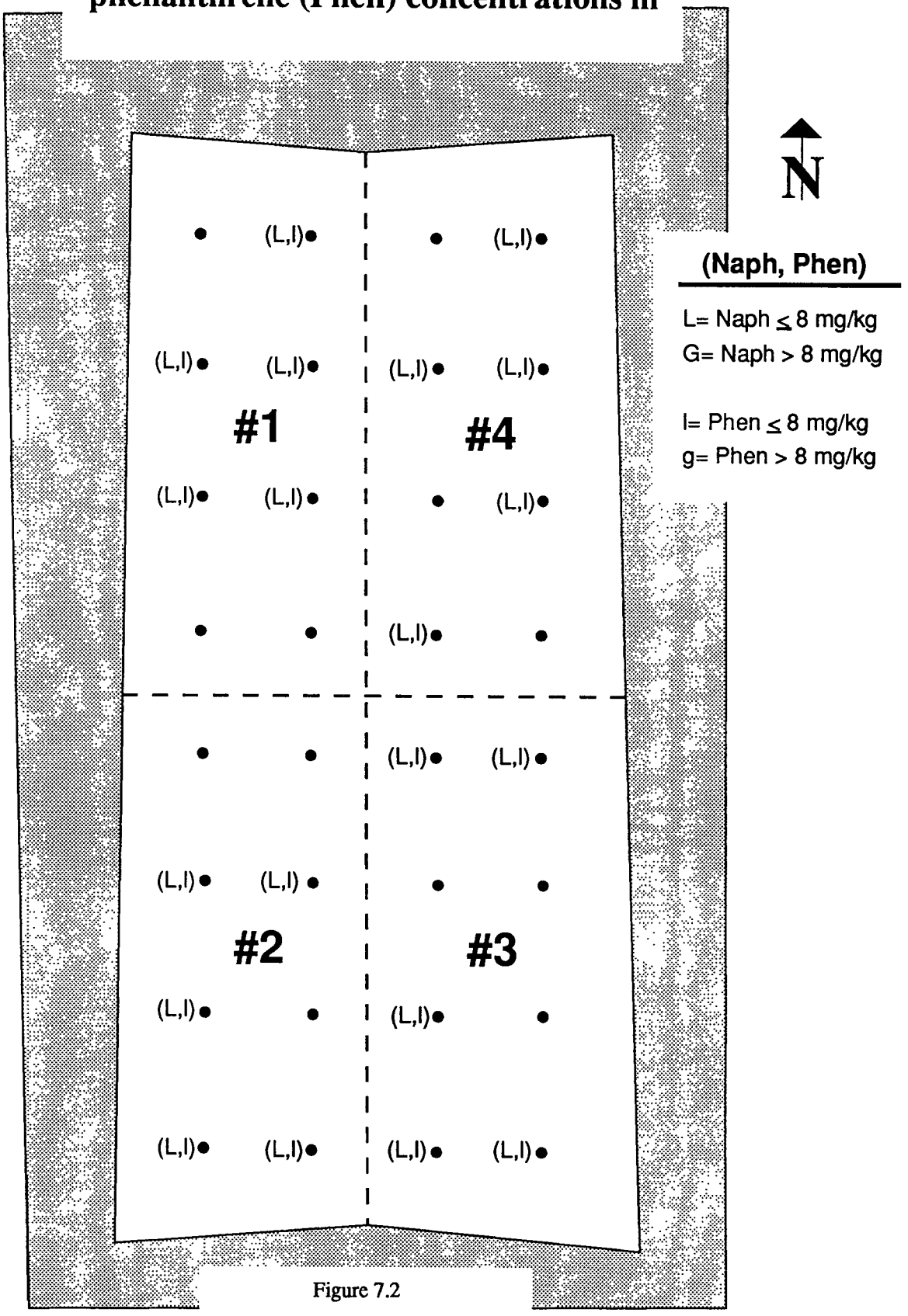

Figure 7.2

Initial naphthalene (Naph) and phenanthrene (Phen) concentrations in

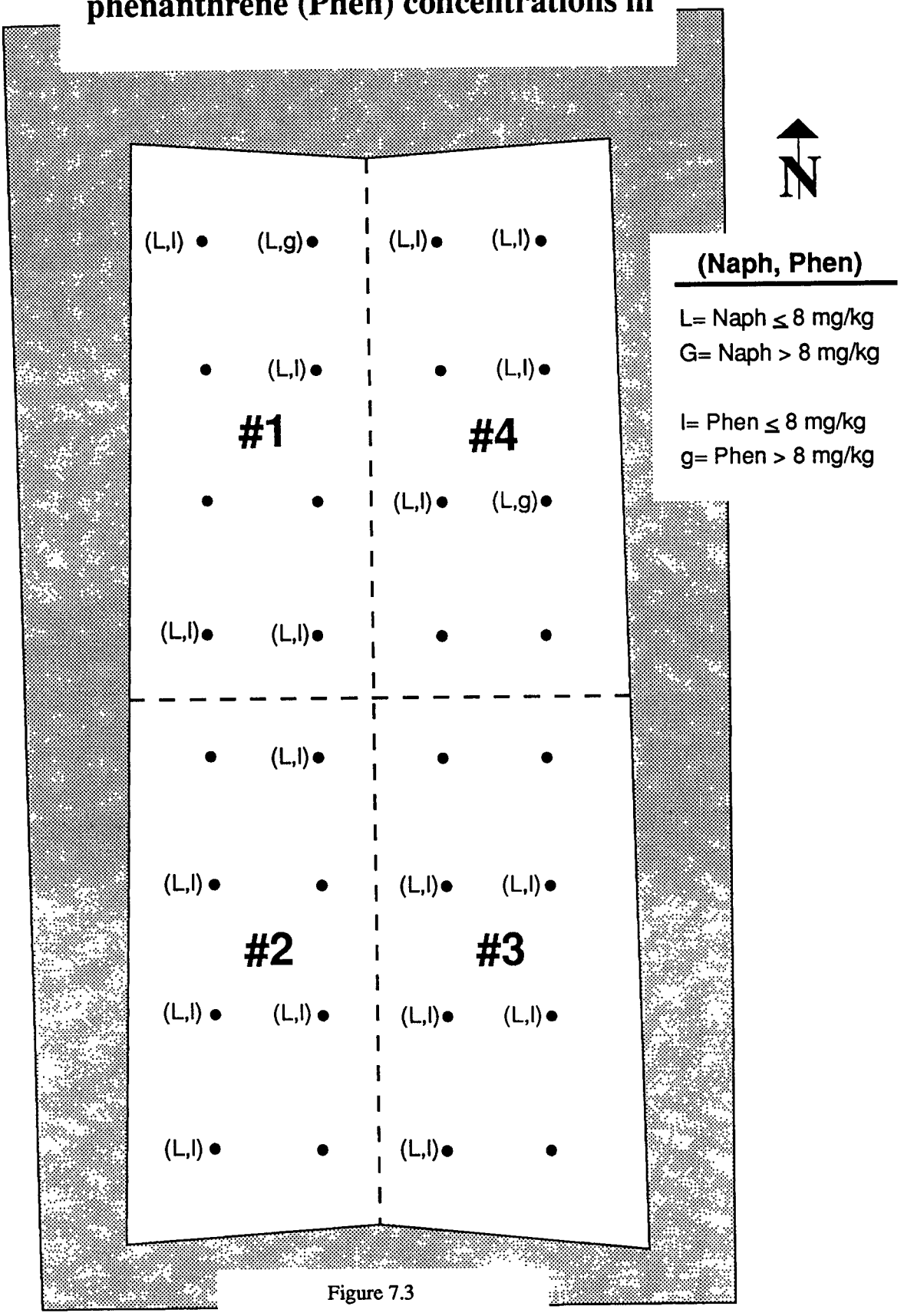

Figure 7.3

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth A

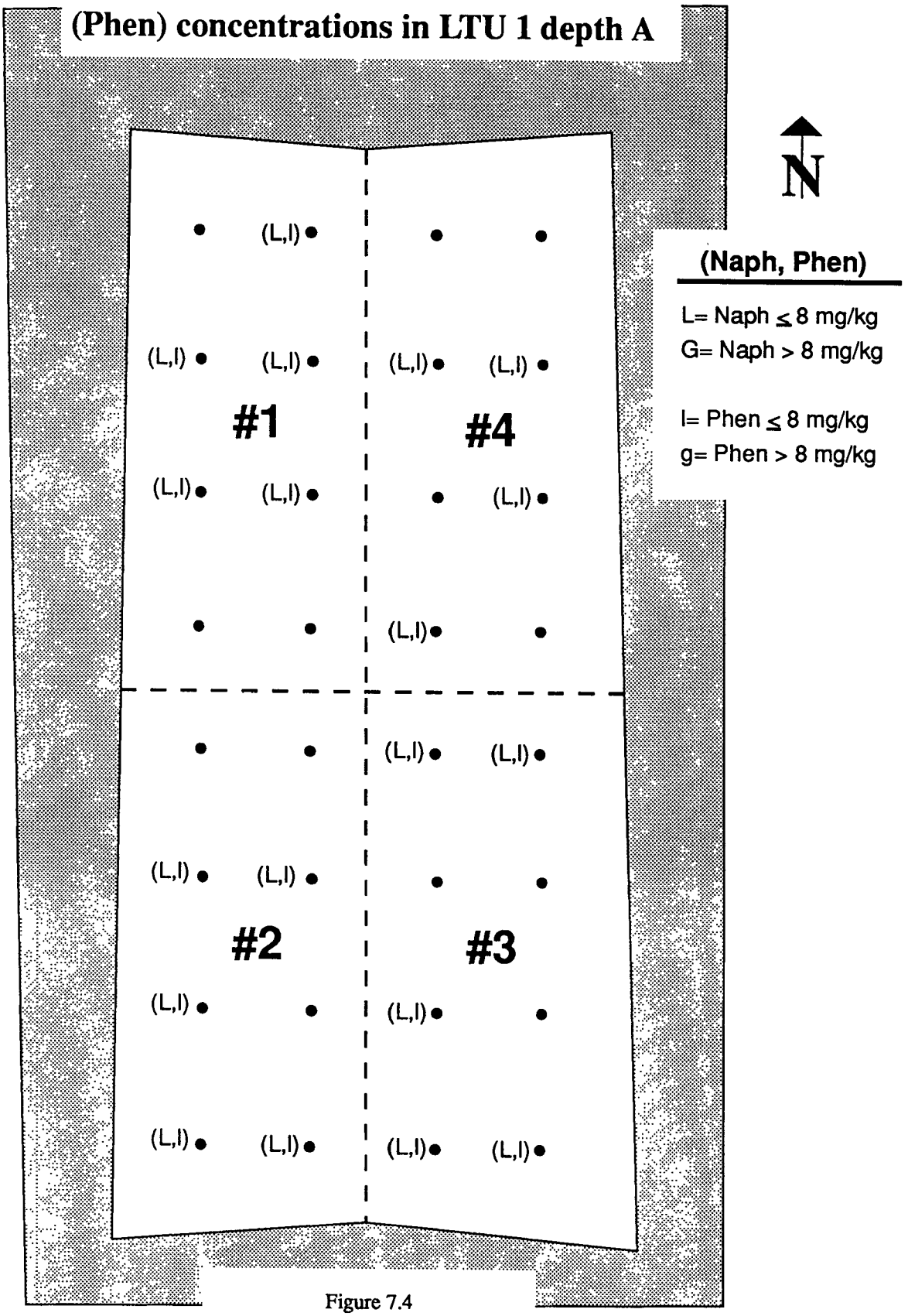

Figure 7.4

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth B

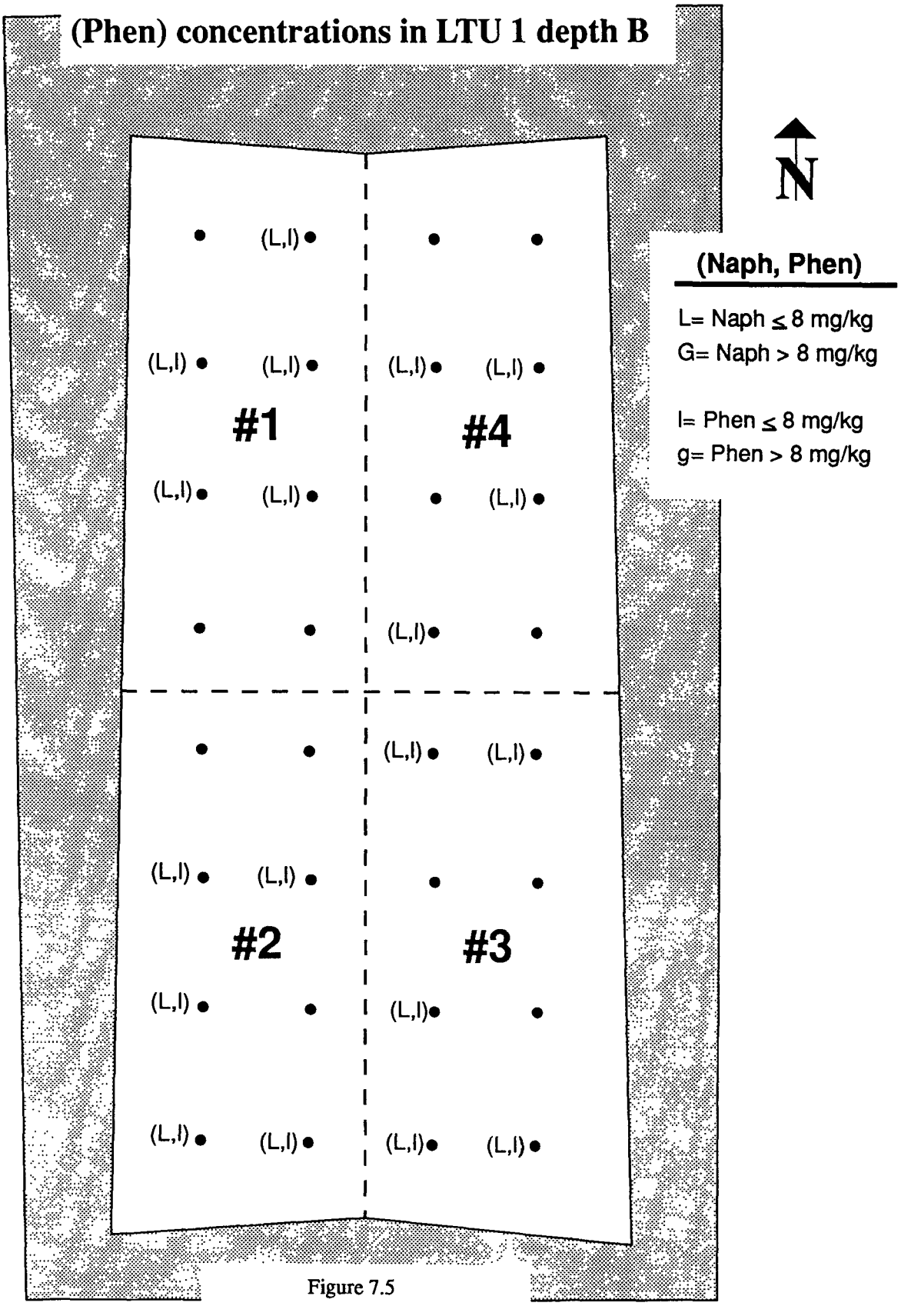

Figure 7.5

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth C

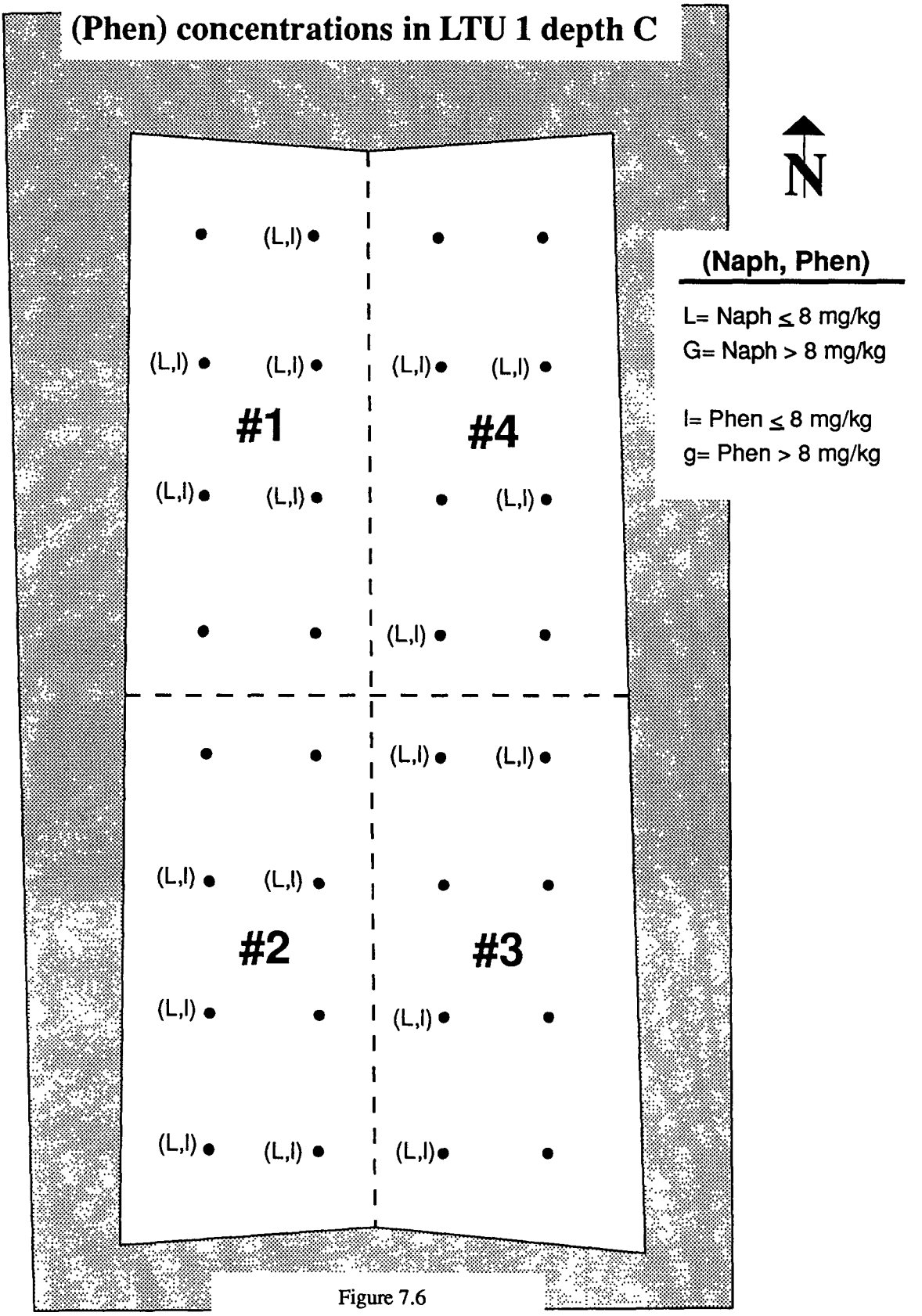

Figure 7.6

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth D

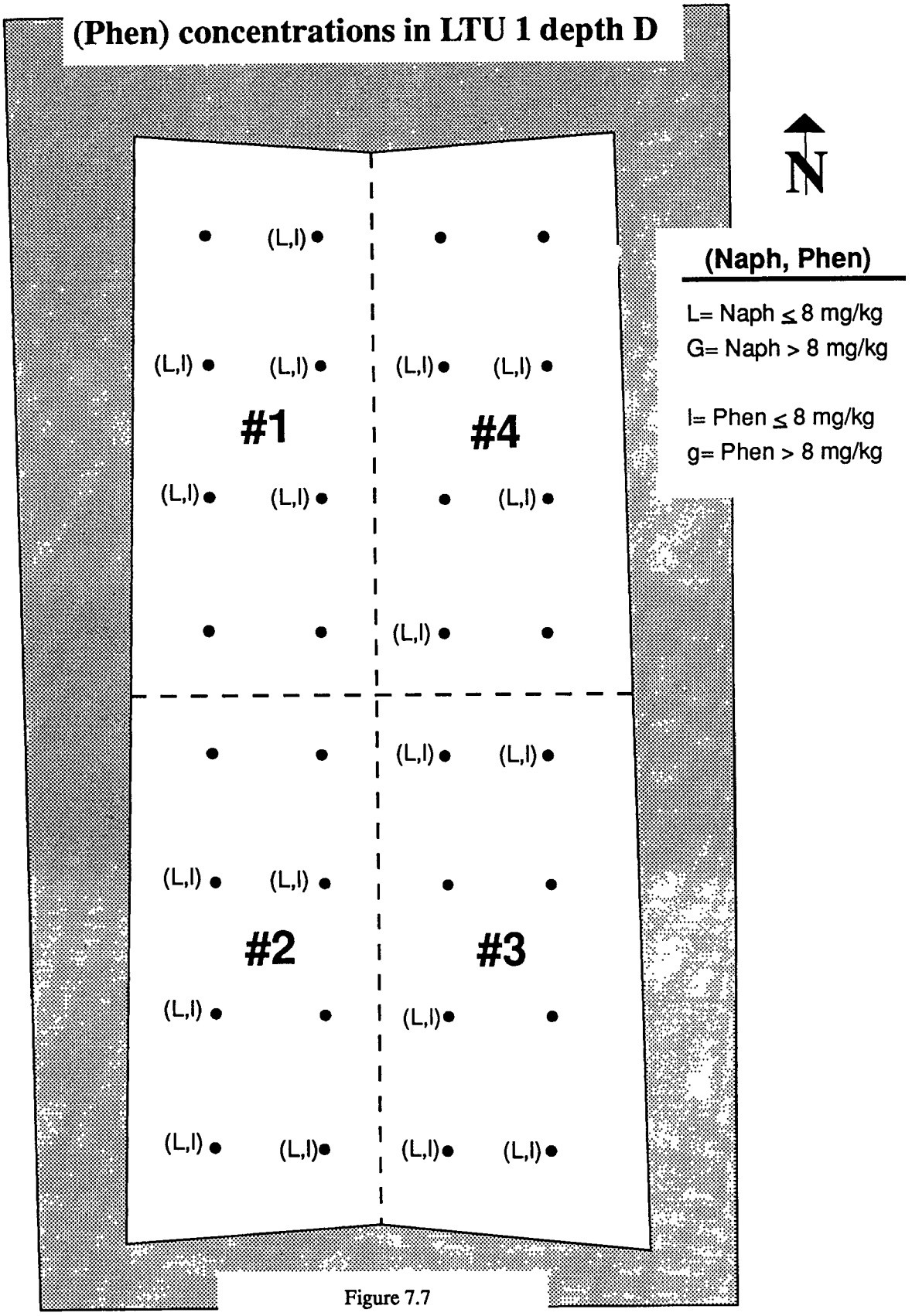

Figure 7.7

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth E

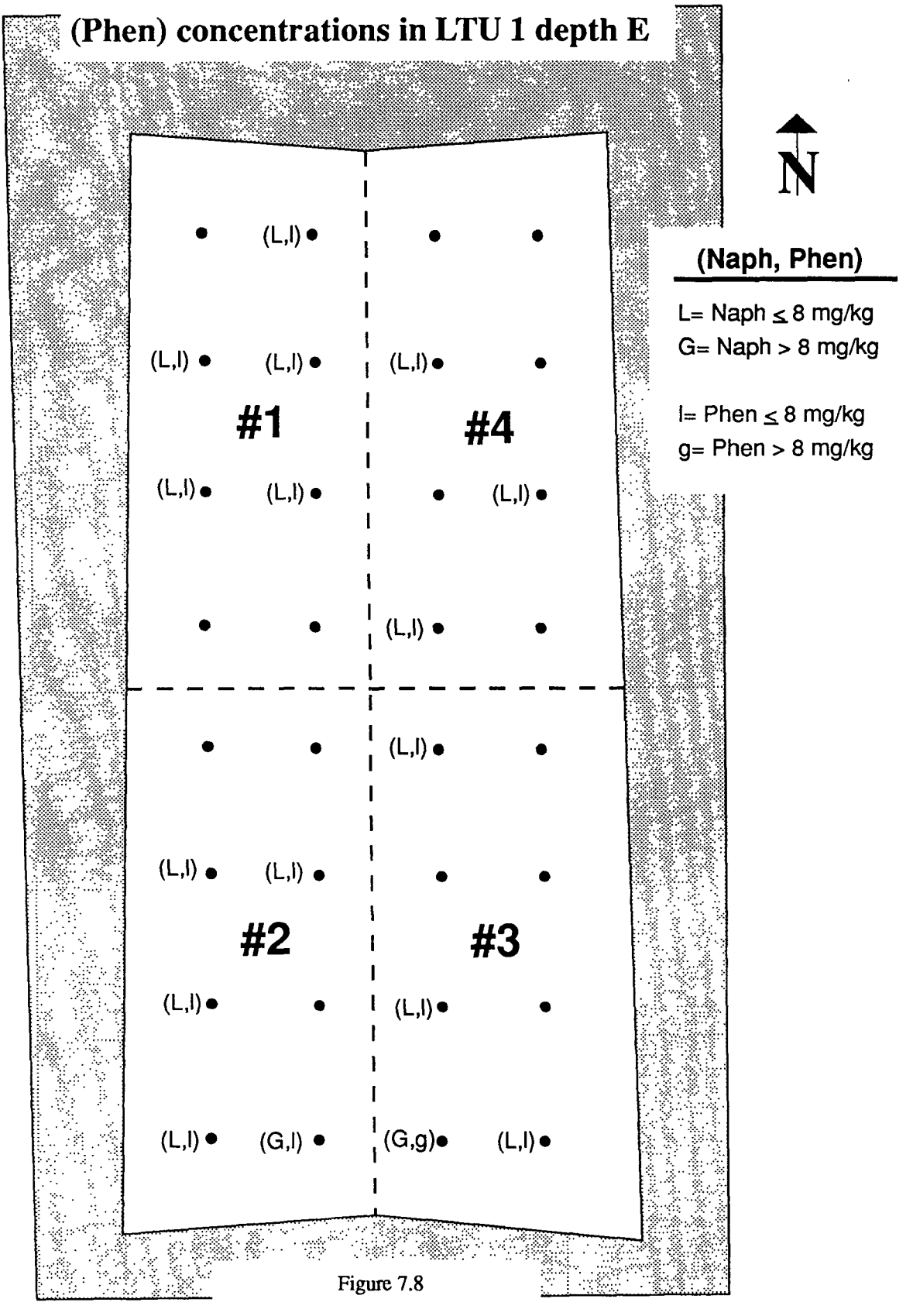

Figure 7.8

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 2 depth A

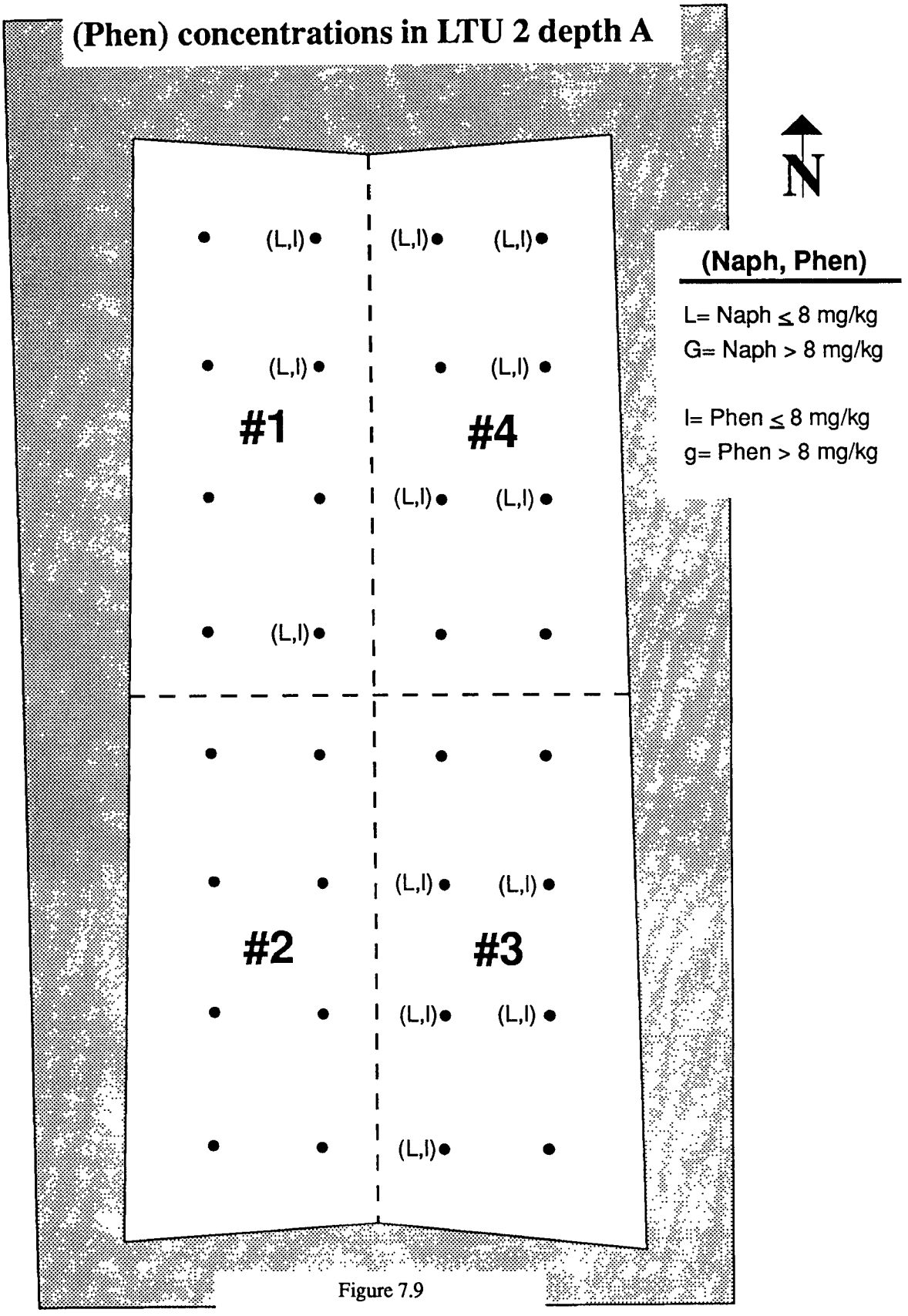

Figure 7.9

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 2 depth B

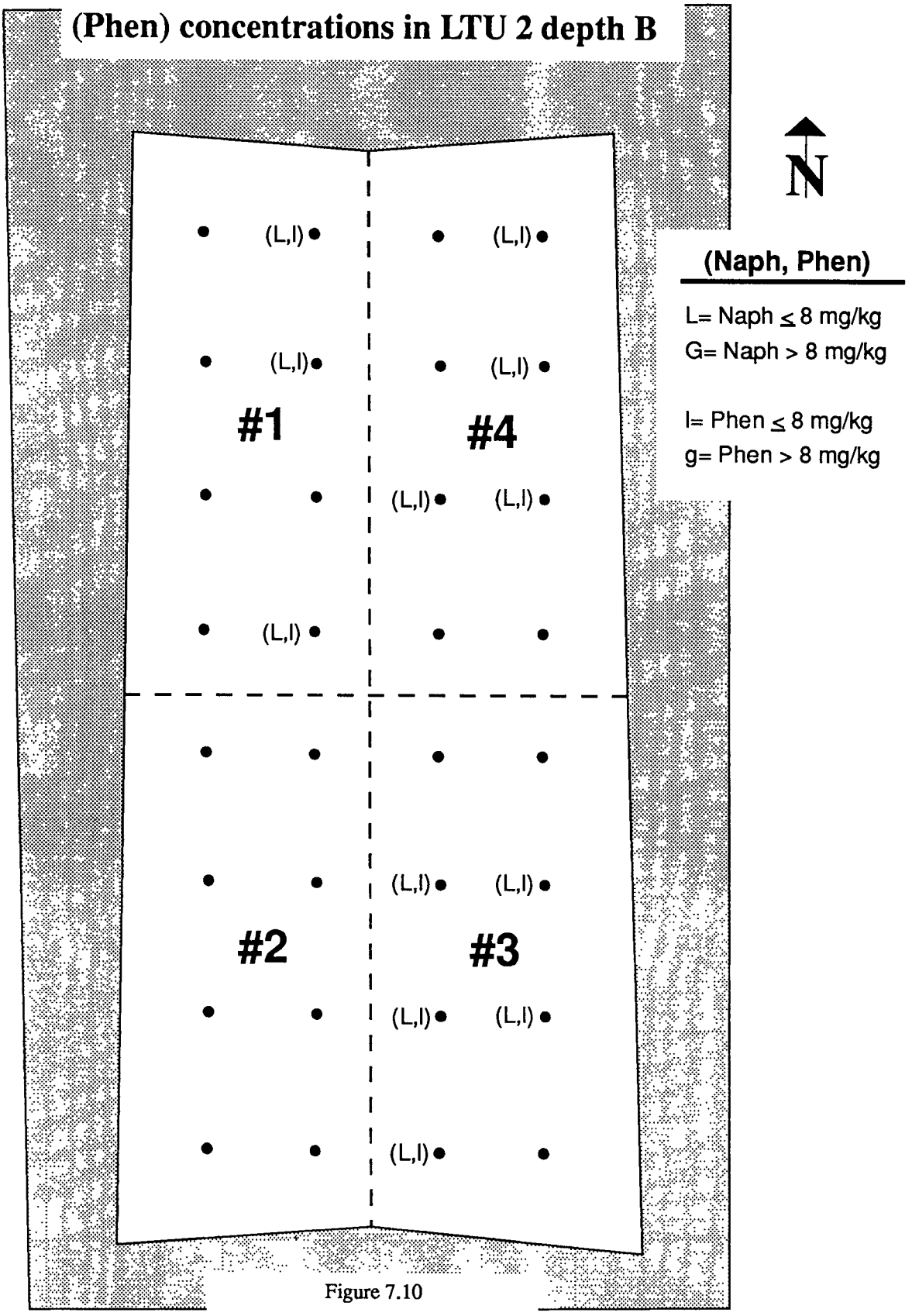

Figure 7.10

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth A

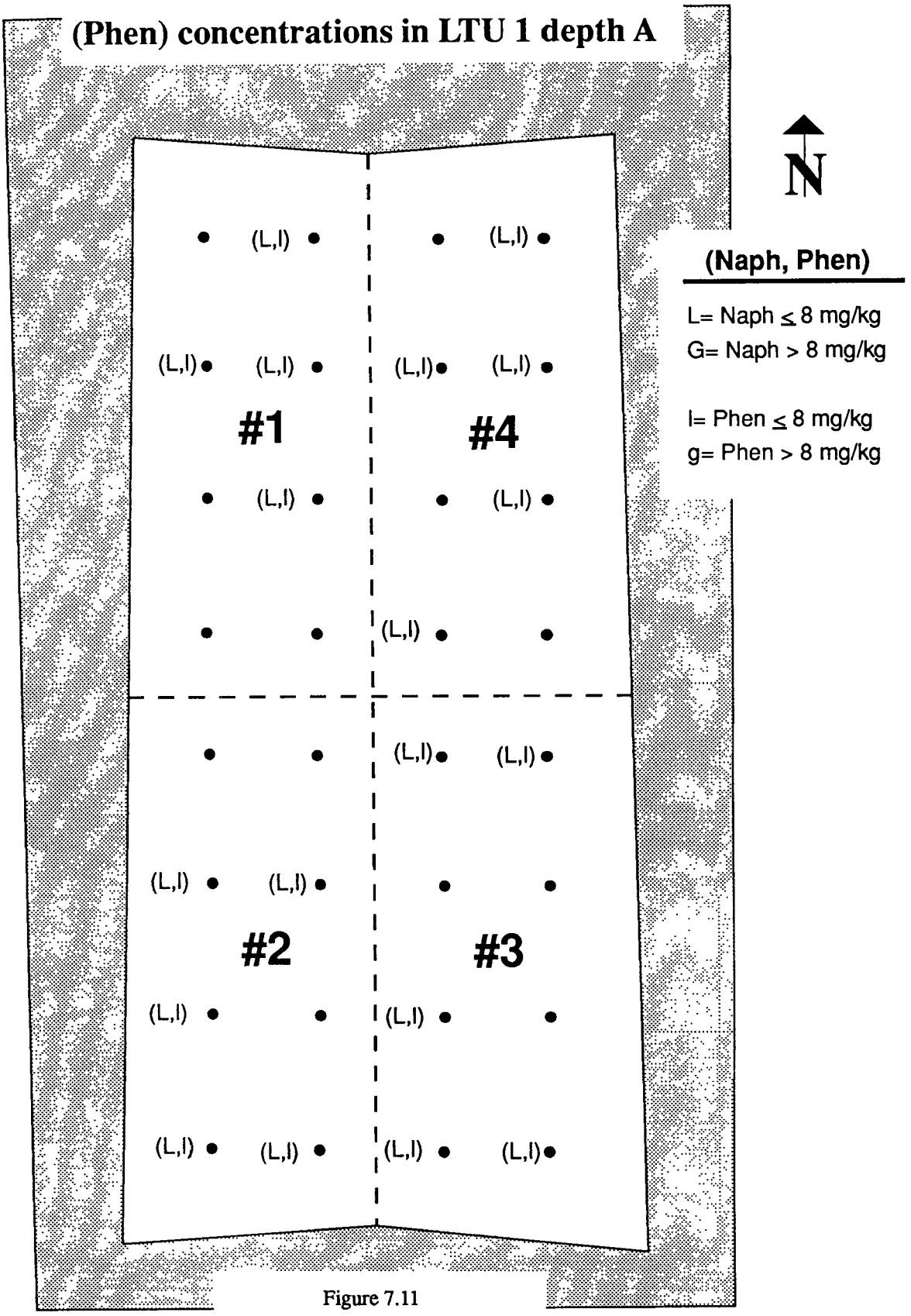

Figure 7.11

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth B

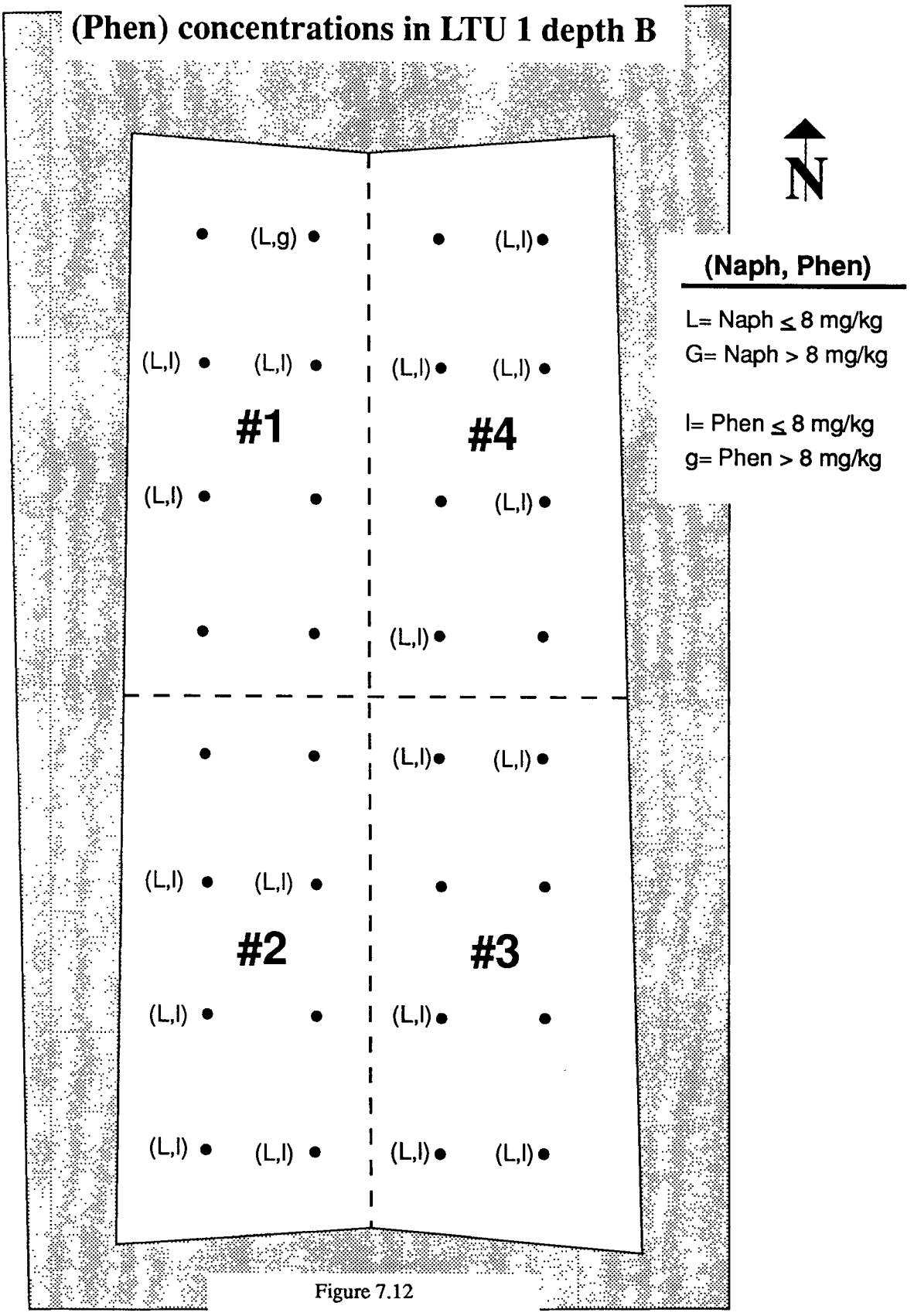

Figure 7.12

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth C

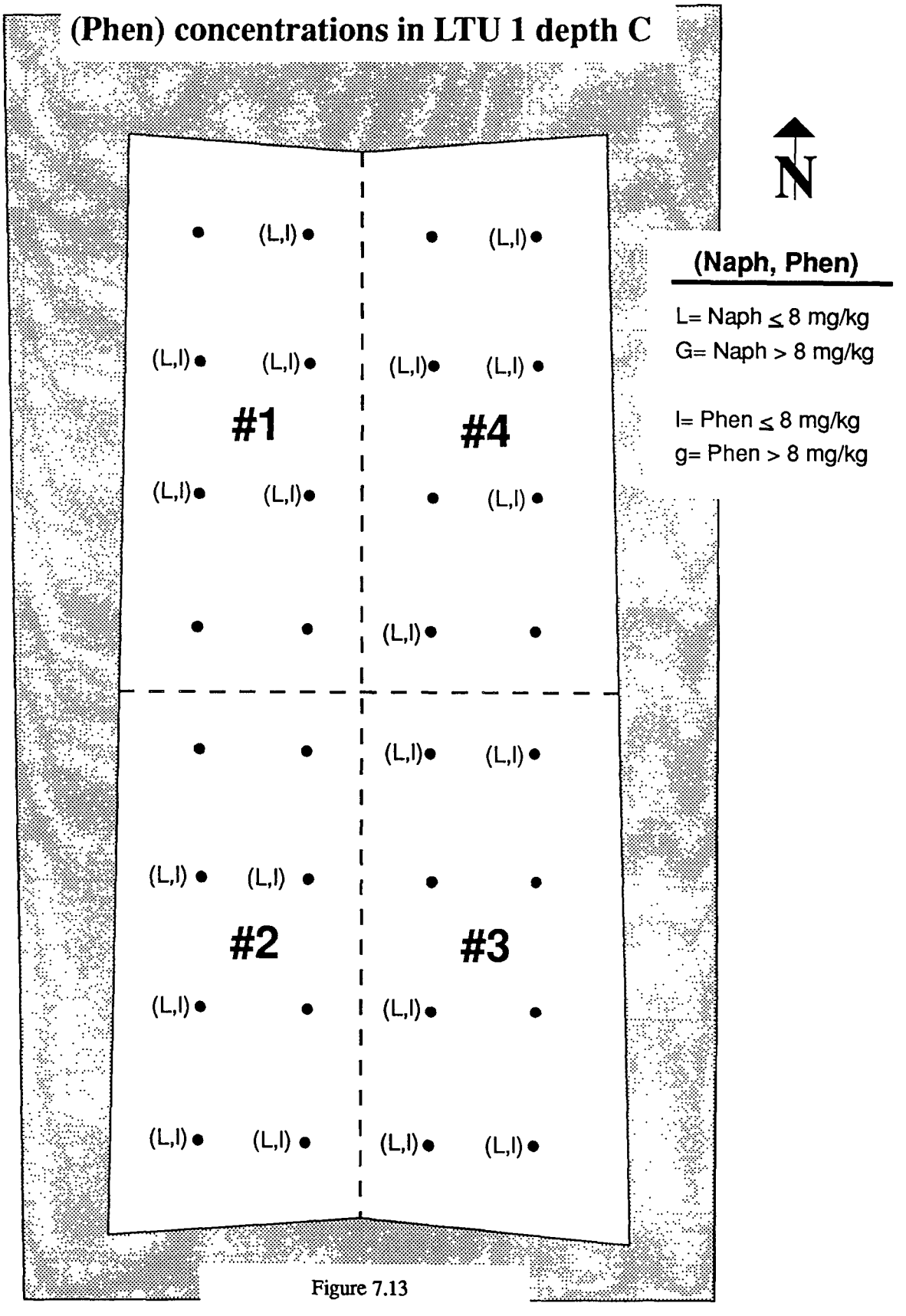

Figure 7.13

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth D

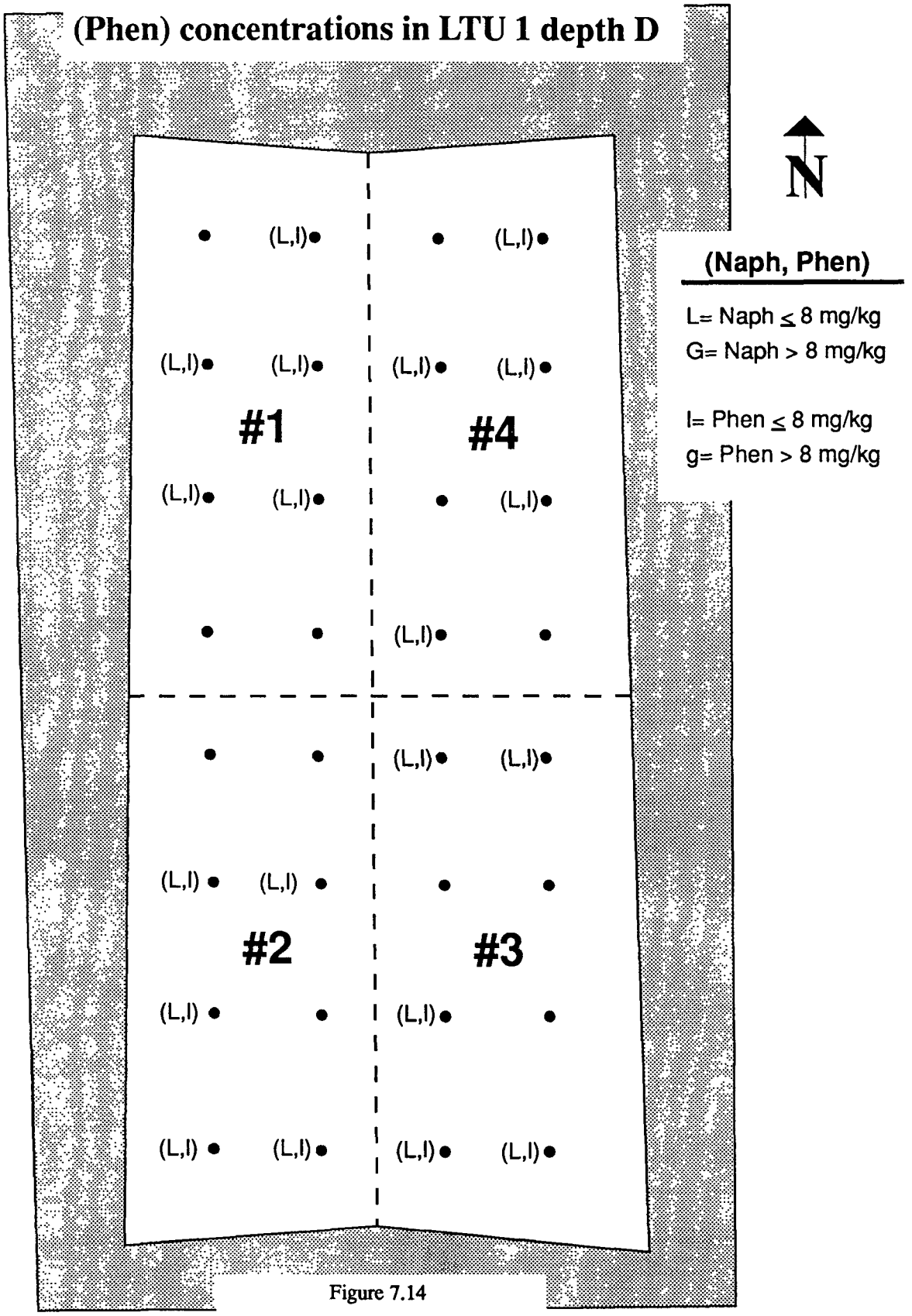

Figure 7.14

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 2 depth A

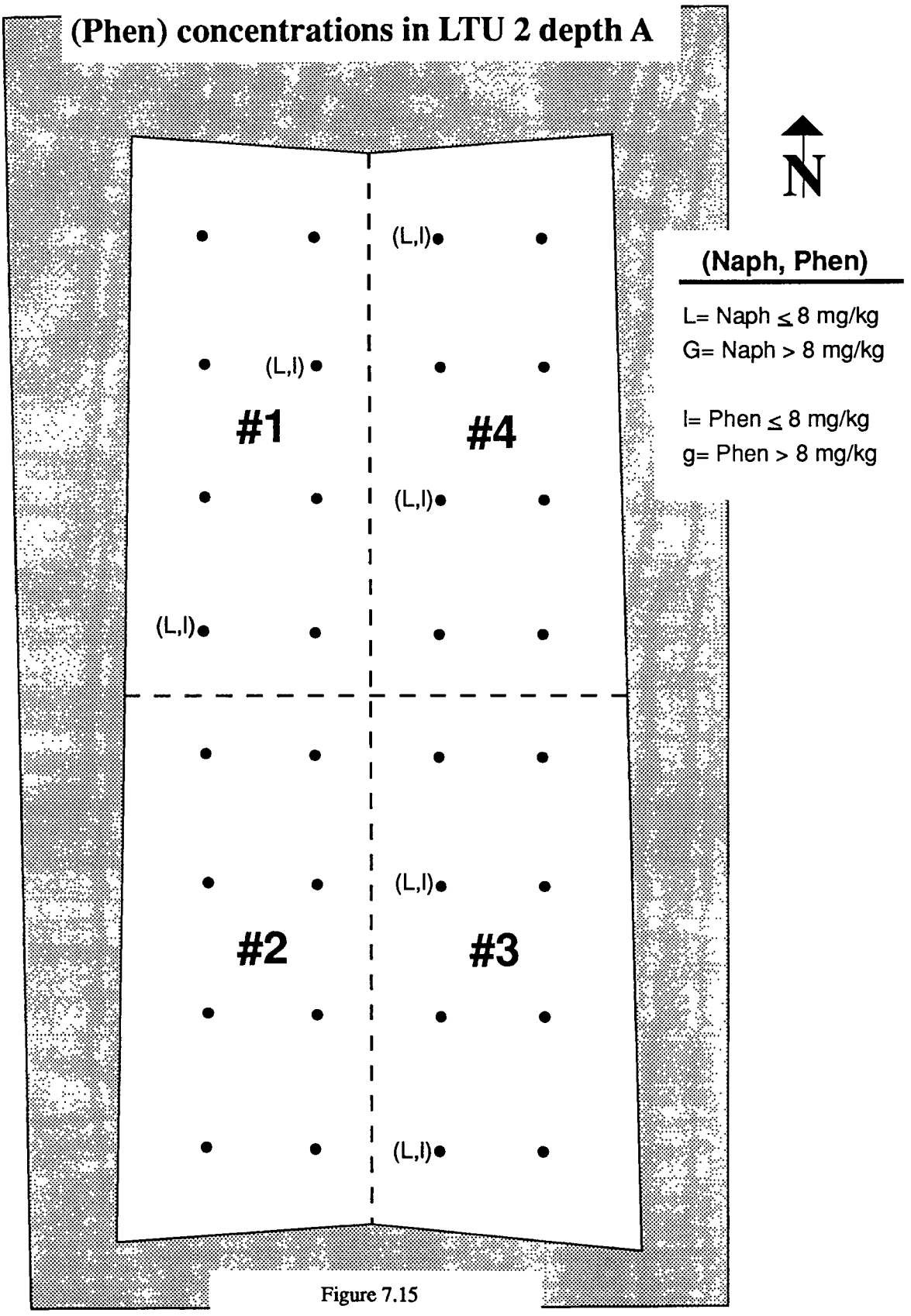

Figure 7.15

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth A

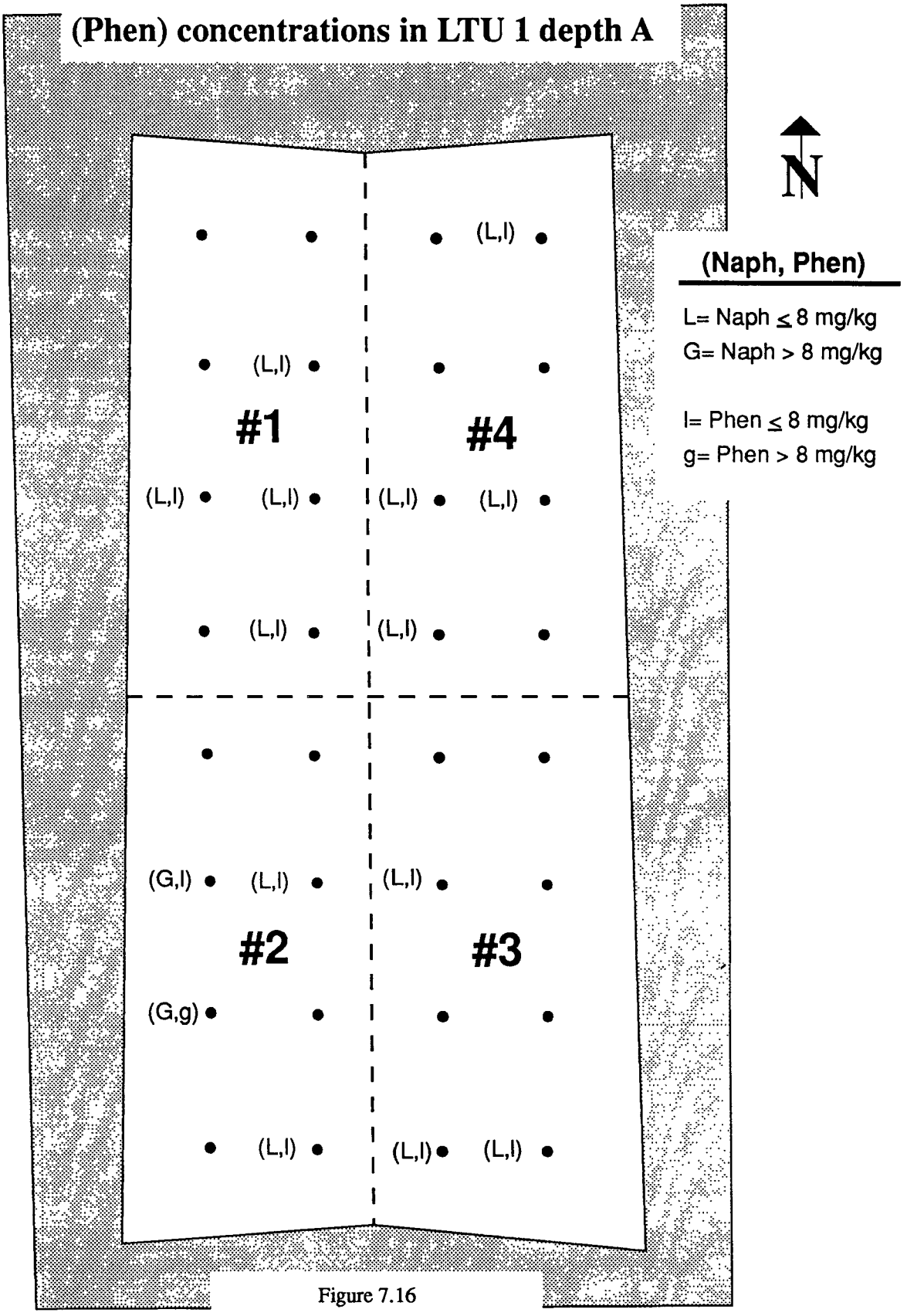

Figure 7.16

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth B

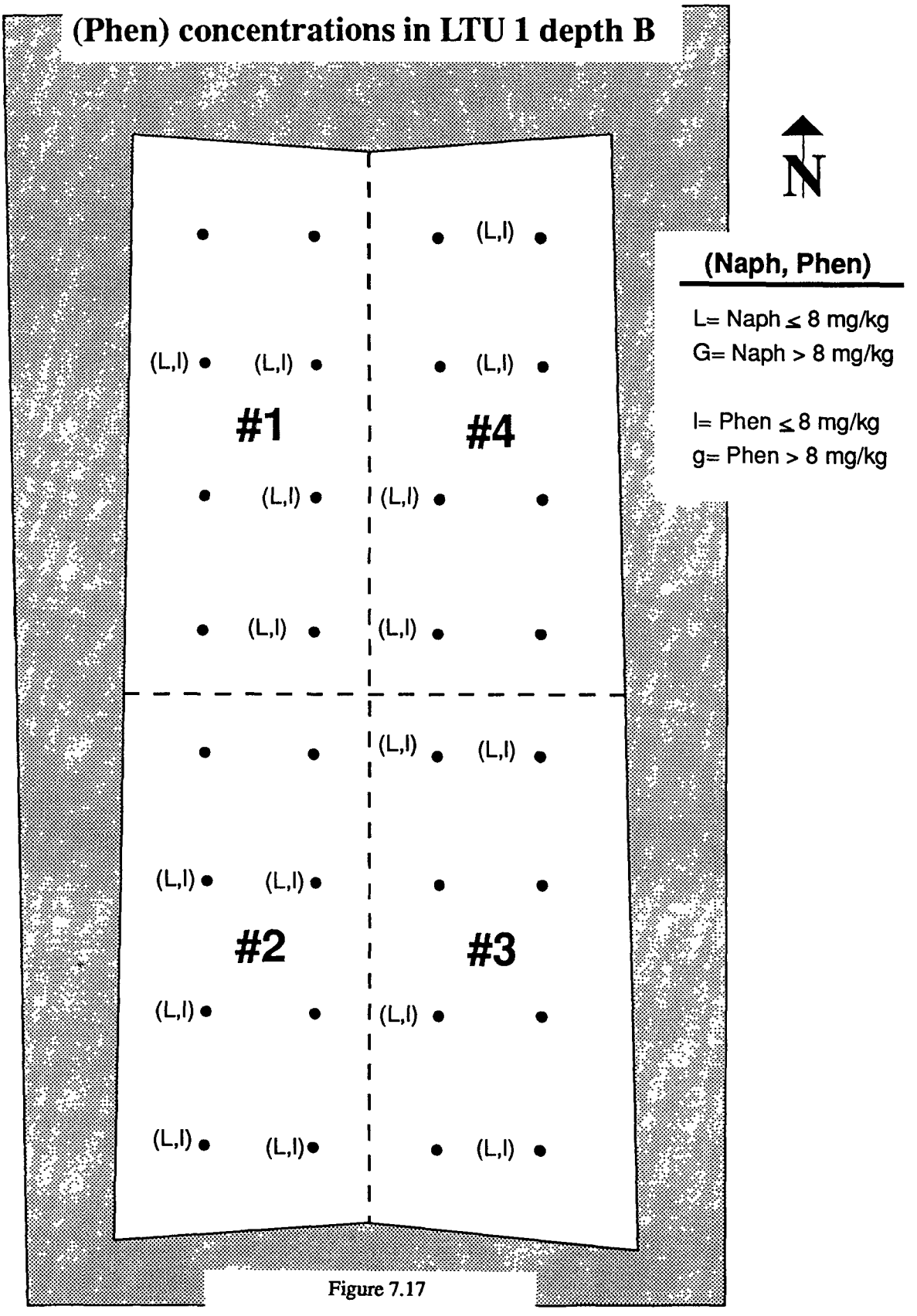

Figure 7.17

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth C

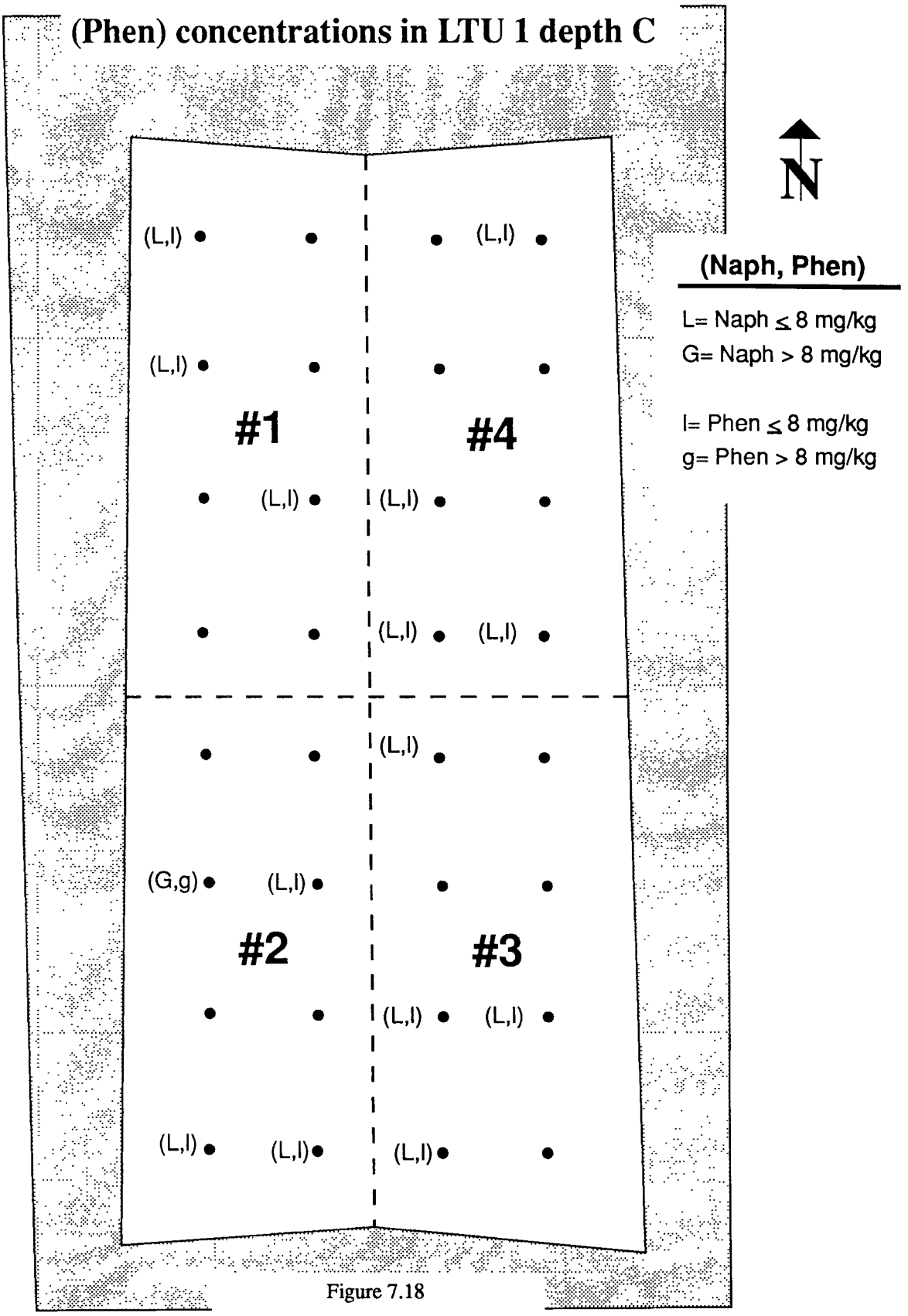

Figure 7.18

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth A

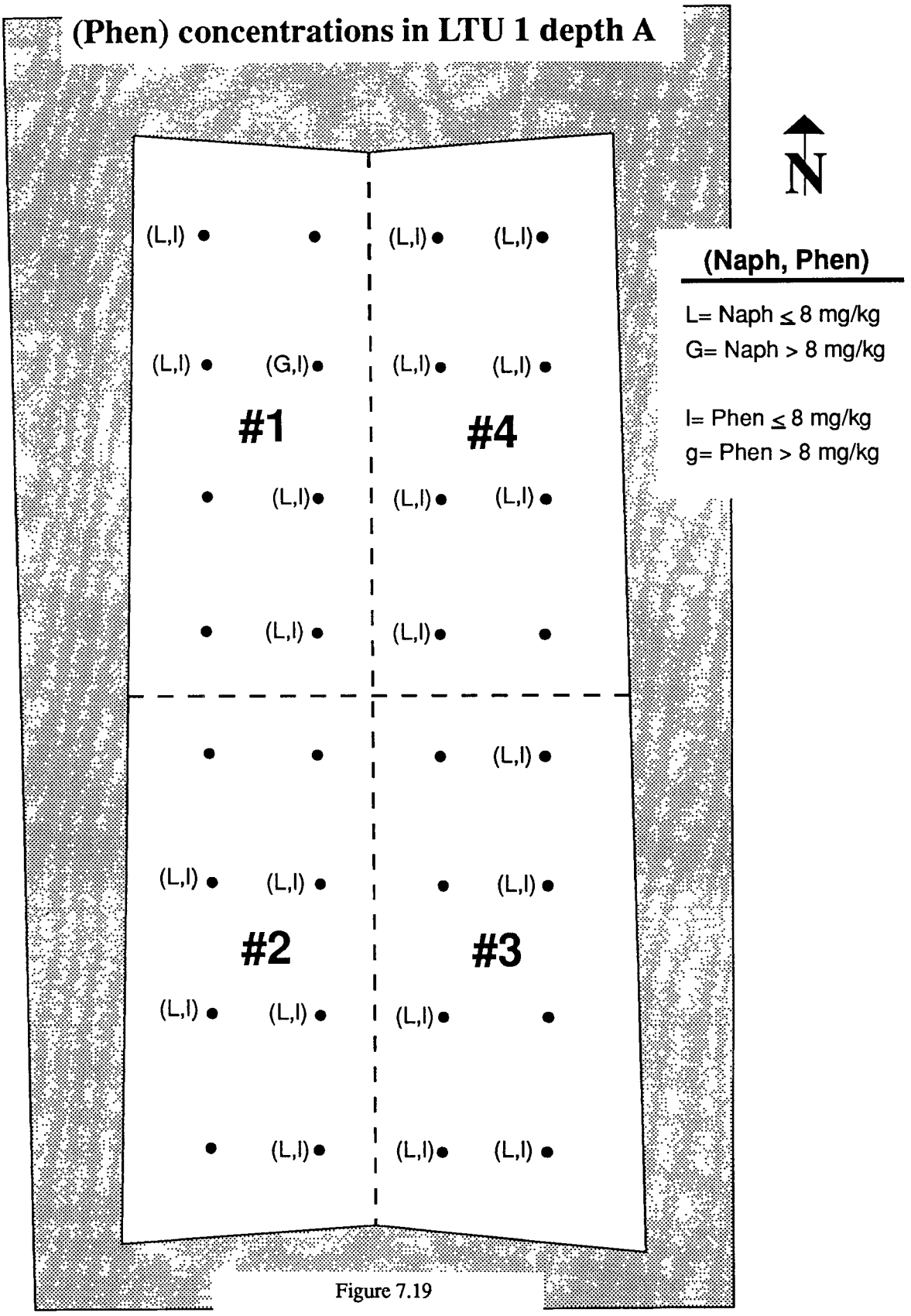

Figure 7.19

Naphthalene (Naph) and phenanthrene (Phen) concentrations in LTU 1 depth B

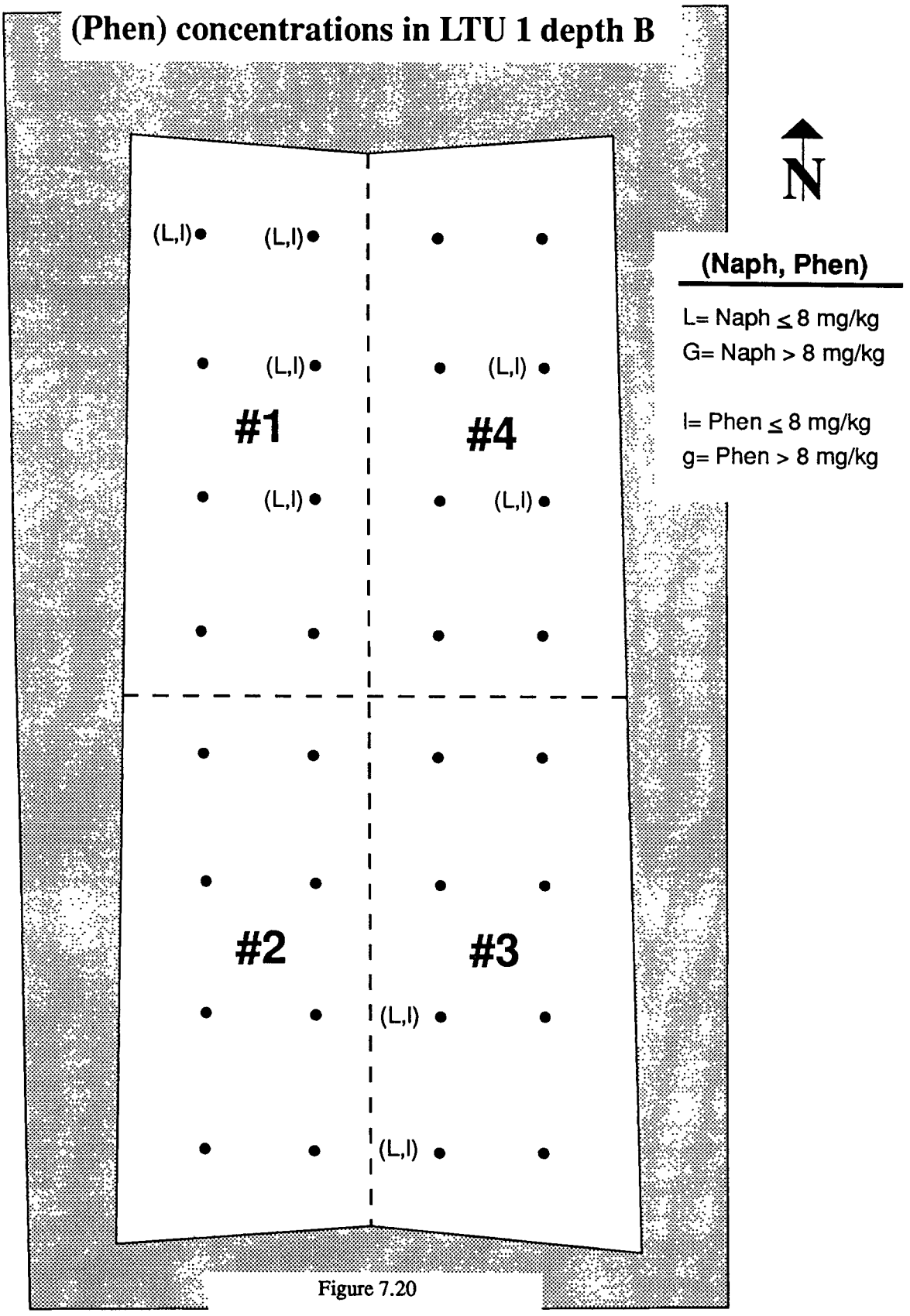

Figure 7.20

Initial total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1

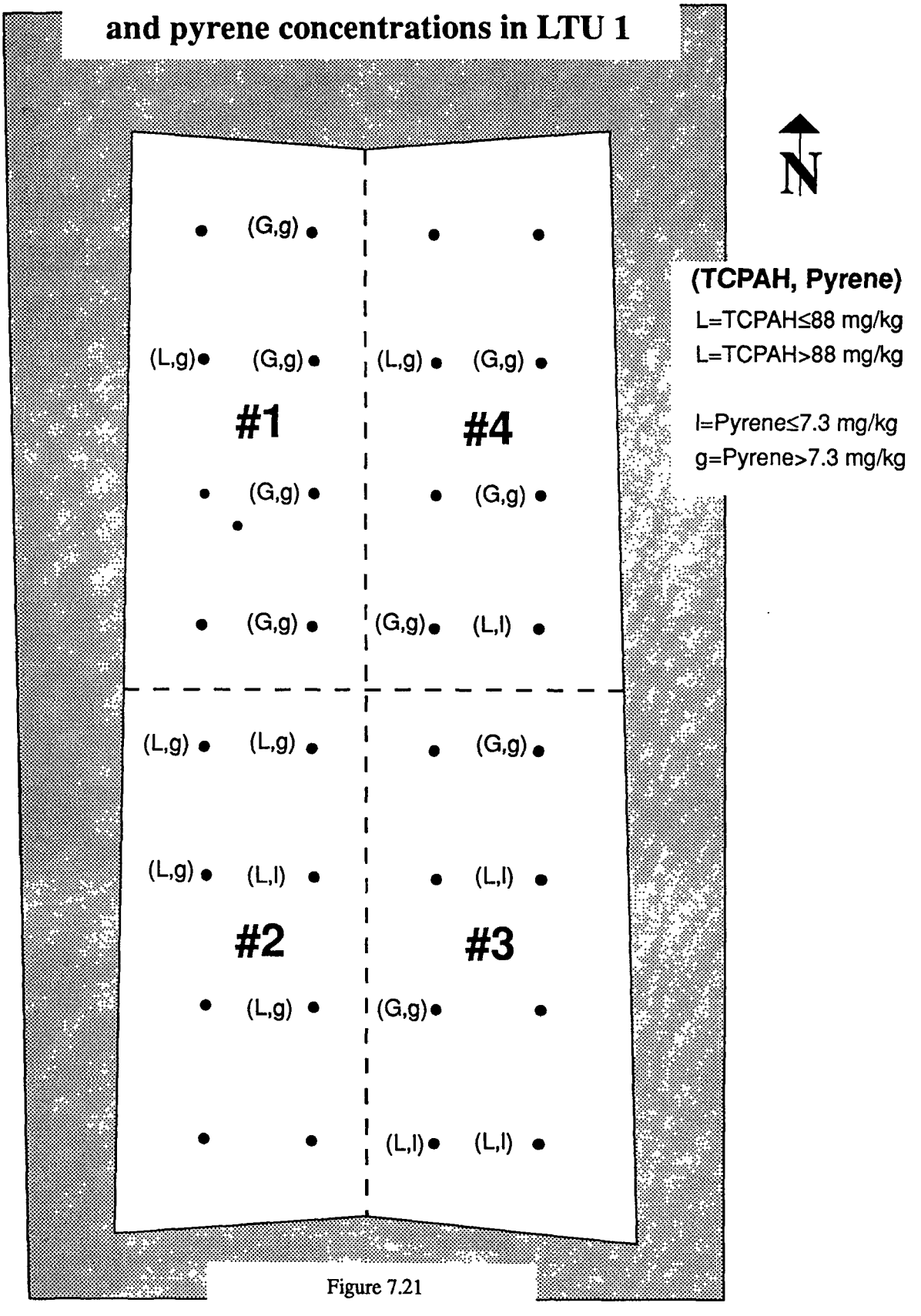

Figure 7.21

Initial total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1

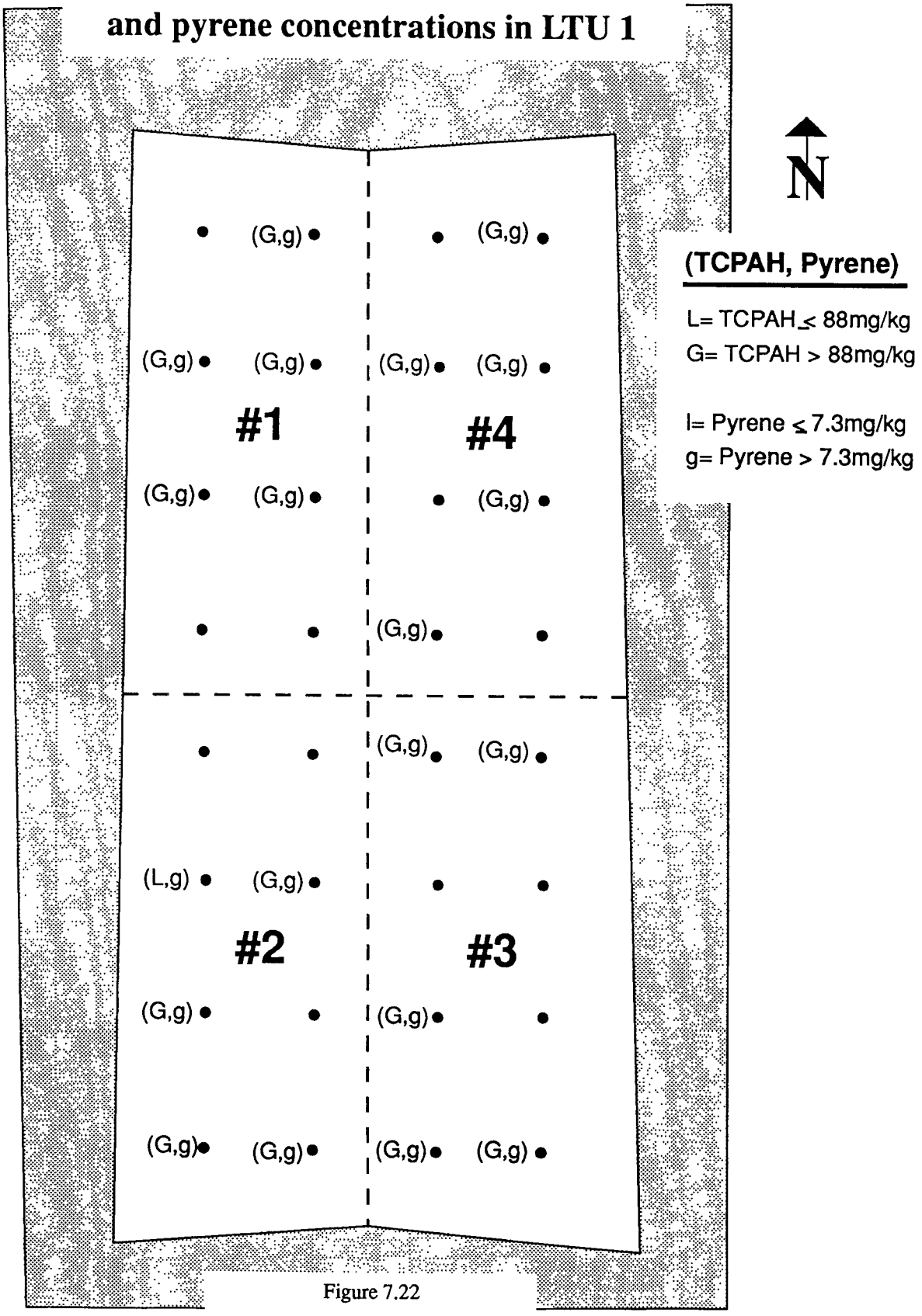

Figure 7.22

Initial total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 2

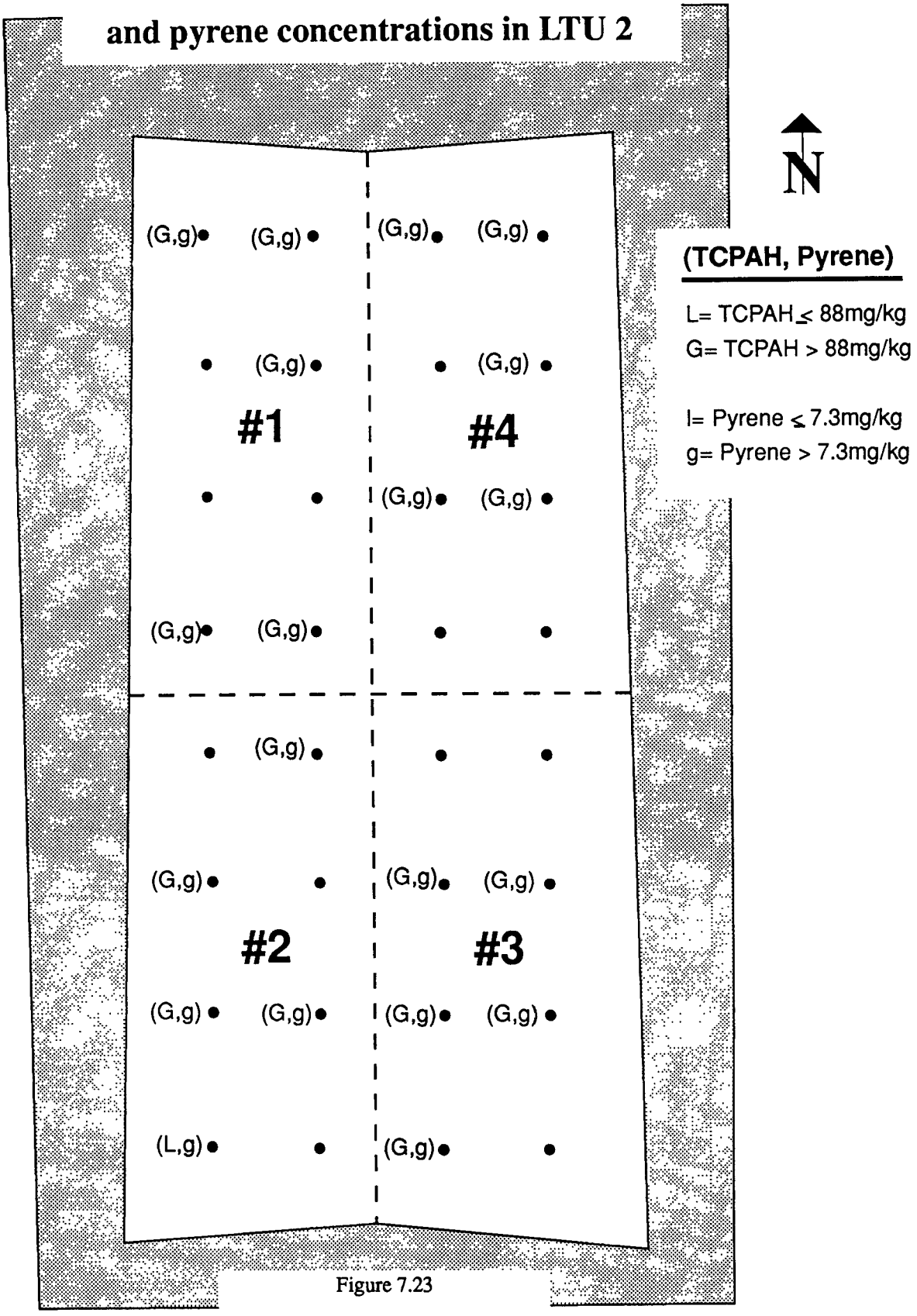

Figure 7.23

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth A samples collected 9/1/92

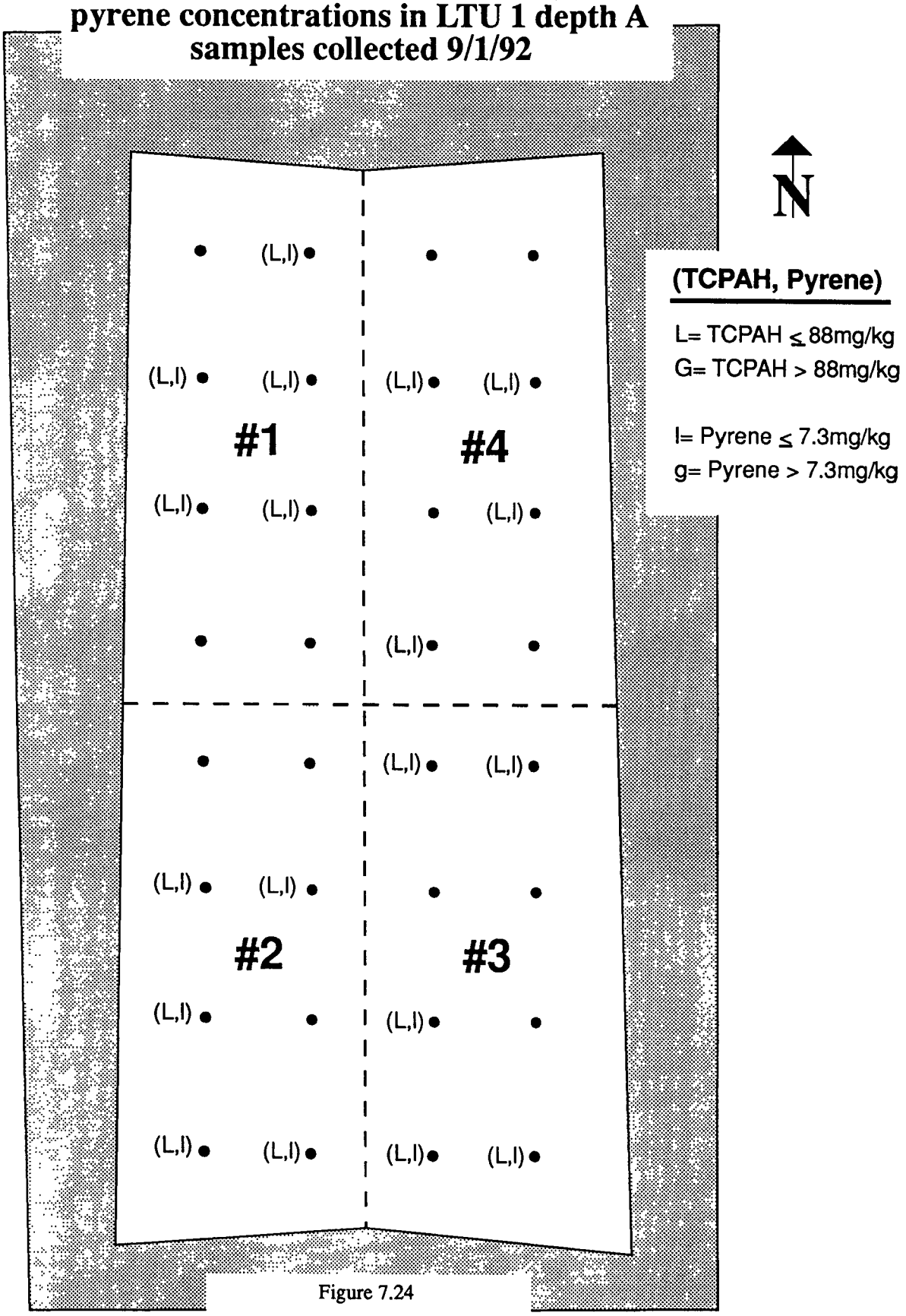

Figure 7.24

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth B samples collected 9/1/92

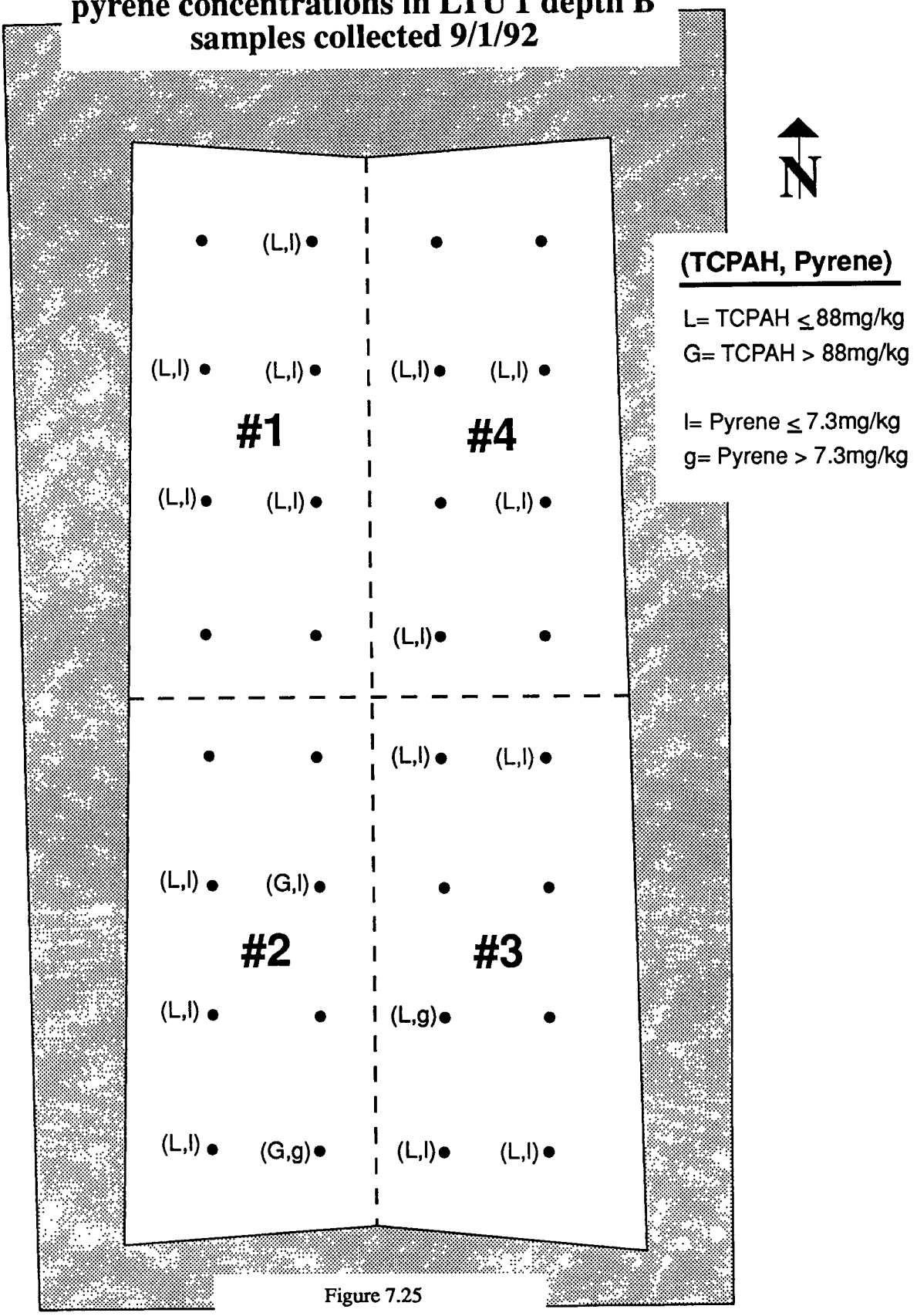

Figure 7.25

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth C samples collected 9/1/92

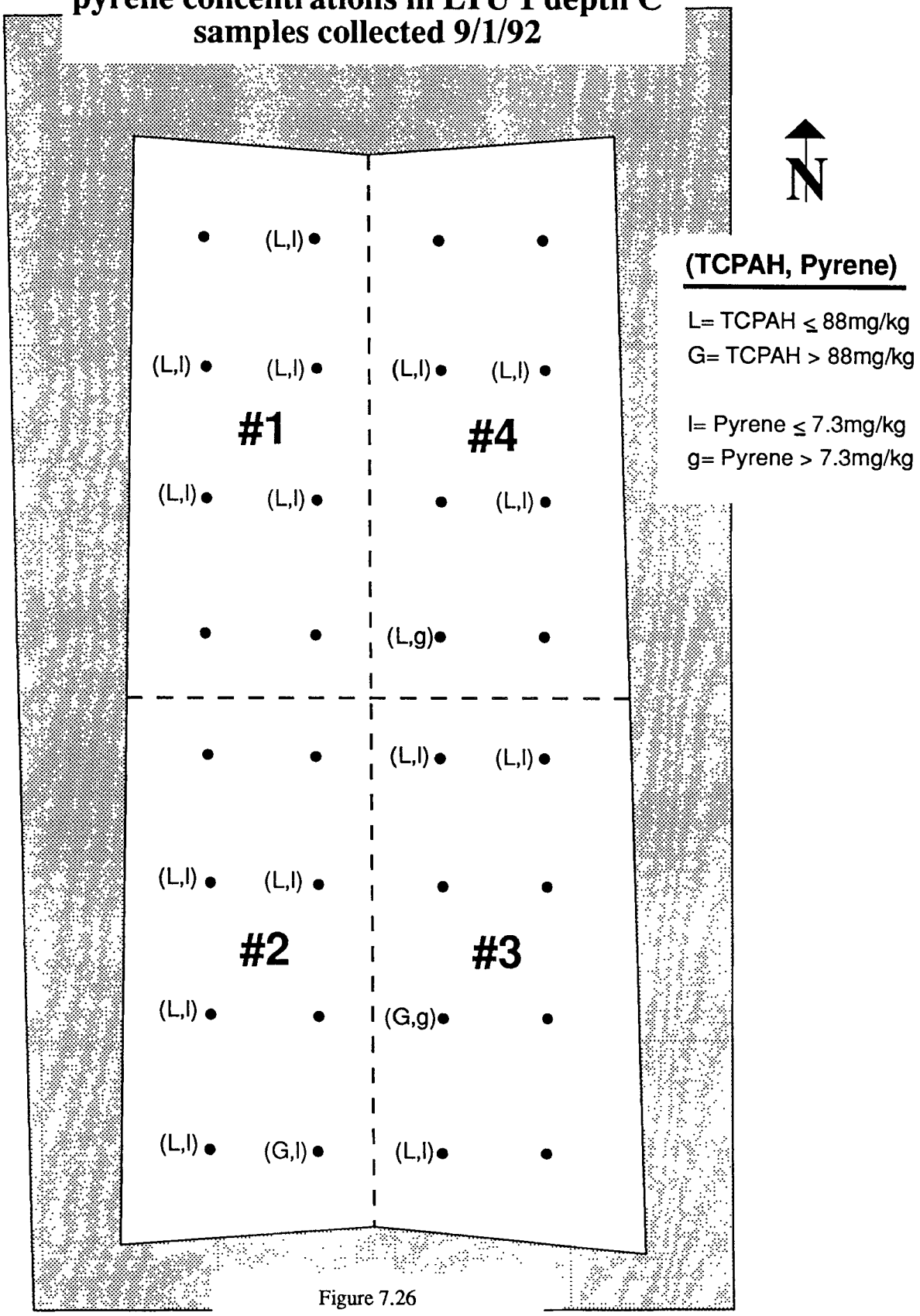

Figure 7.26

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth D samples collected 9/1/92

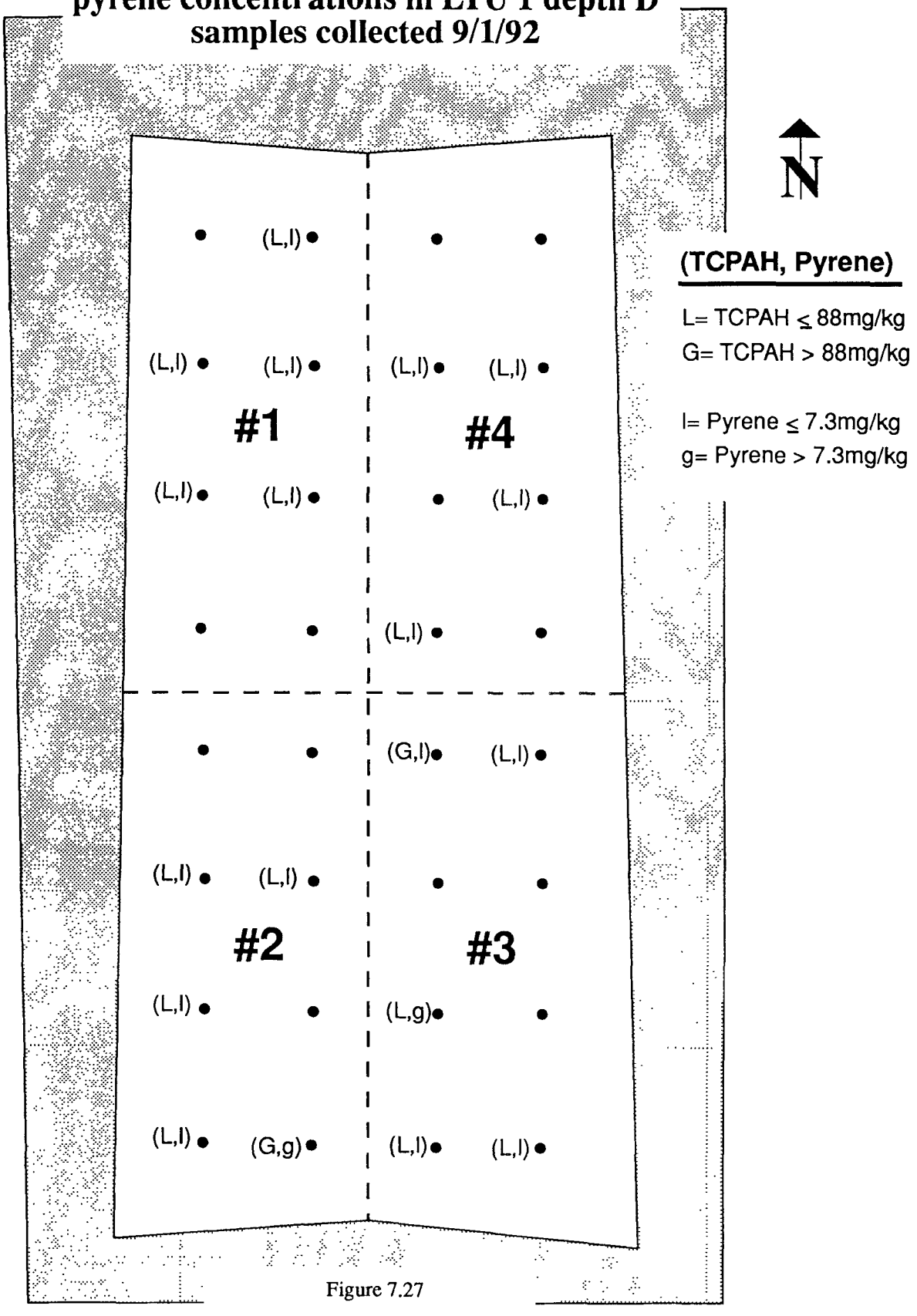

Figure 7.27

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth E samples collected 9/1/92

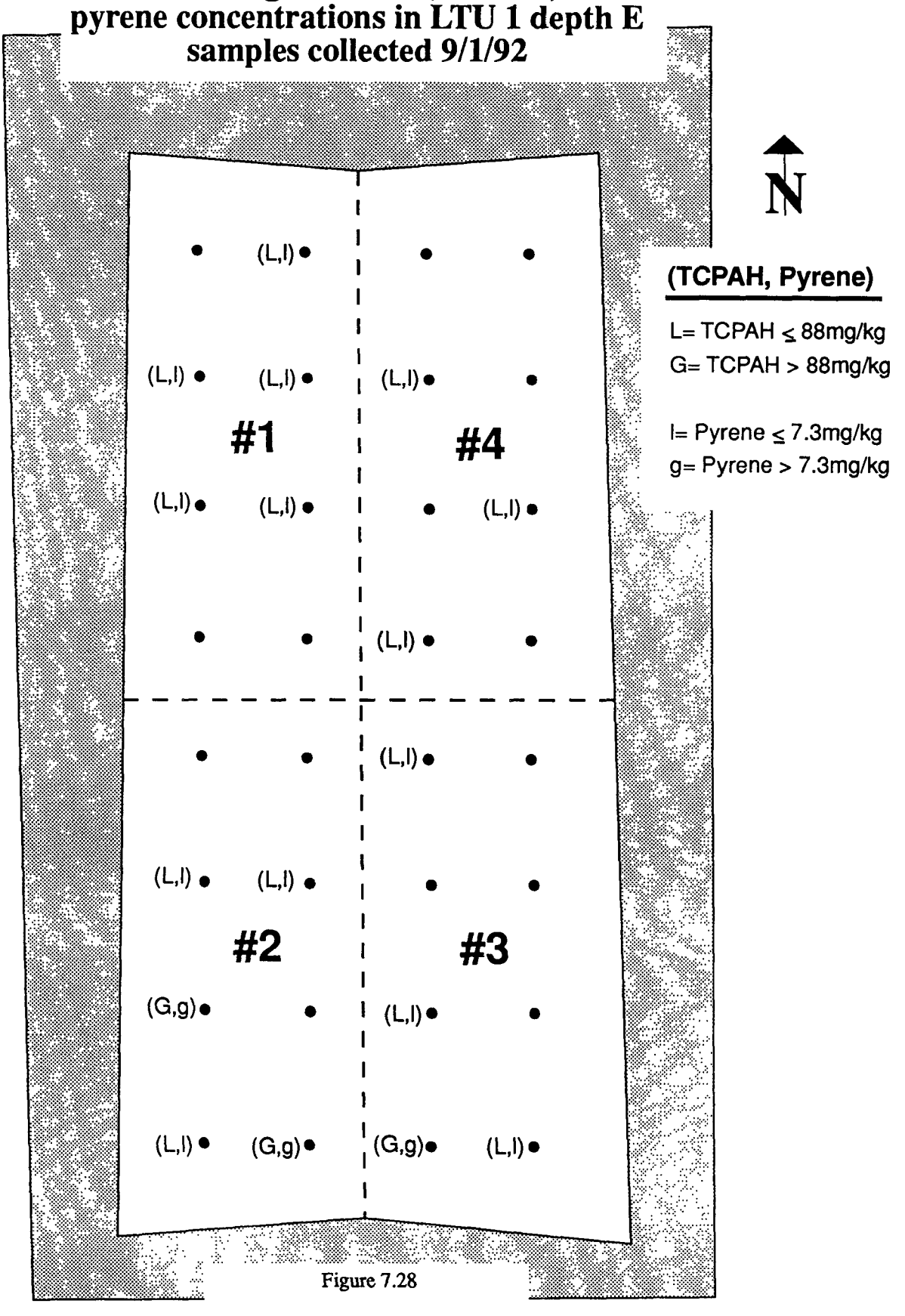

Figure 7.28

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 2 depth A samples collected 9/1/92

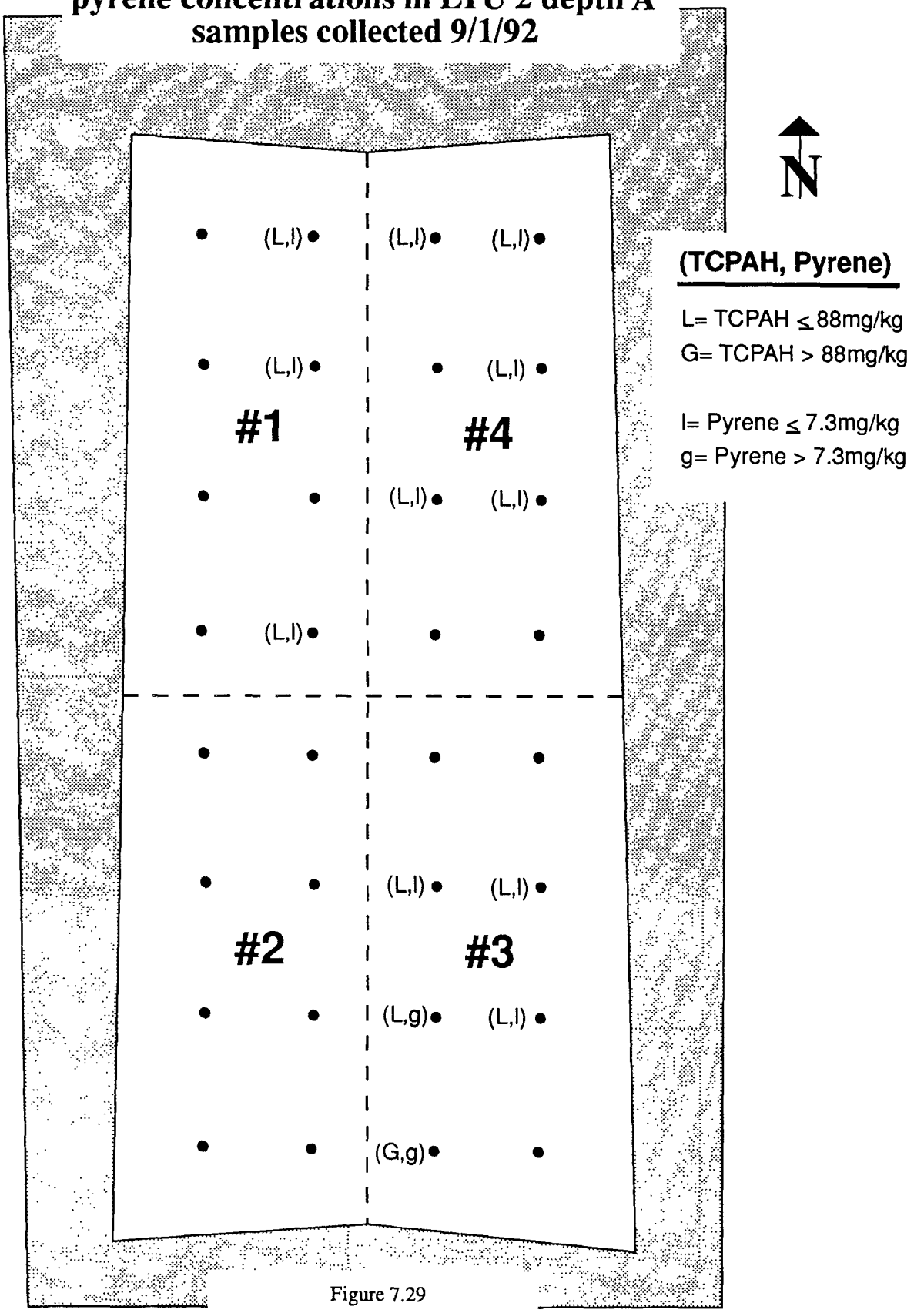

Figure 7.29

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 2 depth B samples collected 9/1/92

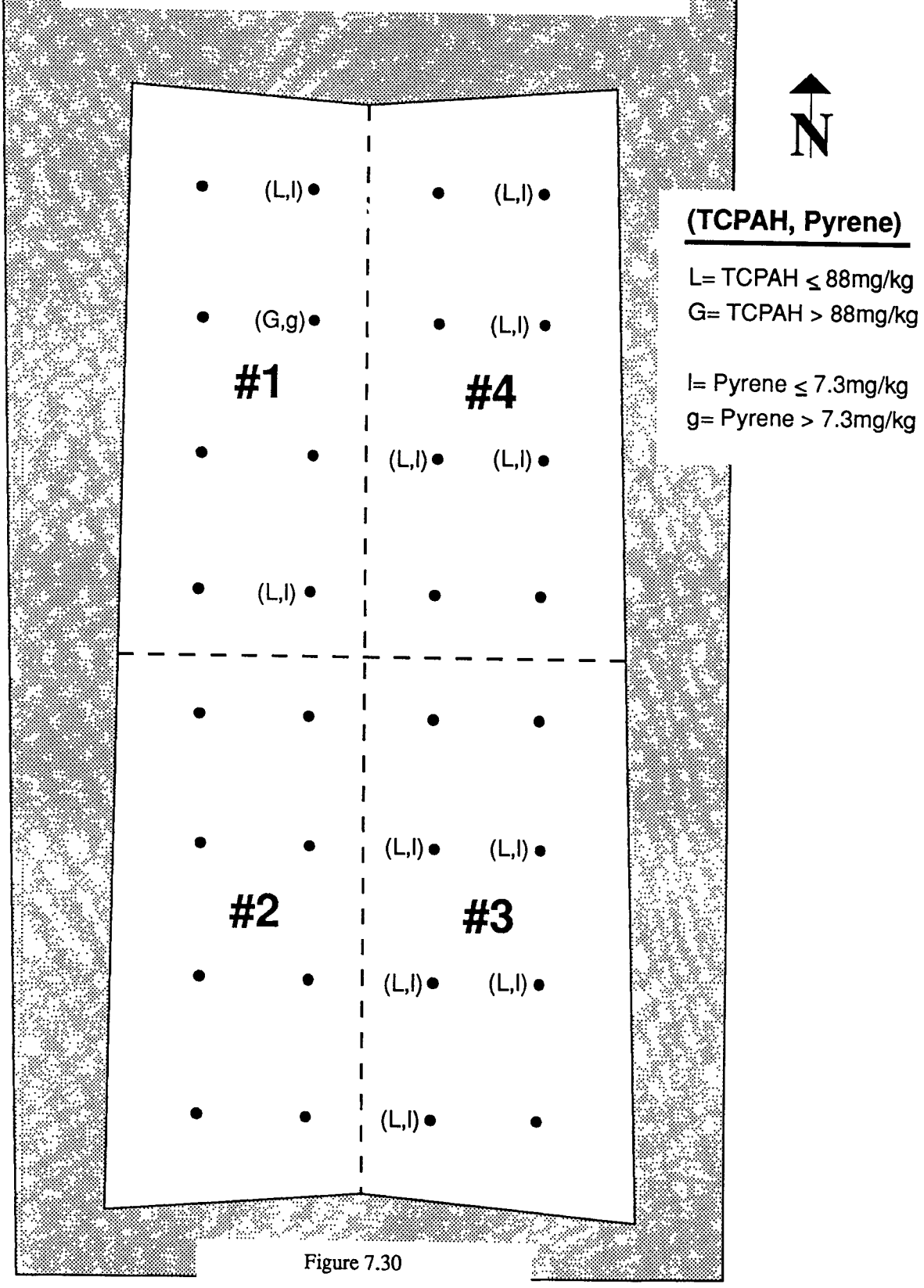

Figure 7.30

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth A samples collected 9/18&19/91

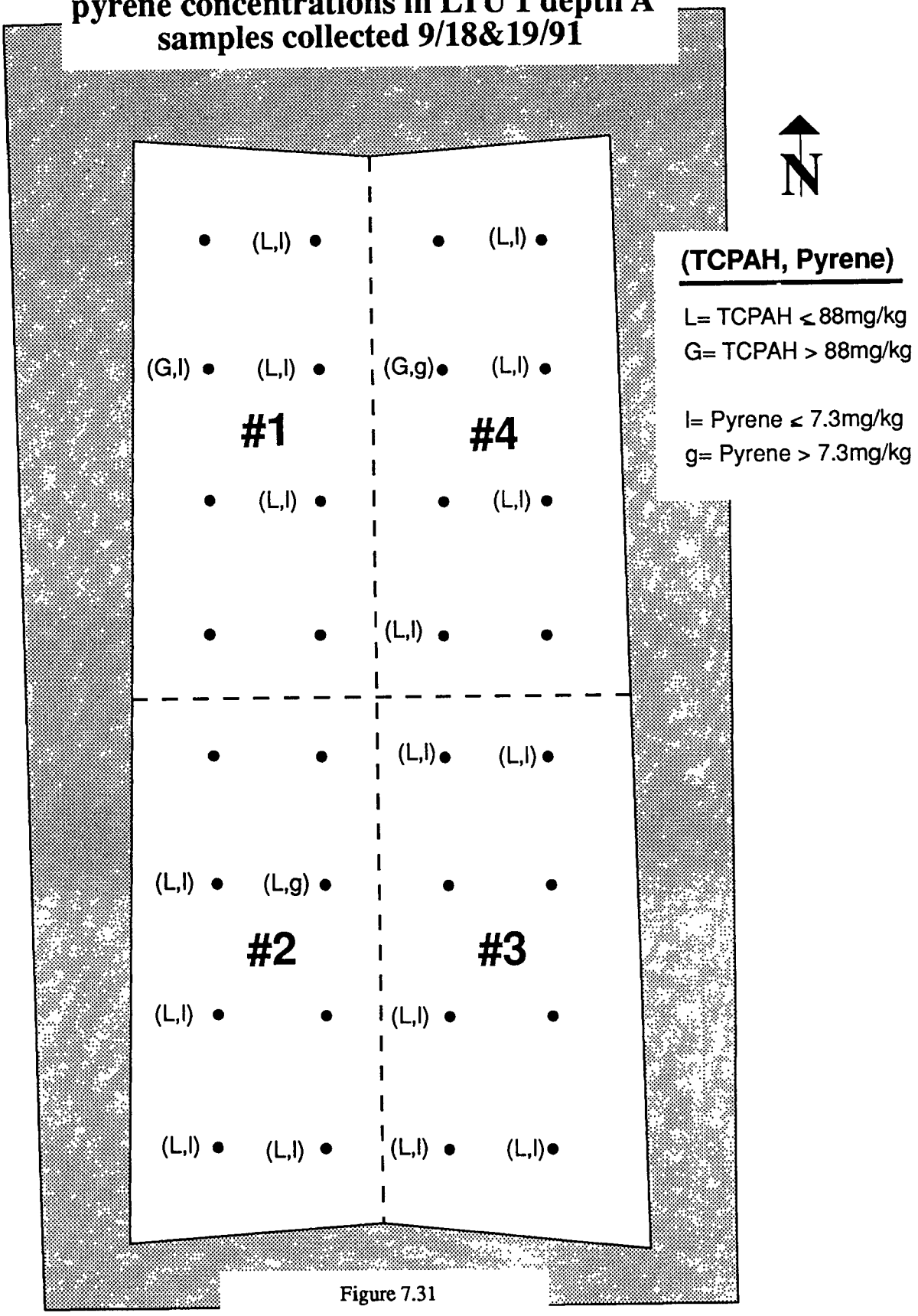

Figure 7.31

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth B samples collected 9/18&19/91

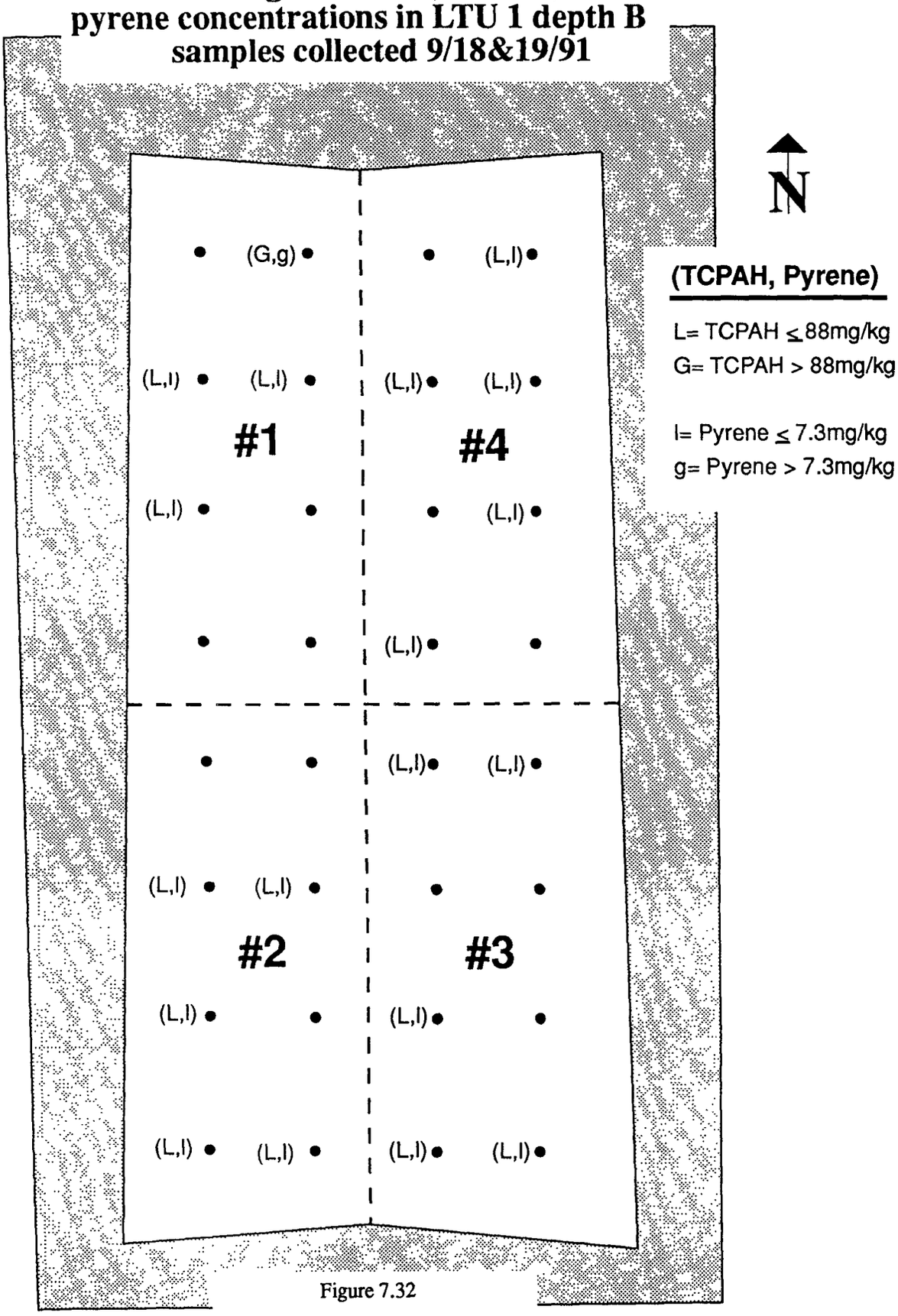

Figure 7.32

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth C samples collected 9/18&19/91

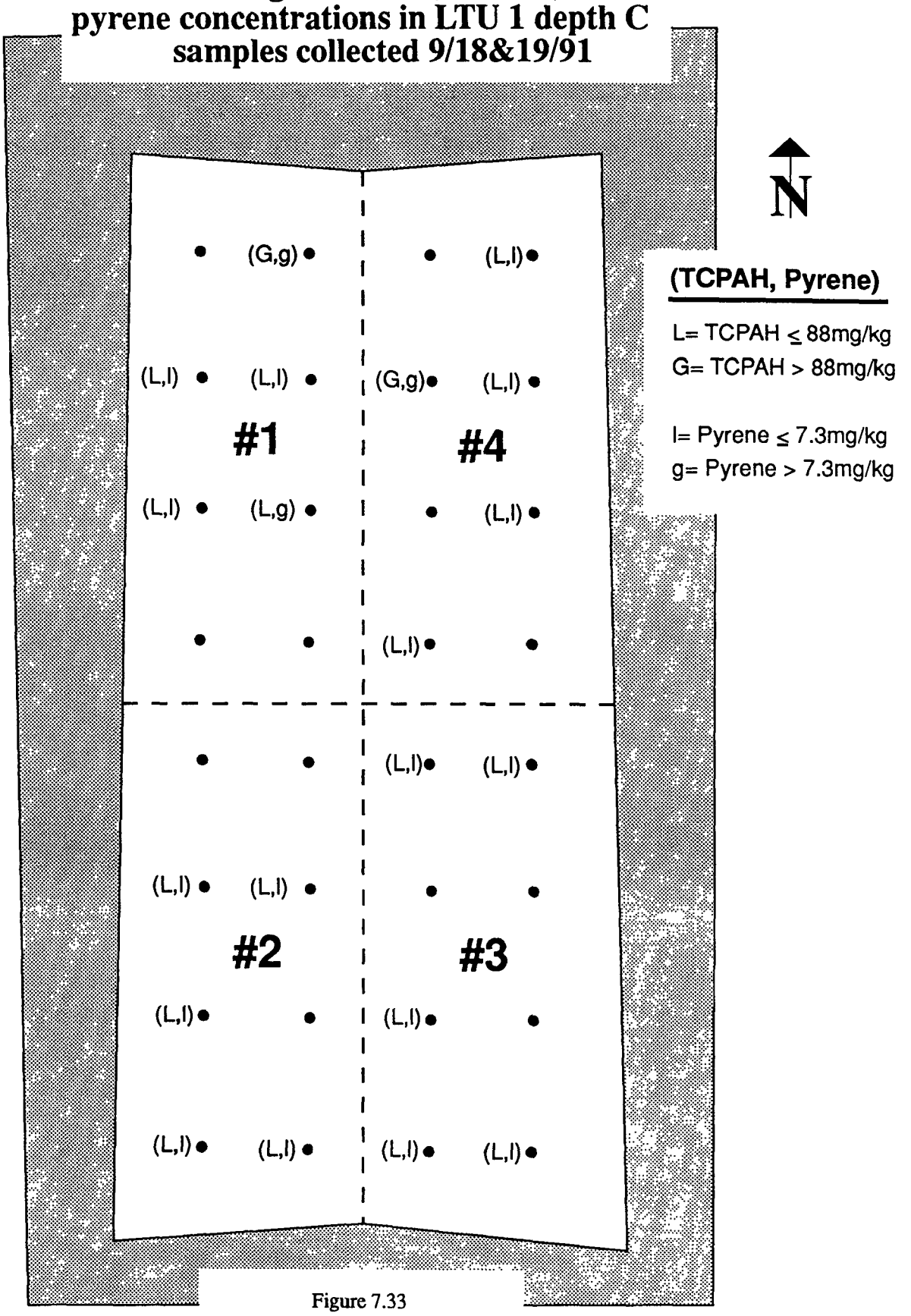

Figure 7.33

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth D samples collected 9/18&19/91

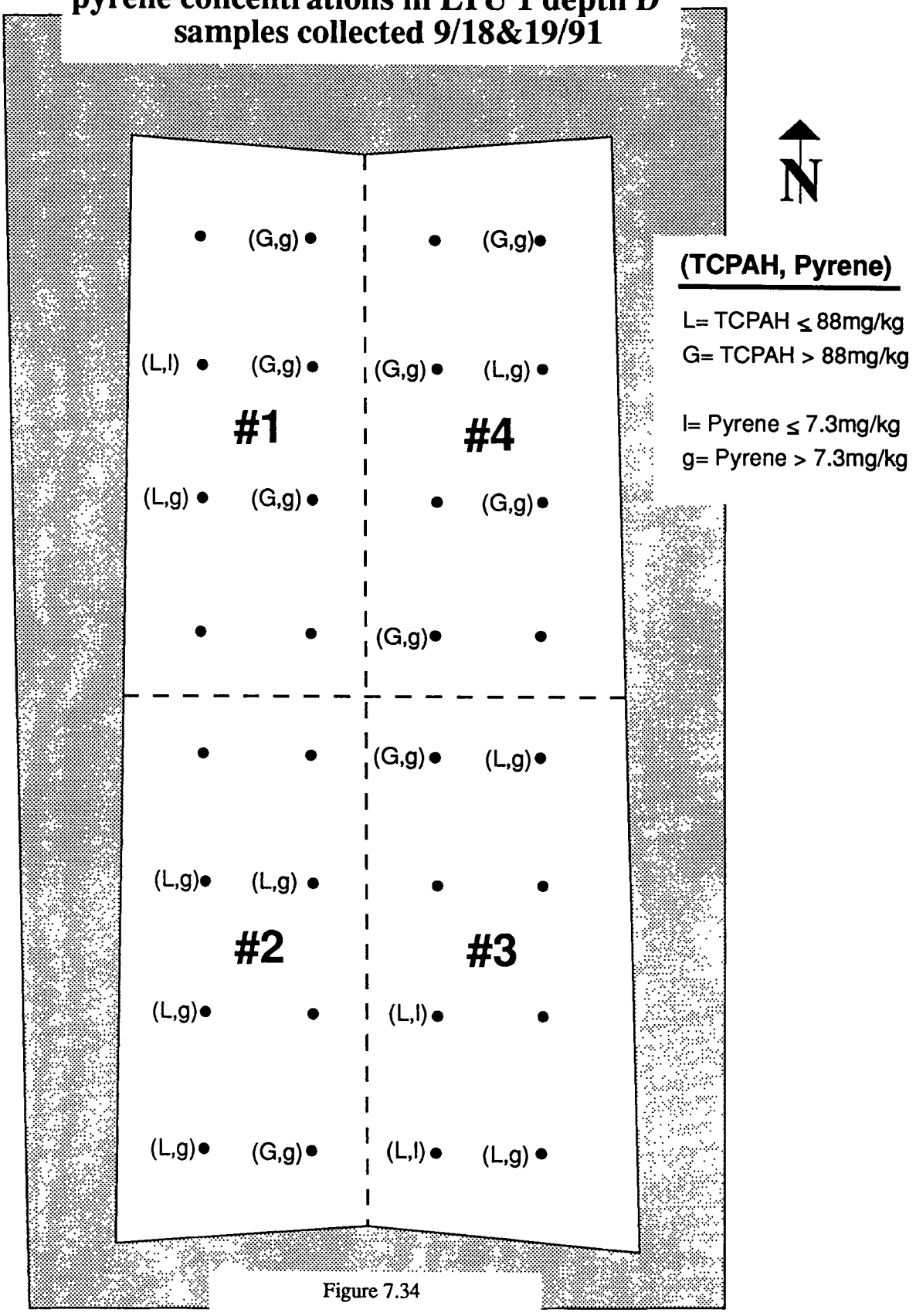

Figure 7.34

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 2 depth A samples collected 9/19/91

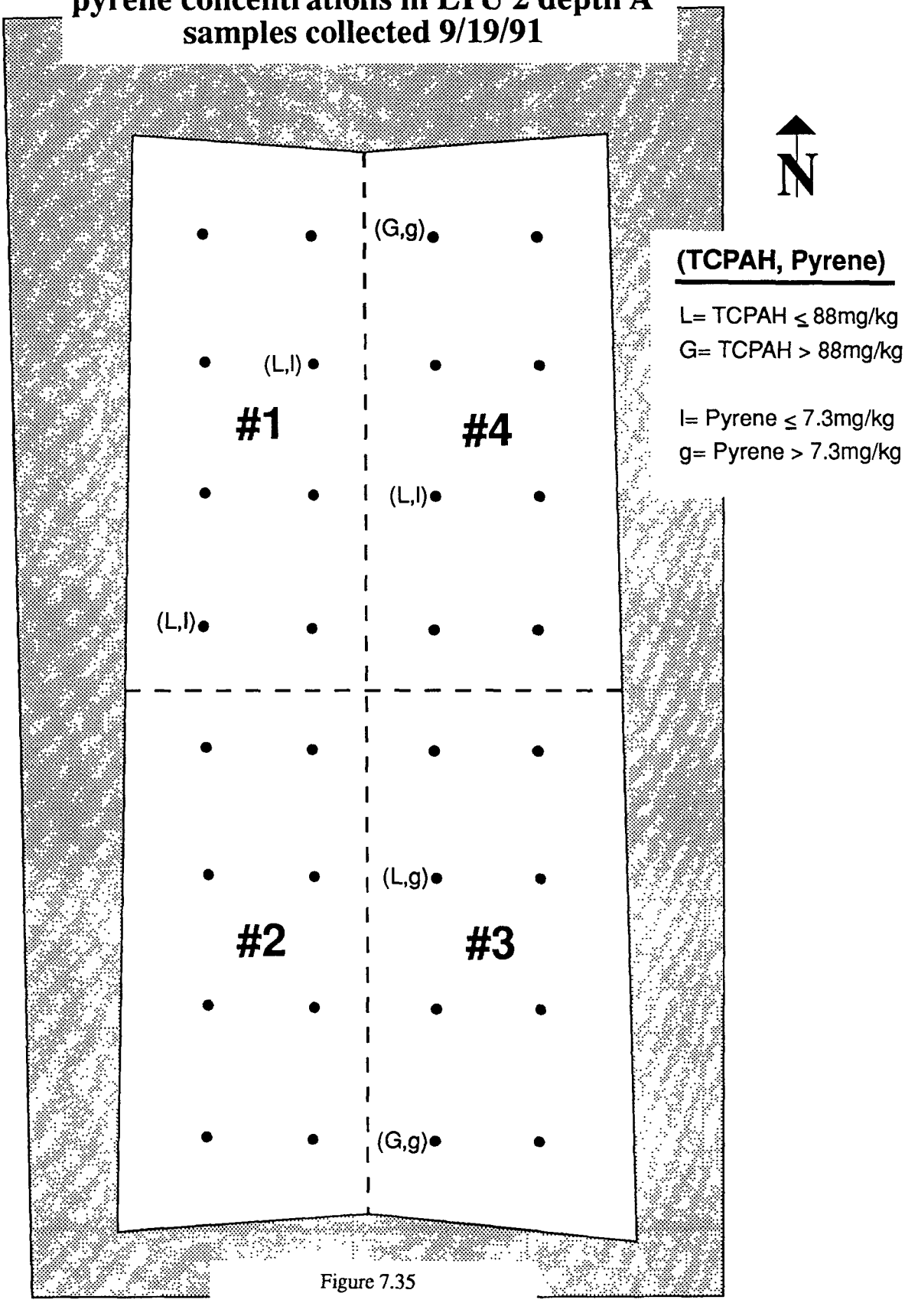

Figure 7.35

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth A samples collected 6/27/91

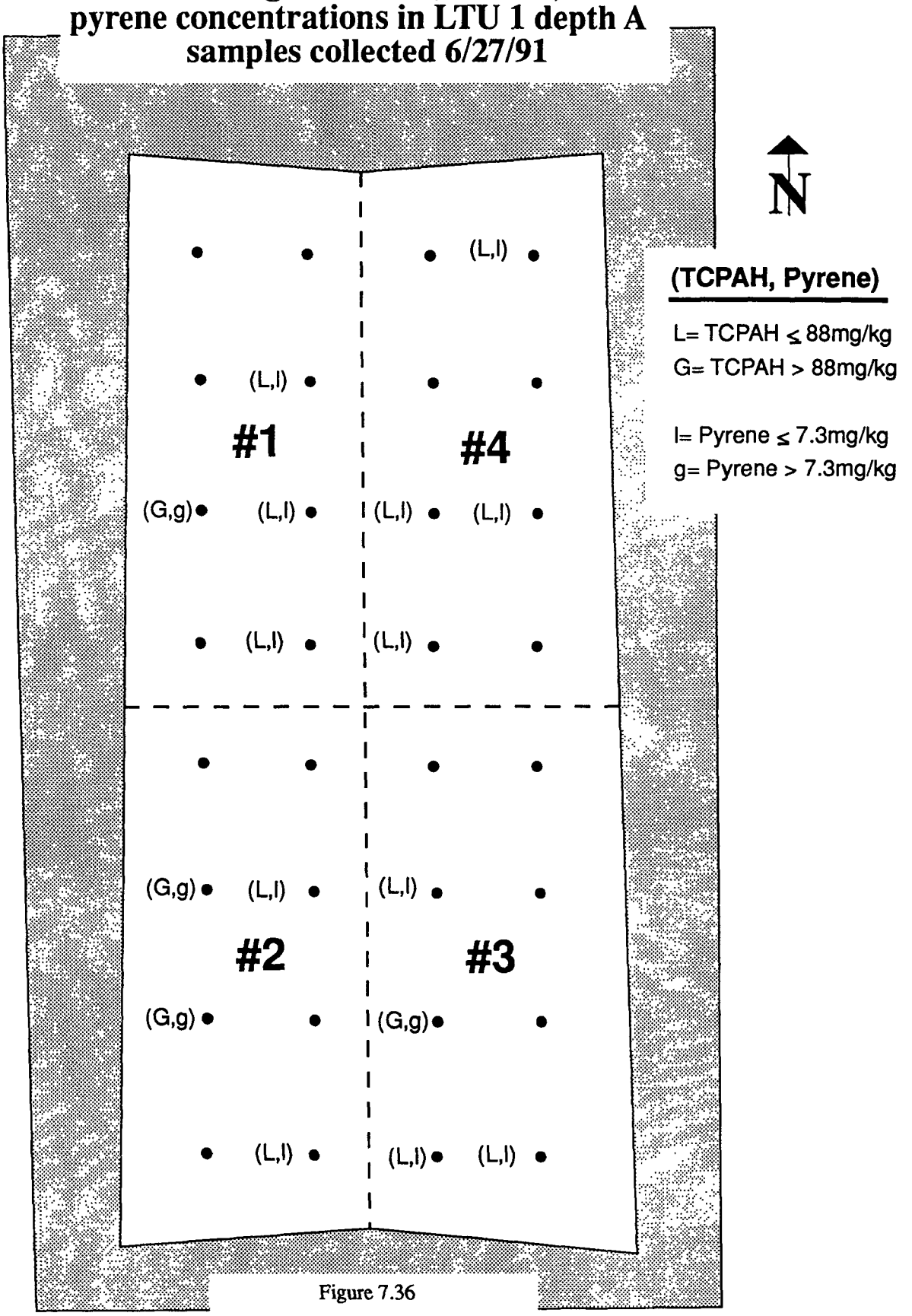

Figure 7.36

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth B samples collected 6/27/91

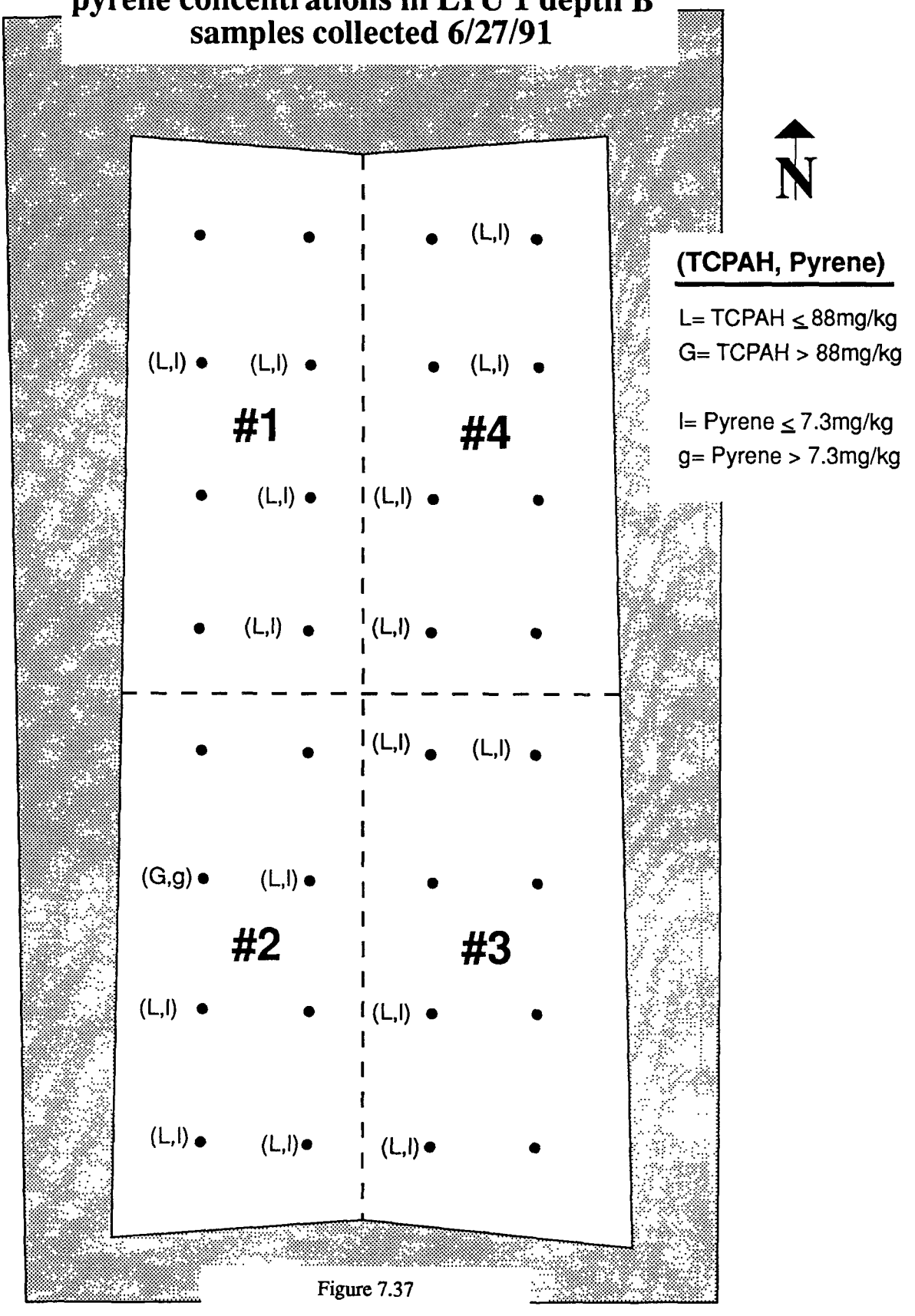

Figure 7.37

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth C samples collected 6/27/91

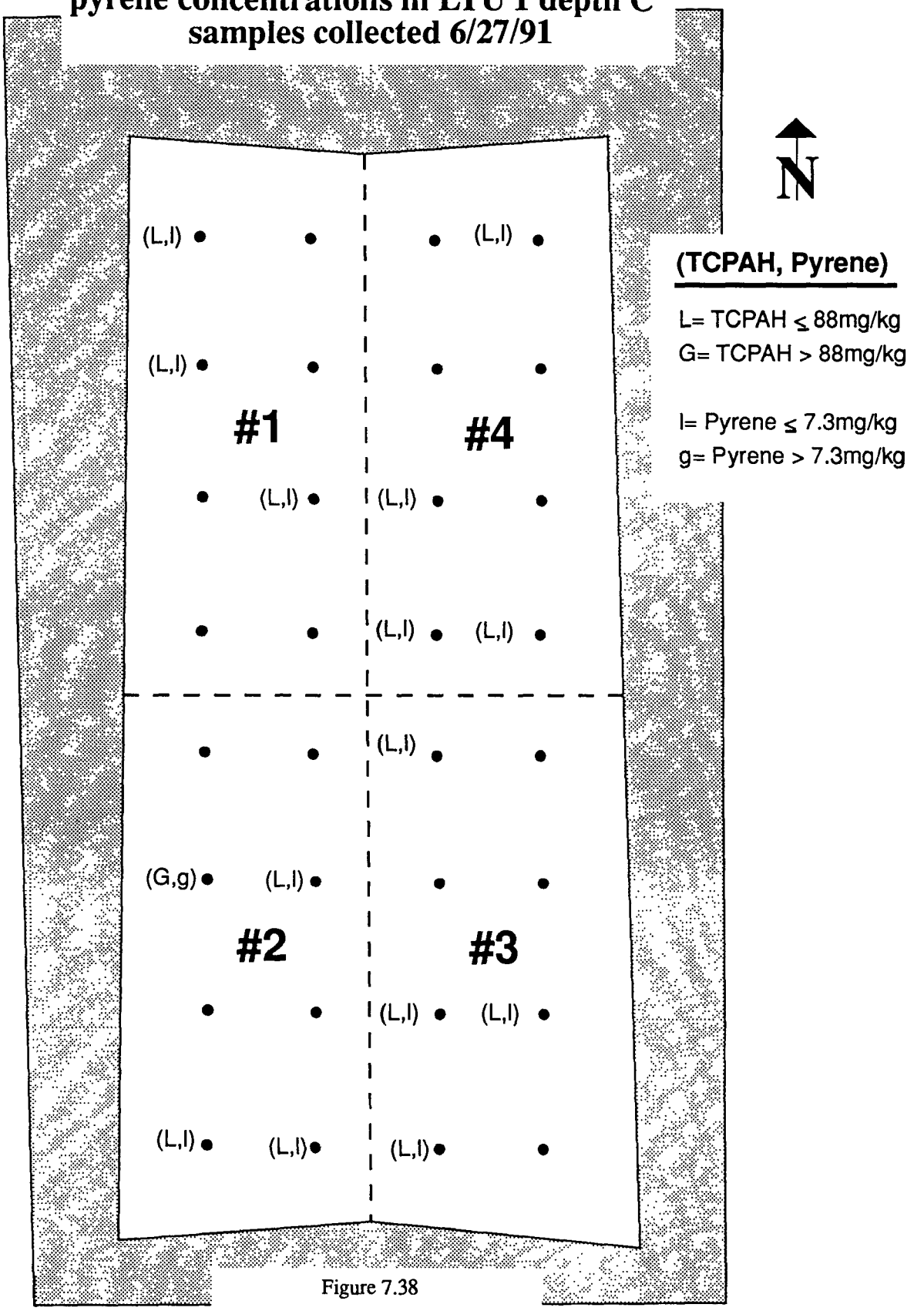

Figure 7.38

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth A samples collected 5/6/91

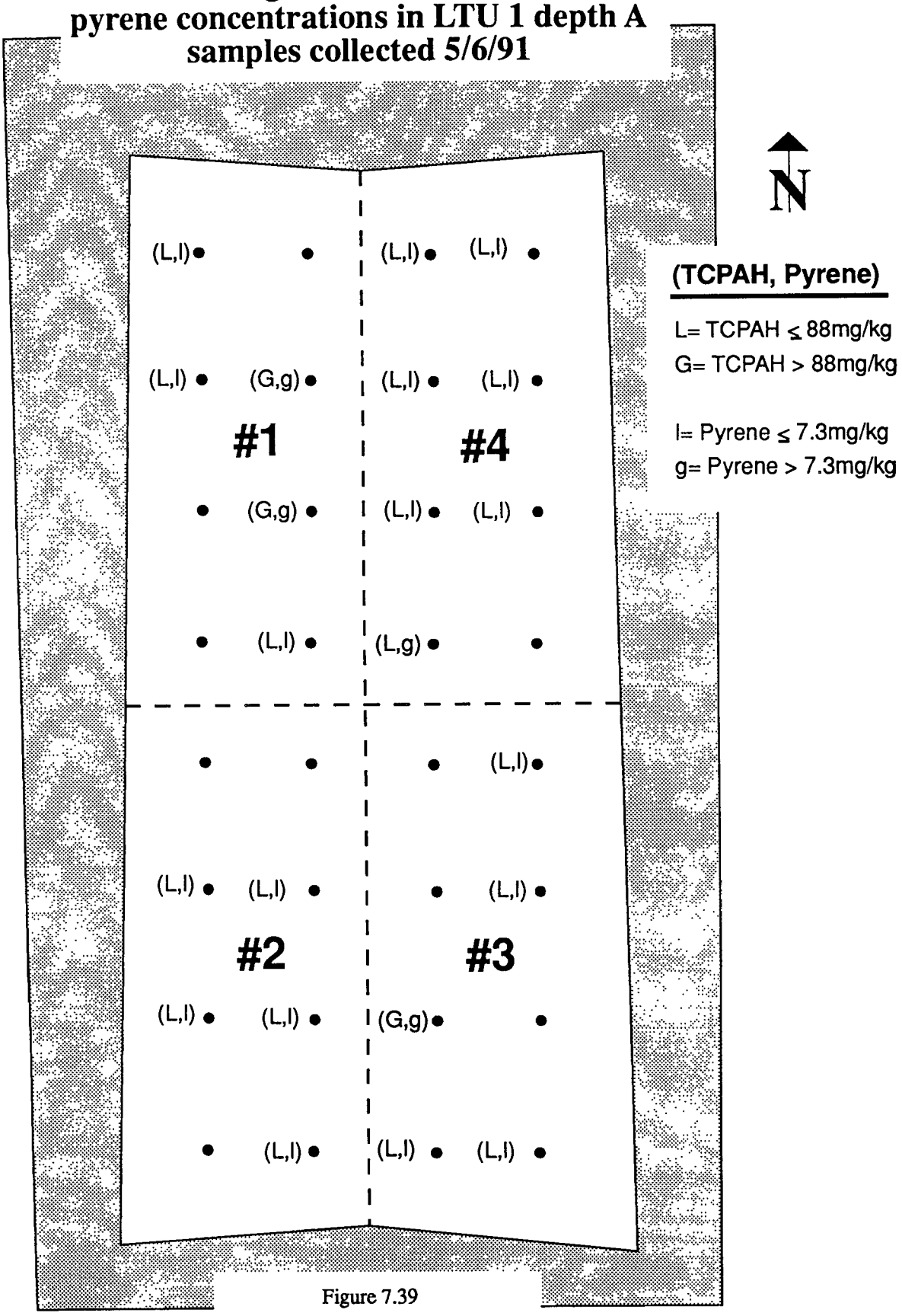

Figure 7.39

Total carcinogenic PAH (TCPAH) and pyrene concentrations in LTU 1 depth B samples collected 5/6/91

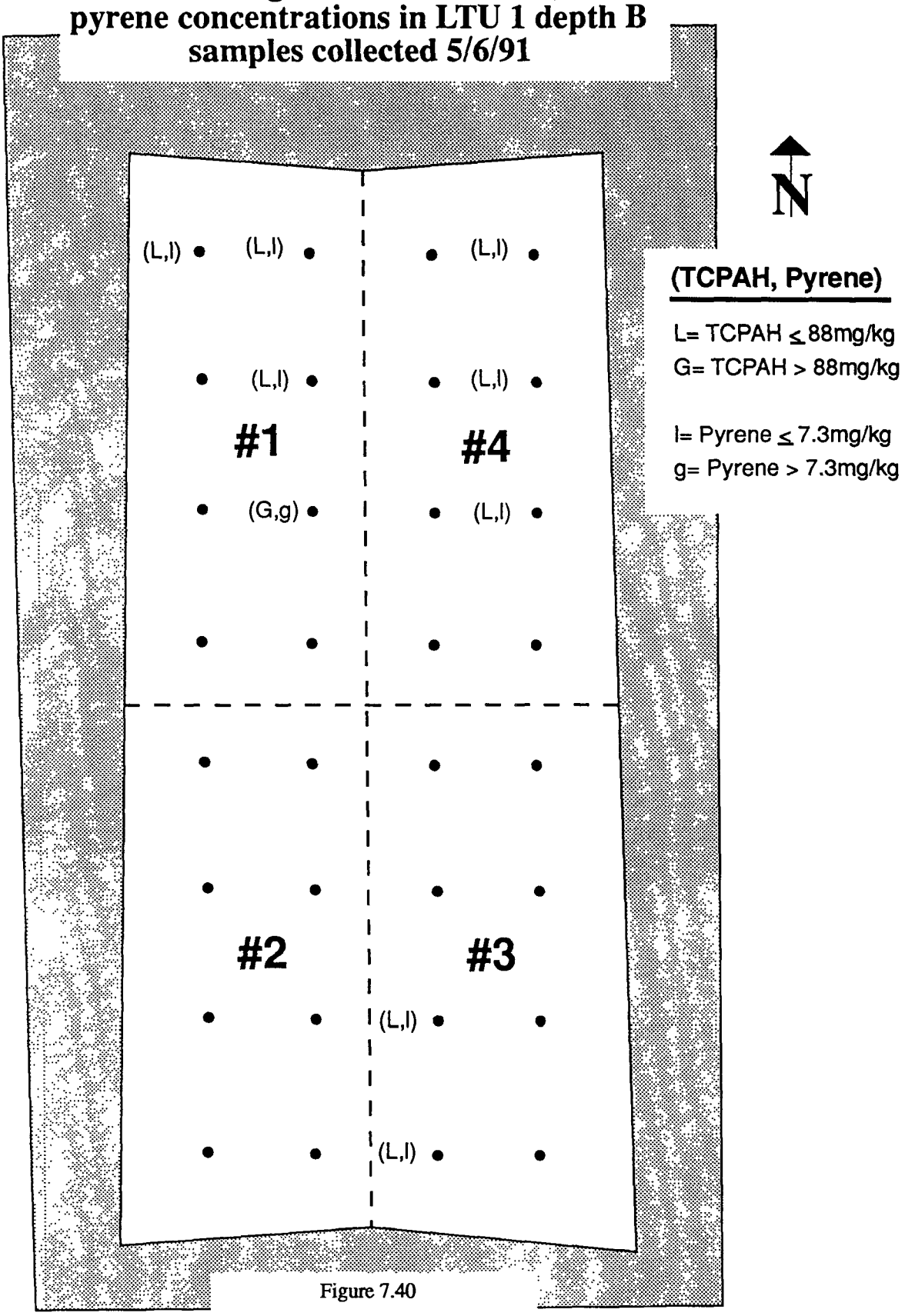

Figure 7.40

Initial PCP concentrations in LTU 1

depth C samples collected 5/8/91

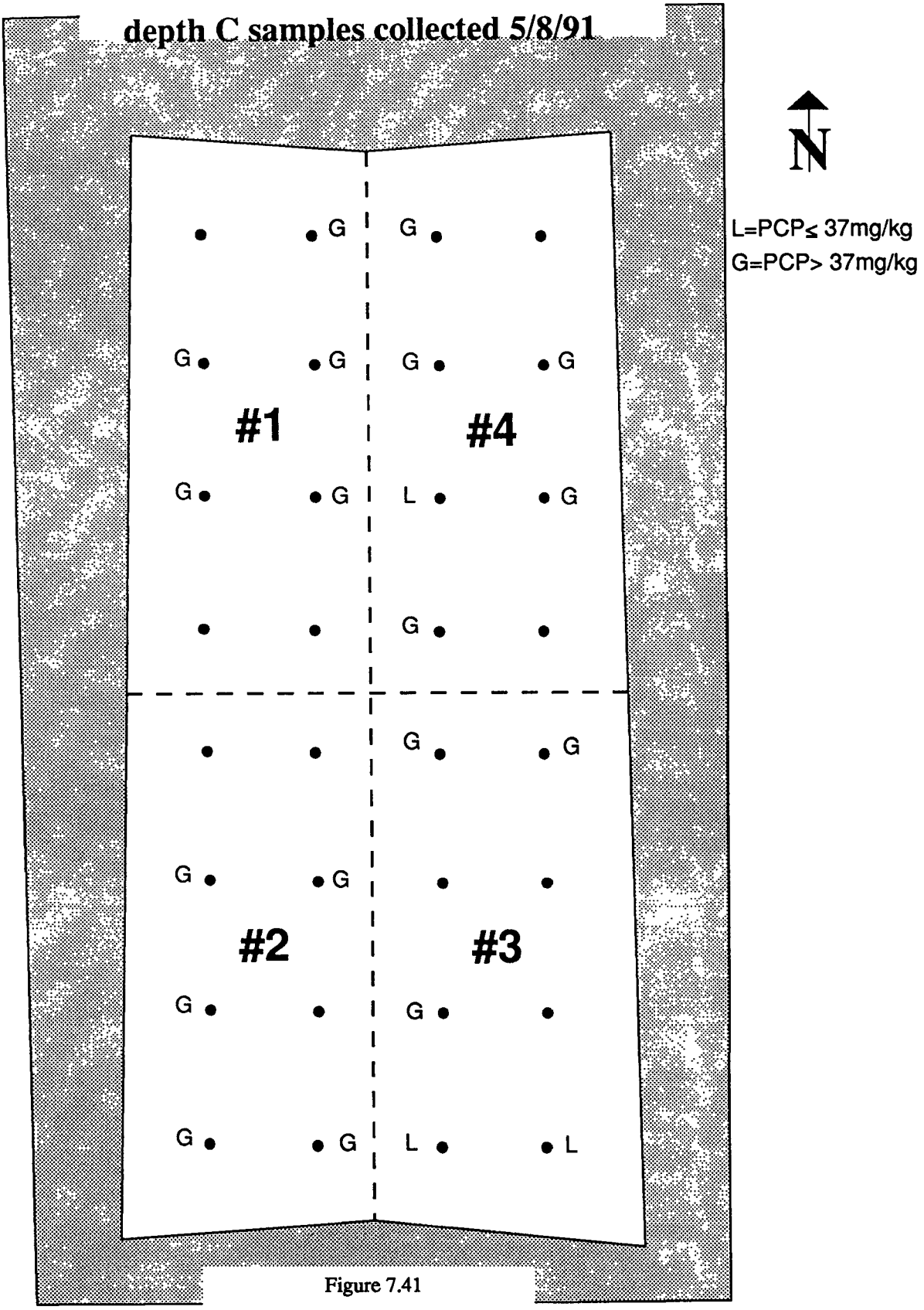

Figure 7.41

Initial PCP concentrations in LTU 1

depth D samples collected 7/27/91

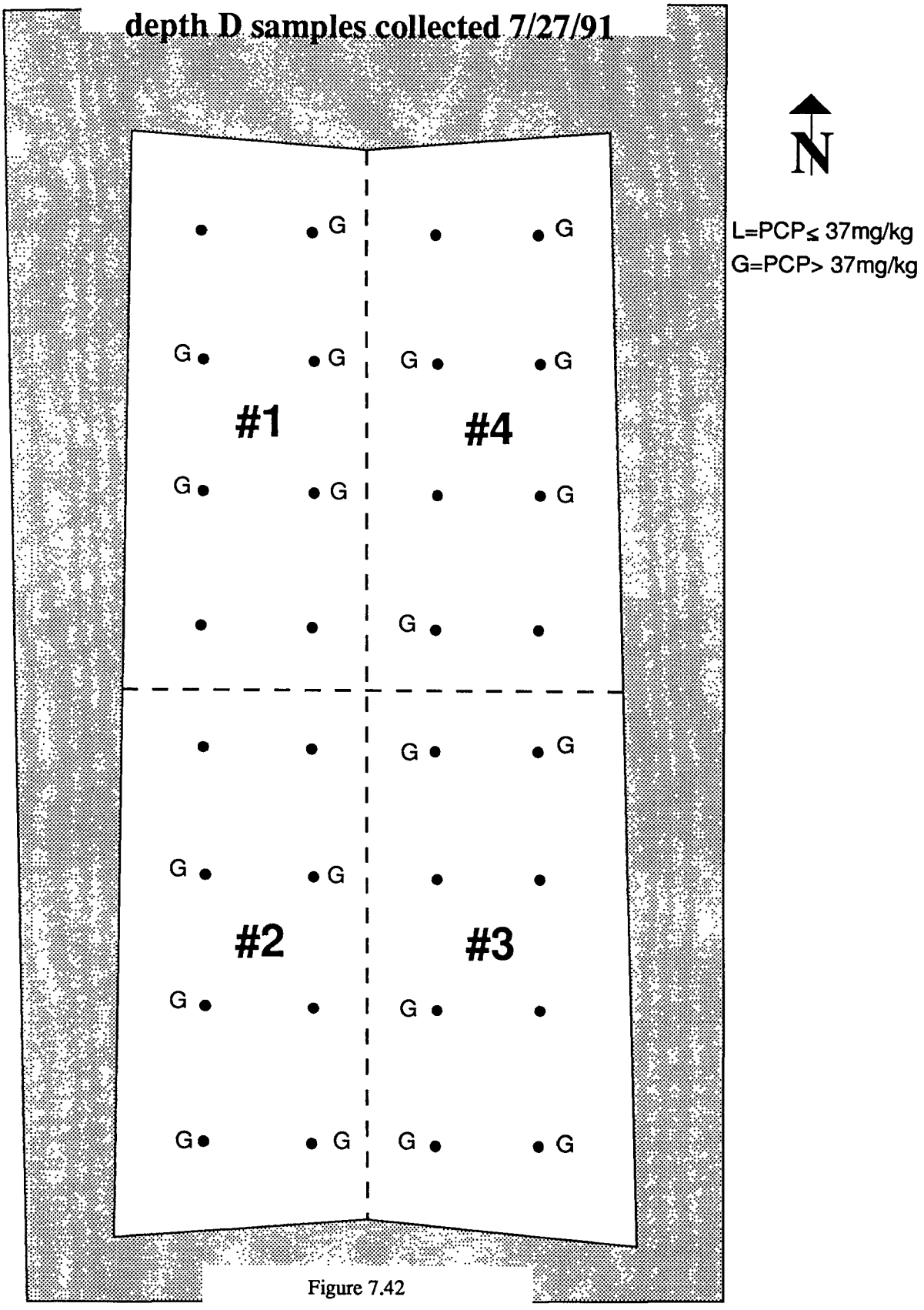

Figure 7.42

Initial PCP concentrations in LTU 2

depth A samples collected 7/27/91

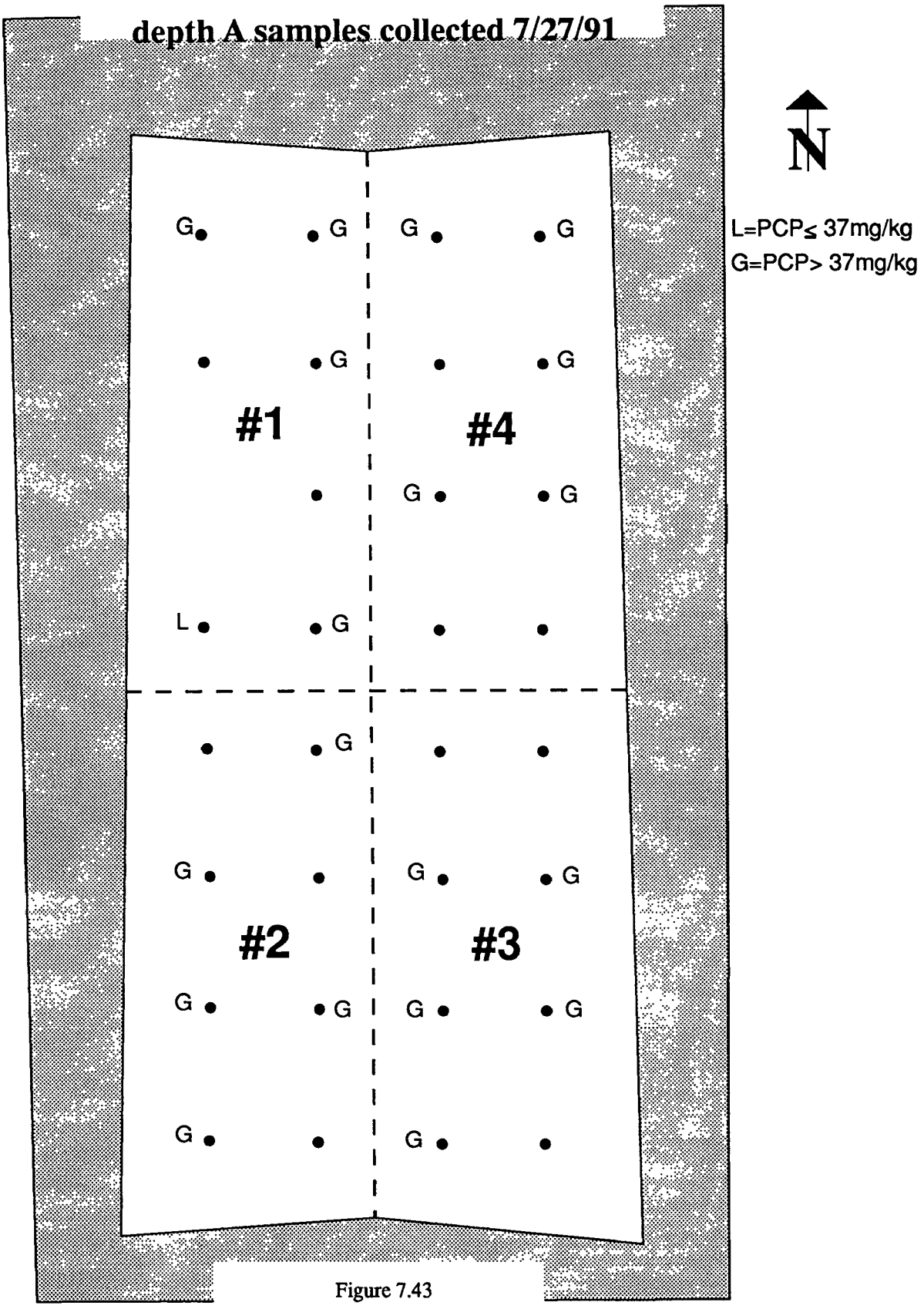

Figure 7.43

PCP concentrations in LTU 1 depth A samples collected 9/1/92

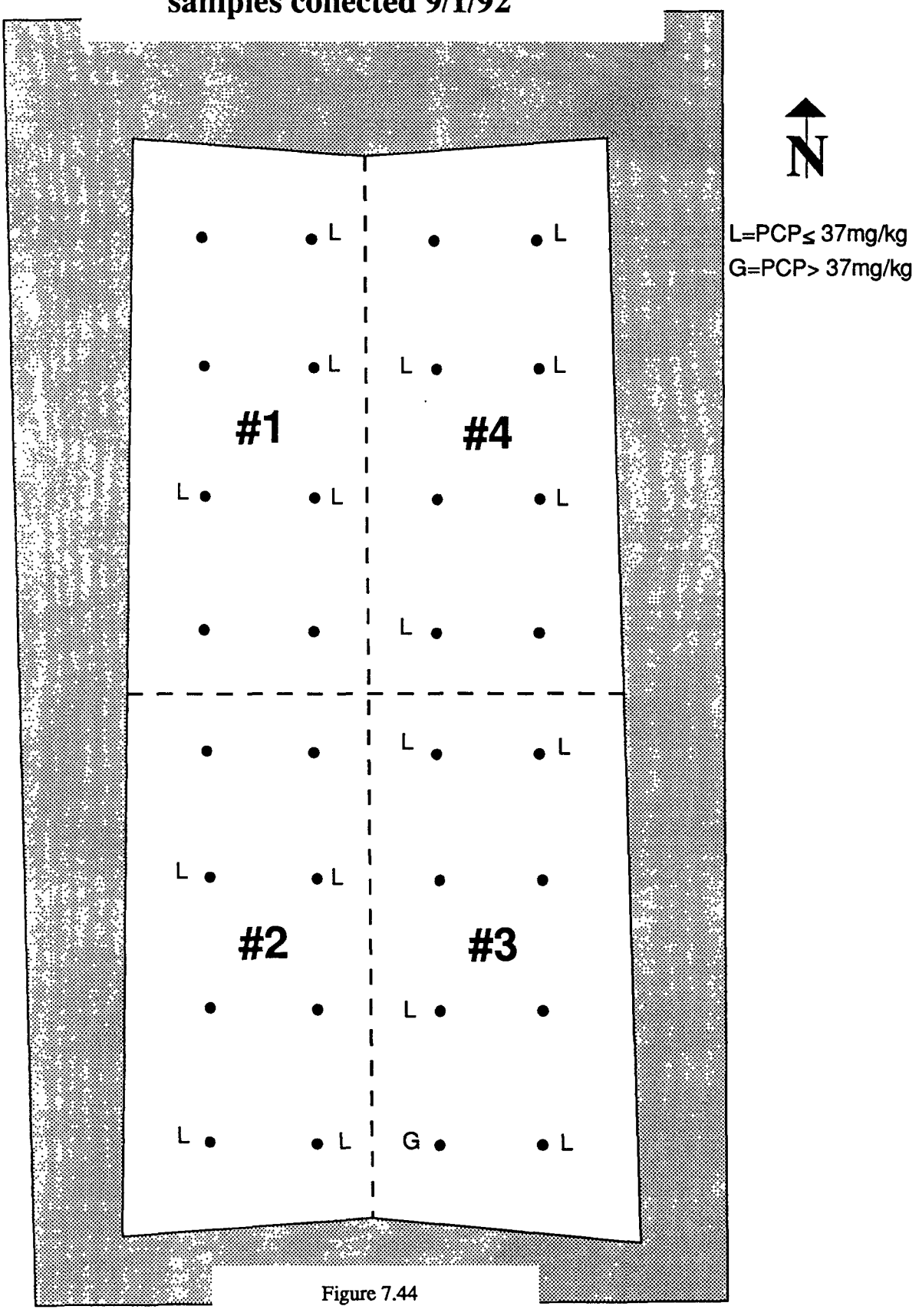

Figure 7.44

PCP concentrations in LTU 1 depth B samples collected 9/1/92

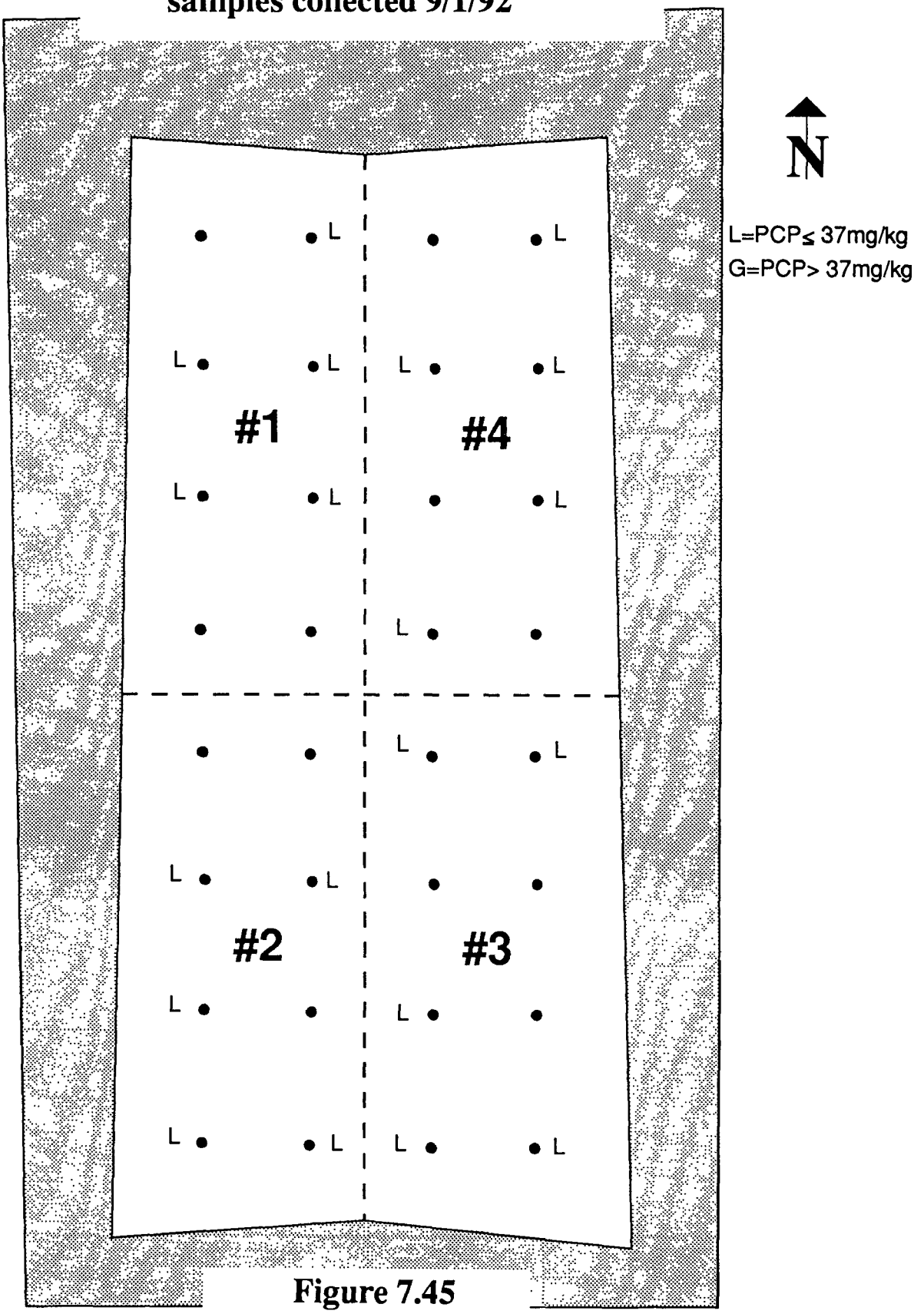

Figure 7.45

PCP concentrations in LTU 1 depth C samples collected 9/1/92

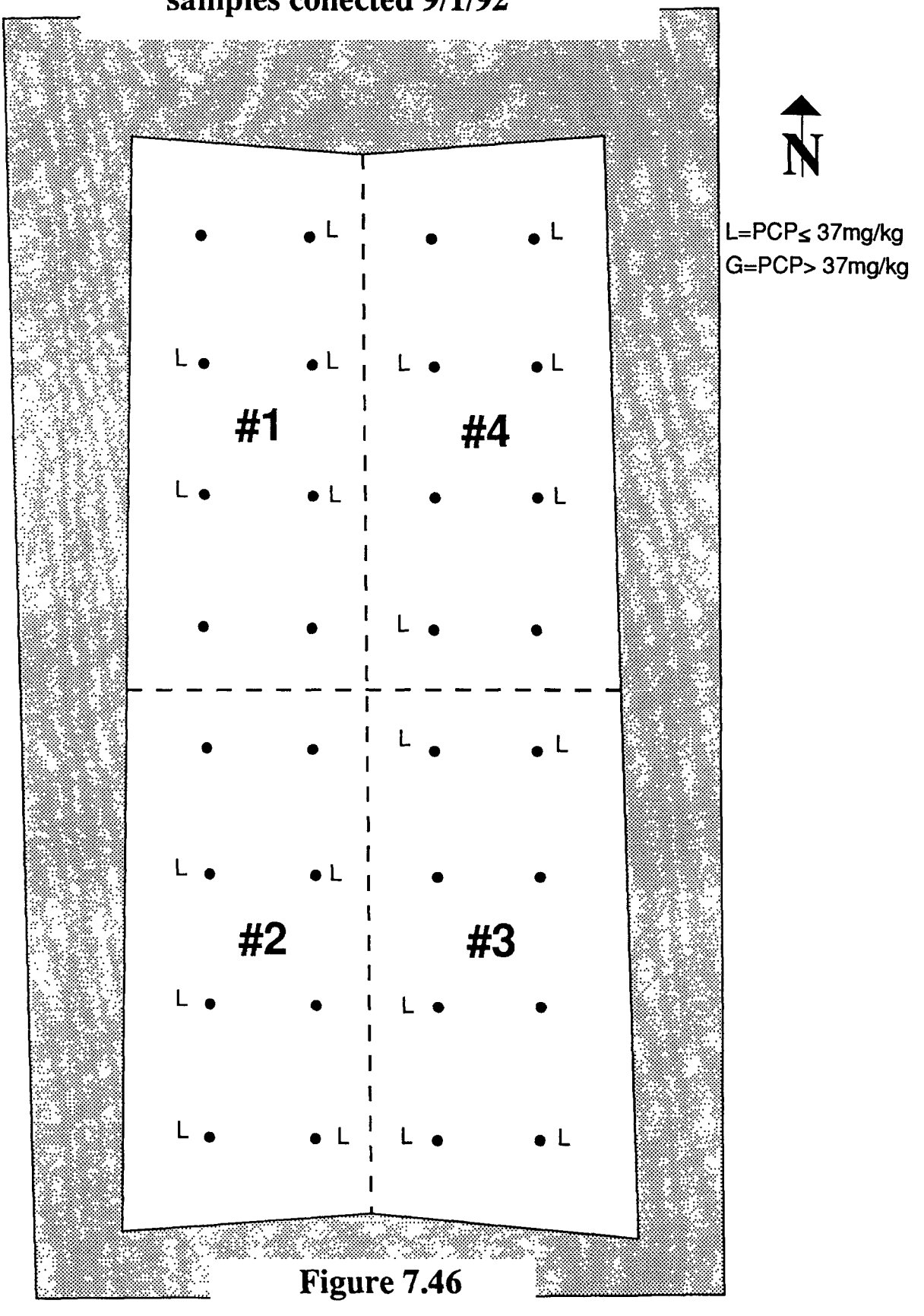

Figure 7.46

PCP concentrations in LTU 1 depth D samples collected 9/1/92

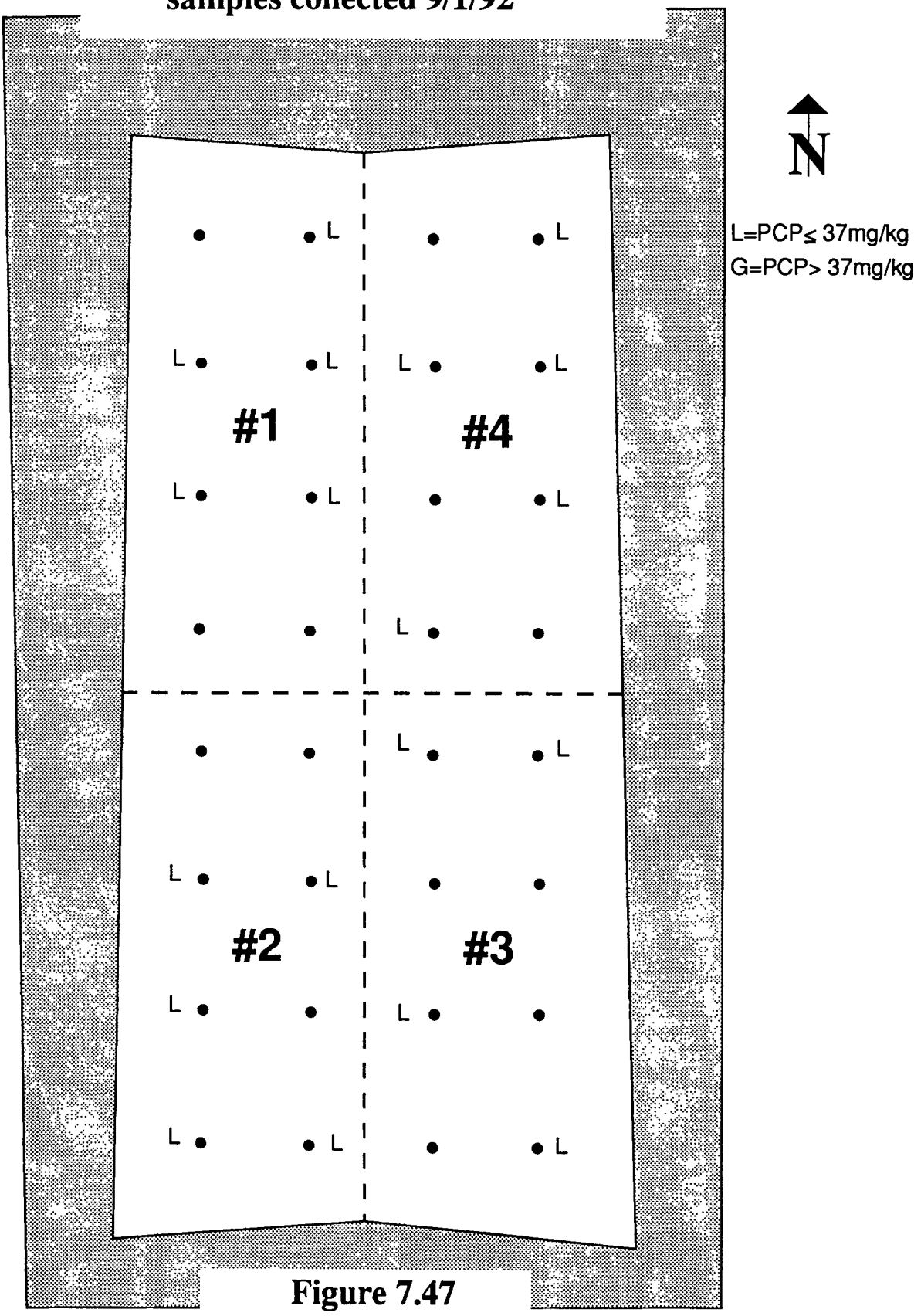

Figure 7.47

PCP concentrations in LTU 1 depth E samples collected 9/1/92

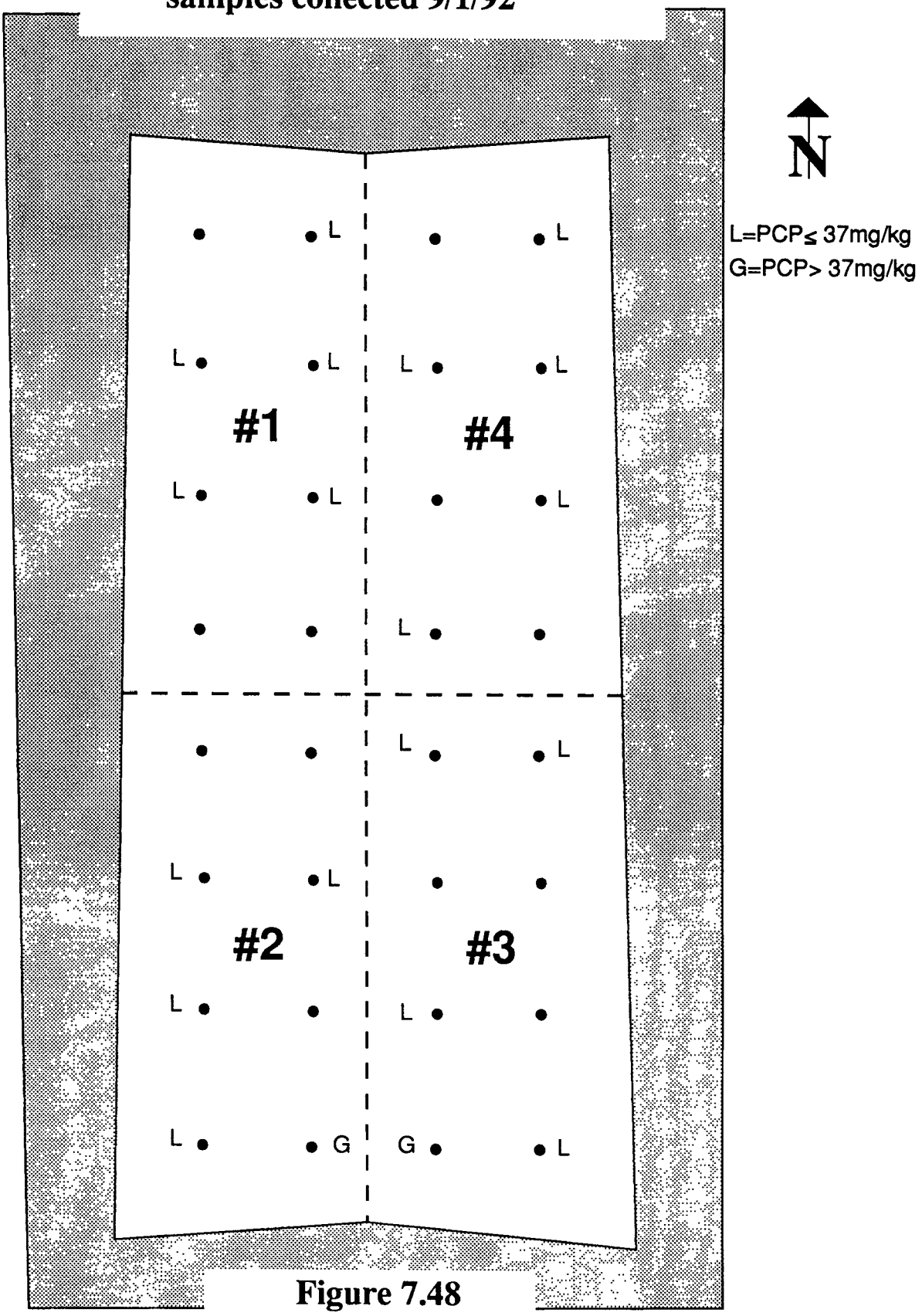

Figure 7.48

PCP concentrations in LTU 2 depth A samples collected 9/2/92

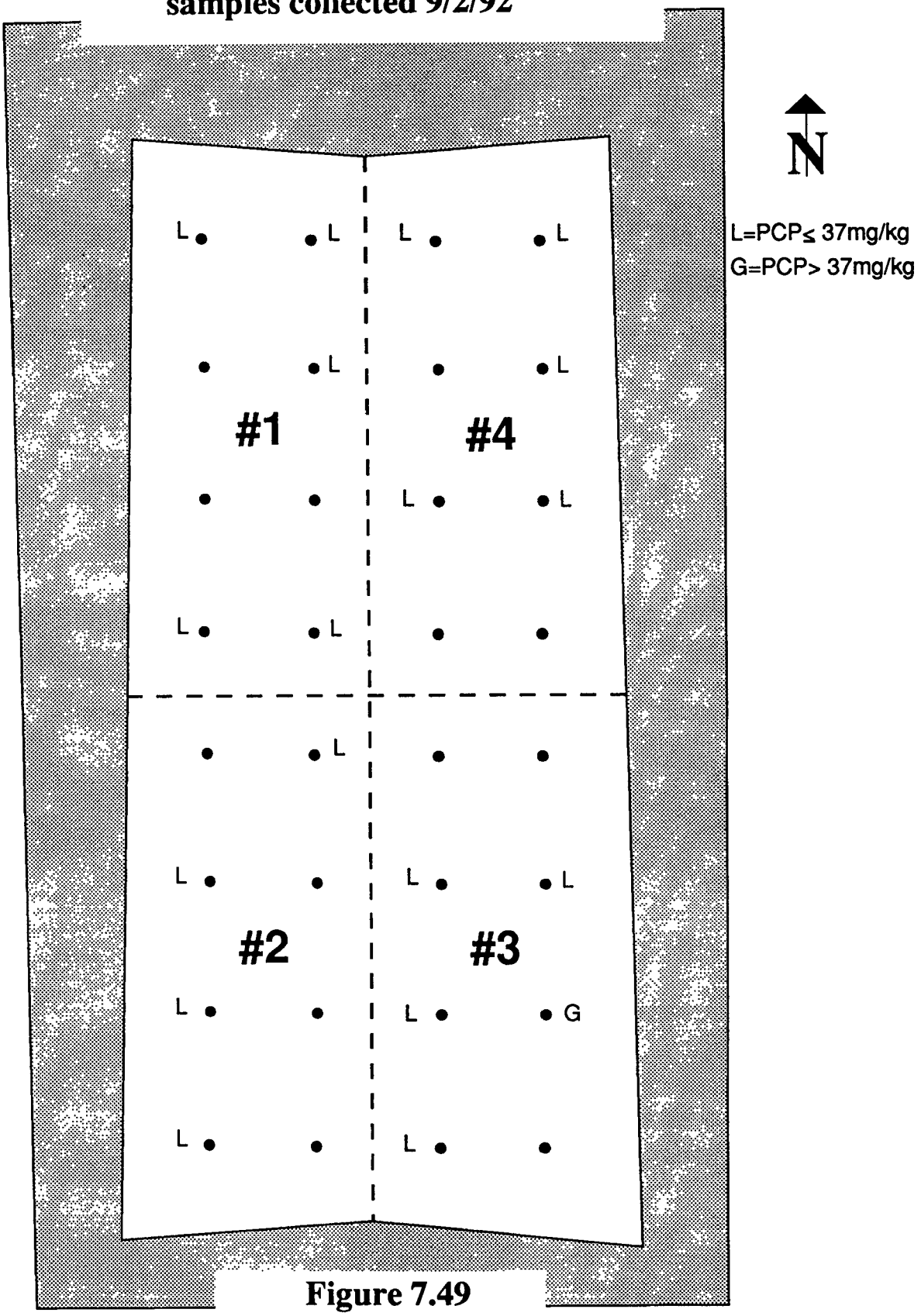

Figure 7.49

PCP concentrations in LTU 2 depth B samples collected 9/2/92

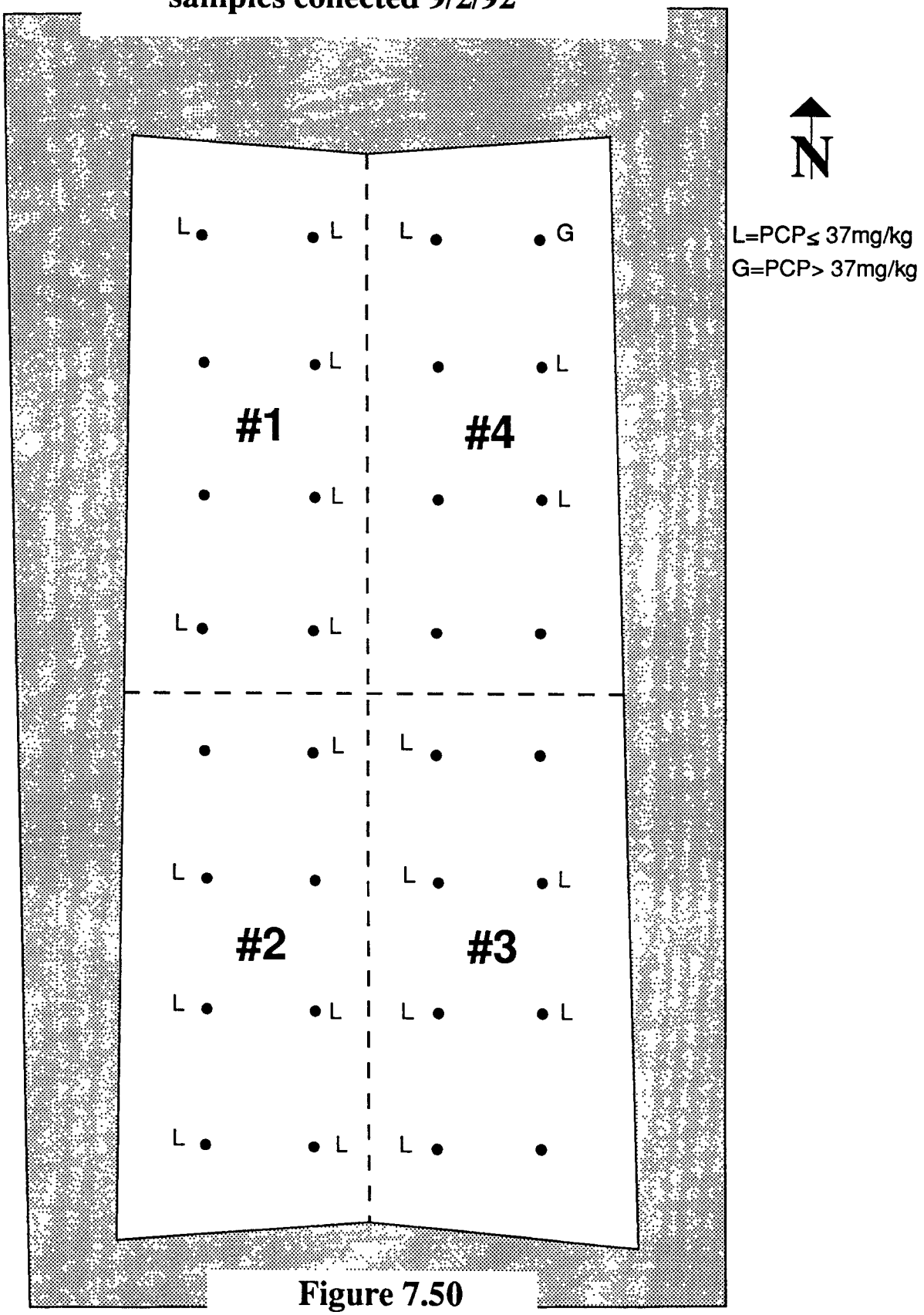

Figure 7.50

PCP concentrations in LTU 1 depth A samples collected 9/18/91

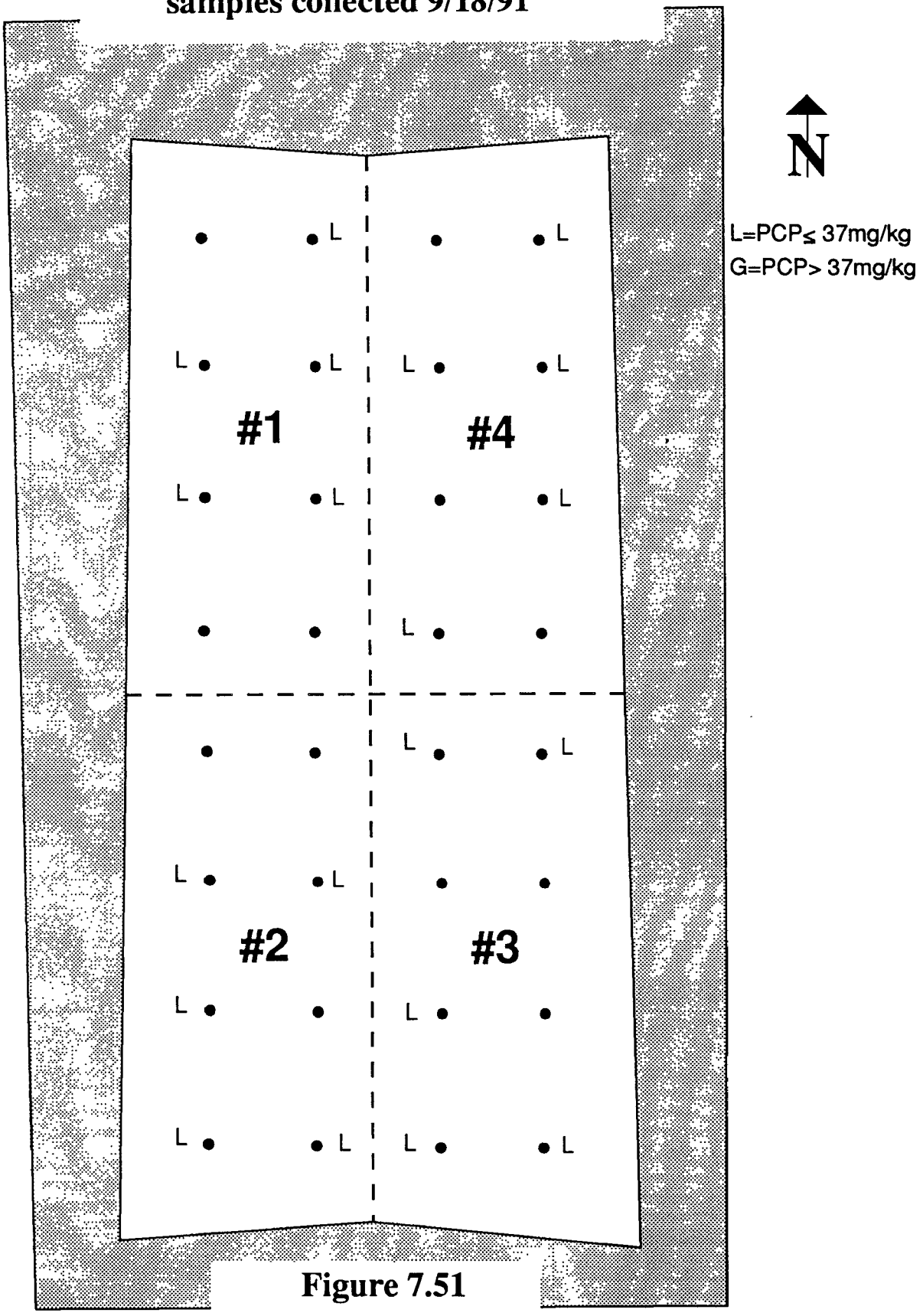

Figure 7.51

PCP concentrations in LTU 1 depth B samples collected 9/18/91

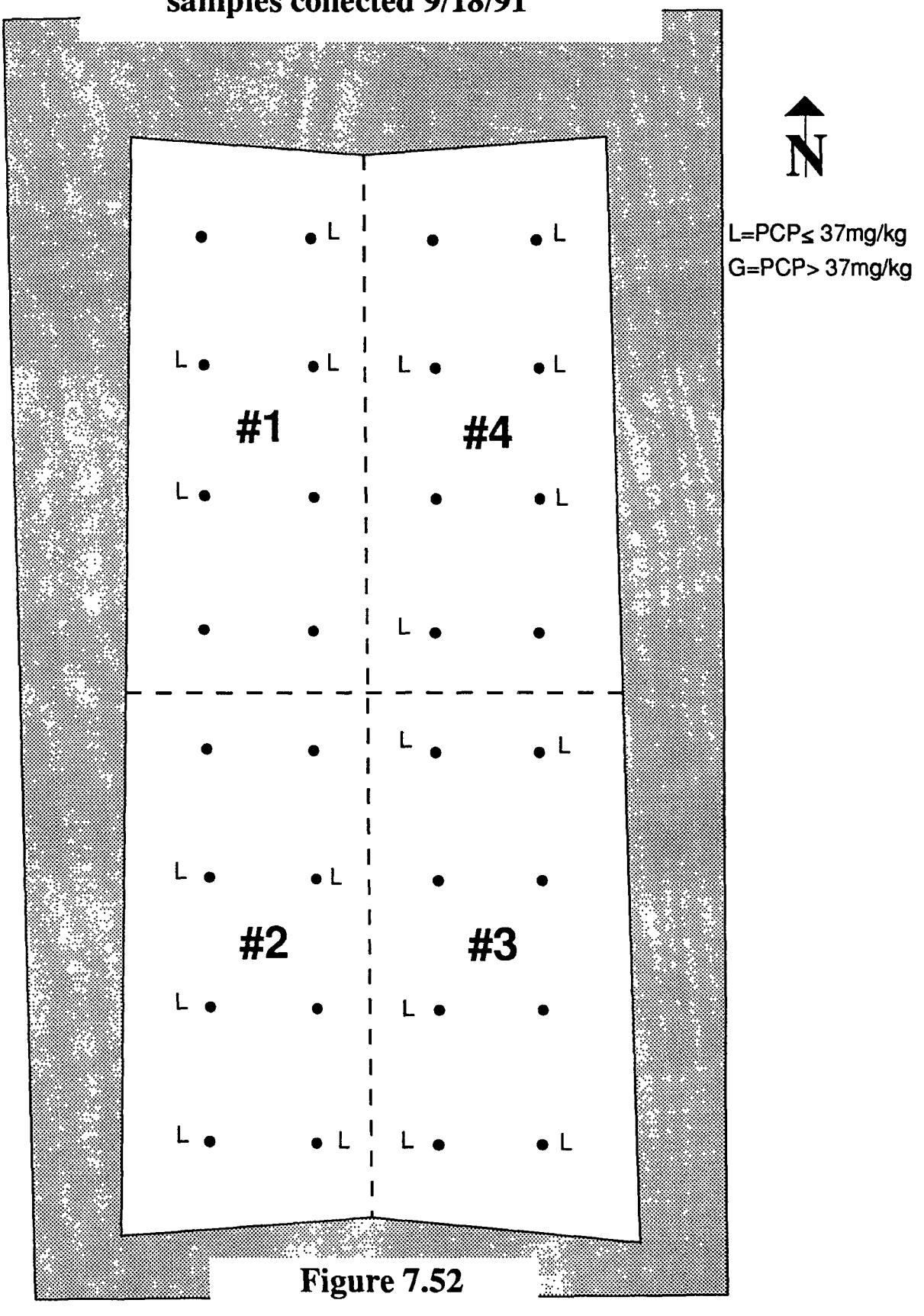

Figure 7.52

PCP concentrations in LTU 1 depth C samples collected 9/18/91

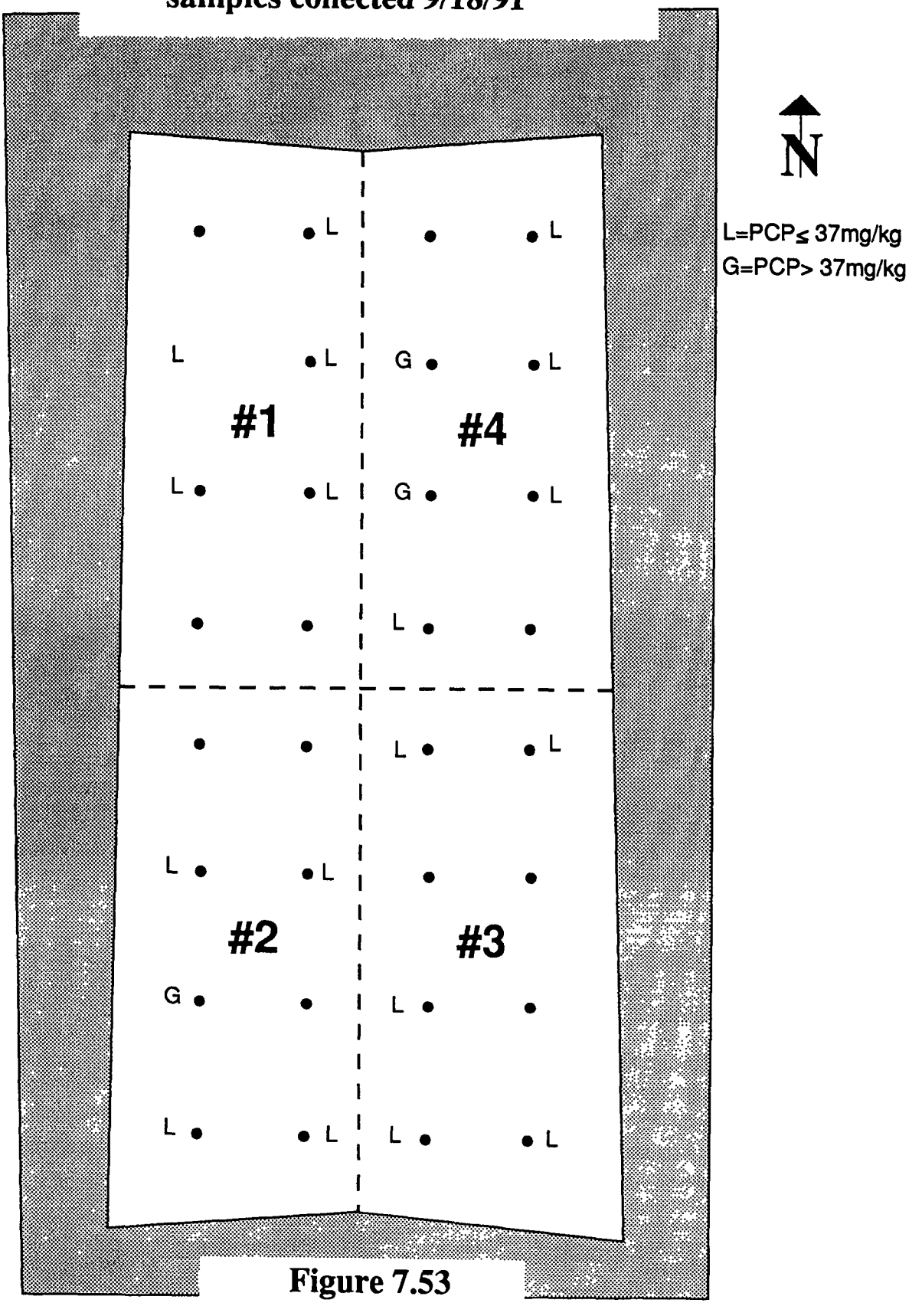

Figure 7.53

PCP concentrations in LTU 1 depth D samples collected 9/18/91

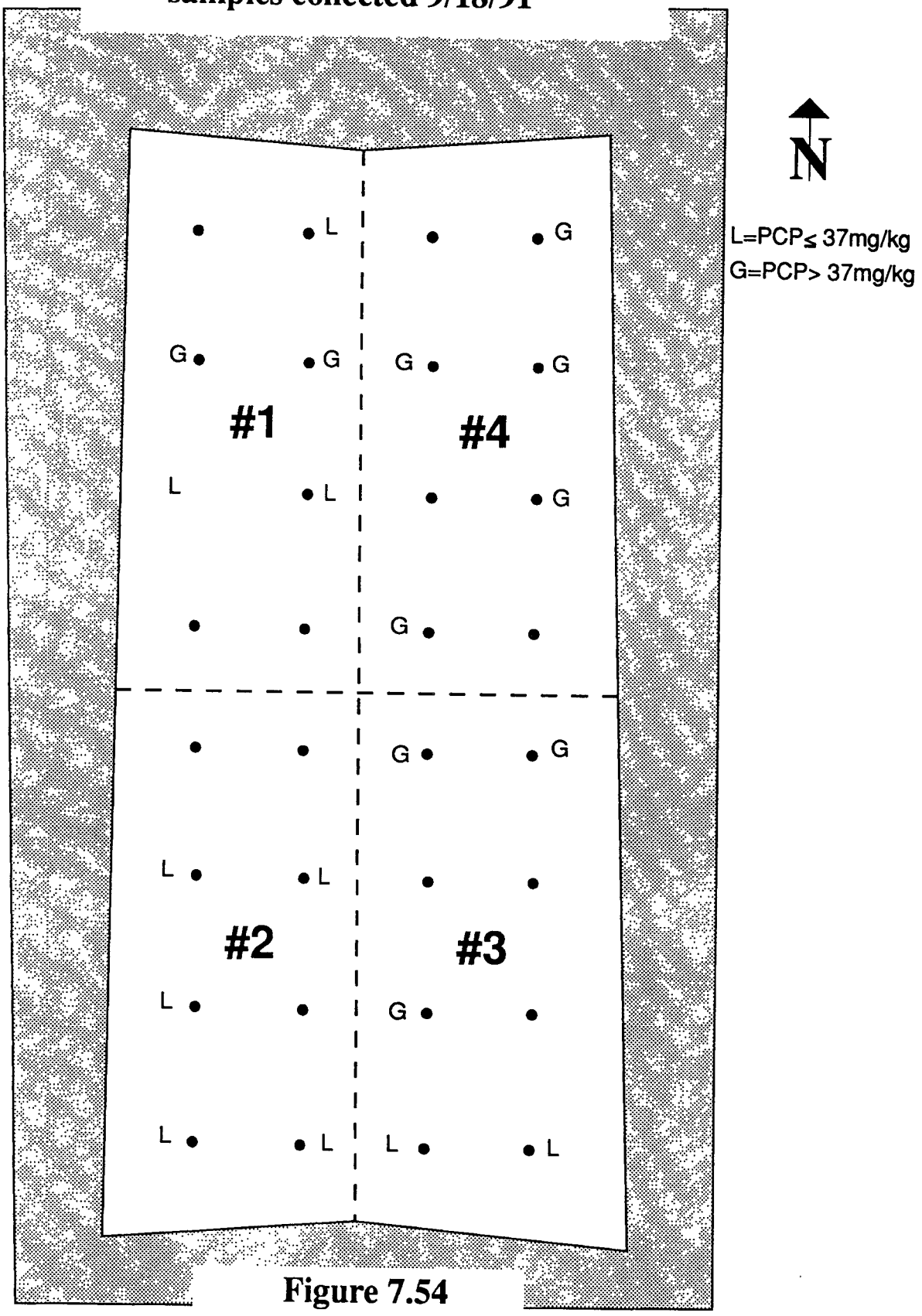

Figure 7.54

PCP concentrations in LTU 2 depth A samples collected 9/19/91

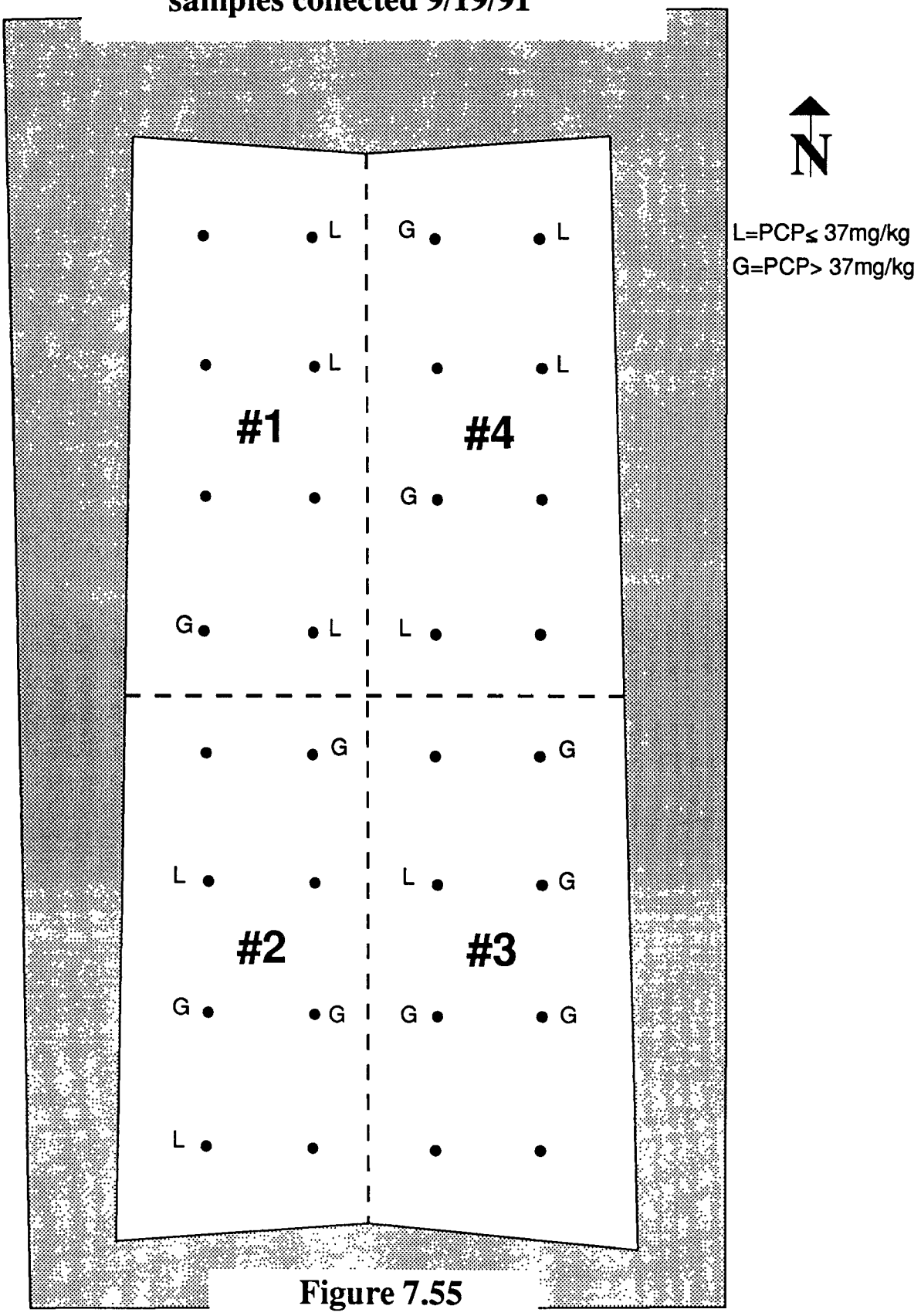

Figure 7.55

PCP concentrations in LTU 1 depth A samples collected 6/27/91

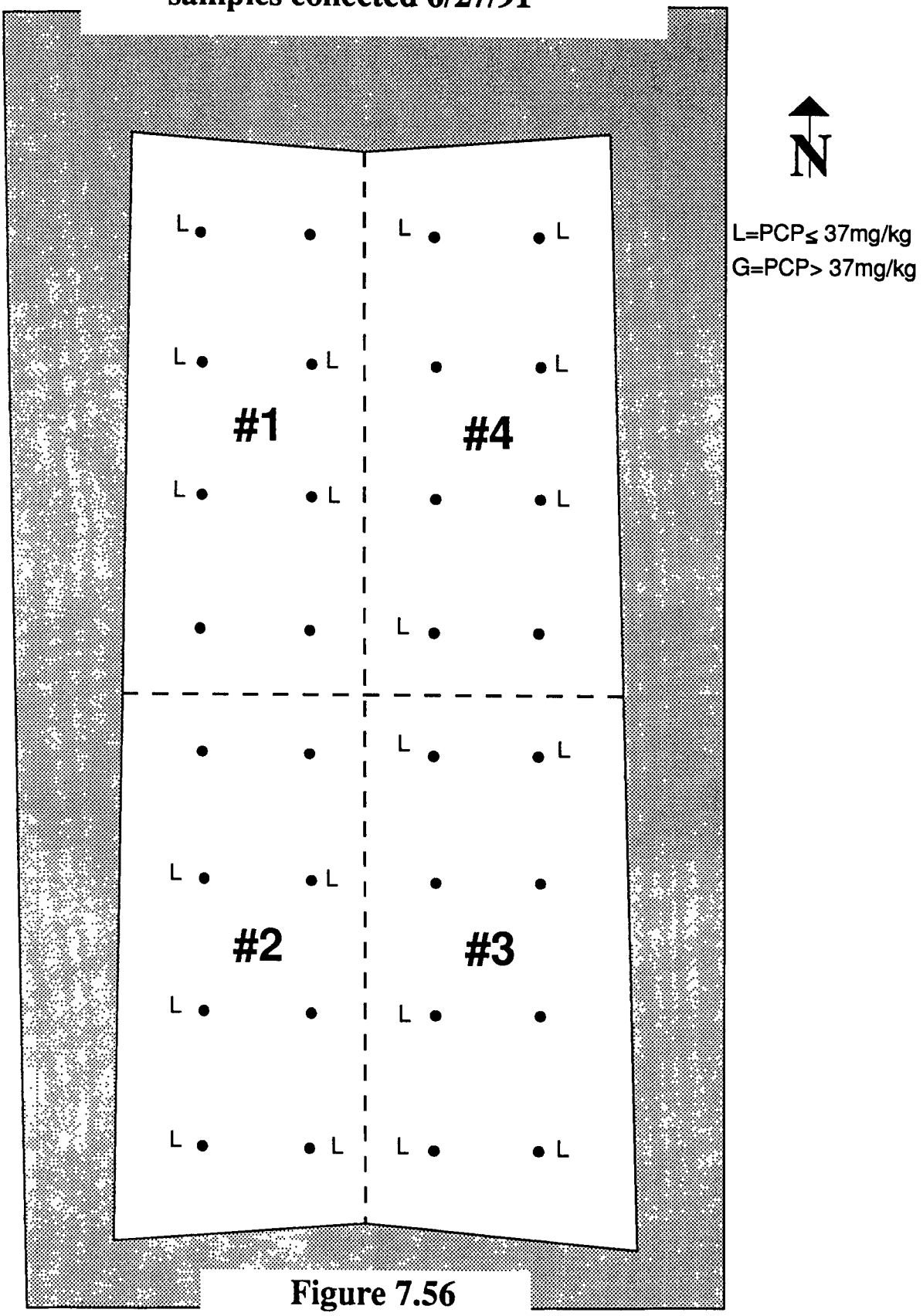

Figure 7.56

PCP concentrations in LTU 1 depth B samples collected 6/27/91

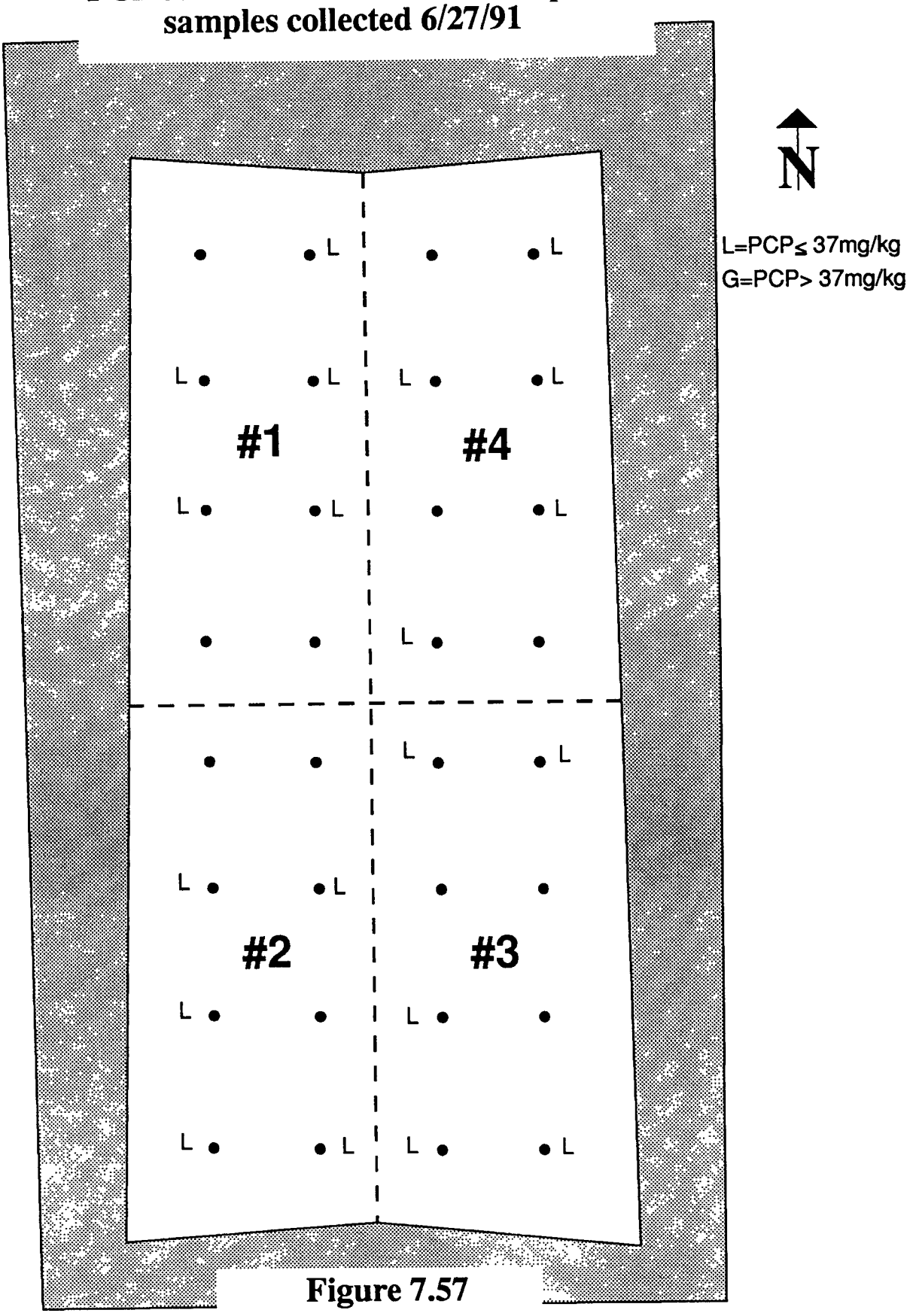

Figure 7.57

PCP concentrations in LTU 1 depth C samples collected 6/27/91

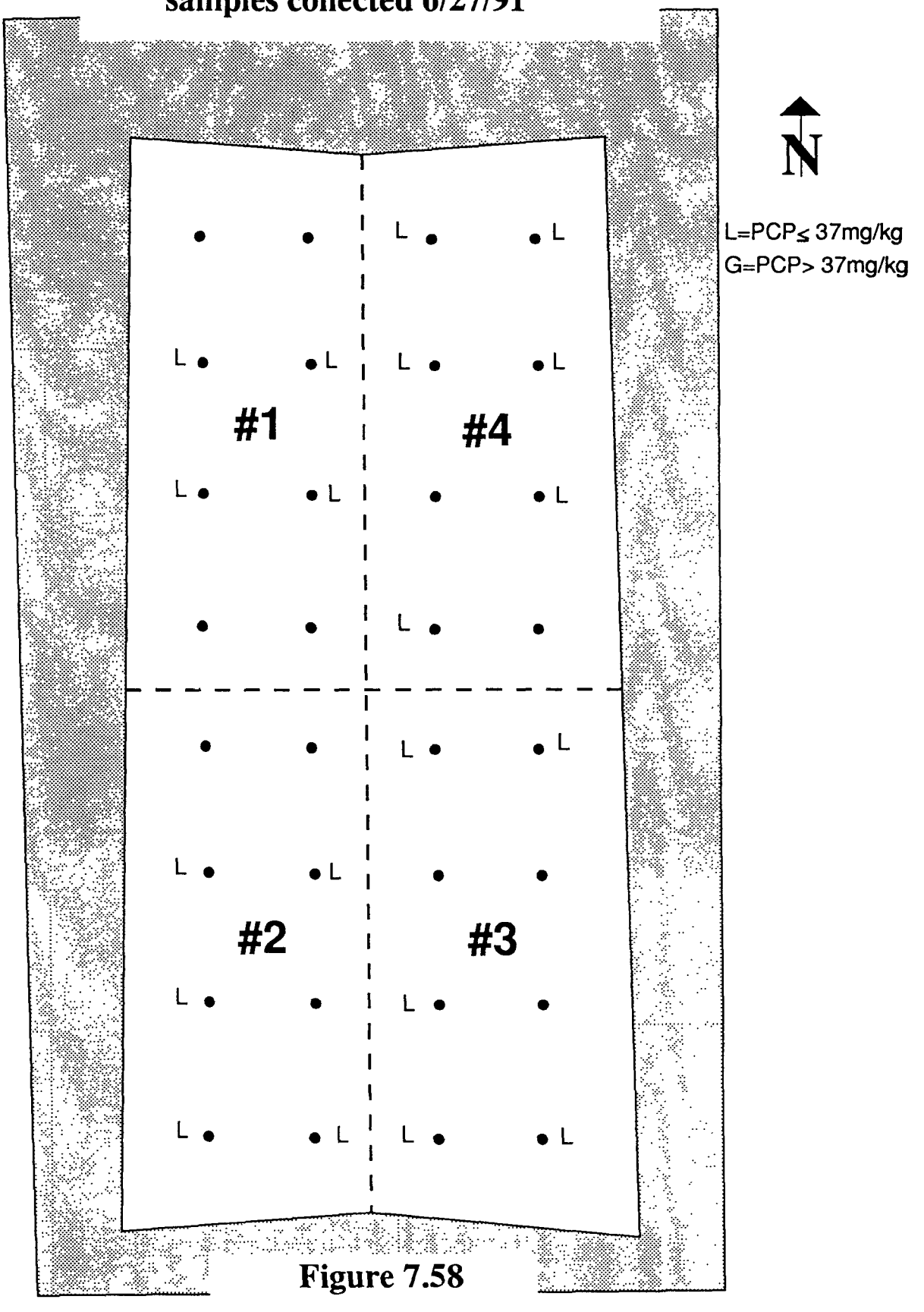

Figure 7.58

PCP concentrations in LTU 1 depth A samples collected 5/6/91

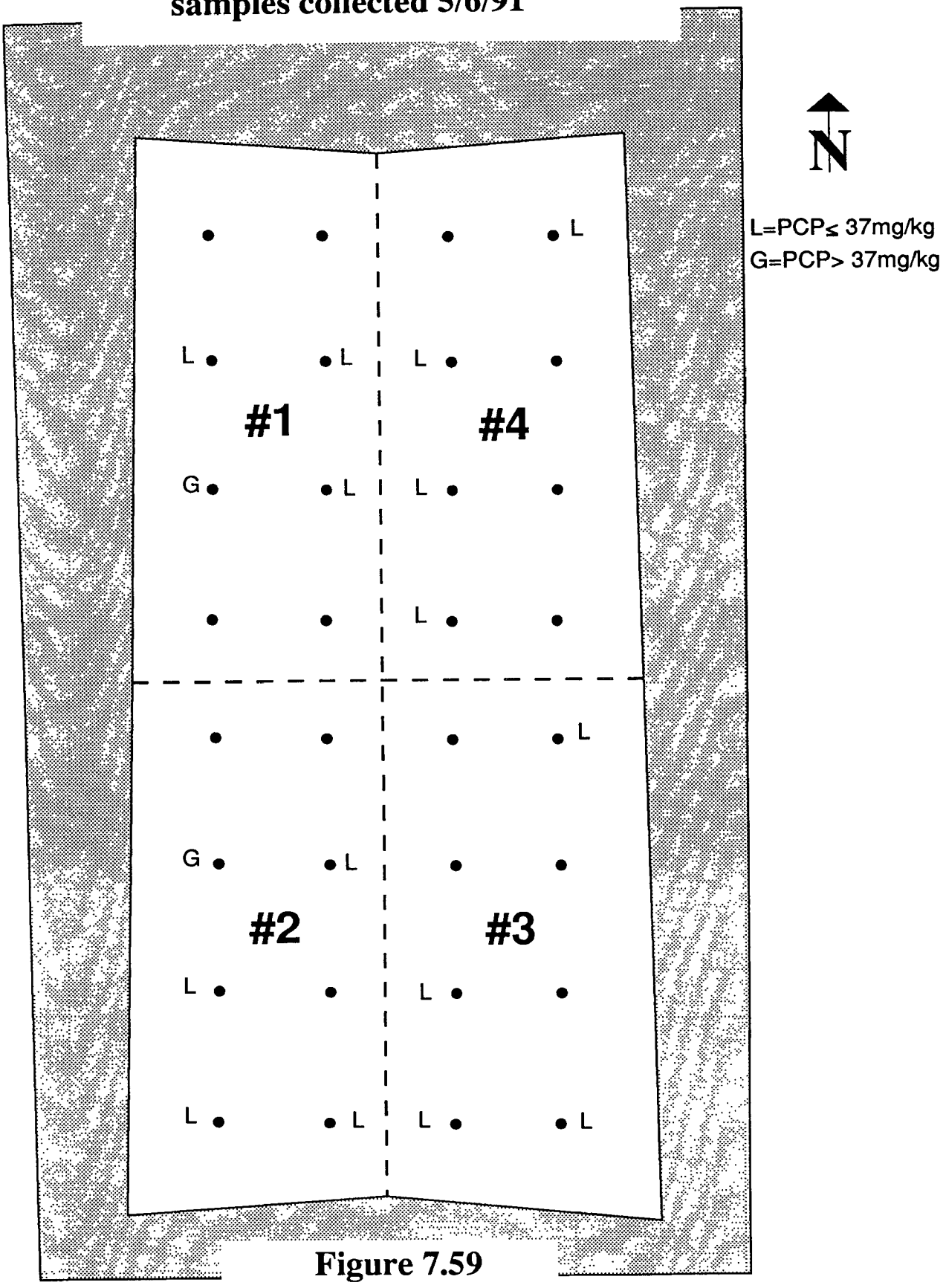

Figure 7.59

PCP concentrations in LTU 1 depth B samples collected 5/6/91

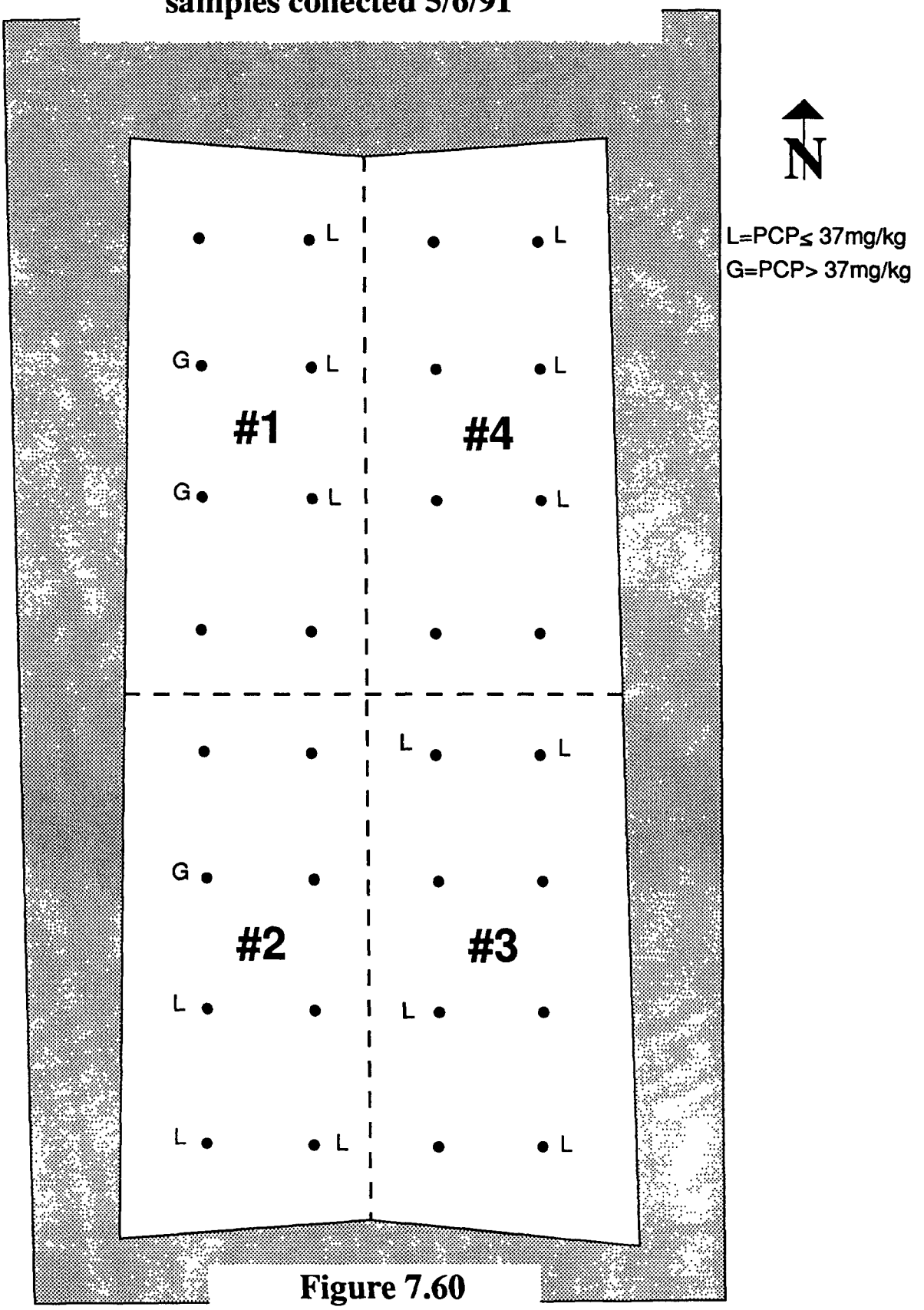

Figure 7.60

Concentrations of O_2 & CO_2 in LTU 1 at depth 1 foot (9/18&19/91)

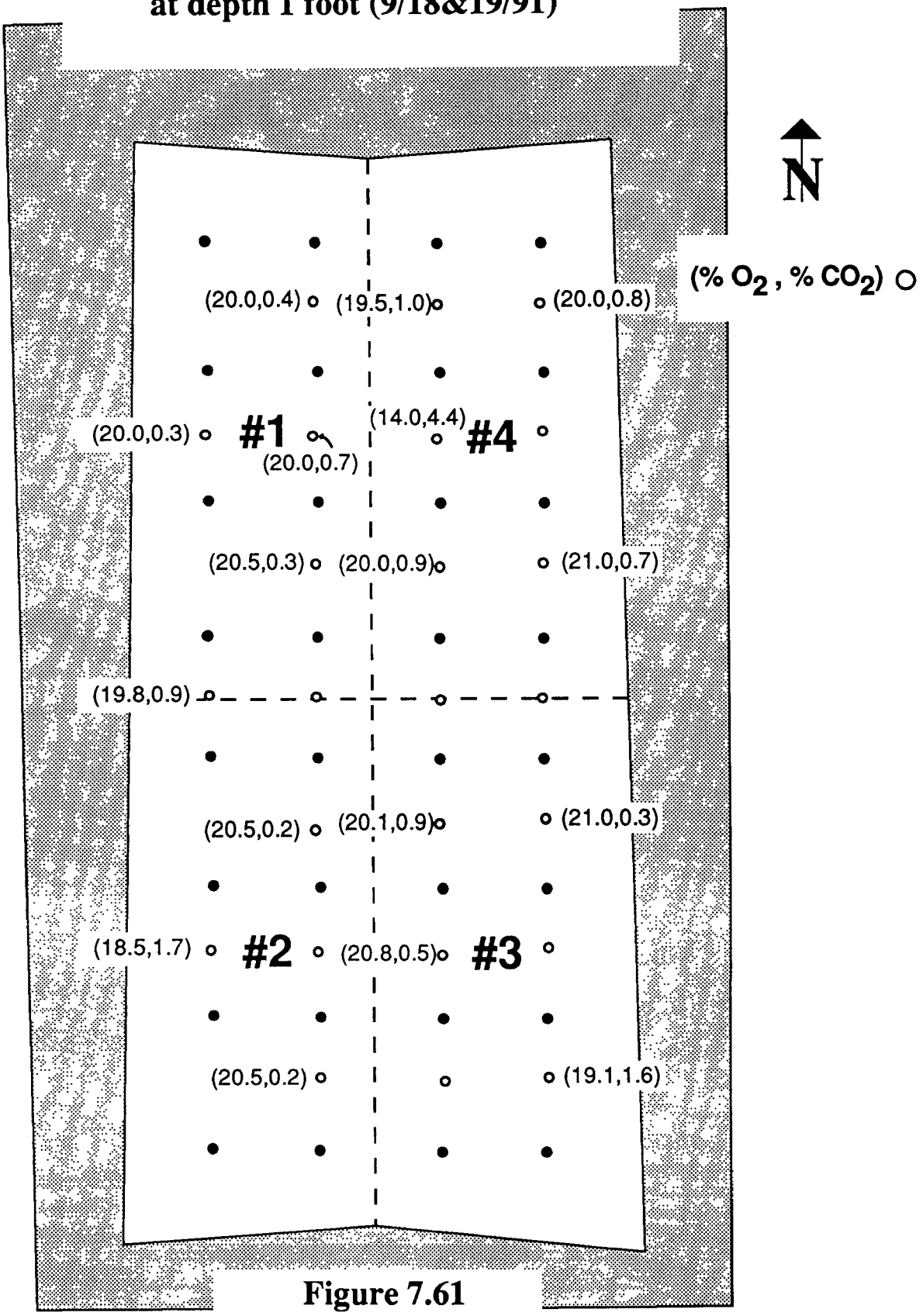

Figure 7.61

Concentrations of O_2 & CO_2 in LTU 1 at depth 2 feet (9/18&19/91)

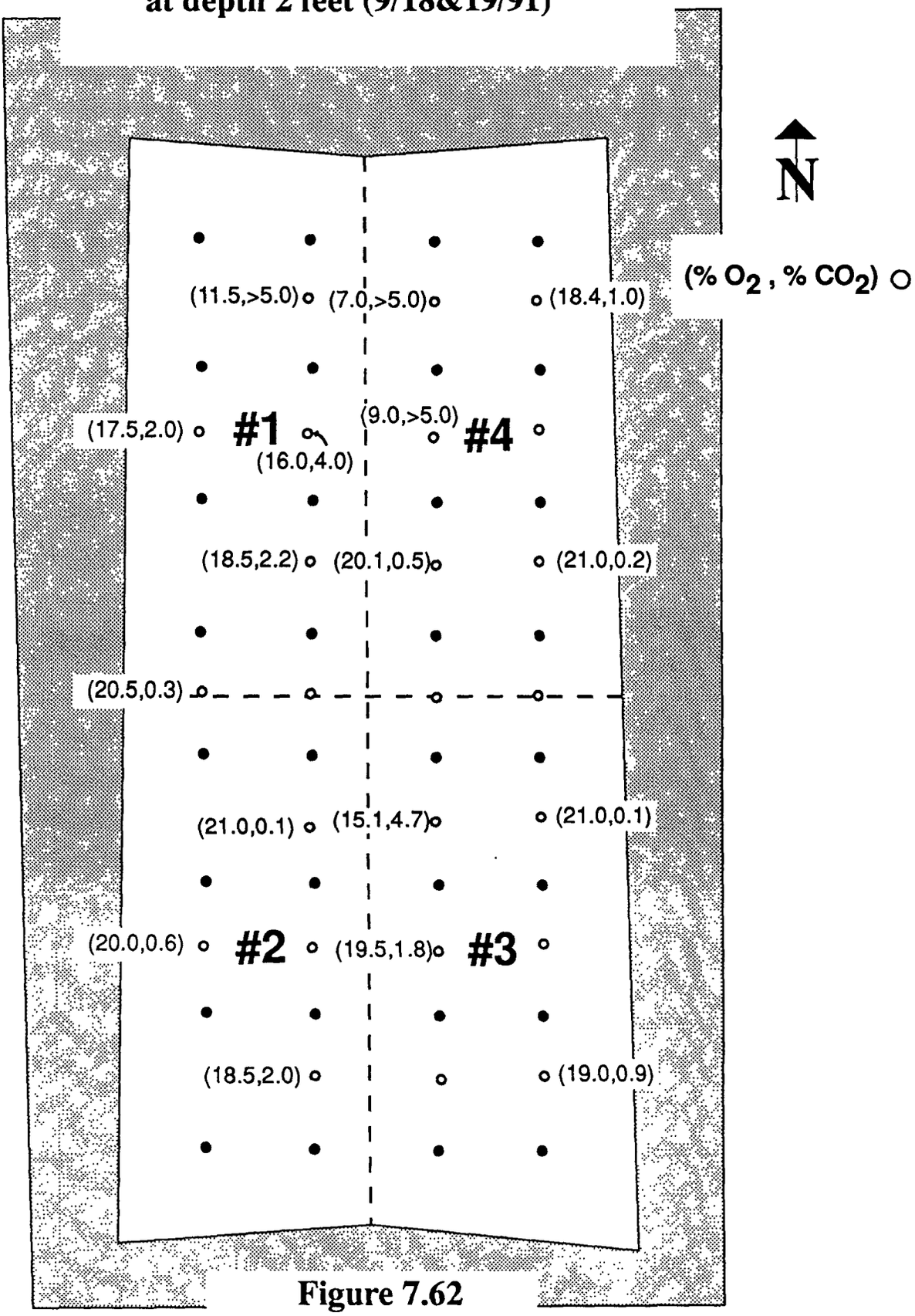

Figure 7.62

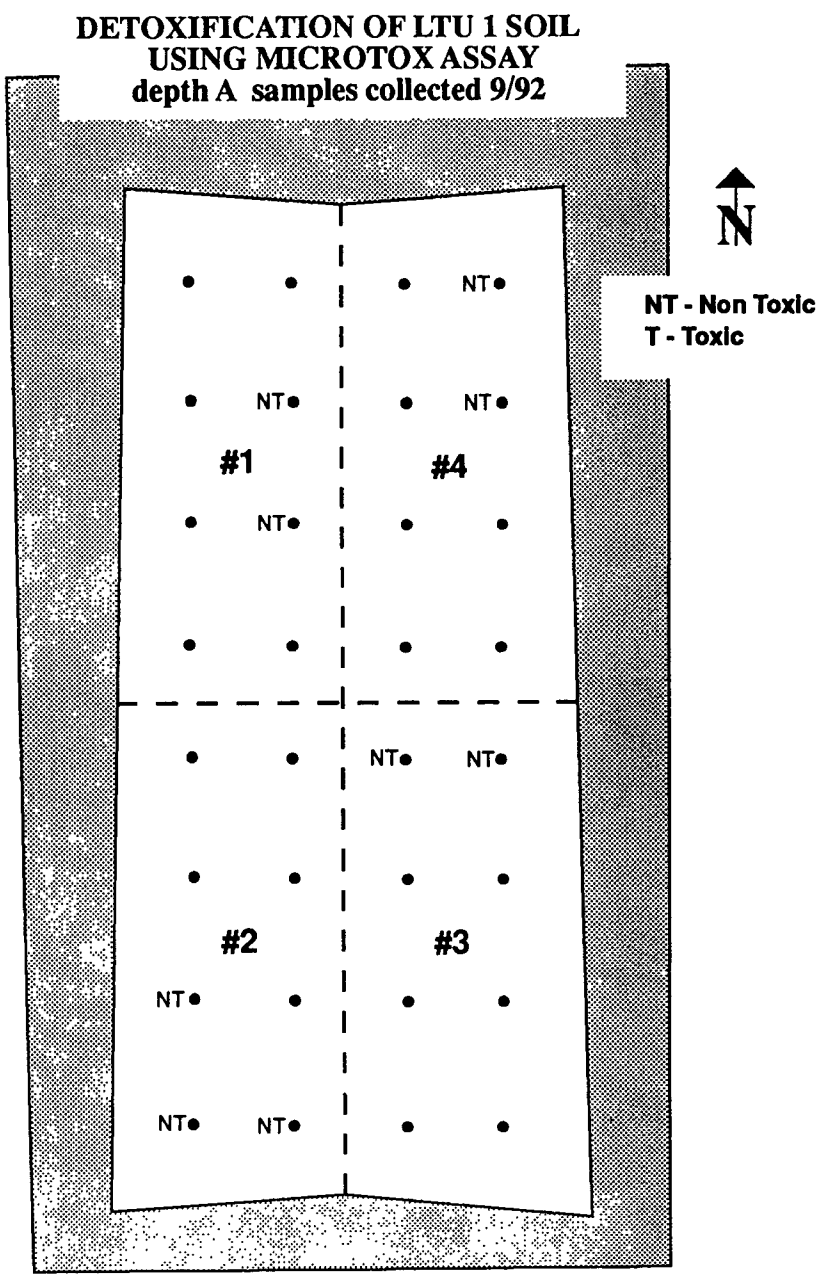

Figure 7.63

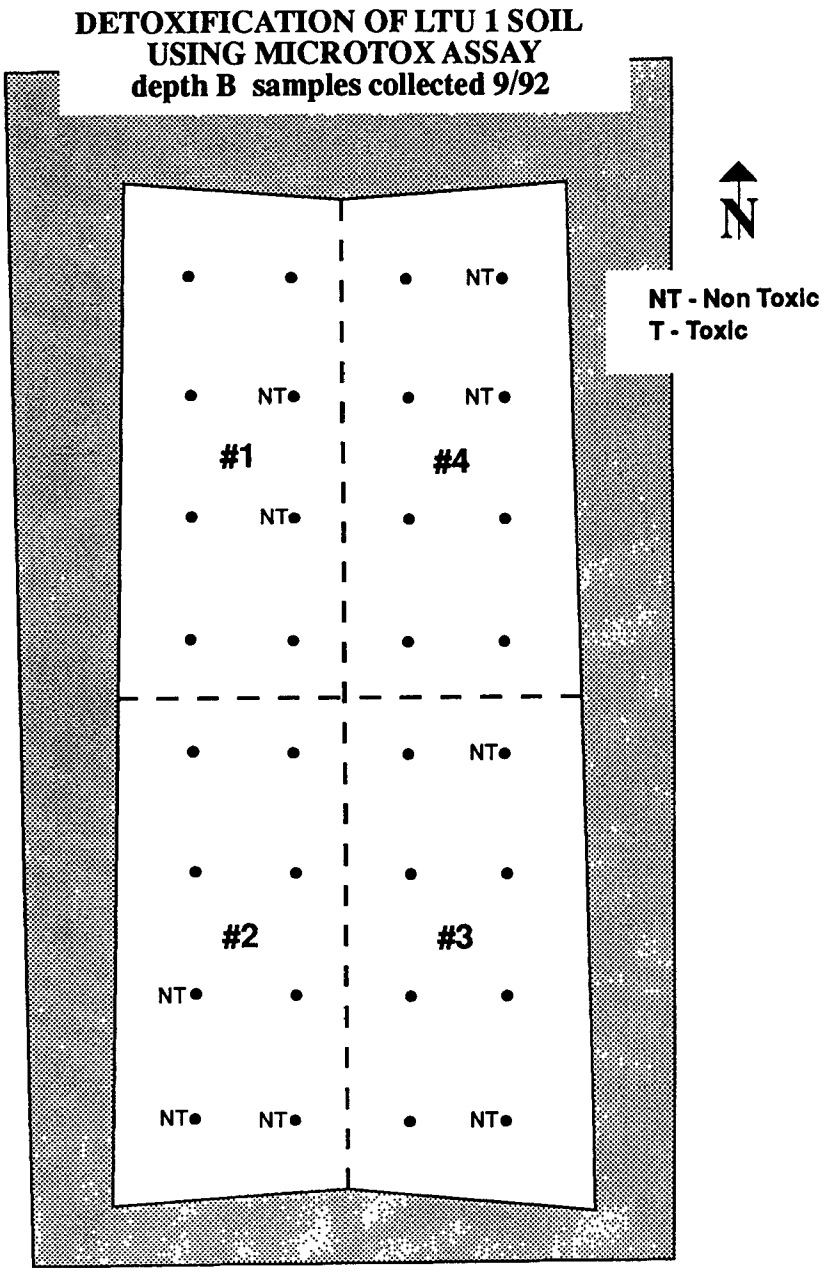

Figure 7.64

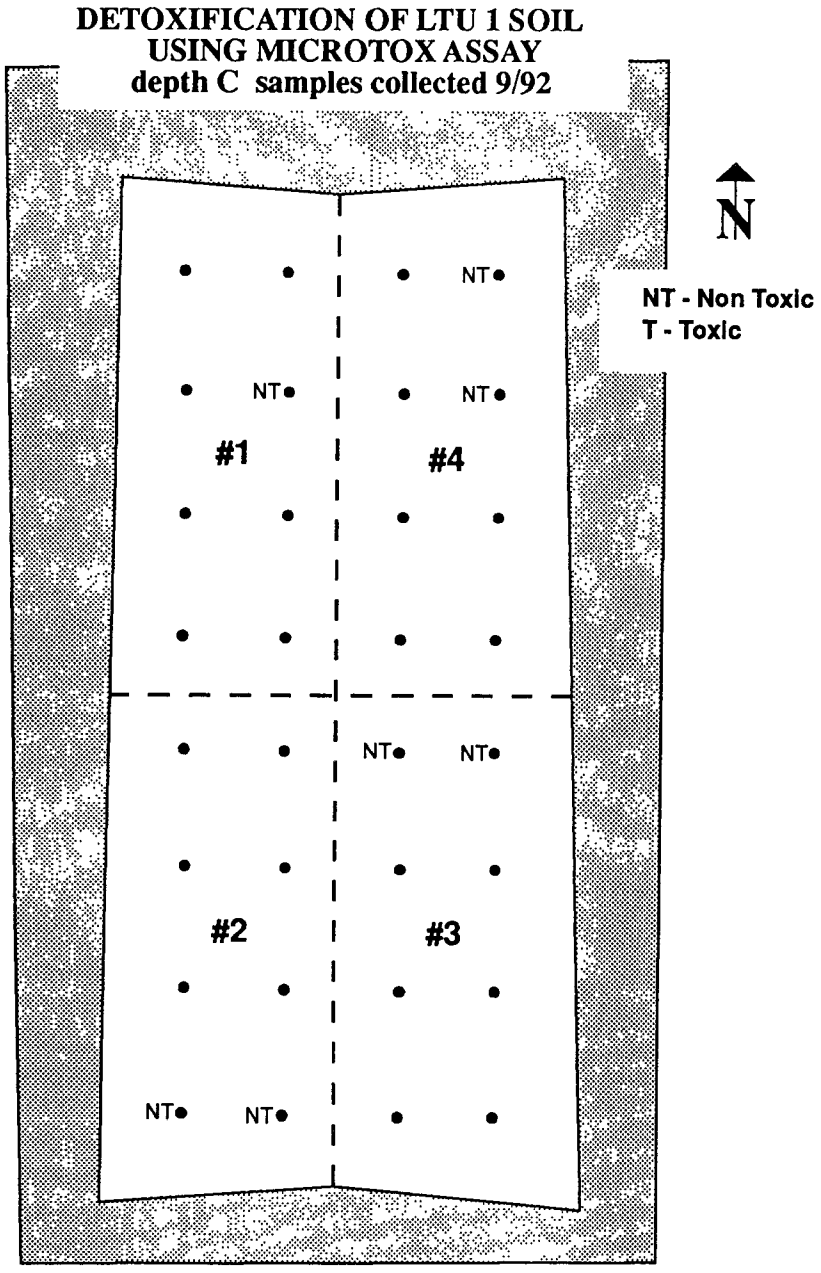

Figure 7.65

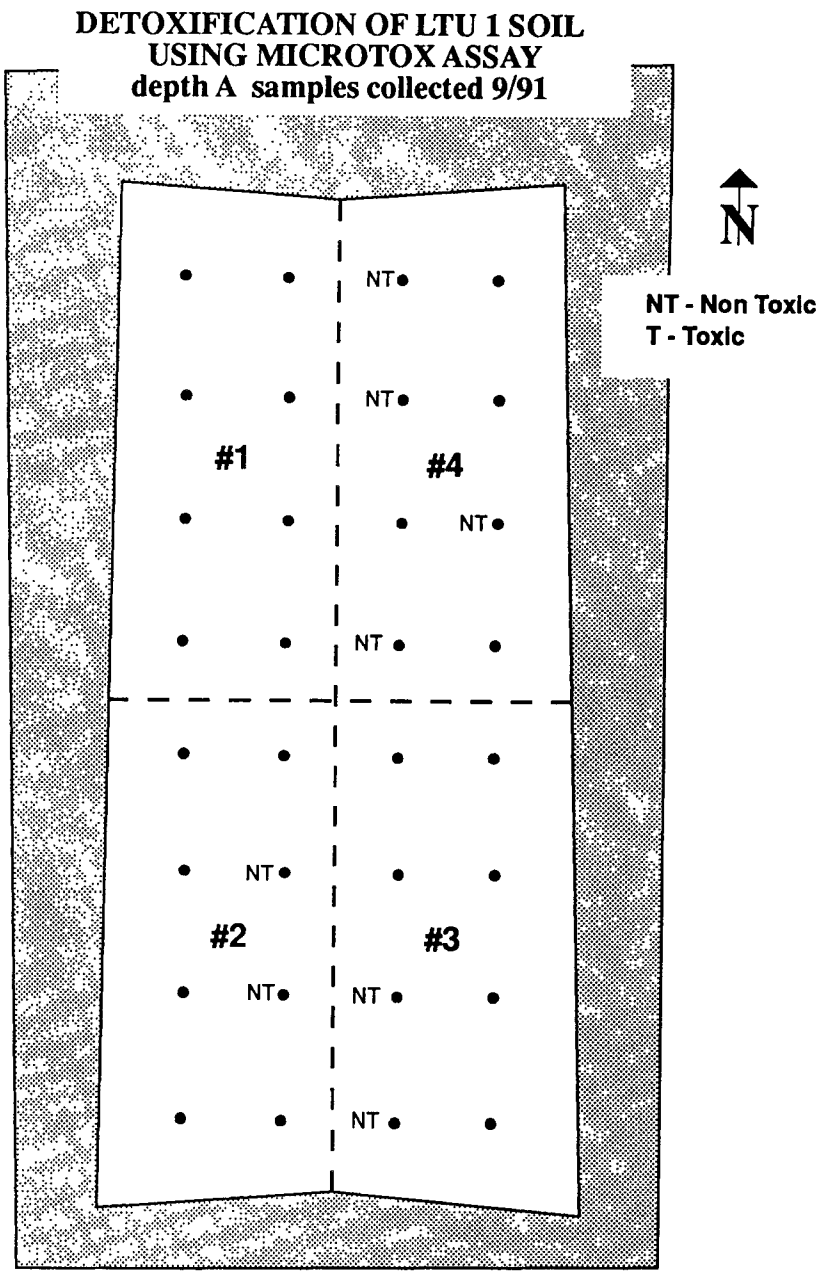

Figure 7.66

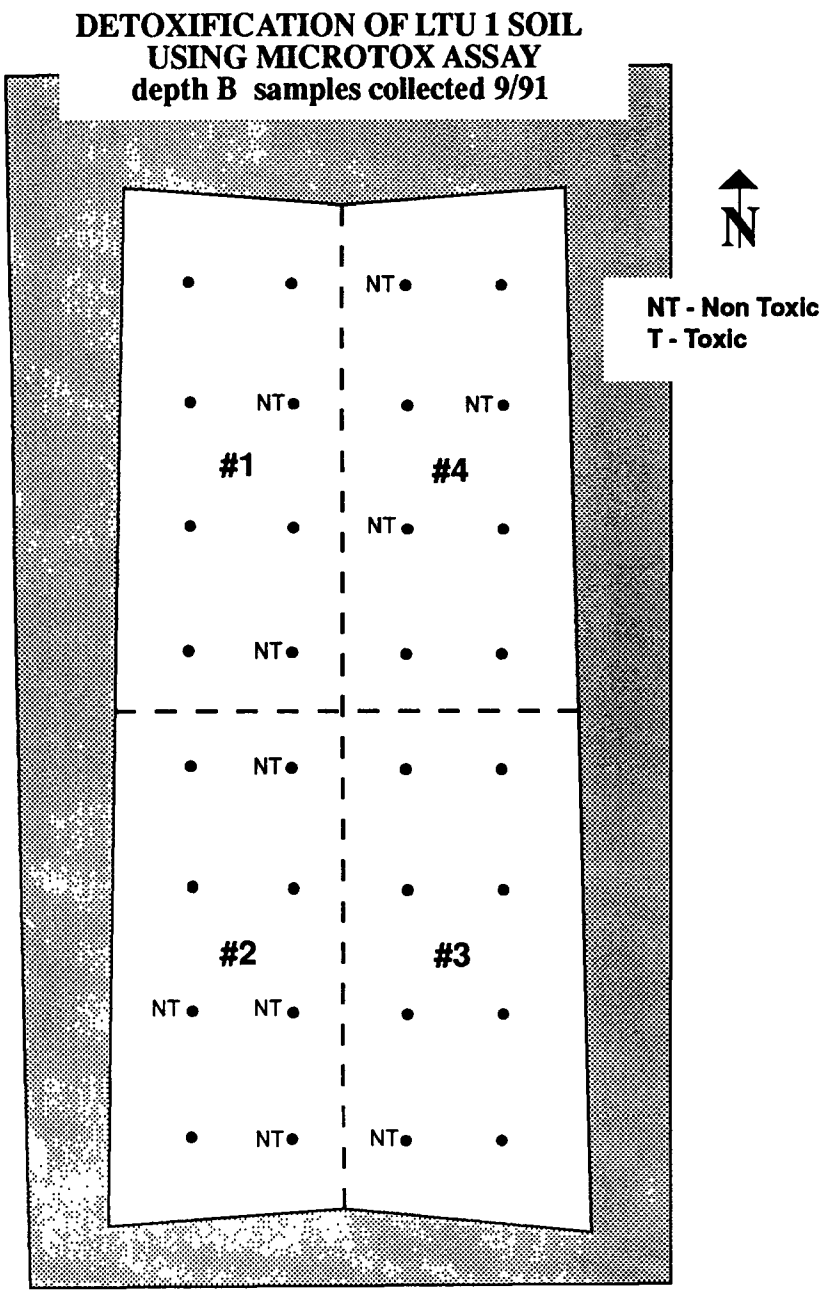

Figure 7.67

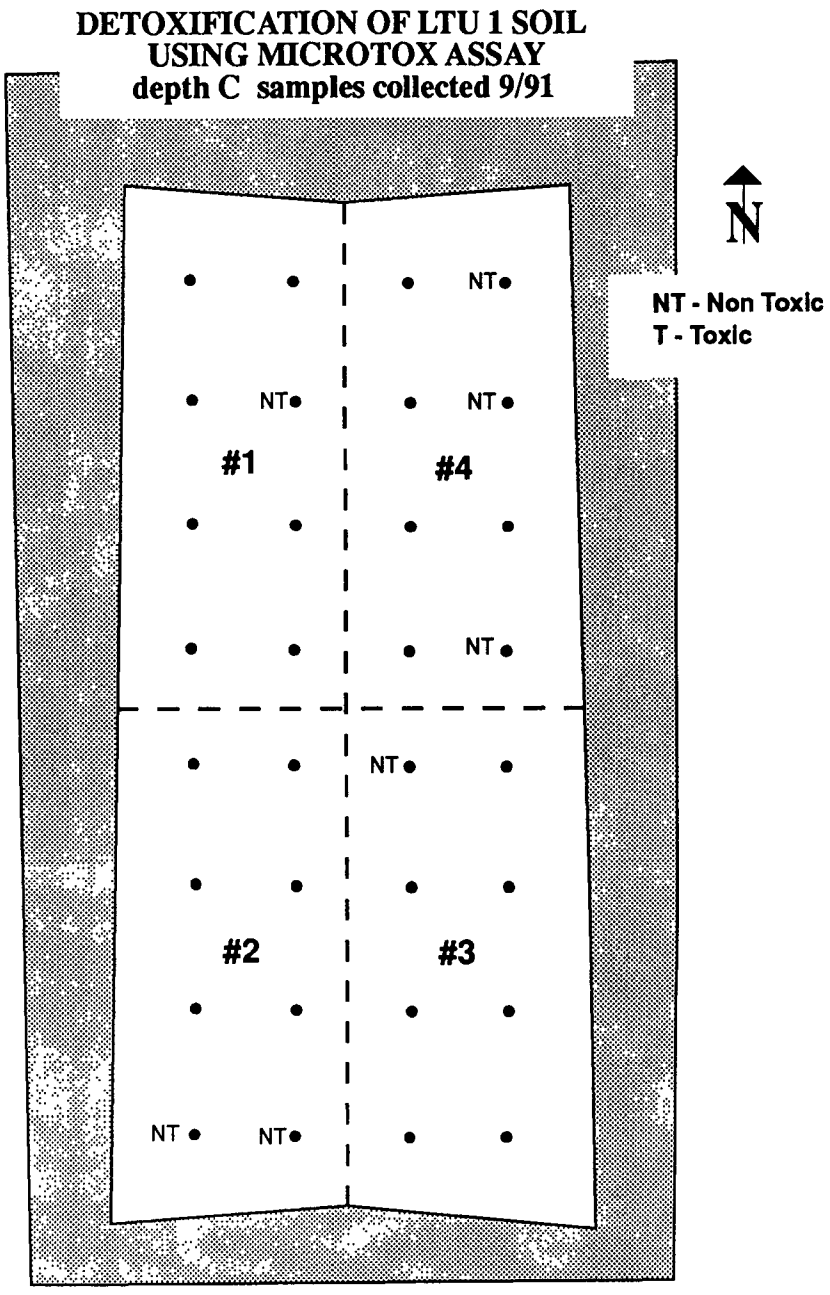

Figure 7.68

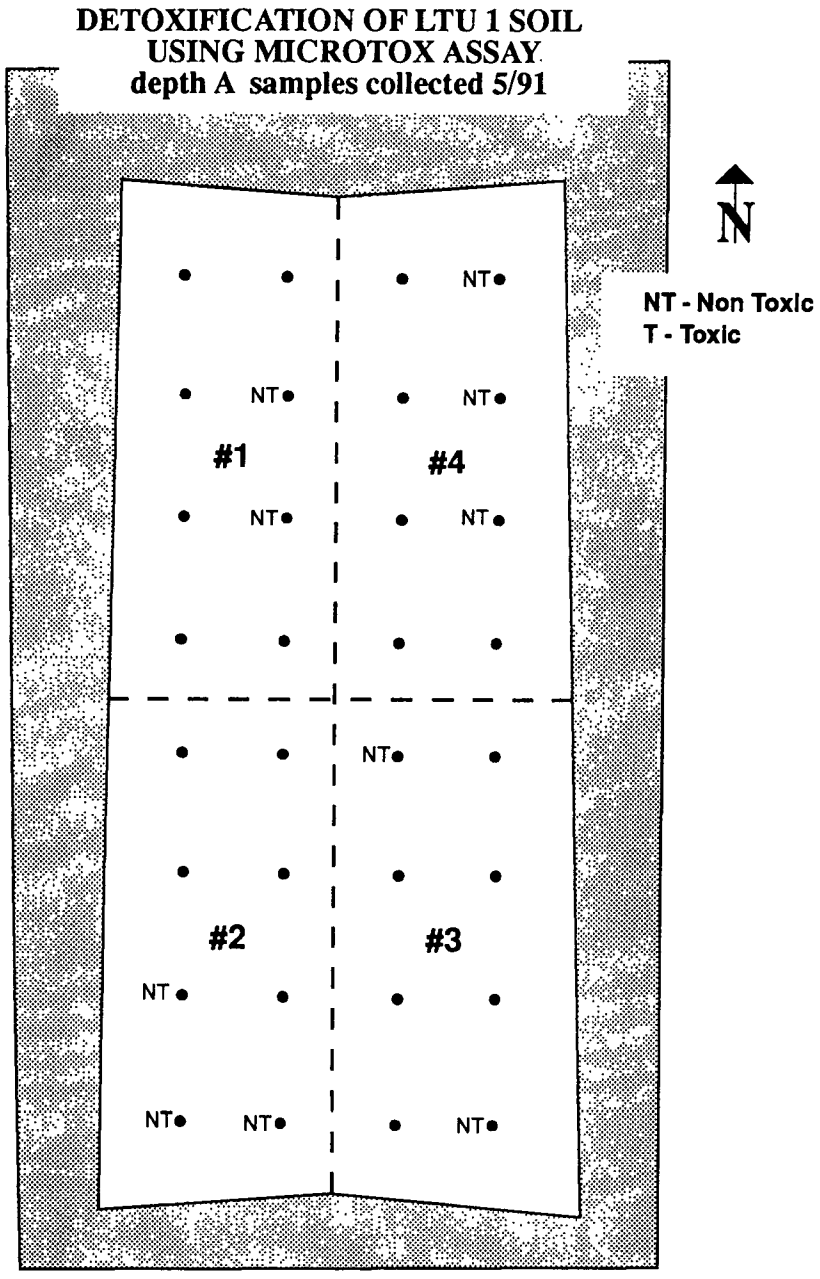

Figure 7.69

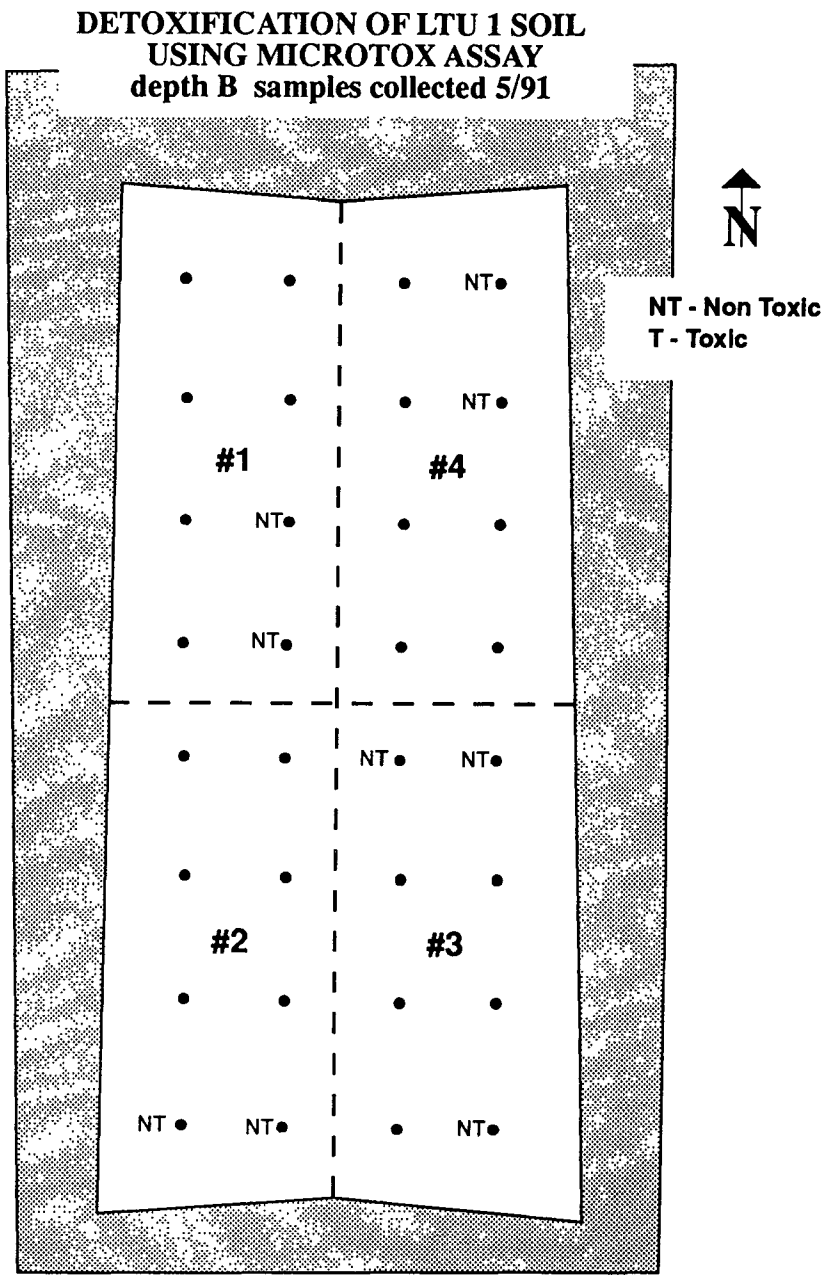

Figure 7.70

Table 7.1. Initial naphthalene and phenanthrene concentrations in LTU 1, depth C samples collected 5/6 & 8/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg)	Phenanthrene (mg/kg)
	Depth C 5/6&8/91	Depth C
2	1.34	<0.95
5	1.24	<0.94
6	1.85	<0.97
10	3.51	1.15
11	3.26	<0.91
12	3.97	1.5
13	12.1	11.0
14	4.76	5.88
15	5.64	5.05
16	10.0	5.67
18	3.03	0.99
20	4.64	3.81
23	10.2	3.08
24	4.49	1.59
25	1.56	<0.95
27	1.44	1.18
28	3.39	2.13
29	1.41	<0.98
30	7.06	2.86
31	4.28	4.13
Mean	4.5	2.5
95% CI for Mean	(3.0-5.9)	(1.2-3.8)
Quad. 1 Mean	6.80	5.50
(95% CI)	(1.4-12.1)	(0.7-10.4)
Quad. 2 Mean	2.80	0.53
(95% CI)	(1.3-4.2)	(0-1.4)
Quad. 3 Mean	4.20	1.60
(95% CI)	(0-8.6)	(0.2-3.0)
Quad. 4 Mean	4.1	2.4
(95% CI)	(1.5-6.7)	(0.1-4.6)

Table 7.2. Initial naphthalene and phenanthrene concentrations in LTU 1, depth D samples collected 7/27/91. The mean and 95 % confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg)	Phenanthrene (mg/kg)
	Depth D 7/27/91	Depth D
2	<0.44	<0.93
3	<0.45	<0.95
6	0.68	<0.93
7	1.34	<0.94
8	0.48	<0.93
9	<0.44	<0.93
11	1.53	<0.94
14	1.99	<0.93
15	1.63	<0.94
16	4.05	<0.95
18	<0.45	<0.94
20	1.16	<0.94
21	0.73	<0.95
23	0.74	<0.93
24	1.35	<0.92
25	<0.45	<0.94
28	0.84	<0.93
30	1.46	<0.93
31	0.99	<0.95
32	2.35	<0.94
Mean	1.1	<0.95
95% CI for Mean	(0.6-1.5)	
Quad. 1 Mean	1.5	<0.95
(95% CI)	(0-3.6)	
Quad. 2 Mean	0.8	<0.95
(95% CI)	(0.03-1.6)	
Quad. 3 Mean	0.7	<0.95
(95% CI)	(0.1-1.3)	
Quad. 4 Mean	1.2	<0.95
(95% CI)	(0.1-2.2)	

Table 7.3. Initial naphthalene and phenanthrene concentrations in LTU 2, depth A samples collected 7/27/91. The mean and 95 % confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg)	Phenanthrene (mg/kg)
	Depth A 7/27/91	Depth A
33	1.47	<0.95
36	1.18	<0.93
38	<0.46	<0.95
39	<0.46	<0.95
40	<0.95	<0.96
42	<0.45	<0.93
44	<0.45	<0.93
45	0.66	<0.95
47	0.55	<0.92
48	3.96	56.5
49	1.14	<0.94
51	1.04	1.01
54	1.03	0.95
55	1.51	1.09
56	1.15	1.50
58	2.44	1.02
59	1.43	1.06
62	3.38	21.3
63	2.74	2.38
64	3.73	2.64
Mean	1.4	4.5
95% CI for Mean	(0.8-2.0)	(0-10.6)
Quad. 1 Mean	1.6	11.3
(95% CI)	(0-3.3)	(0-42.7)
Quad. 2 Mean	<0.46	<0.95
(95% CI)		
Quad. 3 Mean	1.5	1.1
(95% CI)	(0.8-2.2)	(0.9-1.4)
Quad. 4 Mean	2.4	5.5
(95% CI)	(0.8-4.0)	(0-16.6)

Table 7.4. Naphthalene and phenanthrene concentrations in LTU 1, depth A and B samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg) Depth A 9/1/92	Naphthalene (mg/kg) Depth B	Phenanthrene (mg/kg) Depth A 9/1/92	Phenanthrene (mg/kg) Depth B
2	0.98	<0.38	<0.80	<0.80
3	0.85	<0.38	<0.79	<0.79
6	1.05	<0.38	<0.81	<0.80
7	0.94	0.94	<0.81	<0.80
8	1.19	1.00	0.85	<0.81
9	1.53	3.09	1.03	1.60
11	1.40	3.21	0.98	1.60
14	0.86	<0.37	<0.80	<0.78
15	0.66	0.80	<0.81	<0.80
16	1.28	1.04	1.08	0.89
18	0.76	1.34	<0.80	0.82
20	0.91	1.36	0.96	0.94
21	0.86	2.03	0.88	0.95
23	0.96	4.93	0.99	2.59
24	0.66	0.49	<0.81	<0.80
25	0.56	0.50	<0.81	<0.80
28	1.58	1.28	1.68	1.05
30	1.09	1.08	1.05	1.00
31	0.84	0.82	<0.80	<0.79
Mean	1.0	1.3	0.5	0.6
95% CI for Mean	(0.9-1.1)	(0.6-1.9)	(0.2-0.8)	(0.2-1.0)
Quad. 1 Mean	0.9	0.2	0.2	0.2
(95% CI)	(0.6-1.2)	(0-1.0)	(0-8.0)	(0-0.7)
Quad. 2 Mean	1.2	1.6	0.6	0.6
(95% CI)	(0.9-1.4)	(0-3.4)	(0-1.2)	(0-1.7)
Quad. 3 Mean	0.9	1.8	0.7	0.9
(95% CI)	(0.4-1.4)	(0-4.1)	(0-1.6)	(1.3-2.2)
Quad. 4 Mean	0.9	1.2	0.5	0.7
(95% CI)	(0.7-1.1)	(0.7-1.6)	(0-1.4)	(0-1.4)

Table 7.5. Naphthalene and phenanthrene concentrations in LTU 1, depth C and D samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg)	Naphthalene (mg/kg)	Phenanthrene (mg/kg)	Phenanthrene (mg/kg)
	Depth C 9/1/92	Depth D	Depth C 9/1/92	Depth D
2	<0.37	0.79	<0.78	<0.80
3	0.85	1.96	<0.80	1.12
6	0.94	2.51	<0.79	1.59
7	1.30	1.63	0.88	1.01
8	1.67	2.95	1.16	1.68
9	4.85	5.28	1.49	2.44
11	1.53	1.71	0.97	0.83
14	<0.38	1.13	<0.79	1.00
15	0.84	1.38	<0.80	0.99
16	1.15	1.02	0.94	<0.80
18	0.96	1.18	0.88	0.90
20	1.79	1.69	1.26	0.96
21	2.04	1.84	1.44	1.65
23	2.74	3.51	2.30	2.55
24	3.89	2.32	<0.80	<0.80
25		2.41		1.38
28	2.02	2.75	1.24	1.32
30	<0.38	1.45	<0.80	<0.81
31	<0.38	1.24	<0.80	<0.79
Mean	1.5	2.0	0.7	1.0
95% CI for Mean	(0.8-2.0)	(1.5-2.5)	(0.3-1.0)	(0.6-1.4)
Quad. 1 Mean	0.6	1.3	0.2	0.6
(95% CI)	(0-1.2)	(0.7-1.8)	(0-0.7)	(0-1.3)
Quad. 2 Mean	2.1	2.8	0.9	1.5
(95% CI)	(0.1-4.0)	(1.0-4.7)	(0.2-1.6)	(0.7-2.3)
Quad. 3 Mean	2.7	2.2	1.2	1.0
(95% CI)	(1.3-4.1)	(1.4-2.9)	(0-2.8)	(0.1-1.9)
Quad. 4 Mean	0.7	1.4	0.5	0.5
(95% CI)	(0-2.1)	(1.0-1.8)	(0-1.5)	(0-1.3)

Table 7.6. Naphthalene and phenanthrene concentrations in LTU 1, depth E samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg)	Phenanthrene (mg/kg)
	Depth E 9/1/92	Depth E
2	1.36	1.01
3	1.87	1.00
6	3.90	1.69
7	7.61	2.60
8	4.63	1.62
9	10.2	3.79
11	<0.38	0.85
14	1.42	1.02
15	1.87	0.90
16	1.41	0.91
18	1.97	1.18
20	2.23	1.09
21	1.42	1.60
23	1.86	<0.78
24	9.97	9.11
25	5.08	2.43
30	2.37	<0.80
Mean	3.5	1.8
95% CI for Mean	(1.9-5.1)	(0.7-2.9)
Quad. 1 Mean	1.6	1.0
(95% CI)	(1.3-1.9)	(0.9-1.0)
Quad. 2 Mean	5.3	2.1
(95% CI)	(0.5-10.1)	(0.7-3.5)
Quad. 3 Mean	4.6	3.3
(95% CI)	(0-10.9)	(0-9.7)
Quad. 4 Mean	2.2	0.8
(95% CI)	(1.7-2.7)	(0-2.4)

Table 7.7. Naphthalene and phenanthrene concentrations in LTU 2, depth A and B samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg)	Naphthalene (mg/kg)	Phenanthrene (mg/kg)	Phenanthrene (mg/kg)
	Depth A 9/1/92	Depth B	Depth A 9/1/92	Depth B
45	2.47	2.29	<0.81	0.82
47	3.06	2.85	1.66	1.90
48	1.96	1.65	1.78	<0.82
49	3.92		0.99	
51	3.31	5.12	<0.81	<0.81
54	0.71	2.27	<0.80	1.04
55	2.05	2.33	0.94	<0.81
56	4.65	2.76	1.70	0.81
58	1.80	2.36	<0.82	<0.80
59	2.84	1.12	7.04	<0.80
62	1.51	1.43	1.12	0.87
63	1.43	1.59	1.41	<0.80
64	1.51	1.90	<0.80	<0.81
Mean	2.4	2.3	1.3	0.5
95% CI for Mean	(1.7-3.1)	(1.7-3.0)	(0.1-2.4)	(0.1-0.9)
Quad. 1 Mean	2.5	2.3	1.1	0.9
(95% CI)	(1.1-3.9)	(0.8-3.8)	(0-3.6)	(0-3.3)
Quad. 3 Mean	2.4	2.2	1.9	0.4
(95% CI)	(0.6-4.2)	(1.4-2.9)	(0-5.6)	(0-1.0)
Quad. 4 Mean	2.3	2.5	0.7	0.2
(95% CI)	(0.9-3.8)	(-0.3-5.3)	(0-1.5)	(0-5.3)

Table 7.8. Naphthalene and phenanthrene concentrations in LTU 1, depth A and B samples collected 9/18 & 19/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg) Depth A 9/18&19/91	Naphthalene (mg/kg) Depth B	Phenanthrene (mg/kg) Depth A 9/18&19/91	Phenanthrene (mg/kg) Depth B
2	2.83	0.71	1.79	<0.96
3		<0.45		<0.93
6	<0.48	<0.47	<1.00	<0.98
7	<0.49	<0.47	<1.02	<1.00
8	<0.48	<0.47	<0.99	<0.97
9	<0.49	<0.47	<1.00	<0.98
11	1.19	<0.46	3.91	<0.95
14	<0.47		<0.98	
15	<0.47	<0.47	<1.01	1.15
16	0.79	2.57	1.49	23.2
18	<0.46	<0.48	1.04	<0.99
20	<0.46	<0.46	1.65	<0.96
21	<0.46	0.57	<0.97	<0.95
23	<0.47	<0.48	<0.98	<1.00
24	0.49	0.51	<1.00	<0.98
25	<0.47	0.52	<0.98	<0.98
28	0.48	0.50	<0.96	<0.97
30	0.56	0.58	<0.98	<1.00
31	0.59	0.69	1.00	<0.97
32	1.02	0.98	<1.03	<0.99
Mean	0.40	0.4	0.60	1.2
95 % CI for Mean	(0.1-0.8)	(0.1-0.7)	(0.1-1.1)	(0-3.6)
Quad. 1 Mean	0.9	0.8	0.8	6.1
(95% CI)	(0-3.0)	(0-2.8)	(0-2.3)	(0-24.2)
Quad. 2 Mean	0.2	<0.5	0.8	<1.0
(95% CI)	(0-0.9)		(0-3.0)	
Quad. 3 Mean	0.2	0.4	<1.0	<1.0
(95% CI)	(-0.1-0.5)	(0.1-0.7)		
Quad. 4 Mean	0.4	0.5	0.7	<1.0
(95% CI)	(0-1.0)	(0-1.0)	(0-1.6)	

Table 7.9. Naphthalene and phenanthrene concentrations in LTU 1, depth C and D samples collected 9/18 & 19/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg) Depth C 9/18&19/91	Naphthalene (mg/kg) Depth D	Phenanthrene (mg/kg) Depth C 9/18&19/91	Phenanthrene (mg/kg) Depth D
2	<0.45	0.53	<0.94	<0.96
3	<0.46	<0.48	<0.95	<1.00
6	0.49	0.65	<0.97	<0.98
7	<0.47	0.52	<0.98	<0.99
8	<0.46	<0.47	<0.97	1.22
9	0.81	2.17	<0.97	1.57
11	<0.45	<0.45	<0.95	<0.95
14	<0.46	<0.47	<0.97	<0.99
15	<0.47	3.81	<0.98	3.87
16	1.12	0.74	2.52	1.20
18	0.49	<0.47	<0.94	<0.98
20	<0.46	2.14	<0.96	1.80
21	<0.45	0.91	<0.95	<0.99
23	<0.47	1.51	<0.98	1.28
24	0.58	0.73	<0.99	<0.96
25	0.61	0.72	<0.98	0.94
28	0.63	0.52	1.16	<0.96
30	0.80	1.44	1.01	1.49
31	1.04	1.39	<1.01	<1.01
32	1.10	1.67	<0.97	1.30
Mean	0.4	1.0	0.2	0.7
95% CI for Mean	(0.2-0.6)	(0.5-1.4)	(0-0.5)	(0.3-1.2)
Quad. 1 Mean	0.20	1.0	0.50	1.0
(95% CI)	(0-0.8)	(0-3.0)	(0-1.9)	(0-3.1)
Quad. 2 Mean	0.20	0.7	<1.0	0.6
(95% CI)	(0-0.7)	(-0.4-1.8)		(0-1.5)
Quad. 3 Mean	0.4	0.9	0.2	0.4
(95% CI)	(0-0.8)	(0.4-1.3)	(0-0.9)	(0.3-1.2)
Quad. 4 Mean	0.70	1.3	0.20	0.9
(95% CI)	(0.1-1.2)	(0.3-2.3)	(0-1.8)	(0-2.0)

Table 7.10. Naphthalene and phenanthrene concentrations in LTU 2, depth A samples collected 9/19/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg)	Phenanthrene (mg/kg)
	Depth A 9/19/91	Depth A
36	2.08	1.10
47	1.43	<0.94
49	1.56	0.98
51	3.78	1.44
54	3.66	1.57
56	5.95	1.70
LTU Mean	3.1	1.4
95% CI for Mean	(1.3-4.9)	(1.0-1.7)
Quad. 1 Mean	1.8	0.6
(95% CI)	(0-5.9)	(0-7.5)
Quad. 3 Mean	4.8	1.6
(95% CI)	(0-19.4)	(0.8-2.5)
Quad. 4 Mean	2.7	1.2
(95% CI)	(0-16.8)	(0-4.1)

Table 7.11 . Naphthalene and phenanthrene concentrations in LTU 1, depth A and B samples collected 6/27/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg)		Phenanthrene (mg/kg)	
	Depth A 6/27/91	Depth B	Depth A 6/27/91	Depth B
2		1.25		1.39
3	3.58		4.48	
6	12.0	7.84	6.49	6.68
7	19.7	3.87	9.65	2.67
8		1.21		1.13
9	<0.48	0.70	1.07	0.00
11	1.16	1.42	1.55	0.00
14	0.74	1.06	<1.03	1.55
15	<0.47	<0.47	<0.98	<0.96
19	0.78	0.81	<0.96	<0.96
20	2.35	0.86	<0.96	<0.95
21		1.19		<0.96
22	0.77		<0.96	
23	2.98	<0.47	1.97	<0.97
24	0.68		<0.97	
25	<0.46	<0.46	<0.96	<0.96
28		<0.46		<0.96
30	<0.47		<0.98	
31		<0.45		<0.95
32	<0.47	<0.47	<0.98	<0.98
LTU Mean	3.0	2.0	1.6	0.8
95% CI for Mean	(0.1-5.8)	(0.2-2.2)	(0.5-3.1)	(0-1.7)
Quad. 1 Mean	1.7	0.6	1.1	0.7
(95% CI)	(0-4.3)	(0-1.6)	(0-4.7)	(0-2.1)
Quad. 2 Mean	8.2	3.0	4.7	2.1
(95% CI)	(0-23.1)	(0-6.7)	(0-11.2)	(0-5.6)
Quad. 3 Mean	1.1	0.30	0.5	
(95% CI)	(0-3.2)	(0-1.2)	(0-2.06)	
Quad. 4 Mean	0.8	0.4		
(95% CI)	(0-2.5)	(0.4-1.2)		

Table 7.12. Naphthalene and phenanthrene concentrations in LTU 1, depth C samples collected 6/27/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg)	Phenanthrene (mg/kg)
	Depth C 6/27/91	Depth C
1	0.72	<1.02
2	2.16	2.42
6	15.0	9.80
8	0.95	1.37
9	2.23	1.06
11	1.17	1.41
14	0.59	<0.96
19	0.57	<0.97
20	<0.47	<0.96
21	0.91	<0.97
23	<0.46	<0.96
24	1.28	<0.98
26	0.62	<0.96
29	<0.47	<0.98
32	<0.47	<0.96
Mean	1.70	1.00
95% CI for Mean	(0-3.8)	(0-2.5)
Quad. 1 Mean	1.20	0.80
(95% CI)	(0-3.3)	(0-4.3)
Quad. 2 Mean	4.90	3.40
(95% CI)	(0-15.7)	(0-10.2)
Quad. 3 Mean	0.7	0.0
(95% CI)	(0-1.6)	
Quad. 4 Mean	0.1	0.0
(95% CI)	(0-0.6)	

Table 7.13. Naphthalene and phenanthrene concentrations in LTU 1, depth A and B samples collected 5/6/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Naphthalene (mg/kg)		Phenanthrene (mg/kg)	
	Depth A 5/6/91	Depth B	Depth A 5/6/91	Depth B
1	0.65	1.75	<0.95	1.90
2	<0.46		<0.86	
6	<0.45		<0.98	
7	0.57		<0.99	
9	0.56		<0.98	
10	0.62		<0.97	
11	3.47		3.56	
13	<0.46		<0.95	
14	5.81	3.73	4.31	5.69
15	8.16	2.78	4.56	2.61
16		2.16		2.44
17	1.62		<0.96	
19	1.50		<0.96	
18	1.16		1.47	
20	2.64		4.48	
23	2.74	2.71	2.63	2.23
24	2.11	1.56	1.73	1.77
25	1.53		1.03	
27	0.87		<0.95	
28	1.85		<1.00	
30	2.73	1.70	1.44	1.42
31	1.67		<1.02	
32	0.99		<1.08	
LTU Mean	1.98	2.2	0.81	2.4
95% CI for Mean	(1.2-2.7)	(1.6-2.8)	(0.3-1.4)	(1.3-3.6)
Quad. 1 Mean	2.9	2.6	1.8	3.2
(95% CI)	(0-7.7)	(1.2-4.0)	(0-4.8)	(0.4-5.9)
Quad. 2 Mean	1.0		0.7	
(95% CI)	(0-2.8)		(0-2.7)	
Quad. 3 Mean	1.8	2.1	1.1	2.0
(95% CI)	(1.0-2.7)	(0-9.4))	(0-2.5)	(0-4.9)
Quad. 4 Mean	1.8	1.8	1.1	1.3
(95% CI)	(1.1-2.4)	(1.4-2.2)	(0-2.6)	(0-2.9)

Table 7.15. Initial pyrene and total carcinogenic PAH concentrations in LTU 1, depth C samples collected 5/6&8/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)	Total Carcinogenic PAH (mg/kg)
	Depth C 5/6&8/91	Depth C
2	27.6	75.5
5	10.1	44.0
6	12.8	45.5
10	7.39	37.9
11	5.73	50.1
12	16.6	70.2
13	16.3	129
14	300	829
15	182	411
16	268	755
18	7.49	34.1
20	137	438
23	188	554
24	47.8	161
25	3.66	14.6
27	6.32	24.5
28	22.9	161
29	5.16	21.7
30	152	458
31	113	288
Mean	76.5	230
95% CI for Mean	(31.9-121)	(110-350)
Quad. 1 Mean	159	440
(95% CI)	(0-323)	(9.2-870)
Quad. 2 Mean	10.5	49.6
(95% CI)	(5.2-15.9)	(34.2-64.9)
Quad. 3 Mean	53.7	183
(95% CI)	(0-149)	(0-455)
Quad. 4 Mean	82.9	248
(95% CI)	(0-171)	(0-510)

Table 7.16. Initial pyrene and total carcinogenic PAH concentrations in LTU 1, depth D samples collected 7/27/91. The mean and 95 % confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)	Total Carcinogenic PAH (mg/kg)
	Depth D 7/27/91	Depth D
2	58.9	107
3	63.0	106
6	20.4	40.0
7	70.2	131
8	95.1	158
9	54.5	84.3
11	74.8	121
14	199	396
15	207	361
16	197	399
18	193	308
20	214	478
21	125	182
23	103	142
24	63.6	114
25	154	233
28	168	284
30	216	493
31	178	337
32	243	595
Mean	135	254
95% CI for Mean	(102-167)	(179-328)
Quad. 1 Mean	145	274
(95% CI)	(49.9-240)	(83.0-465)
Quad. 2 Mean	63.0	107
(95% CI)	(28.4-97.6)	(50.1-164)
Quad. 3 Mean	123	191
(95% CI)	(71.0-174)	(106-276)
Quad. 4 Mean	209	442
(95% CI)	(178-239)	(294-590)

Table 7.17. Initial pyrene and total carcinogenic PAH concentrations in LTU 2, depth A samples collected 7/27/91. The mean and 95 % confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)	Total Carcinogenic PAH (mg/kg)
	Depth A 7/27/91	Depth A
33	190	393
36	53.4	125
38	123	234
39	146	153
40	34.2	54.9
42	84.6	203
44	58.8	111
45	69.7	157
47	74.7	193
48	150	447
49	64.5	164
51	31.5	92.9
54	46.5	127
55	55.8	156
56	71.4	177
58	69.4	179
59	54.2	135
62	104	321
63	86.5	250
64	130	412
Mean	84.9	204
95% CI for Mean	(65.0-105)	(153.3-255)
Quad. 1 Mean	108	263
(95% CI)	(34.0-181)	(80.9-444)
Quad. 2 Mean	89.4	151
(95% CI)	(32.6-146)	(62.6-240)
Quad. 3 Mean	59.5	155
(95% CI)	(46.3-72.6)	(125-184)
Quad. 4 Mean	83.3	248
(95% CI)	(36.5-130)	(91.9-404)

Table 7.18. Pyrene and total carcinogenic PAH concentrations in LTU 1, depth A and B samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)	Pyrene (mg/kg)	Total Carcinogenic PAH (mg/kg)	Total Carcinogenic PAH (mg/kg)
	Depth A 9/1/92	Depth B	Depth A 9/1/92	Depth B
2	1.12	1.29	22.8	2.24
3	1.15	0.93	7.12	6.49
6	<0.85	<0.84	4.13	0.64
7	1.07	0.99	7.05	9.59
8	1.29	1.40	5.59	5.41
9	3.88	11.83	30.9	174
11	2.35	4.78	51.9	123
14	1.05	1.24	1.80	15.7
15	1.68	1.27	16.9	26.7
16	2.56	1.52	7.32	18.8
18	1.00	1.26	13.2	14.9
20	1.67	1.90	31.6	34.6
21	1.63	2.60	36.3	49.1
23	1.81	21.25	33.8	71.2
24	0.89	0.91	2.61	0.91
25	<0.85	<0.84	1.34	6.53
28	1.83	1.41	29.3	31.2
30	0.90	1.05	18.3	36.3
31	<0.84	<0.84	7.31	7.65
Mean	1.4	2.9	17.3	33.4
95% CI for Mean	(0.9-1.8)	(0.4-5.4)	(10.3-24.4)	(11.6-55.3)
Quad. 1 Mean	1.5	1.3	11.2	14.0
(95% CI)	(0.7-2.3)	(1.0-1.5)	(0.7-21.7)	(1.9-26.1)
Quad. 2 Mean	1.7	3.8	19.9	62.6
(95% CI)	(0-3.5)	(0-9.8)	(0-46.0)	(0-163)
Quad. 3 Mean	1.2	5.2	20.7	31.8
(95% CI)	(0.3-2.2)	(0-16.4)	(0-42.1)	(0-68.2)
Quad. 4 Mean	0.9	1.1	17.6	23.4
(95% CI)	(0-2.0)	(0-2.3)	(1.1-34.1)	(0.6-46.1)

Table 7.19. Pyrene and total carcinogenic PAH concentrations in LTU 1, depth C and D samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)	Pyrene (mg/kg)	Total Carcinogenic PAH (mg/kg)	Total Carcinogenic PAH (mg/kg)
	Depth C 9/1/92	Depth D	Depth C 9/1/92	Depth D
2	1.02	1.33	11.1	26.7
3	1.06	2.61	9.35	30.3
6	1.17	3.78	2.06	37.6
7	1.93	2.83	10.2	17.7
8	2.91	4.08	74.1	60.0
9	5.04	25.4	203	96.4
11	2.53	1.86	17.3	14.5
14	1.37	2.59	14.8	36.3
15	5.87	2.23	39.5	29.5
16	1.67	1.05	32.6	5.04
18	1.32	2.01	10.1	18.1
20	11.84	1.33	53.4	15.6
21	6.62	5.98	54.4	97.0
23	20.1	13.3	148	82.7
24	3.84	3.28	23.8	17.0
25		2.69		33.3
28	1.82	2.93	25.5	41.9
30	<0.94	<0.85	1.76	14.7
31	<0.84	1.63	6.69	35.8
Mean	3.9	4.3	41.0	37.1
95% CI for Mean	(1.3-6.1)	(1.4-7.3)	(13.3-64.4)	(23.1-51.2)
Quad. 1 Mean	2.2	2.0	21.5	25.6
(95% CI)	(0-4.8)	(1.1-2.9)	(4.5-38.5)	(10.7-40.5)
Quad. 2 Mean	2.7	7.6	61.3	45.2
(95% CI)	(0.9-4.5)	(0-20.0)	(0-166)	(3.1-87.3)
Quad. 3 Mean	8.1	4.5	62.9	43.7
(95% CI)	(0-21.2)	(0.7-8.3)	(0-156)	(12.9-74.4)
Quad. 4 Mean	3.3	1.2	18.0	21.0
(95% CI)	(0-12.4)	(0-2.6)	(0-56.0)	(5.2-36.8)

Table 7.20. Pyrene and total carcinogenic PAH concentrations in LTU 1, depth E samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)	Total Carcinogenic PAH (mg/kg)
	Depth E 9/1/92	Depth E
2	1.50	15.5
3	2.26	58.0
6	3.90	68.9
7	9.30	106
8	2.35	28.8
9	97.3	245
11	1.31	2.11
14	2.54	51.8
15	2.11	31.3
16	1.75	16.6
18	2.88	32.7
20	2.14	43.4
21	3.88	33.5
23	5.23	34.3
24	67.9	188
25	6.24	70.2
30	<0.84	28.9
Mean	12.5	62.0
95% CI for Mean	(0-26.4)	(29.2-94.8)
Quad. 1 Mean	2.0	34.6
(95% CI)	(1.5-2.5)	(10.2-59.1)
Quad. 2 Mean	22.8	90.1
(95% CI)	(0-74.7)	(0-208)
Quad. 3 Mean	20.8	81.4
(95% CI)	(0-70.8)	(0-197)
Quad. 4 Mean	1.7	35.0
(95% CI)	(0-5.4)	(16.4-53.6)

Table 7.21. Pyrene and total carcinogenic PAH concentrations in LTU 2, depth A and B samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)	Pyrene (mg/kg)	Total Carcinogenic PAH (mg/kg)	Total Carcinogenic PAH (mg/kg)
	Depth A 9/1/92	Depth B	Depth A 9/1/92	Depth B
45	3.98	4.22	50.8	29.1
47	6.84	8.37	56.4	98.1
48	5.68	5.08	45.8	41.0
49	6.33		83.2	
51	2.26	5.16	13.1	47.4
54	2.33	5.79	9.54	58.7
55	9.00	4.74	56.4	41.6
56	8.05	5.40	91.7	26.6
58	5.11	4.88	27.3	30.8
59	4.90	3.06	25.7	14.6
62	<0.85	<0.85	37.8	23.5
63	<0.84	0.92	43.8	31.2
64	<0.84	<0.85	31.4	30.6
Mean	4.2	4.0	44.1	39.4
95% CI for Mean	(2.3-6.0)	(2.4-5.6)	(29.4-58.8)	(25.6-53.5)
Quad. 1 Mean	5.5	5.9	51.0	56.1
(95% CI)	(1.9-9.1)	(0.4-11.3)	(37.9-64.2)	(0-148)
Quad. 3 Mean	5.9	4.8	42.1	34.5
(95% CI)	(2.6-9.2)	(3.5-6.1)	(1.9-82.4)	(13.8-55.1)
Quad. 4 Mean	1.7	1.5	41.9	33.2
(95% CI)	(0-5.1)	(0-5.4)	(9.8-73.9)	(17.2-49.2)

Table 7.22. Pyrene and total carcinogenic PAH concentrations in LTU 1, depth A and B samples collected 9/18 & 19/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg) Depth A 9/18&19/91	Pyrene (mg/kg) Depth B	Total Carcinogenic PAH (mg/kg) Depth A 9/18&19/91	Total Carcinogenic PAH (mg/kg) Depth B
2	6.07	2.98	80.8	31.3
3		1.02		10.4
6	1.75	3.33	22.5	25.9
7	4.57	3.13	49.1	25.2
8	1.14	<1.02	9.27	1.41
9	1.24	1.36	17.7	13.1
11	8.36	1.35	59.9	19.1
14	2.52		45.5	
15	6.72	<1.03	37.5	51.4
16	3.94	129	47.9	415
18	49.4	1.32	171	7.88
20	2.43	3.09	27.3	20.5
21	1.96	4.86	19.2	24.4
23	1.93	2.41	18.0	26.1
24	<1.06	1.25	<20.2	7.11
25	<1.03	1.32	<19.6	2.18
28	2.18	1.23	6.15	1.23
30	2.04	1.79	18.1	19.0
31	1.84	1.73	15.1	16.4
32	1.36	1.06	1.36	1.06
Mean	5.20	8.5	34.0	37.8
95 % CI for Mean	(0-10.5)	(0-22.6)	(14.8-53.2)	(0-82.4)
Quad. 1 Mean	4.8	33.2	52.9	127.0
(95% CI)	(1.7-7.9)	(0-135)	(22.5-83.3)	(0-434)
Quad. 2 Mean	3.4	1.8	31.7	16.9
(95% CI)	(0-7.3)	(0.1-3.6)	(4.7-58.7)	(4.4-29.5)
Quad. 3 Mean	1.2	2.2	8.7	12.2
(95% CI)	(0-2.6)	(0.3-4.1)	(0-20.3)	(0-27.2)
Quad. 4 Mean	11.4	1.8	46.6	13.0
(95% CI)	(0-37.8)	(0.8-2.8)	(0-134)	(2.7-23.2)

Table 7.23. Pyrene and total carcinogenic PAH concentrations in LTU 1, depth C and D samples collected 9/18 & 19/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)	Pyrene (mg/kg)	Total Carcinogenic PAH (mg/kg)	Total Carcinogenic PAH (mg/kg)
	Depth C 9/18&19/91	Depth D	Depth C 9/18&19/91	Depth D
2	4.99	2.71	33.9	20.3
3	1.26	11.1	9.50	38.2
6	4.94	9.85	31.9	45.2
7	4.57	7.42	45.4	46.6
8	1.64	8.22	13.1	47.7
9	9.48	11.6	34.0	121
11	3.47	9.40	56.6	56.2
14	7.41	48.9	69.1	125
15	1.71	160	25.0	443
16	11.7	11.6	113	84.6
18	16.4	67.4	98.0	165
20	5.59	132	22.2	304
21	6.65	56.9	19.6	156
23	4.24	6.53	41.1	39.9
24	1.17	2.52	2.10	10.9
25	1.04	10.5	1.90	29.3
28	1.70	9.71	2.71	14.9
30	2.59	65.7	14.8	137
31	1.66	12.3	19.7	40.0
32	1.35	61.0	6.13	129
Mean	4.6	35.3	33.0	103
95% CI for Mean	(2.8-6.6)	(14.5-56.0)	(18.5-47.4)	(52.5-153)
Quad. 1 Mean	5.40	46.9	50.1	142.4
(95% CI)	(0.1-10.8)	(0-128)	(0-102)	(0-357)
Quad. 2 Mean	4.80	9.3	36.2	63.2
(95% CI)	(1.2-8.4)	(7.2-11.3)	(16.0-56.4)	(23.1-103)
Quad. 3 Mean	3	17.2	13.4	50.2
(95% CI)	(0-6.0)	(0-45.0)	(0-34.8)	(0-125)
Quad. 4 Mean	5.50	67.6	32.2	155
(95% CI)	(0-13.3)	(14.8-120)	(0-78.5)	(36.1-274)

Table 7.24. Pyrene and total carcinogenic PAH concentrations in LTU 2, depth A samples collected 9/19/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)	Total Carcinogenic PAH (mg/kg)
	Depth A 9/19/91	Depth A
36	3.38	11.8
47	7.16	28.9
49	106	228
51	4.54	44.8
54	37.2	82.8
56	101	219
LTU Mean	43.2	103
95% CI for Mean	(-7.6-94.0)	(1.2-204)
Quad. 1 Mean	5.3	20.4
(95% CI)	(-18.7-29.3)	(-88.5-129)
Quad. 4 Mean	69.0	151
(95% CI)	(-334-472)	(-716-1018)
Quad. 3 Mean	55.4	136
(95% CI)	(-591-702)	(-1020-1298)

Table 7.25. Pyrene and total carcinogenic PAH concentrations in LTU 1 depth A and B samples collected 6/27/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)		Total Carcinogenic PAH (mg/kg)	
	Depth A 6/27/91	Depth B	Depth A 6/27/91	Depth B
2		3.42		42.7
3	10.7		111	
6	18.3	17.0	147	212
7	16.7	5.79	194	54.7
8		1.58		11.9
9	1.87	1.58	8.12	7.33
11	3.50	2.09	29.0	26.9
13	6.22	<1.00	42.3	<19.2
14	1.36	0.00	4.44	12.3
15	<1.03	<1.02	<19.8	<19.5
19	<1.01	2.09	1.70	41.8
20	5.72	2.93	54.81	40.3
21		2.65		47.0
22	4.28		29.15	
23	11.60	1.47	113.82	4.48
24	1.40	<1.01	7.01	<19.3
25	<1.01		<19.3	
28		<1.01		<19.4
30	<1.03		<19.7	
31	<0.99		<19.0	
32	<1.03	<1.03	<19.7	<19.8
LTU Mean	5.1	4.5	82.2	52.6
95% CI for Mean	(1.9-8.3)	(0-9.8)	(0-166)	(0-120)
Quad. 1 Mean	4.6	1.7	57.9	27.5
(95% CI)	(0-12.3)	(0-23.4)	(0-737)	(0-220)
Quad. 2 Mean	10.1	5.6	94.3	62.7
(95% CI)	(0-12.5)	(0-13.8)	(0-238)	(0-169)
Quad. 3 Mean	4.3	1.0	37.5	12.9
(95% CI)	(0 - 12.5)	(0-3.1)	(0-121)	(0-49.2)
Quad. 4 Mean	1.4	1.3	14.1	20.5
(95% CI)	(0-6.0)	(0-3.6)	(0-57.3)	(0-58.2)

Table 7.26. Pyrene and total carcinogenic PAH concentrations in LTU 1, depth C samples collected 6/27/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)	Total Carcinogenic PAH (mg/kg)
	Depth C 6/27/91	Depth C
2	9.43	57.3
6	38.7	339
8	3.31	26.0
9	3.01	20.2
11	3.49	63.3
14	<1.01	<19.2
19	1.89	16.4
20	1.14	10.3
21	1.16	13.3
23	1.06	2.2
24	3.42	28.3
26	1.45	4.5
29	1.22	1.2
32	<1.02	<19.6
Mean	4.8	40.1
95% CI for Mean	(0-10.2)	(0-87.2)
Quad. 1 Mean	4.1	25.3
(95% CI)	(0-16.1)	(0-98.0)
Quad. 2 Mean	12.1	112
(95% CI)	(0-40.4)	(0-355)
Quad. 3 Mean	1.8	12.1
(95% CI)	(0.0-3.5)	(0-30.9)
Quad. 4 Mean	1.1	7.0
(95% CI)	(0-2.3)	(0-19.4)

Table 7.27. Pyrene and total carcinogenic PAH concentrations in LTU 1, depth A and B samples collected 5/6/91. The mean and 95% confidence interval are shown for each quadrant.

Field Core	Pyrene (mg/kg)		Total Carcinogenic PAH (mg/kg)	
	Depth A 5/6/91	Depth B	Depth A 5/6/91	Depth B
1	1.69	3.92	4.21	41.3
2	<0.90		<17.2	
6	<1.03		<19.4	
7	<1.04		1.37	
9	<1.03		1.16	
10	<1.01		<19.4	
11	6.80		68.1	
13	<1.00		1.19	
14	19.9	11.2	136	116
15	15.6	4.26	139	79.2
16		4.90		49.3
17	1.62		30.6	
18	<1.04		2.06	
19	1.70		23.9	
20	8.49		71.0	
23	11.0	4.72	94.8	66.1
24	4.40	1.83	43.9	28.0
25	3.07		11.2	
27	1.09		4.07	
28	2.51		15.5	
30	5.28	4.78	65.8	40.9
31	3.43	2.28	8.23	37.1
32	2.12	3.52		
LTU Mean	4.03	4.7	32.9	57.2
95% CI for Mean	(1.6-6.4)	(2.4-7.1)	(13.4-52.5)	(33.1-81.3)
Quad. 1 Mean	7.3	6.1	55.8	71.4
(95% CI)	(0-18.9)	(0.6-11.5)	(0-148)	(17.8-125)
Quad. 2 Mean	1.4		14.1	
(95% CI)	(0-5.1)		(0-51.6)	
Quad. 3 Mean	4.4	3.3	33.9	47.1
(95% CI)	(0-9.3)	(0-21.6)	(0-80.2)	(0-289)
Quad. 4 Mean	3.2	3.5	29.3	39.0
(95% CI)	(0.6-5.9)	(0-19.4)	(2.7-55.9)	(14.9-63.0)

Table 7.29. Initial pentachlorophenol concentrations in LTU 1 depth C samples collected 5/8/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	431.88	214.9	(44.8-385.0)
	3	240.61		
	14	183.04		
	15	154.70		
	16	64.25		
2	6	93.46	211.4	(63.9-358.8)
	7	184.34		
	8	216.70		
	9	407.67		
	11	154.77		
3	21	141.85	63.9	(-14.2-141.9)
	23	119.56		
	24	5.41		
	25	13.02		
	28	39.43		
4	17	87.31	53.8	(27.8-79.9)
	18	67.82		
	19	13.13		
	20	50.22		
	30	45.49		
	31	59.05		
	LTU Mean	132.1		
	95% CI for LTU Mean	(78.6-185.6)		

Table 7.30. Initial pentachlorophenol concentrations in LTU 1 depth D samples collected 7/27/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	85.84	130.6	(78.6-182.7)
	3	156.03		
	14	171.50		
	15	155.04		
	16	84.67		
2	6	55.96	101	(49.0-151.7)
	7	127.90		
	8	143.00		
	9	119.22		
	11	57.25		
3	21	79.57	79.4	(47.0-111.8)
	23	67.07		
	24	58.09		
	25	68.23		
	28	124.00		
4	18	160.84	167	(83-250.9)
	20	117.17		
	30	224.97		
	31	87.17		
	32	244.64		
	LTU Mean	119.40		
	95% CI for LTU Mean	(93.9-145.0)		

Table 7.31. Initial pentachlorophenol concentrations in LTU 2 depth A samples collected 7/27/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	33	124.59	141.3	(-22.4-305)
	36	35.31		
	45	84.62		
	47	91.79		
	48	370.07		
2	38	76.98	66.6	(41.3-91.8)
	39	56.84		
	40	55.35		
	42	97.02		
	44	46.66		
3	54	61.66	71.3	(54.7-87.9)
	55	61.71		
	56	76.78		
	58	92.47		
	59	63.88		
4	49	104.87	126.4	(51.5-201.3)
	51	57.28		
	62	207.86		
	63	94.76		
	64	167.26		
	LTU Mean	101.40		
	95% CI for LTU Mean	(66.1-136.7)		

Table 7.32. Pentachlorophenol concentrations in LTU 1 depth A samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	3	8.24	8.7	(6.32-11.1)
	14	6.91		
	15	9.24		
	16	10.45		
2	6	6.59	3.9	(-0.5-8.4)
	8	4.46		
	9	4.68		
	11	<3.7		
3	21	7.95	13.5	(-4.6-31.6)
	23	7.60		
	24	39.56		
	25	7.12		
	28	5.50		
4	18	3.38	2.8	(-0.5-6.2)
	20	5.06		
	30	<3.74		
	31	<3.71		
	32	5.63		
	LTU Mean	7.4		
	95% CI for LTU Mean	(3.1-11.6)		

Table 7.33. Pentachlorophenol concentrations in LTU 1 depth B samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	9.88	5.9	(0.2-11.5)
	3	7.11		
	14	2.26		
	15	<3.74		
	16	10.10		
2	6	7.30	7.5	(2.7-12.3)
	7	3.71		
	8	3.63		
	9	12.00		
	11	10.66		
3	21	17.84	7.8	(-3.2-18.9)
	23	16.93		
	24	<3.72		
	25	<3.72		
	28	4.37		
4	18	10.43	8.5	(4.0-13.0)
	20	13.85		
	30	5.61		
	31	5.34		
	32	7.30		
	LTU Mean	7.4		
	95% CI for LTU Mean	(4.9-9.9)		

Table 7.34. Pentachlorophenol concentrations in LTU 1 depth C samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	9.59	8.1	(3.6-12.7)
	3	10.39		
	14	4.75		
	15	12.12		
	16	3.83		
2	6	13.30	11.2	(7.8-14.5)
	7	7.65		
	8	8.83		
	9	13.02		
	11	13.08		
3	21	13.95	14.1	(4.3-23.8)
	23	26.53		
	24	9.54		
	25	14.73		
	28	5.60		
4	18	9.54	8.5	(-6.6-23.6)
	20	29.05		
	30	<3.72		
	31	<3.72		
	32	3.67		
	LTU Mean	10.5		
	95% CI for LTU Mean	(7.0-13.9)		

Table 7.35. Pentachlorophenol concentrations in LTU 1 depth D samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	11.10	19.8	(9.4-30.1)
	3	17.35		
	14	13.73		
	15	25.96		
	16	30.79		
2	6	20.49	16.3	(10.8-21.7)
	7	18.12		
	8	11.39		
	9	19.57		
	11	11.70		
3	21	20.69	15.3	(2.0-28.5)
	23	31.43		
	24	10.54		
	25	5.98		
	28	7.73		
4	18	17.57	16.3	(6.0-26.6)
	20	14.77		
	30	3.97		
	31	26.97		
	32	18.27		
	LTU Mean	16.9		
	95% CI for LTU Mean	(13.3-20.5)		

Table 7.36. Pentachlorophenol concentrations in LTU 1 depth E samples collected 9/1/92. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	16.69	18.9	(10.0-27.8)
	3	19.17		
	14	8.33		
	15	27.62		
	16	22.57		
2	6	20.90	23.5	(2.9-44.1)
	7	21.84		
	8	9.88		
	9	51.80		
	11	13.22		
3	18	30.98	18.1	(6.4-29.9)
	20	19.21		
	30	4.83		
	31	20.33		
	32	15.39		
4	21	13.54	32.3	(-5.5-70.1)
	23	30.00		
	24	85.10		
	25	21.94		
	28	10.94		
	LTU Mean	23.2		
	95% CI for LTU Mean	(14.9-31.5)		

Table 7.37. Pentachlorophenol concentrations in LTU 2 depth A samples collected 9/2/92. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	33	14.48	20.5	(7.5-33.4)
	36	26.01		
	45	6.31		
	47	33.34		
	48	22.15		
2	38	20.44	15.4	(5.5-25.4)
	39	19.32		
	40	15.30		
	44	6.66		
3	54	13.42	26.0	(14.9-37.1)
	55	21.25		
	56	30.01		
	58	36.68		
	59	28.72		
4	49	15.55	16.3	(5.5-27.1)
	51	5.76		
	62	17.04		
	63	29.71		
	64	13.39		
	LTU Mean	19.8		
	95% CI for LTU Mean	(15.4-24.2)		

Table 7.38. Pentachlorophenol concentrations in LTU 2 depth B samples collected 9/2/92. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	33	19.32	17.0	(6.4-27.6)
	36	13.82		
	45	16.06		
	47	29.51		
	48	6.12		
2	38	21.28	16.7	(10.0-23.4)
	39	20.29		
	40	17.90		
	42	16.42		
	44	7.66		
3	54	33.07	22.5	(11.6-33.4)
	55	9.75		
	56	27.00		
	58	23.80		
	59	19.08		
4	49	23.48	22.5	(8.8-36.1)
	51	10.59		
	62	12.95		
	63	28.20		
	64	37.18		
	LTU Mean	19.7		
	95% CI for LTU Mean	(15.7-23.6)		

Table 7.39. Pentachlorophenol concentrations in LTU 1 depth A samples collected 9/18/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	13.29	9.7	(3.6-15.8)
	3	13.25		
	14	2.60		
	15	6.42		
	16	12.86		
2	6	5.08	15	(3.2-26.9)
	7	29.55		
	8	11.22		
	9	19.07		
	11	10.30		
3	21	3.43	6	(2.16-9.8)
	23	5.85		
	24	6.94		
	25	3.06		
	28	10.68		
4	18	4.73	4.5	(2.6-6.4)
	20	2.54		
	30	4.09		
	31	6.75		
	32	4.51		
	LTU Mean	8.8		
	95% CI for LTU Mean	(5.7-11.9)		

Table 7.40. Pentachlorophenol concentrations in LTU 1 depth B samples collected 9/18/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	9.65	7.7	(2.1-13.2)
	3	11.44		
	15	3.78		
	16	5.86		
2	6	7.19	6.7	(4.3-9.2)
	7	8.53		
	8	3.75		
	9	5.80		
	11	8.37		
3	21	10.07	7.8	(4.1-11.5)
	23	4.20		
	24	4.93		
	25	10.47		
	28	9.31		
4	18	3.22	5	(2.9-7.2)
	20	6.03		
	30	6.77		
	31	5.99		
	32	3.08		
	LTU Mean	6.80		
	95% CI for LTU Mean	(5.5-8.0)		

Table 7.41. Pentachlorophenol concentrations in LTU 1 depth C samples collected 9/18/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	5.59	6.4	(-1.8-14.6)
	3	3.45		
	14	18.01		
	15	2.89		
	16	2.12		
2	6	12.54	18.4	(-4.7-41.4)
	7	50.93		
	8	11.16		
	9	13.26		
	11	3.91		
3	21	19.63	15.1	(9.1-21.1)
	23	14.07		
	24	20.62		
	25	10.06		
	28	11.05		
4	18	48.14	39.1	(-5.0-83.2)
	19	119.89		
	20	28.19		
	30	14.58		
	31	16.92		
	32	7.05		
	LTU Mean	20.70		
	95% CI for LTU Mean	(8.7-32.6)		

Table 7.42. Pentachlorophenol concentrations in LTU 1 depth D samples collected 9/18/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	53.36	33.7	(4.8-62.5)
	3	14.62		
	14	22.64		
	15	63.70		
	16	14.06		
2	6	33.96	26	(15.2-36.8)
	7	28.44		
	8	29.51		
	9	27.06		
	11	11.18		
3	21	41.96	34.5	(19.4-49.5)
	23	36.55		
	24	16.38		
	25	29.76		
	28	47.79		
4	18	57.11	67.8	(30.9-104.6)
	20	56.54		
	30	70.20		
	31	38.20		
	32	116.78		
	LTU Mean	40.50		
	95% CI for LTU Mean	(28.9-52.1)		

Table 7.43. Pentachlorophenol concentrations in LTU 2 depth A samples collected 9/19/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	36	49.11	23.9	(-4.5-52.4)
	45	7.85		
	47	15.79		
	48	23.01		
2	38	34.09	258.4	(-372.9-889.7)
	39	37.60		
	40	14.86		
	42	1167.76		
	44	37.61		
3	54	21.74	73.6	(21.2-126.0)
	55	103.96		
	58	118.61		
	59	86.37		
	60	37.18		
4	49	15.16	36.0	(2.7-69.3)
	51	82.96		
	52	24.81		
	63	30.11		
	64	26.91		
	LTU Mean	101.90		
	95% CI for LTU Mean	(-23.9-227.2)		

Table 7.44. Pentachlorophenol concentrations in LTU 1 depth A samples collected 6/27/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	1	12.70	11.7	(1.3-22.1)
	2	17.46		
	3	21.48		
	14	5.83		
	15	0.89		
2	6	8.29	10.2	(2.9-17.5)
	7	20.28		
	8	5.54		
	9	9.77		
	11	7.08		
3	21	8.67	10.2	(-.04-20.3)
	23	24.44		
	24	8.13		
	25	4.10		
	28	5.42		
4	17	4.34	9	(.7-17.2)
	20	17.76		
	30	12.47		
	31	9.44		
	32	0.81		
	LTU Mean	10.2		
	95% CI for LTU Mean	(7.1-13.4)		

Table 7.45. Pentachlorophenol concentrations in LTU 1 depth B samples collected 6/27/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	5.63	4.3	(3.1-5.5)
	3	4.82		
	14	4.40		
	15	3.17		
	16	3.67		
2	6	8.52	9.7	(1.4-18.1)
	7	19.76		
	8	10.33		
	9	0.96		
	11	9.14		
3	21	3.46	5.3	(2.6-8.1)
	23	6.33		
	24	6.22		
	25	2.69		
	28	8.03		
4	18	7.49	5.4	(1.7-9.1)
	20	4.11		
	30	6.46		
	31	8.18		
	32	0.88		
	LTU Mean	6.2		
	95% CI for LTU Mean	(4.3-8.1)		

Table 7.46. Pentachlorophenol concentrations in LTU 1 depth C samples collected 6/27/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	5.51	4.9	(0.9-8.9)
	3	8.21		
	14	2.88		
	15	2.96		
2	6	23.89	14.2	(5.9-22.4)
	7	15.05		
	8	10.93		
	9	15.14		
	11	5.87		
3	21	7.63	8.7	(3.7-13.7)
	23	3.17		
	24	8.52		
	25	9.73		
	28	14.43		
4	17	22.41	11.7	(3-20.4)
	18	9.81		
	20	3.17		
	30	8.72		
	31	13.22		
	32	9.92		
	LTU Mean	10.10		
	95% CI for LTU Mean	(7.3-12.8)		

Table 7.47. Pentachlorophenol concentrations in LTU 1 depth A samples collected 5/6/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	9.63	24	(-6.0-54.1)
	3	51.88		
	14	17.63		
	15	17.06		
2	6	61.01	26.9	(0.7-53.0)
	7	32.52		
	8	19.05		
	9	10.08		
	11	11.62		
3	23	20.99	8.6	(-4.5-21.8)
	24	5.18		
	25	3.40		
	28	4.98		
4	18	17.85	9.5	(-1.9-20.8)
	19	11.61		
	20	7.54		
	32	0.85		
	LTU Mean	17.80		
	95% CI for LTU Mean	(9.3-26.3)		

Table 7.48. Pentachlorophenol concentrations in LTU 1 depth B samples collected 5/6/91. The mean and 95% confidence interval are shown for each quadrant.

LTU Quadrant	Core No.	PCP (mg/kg)	Quadrant Mean PCP (mg/kg)	95% CI for Mean
1	2	44.69	20.9	(-1.3-43.1)
	3	34.57		
	14	9.16		
	15	13.54		
	16	2.56		
2	6	37.98	25.9	(6.9-45.0)
	7	34.40		
	8	14.85		
	9	16.49		
3	21	4.85	5.5	(2.4-8.5)
	23	3.89		
	25	4.80		
	28	8.27		
4	30	5.52	6.3	(2.5-10.1)
	31	5.29		
	32	8.07		
	LTU Mean	15.6		
	95% CI for LTU Mean	(8.1-23.1)		

Table 7.51 Average distribution of phenanthrene in the microcosms in the biological mineralization and humification study.

Soil Sample Depth A, 5/6/91	Moisture (% Field Capacity)	Temperature (° C)	% Volatilization	% Mineralization	% Solvent Extractable	% Soil Bound	% Mass Recovered
Core 12	80	20	0.19	4.62	5.19	40.08	50.08
Core 12	80	10	0.25	4.05	16.89	50.79	71.99
Core 12	40	20	0.27	7.23	19.64	49.10	76.24
Core 12	40	10	0.90	0.76	14.72	58.14	73.71
Core 15	80	20	0.12	5.22	8.13	88.08	101.55
Core 15	80	10	0.70	0.83	19.24	89.03	109.17
Core 15	40	20	0.15	2.09	45.84	45.14	93.23
Core 15	40	10	0.20	0.31	27.38	63.54	91.25

Table 7.52 Average distribution of pentachlorophenol in the microcosms in the biological mineralization and humification study.

Soil Sample	Moisture (% Field Capacity)	Temperature (° C)	% Volatilization	% Mineralization	% Solvent Extractable	% Soil Bound	% Mass Recovered
Depth D, 7/27/91	80	20	0.22	3.65	50.48	12.27	66.62
Depth D, 7/27/91	80	10	0.30	0.67	20.38	34.01	55.09
Depth D, 7/27/91	40	20	0.20	0.40	58.14	35.49	94.06
Depth D, 7/27/91	40	10	0.20	0.86	56.15	26.12	83.16
Depth C, 5/8/91	80	20	0.12	3.11	15.61	33.22	52.06
Depth C, 5/8/91	80	10	0.31	1.76	28.52	63.20	93.79
Depth C, 5/8/91	40	20	0.10	1.27	26.02	36.27	63.66
Depth C, 5/8/91	40	10	1.02	9.19	26.95	24.11	61.27

B - 1: PAHs edited 9/21/93

Date Collected	Field Core	ID Lift	UWRL ID #	dry wt Naphthalene mg/kg	dry wt Acenaphthylene mg/kg	dry wt Acenaphthene mg/kg	dry wt Fluorene mg/kg	dry wt Phenanthrene mg/kg	dry wt Anthracene mg/kg	dry wt Fluoranthene mg/kg	dry wt Pyrene mg/kg	dry wt Benzo(a)anthracene mg/kg	dry wt Chrysene mg/kg
5/6/91	1	A	1748	0.65	0.60	0.36	<0.333	<0.948	<1.077	1.10	1.69	<1.661	1.42
5/6/91	2	A	1750	<0.455	0.33	0.08	<0.301	<0.859	<0.975	<0.685	<0.902	<1.504	<0.994
5/6/91	6	A	1762	<0.45	0.47	0.14	<0.345	<0.984	<1.117	<0.785	<1.034	<1.723	<1.138
5/6/91	7	A	1765	0.57	0.52	0.16	<0.347	<0.989	<1.124	<0.790	<1.040	<1.734	1.37
5/6/91	9	A	1771	0.56	0.45	0.16	<0.344	<0.980	<1.113	<0.782	<0.1029	<1.717	1.16
5/6/91	10	A	1774	0.62	0.42	0.12	<0.339	<0.965	<1.096	<0.77	<1.014	<1.69	<1.117
5/6/91	11	A	1777	3.47	1.41	1.98	1.73	3.56	5.00	5.31	6.80	4.02	3.66
5/6/91	13	A	1783	<0.455	0.48	0.14	<0.334	<0.952	<1.082	<0.760	<1.001	<1.669	1.19
5/6/91	14	A	1786	5.81	1.87	2.28	1.80	4.31	9.86	15.61	19.92	11.62	9.27
5/6/91	15	A	1790	8.16	2.60	2.34	2.12	4.56	7.45	11.30	15.56	9.53	7.36
5/6/91	17	A	1796	1.62	0.99	0.29	<0.335	<0.955	3.93	1.90	1.62	<1.673	2.08
5/6/91	18	A	1798	1.16	<0.30	0.16	1.73	1.47	14.03	<0.79	<1.04	<1.73	<1.14
5/6/91	18	A	1798	1.16	<0.30	0.16	1.73	1.47	14.03	<0.79	<1.04	<1.73	<1.14
5/6/91	19	A	1801	1.50	0.73	0.19	<0.336	<0.959	1.71	1.79	1.73	<1.680	1.65
5/6/91	20	A	1804	2.64	1.16	1.42	2.00	4.48	13.97	8.14	8.49	4.05	4.45
5/6/91	23	A	1813	2.74	1.51	1.04	1.32	2.63	3.10	6.18	11.05	3.66	3.41
5/6/91	24	A	1816	2.11	1.08	0.83	1.15	1.73	1.60	2.50	4.40	1.93	1.73
5/6/91	25	A	1819	1.53	<0.30	0.43	0.59	1.03	1.17	2.30	3.07	<1.75	1.21
5/6/91	27	A	1825	0.87	0.42	0.17	<0.335	<0.954	<1.083	<0.761	1.09	<1.671	1.24
5/6/91	28	A	1828	1.85	0.55	<0.11	0.58	<1.00	1.24	1.83	2.51	<1.75	<1.16
5/6/91	30	A	1834	2.73	0.97	0.69	0.89	1.44	5.13	3.16	5.28	7.64	2.57
5/6/91	31	A	1837	1.67	<0.31	0.44	0.51	<1.02	<1.15	1.66	3.43	<1.78	<1.18
5/6/91	32	A	1840	0.99	<0.33	<0.11	<0.38	<1.08	1.87	1.40	2.12	<1.89	<1.25
5/6/91	1	B	1747	1.75	0.96	0.84	1.24	1.90	1.46	15.21	3.92	2.80	1.76
5/6/91	14	B	1787 A	3.73	1.80	2.06	1.93	5.69	12.86	9.41	11.16	6.39	5.95
5/6/91	15	B	1791	2.78	1.45	1.07	1.37	2.61	5.91	4.22	4.26	3.73	3.32
5/6/91	16	B	1794	2.16	1.08	1.06	1.31	2.44	3.15	3.63	4.90	3.21	3.33
5/6/91	23	B	1814	2.71	1.44	1.09	1.27	2.23	2.57	3.65	4.72	2.67	3.69
5/6/91	24	B	1817 A	1.56	0.97	0.79	1.17	1.77	1.30	1.54	1.83	3.17	1.16
5/6/91	30	B	1835	1.70	0.62	0.63	0.68	1.42	1.64	2.77	4.78	5.37	1.86
5/6/91	31	B	1838	1.98	0.77	<0.10	0.60	<0.98	1.51	1.79	2.28	2.05	<1.14
5/8/91	2	C	1752	1.34	0.53	0.26	<0.331	<0.945	1.31	9.96	27.60	4.84	6.10
5/8/91	5	C	1761	1.24	0.52	0.20	<0.331	<0.944	<1.072	5.96	10.14	3.03	3.90
5/8/91	6	C	1764	1.85	0.46	0.20	<0.331	0.98	2.00	5.62	12.83	2.78	3.84
5/8/91	10	C	1776	3.51	0.51	0.35	<0.343	1.15	2.50	2.70	7.38	2.15	3.37
5/8/91	11	C	1779	3.26	0.55	0.25	<0.319	<0.908	4.18	6.21	5.73	2.01	3.84

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Date Collected	Field Core	ID Lift	UWRL ID #	dry wt Naphthalene mg/kg	dry wt Acenaphthylene mg/kg	dry wt Acenaphthene mg/kg	dry wt Fluorene mg/kg	dry wt Phenanthrene mg/kg	dry wt Anthracene mg/kg	dry wt Fluoranthene mg/kg	dry wt Pyrene mg/kg	dry wt Benzo(a)anthracene mg/kg	dry wt Chrysene mg/kg
5/8/91	12	C	1782	3.97	0.52	0.35	<0.318	1.50	2.59	6.92	16.59	3.69	4.99
5/8/91	13	C	1785	12.10	5.19	5.65	4.36	11.03	11.66	9.35	16.32	8.98	12.33
5/8/91	14	C	1789	4.76	2.47	3.54	3.06	5.88	11.85	171.46	300.47	94.29	80.41
5/8/91	15	C	1792	5.64	1.64	1.92	1.88	5.05	6.71	58.91	182.42	40.21	34.25
5/8/91	16	C	1795	10.02	3.04	2.90	2.58	5.67	15.08	51.72	267.67	51.43	51.65
5/8/91	18	C	1800	1.65	<0.280	0.28	0.41	<0.932	<1.048	1.71	7.49	2.18	2.69
5/8/91	20	C	1806	4.64	1.87	2.27	2.36	3.81	5.53	46.68	136.76	34.20	32.01
5/8/91	23	C	1815	10.16	1.66	2.03	1.89	3.08	6.01	62.78	188.29	53.86	50.91
5/8/91	24	C	1818	4.49	0.95	0.88	0.66	1.59	2.73	8.59	47.78	13.13	10.58
5/8/91	25	C	1821	0.87	<0.289	0.14	<0.334	<0.951	<1.080	0.86	3.66	<1.665	1.74
5/8/91	27	C	1827	0.74	<0.277	<0.096	0.50	<0.913	5.71	0.90	6.32	2.52	1.63
5/8/91	28	C	1830	3.39	1.25	0.84	1.55	2.13	9.21	10.68	22.89	7.31	8.08
5/8/91	29	C	1833	0.82	<0.298	<0.103	<0.344	<0.982	<1.115	0.91	5.16	<1.720	1.65
5/8/91	30	C	1836	7.06	1.83	1.51	1.42	2.86	7.04	39.17	151.95	34.38	40.07
5/8/91	31	C	1839	4.28	1.86	1.72	1.92	4.13	29.79	19.21	112.66	21.46	19.68
6/27/91	3	A	1859	3.58	1.25	1.72	2.07	4.48	74.02	8.14	10.68	4.90	7.49
6/27/91	6	A	1868A	12.02	2.73	2.59	3.01	6.49	126.06	14.48	18.32	7.72	10.60
6/27/91	7	A	1871	19.68	5.06	3.13	3.18	9.65	101.48	14.16	16.72	11.07	12.49
6/27/91	9	A	1877	<0.48	0.97	0.95	0.72	1.07	3.58	1.40	1.87	<1.75	<1.16
6/27/91	11	A	1883	1.16	1.00	1.31	1.03	1.55	8.62	3.04	3.50	<1.73	2.62
6/27/91	13	A	1889	2.46	0.36	0.26	0.43	<0.95	6.09	2.39	6.22	2.39	3.94
6/27/91	14	A	1892	0.74	0.87	0.94	<0.36	<1.03	6.00	1.17	1.36	<1.80	<1.19
6/27/91	15	A	1895	<0.47	<0.30	<0.10	<0.35	<0.98	<1.12	<0.79	<1.03	<1.72	<1.14
6/27/91	19	A	1907	0.78	<0.29	<0.10	<0.34	<0.96	<1.09	<0.77	<1.01	<1.69	<1.11
6/27/91	20	A	1910	2.35	0.39	0.21	<0.34	<0.96	3.57	2.76	5.72	<1.68	2.93
6/27/91	22	A	1916	0.77	<0.29	<0.10	<0.34	<0.96	<1.09	0.86	4.28	<1.68	2.52
6/27/91	23	A	1919	2.98	0.68	0.63	0.70	1.97	6.00	4.52	11.56	5.21	5.81
6/27/91	24	A	1922	0.68	<0.30	<0.10	<0.34	<0.97	<1.11	<0.78	1.40	<1.71	1.12
6/27/91	25	A	1925	<0.46	<0.29	<0.10	<0.34	<0.96	<1.09	<0.77	<1.01	<1.68	<1.11
6/27/91	30	A	1940	<0.47	<0.30	<0.10	<0.34	<0.98	<1.12	<0.78	<1.03	<1.72	<1.14
6/27/91	32	A	1946	<0.47	<0.30	<0.10	<0.34	<0.98	<1.11	<0.78	<1.03	<1.72	<1.13
6/27/91	2	B	1857	1.25	1.07	1.05	0.85	1.39	9.07	3.60	3.42	1.95	3.08
6/27/91	6	B	1869	7.84	4.83	2.13	2.50	6.68	71.81	9.92	16.96	7.50	11.52
6/27/91	7	B	1872	3.87	1.31	1.29	1.27	2.67	18.18	4.77	5.79	3.64	3.40
6/27/91	8	B	1875	1.21	0.85	0.94	<0.35	1.13	7.57	1.29	1.58	3.66	1.36
6/27/91	9	B	1878	0.70	0.87	0.91	0.67	<0.98	<1.11	1.37	1.58	<1.71	<1.14

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	Field	ID		dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt
Date			UWRL	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene
Collected	Core	Lift	ID #	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
6/27/91	11	B	1884	1.42	1.30	1.05	1.01	<0.99	8.97	1.73	2.09	<1.72	1.46
6/27/91	13	B	1890	<0.46	<0.29	<0.10	<0.34	<0.96	<1.09	<0.76	<1.00	<1.67	<1.11
6/27/91	14	B	1893	1.06	0.83	0.97	<0.34	1.55	3.55	<0.78	<1.03	1.77	1.48
6/27/91	15	B	1896	<0.47	<0.30	<0.10	<0.34	<0.97	<1.10	<0.77	<1.02	<1.70	<1.12
6/27/91	19	B	1908	0.81	0.38	<0.10	<0.34	<0.96	2.58	1.11	2.09	<1.68	3.79
6/27/91	20	B	1911	0.86	0.44	0.15	<0.33	<0.95	2.49	1.67	2.93	2.39	2.30
6/27/91	21	B	1914	1.19	0.54	<0.10	<0.34	<0.96	1.96	1.16	2.65	<1.68	3.24
6/27/91	23	B	1920	<0.47	<0.29	0.17	<0.34	<0.97	<1.10	1.52	1.47	<1.70	1.50
6/27/91	25	B	1926	<0.46	<0.29	0.11	<0.34	<0.96	<1.09	<0.77	<1.01	<1.69	<1.11
6/27/91	28	B	1935	<0.46	<0.30	<0.10	<0.34	<0.96	<1.10	<0.77	<1.01	<1.69	<1.12
6/27/91	31	B	1944	<0.45	<0.29	<0.10	<0.33	<0.95	<1.07	<0.75	<0.99	<1.66	<1.09
6/27/91	32	B	1947	<0.47	<0.30	<0.10	<0.35	<0.98	<1.12	<0.79	<1.03	<1.72	<1.14
6/27/91	1	C	1855	0.72	<0.31	<0.11	<0.36	<1.02	<1.16	0.97	2.80	<1.78	2.04
6/27/91	2	C	1858	2.16	1.20	1.30	1.21	2.42	13.40	5.04	9.43	2.44	4.35
6/27/91	6	C	1870	15.04	4.76	2.72	3.05	9.80	149.12	24.99	38.74	16.58	18.90
6/27/91	8	C	1876	0.95	1.06	1.03	1.22	1.37	17.03	2.08	3.31	2.08	2.12
6/27/91	9	C	1879	2.23	0.99	1.01	0.80	1.06	1.24	1.61	3.01	<1.76	2.94
6/27/91	11	C	1885	1.17	1.38	1.01	<0.34	1.41	7.46	2.42	3.49	1.81	5.10
6/27/91	14	C	1894	0.59	<0.29	<0.10	<0.34	<0.96	<1.09	<0.76	<1.01	<1.68	<1.11
6/27/91	19	C	1909	0.57	<0.30	<0.10	<0.34	<0.97	<1.11	<0.78	1.89	<1.71	1.26
6/27/91	20	C	1912	<0.47	<0.30	<0.10	<0.34	<0.97	<1.11	<0.78	1.14	<1.71	1.89
6/27/91	21	C	1915	0.91	<0.29	<0.10	<0.34	<0.97	<1.10	<0.77	1.16	<1.69	1.47
6/27/91	23	C	1921	<0.46	<0.29	<0.10	<0.34	<0.96	<1.10	<0.77	1.06	<1.69	1.19
6/27/91	24	C	1924	1.28	<0.30	<0.10	<0.34	<0.98	<1.11	0.85	3.42	<1.71	3.45
6/27/91	26	C	1930	0.62	<0.30	<0.10	<0.34	<0.96	<1.09	<0.77	1.45	<1.68	1.23
6/27/91	29	C	1939	<0.47	<0.30	<0.10	<0.34	<0.98	<1.12	<0.78	1.22	<1.72	<1.14
6/27/91	32	C	1948	<0.47	<0.30	<0.10	<0.34	<0.97	<1.11	<0.78	<1.02	<1.71	<1.13
7/27/91	33	A	2059	1.47	0.35	0.30	0.80	<0.95	15.13	91.89	190.05	26.63	29.02
7/27/91	36	A	2062	1.18	0.72	0.21	<0.33	<0.93	3.00	3.60	53.35	2.57	<1.07
7/27/91	38	A	2064	<0.46	0.35	<0.10	0.64	<0.95	8.88	56.60	123.40	13.23	8.85
7/27/91	39	A	2065	<0.46	<0.29	<0.10	<0.33	<0.95	<1.08	7.32	145.95	<1.67	<1.10
7/27/91	40	A	2066	<0.46	<0.29	<0.10	<0.34	<0.96	1.20	8.12	34.16	3.00	1.91
7/27/91	42	A	2068	<0.45	<0.28	2.65	2.69	<0.93	51.05	65.50	84.57	12.53	14.98
7/27/91	44	A	2070	<0.45	<0.28	<0.10	<0.33	<0.93	6.47	3.38	58.77	9.30	5.56
7/27/91	45	A	2071	0.66	<0.29	<0.10	0.47	<0.95	4.79	38.33	69.75	11.25	7.80
7/27/91	47	A	2073	0.55	<0.28	0.44	0.79	<0.92	4.53	72.52	74.68	11.28	7.65

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	Field	ID		dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt
Date			UWRL	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene
Collected	Core	Lift	ID #	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
7/27/91	48	A	2074	3.96	1.35	70.87	17.02	56.54	193.24	143.41	150.26	36.34	42.64
7/27/91	49	A	2075	1.14	<0.29	1.03	0.33	<0.94	10.02	47.30	64.45	13.53	13.08
7/27/91	51	A	2077	1.04	0.32	2.13	0.46	1.01	5.76	29.29	31.54	11.03	8.80
7/27/91	54	A	2080	1.03	0.30	0.70	0.57	0.95	8.88	27.99	46.51	18.96	11.51
7/27/91	55	A	2081-1	1.51	0.36	1.02	0.57	1.09	9.83	40.54	55.81	18.00	15.95
7/27/91	56	A	2082	1.15	0.57	1.04	0.68	1.50	13.69	31.39	71.40	21.33	16.77
7/27/91	58	A	2084	2.44	0.49	0.93	0.58	1.02	6.44	41.12	69.43	20.42	14.16
7/27/91	59	A	2085	1.43	0.43	0.85	0.44	1.06	8.14	22.42	54.21	14.96	13.15
7/27/91	62	A	2088	3.38	2.46	43.06	4.73	21.32	245.74	88.69	103.72	27.40	28.72
7/27/91	63	A	2089	2.74	0.71	6.32	1.07	2.38	27.36	69.72	86.47	23.24	22.36
7/27/91	64	A	2090	3.73	1.03	4.86	0.77	2.64	38.02	100.20	130.29	38.08	41.71
7/27/91	2	D	2028	<0.44	<0.28	<0.10	<0.33	<0.93	2.07	1.58	58.95	5.79	6.76
7/27/91	3	D	2029	<0.45	<0.29	<0.10	<0.33	<0.95	<1.08	7.48	62.97	9.35	<1.10
7/27/91	6	D	2032	0.68	<0.28	<0.10	<0.33	<0.93	2.67	<0.75	20.40	<1.63	<1.08
7/27/91	7	D	2033	1.34	<0.29	<0.10	<0.33	<0.94	<1.07	19.04	70.25	6.17	2.94
7/27/91	8	D	2034	0.48	0.39	<0.10	0.60	<0.93	5.15	21.70	95.09	10.28	6.75
7/27/91	9	D	2035	<0.44	<0.28	<0.10	<0.32	<0.93	2.19	8.56	54.54	6.95	<1.07
7/27/91	11	D	2037	1.53	<0.29	<0.10	<0.33	<0.94	3.05	5.05	74.77	5.28	<1.09
7/27/91	14	D	2040	1.99	0.40	0.45	1.93	<0.93	32.03	96.55	199.01	28.44	29.99
7/27/91	15	D	2041	1.63	0.77	0.14	0.60	<0.94	7.97	36.67	206.70	25.13	26.62
7/27/91	16	D	2042	4.05	1.03	0.69	2.01	<0.95	92.52	20.76	196.72	24.62	28.52
7/27/91	18	D	2044	<0.45	0.68	<0.10	0.36	<0.94	<1.07	26.32	193.23	26.27	21.14
7/27/91	20	D	2046	1.16	0.65	0.17	0.47	<0.94	9.05	97.75	213.71	38.51	41.60
7/27/91	21	D	2047	0.73	0.50	<0.10	<0.33	<0.95	8.37	2.76	125.26	8.38	6.74
7/27/91	23	D	2049	0.74	0.47	<0.10	0.46	<0.93	7.82	<0.74	102.62	4.06	<1.08
7/27/91	24	D	2050	1.35	0.42	0.10	<0.32	<0.92	4.05	6.34	63.62	1.66	<1.07
7/27/91	25	D	2051	<0.45	0.55	<0.10	<0.33	<0.94	1.80	16.46	153.88	19.50	5.18
7/27/91	28	D	2054	0.84	0.45	0.17	0.37	<0.93	5.04	36.08	168.07	21.33	17.29
7/27/91	30	D	2056	1.46	0.51	0.43	1.27	<0.93	27.80	131.43	216.12	36.14	48.24
7/27/91	31	D	2057	0.99	0.82	0.19	0.55	<0.95	5.64	36.85	177.61	26.66	23.81
7/27/91	32	D	2058	2.35	1.03	11.50	2.24	<0.94	211.43	177.81	242.66	48.72	62.20
9/18/91	2	A	2524	2.83	1.21	1.06	0.74	1.79	14.50	5.27	6.07	5.05	4.49
9/18/91	6	A	2532	<0.48	<0.30	0.42	<0.35	<1.00	2.47	1.45	1.75	<1.74	2.27
9/18/91	7	A	2536	<0.49	0.58	0.57	0.60	<1.02	7.85	2.94	4.57	3.66	3.21
9/18/91	8	A	2540	<0.48	<0.30	0.30	<0.35	<0.99	<1.13	0.97	1.14	<1.74	1.26
9/18/91	9	A	2544	<0.49	<0.31	0.35	<0.36	<1.02	<1.16	0.94	1.24	<1.78	1.76

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	Field	ID		dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt
Date			UWRL	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene
Collected	Core	Lift	ID #	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
9/18/91	11	A	2552	1.19	0.40	0.59	0.63	3.91	13.07	9.75	8.36	5.03	4.71
9/18/91	14	A	2506	<0.47	0.32	0.52	<0.34	<0.98	3.20	1.81	2.52	4.46	2.02
9/18/91	15	A	2556	<0.48	0.34	0.38	0.39	<1.01	5.67	2.25	6.72	<1.77	3.10
9/18/91	16	A	2560	0.79	0.34	0.64	0.96	1.49	28.30	3.22	3.94	<1.74	4.80
9/18/91	2	B	2525	0.71	0.32	0.41	0.36	<0.96	4.79	2.30	2.98	2.73	2.69
9/18/91	3	B	2529	<0.45	<0.28	0.29	<0.33	<0.93	1.35	0.86	1.02	<1.63	1.67
9/18/91	6	B	2533	<0.47	0.39	0.40	<0.34	<0.98	5.64	2.59	3.33	<1.71	2.37
9/18/91	7	B	2537	<0.48	0.38	0.38	0.36	<1.00	3.22	2.04	3.13	<1.75	5.24
9/18/91	8	B	2541	<0.47	<0.30	0.27	<0.34	<0.97	<1.11	<0.78	<1.02	<1.70	1.41
9/18/91	9	B	2545	<0.47	<0.30	<0.10	<0.34	<0.98	1.92	0.86	1.36	2.25	1.57
9/18/91	11	B	2553	<0.46	<0.29	0.35	<0.33	<0.95	<1.08	1.24	1.35	2.11	1.60
9/18/91	15	B	2557	<0.47	0.36	0.40	0.37	1.15	5.63	4.08	<1.03	1.98	1.97
9/18/91	16	B	2561	2.57	0.97	12.36	5.26	23.15	293.19	140.14	128.90	28.05	36.10
9/18/91	2	C	2526	<0.45	0.30	0.40	<0.33	<0.94	3.17	2.53	4.99	2.24	2.59
9/18/91	3	C	2530	<0.46	<0.29	0.30	<0.33	<0.95	<1.08	0.94	1.26	<1.67	<1.11
9/18/91	6	C	2534	0.49	0.49	0.43	<0.34	<0.97	4.57	2.72	4.94	2.38	3.31
9/18/91	7	C	2538	<0.47	0.48	0.43	<0.34	<0.98	2.19	<0.78	4.57	1.74	3.13
9/18/91	8	C	2542	<0.46	<0.29	0.27	<0.34	<0.97	<1.10	1.10	1.64	1.77	1.41
9/18/91	9	C	2546	0.81	0.38	0.48	<0.34	<0.97	4.33	3.11	9.48	2.18	4.71
9/18/91	11	C	2554	<0.45	<0.29	0.32	<0.33	<0.95	1.87	1.57	3.47	1.74	3.62
9/18/91	14	C	2508	<0.46	0.46	0.40	0.48	<0.97	5.42	1.72	7.41	6.92	4.01
9/18/91	15	C	2558	<0.47	<0.30	0.33	<0.34	<0.98	2.66	0.95	1.71	2.73	2.03
9/18/91	16	C	2562	1.12	0.80	0.83	0.89	2.52	26.09	10.62	11.68	7.85	8.23
9/18/91	2	D	2527	0.53	0.31	0.39	<0.34	<0.96	3.26	1.70	2.71	1.88	1.72
9/18/91	3	D	2531	<0.48	0.34	0.38	0.41	<1.00	3.21	1.55	11.15	2.17	3.23
9/18/91	6	D	2535	0.65	0.45	0.58	0.35	<0.98	8.29	3.40	9.85	3.52	3.94
9/18/91	7	D	2539	0.52	0.38	0.41	<0.35	<0.99	5.21	2.52	7.42	1.81	3.39
9/18/91	8	D	2543	<0.47	0.41	0.38	0.84	1.22	11.97	2.72	8.22	1.88	3.46
9/18/91	9	D	2547	2.17	1.48	0.80	0.56	1.57	20.04	4.43	11.65	4.79	5.05
9/18/91	11	D	2555	<0.45	0.39	0.38	<0.33	<0.95	3.29	1.77	9.40	2.74	4.07
9/18/91	14	D	2509	<0.47	0.34	0.45	0.41	<0.99	8.12	3.01	48.92	14.43	11.35
9/18/91	15	D	2559	3.81	2.66	1.08	4.22	3.87	85.21	16.70	159.97	21.36	32.30
9/18/91	16	D	2563	0.74	0.58	0.49	<0.33	1.20	11.10	4.67	11.59	7.99	<1.10
9/19/91	18	A	2568	<0.46	0.50	1.34	0.69	1.04	10.03	33.42	49.41	13.74	14.80
9/19/91	20	A	2576	<0.46	0.35	0.31	<0.34	1.65	<1.10	1.09	2.43	1.74	2.48
9/19/91	21	A	2580	<0.46	<0.29	0.31	<0.34	<0.97	1.35	0.93	1.96	<1.69	2.21

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	Field	ID		dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt
Date			UWRL	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene
Collected	Core	Lift	ID #	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
9/19/91	23	A	2588	<0.47	<0.30	<0.10	<0.34	<0.98	<1.11	1.51	1.93	<1.71	2.05
9/19/91	24	A	2592	0.49	0.40	0.74	<0.35	<1.00	<1.14	<0.80	<1.06	<1.76	<1.16
9/19/91	25	A	2596	<0.47	0.37	0.70	<0.34	<0.98	<1.11	<0.78	<1.03	<1.71	<1.13
9/19/91	28	A	2608	0.48	0.40	0.71	<0.34	<0.96	3.13	0.90	2.18	<1.68	1.42
9/19/91	30	A	2616	0.56	0.45	0.75	<0.34	<0.98	3.12	1.46	2.04	<1.72	1.96
9/19/91	31	A	2620	0.59	0.44	0.75	<0.34	1.00	2.73	1.31	1.84	<1.70	1.70
9/19/91	32	A	2624	1.02	0.49	0.46	<0.36	<1.03	<1.17	<0.82	1.36	<1.80	<1.19
9/19/91	36	A	2835	2.08	0.54	0.65	0.84	1.10	6.84	1.64	3.38	<1.63	2.06
9/19/91	47	A	2831	1.43	0.63	0.58	0.87	<0.94	3.63	1.34	7.16	2.20	3.22
9/19/91	49	A	2816	1.56	0.86	0.67	<0.33	0.98	12.65	33.59	106.28	25.66	19.73
9/19/91	51	A	2818	3.78	0.74	0.76	0.83	1.44	8.16	2.57	4.54	3.21	4.62
9/19/91	54	A	2821	3.66	0.70	0.79	0.94	1.57	13.03	2.35	37.23	3.57	5.66
9/19/91	56	A	2823	5.95	0.67	0.99	1.38	1.70	17.72	68.88	100.72	17.76	16.67
9/19/91	18	B	2569	<0.48	<0.30	0.33	<0.35	<0.99	<1.13	0.89	1.32	<1.74	<1.15
9/19/91	20	B	2577	<0.46	0.38	0.35	<0.34	<0.96	4.31	1.57	3.09	2.32	1.80
9/19/91	21	B	2581	0.57	<0.29	0.36	<0.33	<0.95	<1.07	1.25	4.86	<1.65	2.77
9/19/91	23	B	2589	<0.48	<0.30	<0.10	<0.35	<1.00	2.30	1.63	2.41	<1.75	2.34
9/19/91	24	B	2593	0.51	0.44	0.74	<0.34	<0.98	1.45	0.93	1.25	<1.72	1.58
9/19/91	25	B	2597	0.52	0.38	0.73	<0.34	<0.98	<1.11	0.86	1.32	<1.72	<1.14
9/19/91	28	B	2609	0.50	0.36	0.69	<0.34	<0.97	<1.10	<0.77	1.23	<1.69	<1.12
9/19/91	30	B	2617	0.58	0.54	0.74	<0.35	<1.00	3.12	1.43	1.79	<1.75	1.77
9/19/91	31	B	2621	0.69	0.64	0.73	0.35	<0.97	3.88	1.15	1.73	1.86	1.71
9/19/91	32	B	2625	0.98	0.49	0.48	0.74	<0.99	<1.13	<0.79	1.06	<1.73	<1.15
9/19/91	18	C	2570	0.49	0.60	0.51	0.51	<0.94	7.71	5.96	16.38	10.64	8.94
9/19/91	20	C	2578	<0.46	<0.29	0.46	<0.34	<0.96	3.39	2.25	5.59	2.06	2.44
9/19/91	21	C	2582	<0.45	<0.29	0.39	0.37	<0.95	3.46	2.53	6.65	2.44	2.31
9/19/91	23	C	2590	<0.47	<0.30	0.40	0.35	<0.98	4.01	1.99	4.24	<1.71	2.93
9/19/91	24	C	2594	0.58	0.37	0.73	<0.35	<0.99	1.28	0.93	1.17	<1.72	<1.14
9/19/91	25	C	2598	0.61	0.41	0.74	<0.34	<0.98	1.19	0.86	1.04	<1.71	<1.13
9/19/91	28	C	2610	0.63	0.37	0.72	0.45	1.16	37.51	1.01	1.70	<1.69	<1.12
9/19/91	30	C	2618	0.80	0.50	0.77	<0.35	1.01	3.72	1.95	2.59	<1.75	1.79
9/19/91	31	C	2622	1.04	0.72	0.55	0.83	<1.01	4.94	1.25	1.66	<1.76	1.25
9/19/91	32	C	2626	1.10	0.58	0.51	0.72	<0.97	2.03	0.83	1.35	<1.70	<1.13
9/19/91	18	D	2571	<0.47	0.56	0.39	<0.34	<0.98	11.65	6.27	67.44	14.10	13.19
9/19/91	20	D	2579	2.14	1.57	1.14	1.36	1.80	20.24	7.51	131.65	27.74	29.29
9/19/91	21	D	2583	0.91	0.85	0.51	<0.35	<0.99	10.58	4.64	56.90	8.60	11.18

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	Field	ID		dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt
Date			UWRL	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene
Collected	Core	Lift	ID #	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
9/19/91	23	D	2591	1.51	0.72	0.64	1.00	1.28	10.61	1.91	6.53	2.54	4.16
9/19/91	24	D	2595	0.73	0.43	0.74	<0.34	<0.96	3.59	1.24	2.52	<1.68	1.44
9/19/91	25	D	2599	0.72	0.51	0.76	<0.33	0.94	3.76	1.99	10.46	2.05	2.40
9/19/91	28	D	2611	0.52	0.37	0.71	<0.34	<0.96	3.28	1.09	9.71	<1.68	1.85
9/19/91	30	D	2619	1.44	0.75	0.93	<0.35	1.49	20.91	5.88	65.74	13.07	12.00
9/19/91	31	D	2623	1.39	0.66	0.58	0.88	<1.01	6.40	1.35	12.26	2.57	3.38
9/19/91	32	D	2627	1.67	0.81	0.62	0.94	1.30	17.13	5.58	60.98	13.75	8.51
9/1/92	2	A	574	0.98	0.56	0.45	0.67	<0.80	5.59	2.33	1.12	<1.39	0.94
9/1/92	3	A	579	0.85	0.53	0.44	0.62	<0.79	3.02	0.96	1.15	<1.39	1.13
9/1/92	6	A	594	1.05	0.43	0.45	<0.28	<0.81	<0.91	2.12	<0.85	<1.41	<0.93
9/1/92	7	A	599	0.94	0.47	0.42	0.63	<0.81	2.25	0.75	1.07	<1.41	1.05
9/1/92	8	A	604	1.19	0.88	0.49	0.77	0.85	7.85	0.94	1.29	<1.42	1.65
9/1/92	9	A	609	1.53	0.72	0.57	0.71	1.03	10.24	2.05	3.88	2.08	3.41
9/1/92	11	A	619	1.40	1.01	0.60	0.74	0.98	7.15	1.61	2.35	1.42	3.22
9/1/92	14	A	634	0.86	0.45	0.52	0.68	<0.80	3.24	0.75	1.05	<1.39	<0.92
9/1/92	15	A	639	0.66	0.67	0.74	0.67	<0.81	3.42	1.13	1.68	<1.42	1.40
9/1/92	16	A	644	1.28	0.63	0.88	0.84	1.08	19.74	1.39	2.56	<1.43	1.32
9/1/92	18	A	654	0.76	0.64	0.74	0.60	<0.80	3.27	0.86	1.00	<1.40	1.25
9/1/92	20	A	664	0.91	0.68	0.76	0.63	0.96	3.89	1.49	1.67	<1.40	2.22
9/1/92	21	A	669A	0.86	1.04	0.80	<0.28	0.88	4.86	1.31	1.63	1.45	2.19
9/1/92	23	A	679	0.96	0.89	0.81	0.68	0.99	6.43	1.40	1.81	1.80	2.69
9/1/92	24	A	684	0.66	<0.25	<0.09	<0.28	<0.81	<0.92	<0.65	0.89	<1.41	<0.94
9/1/92	25	A	689	0.56	<0.25	<0.09	<0.28	<0.81	<0.92	<0.65	<0.85	<1.42	<0.94
9/1/92	28	A	704	1.58	0.99	0.79	1.44	1.68	3.76	1.89	1.83	4.63	2.47
9/1/92	30	A	714dup1	1.09	0.99	0.80	1.38	1.05	1.14	1.03	0.90	2.82	1.06
9/1/92	31	A	719	0.84	<0.24	<0.08	<0.28	<0.80	1.16	0.68	<0.84	<1.40	1.30
9/1/92	45	A	759	2.47	0.39	0.26	<0.29	<0.81	5.84	2.52	3.98	<1.42	1.46
9/1/92	47	A	763	3.06	0.64	0.27	0.46	1.66	29.30	3.54	6.84	2.41	2.93
9/1/92	48	A	765	1.96	0.50	0.19	<0.29	1.78	23.48	2.38	5.68	1.61	1.72
9/1/92	49	A	767	3.92	0.66	0.28	<0.28	0.99	5.55	3.52	6.33	2.07	3.45
9/1/92	51	A	771	3.31	<0.25	0.17	<0.28	<0.81	2.30	0.90	2.26	<1.42	<0.94
9/1/92	54	A	777	0.71	<0.24	<0.08	<0.28	<0.80	<0.91	1.25	2.33	<1.40	<0.93
9/1/92	55	A	779a	2.05	0.82	0.15	<0.28	0.94	10.98	4.69	9.00	2.36	2.90
9/1/92	56	A	781	4.65	0.97	0.44	<0.29	1.70	16.58	5.17	8.05	1.73	3.00
9/1/92	58	A	785	1.80	0.43	0.11	<0.29	<0.82	4.41	2.40	5.11	<1.43	1.09
9/1/92	59	A	787	2.84	0.63	0.16	5.14	7.04	108.57	3.14	4.90	1.67	1.14

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Date Collected	Field Core	ID Lift	UWRL ID #	dry wt Naphthalene mg/kg	dry wt Acenaphthylene mg/kg	dry wt Acenaphthene mg/kg	dry wt Fluorene mg/kg	dry wt Phenanthrene mg/kg	dry wt Anthracene mg/kg	dry wt Fluoranthene mg/kg	dry wt Pyrene mg/kg	dry wt Benzo(a)anthracene mg/kg	dry wt Chrysene mg/kg
9/1/92	62	A	793	1.51	0.38	0.21	<0.28	1.12	11.39	2.34	<0.85	3.46	2.17
9/1/92	63	A	795	1.43	0.38	0.15	0.65	1.41	20.49	1.63	<0.84	3.17	2.52
9/1/92	64	A	797	1.51	0.27	0.19	<0.28	<0.80	2.48	1.44	<0.84	2.40	2.15
9/1/92	2	B	575	<0.38	0.47	0.44	0.64	<0.80	6.30	0.94	1.29	<1.39	<0.92
9/1/92	3	B	580	<0.38	0.63	0.40	<0.28	<0.79	3.35	0.69	0.93	<1.39	1.05
9/1/92	6	B	595	<0.38	0.41	0.40	<0.28	<0.80	<0.90	0.64	<0.84	<1.39	<0.92
9/1/92	7	B	600	0.94	0.48	0.42	0.59	<0.80	<0.91	0.90	0.99	<1.40	<0.93
9/1/92	8	B	605	1.00	0.52	0.46	0.70	<0.81	2.52	0.99	1.40	<1.41	1.65
9/1/92	9	B	610A	3.09	0.68	0.67	1.32	1.60	11.22	5.75	11.83	4.93	10.55
9/1/92	11	B	620	3.21	2.28	0.82	1.01	1.60	22.86	3.04	4.78	3.20	5.18
9/1/92	14	B	635	<0.37	0.62	0.47	<0.28	<0.78	9.67	0.80	1.24	<1.36	1.70
9/1/92	15	B	640	0.80	0.72	0.76	0.61	<0.80	2.13	1.35	1.27	<1.40	1.45
9/1/92	16	B	645	1.04	0.74	0.81	0.83	0.89	5.16	1.32	1.52	<1.41	1.64
9/1/92	18	B	655	1.34	0.74	0.75	0.59	0.82	2.93	1.03	1.26	<1.39	1.28
9/1/92	20	B	665	1.36	0.88	0.80	<0.28	0.94	5.75	1.38	1.90	1.56	1.87
9/1/92	21	B	670S1	2.03	0.88	0.90	0.72	0.95	7.77	1.28	2.60	1.54	2.31
9/1/92	23	B	680	4.93	0.96	1.10	1.23	2.59	17.28	3.21	21.25	2.72	4.74
9/1/92	24	B	685	0.49	<0.24	<0.08	<0.28	<0.80	<0.91	<0.64	0.91	<1.40	<0.93
9/1/92	25	B	690	0.50	0.30	<0.08	<0.28	<0.80	<0.91	<0.64	<0.84	<1.40	<0.93
9/1/92	28	B	705	1.28	1.07	0.79	1.39	1.05	1.76	1.18	1.41	2.95	2.02
9/1/92	30	B	715	1.08	1.23	0.75	1.28	1.00	1.50	1.16	1.05	2.94	2.06
9/1/92	31	B	720	0.82	<0.24	<0.08	<0.28	<0.79	4.52	<0.64	<0.84	<1.39	1.23
9/1/92	45	B	760	2.29	<0.24	0.17	<0.28	0.82	3.28	2.09	4.22	<1.41	2.07
9/1/92	47	B	764	2.85	0.97	0.29	0.47	1.90	32.85	4.25	8.37	3.16	4.44
9/1/92	48	B	766	1.65	0.35	<0.09	<0.29	<0.82	6.60	2.53	5.08	<1.43	1.76
9/1/92	51	B	772	5.12	0.41	0.30	<0.28	<0.81	3.41	2.29	5.16	<1.42	2.43
9/1/92	54	B	778	2.27	0.76	0.19	<0.28	1.04	8.99	3.17	5.79	2.22	2.31
9/1/92	55	B	780	2.33	0.40	0.14	<0.28	<0.81	7.72	2.24	4.74	1.97	1.98
9/1/92	56	B	782	2.76	<0.25	0.20	<0.28	0.81	6.61	2.80	5.40	1.74	<0.93
9/1/92	58	B	786	2.36	0.46	0.12	<0.28	<0.80	9.66	2.17	4.88	<1.40	1.10
9/1/92	59	B	788	1.12	0.36	0.09	<0.28	<0.80	2.99	1.85	3.06	<1.39	<0.92
9/1/92	62	B	794	1.43	0.27	0.16	<0.28	0.87	7.72	1.83	<0.85	2.66	2.00
9/1/92	63	B	796	1.59	0.33	0.17	<0.28	<0.80	2.68	1.11	0.92	1.98	2.34
9/1/92	64	B	798	1.90	0.25	0.23	<0.28	<0.81	2.27	1.96	<0.85	2.94	2.44
9/1/92	2	C	576	<0.37	0.54	0.40	<0.27	<0.78	<0.88	<0.62	1.02	<1.36	0.91
9/1/92	3	C	581	0.85	0.66	0.43	0.68	<0.80	3.53	0.81	1.06	<1.39	1.02

B - 1: PAHs edited 9/21/93

	Field	ID		dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt
Date			UWRL	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene
Collected	Core	Lift	ID #	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
9/1/92	6	C	596	0.94	0.44	0.46	0.61	<0.79	1.26	0.88	1.17	<1.38	<0.92
9/1/92	7	C	601	1.30	0.62	0.53	<0.28	0.88	5.12	1.53	1.93	<1.39	1.54
9/1/92	8	C	606	1.67	0.70	0.64	<0.28	1.16	7.08	2.28	2.91	2.35	3.06
9/1/92	9	C	611	4.85	4.37	0.80	1.33	1.49	48.92	4.08	5.04	4.40	6.96
9/1/92	11	C	621	1.53	0.81	0.59	0.71	0.97	6.27	1.40	2.53	<1.40	1.61
9/1/92	14	C	636	<0.38	0.64	0.42	0.66	<0.79	2.33	0.71	1.37	<1.39	1.02
9/1/92	15	C	641	0.84	0.84	0.75	<0.28	<0.80	2.93	1.10	5.87	1.62	2.58
9/1/92	16	C	646	1.15	0.73	0.78	0.65	0.94	2.98	1.32	1.67	1.44	2.06
9/1/92	18	C	656	0.96	0.66	0.76	0.59	0.88	2.70	1.11	1.32	<1.39	1.07
9/1/92	20	C	666	1.79	0.78	0.89	0.76	1.26	6.36	2.58	11.84	3.05	4.14
9/1/92	21	C	671	2.04	0.97	0.96	<0.28	1.44	15.72	2.43	6.62	2.28	4.11
9/1/92	23	C	681	2.74	1.46	1.07	1.22	2.30	69.65	8.17	20.10	7.93	7.77
9/1/92	23	C	682S1	3.51	1.24	1.17	1.35	2.55	23.10	3.45	13.26	4.31	5.70
9/1/92	24	C	686	3.89	0.58	0.23	<0.28	<0.80	3.21	1.57	3.84	<1.39	1.01
9/1/92	28	C	706	2.02	0.76	8.19	1.36	1.24	1.48	1.48	1.82	3.19	1.53
9/1/92	30	C	716	<0.38	<0.24	<0.08	<0.28	<0.80	<0.91	<0.64	<0.94	<1.40	<0.93
9/1/92	31	C	721	<0.38	<0.24	<0.08	<0.28	<0.80	<0.91	<0.64	<0.84	<1.40	<0.93
9/1/92	2	D	577	0.79	0.63	0.47	0.67	<0.80	3.37	0.80	1.33	<1.39	1.62
9/1/92	3	D	582	1.96	0.65	0.55	0.71	1.12	13.65	1.91	2.61	1.74	2.41
9/1/92	6	D	597	2.51	0.92	0.71	0.81	1.59	12.63	2.01	3.78	2.63	3.53
9/1/92	7	D	602	1.63	0.65	0.63	0.79	1.01	7.00	1.33	2.83	<1.40	2.37
9/1/92	8	D	607	2.95	1.74	0.74	1.05	1.68	31.79	2.60	4.08	2.49	3.45
9/1/92	9	D	612	5.28	1.06	0.97	1.03	2.44	19.73	5.86	25.38	5.64	10.75
9/1/92	11	D	622	1.71	0.79	0.54	0.72	0.83	10.22	1.13	1.86	1.49	1.02
9/1/92	14	D	637	1.13	0.79	0.78	0.73	1.00	6.15	1.34	2.59	1.78	2.21
9/1/92	15	D	642A	1.38	0.88	0.81	0.79	0.99	6.02	1.33	2.23	<1.40	1.43
9/1/92	16	D	647	1.02	0.66	0.76	0.63	<0.80	2.18	0.88	1.05	<1.41	<0.93
9/1/92	18	D	657	1.18	0.76	0.79	0.64	0.90	5.63	1.15	2.01	<1.42	1.43
9/1/92	20	D	667	1.69	0.67	0.80	0.65	0.96	15.90	1.27	1.33	<1.41	1.37
9/1/92	21	D	672	1.84	1.78	0.95	<0.28	1.65	29.63	2.96	5.98	3.47	4.78
9/1/92	24	D	687	2.32	0.27	0.15	<0.28	<0.80	2.35	1.34	3.28	<1.41	<0.93
9/1/92	25	D	692	2.41	1.07	0.86	1.44	1.38	1.98	1.57	2.69	3.11	1.75
9/1/92	30	D	717	1.45	<0.25	0.15	<0.28	<0.81	2.67	0.89	<0.85	2.94	2.92
9/1/92	31	D	722	1.24	<0.24	0.14	<0.28	<0.79	6.68	1.77	1.63	16.11	3.89
9/1/92	2	E	578	1.36	0.73	0.55	0.79	1.01	10.79	0.97	1.50	<1.39	1.14
9/1/92	3	E	583A	1.87	1.20	0.65	0.74	1.00	8.95	1.72	2.26	2.29	2.42

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	Field	ID		dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	dry wt
Date			UWRL	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene
Collected	Core	Lift	ID #	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
9/1/92	6	E	598	3.90	1.38	0.87	1.02	1.69	15.51	2.21	3.90	2.96	3.20
9/1/92	7	E	603	7.61	1.29	1.04	1.66	2.60	88.76	5.22	9.30	3.26	4.81
9/1/92	8	E	608	4.63	0.72	0.84	0.84	1.62	9.24	2.24	2.35	<1.38	1.16
9/1/92	9	E	613	10.22	1.38	1.29	1.67	3.79	125.98	30.06	97.29	18.08	21.00
9/1/92	11	E	623	<0.38	0.50	0.52	0.80	0.85	11.64	0.80	1.31	<1.39	<0.92
9/1/92	14	E	638	1.42	1.02	0.88	0.81	1.02	10.74	1.79	2.54	1.66	2.42
9/1/92	15	E	643	1.87	0.84	0.82	0.66	0.90	5.39	1.19	2.11	<1.39	1.91
9/1/92	16	E	648	1.41	0.71	0.77	0.65	0.91	5.37	1.19	1.75	<1.40	1.44
9/1/92	18	E	658	1.97	0.79	0.88	0.75	1.18	7.04	1.82	2.88	1.65	1.85
9/1/92	20	E	668	2.23	0.85	0.83	0.81	1.09	15.45	1.25	2.14	1.65	9.68
9/1/92	21	E	673	1.42	0.98	0.89	0.83	1.60	16.49	2.34	3.88	2.04	2.55
9/1/92	23	E	683	1.86	0.61	0.11	<0.27	<0.78	7.31	2.28	5.23	<1.37	1.76
9/1/92	24	E	688	9.97	0.98	0.89	4.91	9.11	100.29	38.32	67.90	17.72	17.93
9/1/92	25	E	693	5.08	1.68	1.19	1.78	2.43	8.48	3.64	6.24	4.71	4.00
9/1/92	30	E	718	2.37	<0.24	0.18	<0.28	<0.80	2.38	1.51	<0.84	2.37	2.38
9/1/93	28	D	707	2.75	1.04	0.85	1.41	1.32	2.30	1.72	2.93	3.51	2.96

B - 1: PAHs edited 9/21/93

Date Collected	Field Core	ID Lift	UWRL ID #	dry wt B(b)fluoranthene mg/kg	dry wt B(k)fluoranthene mg/kg	dry wt Benzo(a)pyrene mg/kg	dry wt Indeno(123)p mg/kg	dry wt DB(ah)anthracene mg/kg	dry wt Benzo(ghi)perylene mg/kg	total carcinogenic PAH mg/Kg	total PAH mg/kg
5/6/91	1	A	1748	<1.487	<1.602	<2.499	<3.699	<1.567	<3.671	4.21	5.81
5/6/91	2	A	1750	<1.347	<1.451	<2.264	<3.351	<1.419	<3.325	<17.24	0.41
5/6/91	6	A	1762	<1.543	<1.662	<2.593	<3.838	<1.626	<3.809	<19.75	0.61
5/6/91	7	A	1765	<1.553	<1.672	<2.608	<3.861	<1.635	<3.832	1.37	2.62
5/6/91	9	A	1771	<1.537	<1.655	<2.583	<3.832	<1.619	<3.794	1.16	2.33
5/6/91	10	A	1774	<1.514	<1.63	<2.543	<3.765	<1.595	<3.736	<19.37	1.16
5/6/91	11	A	1777	13.98	7.26	13.53	7.60	3.88	5.93	71.98	89.15
5/6/91	13	A	1783	<1.495	<1.609	<2.511	<3.717	<1.574	<3.688	1.19	1.81
5/6/91	14	A	1786	25.15	8.30	17.64	12.06	5.16	11.07	135.79	161.73
5/6/91	15	A	1790	18.24	10.78	20.15	18.25	8.38	19.39	138.95	166.19
5/6/91	17	A	1796	4.99	2.29	5.05	4.59	3.42	4.68	30.62	37.45
5/6/91	18	A	1798	2.06	<1.67	<2.60	<3.85	<1.63	<3.82	2.06	20.62
5/6/91	18	A	1798	2.06	<1.67	<2.60	<3.85	<1.63	<3.82	2.06	20.62
5/6/91	19	A	1801	4.19	2.52	4.95	3.97	3.08	<3.714	23.88	28.01
5/6/91	20	A	1804	17.44	6.69	9.84	6.50	<1.61	5.39	70.99	96.66
5/6/91	23	A	1813	17.52	8.90	13.81	12.00	7.36	10.97	94.85	107.20
5/6/91	24	A	1816	6.58	2.29	4.62	8.07	4.81	6.94	43.87	52.36
5/6/91	25	A	1819	4.65	<1.69	<2.63	<3.90	<1.65	<3.87	11.23	15.98
5/6/91	27	A	1825	<1.497	<1.612	<2.515	<3.722	1.73	<3.694	4.07	5.52
5/6/91	28	A	1828	4.29	1.82	2.78	<3.90	1.67	<3.87	14.91	19.13
5/6/91	30	A	1834	14.70	2.03	8.18	8.23	6.76	7.25	65.82	77.67
5/6/91	31	A	1837	3.13	<1.71	<2.67	<3.96	<1.68	<3.93	8.23	10.85
5/6/91	32	A	1840	<1.69	<1.82	<2.84	<4.10	<1.78	<4.18	3.52	6.38
5/6/91	1	B	1747	8.61	1.75	3.99	<3.79	2.64	<3.76	40.68	48.84
5/6/91	14	B	1787 A	25.30	7.18	19.20	15.03	4.73	11.18	115.54	143.62
5/6/91	15	B	1791	19.82	6.07	13.68	11.89	4.38	7.87	79.23	94.43
5/6/91	16	B	1794	9.08	5.69	10.23	5.45	3.06	3.82	52.41	63.61
5/6/91	23	B	1814	5.81	5.83	9.32	13.08	6.13	11.25	66.13	77.45
5/6/91	24	B	1817 A	5.62	2.42	3.96	4.42	3.49	3.88	31.49	39.04
5/6/91	30	B	1835	3.30	3.35	5.63	5.30	4.54	3.96	40.86	47.55
5/6/91	31	B	1838	8.04	2.25	5.12	6.04	5.58	3.91	37.07	41.93
5/8/91	2	C	1752	6.78	6.50	6.55	3.97	3.24	<3.658	75.55	78.99
5/8/91	5	C	1761	4.54	4.15	5.13	4.39	2.80	<3.655	44.05	46.00
5/8/91	6	C	1764	8.21	3.47	5.80	<3.682	2.96	<3.656	45.52	51.01
5/8/91	10	C	1776	9.76	2.95	6.55	<3.812	3.01	<3.783	37.87	45.89
5/8/91	11	C	1779	11.95	3.69	8.96	4.53	3.19	<3.518	50.13	58.36

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Date Collected	Field Core	ID Lift	UWRL ID #	dry wt B(b)fluoranthene mg/kg	dry wt B(k)fluoranthene mg/kg	dry wt Benzo(a)pyrene mg/kg	dry wt Indeno(123)p mg/kg	dry wt DB(ah)anthracene mg/kg	dry wt Benzo(ghi)perylene mg/kg	total carcinogenic PAH mg/Kg	total PAH mg/kg
5/8/91	12	C	1782	15.97	1.85	7.89	4.87	2.95	4.48	70.21	79.13
5/8/91	13	C	1785	16.07	10.43	13.81	15.85	11.84	13.71	128.71	178.68
5/8/91	14	C	1789	53.18	48.31	38.36	16.42	9.28	16.92	829.10	860.65
5/8/91	15	C	1792	32.22	21.42	17.24	10.29	5.86	8.20	411.03	433.87
5/8/91	16	C	1795	106.59	67.35	69.82	37.10	22.76	28.75	754.85	794.15
5/8/91	18	C	1800	2.78	3.25	4.81	4.39	<1.525	4.76	34.06	36.40
5/8/91	20	C	1806	52.59	40.76	43.11	19.31	13.20	19.24	437.88	458.36
5/8/91	23	C	1815	59.25	48.31	43.98	18.09	13.95	14.61	554.02	578.85
5/8/91	24	C	1818	22.35	18.47	14.27	11.45	6.13	8.63	161.38	172.68
5/8/91	25	C	1821	3.16	1.69	3.48	<3.710	<1.571	<3.681	14.59	15.60
5/8/91	27	C	1827	3.67	2.12	3.56	3.79	<1.509	<3.535	24.49	31.44
5/8/91	28	C	1830	35.65	28.21	15.65	13.35	8.60	10.88	161.31	179.68
5/8/91	29	C	1833	4.11	1.95	4.05	3.85	<1.525	<3.581	21.68	22.49
5/8/91	30	C	1836	51.20	48.93	41.79	16.69	16.82	16.64	457.65	479.37
5/8/91	31	C	1839	24.24	24.58	24.57	13.94	13.16	14.73	288.22	331.93
6/27/91	3	A	1859	18.32	14.13	20.54	13.52	<1.57	13.63	111.36	198.48
6/27/91	6	A	1868A	19.14	14.87	24.17	14.94	5.91	16.72	146.88	299.79
6/27/91	7	A	1871	21.69	15.57	32.99	30.64	9.73	28.46	193.52	335.71
6/27/91	9	A	1877	1.78	<1.69	<2.63	<3.90	<1.65	<3.87	5.05	12.34
6/27/91	11	A	1883	4.27	2.45	5.14	3.97	<1.64	3.99	28.97	43.64
6/27/91	13	A	1889	6.37	3.39	6.51	4.58	1.86	4.70	42.34	51.93
6/27/91	14	A	1892	1.92	<1.73	<2.71	<4.01	<1.70	<3.98	4.44	12.99
6/27/91	15	A	1895	<1.54	<1.66	<2.59	<3.84	<1.63	<3.81	<19.8	<23.1
6/27/91	19	A	1907	1.70	<1.66	<2.54	<3.76	<1.59	<3.73	1.70	2.48
6/27/91	20	A	1910	7.53	7.39	8.31	9.52	3.51	7.13	54.81	61.33
6/27/91	22	A	1916	6.88	3.51	5.57	<3.75	1.77	3.77	29.15	29.92
6/27/91	23	A	1919	17.99	12.97	19.15	15.31	5.43	15.87	113.82	126.78
6/27/91	24	A	1922	<1.53	1.72	2.77	<3.80	<1.61	<3.77	7.01	7.70
6/27/91	25	A	1925	<1.51	<1.62	<2.53	<3.75	<1.59	<3.72	<19.3	<22.5
6/27/91	30	A	1940	<1.54	<1.66	<2.59	<3.83	<1.62	<3.81	<19.7	<23.0
6/27/91	32	A	1946	<1.54	<1.66	<2.58	<3.82	<1.62	<3.79	<19.7	<23.0
6/27/91	2	B	1857	5.59	3.82	8.93	5.23	2.12	7.07	44.82	59.50
6/27/91	6	B	1869	26.11	14.69	36.94	33.32	14.17	41.33	212.47	308.27
6/27/91	7	B	1872	6.84	4.10	9.05	7.10	2.50	10.07	57.25	85.84
6/27/91	8	B	1875	2.27	<1.68	<2.62	<3.88	<1.64	<3.85	10.17	21.87
6/27/91	9	B	1878	2.64	<1.65	<2.58	<3.82	<1.62	<3.79	5.59	8.74

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Date Collected	Field Core	ID Lift	UWRL ID #	dry wt B(b)fluoranthene mg/kg	dry wt B(k)fluoranthene mg/kg	dry wt Benzo(a)pyrene mg/kg	dry wt Indeno(123)p mg/kg	dry wt DB(ah)anthracene mg/kg	dry wt Benzo(ghi)perylene mg/kg	total carcinogenic PAH mg/Kg	total PAH mg/kg
6/27/91	11	B	1884	4.44	2.52	5.12	4.50	<1.63	5.08	26.95	40.70
6/27/91	13	B	1890	<1.50	<1.63	<2.52	<3.73	<1.58	<3.70	<19.2	<22.4
6/27/91	14	B	1893	3.93	<1.65	2.68	<3.81	<1.61	<3.78	9.86	17.81
6/27/91	15	B	1896	<1.52	<1.64	<2.56	<3.79	<1.60	<3.76	<19.5	<22.8
6/27/91	19	B	1908	5.33	6.12	8.80	5.93	2.33	6.25	41.75	45.53
6/27/91	20	B	1911	8.98	5.08	6.24	5.27	<1.56	5.46	40.31	44.24
6/27/91	21	B	1914	7.36	5.23	8.47	7.21	2.85	8.81	46.97	50.65
6/27/91	23	B	1920	<1.52	<1.64	<2.56	<3.79	<1.60	<3.76	4.48	4.66
6/27/91	25	B	1926	<1.51	<1.63	<2.54	<3.76	<1.59	<3.73	<19.3	0.11
6/27/91	28	B	1935	<1.51	<1.63	<2.54	<3.76	<1.59	<3.74	<19.4	<22.6
6/27/91	31	B	1944	<1.48	<1.60	<2.49	<3.69	<1.56	<3.66	<19.0	<22.2
6/27/91	32	B	1947	<1.54	<1.66	<2.59	<3.84	<1.63	<3.81	<19.8	<23.1
6/27/91	1	C	1855	2.92	2.42	3.26	<3.97	<1.68	4.27	18.68	19.40
6/27/91	2	C	1858	8.52	6.59	10.82	4.74	2.19	5.40	59.52	81.20
6/27/91	6	C	1870	55.14	30.47	61.77	43.73	17.86	31.24	339.42	523.91
6/27/91	8	C	1876	4.31	2.97	4.15	4.94	<1.66	<3.89	25.97	48.63
6/27/91	9	C	1879	4.17	2.28	3.06	<3.92	<1.66	<3.89	17.08	24.40
6/27/91	11	C	1885	14.66	7.65	14.67	6.16	2.96	7.41	66.31	78.74
6/27/91	14	C	1894	<1.50	<1.62	<2.52	<3.74	<1.58	<3.71	<19.2	0.59
6/27/91	19	C	1909	2.79	2.15	4.32	4.02	<1.61	<3.77	16.43	17.00
6/27/91	20	C	1912	2.45	1.86	3.01	<3.80	<1.61	<3.77	10.35	10.35
6/27/91	21	C	1915	2.92	<1.63	3.43	<3.77	<1.60	4.32	13.31	14.22
6/27/91	23	C	1921	<1.51	<1.63	<2.54	<3.76	<1.59	<3.74	2.25	2.25
6/27/91	24	C	1924	4.35	2.55	4.31	4.99	<1.61	4.36	28.29	29.57
6/27/91	26	C	1930	1.85	<1.62	<2.53	<3.74	<1.59	<3.72	4.53	5.15
6/27/91	29	C	1939	<1.54	<1.66	<2.59	<3.84	<1.63	<3.81	1.22	1.22
6/27/91	32	C	1948	<1.53	<1.65	<2.57	<3.80	<1.61	<3.77	<19.6	<22.9
7/27/91	33	A	2059	29.44	13.22	12.32	<3.72	<1.58	<3.69	392.56	410.59
7/27/91	36	A	2062	39.25	7.89	9.25	<3.62	<1.53	5.29	121.20	126.32
7/27/91	38	A	2064	18.92	8.01	5.17	<3.71	<1.57	<3.68	234.18	244.05
7/27/91	39	A	2065	<1.49	<1.61	<2.51	<3.72	<1.57	<3.69	153.28	153.28
7/27/91	40	A	2066	5.77	1.95	<2.53	<3.75	<1.59	<3.72	54.91	56.12
7/27/91	42	A	2068	18.28	3.61	3.13	<3.63	<1.54	<3.60	202.60	258.99
7/27/91	44	A	2070	12.51	10.87	10.85	<3.63	<1.54	<3.61	111.22	117.70
7/27/91	45	A	2071	11.97	11.71	6.53	<3.70	<1.56	<3.67	157.33	163.25
7/27/91	47	A	2073	14.54	6.39	5.50	<3.59	<1.52	<3.56	192.56	198.87

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Date Collected	Field Core	ID Lift	UWRL ID #	dry wt B(b)fluoranthene mg/kg	dry wt B(k)fluoranthene mg/kg	dry wt Benzo(a)pyrene mg/kg	dry wt Indeno(123)p mg/kg	dry wt DB(ah)anthracene mg/kg	dry wt Benzo(ghi)perylene mg/kg	total carcinogenic PAH mg/Kg	total PAH mg/kg
7/27/91	48	A	2074	35.82	13.31	17.65	<2.59	<1.52	7.09	446.51	789.49
7/27/91	49	A	2075	14.11	7.82	4.20	<3.66	<1.55	<3.63	164.49	177.02
7/27/91	51	A	2077	3.37	4.04	3.24	<3.66	<1.55	<3.64	91.31	102.03
7/27/91	54	A	2080	7.37	6.20	5.76	<3.71	<1.57	<3.68	124.30	136.72
7/27/91	55	A	2081-1	8.33	7.05	7.82	<3.73	1.79	<3.70	155.28	169.67
7/27/91	56	A	2082	13.72	7.61	9.91	4.65	2.58	<3.64	179.37	198.01
7/27/91	58	A	2084	12.34	9.64	8.18	<3.74	3.05	<3.71	178.35	190.26
7/27/91	59	A	2085	12.49	7.66	7.05	<3.71	<1.57	<3.68	131.95	144.31
7/27/91	62	A	2088	26.10	13.27	15.91	7.09	4.95	5.28	321.14	641.83
7/27/91	63	A	2089	20.28	11.76	11.36	4.41	1.90	<3.73	251.50	292.09
7/27/91	64	A	2090	26.27	17.56	25.89	14.82	6.64	10.53	411.99	463.04
7/27/91	2	D	2028	17.85	7.66	8.44	<3.62	<1.53	<3.59	107.03	109.10
7/27/91	3	D	2029	17.77	1.62	6.33	<3.70	1.72	<3.68	107.24	107.24
7/27/91	6	D	2032	8.88	5.54	5.18	<3.70	<1.54	<3.62	40.00	43.35
7/27/91	7	D	2033	19.51	4.87	8.47	<3.68	<1.56	<3.65	131.25	132.59
7/27/91	8	D	2034	13.91	5.65	4.82	<3.62	<1.53	<3.59	158.20	164.83
7/27/91	9	D	2035	9.23	5.03	<2.44	<3.61	<1.53	<3.59	84.32	86.51
7/27/91	11	D	2037	23.54	4.06	8.65	<3.68	<1.56	<3.65	121.36	125.94
7/27/91	14	D	2040	23.09	10.12	9.04	<3.63	<1.54	<3.60	396.24	433.04
7/27/91	15	D	2041	41.39	10.07	13.15	<3.67	<1.56	<3.64	359.74	370.83
7/27/91	16	D	2042	53.80	23.46	16.79	11.22	8.97	14.61	399.47	499.77
7/27/91	18	D	2044	25.59	10.49	4.50	<3.68	2.68	<3.65	310.21	311.25
7/27/91	20	D	2046	41.32	17.83	11.36	7.20	2.64	8.53	480.45	491.96
7/27/91	21	D	2047	18.01	14.36	6.56	<3.71	<1.57	<3.68	182.07	191.67
7/27/91	23	D	2049	23.37	7.94	3.55	<3.62	<1.53	<3.59	141.54	151.04
7/27/91	24	D	2050	29.83	4.36	7.87	<3.59	<1.52	<3.56	113.69	119.62
7/27/91	25	D	2051	20.93	8.58	8.85	<3.65	<1.55	<3.62	233.39	235.73
7/27/91	28	D	2054	16.91	16.48	7.72	<3.63	<1.54	<3.60	283.88	290.75
7/27/91	30	D	2056	31.66	9.95	12.44	<3.64	1.86	4.49	492.33	523.80
7/27/91	31	D	2057	37.95	9.90	8.30	<3.69	3.98	8.25	333.30	341.49
7/27/91	32	D	2058	27.31	17.12	8.94	4.76	<1.56	5.59	595.13	823.68
9/18/91	2	A	2524	10.57	7.22	12.55	13.15	4.20	12.27	80.84	102.97
9/18/91	6	A	2532	6.40	3.06	3.66	3.92	<1.64	<3.85	22.51	25.39
9/18/91	7	A	2536	6.20	4.83	7.43	5.52	4.17	6.59	49.13	58.73
9/18/91	8	A	2540	1.92	2.00	<2.61	<3.87	2.73	<3.84	10.00	10.30
9/18/91	9	A	2544	3.13	2.78	3.84	<3.97	4.00	<3.94	17.68	18.03

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Date Collected	Field Core	ID Lift	UWRL ID #	dry wt B(b)fluoranthene mg/kg	dry wt B(k)fluoranthene mg/kg	dry wt Benzo(a)pyrene mg/kg	dry wt Indeno(123)p mg/kg	dry wt DB(ah)anthracene mg/kg	dry wt Benzo(ghi)perylene mg/kg	total carcinogenic PAH mg/Kg	total PAH mg/kg
9/18/91	11	A	2552	7.48	4.98	6.46	5.05	3.84	4.26	59.92	79.71
9/18/91	14	A	2506	6.71	3.43	8.05	6.81	4.84	4.88	45.53	49.57
9/18/91	15	A	2556	5.35	3.97	5.52	5.41	2.93	5.14	40.40	47.19
9/18/91	16	A	2560	7.72	5.48	5.97	7.31	4.47	4.97	47.89	80.41
9/18/91	2	B	2525	6.40	3.27	6.52	4.37	<1.58	<3.70	31.25	37.84
9/18/91	3	B	2529	2.97	1.75	<2.46	<3.64	<1.54	<3.61	8.28	9.92
9/18/91	6	B	2533	6.49	3.00	4.06	4.08	<1.61	<3.78	25.93	32.36
9/18/91	7	B	2537	3.39	3.86	4.35	<3.91	3.18	<3.88	25.19	29.53
9/18/91	8	B	2541	<1.53	<1.65	<2.57	<3.80	<1.61	<3.77	1.41	1.69
9/18/91	9	B	2545	3.71	<1.66	3.32	<3.84	2.54	<3.81	15.62	17.54
9/18/91	11	B	2553	4.54	2.08	3.37	<3.71	3.59	<3.68	19.89	20.24
9/18/91	15	B	2557	11.25	3.85	10.56	6.54	5.44	5.78	51.45	59.36
9/18/91	16	B	2561	22.98	13.60	21.56	9.13	7.06	7.30	414.84	752.34
9/18/91	2	C	2526	6.23	3.51	6.33	5.46	2.40	<3.65	36.27	40.14
9/18/91	3	C	2530	2.06	2.31	<2.51	<3.72	1.99	<3.69	8.55	8.85
9/18/91	6	C	2534	3.70	4.70	5.66	4.48	3.64	<3.74	35.54	41.52
9/18/91	7	C	2538	10.66	3.53	7.03	<3.81	5.70	5.75	42.12	45.21
9/18/91	8	C	2542	4.34	<1.63	2.86	<3.77	<1.60	<3.74	13.12	13.39
9/18/91	9	C	2546	9.09	5.75	9.79	<3.79	3.30	4.54	33.99	37.02
9/18/91	11	C	2554	12.24	6.36	10.55	6.05	5.85	5.11	56.58	58.77
9/18/91	14	C	2508	11.82	6.67	10.97	7.01	5.85	6.70	69.09	75.86
9/18/91	15	C	2558	4.63	1.81	3.27	3.92	<1.61	3.97	25.02	28.01
9/18/91	16	C	2562	17.85	11.26	16.48	11.47	8.99	8.72	113.16	145.42
9/18/91	2	D	2527	5.24	2.03	2.98	<3.74	<1.59	<3.72	18.27	22.75
9/18/91	3	D	2531	5.77	5.37	5.24	<3.90	<1.65	<3.87	34.48	38.82
9/18/91	6	D	2535	9.44	6.15	5.57	<3.83	<1.62	<3.80	41.87	52.19
9/18/91	7	D	2539	7.15	7.14	7.79	<3.87	4.65	4.70	46.57	53.09
9/18/91	8	D	2543	12.00	4.54	6.76	<3.80	4.77	<3.77	44.35	59.18
9/18/91	9	D	2547	13.18	13.13	15.74	12.91	18.90	20.84	120.62	147.23
9/18/91	11	D	2555	15.95	5.28	10.23	<3.70	<1.57	<3.67	49.44	53.50
9/18/91	14	D	2509	15.11	14.14	11.88	6.62	2.87	<3.82	128.34	137.65
9/18/91	15	D	2559	56.54	38.96	42.06	28.02	20.32	27.10	443.32	544.17
9/18/91	16	D	2563	19.97	8.12	14.51	7.90	4.05	5.85	84.64	98.76
9/19/91	18	A	2568	18.34	11.64	12.87	7.88	4.71	4.40	171.22	184.81
9/19/91	20	A	2576	5.84	3.38	6.09	4.24	<1.59	<3.74	27.28	29.60
9/19/91	21	A	2580	3.16	3.02	4.30	<3.76	<1.59	<3.74	15.57	17.24

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Date Collected	Field Core	ID Lift	UWRL ID #	dry wt B(b)fluoranthene mg/kg	dry wt B(k)fluoranthene mg/kg	dry wt Benzo(a)pyrene mg/kg	dry wt Indeno(123)p mg/kg	dry wt DB(ah)anthracene mg/kg	dry wt Benzo(ghi)perylene mg/kg	total carcinogenic PAH mg/Kg	total PAH mg/kg
9/19/91	23	A	2588	2.83	1.71	3.47	4.45	3.36	<3.79	21.32	21.32
9/19/91	24	A	2592	<1.57	<1.70	<2.64	<3.91	<1.66	<3.89	<20.2	1.62
9/19/91	25	A	2596	<1.53	<1.65	<2.57	<3.81	<1.61	<3.78	<19.6	1.07
9/19/91	28	A	2608	1.65	<1.63	<2.54	<3.76	<1.59	<3.73	6.15	10.88
9/19/91	30	A	2616	2.58	2.20	5.23	<3.84	1.66	<3.81	17.13	22.02
9/19/91	31	A	2620	2.70	1.69	3.84	<3.78	<1.60	<3.75	13.07	18.57
9/19/91	32	A	2624	<1.62	<1.74	<2.71	<4.02	<1.70	<3.99	1.36	3.33
9/19/91	36	A	2835	2.15	2.56	<2.45	<3.63	<1.54	<3.60	11.79	23.84
9/19/91	47	A	2831	4.09	5.62	5.29	<3.65	<1.54	<3.62	28.92	36.05
9/19/91	49	A	2816	15.46	10.91	11.95	4.14	1.82	<3.60	229.54	246.27
9/19/91	51	A	2818	11.25	7.32	7.34	3.94	1.89	<3.59	46.69	62.41
9/19/91	54	A	2821	15.19	7.51	8.05	<3.70	<1.57	<3.67	79.55	100.24
9/19/91	56	A	2823	5.60	4.41	5.27	<3.73	<1.58	<3.70	219.32	247.73
9/19/91	18	B	2569	3.18	2.49	<2.62	<3.88	<1.64	<3.85	7.88	8.22
9/19/91	20	B	2577	5.48	2.50	3.76	<3.75	<1.59	<3.72	20.52	25.56
9/19/91	21	B	2581	6.67	1.92	4.43	<3.69	2.66	<3.66	24.56	25.49
9/19/91	23	B	2589	5.31	1.86	3.91	<3.89	3.55	4.99	26.01	28.31
9/19/91	24	B	2593	1.73	<1.66	<2.59	<3.80	<1.62	<3.80	5.49	8.64
9/19/91	25	B	2597	<1.54	<1.66	<2.58	<3.83	<1.62	<3.80	2.18	3.81
9/19/91	28	B	2609	<1.52	<1.63	<2.55	<3.77	<1.60	<3.74	1.23	2.79
9/19/91	30	B	2617	2.95	2.21	5.69	<3.90	1.80	<3.87	17.64	22.62
9/19/91	31	B	2621	1.94	1.80	3.32	<3.78	2.67	<3.75	16.17	22.45
9/19/91	32	B	2625	<1.55	<1.67	<2.61	<4.02	<1.64	<3.84	1.06	3.75
9/19/91	18	C	2570	15.60	10.12	12.27	7.67	5.34	5.10	98.03	107.86
9/19/91	20	C	2578	4.05	2.18	3.63	<3.75	<1.59	<3.73	22.21	26.05
9/19/91	21	C	2582	2.67	<1.60	3.04	<3.70	<1.56	<3.67	19.64	23.86
9/19/91	23	C	2590	7.19	3.47	7.16	5.31	4.24	4.54	41.07	45.83
9/19/91	24	C	2594	<1.55	<1.66	<2.60	<3.85	<1.63	<3.82	2.10	5.05
9/19/91	25	C	2598	<1.53	<1.65	<2.57	<3.80	<1.61	<3.77	1.90	4.84
9/19/91	28	C	2610	<1.51	<1.63	<2.54	<3.76	<1.59	<3.73	2.71	43.55
9/19/91	30	C	2618	2.86	<1.69	3.03	<3.89	<1.65	<3.86	12.21	19.01
9/19/91	31	C	2622	3.21	<1.70	3.60	4.47	<1.66	4.25	19.69	27.77
9/19/91	32	C	2626	1.75	<1.64	<2.56	<3.76	<1.61	<3.76	3.93	8.87
9/19/91	18	D	2571	23.42	15.37	15.39	4.68	4.69	<3.79	164.55	177.15
9/19/91	20	D	2579	36.15	18.99	31.01	12.83	9.06	<3.72	304.22	332.46
9/19/91	21	D	2583	28.25	11.46	14.90	7.96	5.94	6.07	155.90	168.76

B - 1: PAHs edited 9/21/93

Date Collected	Field Core	ID Lift	UWRL ID #	dry wt B(b)fluoranthene mg/kg	dry wt B(k)fluoranthene mg/kg	dry wt Benzo(a)pyrene mg/kg	dry wt Indeno(123)p mg/kg	dry wt DB(ah)anthracene mg/kg	dry wt Benzo(ghi)perylene mg/kg	total carcinogenic PAH mg/Kg	total PAH mg/kg
9/19/91	23	D	2591	8.03	6.75	6.53	<3.91	2.18	<3.88	38.63	54.38
9/19/91	24	D	2595	2.11	2.01	<2.54	<3.76	<1.59	<3.73	9.32	14.80
9/19/91	25	D	2599	3.31	2.80	4.20	<3.67	<1.55	<3.64	27.21	33.90
9/19/91	28	D	2611	2.27	<1.63	<2.54	<3.76	<1.59	<3.73	14.93	19.82
9/19/91	30	D	2619	11.96	10.97	13.51	<3.93	<1.66	<3.90	133.13	158.65
9/19/91	31	D	2623	6.45	4.47	5.72	<3.95	1.72	<3.91	37.91	47.83
9/19/91	32	D	2627	14.41	7.36	8.35	4.55	2.52	5.64	131.65	154.12
9/1/92	2	A	574	2.93	3.60	5.79	<3.11	1.92	3.21	21.84	30.09
9/1/92	3	A	579	1.36	<1.34	2.52	<3.10	<1.31	<3.07	7.12	12.59
9/1/92	6	A	594	<1.26	<1.36	<2.12	<3.14	<1.33	<3.12	2.12	4.05
9/1/92	7	A	599	1.87	<1.36	2.31	<3.14	<1.33	<3.12	7.05	11.75
9/1/92	8	A	604	<1.27	<1.37	<2.14	<3.17	<1.34	<3.14	3.87	15.91
9/1/92	9	A	609	5.08	4.67	6.80	<3.13	1.36	<3.10	29.33	44.13
9/1/92	11	A	619	14.15	5.22	14.26	4.58	3.05	5.08	54.95	66.83
9/1/92	14	A	634	<1.25	<1.35	<2.10	<3.11	<1.32	<3.08	1.80	7.54
9/1/92	15	A	639	4.78	1.51	4.03	<3.16	1.59	<3.14	16.12	22.28
9/1/92	16	A	644	2.05	<1.38	<2.15	<3.19	<1.35	<3.16	7.32	31.77
9/1/92	18	A	654	3.29	1.70	3.34	<3.12	<1.32	<3.10	11.44	17.45
9/1/92	20	A	664	4.86	3.56	8.38	4.76	1.90	4.65	33.49	41.33
9/1/92	21	A	669A	6.04	3.68	9.28	4.96	2.41	5.72	38.66	47.10
9/1/92	23	A	679	5.08	2.65	7.08	5.25	<1.33	6.07	33.84	44.59
9/1/92	24	A	684	1.72	<1.37	<2.13	<3.15	1.87	<3.13	4.48	5.14
9/1/92	25	A	689	1.34	<1.37	<2.14	<3.17	1.35	<3.14	2.69	3.25
9/1/92	28	A	704	5.00	4.32	6.57	<3.12	2.44	<3.10	29.15	39.38
9/1/92	30	A	714dup1	3.37	2.97	3.90	<3.14	2.34	<3.12	18.38	24.83
9/1/92	31	A	719	2.09	1.64	<2.10	<3.11	<1.32	<3.09	5.70	7.70
9/1/92	45	A	759	17.47	5.02	8.84	3.89	3.82	3.85	50.85	59.81
9/1/92	47	A	763	19.62	8.27	9.90	<3.11	<1.32	<3.09	53.52	88.91
9/1/92	48	A	765	17.77	4.64	8.91	<3.18	<1.35	<3.16	42.71	70.63
9/1/92	49	A	767	25.60	12.73	16.89	5.03	3.22	4.36	83.20	94.60
9/1/92	51	A	771	2.92	1.77	3.33	<3.17	1.54	<3.14	12.71	18.49
9/1/92	54	A	777	3.58	<1.35	2.38	<3.12	1.59	<3.10	11.13	11.85
9/1/92	55	A	779a	14.34	4.55	10.25	4.84	<1.33	3.47	56.41	71.35
9/1/92	56	A	781	29.59	10.28	18.11	4.58	6.13	5.03	91.67	116.01
9/1/92	58	A	785	7.86	3.26	5.46	<3.19	1.88	<3.16	27.05	33.81
9/1/92	59	A	787	4.44	2.53	5.65	<3.17	2.87	<3.15	26.34	150.72

B - 1: PAHs edited 9/21/93

Date Collected	Field Core	ID Lift	UWRL ID #	dry wt B(b)fluoranthene mg/kg	dry wt B(k)fluoranthene mg/kg	dry wt Benzo(a)pyrene mg/kg	dry wt Indeno(123)p mg/kg	dry wt DB(ah)anthracene mg/kg	dry wt Benzo(ghi)perylene mg/kg	total carcinogenic PAH mg/Kg	total PAH mg/kg
9/1/92	62	A	793	5.37	4.25	5.53	5.74	4.00	4.90	37.76	52.39
9/1/92	63	A	795	11.88	4.11	4.51	5.91	4.04	6.04	43.82	68.32
9/1/92	64	A	797	5.72	4.49	5.41	5.33	<1.32	4.47	31.41	35.86
9/1/92	2	B	575	<1.25	<1.34	<2.09	<3.10	<1.31	<3.08	2.24	10.09
9/1/92	3	B	580	1.27	<1.34	<2.09	<3.09	<1.31	<3.07	3.93	8.32
9/1/92	6	B	595	<1.25	<1.34	<2.09	<3.10	<1.31	<3.08	0.64	1.45
9/1/92	7	B	600	2.96	2.19	2.55	<3.13	<1.32	<3.10	9.59	12.02
9/1/92	8	B	605	<1.26	<1.36	<2.12	<3.14	<1.33	<3.12	4.04	9.24
9/1/92	9	B	610A	35.14	22.85	42.36	21.23	5.82	13.55	174.00	192.57
9/1/92	11	B	620	22.65	16.19	33.72	16.16	6.53	11.88	123.34	155.12
9/1/92	14	B	635	3.96	3.04	4.98	<3.04	<1.29	<3.01	15.72	26.48
9/1/92	15	B	640	5.80	1.55	5.37	5.52	3.06	4.36	29.74	34.76
9/1/92	16	B	645	4.38	1.82	5.16	<3.14	1.55	<3.11	17.38	26.86
9/1/92	18	B	655	2.01	<1.35	2.90	<3.11	<1.32	3.30	11.78	18.94
9/1/92	20	B	665	5.28	2.86	8.38	5.06	1.45	6.35	36.09	45.83
9/1/92	21	B	670S1	10.11	4.83	10.36	6.91	2.88	9.14	51.97	65.23
9/1/92	23	B	680	10.58	8.19	10.61	5.55	<1.32	4.32	71.17	99.26
9/1/92	24	B	685	<1.26	<1.35	<2.11	<3.12	<1.32	<3.10	0.91	1.40
9/1/92	25	B	690	1.91	<1.35	2.60	<3.12	<1.32	<3.10	4.51	5.32
9/1/92	28	B	705	4.62	4.53	7.11	4.24	3.14	<3.11	31.20	38.54
9/1/92	30	B	715	7.78	4.85	8.69	4.19	3.56	<3.10	36.27	43.12
9/1/92	31	B	720	2.41	2.23	<2.09	<3.10	<1.31	<3.08	5.88	11.21
9/1/92	45	B	760	8.20	3.41	7.12	<3.14	<1.33	<3.12	27.12	33.67
9/1/92	47	B	764	28.28	9.71	16.21	20.42	3.04	3.31	101.18	140.49
9/1/92	48	B	766	11.28	7.11	10.40	<3.18	2.25	<3.15	40.41	49.01
9/1/92	51	B	772	12.43	4.41	10.79	5.28	1.93	4.58	49.30	58.54
9/1/92	54	B	778	17.76	7.39	12.47	4.08	2.39	3.56	61.13	74.38
9/1/92	55	B	780	11.88	4.53	10.24	3.97	<1.33	<3.12	41.55	52.14
9/1/92	56	B	782	6.79	3.33	5.01	<3.15	2.28	<3.12	27.36	37.74
9/1/92	58	B	786	11.96	2.49	6.11	<3.13	2.90	<3.11	31.60	44.21
9/1/92	59	B	788	3.50	1.53	3.31	<3.10	1.77	<3.08	15.02	19.57
9/1/92	62	B	794	3.58	2.64	3.45	3.83	1.39	3.55	24.94	35.38
9/1/92	63	B	796	<1.26	6.40	8.01	5.54	<1.32	4.88	31.18	35.95
9/1/92	64	B	798	6.12	4.07	4.93	4.70	<1.33	3.49	30.64	35.29
9/1/92	2	C	576	2.02	1.97	3.46	<3.10	<1.28	<3.01	9.38	10.32
9/1/92	3	C	581	1.48	<1.35	2.37	<3.11	<1.32	<3.08	6.74	12.89

B - 1: PAHs edited 9/21/93

Date Collected	Field Core	ID Lift	UWRL ID #	dry wt B(b)fluoranthene mg/kg	dry wt B(k)fluoranthene mg/kg	dry wt Benzo(a)pyrene mg/kg	dry wt Indeno(123)p mg/kg	dry wt DB(ah)anthracene mg/kg	dry wt Benzo(ghi)perylene mg/kg	total carcinogenic PAH mg/Kg	total PAH mg/kg
9/1/92	6	C	596	<1.24	<1.34	<2.08	<3.09	<1.31	<3.06	2.06	5.76
9/1/92	7	C	601	1.37	1.44	2.43	<3.09	<1.31	<3.07	10.23	18.69
9/1/92	8	C	606	11.43	6.52	16.43	12.62	4.46	11.99	74.06	85.31
9/1/92	9	C	611	50.62	26.96	55.08	19.47	11.28	19.18	203.07	264.83
9/1/92	11	C	621	2.65	3.50	4.13	<3.13	<1.32	<3.10	15.82	26.71
9/1/92	14	C	636	3.18	2.51	4.43	<3.09	<1.31	<3.07	13.22	17.27
9/1/92	15	C	641	7.65	4.32	6.53	4.27	2.36	5.57	41.86	47.22
9/1/92	16	C	646	5.55	2.55	7.41	5.35	2.20	5.26	34.83	42.06
9/1/92	18	C	656	1.80	<1.34	3.00	<3.10	<1.31	<3.08	8.29	14.85
9/1/92	20	C	666	8.94	6.32	8.31	3.83	1.72	4.42	55.14	66.97
9/1/92	21	C	671	9.96	8.34	9.63	6.11	1.65	4.91	56.02	77.15
9/1/92	23	C	681	22.65	19.33	27.63	14.18	6.32	13.66	147.74	226.19
9/1/92	23	C	682S1	15.06	8.55	14.93	9.73	1.66	7.66	84.31	117.24
9/1/92	24	C	686	4.73	1.37	4.36	<3.11	4.05	<3.09	20.93	28.84
9/1/92	28	C	706	5.82	3.37	5.88	<3.11	2.26	<3.09	25.35	40.41
9/1/92	30	C	716	<1.25	1.76	<2.11	<3.12	<1.32	<3.09	1.76	1.76
9/1/92	31	C	721	1.87	2.41	<2.11	<3.12	<1.32	<3.10	4.28	4.28
9/1/92	2	D	577	4.06	3.94	6.16	4.34	1.84	4.45	28.54	34.46
9/1/92	3	D	582	4.49	4.82	6.80	4.06	<1.32	3.23	32.08	50.72
9/1/92	6	D	597	10.43	5.40	6.87	<3.12	<1.32	<3.09	34.64	53.81
9/1/92	7	D	602	4.39	2.79	4.00	<3.11	<1.32	<3.09	17.71	29.41
9/1/92	8	D	607	11.94	9.39	16.06	5.01	2.64	5.00	62.65	102.61
9/1/92	9	D	612	17.84	6.95	14.01	5.92	<1.34	4.00	96.37	126.87
9/1/92	11	D	622	2.41	2.41	2.50	<3.17	<1.34	<3.15	12.81	27.63
9/1/92	14	D	637	9.06	3.79	6.82	4.61	1.83	4.11	38.14	48.73
9/1/92	15	D	642A	5.25	3.35	6.74	4.79	2.58	4.40	32.11	42.96
9/1/92	16	D	647	1.46	<1.36	<2.12	<3.13	<1.33	<3.11	3.39	8.63
9/1/92	18	D	657	4.73	2.73	3.89	<3.17	<1.34	<3.15	15.94	25.83
9/1/92	20	D	667	3.76	2.08	2.98	<3.15	1.36	<3.13	14.16	34.83
9/1/92	21	D	672	15.04	12.79	17.65	12.37	10.18	11.81	97.04	132.88
9/1/92	24	D	687	5.53	1.60	3.95	<3.14	2.16	<3.11	17.84	22.93
9/1/92	25	D	692	8.23	6.35	7.30	<3.17	2.72	<3.15	33.71	42.86
9/1/92	30	D	717	2.62	3.53	<2.13	<3.16	<1.34	<3.13	12.91	17.18
9/1/92	31	D	722	4.82	2.13	2.97	<3.10	<1.31	<3.08	33.33	41.39
9/1/92	2	E	578	3.12	1.72	4.26	<3.09	<1.31	<3.07	12.71	27.94
9/1/92	3	E	583A	13.36	6.41	13.51	6.30	3.66	6.10	58.04	72.45

B - 1: PAHs edited 9/21/93

	Field	ID		dry wt	dry wt	dry wt	dry wt	dry wt	dry wt	total	
Date			UWRL	B(b)fluoranthene	B(k)fluoranthene	Benzo(a)pyrene	Indeno(123)p	DB(ah)anthracene	Benzo(ghi)perylene	carcinogenic	total PAH
Collected	Core	Lift	ID #	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	PAH mg/Kg	mg/kg
9/1/92	6	E	598	9.26	14.37	16.26	9.34	2.24	7.40	71.16	95.51
9/1/92	7	E	603	23.20	9.93	23.69	12.64	3.60	10.51	106.16	209.11
9/1/92	8	E	608	6.03	4.21	5.91	<3.08	2.30	3.83	28.03	45.93
9/1/92	9	E	613	29.71	13.72	20.18	5.82	4.27	4.48	244.59	388.91
9/1/92	11	E	623	<1.24	<1.34	<2.08	<3.09	<1.31	<3.06	2.11	16.42
9/1/92	14	E	638	8.85	5.40	9.61	7.80	4.00	7.75	51.82	67.71
9/1/92	15	E	643	6.49	4.28	6.78	3.86	2.25	4.68	33.56	44.03
9/1/92	16	E	648	3.87	2.07	3.98	<3.12	<1.32	<3.09	14.30	24.12
9/1/92	18	E	658	8.24	2.42	6.09	3.83	1.49	3.87	34.14	46.76
9/1/92	20	E	668	5.33	8.21	5.96	<3.04	6.29	<3.01	40.51	61.77
9/1/92	21	E	673	6.67	3.58	5.77	3.40	2.66	3.32	36.20	58.41
9/1/92	23	E	683	8.87	3.90	6.73	<3.05	3.27	<3.03	32.04	41.93
9/1/92	24	E	688	10.42	12.55	9.18	4.09	5.40	4.11	187.64	313.79
9/1/92	25	E	693	11.11	10.54	12.66	5.37	5.12	6.84	70.23	90.86
9/1/92	30	E	718	4.85	4.60	4.46	4.47	2.19	4.30	31.14	36.06
9/1/93	28	D	707	8.01	10.98	8.16	4.08	3.17	<3.08	41.94	51.63

B - 2 PCP concentrations in LTU soil samples

data sampled	UWRL #	core	lift	mg/kg PCP
5/6/91	1750	2	A	9.63
5/6/91	1753	3	A	51.88
5/6/91	1762	6	A	61.01
5/6/91	1765	7	A	32.52
5/6/91	1768	8	A	19.05
5/6/91	1771	9	A	10.08
5/6/91	1777	11	A	11.62
5/6/91	1786	14	A	17.63
5/6/91	1790	15	A	17.06
5/6/91	1798	18	A	17.85
5/6/91	1801	19	A	11.61
5/6/91	1804	20	A	7.54
5/6/91	1807 A	21	A	8.34
5/6/91	1813	23	A	20.99
5/6/91	1816	24	A	5.18
5/6/91	1819	25	A	3.40
5/6/91	1828	28	A	4.98
5/6/91	1834	30	A	16.90
5/6/91	1837	31	A	17.33
5/6/91	1840	32	A	0.85
5/6/91	1751	2	B	44.69
5/6/91	1754	3	B	34.57
5/6/91	1763	6	B	37.98
5/6/91	1766	7	B	34.40
5/6/91	1769	8	B	14.85
5/6/91	1772	9	B	16.49
5/6/91	1778	11	B	14.49
5/6/91	1787 A	14	B	9.16
5/6/91	1791	15	B	13.54
5/6/91	1794	16	B	2.56
5/6/91	1808	21	B	4.85
5/6/91	1814	23	B	3.89
5/6/91	1817A	24	B	5.14
5/6/91	1820	25	B	4.80
5/6/91	1829	28	B	8.27
5/6/91	1835	30	B	5.52
5/6/91	1838	31	B	5.29
5/6/91	1841	32	B	8.07
5/6/91	1752	2	C	431.88
5/6/91	1755	3	C	240.61
5/6/91	1764	6	C	93.46
5/6/91	1767	7	C	184.34
5/6/91	1770	8	C	216.70
5/6/91	1773	9	C	407.67
5/6/91	1779	11	C	154.77
5/6/91	1789	14	C	183.04
5/6/91	1792	15	C	154.70

B - 2 PCP concentrations in LTU soil samples (continued)

5/6/91	1795	16	C	64.25
5/6/91	1788	17	C	87.31
5/6/91	1800	18	C	67.82
5/6/91	1803	19	C	13.13
5/6/91	1806	20	C	50.22
5/6/91	1809	21	C	141.85
5/6/91	1815	23	C	119.56
5/6/91	1818	24	C	5.41
5/6/91	1821	25	C	13.02
5/6/91	1830	28	C	39.43
5/6/91	1836	30	C	45.49
5/6/91	1839	31	C	59.05
6/27/91	1853	1	A	12.70
6/27/91	1856	2	A	17.46
6/27/91	1859	3	A	21.48
6/27/91	1868a	6	A	8.29
6/27/91	1871	7	A	20.28
6/27/91	1874	8	A	5.54
6/27/91	1877	9	A	9.77
6/27/91	1883	11	A	7.08
6/27/91	1892	14	A	5.83
6/27/91	1895	15	A	0.89
6/27/91	1901	17	A	4.34
6/27/91	1910	20	A	17.76
6/27/91	1913	21	A	8.67
6/27/91	1919	23	A	24.44
6/27/91	1922	24	A	8.13
6/27/91	1925	25	A	4.10
6/27/91	1934	28	A	5.42
6/27/91	1940	30	A	12.47
6/27/91	1943	31	A	9.44
6/27/91	1946	32	A	0.81
6/27/91	1857	2	B	5.63
6/27/91	1860	3	B	4.82
6/27/91	1869	6	B	8.52
6/27/91	1872	7	B	19.76
6/27/91	1875	8	B	10.33
6/27/91	1878	9	B	0.96
6/27/91	1884	11	B	9.14
6/27/91	1893	14	B	4.40
6/27/91	1896	15	B	3.17
6/27/91	1899	16	B	3.67
6/27/91	1905	18	B	7.49
6/27/91	1911	20	B	4.11
6/27/91	1914	21	B	3.46
6/27/91	1920	23	B	6.33
6/27/91	1923	24	B	6.22
6/27/91	1926	25	B	2.69
6/27/91	1935	28	B	8.03
6/27/91	1941	30	B	6.46
6/27/91	1942	30	B	8.72

B - 2 PCP concentrations in LTU soil samples (continued)

6/27/91	1944	31	B	8.18
6/27/91	1947	32	B	0.88
6/27/91	1858	2	C	5.51
6/27/91	1861	3	C	8.21
6/27/91	1870	6	C	23.89
6/27/91	1873	7	C	15.05
6/27/91	1876	8	C	10.93
6/27/91	1879	9	C	15.14
6/27/91	1885	11	C	5.87
6/27/91	1894	14	C	2.88
6/27/91	1897	15	C	2.96
6/27/91	1903	17	C	22.41
6/27/91	1906	18	C	9.81
6/27/91	1912	20	C	3.17
6/27/91	1915	21	C	7.63
6/27/91	1921	23	C	3.17
6/27/91	1924	24	C	8.52
6/27/91	1927	25	C	9.73
6/27/91	1936	28	C	14.43
6/27/91	1945	31	C	13.22
6/27/91	1948	32	C	9.92
7/27/91	2059	33	A	124.59
7/27/91	2062	36	A	35.31
7/27/91	2064	38	A	76.98
7/27/91	2065	39	A	56.84
7/27/91	2066	40	A	55.35
7/27/91	2068	42	A	97.02
7/27/91	2070	44	A	46.66
7/27/91	2071	45	A	84.62
7/27/91	2073	47	A	91.79
7/27/91	2074	48	A	370.07
7/27/91	2075	49	A	104.87
7/27/91	2077	51	A	57.28
7/27/91	2080	54	A	61.66
7/27/91	2081	55	A	61.71
7/27/91	2082	56	A	76.78
7/27/91	2084	58	A	92.47
7/27/91	2085	59	A	63.88
7/27/91	2088	62	A	207.86
7/27/91	2089	63	A	94.76
7/27/91	2090	64	A	167.26
7/27/91	2028	2	D	85.84
7/27/91	2029	3	D	156.03
7/27/91	2032	6	D	55.96
7/27/91	2033	7	D	127.90
7/27/91	2034	8	D	143.00
7/27/91	2035	9	D	119.22
7/27/91	2037	11	D	57.25
7/27/91	2040	14	D	171.50
7/27/91	2041	15	D	155.04
7/27/91	2042	16	D	84.67

B - 2 PCP concentrations in LTU soil samples (continued)

7/27/91	2044	18	D	160.84
7/27/91	2046	20	D	117.17
7/27/91	2047	21	D	79.57
7/27/91	2049	23	D	67 07
7/27/91	2050	24	D	58.09
7/27/91	2051	25	D	68.23
7/27/91	2054	28	D	124.00
7/27/91	2056	30	D	224.97
7/27/91	2057	31	D	87.17
7/27/91	2058	32	D	244.64
9/18/91	2524	2	A	13.29
9/18/91	2528	3	A	13.25
9/18/91	2532	6	A	5 08
9/18/91	2536	7	A	29.55
9/18/91	2540	8	A	11.22
9/18/91	2544	9	A	19 07
9/18/91	2552	11	A	10.30
9/18/91	2506	14	A	2.60
9/18/91	2556	15	A	6 42
9/18/91	2560	16	A	12.86
9/18/91	2568	18	A	4 73
9/18/91	2576	20	A	2 54
9/18/91	2580	21	A	3.43
9/18/91	2588	23	A	5.85
9/18/91	2592	24	A	6.94
9/18/91	2596	25	A	3.06
9/18/91	2608	28	A	10.68
9/18/91	2616	30	A	4 09
9/18/91	2620	31	A	6.75
9/18/91	2624	32	A	4.51
9/18/91	2835	36	A	49.11
9/18/91	2837	38	A	34.09
9/18/91	2838	39	A	37.60
9/18/91	2840	40	A	14.86
9/18/91	2825	42	A	1167.76
9/18/91	2828	44	A	37 61
9/18/91	2829	45	A	7.85
9/18/91	2831	47	A	15.79
9/18/91	2832	48	A	23.01
9/18/91	2816	49	A	15.16
9/18/91	2818	51	A	82.96
9/18/91	2819	52	A	24.81
9/18/91	2821	54	A	21.74
9/18/91	2822	55	A	103.96
9/18/91	2809	58	A	118.61
9/18/91	2810	59	A	86.37
9/18/91	2811	60	A	37.18
9/18/91	2814	63	A	30.11
9/18/91	2815	64	A	26 91
9/18/91	2525	2	B	9 65
9/18/91	2529	3	B	11.44

B - 2 PCP concentrations in LTU soil samples (continued)

9/18/91	2533	6	B	7.19	
9/18/91	2537	7	B	8.53	
9/18/91	2541	8	B	3.75	
9/18/91	2545	9	B	5 80	
9/18/91	2553	11	B	8.37	
9/18/91	2557	15	B	3.78	
9/18/91	2561	16	B	5.86	9/18/91
	2569	18	B	3.22	
9/18/91	2577	20	B	6.03	
9/18/91	2581	21	B	10.07	
9/18/91	2589	23	B	4.20	
9/18/91	2593	24	B	4.93	
9/18/91	2597	25	B	10.47	
9/18/91	2609	28	B	9.31	
9/18/91	2617	30	B	6.77	
9/18/91	2621	31	B	5 99	
9/18/91	2625	32	B	3.08	
9/18/91	2526	2	C	5.59	
9/18/91	2530	3	C	3.45	
9/18/91	2534	6	C	12.54	
9/18/91	2538	7	C	50.93	
9/18/91	2542	8	C	11.16	
9/18/91	2546	9	C	13.26	
9/18/91	2554	11	C	3.91	
9/18/91	2508	14	C	18.01	
9/18/91	2558	15	C	2.89	
9/18/91	2562	16	C	2.12	
9/18/91	2570	18	C	48.14	
9/18/91	2574	19	C	119.89	
9/18/91	2578	20	C	28.19	
9/18/91	2582	21	C	19.63	
9/18/91	2590	23	C	14.07	
9/18/91	2594	24	C	20.62	
9/18/91	2598	25	C	10.06	
9/18/91	2610	28	C	11.05	
9/18/91	2618	30	C	14.58	
9/18/91	2622	31	C	16.92	
9/18/91	2626	32	C	7.05	
9/18/91	2527	2	D	53.36	
9/18/91	2531	3	D	14.62	
9/18/91	2535	6	D	33.96	
9/18/91	2539	7	D	28.44	
9/18/91	2543	8	D	29.51	
9/18/91	2547	9	D	27.06	
9/18/91	2555	11	D	11.18	
9/18/91	2509	14	D	22.64	
9/18/91	2559	15	D	63.70	
9/18/91	2563	16	D	14.06	
9/18/91	2571	18	D	57.11	
9/18/91	2579	20	D	56.54	
9/18/91	2583	21	D	41.96	

B - 2 PCP concentrations in LTU soil samples (continued)

9/18/91	2591	23	D	36.55
9/18/91	2595	24	D	16.38
9/18/91	2599	25	D	29.76
9/18/91	2611	28	D	47.79
9/18/91	2619	30	D	70.20
9/18/91	2623	31	D	38.20
9/18/91	2627	32	D	116.78
9/1/92	579	3	A	8.24
9/1/92	594	6	A	6.59
9/1/92	604	8	A	4.46
9/1/92	609	9	A	4.68
9/1/92	619	11	A	<3.7
9/1/92	634	14	A	6.91
9/1/92	639	15	A	9.24
9/1/92	644	16	A	10.45
9/1/92	654	18	A	3 38
9/1/92	664	20	A	5 06
9/1/92	669A	21	A	7.95
9/1/92	679	23	A	7.60
9/1/92	684	24	A	39.56
9/1/92	689	25	A	7.12
9/1/92	741	26	A	26.01
9/1/92	704	28	A	5.50
9/1/92	714	30	A	<3.74
9/1/92	719	31	A	<3.71
9/1/92	724	32	A	5.63
9/1/92	735	33	A	14.48
9/1/92	745	38	A	20.44
9/1/92	747	39	A	19 32
9/1/92	749	40	A	15.30
9/1/92	757	44	A	6.66
9/1/92	759	45	A	6.31
9/1/92	763	47	A	33 34
9/1/92	765	48	A	22.15
9/1/92	767	49	A	15.55
9/1/92	771	51	A	5.76
9/1/92	777	54	A	13.42
9/1/92	779A	55	A	21.25
9/1/92	781	56	A	30.01
9/1/92	785	58	A	36.68
9/1/92	787	59	A	28.72
9/1/92	793	62	A	17 04
9/1/92	795	63	A	29.71
9/1/92	797	64	A	13.39
9/1/92	575	2	B	9.88
9/1/92	580	3	B	7.11
9/1/92	595	6	B	7.30
9/1/92	600	7	B	3.71
9/1/92	605	8	B	3 63
9/1/92	610A	9	B	12.00
9/1/92	620	11	B	10.66

B - 2 PCP concentrations in LTU soil samples (continued)

9/1/92	635	14	B	2.26
9/1/92	640	15	B	<3.74
9/1/92	645	16	B	10.10
9/1/92	655	18	B	10.43
9/1/92	665	20	B	13.85
9/1/92	670	21	B	17.84
9/1/92	680	23	B	16.93
9/1/92	685	24	B	<3.72
9/1/92	690	25	B	<3.72
9/1/92	705	28	B	4.37
9/1/92	715	30	B	5.61
9/1/92	720	31	B	5.34
9/1/92	725	32	B	7.30
9/1/92	736	33	B	19.32
9/1/92	742	36	B	13.82
9/1/92	746	38	B	21.28
9/1/92	748	39	B	20.29
9/1/92	750A	40	B	17.90
9/1/92	754	42	B	16.42
9/1/92	758	44	B	7.66
9/1/92	760	45	B	16.06
9/1/92	778	45	B	33.07
9/1/92	764	47	B	29.51
9/1/92	766	48	B	6.12
9/1/92	768	49	B	23.48
9/1/92	772	51	B	10.59
9/1/92	780	55	B	9.75
9/1/92	782	56	B	27.00
9/1/92	786	58	B	23.80
9/1/92	788	59	B	19.08
9/1/92	794	62	B	12.95
9/1/92	796	63	B	28.20
9/1/92	798	64	B	37.18
9/1/92	576	2	C	9.59
9/1/92	581	3	C	10.39
9/1/92	596	6	C	13.30
9/1/92	601	7	C	7.65
9/1/92	606	8	C	8.83
9/1/92	611	9	C	13.02
9/1/92	621	11	C	13.08
9/1/92	636	14	C	4.75
9/1/92	641	15	C	12.12
9/1/92	646	16	C	3.83
9/1/92	656	18	C	9.54
9/1/92	666	20	C	29.05
9/1/92	671	21	C	13.95
9/1/92	681	23	C	26.53
9/1/92	686	24	C	9.54
9/1/92	691A	25	C	14.73
9/1/92	706	28	C	5.60
9/1/92	716	30	C	<3.72

B - 2 PCP concentrations in LTU soil samples (continued)

9/1/92	721	31	C	<3.72
9/1/92	726	32	C	3.67
9/1/92	577	2	D	11.10
9/1/92	582	3	D	17.35
9/1/92	597	6	D	20.49
9/1/92	602	7	D	18.12
9/1/92	607	8	D	11.39
9/1/92	612	9	D	19.57
9/1/92	622	11	D	11.70
9/1/92	637	14	D	13.73
9/1/92	642A	15	D	25.96
9/1/92	647	16	D	30.79
9/1/92	657	18	D	17.57
9/1/92	667	20	D	14.77
9/1/92	672	21	D	20.69
9/1/92	682	23	D	31.43
9/1/92	687	24	D	10.54
9/1/92	692	25	D	5 98
9/1/92	707	28	D	7.73
9/1/92	717	30	D	3.97
9/1/92	722	31	D	26.97
9/1/92	727	32	D	18.27
9/1/92	578	2	E	16.69
9/1/92	583A	3	E	19 17
9/1/92	598	6	E	20.90
9/1/92	603	7	E	21.84
9/1/92	608	8	E	9.88
9/1/92	613	9	E	51.80
9/1/92	623	11	E	13.22
9/1/92	638	14	E	8.33
9/1/92	643	15	E	27.62
9/1/92	648	16	E	22.57
9/1/92	658	18	E	30.98
9/1/92	668	20	E	19.21
9/1/92	673	21	E	13.54
9/1/92	683	23	E	30.00
9/1/92	688	24	E	85.10
9/1/92	693	25	E	21.94
9/1/92	708	28	E	10.94
9/1/92	718	30	E	4.83
9/1/92	723A	31	E	20.33
9/1/92	728	32	E	15.39

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