Background Data Analysis Report Fort Richardson, Alaska

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1 Introduction

Ecology and Environment, Inc., (E & E) was contracted by the United States Army Corps of Engineers (the Corps), Alaska District, in June 1995 to perform a study to determine the background concentrations of selected chemicals and metals in soil and groundwater at Fort Richardson, Alaska, using available data developed during previous studies (see Table 1-1). E & E's work was performed under Contract No. DACA85-93-D-0009, Delivery Order No. 0028.

Fort Richardson occupies approximately 62,000 acres within the Municipality of Anchorage in south-central Alaska and has been in operation since 1940. The post is bounded by the municipality to the south and east, Elmendorf Air Force Base to the west, and Eagle Bay and Knik Arm to the north.

Fort Richardson was listed on the United States Environmental Protection Agency's (EPA's) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priority List (NPL) in June 1993 because of known soil and groundwater contamination. For the purposes of the CERCLA investigation, Fort Richardson was divided into four operable units.

1.1 Project Background

The objective of this study is to determine background levels in soil and groundwater at Fort Richardson of Resource Conservation and Recovery Act (RCRA) metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), several non-RCRA metals (nickel, copper, zinc), and the pesticides dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyl-dichloroethane (DDD), and dichlorodiphenyldichloroethylene (DDE). For the purposes of this report, background levels mean those concentrations in soil and groundwater occurring naturally under ambient conditions and not increased by anthropogenic sources (EPA 1989a, 1989b). This strict definition for background is only applicable to inorganic (metal) substances. For this project, an exception is made for the chlorinated organic pesticides

DDT, DDD, and DDE because of the ubiquitous historical use of these pesticides at Fort Richardson.

Background levels were to be determined using existing data for soil and groundwater. These data were obtained from analysis of samples from areas suspected to be contaminated. These studies were not specifically designed to determine background concentrations. Nevertheless, it is assumed that it is possible, using statistical methods, to differentiate between data representative of background (or uncontaminated) levels and data representative of contaminated levels. The background levels will be used to establish cleanup levels for the operable units and other projects being conducted at Fort Richardson.

E & E reviewed the existing environmental investigation report files at Fort Richardson to obtain the analytical data to be used in this project. Applicable data were entered into a relational database, which has been provided to the Corps under separate cover. The applicable data were statistically evaluated to sort the data into "background" and "contaminated" subsets. The background subset was used to determine the means, upper confidence limits (UCLs), and upper tolerance limits (UTLs) for various chemicals in several media. These determinations were subject to the following constraints and additional considerations:

- Soil samples were classified into three groups based on sample depth: surface (0 to 0.5 foot), rootzone (0.5 to 3.0 feet), and subsurface (greater than 3.0 feet). The effect of the groups on the statistical parameters were to be evaluated and, if significant, incorporated into the statistical calculations;

- The effect of different geological units on the statistical parameters were evaluated and, if significant, incorporated into the statistical calculations as additional groups;

- Background levels for DDT, DDE, and DDD were determined only for surface and rootzone soils; and

- Groundwater analytical results were divided into filtered and unfiltered results.

A United States Geological Survey (USGS) map (USGS 1964) was used to determine the geological units in the study area, which include surficial deposits, but exclude windblown sand and silt. The two geological units included in the study were Qay2 and Qey. (There were insufficient numbers of soil samples in other geological units in Fort Richardson to allow evaluation of those units.) The USGS map (USGS 1964) defines Qay2 as "older outwash-stream deposits, lakes phase." These deposits are predominantly sand and gravel.

The USGS map (USGS 1964) defines Qey as "end-moraine deposits of Knik-Matanuska Glacier."

A map of Fort Richardson (see Drawing 1 following the appendices) was prepared indicating the sample locations/types (surface soil, soil boring, or groundwater well) for the existing data. Plates 1 and 2 list each sampling location, a description of the sample type, sample number, and easting and northing of each location. It should be noted that many of the indicated sampling locations, particularly those for surface soils and to a lesser extent soil borings, are approximate. Survey information for these sampling locations was not available, and locations were estimated using unsurveyed site plans.

The approach used to determine the background concentration data sets is outlined in Section 2. The statistical calculations employed are routine and are described in detail in EPA guidance (EPA 1989a, EPA 1992b). There are, however, several key statistical considerations in the present study (e.g., large sample population) that merit discussion, which are presented in Section 2. The statistical results relevant to the identification of the background data and the final statistical calculations are presented in Section 3. Section 4 compares this background characterization of Fort Richardson to background characterizations of Elmendorf Air Force Base. Section 5 presents a summary of the results, the conclusions of the study, and a discussion of how the results of the study will be used for assessment with regard to the EPA risk assessment rationale and procedures. References used in the preparation of this report are presented in Section 6.

1.2 Technical Overview

In assessing the potential impact of contamination at any location, reasonable values for representative concentrations of the chemicals of interest must be derived for both background and contaminated areas. Because of variability in the natural distributions of metals the random distribution of pesticides, and because only a finite number of samples can be collected during any site investigation, the determination of representative concentrations can only be approximate. The accuracy of these concentrations is dependent upon both the actual occurrence and true (but unknown) distribution and the particulars of the sampling itself. Thus, for each estimated representative concentration, it is necessary to provide an indication of the accuracy of that estimate (i.e., upper and lower bounds [or confidence limits]).

In environmental statistics, the most common representative value of a sample population (in this case, the concentration data set) is the average or arithmetic mean. A commonly used estimate of upper and lower bounds to the mean is the confidence interval, which is expressed as a percentage corresponding to the probability that the true mean lies within the interval (Helsel and Hirsch 1992). Thus, for a 95% confidence interval, there is a 95% probability that the true mean of the concentration lies within the specified interval. In cases where only an upper bound to the estimated mean is needed, a one-sided UCL is used. Here the corresponding percentage indicates the probability that the true mean is at or below the specified UCL.

These statistically derived quantities are applied widely in site characterization, risk assessment, and routine monitoring activities. For example, the arithmetic mean typically is used as the single number that characterizes the level or intensity of contamination by a chemical. The 95% UCL of the arithmetic mean is specifically prescribed for the determination of the concentration terms in the exposure/intake calculations in human health risk assessments (EPA 1992a). Finally, confidence intervals are used in compliance monitoring of groundwater at sites where contamination has previously been detected (EPA 1989c).

Another useful quantity in environmental statistics is the upper tolerance limit (UTL). While similar to the UCL, which provides an upper bound to the mean, the UTL contains a certain portion of the sample population and does not reflect an estimation of the mean. For example, 95% of all sample values are at or below the 95% tolerance limit. The calculation of a UTL requires the specification of two parameters. The first is the coverage, which is that proportion of the sample population that the tolerance limit is designed to contain. The second parameter is the degree of confidence with which the interval reaches the specified coverage. This is analogous to specifying the confidence level in a confidence interval.

In summary, soil and groundwater data obtained from previous environmental investigations at Fort Richardson were used in the calculations. As noted in Section 1.1, each chemical and metal data set was potentially obtained from a mixture of background or contaminated samples. This made necessary the preliminary task of identifying and separating out each sample into one of these two categories. The mean, UCL, and UTL (for a 95% coverage at 95% confidence) calculations were then applied to the edited background data in order to characterize the background concentrations for the selected chemicals and metals in soil and groundwater at Fort Richardson.

Chemical Quality Assurance Reports (CQARs) were obtained for most of the reports listed in Table 1-1. The CQARs were reviewed in order to evaluate the quality of the data included in those reports and the suitability of that data for use in the background characterization study. The laboratory and quality control (QC) notes found in the CQARs were examined to identify data that were rejected or otherwise unusable. These data were then excluded from the characterization study. All samples that according to the laboratory or QC notes were estimated, questionable, or otherwise adversely affected were used in the characterization study. The laboratory and QC notes for the adversely affected data were included in two data fields of the database developed for the characterization study.

Finally, because the data used to estimate the soil background concentrations were not originally collected for that purpose, some uncertainty exists in identifying true background data sets. In this context, the consistency between the different findings in the various analyses and the expected behavior for typical background populations was an important check of the appropriateness of the final edited data sets. For example, the normality or lognormality observed for several of the trace metals that were not expected to be major contaminants at the facility suggested that these were indeed single populations (i.e., background populations). Thus, background characterization based on these data are likely very good. The concurrent lognormality of these metals provided some assurance that the soil samples used were representative of the different geological units and depths considered. Anomalies observed in the distributions of any other chemicals in the data set were judged more likely to be related to real causes (e.g., contamination, laboratory analyses, etc).

Table 1-1

ENVIRONMENTAL INVESTIGATION REPORTS USED TO OBTAIN ANALYTICAL DATA
BACKGROUND DATA ANALYSIS
FORT RICHARDSON, ALASKA

Report Title	Prepared By	Date
Release Investigation Report, Underground Storage Tank Sites, Fort Richardson, Alaska	Harding Lawson Associates	March 1994
Release Investigation Report, PX Gas Station, Building 710, Fort Richardson, Alaska	Harding Lawson Associates	April 1994
Site Assessment/Release Investigation and Corrective Action Plan, Site 4, Building 35752, High-Frequency Transmitter Site, Fort Richardson. Alaska	Harding Lawson Associates	April 1994
Preliminary Source Evaluation 2, Operable Unit D (Draft)	ENSR Consulting and Engineering	April 1995
Building 27004 Report, UST Release Investigations, A Seven Fuel Tank Locations, Fort Richardson, Alaska	Dames & Moore	July 1994
Building 782 Report, UST Release Investigations, A Seven Fuel Tank Locations, Fort Richardson, Alaska (Contract No. DACA 85-93-D-0008)	Dames & Moore	July 1994
Building 47662 and 47641 Release Investigations Report, UST Release Investigations, A Seven Fuel Tank Locations, Fort Richardson, Alaska (Contract No. DACA 85-93-D-0008)	Dames & Moore	August 1994
Building 712 Report, UST Release Investigations, A Fort Richardson, Alaska (Contract No. DACA 85-93-D-0008)	Dames & Moore	September 1994
Building 762 Report, UST Release Investigations, A Fort Richardson, Alaska (Contract No. DACA 85-93-D-0008)	Dames & Moore	September 1994
Fort Richardson Landfill Report, Anchorage, Alaska (Contract No. DAC85-88-D-0014)	Ecology & Environment, Inc.	1991
Addendum To The Fort Richardson Landfill Report, Anchorage, Alaska (Contract No. DAC85-88-D-0014)	Ecology & Environment, Inc.	December 1994
Contaminated Soil Stockpiles, Fort Richardson, Fort Wainwright and Fort Greely, Alaska (Contract No. DAC85-88-D-0014)	Ecology & Environment, Inc.	February 1992
Site Investigation Project Report For Fire Training Pits At Fort Richardson, Fort Wainwright and Fort Greely, Alaska (Contract No. DACA85-88-D-0014)	Ecology & Environment, Inc.	September 1993
Closure Plan For The Circle Road Drum Site, Fort Richardson, Alaska	America North/EMCON, Inc.	March 1993
Release Investigation Report and Corrective Action Plan Building 45590, Fort Richardson, Alaska (Contract No. DACA85-93-D-0013)	EMCON Alaska, Inc.	September 1994
Release Investigation Report, UST 13A, Building 732, Fort Richardson, Alaska (Contract No. DACA85-93-D-0013)	EMCON Alaska, Inc.	January 1995
Building 45590, Quarterly Groundwater Monitoring, Fort Richardson, Alaska	EMCON Alaska, Inc.	January 1995

Table 1-1

ENVIRONMENTAL INVESTIGATION REPORTS USED TO OBTAIN ANALYTICAL DATA
BACKGROUND DATA ANALYSIS
FORT RICHARDSON, ALASKA

Report Title	Prepared By	Date
Sampling Report for Groundwater Monitoring Network at Fort Richardson, Alaska	ENSR Consulting and Engineering	January 1994
Groundwater Study Fort Richardson, Alaska	Corps, Geotechnical Branch	July 1991
Groundwater Study Fort Richardson, Alaska	Corps, Geotechnical Branch	July 1992
Groundwater Study (Spring 1994) Fort Richardson, Alaska	Corps, Geotechnical Branch	July 1994
Groundwater Study (Spring 1995) Fort Richardson, Alaska (Obtained data, not yet released as a report)	Corps, Geotechnical Branch	Not yet released
Soil Pile Characterization, Fort Richardson, Alaska	Alaska District Army Corps of Engineers (Corps), Geotechnical Branch	November 1993
Release Investigation, January - March 1995, Building 987, Fort Richardson	Corps, Geotechnical Branch	June 1995
POL Lab/Building 986, Fort Richardson, Alaska	Corps, Geotechnical Branch	1991
Support Storage Building, Building 732, Fort Richardson, Alaska	Corps, Geotechnical Branch	1993
Sludge Bin, Building 985, Fort Richardson, Alaska	Corps, Geotechnical Branch	1993
Building 726, Fort Richardson, Alaska	Corps, Geotechnical Branch	1995

2 Methodology

2.1 General Considerations

Prior to performing statistical calculations to obtain the means, UCLs, and UTLs, it was necessary to develop a data set to represent background. This data set was developed by removing "high-lying" outliers possibly indicating contaminated samples. It should be noted that the general method used in this study—using pre-existing data to extract information on background concentrations—is atypical.

2.2 Methodology

The protocol for estimating the UCLs and the UTLs was applied separately to each chemical data set. That protocol is briefly described in this section, and additional discussion on the individual statistical techniques that were used are presented below.

The protocol was as follows:

1. The data for a particular chemical or metal species were pooled into a single initial data set.

2. Frequencies of detection were calculated for each pooled data set. Those data sets with low percentages of detection were set aside until Step 9 below.

3. If a data set had a large number of detects, it was tested for concentration differences as a function of both geological unit and of depth. This was done using Analysis of Variance (ANOVA). The geological unit groups tested were Qay2 and Qey; the depth groups tested were surface, rootzone, and subsurface. A p-value of less than 0.05 was used to indicate that differences exist, i.e., the ANOVA was carried out at 5% significance or 95% confidence.

4. The data were then examined for contamination. Contamination was tentatively identified by constructing probability plots and noting anomalies in the upper range of the data. (As a practical matter, the log-transformed data were actually used to construct the probability

plots, thereby reducing the impact of extreme values on the scales of the plots.) Anomalies indicative of contamination included nonlinearity, single points that were well above the main body of data, and small clusters of "high-lying" points that appeared to be distinct from the main body either by virtue of separation or having a clearly different slope. If differences by geological unit and/or depth were indicated in the ANOVA tests, then each group was plotted and examined separately. If no differences were found by the ANOVA tests, then the entire data set was plotted and examined.

5. Any tentatively identified contamination was eliminated from the data set(s). This was done by using upper cutoff limits based on the observations in Step 4. The edited data sets were used for the background analysis.

6. Edited background data sets were pooled and re-examined for group differences using ANOVA, again at 95% confidence. In addition, the coefficient of skewness was used to determine the approximate normality and/or lognormality.

7. The 95% one-sided UCL was calculated for each data set, both for the entire data set and for any groups identified in the ANOVA in Step 6.

8. The 95% one-sided UTLs were calculated for each data set, both for the entire data set and for any groups identified in the ANOVA in Step 6.

9. Nonparametric estimates of the 95% UCLs and 95% UTLs were developed, where possible, for data sets with a low number of detects.

2.3 Statistical Considerations

Parametric and Nonparametric Calculations

Parametric and nonparametric calculations were used in this study. A parametric technique is one in which assumptions have been made about the way the data is distributed. A nonparemetric technique is one in which no assumptions are made regarding the data's distribution. Most parametric tests assume that the data are normally distributed (i.e., the values in the data set are symmetrically distributed about the mean, or average value) and the overall distribution of values is along a bell curve. Parametric tests are, in general, statistically more powerful than nonparametric tests, but are only valid and should only be used if the data are normally distributed. If the data set is not normally distributed, either it must be mathematically transformed into a normal distribution before parametric testing, or the corresponding nonparametric test must be used.

The statistical techniques employed in this study can be characterized by their intended use: to describe single groupings or subsets of the data (descriptive statistics, e.g. average, minimum, maximum), and to determine the relationships between two or more such groups with one another (e.g., ANOVA).

Descriptive Statistics

Descriptive statistics are used to describe a data set. For example, the average concentration of a chemical or metal in an environmental medium provides information on the level or magnitude of that chemical's or metal's occurrence in that medium. The average, or arithmetic mean, is the sum of values in the data set divided by the number of values and often is the single number used to characterize a data set.

The median of a data set also can be a useful indicator of the level of occurrence for the chemical or metal in the medium. The median is the midpoint of the data: 50% of the values lie below it and 50% lie above it. If the distribution of the data are symmetric (i.e., not skewed to the high or low side), then the arithmetic mean and median values are close to one another. If the data are skewed, the arithmetic mean and median values are further apart. The median is also called the 50th percentile.

Descriptive statistics also may be used to characterize the spread or variability of a parameter (e.g., concentration). The minimum and maximum values of the parameter indicate the range, or extreme values, of the parameter in the medium. While helpful, these two statistics are not completely accurate indicators of the data's variability. Environmental data sets often have outliers, which are values that are exceptionally low or high relative to the rest of the data. When this is the case, the minimum and/or maximum values can be misleading with respect to the variability of the bulk of the data.

Another measure of the variability of a data set is the standard deviation. The standard deviation is a better measure of the variability than the minimum and maximum values because it takes into account all of the data available. The standard deviation is the square root of the variance. Mathematically, the variance is the arithmetic average of the square of the difference between each observed value and the arithmetic mean of all values in the data set. The use of differences between observed values and the arithmetic mean value is the key concept behind the definition of the variance, and hence the standard deviation. The squaring of those differences is a mathematical device that ensures the contribution of each data point is either positive or zero. If this were not done, the variance would necessarily be zero.

A simple use of the standard deviation is to compare it to the arithmetic mean. The greater the ratio of the standard deviation to the arithmetic mean, the greater the variability of the data set. The ratio of the standard deviation to the arithmetic mean is called the coefficient of variation.

Another statistic used in this study—the frequency of detection—is the fraction (often expressed as a percentage) of detection of a particular chemical or metal in a given data set.

ANOVA Method

ANOVA was used to determine any differences in concentration as a function of geological unit and/or depth. That is, geological unit and depth are the factors examined by ANOVA. ANOVA compares the variation of the of the data within the individual groups (Qay2 and Qey for geologic unit, and surface, rootzone, and subsurface for depth) with the variation between groups. The statistical quality 'variance' is used as the measure of this variation (i.e., the variance between groups to the in-group variance). If the average concentration of a chemical or metal in one or more groups is very different from the average concentrations in the other groups, then the variance between groups will be large relative to the error.

The variance between groups and the in-group variance, also known as the error, are mathematically manipulated in order to arrive at a test statistic. A test statistic is simply a number that in some way represents a statistical property of the studied data set, in this case the group data. Statistics are used to test hypotheses or assumptions. In the present case, if a test statistic resulting from an ANOVA test is less than a critical value, then there is no statistically significant evidence that the groups being analyzed differ from one another. Conversely, if the test statistic exceeds the critical value, then there is significant statistical evidence that they differ; in other words, the concentrations are significantly different in a statistical sense.

The ideas of a critical value and statistical significance are bound together. The essence of the statistical test is as follows. Given a certain assumption or hypothesis (e.g., the average concentration of a chemical or metal is the same [statistically] in all of the groups), are the actual observations probable? The test statistics are tabulated as a function of probability. Level of significance controls the probability or rate at which the assumption or hypothesis is asserted to be true when in fact it is not. Such errors are called Type I errors. A commonly used level of significance is 5%; a 5% level of significance means that Type I errors occur at rate of 5 in every 100 tests.

In addition to a test statistic, an ANOVA calculation also produces a *p*-value, which is a probability and is expressed as a value ranging from 0.0 to 1.0. The *p*-value and the statistic are complementary concepts; the *p*-value is of more interest in this study. In a statistical test the *p*-value is the probability that the resulting test statistic is significant. If the *p*-value exceeds a given critical significance level, then the hypothesis being tested is accepted; if the *p*-value is less than the critical value, the hypothesis is rejected. The hypotheses tested in this present study are: there is no difference in concentration as a function of geological unit and there is no difference in concentration as a function of depth. Thus, if the *p*-value equals or exceeds the critical value, the hypothesis is acceptable and there is no statistically significant difference in concentration as a function of the different geological units or depth zones.

According to EPA protocol (EPA 1989c, 1992b), ANOVA is used when the percent of nondetects is 15% or less. Two additional requirements for the use of ANOVA are: the data tested must be normally distributed and the variance or spread in the data for the groups being compared must be roughly the same. The tests for normality requirements are discussed below. The equality of variances was not tested formally. This was not considered a serious omission because other, less-stringent tests (Kruskal-Wallis) that do not depend on either normality or equality of variances were run as a check on the ANOVA tests. There were no differences between the ANOVA and the Kruskal-Wallis results for all chemicals or metals and all comparisons.

When the above conditions cannot be met, it is inappropriate to use ANOVA; thus, the Kruskal-Wallis test is used. The rationale for this test is that, if the different groups being tested belong to a common distribution, then the average rank of the groups should be approximately the same. It assumes that each group is comprised of roughly the same mix of low, moderate, and high values from the total set of data. The rank of a datum (i.e., single data point or sample) is merely its location in the total data set after that set has been sorted from lowest value to highest value.

In the Kruskal-Wallis test, each datum in the overall data set is replaced by its rank. Provisions are made for the multiple occurrence of an observed value. A comparison test is then performed on the ranked data set. The Kruskal-Wallis test is approximately equivalent to performing ANOVA on the data ranks. An advantage of the Kruskal-Wallis test is that, because the conditions of normality and equal variances in the original data required for ANOVA are relaxed, it can be applied where ANOVA cannot.

Tests for Normality

Current EPA guidance (EPA 1992c) recommends three methods of testing for normality: calculating the coefficient of skewness, constructing probability plots, and the Shapiro-Wilk test. This study used the coefficients of skewness and probability plots. The coefficient of skewness does not directly measure the normality of the data but instead tests for skewness (i.e., a tail on either the upper end or lower end of the data distribution). The sign of the coefficient is determined by whether the tail is at the low or the high end of the distribution. A low absolute value of the coefficient of skewness is indicative of a more symmetric distribution and, therefore, of a distribution more likely to be approximately a normal or bell shape.

According to EPA's RCRA guidance, distributions with a coefficient of skewness between -1 and 1 are sufficiently symmetric to approximate a normal distribution within the context of an ANOVA test. If a data set has a coefficient of skewness outside this range, the data are not sufficiently normal and ANOVA should be abandoned in favor of Kruskal-Wallis.

In addition to the coefficient of skewness, probability plots were constructed for both original and transformed data. The extent to which these plots were linear confirmed the assessment of normality based on the skewness.

Calculation of Upper Confidence Limits

For normally distributed data, the 95% UCL is calculated using (EPA 1992a; Gilbert 1987):

$$UCL = x + t * s / \sqrt{n}$$

where

UCL = upper confidence limit,
x = mean of the data,
s = standard deviation of the data,
t = 95th percentile of Student's t-distribution, and
n = number of samples.

The t-statistic is a function of the number of samples. The resulting UCL has units of concentration.

For lognormally distributed data, the 95% UCL is calculated using (EPA 1992a; Gilbert 1987):

$$UCL = \exp\left(x + 0.5 * s^2 + s * H / \sqrt{(n - 1)}\right.$$

where

x = mean of the logtransformed data,
s = standard deviation of the log-transformed data,
H = H-statistic, and
n = number of samples.

The value of the H-statistic depends on both n and s and has been tabulated by Gilbert (1987), and in this study the approximate values for H were obtained by bilinear interpolation of that table. The resulting UCL calculated in this fashion also has units of concentration.

When the data are neither normally nor lognormally distributed, the nonparametric 95% confidence interval can be estimated, assuming a sufficiently high percentage of detection, by the expression (EPA 1989c):

$$UCL = n / 2 + Z_{0.95} * \sqrt{(n / 4)}$$

where $Z_{0.95}$ is the 95th percentile from the normal distribution and equals 1.6449. This UCL also has units of concentration.

Calculation of Upper Tolerance Limits

For normally distributed data, the 95% UTL is calculated using (EPA 1989, 1992b):

$$UTL = x + K * s$$

where

UTL = upper tolerance limit,
x = mean of the data,
s = standard deviation of the data, and
K = one-sided tolerance factor for 95% coverage and 95% confidence.

The tolerance factor K depends on the number of samples. It is tabulated for 95% coverage and 95% confidence in EPA 1989. The UTL calculated in this fashion has units of concentration.

For lognormally distributed data, the 95% UTL is calculated using (EPA 1989c):

$$UTL = x + K * s$$

where

UTL = upper tolerance limit,
x = mean of the logtransformed data,
s = standard deviation of the log transformed data, and
K = one-sided tolerance factor for 95% average coverage and 95% confidence.

Note that the units here are log(concentration).

EPA guidance (EPA 1989c) states that where the UTL for lognormal data is used, the data to be compared should be log-transformed first and then compared with the UTL. It is mathematically valid to compare the original data with the back-transformed UTL (i.e., with exp[UTL]). The back-transformed UTL has units of concentration.

When the data are neither normally nor lognormally distributed, it may be possible to estimate a nonparametric UTL. This is done by noting that the average level of coverage of nonparametric UTL is related to number of samples. n, and the rank of the UTL by EPA 1992b:

$$Coverage = 1 - ((n + 1) - r) / (n + 1)$$

The rank of the 95% UTL having 95% coverage can then be found by setting the coverage equal to 0.95 can solving for r:

$$r = 0.95 * (n + 1)$$

The 95% UTL is then taken as that data value having rank r.

Finally, if an estimated 95% UTL (either parametric or nonparametric) exceeded the maximum observed value, then that estimate was reset to the observed maximum.

3 Results

3.1 Introduction

The results of the background data set determinations and statistical calculations are presented in this section. The results for soils are presented in two groups. The first group includes metals and a chemical that were detected in a high percentage of samples (arsenic, barium, chromium, copper, nickel, lead, and zinc). Parametric estimates of the means, UCLs, and UTLs were easily derived. Also included in this group was DDT, which had a detection rate of 46.6%. These detects were used to calculate, using Aitcheson's correction (EPA 1992c), estimates for the mean and standard deviation for the entire DDT data set. The corrected mean and standard deviation were then used to make parametric estimates of the DDT UCL and UTL. The second group, which included chemicals and metals that were not detected in a high percentage of samples (cadmium, mercury, selenium, silver, DDE, and DDD), required nonparametric techniques. Nonparametric estimates were also made for the DDT data set.

The filtered groundwater data set contains a moderate to high number of nondetects; therefore, it was amendable only to nonparametric analysis, and only for barium, copper, lead, and zinc. The unfiltered data have a higher percentage of detects than the filtered data. However, unfiltered data are often dependent on the mechanics of the sampling process in the field and therefore are of limited value in characterizing groundwater. Although statistical calculations were not performed on the unfiltered data, probability plots for metals also are presented.

The results for the soil data are presented in Section 3.2. The manner of presentation follows the methodology outlined in Section 2.2: the determination of the percentage of detects, ANOVA on unedited data, determination of final background values using cutoffs and ANOVA on the cutoff or edited data, and, finally, evaluation of UCLs and UTLs.

The results for the groundwater are presented in Section 3.3

3.2 Soils

3.2.1 Development of the Background Data Sets

Before background means, UCLs, and UTLs could be calculated, it was necessary to screen the compiled data to build background data sets. For data sets with a high percentage of detects, any groups corresponding to distinct populations associated with different geological units (Qay2 and Qey) or the three sampling depth intervals (surface, rootzone, and subsurface) were identified using ANOVA. Once all of these populations or data sets were identified, probability plots were constructed and, using professional judgment, upper cutoff concentrations were determined. Values above the cutoffs were assumed to be resultant from contamination and were eliminated from the data sets.

The resulting edited data sets were checked for normality and/or lognormality and then re-examined using ANOVA for differences in concentration as a function of geological unit and/or depth. The data sets remaining after this process were used to calculate the parametric UCL and UTL.

For approximately half of the 14 chemicals and metals, the percentages of detects were low. In these cases, the delineation of distinct populations by different geological units or depth zones was not practical. Therefore, when possible, the entire compiled data sets were culled for contamination or extreme outliers and then used to estimate nonparametric UCLs and UTLs.

Percentage of Detects

Because too many nondetects in a sample data set limits the ability of ANOVA to discern true differences between groups in that data set, ANOVA can only be attempted with data sets having a percentage of detects of greater than 85% (EPA 1992). Therefore, the initial step in the present study was the calculation of the percentage of detects in the compiled data set for each chemical. From these percentages, a determination of which chemical data sets were amenable to ANOVA testing could be made.

The percentages of detects and the minimum and maximum observed values for each of the fourteen chemicals and metals (arsenic, barium, cadmium, chromium, copper, DDD, DDE, DDT, lead, mercury, nickel, selenium, silver, and zinc) in the compiled data set are presented in Table 3-1. This table shows that seven metals (arsenic, barium, chromium, copper, lead, nickel, and zinc) have high percentages of detects, four metals and two chemicals (cadmium, DDD, DDE, mercury, selenium, and silver) have low percentages of detects, and one chemical (DDT) is intermediate. Only those data sets having a high percentage of detects were retained for the ANOVA; consequently, these were the only data sets for which distinct differences in concentration by geological unit or depth were identified.

Differences by Geological Unit and/or Depth (ANOVA)

ANOVA was performed on the compiled data sets for arsenic, barium, chromium, copper, lead, nickel, and zinc. Each data set was tested to identify statistically significant differences between analyte concentrations as a function of either geological unit (Qay2 and Qey) or sample depth (surface, rootzone, and subsurface).

The results of the ANOVA calculations are summarized in Table 3-2. A *p*-value less than 0.05 indicates that one or more of the groups being tested is statistically different than the remaining groups in the data set. For example, in the case of arsenic, the *p*-value for the geological units ANOVA test is 0.000. This is less than 0.05, indicating that there is a significant statistical difference between the arsenic concentrations in the Qay2 samples and the arsenic concentrations in the Qey samples. Similarly the arsenic depth ANOVA *p*-value is 0.000, also indicating that the arsenic concentrations in the samples of at least one of the three depth zones are statistically significantly different from the concentrations in the other two zones.

A *p*-value equal to or greater than 0.05 indicates that no statistically significant differences exist between the groups being tested. When tested by geological unit and depth, the *p*-values for the nickel data set are both greater than 0.05. Thus, it can be concluded that there are no statistically significant differences between the nickel concentrations either as a function of geological unit or as a function of sample depth.

As can be seen in Table 3-2, the arsenic data set was the only one for which statistical differences in concentration by both geological unit and depth were evident. Nickel was the only data set in which no statistical differences were found. Statistical differences by depth only were indicated for barium, lead, and zinc; and statistical differences by only geological unit were indicated for chromium and copper.

Final Background Data Sets

Guided by the ANOVA results described above, concentration probability plots were constructed for the analytical results of each distinct group:

- The surface, rootzone, and subsurface samples of barium, lead, and zinc;
- The Qay2 and Qey samples of chromium and copper; and

- The surface, rootzone, subsurface, Qay2, and Qey samples of arsenic.

A single plot using all of the sample concentrations of nickel also was constructed. The plots are shown in Figures 3-1 through 3-18.

Each probability plot was assessed to determine an upper cutoff concentration for the corresponding data set. All values above the cutoffs were assumed to be contaminated and, therefore, eliminated from the data sets. Values below the cutoff were retained as background.

The background data sets were checked for normality and/or lognormality by calculating the coefficient of skewness for both the data and the log-transformed data, respectively (EPA 1992b). For reasonably symmetric and, hence, approximately normally distributed sample populations, the coefficient of skewness is between -1 and 1. Thus, if a background data set has a coefficient of skewness falling within this range, that population would be considered to have a normal distribution. If the log-transformed data's coefficient falls in this range, then the population's distribution is considered to be lognormal.

Table 3-3 shows the cutoffs and the calculated coefficient of skewness for each background group's data set. Skewness was evaluated for both the group data sets (e.g., barium surface samples) and the pooled data sets for each chemical or metal (e.g., the composite of the surface, rootzone, and subsurface samples for barium). Finally, the table also indicates whether each particular background population is normal or lognormal.

Elimination of higher values (i.e., contamination) from the data sets can significantly change the variance of the tested populations. Therefore, it was necessary to repeat the earlier ANOVA calculations on the final sample data sets. This was done for arsenic, barium, chromium, copper, lead, nickel, and zinc. These final ANOVA calculations were performed on either the untransformed data or the log-transformed data, depending on whether the data set was normally or lognormally distributed. Two changes were found as a result of this re-evaluation of group differences: zinc no longer showed any difference in concentration as a function of depth and nickel concentration varies as a function of depth. The grouping shown in Table 3-3 reflects the results of the final round of ANOVA calculations. Thus, zinc has only one entry—all.

The probability plots for the remaining chemicals and metals are shown on Figures 3-19 through 3-25. The data sets for the cadmium, mercury, selenium, and silver had low percentages of detects; therefore, ANOVA was not performed on these data sets to determine differences in concentration as a function of either geological unit or depth. To eliminate contamination, each data set was assessed on a case-by-case basis at the time of the nonparametric UCL and UTL calculations discussed below. ANOVA was not performed on DDD, DDE, or DDT because these chemicals are anthropogenic in origin and only surface concentrations were of interest.

3.2.2 Calculation of UCLs and UTLs

Depending on the percentage of detects, both parametric estimates and nonparametric estimates of the 95% UCLs and 95% UTLs were made for arsenic, barium, cadmium, chromium, copper, DDD, DDE, DDT, lead, mercury, nickel, selenium, silver, and zinc (see Table 3-4). In addition, the corresponding means, medians, minimum values, and maximum values have been included in the table for comparisons. It was not possible, however, to calculate the means and medians for chemicals or metals that had low percentages of detects.

Parametric Calculations

The calculations for arsenic, barium, chromium, copper, lead, nickel, and zinc were performed using the parametric formulas given in Section 2 and assuming either a normal or lognormal distribution, as indicated in Table 3-3. The UCLs and UTLs were calculated both for the groups given in Table 3-3 (e.g., barium concentrations in surface samples), and for the total, or composite, groups (e.g., all barium concentrations).

The DDT sample data set had a detection frequency of 46.6%. A probability plot of the detected values only suggested that the detects were lognormally distributed (see Figure 3-26). The skewness of the log-transformed of the detects data only was well below 1.0, suggesting lognormality. In view of these results, the mean and standard deviation of the log-transformed DDT detect values were calculated, Aitcheson's correction (EPA 1992) was applied to those results, and adjusted values for the mean and standard deviation of the entire log-transformed DDT data set were derived. These values were then used to estimate the 95% UCL and 95% UTL following the methods described in Section 2 for a lognormal population. These estimates have been included in Table 3-4 along with the nonparametric UCL and UTL.

Nonparametric Calculations

As noted above, low percentages of detects were observed for the remaining metals in the soil data set (silver, cadmium, mercury, and selenium) and for the DDT degradation products DDD and DDE. Because of this, it was not possible to calculate the means, parametric UCLs, or parametric UTLs for these substances. However, medians, nonparametric UCLs, and nonparametric UTLs were estimated, where possible. The percentages of detects were still too low in some cases for nonparametric estimates. Nonparametric estimates were also made for the DDT data set, allowing a comparison with the corrected parametric estimates derived above.

Prior to the nonparametric UCL and UTL calculations, outliers were identified and deleted. Two very high values were deleted from the mercury data set, and two were deleted from the selenium data set. All of the deleted data were from samples collected from the Grease Pit.

Because of the low percentages of detects (less than 50%), nonparametric UCLs could not be calculated. Nonparametric UTLs were estimated for each of the chemicals or metals using the maximum values in their respective data sets. For DDD and selenium, the maximum values were nondetects, and their actual values were not known; therefore, the second highest values were used to estimate their UTLs. Because of the large number of samples in each data set, the minimum coverage for the 90% confidence UTL lies above 95%, regardless of whether the maximum or second highest values are used.

3.3 Groundwater

3.3.1 Filtered Groundwater

Probability plots for the filtered groundwater data for the metals are shown on Figures 3-27 through Figure 3-37. Examination of these plots and the corresponding data sets indicated that nonparametric 95% UTLs could be estimated only for barium, copper, lead, and zinc; the percentage of detects for the other metals in the data set were too low. In addition, the median and nonparametric 95% UCL could only be estimated for barium, again because of the low percentages of detects. The UCL and UTL estimates that were made are summarized in Table 3-5 along with the minimum and maximum observed values.

3.3.2 Unfiltered Groundwater

Based on previous experience with groundwater investigations in Alaska, E & E did not perform statistical calculations to determine background levels for unfiltered groundwater. The minimum and maximum observed values, and, where possible, the median values, are presented in Table 3-5. Probability plots for the metals are shown in Figures 3-38 through 3-48. Unfiltered groundwater samples from glaciofluvial aquifers such as those underlying Fort Richardson are generally turbid because of very fine soil particles, which causes elevated concentrations of metals in unfiltered samples. The supposition that there is a much higher frequency of detects for unfiltered samples than for filtered samples collected from the same wells as part of the same studies is borne out by a comparison of the filtered and unfiltered sample results from the various groundwater studies conducted at Fort Richardson. The amount of turbidity in a given well also can be greatly affected by the specifics of the sampling process (e.g., the rate at which the well is pumped, the interval between sampling events, etc.). E & E had no information regarding the sampling methods that were employed to obtain the various unfiltered samples, potentially making the use of these samples even more suspect.

Table 3-1

PERCENTAGE OF DETECTS IN COMPILED SOIL DATA BACKGROUND DATA ANALYSIS
FORT RICHARDSON, ALASKA

Chemical	Number Detects	Number Samples	% Detects
Arsenic	457	461	99.13
Barium	320	320	100.00
Cadmium	36	397	9.07
Chromium	468	470	99.57
Copper	85	86	98.84
DDD	6	57	10.53
DDE	11	57	19.30
DDT	27	58	46.55
Lead	671	689	97.39
Mercury	13	302	4.30
Nickel	182	185	98.38
Selenium	40	252	15.87
Silver	10	264	3.79
Zinc	83	86	96.51

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Table 3-2

ANOVA RESULTS FOR COMPILED SOIL DATA SETS BACKGROUND DATA ANALYSIS FORT RICHARDSON, ALASKA

Chemical	Groups Tested	p-value	Groups Different
Arsenic	Geological unit	0.000	Yes
	Depth	0.006	Yes
Barium	Geological unit	0.120	No
	Depth	0.000	Yes
Chromium	Geological unit	0.000	Yes
	Depth	0.431	No
Copper	Geological unit	0.001	Yes
	Depth	0.853	No
Lead	Geological unit	0.530	No
	Depth	0.000	Yes
Nickel	Geological unit	0.217	No
	Depth	0.109	No
Zinc	Geological unit	0.238	No
	Depth	0.004	Yes

Table 3-3

DISTRIBUTIONS OF EDITED BACKGROUND SOIL DATA SETS
BACKGROUND DATA ANALYSIS
FORT RICHARDSON, ALASKA

Chemical	Group	Cutoff (ppm)	Coefficient of Skewness		Distribution
			Untransformed	Logtransformed	
Arsenic	All	—	0.537	-2.754	Normal
	Surface	16	0.641	-2.155	Normal
	Rootzone	16	1.941	0.984	Lognormal
	Subsurface	16	0.460	-2.830	Normal
	Qay2	16	0.837	-1.513	Normal
	Qey	16	0.139	2.594	Normal
Barium	All	—	1.128	-1.328	Normal
	Surface	160	0.365	0.577	Normal
	Rootzone	160	1.413	0.322	Lognormal
	Subsurface	160	1.400	-1.629	Normal
Chromium	All	—	-0.072	-4.634	Normal
	Qay2	63	0.093	-1.412	Normal
	Qey	63	0.052	-4.100	Normal
Copper	All	—	-0.647	-3.000	Normal
	Qay2	63	-0.405	-2.182	Normal
	Qey	63	-0.740	-2.088	Normal
DDT	Surface detects	—	2.734	0.365	Lognormal
Lead	All	—	2.466	0.355	Lognormal
	Surface	30	1.337	0.232	Lognormal
	Rootzone	30	1.552	0.497	Lognormal
	Subsurface	40	2.817	0.015	Lognormal
Nickel	All	—	-0.229	-2.891	Normal
	Surface	—	-0.648	-2.582	Normal
	Rootzone	—	1.050	0.503	Lognormal
	Subsurface	—	-0.171	-2.912	Normal
Zinc	All	—	0.135	-4.149	Normal

Table 3-4

SOIL BACKGROUND UCLS AND UTLS
EDITED BACKGROUND DATA ANALYSIS
FORT RICHARDSON, ALASKA

Chemical	Group	n	95%UCL	95%UTL	Mean	Median	Minimum	Maximum	Calculation
Arsenic	All	445	5.88	8.84	5.74	6	0.25	13	Parametric
	Surface	71	7.04	9.91	6.66	6.3	1	13	Parametric
	Rootzone	45	6.59	9.17	6.55	6	4	12	Parametric
	Subsurface	329	5.59	8.43	5.43	5	0.25	12	Parametric
	Qay2	341	6.16	8.97	6.00	6	0.8	11	Parametric
	Qey	98	5.20	8.12	4.87	5	0.25	13	Parametric
Barium	All	306	60.05	95.19	57.9	53	2.5	154	Parametric
	Surface	52	70.02	104.69	64.5	64.5	17.9	123	Parametric
	Rootzone	44	65.21	101.66	64.4	59	32	150	Parametric
	Subsurface	210	56.37	89.19	54.0	51	2.5	154	Parametric
Cadmium	All	397	—	2.2	—	—	0.001	12.8	Nonparametric[b]
Chromium	All	465	31.76	43.84	31.2	31	1	58	Parametric
	Qay2	362	32.58	43.66	32.0	31	7.2	58	Parametric
	Qey	97	29.76	43.51	28.2	28	1	53	Parametric
Copper	All	80	34.72	51.89	32.6	34.25	1	54	Parametric
	Qay2	25	25.73	40.07	22.2	24	1	39	Parametric
	Qey	55	39	52.13	37.4	37	10	54	Parametric
DDD	All	59	—	—	—	—	0.001	0.15	Not calculated
DDE	All	59	—	0.07	—	—	0.001	0.09	Not calculated

Table 3-4

SOIL BACKGROUND UCLS AND UTLS
EDITED BACKGROUND DATA ANALYSIS
FORT RICHARDSON, ALASKA

Chemical	Group	n	95%UCL	95%UTL	Mean	Median	Minimum	Maximum	Calculation
DDT[a]	All	29	1.08	0.81	0.20	0.09	0.001	1.54	Parametric
DDT	All	58	—	0.07	—	—	0.001	1.54	Nonparametric[b]
Lead	All	660	7.82	14.25	7.56	6.2	0.94	29	Parametric
	Surface	69	11.95	21.74	11.8	10	3.7	27	Parametric
	Rootzone	64	10.44	18.60	9.97	8.35	3.6	28	Parametric
	Subsurface	527	6.92	11.69	6.70	6	0.94	29	Parametric
Mercury	All	302	—	—	—	—	0.03	0.6	Not calculated
Nickel	All	183	36.56	50.64	35.4	35	5	63	Parametric
	Surface	49	35.41	48.73	33.22	33	5	49	Parametric
	Rootzone	37	38.55	50.81	38.24	37	27	60	Parametric
	Subsurface	97	37.10	51.47	35.49	35	5	63	Parametric
Selenium	All	252	—	—	—	—	0.027	2.5	Not calculated
Silver	All	264	—	—	—	—	0.26	4.2	Not calculated
Zinc	All	83	53.57	80.79	50.2	50	0.5	108	Parametric

[a] Aitcheson's correction applied to log-transform of censored data set.

[b] Expected average coverage is 95%.

Table 3-5

GROUNDWATER SAMPLE STATISTICS
BACKGROUND DATA ANALYSIS
FORT RICHARDSON, ALASKA

Chemical[a]	Number Samples	Number Detects	% Detects	Median	Minimum	Maximum	95%UCL	95%UTL[b]
Filtered Samples:								
Arsenic	162	10	6.17	—	1.00	9.9	—	—
Barium	163	85	52.15	7	0.50	510	—	40
Cadmium	163	1	0.61	—	0.25	0.84	—	—
Chromium	163	6	3.68	—	1.00	46	—	—
Copper	129	11	8.53	—	2.50	23	—	14
Lead	161	15	9.32	—	0.23	11,200	—	4.4
Mercury	162	11	6.79	—	0.10	0.64	—	—
Nickel	130	1	0.77	—	2.50	63	—	—
Zinc	129	39	30.23	—	1.00	1,300	—	91
Unfiltered Samples:								
Arsenic	163	35	21.47	—	1.00	430	—	—
Barium	156	105	67.31	10	2.50	2,100	—	—
Cadmium	164	5	3.05	—	0.03	7	—	—
Chromium	164	46	28.05	—	1.00	1,900	—	—
Copper	127	49	38.58	—	2.50	323	—	—
Lead	163	69	42.33	—	1.00	240	—	—
Mercury	155	16	10.32	—	0.10	5.7	—	—
Nickel	137	25	18.25	—	2.50	546	—	—
Zinc	127	74	58.27	10	1.00	1,900	—	—

Note: Means were not calculated. The low percentage of detects and lack of knowledge of population distributions make interpretation meaningless.

[a] Selenium and silver not included in table. All sample results, filtered and unfiltered, were nondetects.
[b] Expected average coverage is 95%.

JT5100\ARSENIC.CDR (P1)

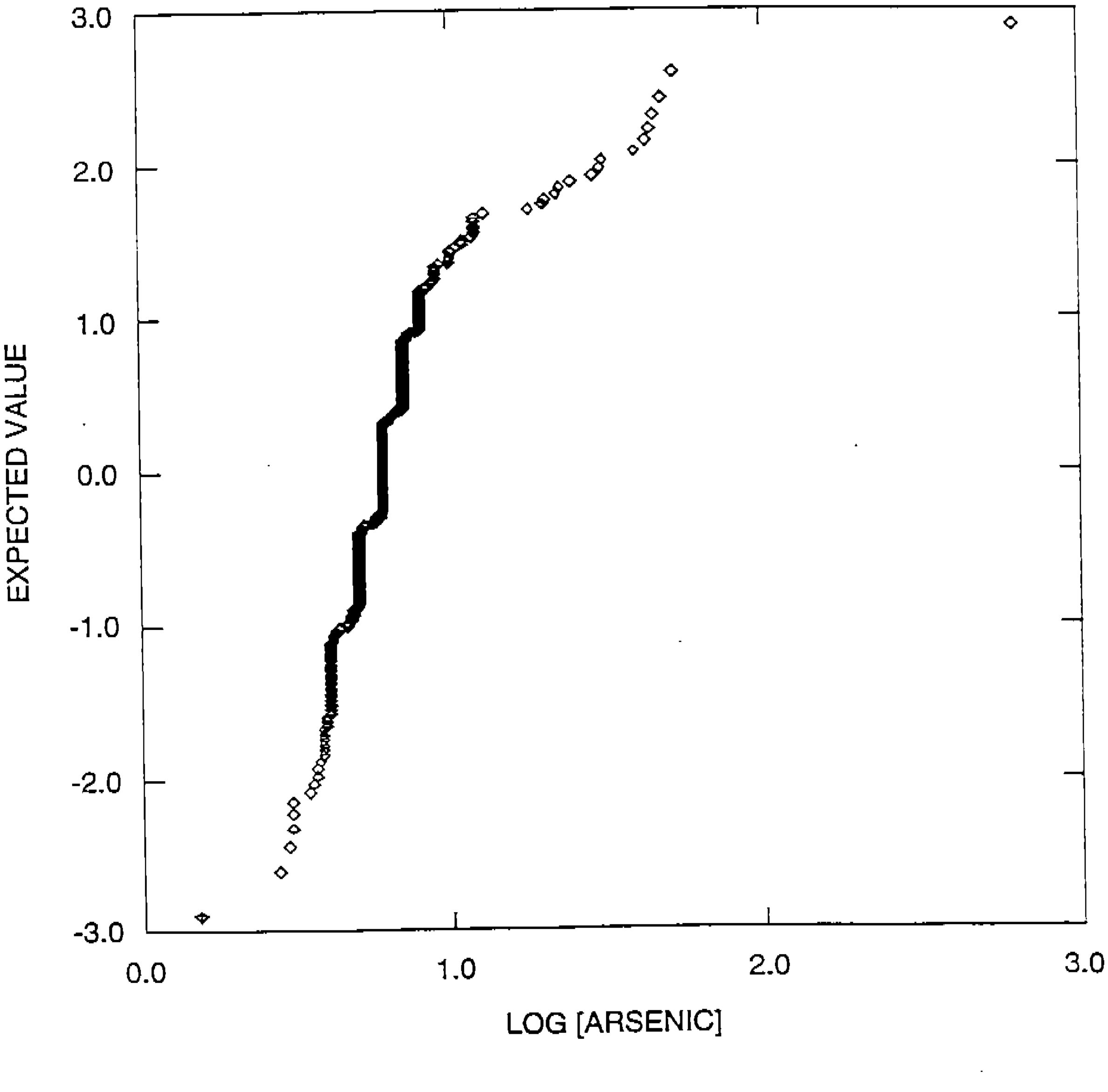

Figure 3-1 PROBABILITY PLOT FOR ARSENIC - QAY2 SAMPLES

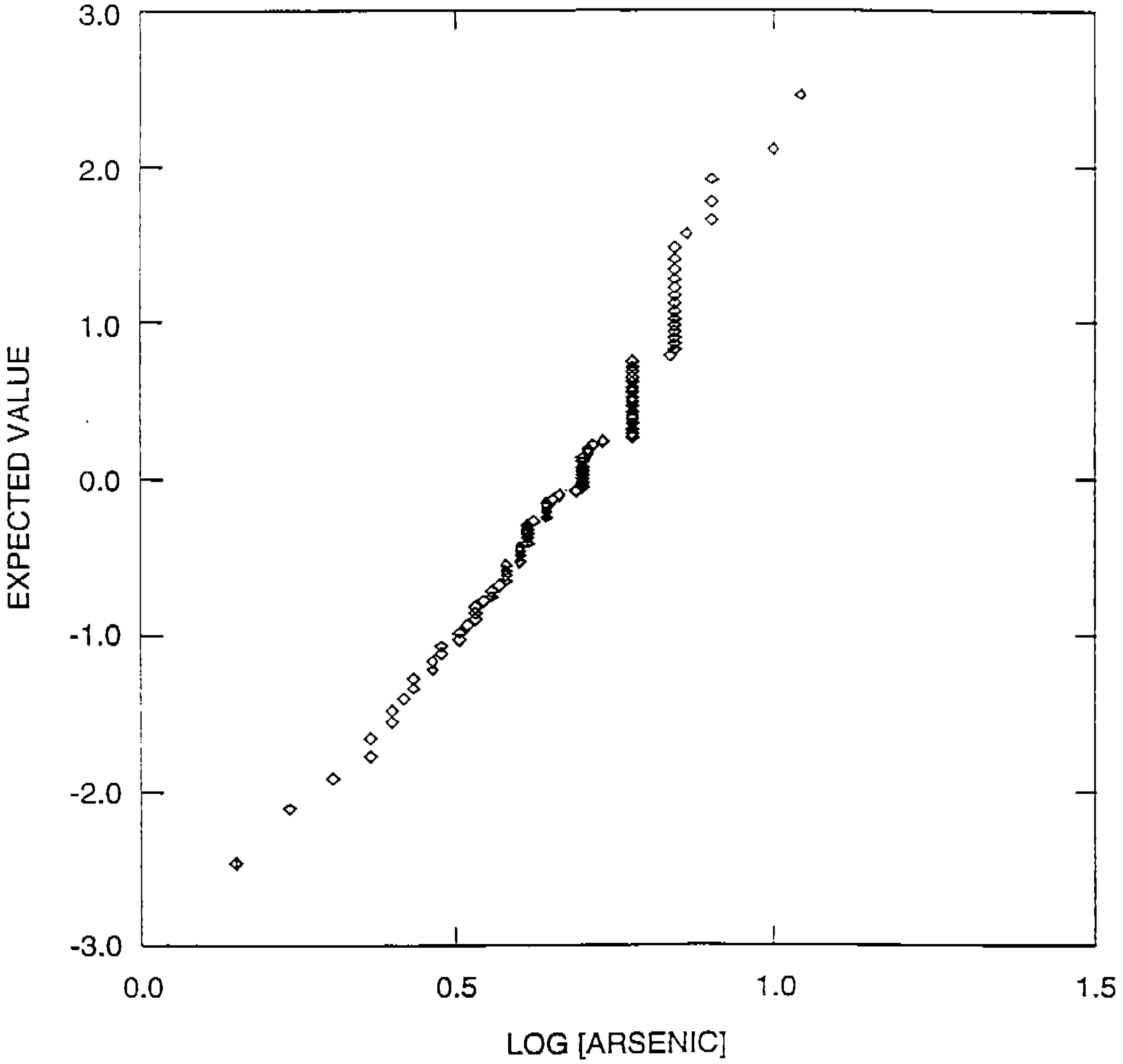

Figure 3-2 PROBABILITY PLOT FOR ARSENIC - QEY SAMPLES

JT5100\ARSENIC.CDR (P3)

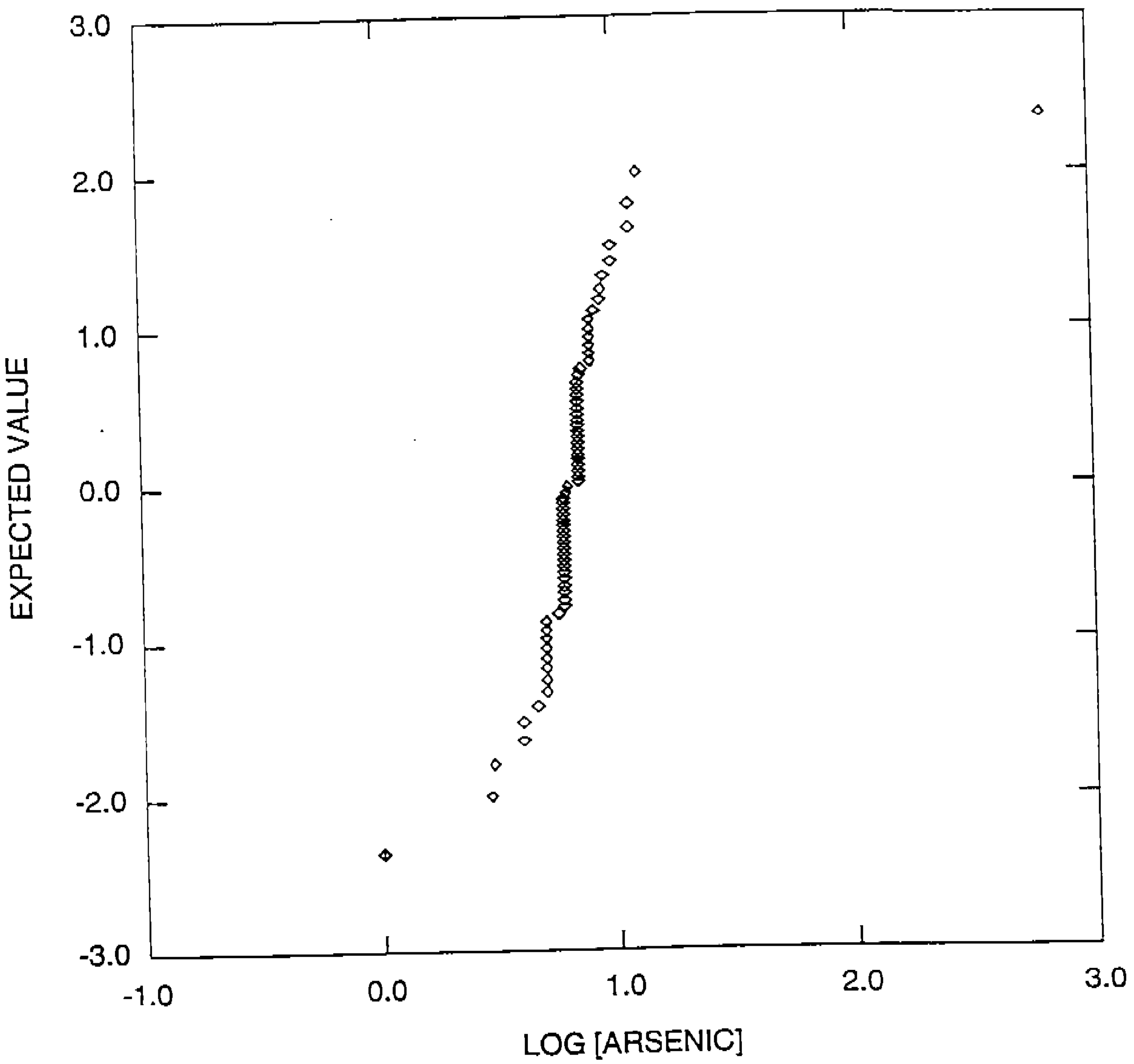

Figure 3-3 PROBABILITY PLOT FOR ARSENIC - SURFACE SAMPLES

JT5100\ARSENIC.CDR (P4)

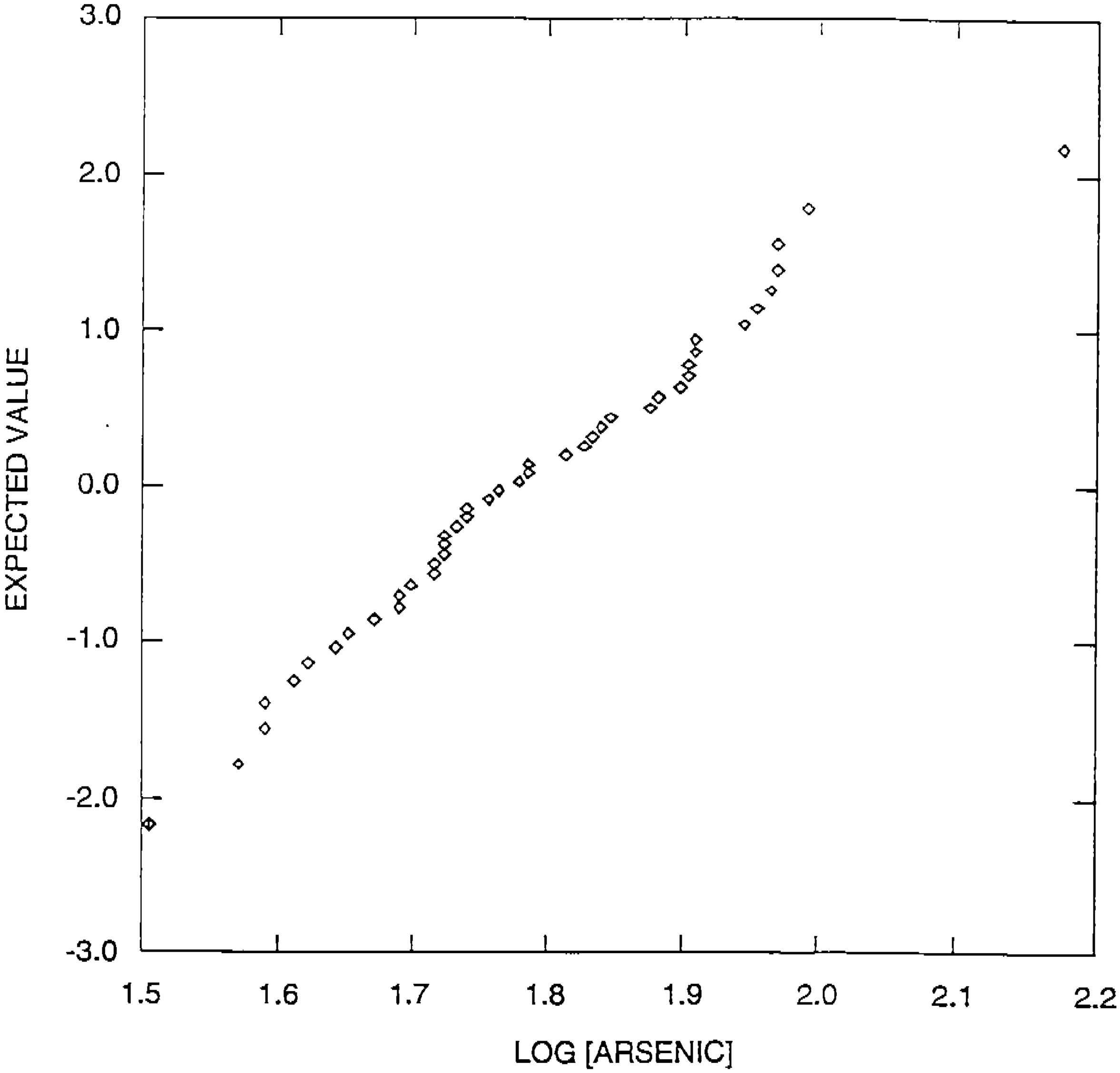

Figure 3-4 **PROBABILITY PLOT FOR ARSENIC - ROOTZONE SAMPLES**

JT5100\ARSENIC.CDR (P5)

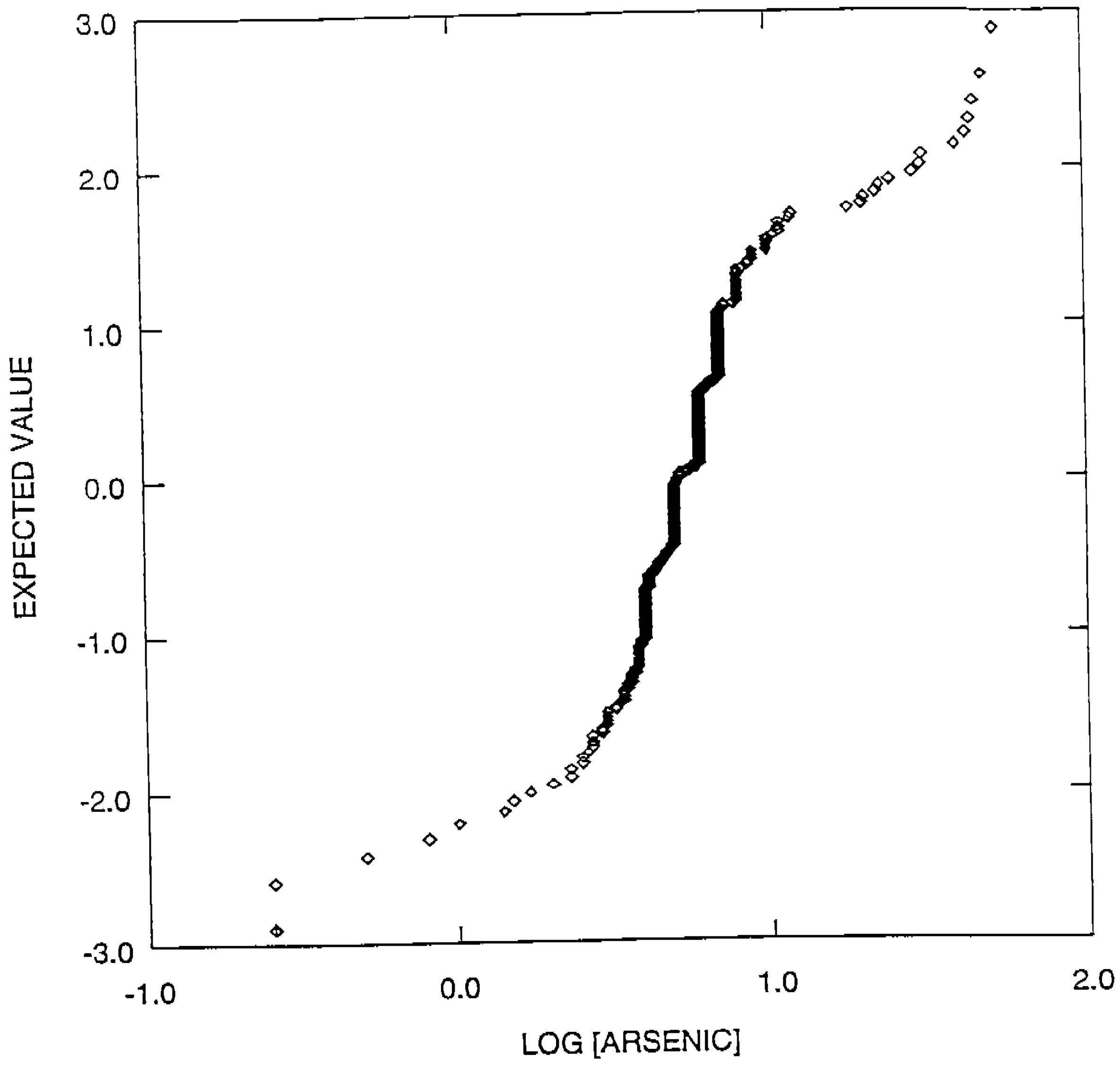

Figure 3-5 PROBABILITY PLOT FOR ARSENIC - SUBSURFACE SAMPLES

JT5100\BARIUM.CDR (P1)

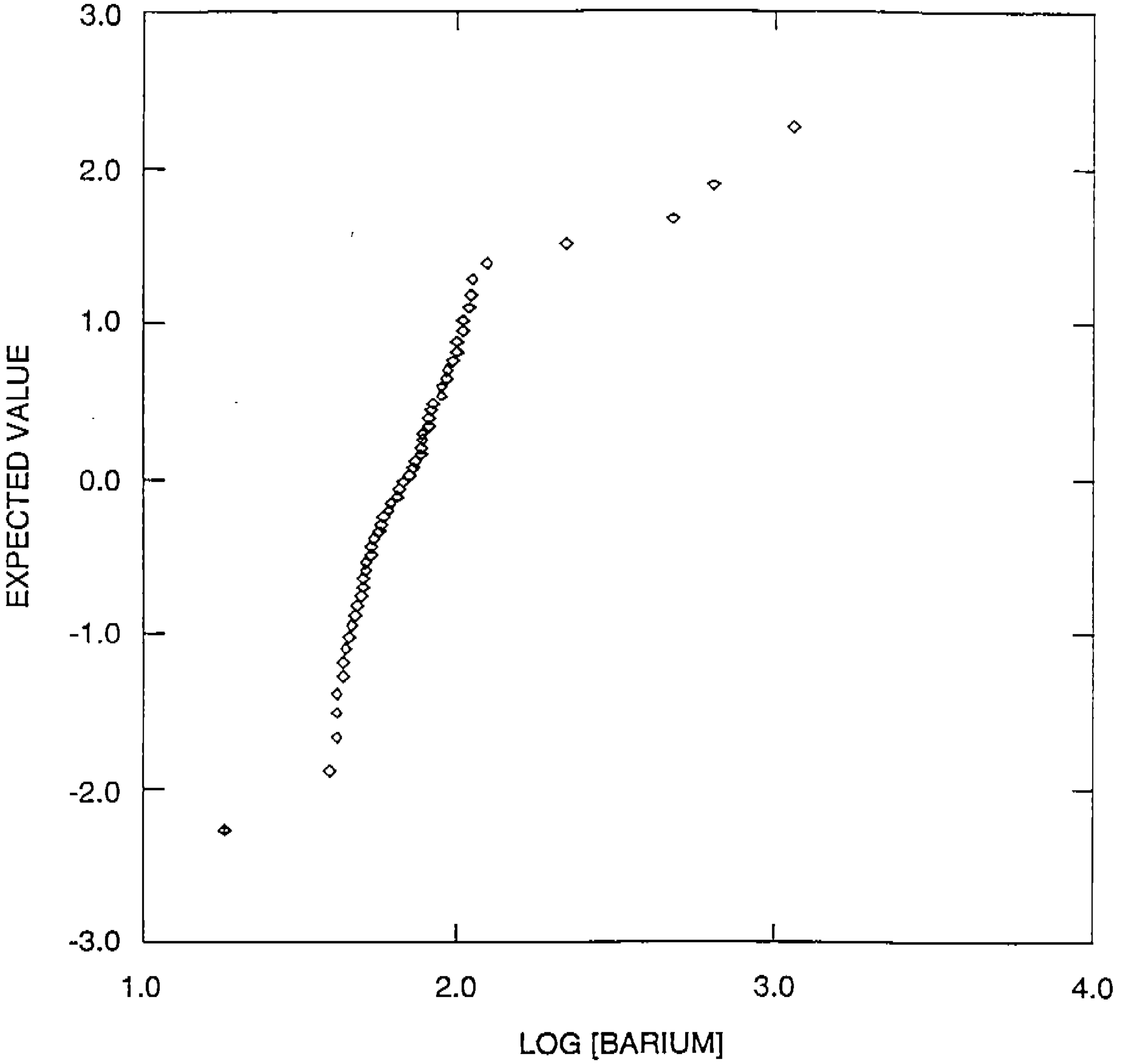

Figure 3-6 **PROBABILITY PLOT FOR BARIUM - SURFACE SAMPLES**

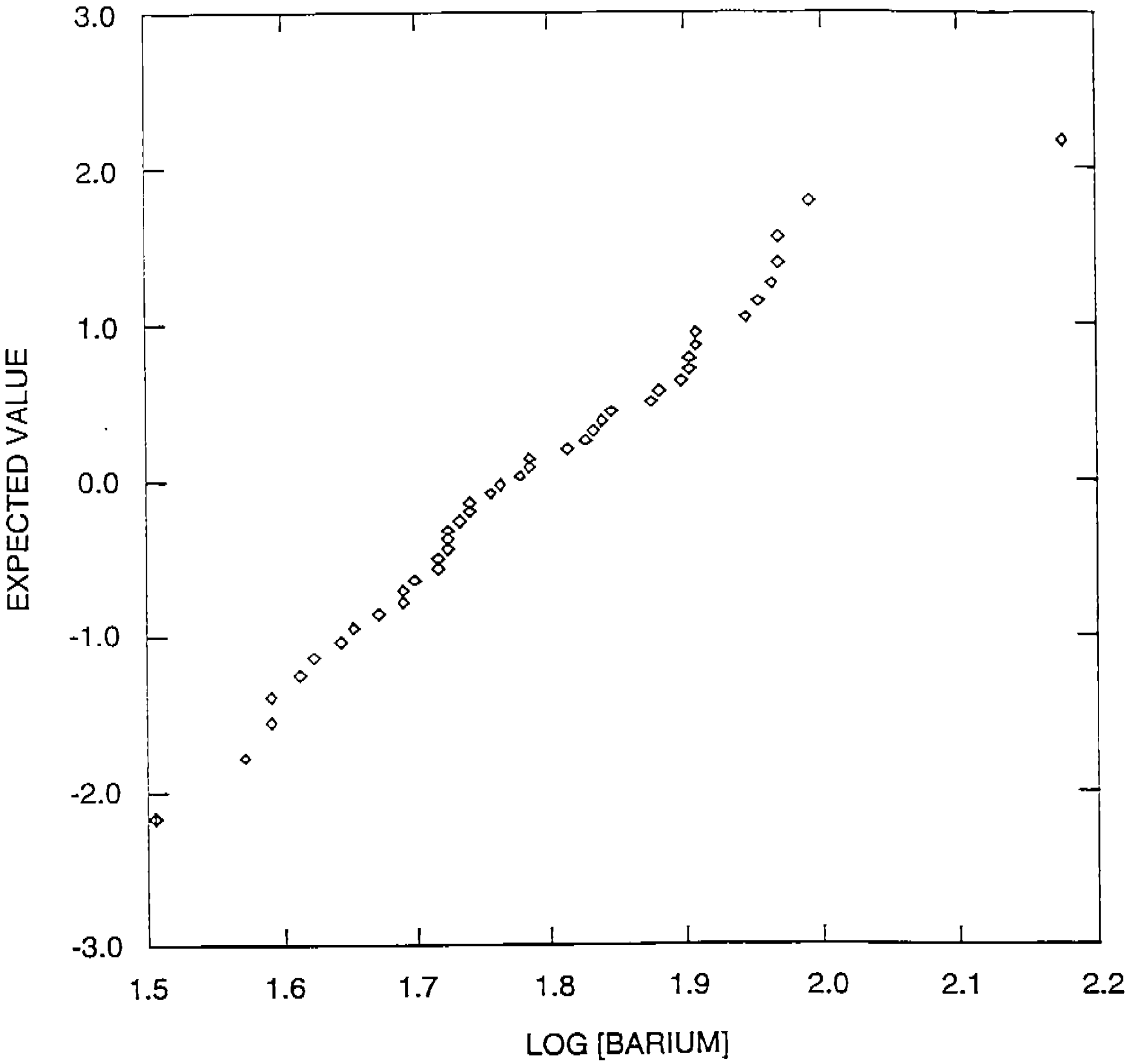

Figure 3-7 **PROBABILITY PLOT FOR BARIUM - ROOTZONE SAMPLES**

JT5100\BARIUM.CDR (P3)

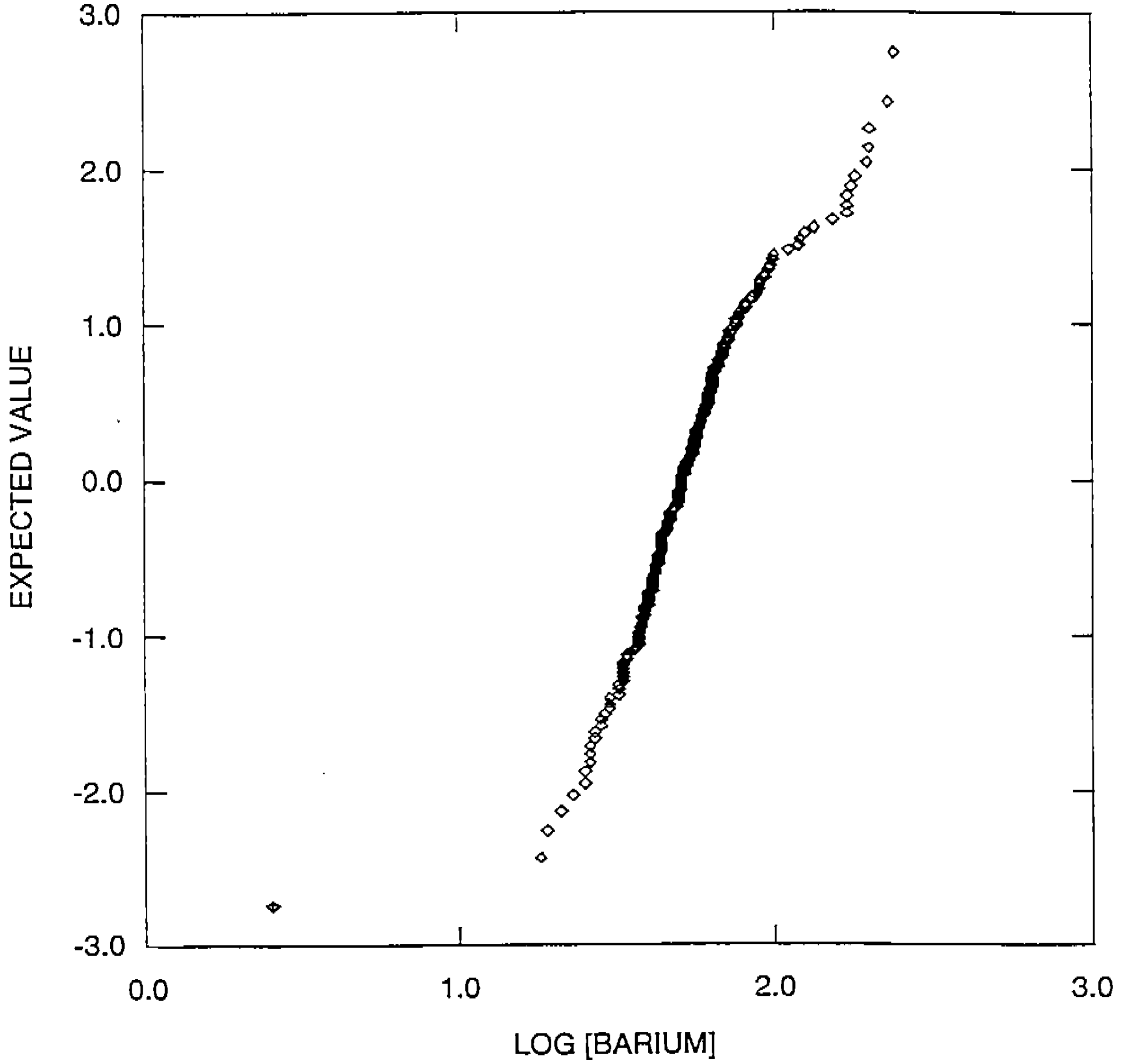

Figure 3-8 PROBABILITY PLOT FOR BARIUM - SUBSURFACE SAMPLES

JT5100\CHROMIUM.CDR (P1)

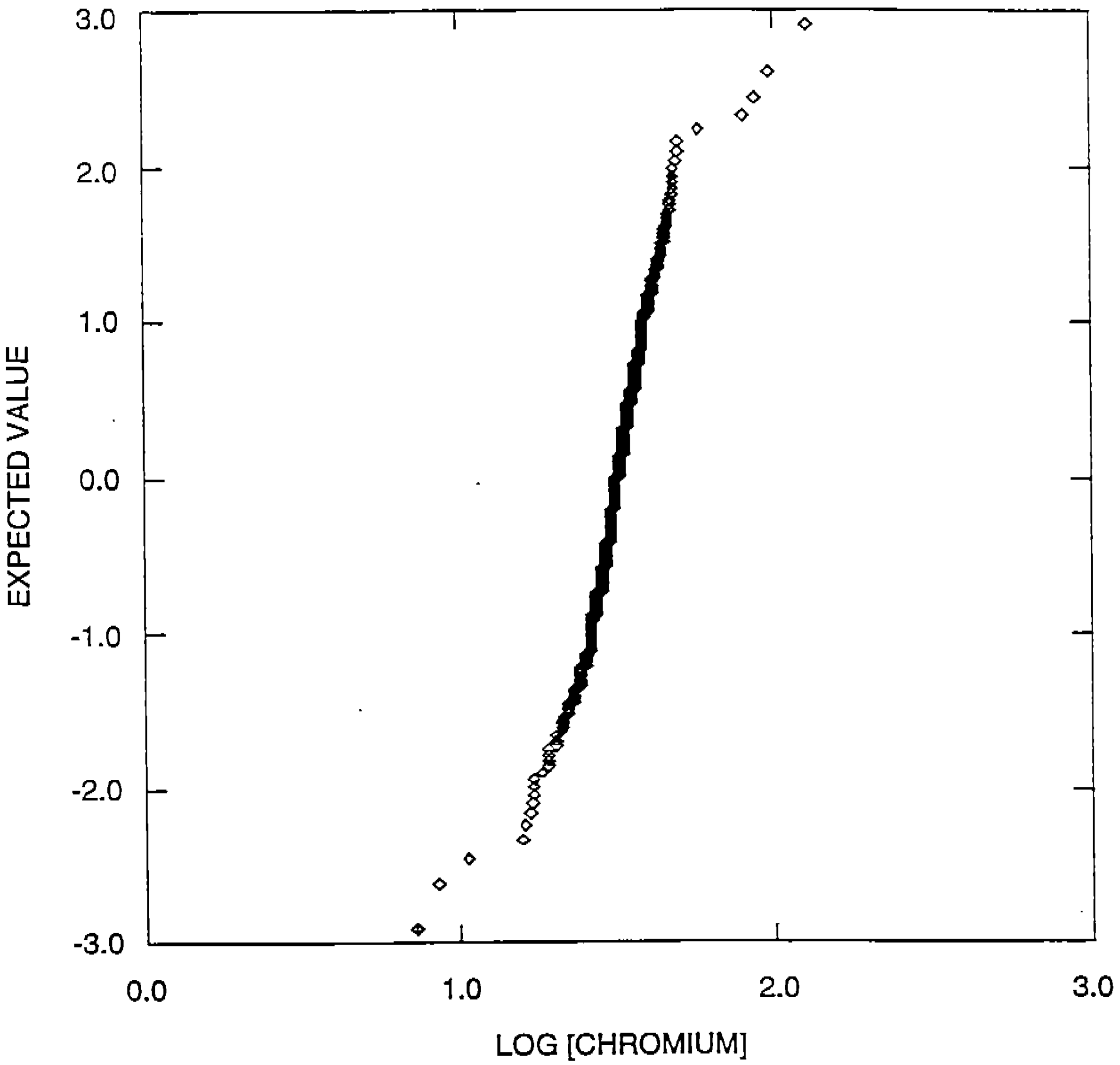

Figure 3-9 **PROBABILITY PLOT FOR CHROMIUM - QAY2 SAMPLES**

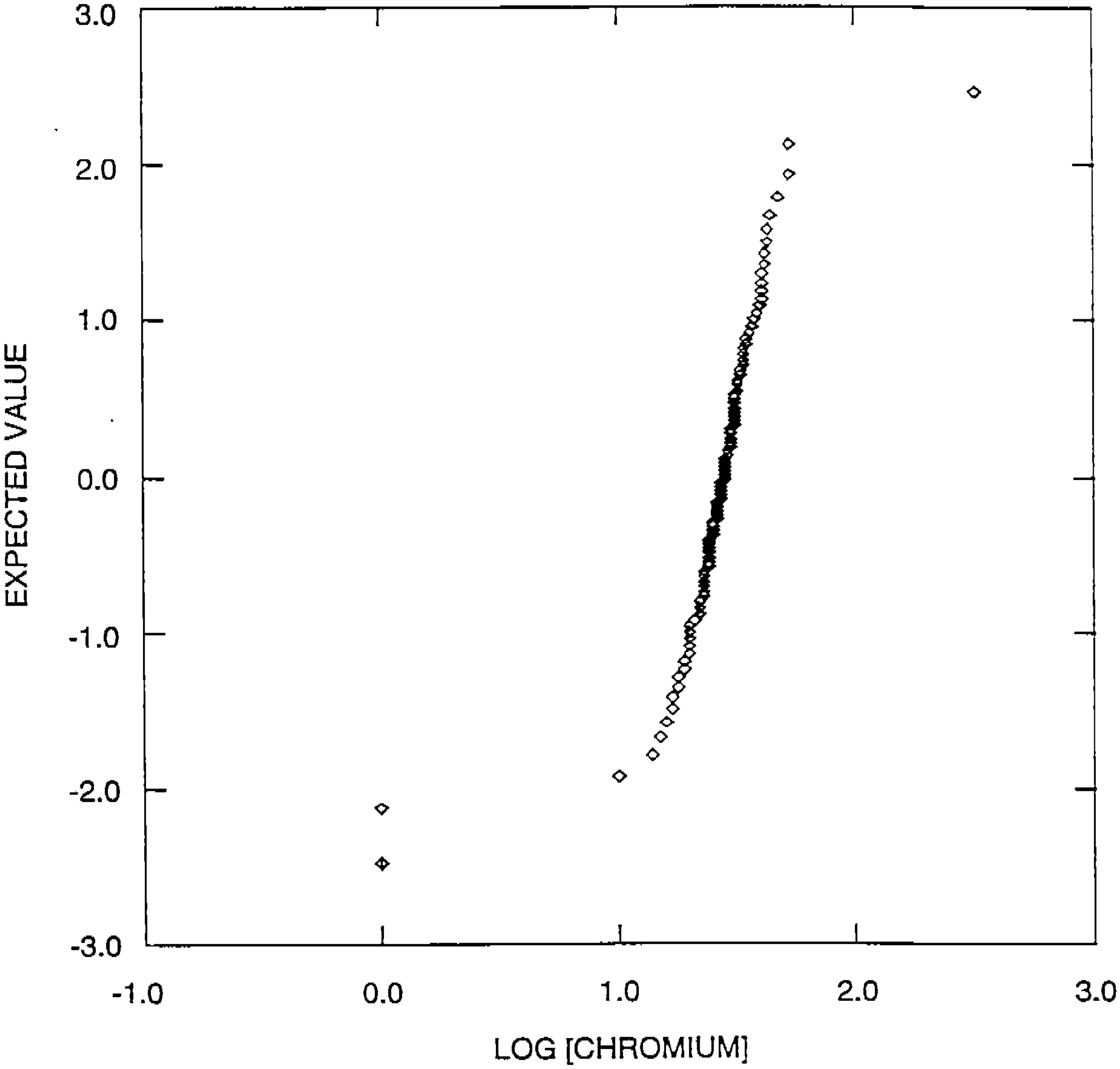

Figure 3-10 **PROBABILITY PLOT FOR CHROMIUM - QEY SAMPLES**

JT5100\COPPER.CDR (P1)

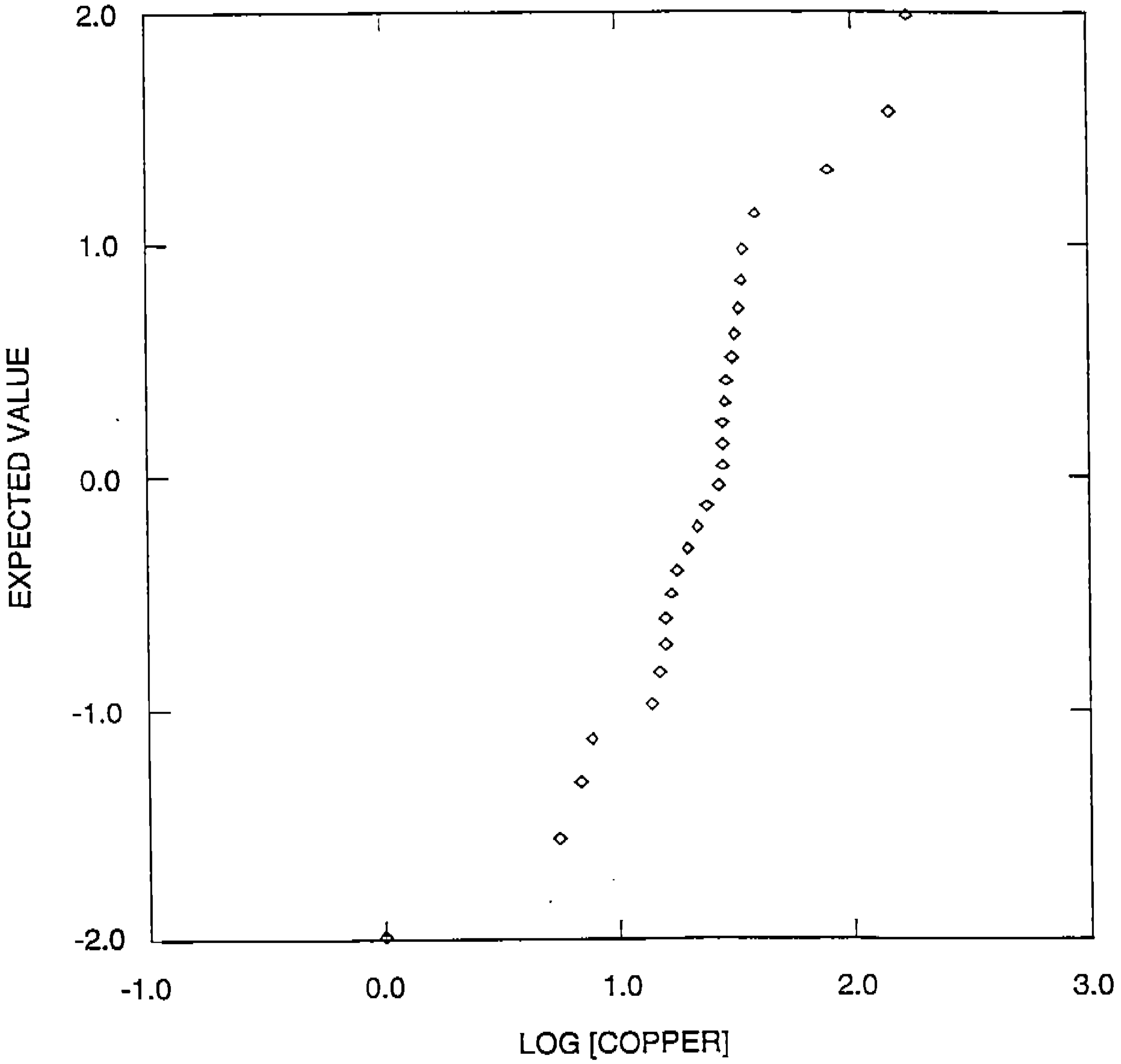

Figure 3-11 PROBABILITY PLOT FOR COPPER - QAY2 SAMPLES

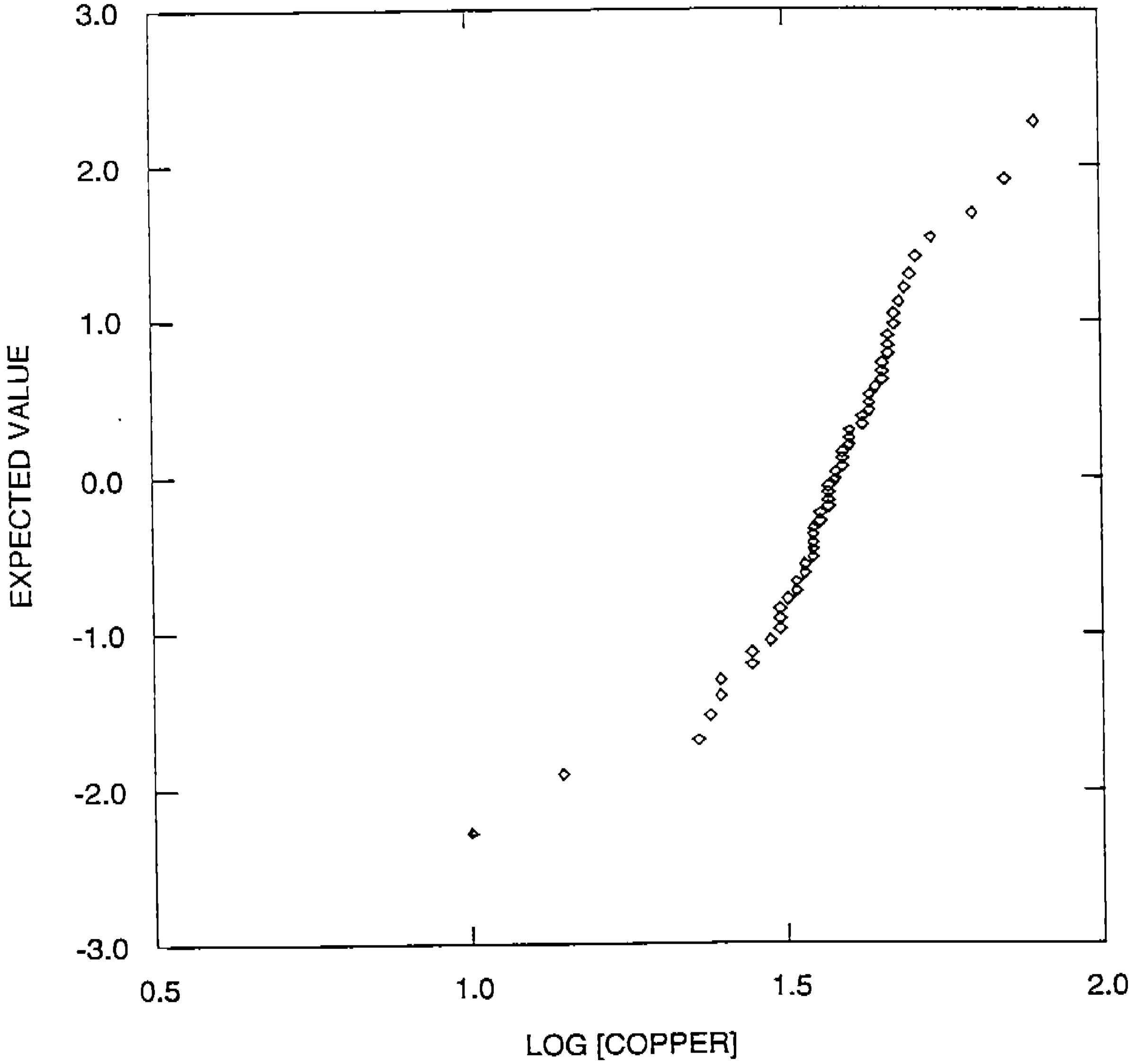

Figure 3-12 PROBABILITY PLOT FOR COPPER - QEY SAMPLES

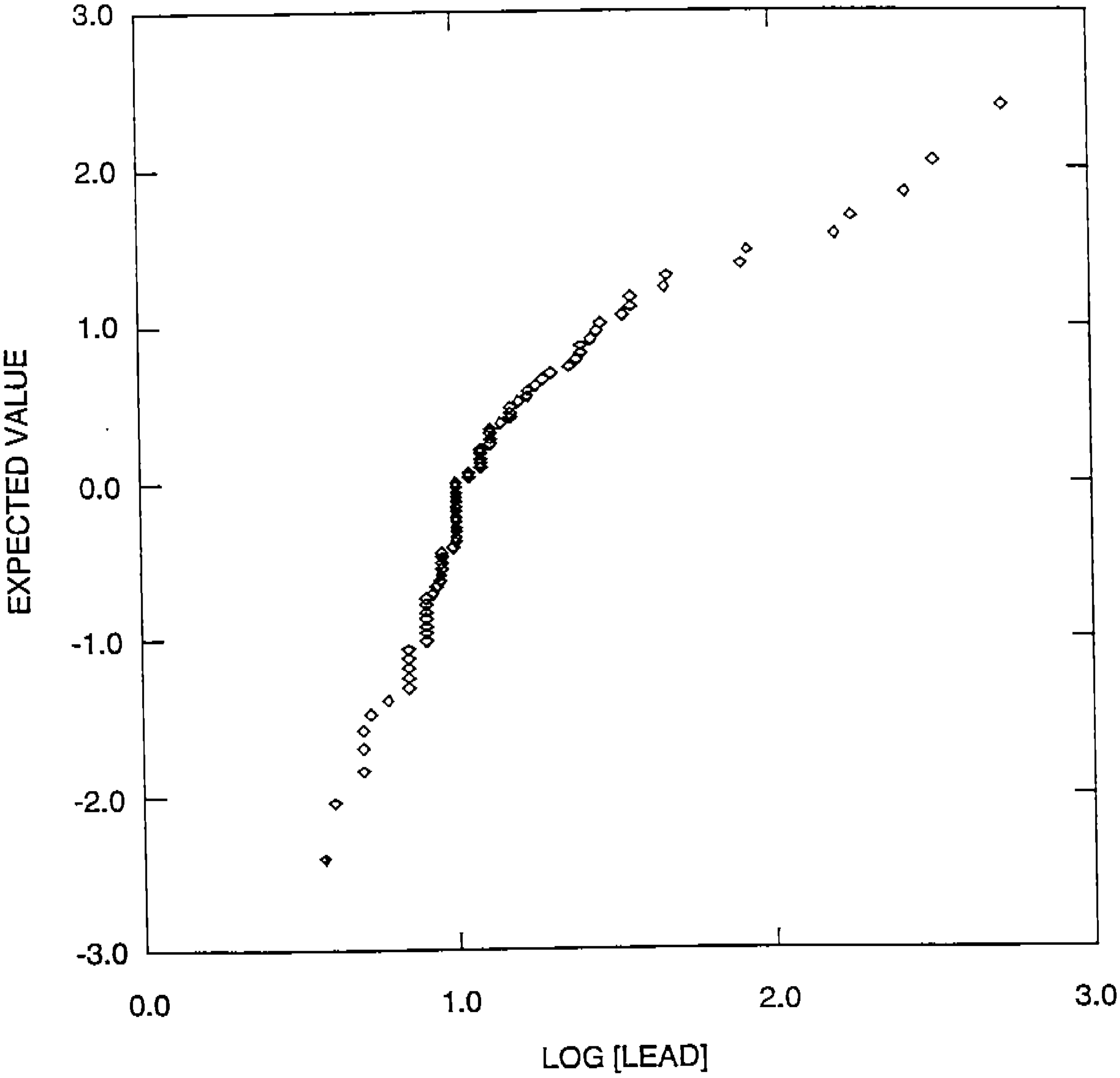

Figure 3-13 **PROBABILITY PLOT FOR LEAD - SURFACE SAMPLES**

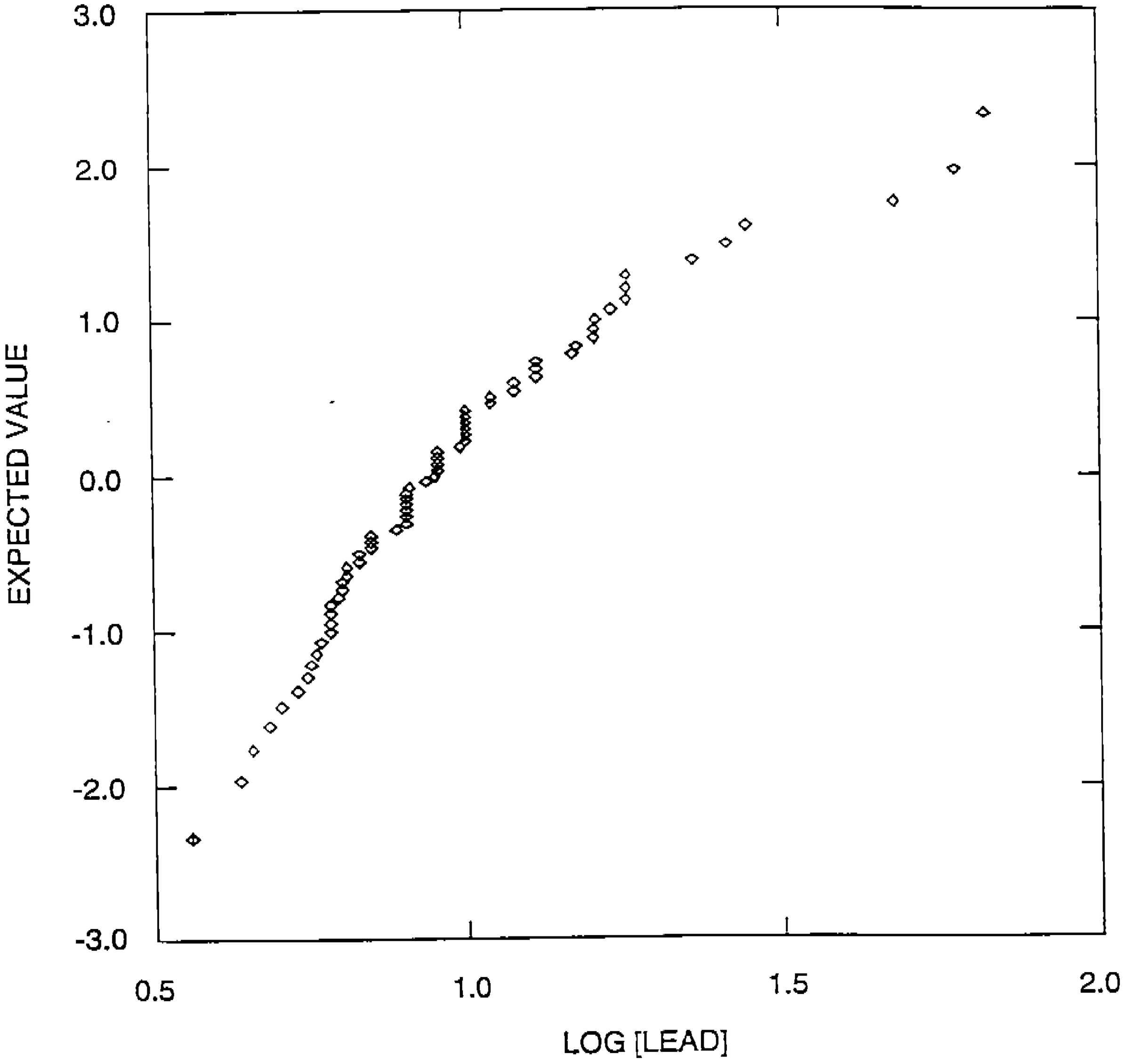

Figure 3-14 PROBABILITY PLOT FOR LEAD - ROOTZONE SAMPLES

JT5100\LEAD.CDR (P3)

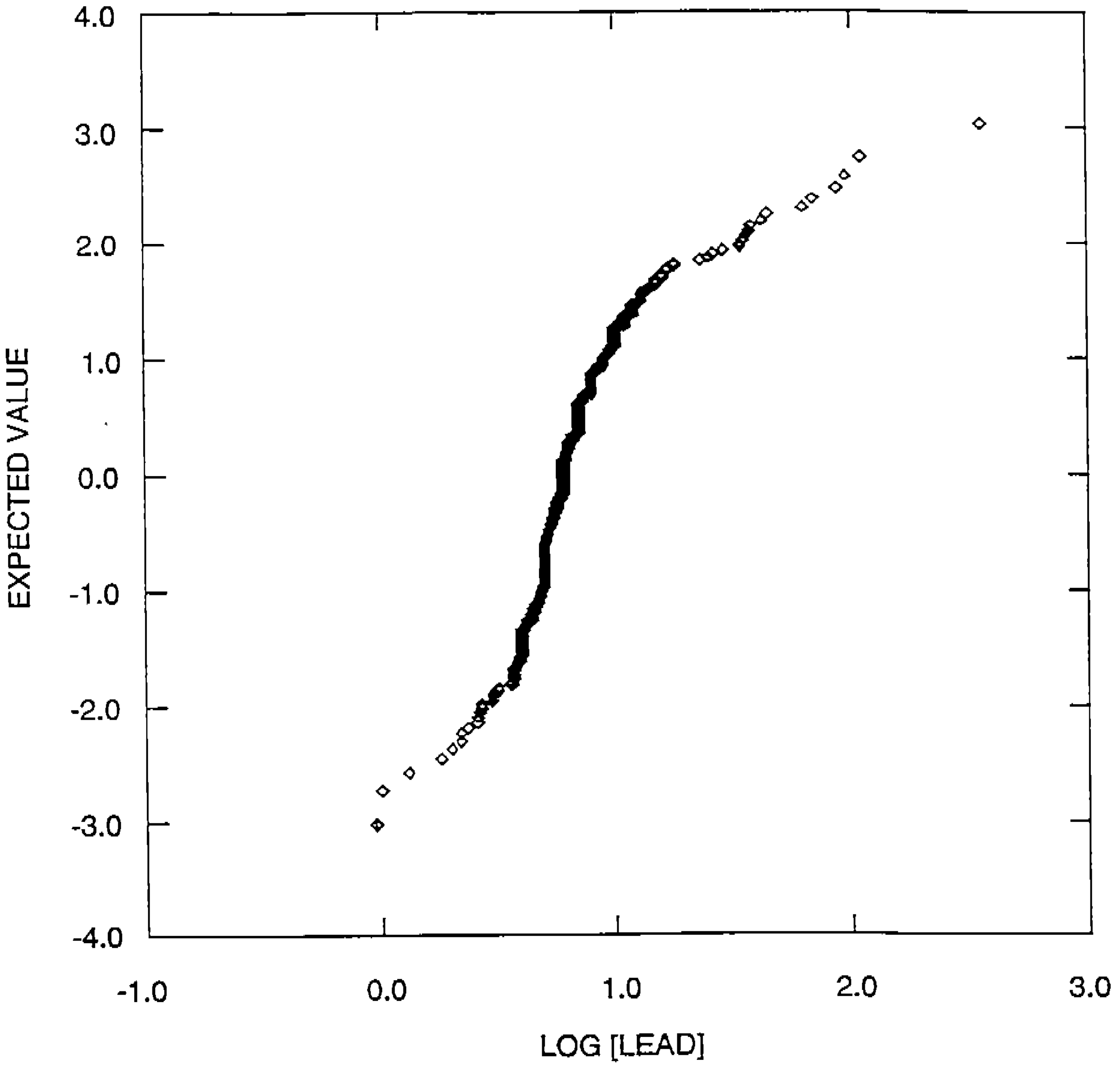

Figure 3-15 PROBABILITY PLOT FOR LEAD - SUBSURFACE SAMPLES

JT5100\NICKEL.CDR

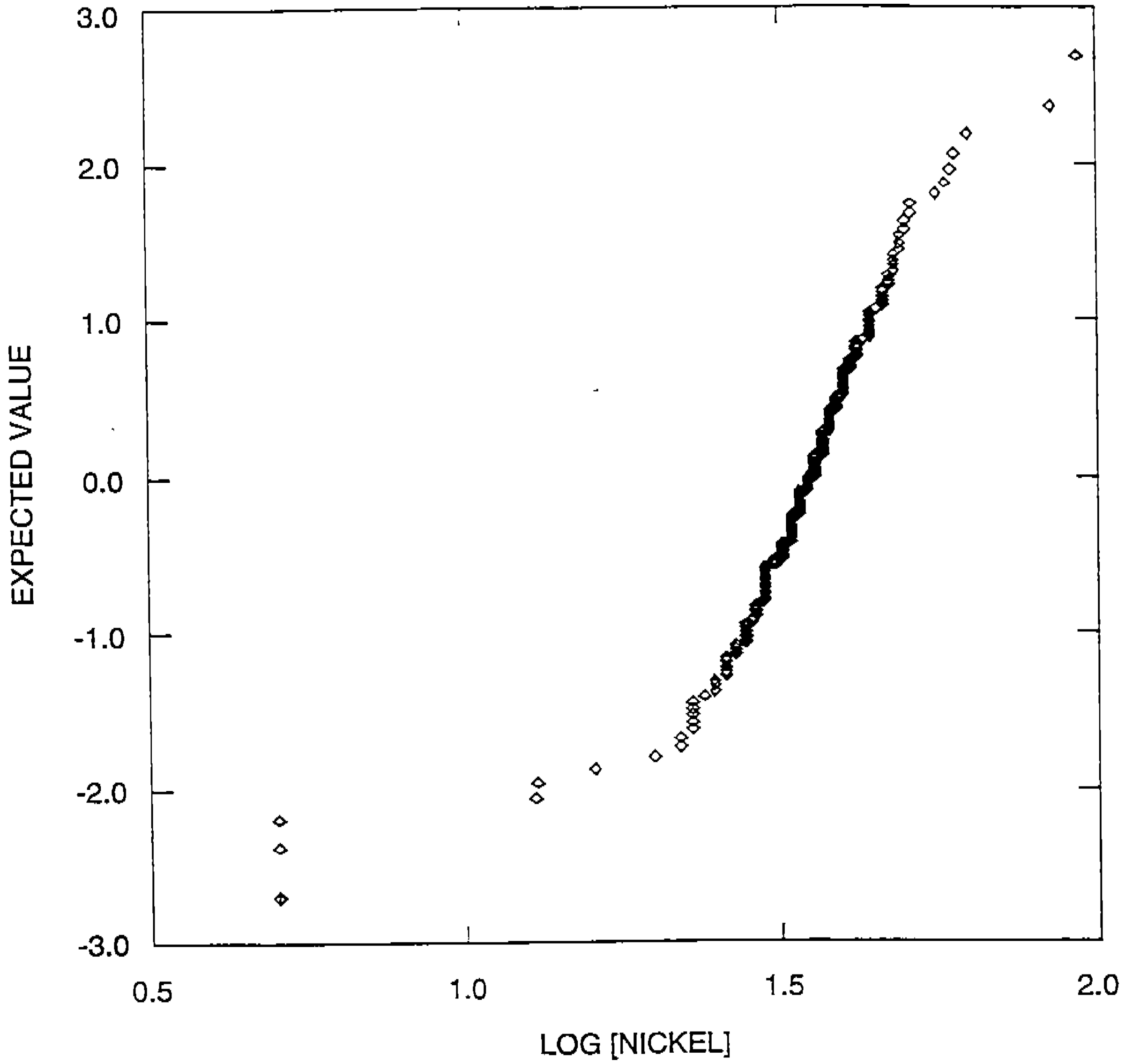

Figure 3-16 **PROBABILITY PLOT FOR NICKEL - ALL SAMPLES**

JT5100\ZINC.CDR (P1)

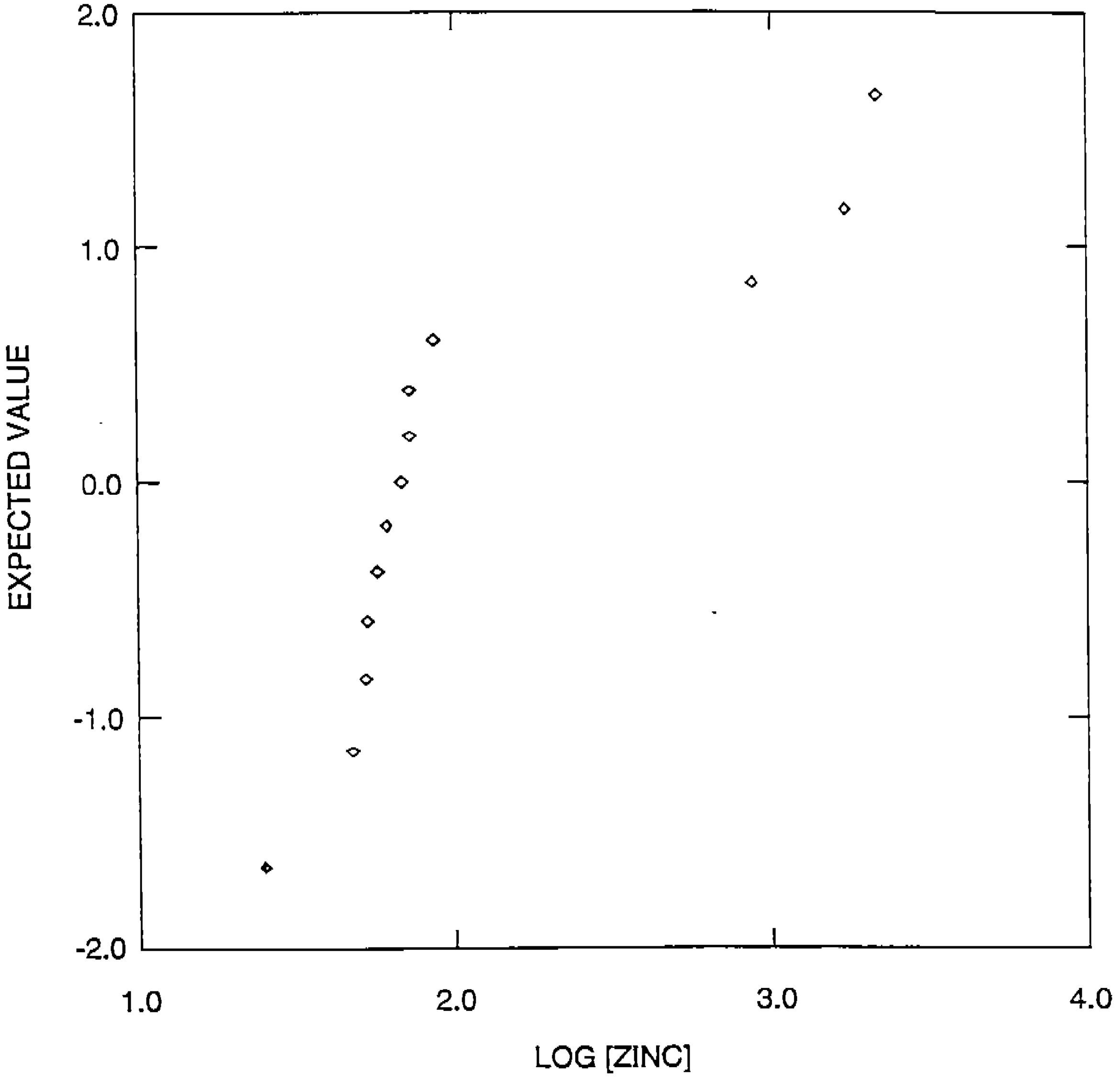

Figure 3-17 PROBABILITY PLOT FOR ZINC - SURFACE SAMPLES

JT5100\ZINC.CDR (P2)

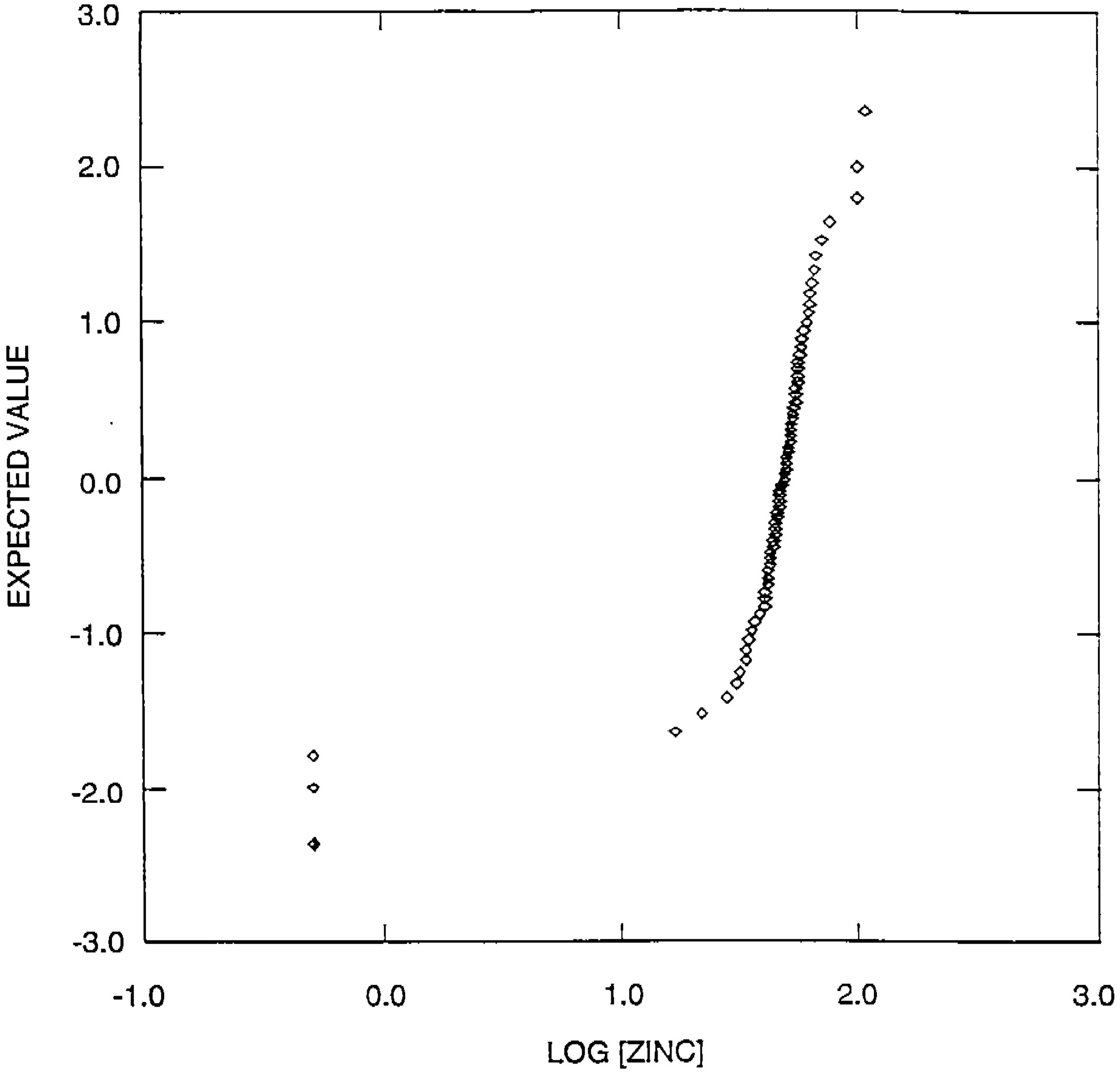

Figure 3-18 **PROBABILITY PLOT FOR ZINC - SUBSURFACE SAMPLES**

JT5100\CADMIUM.CDR

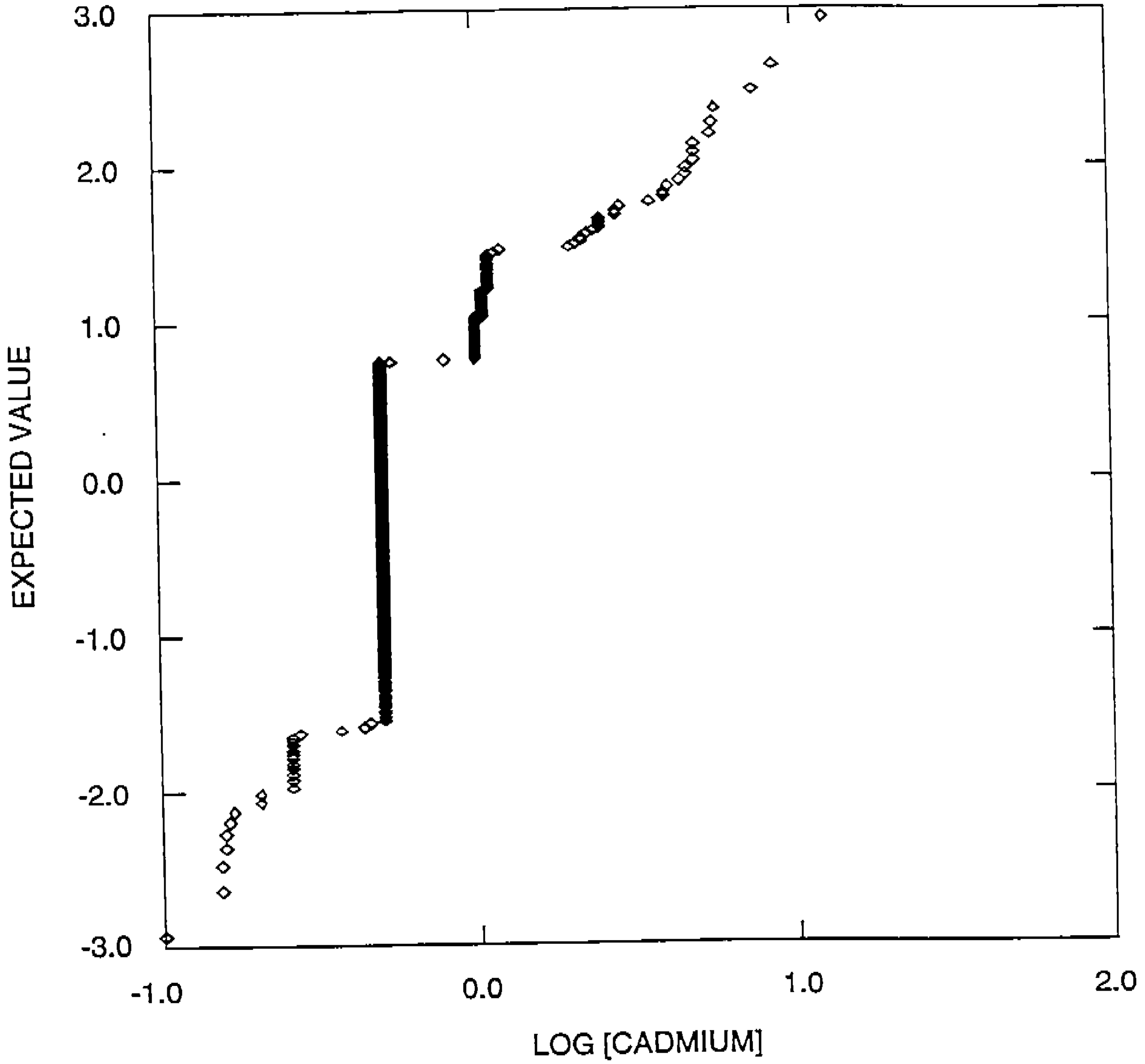

Figure 3-19 PROBABILITY PLOT FOR CADMIUM - ALL SAMPLES

JT5100\DDD.CDR

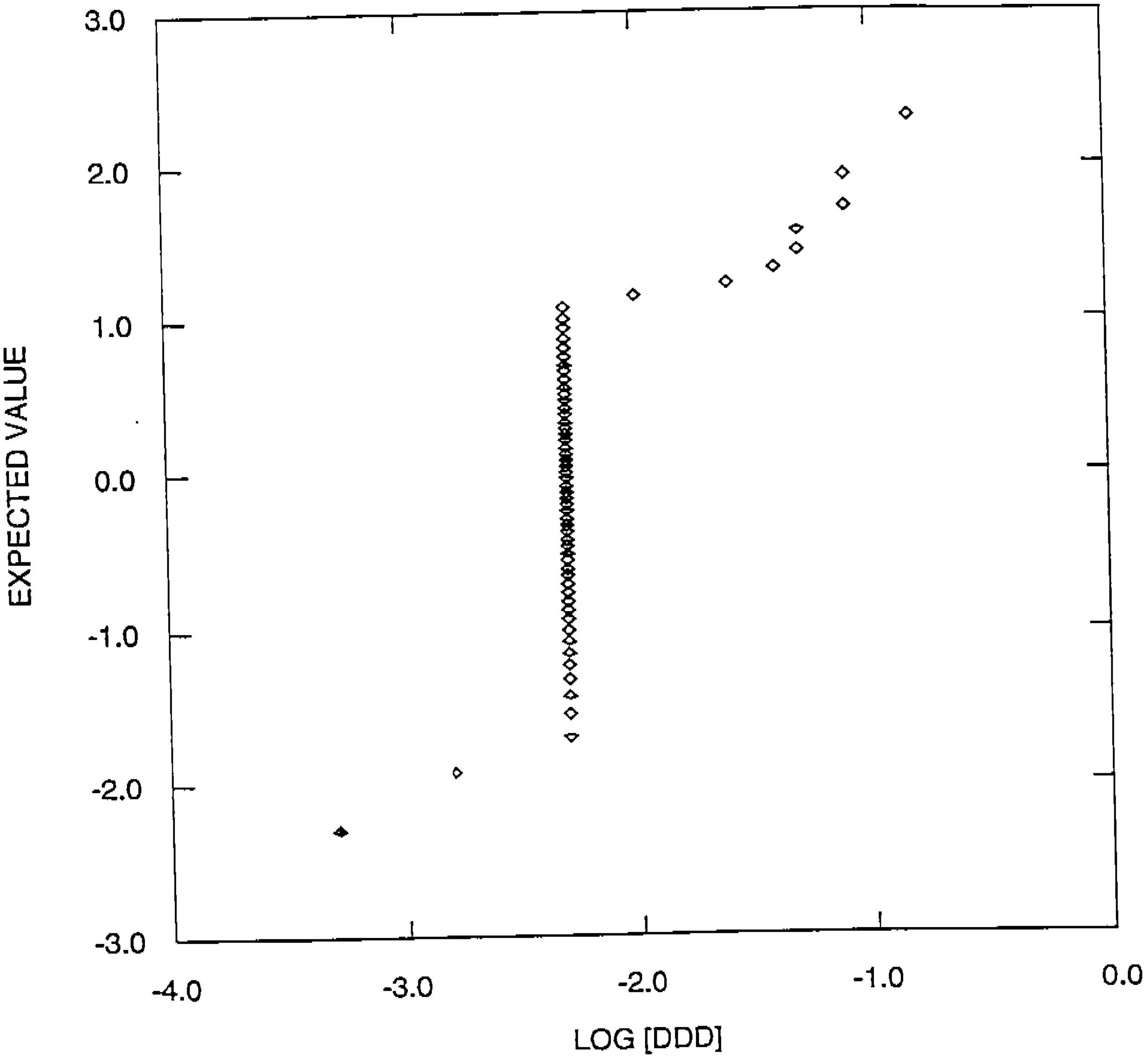

Figure 3-20 PROBABILITY PLOT FOR DDD - SURFACE SAMPLES

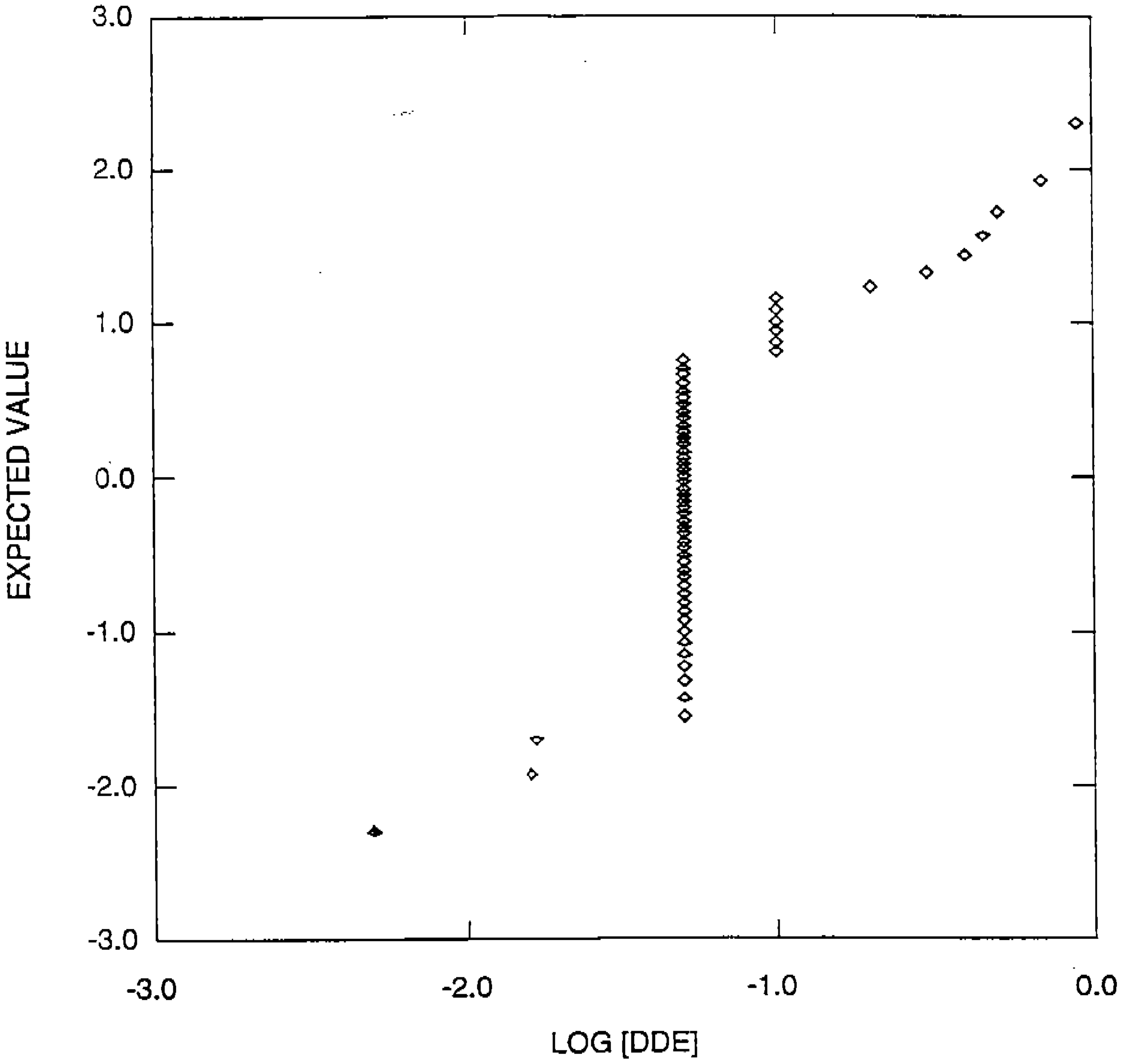

Figure 3-21 PROBABILITY PLOT FOR DDE - SURFACE SAMPLES

JT5100\DDT.CDR

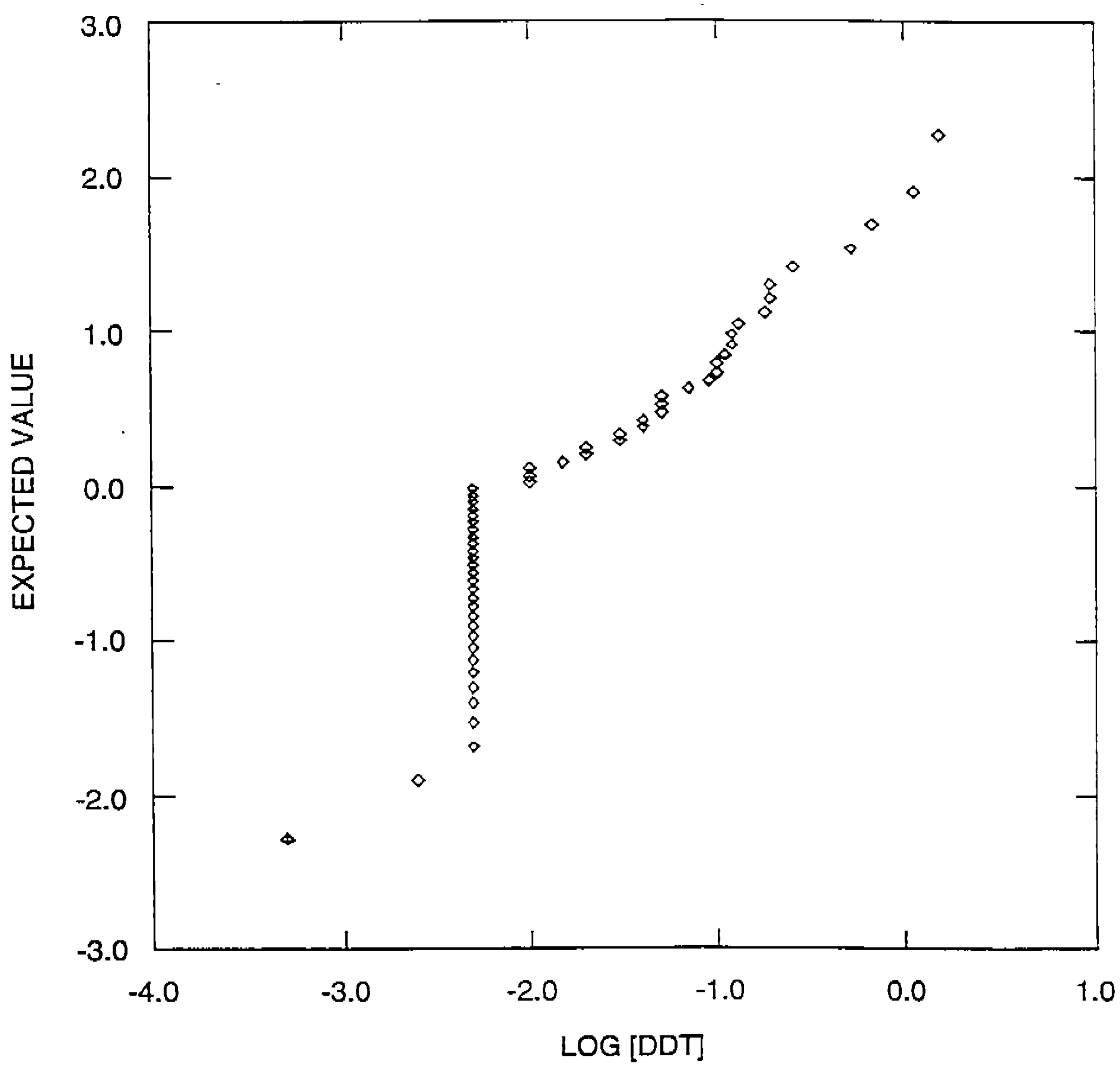

Figure 3-22 PROBABILITY PLOT FOR DDT - SURFACE SAMPLES

JT5100\MERCURY.CDR

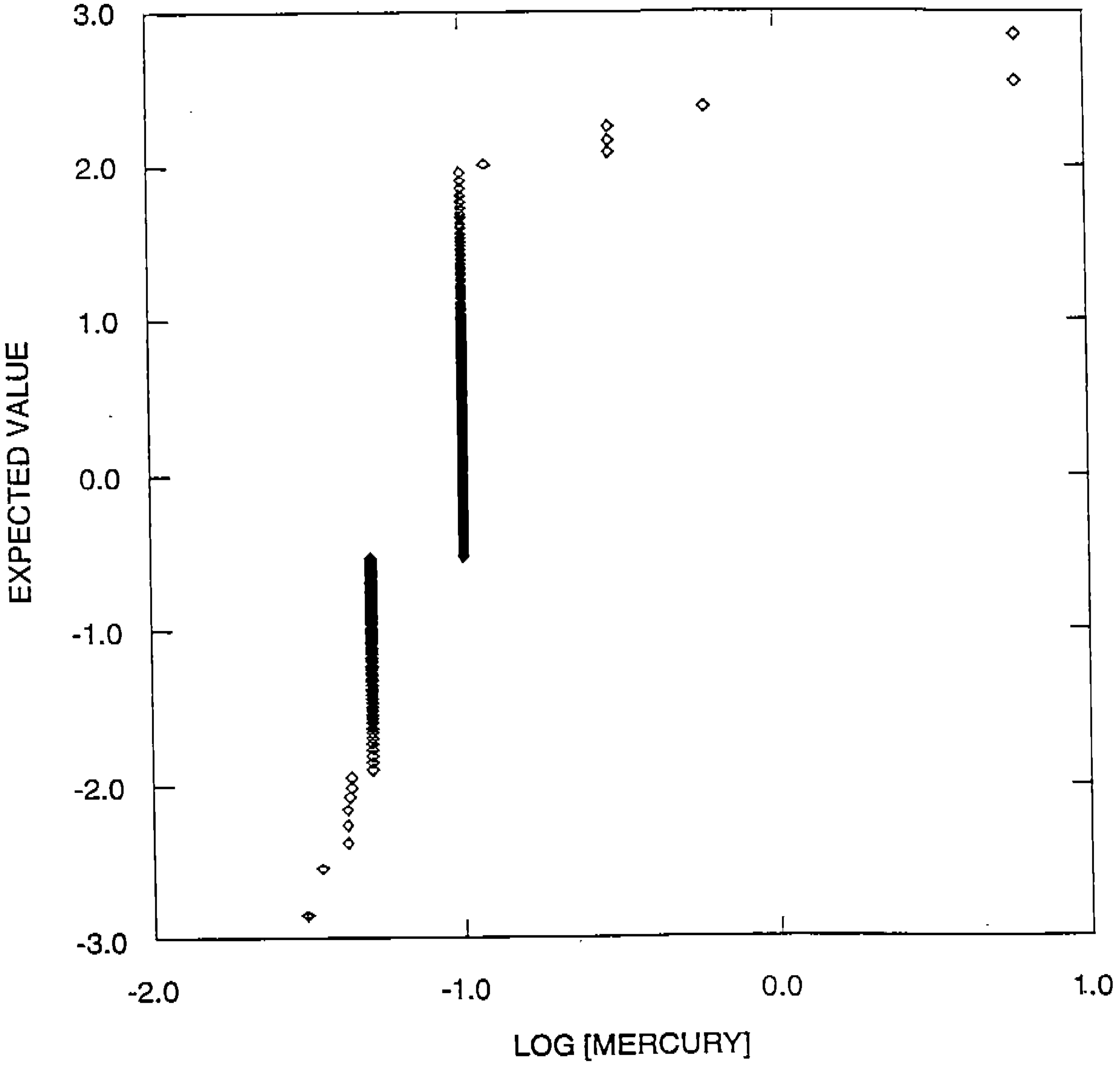

Figure 3-23 PROBABILITY PLOT FOR MERCURY - ALL SAMPLES

JT5100\SELENIUM.CDR

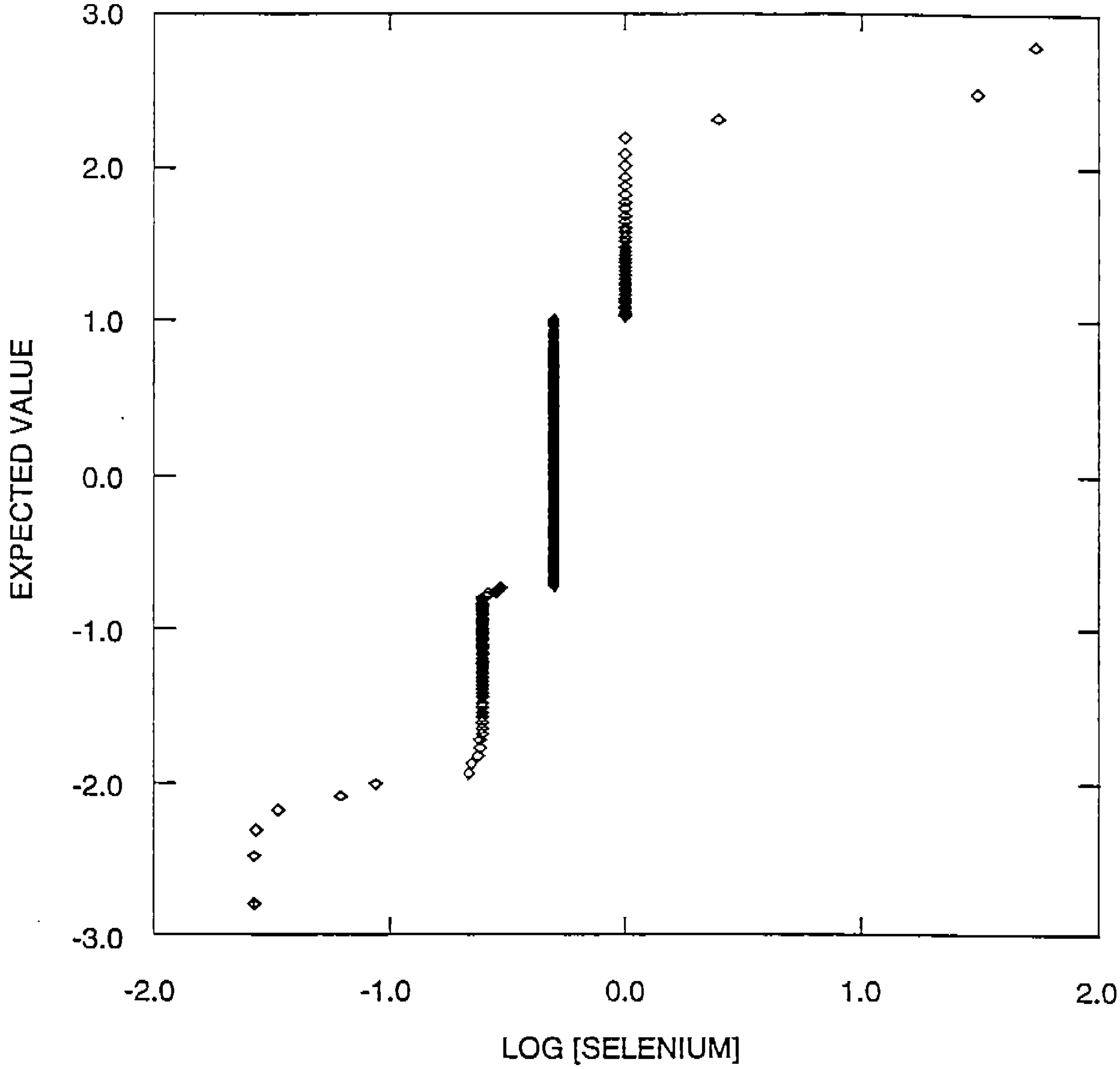

Figure 3-24 PROBABILITY PLOT FOR SELENIUM - ALL SAMPLES

JT5100\SILVER.CDR

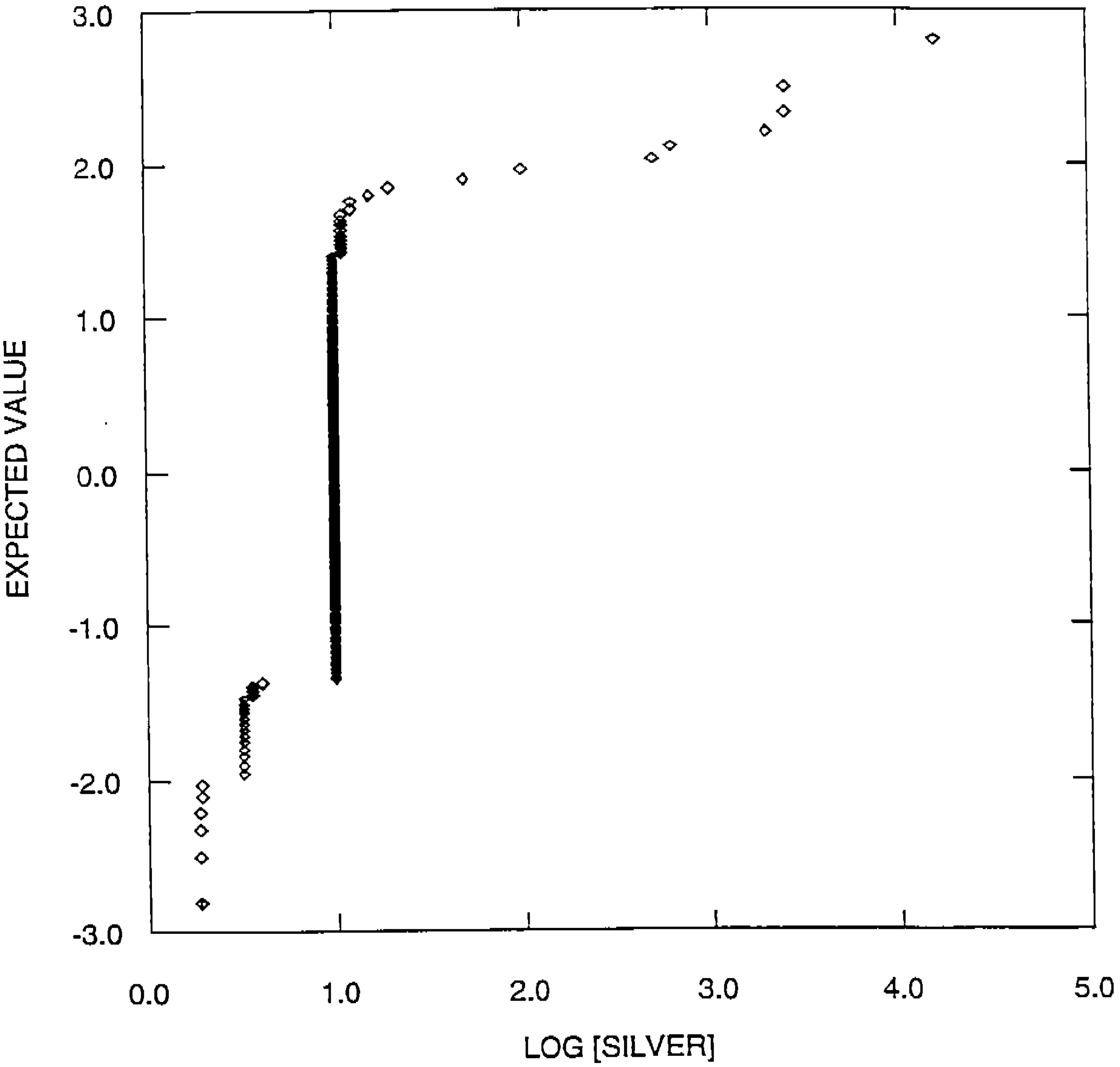

Figure 3-25 PROBABILITY PLOT FOR SILVER - ALL SAMPLES

JT5100\FILTERED\PROPLOT1.CDR (P1)

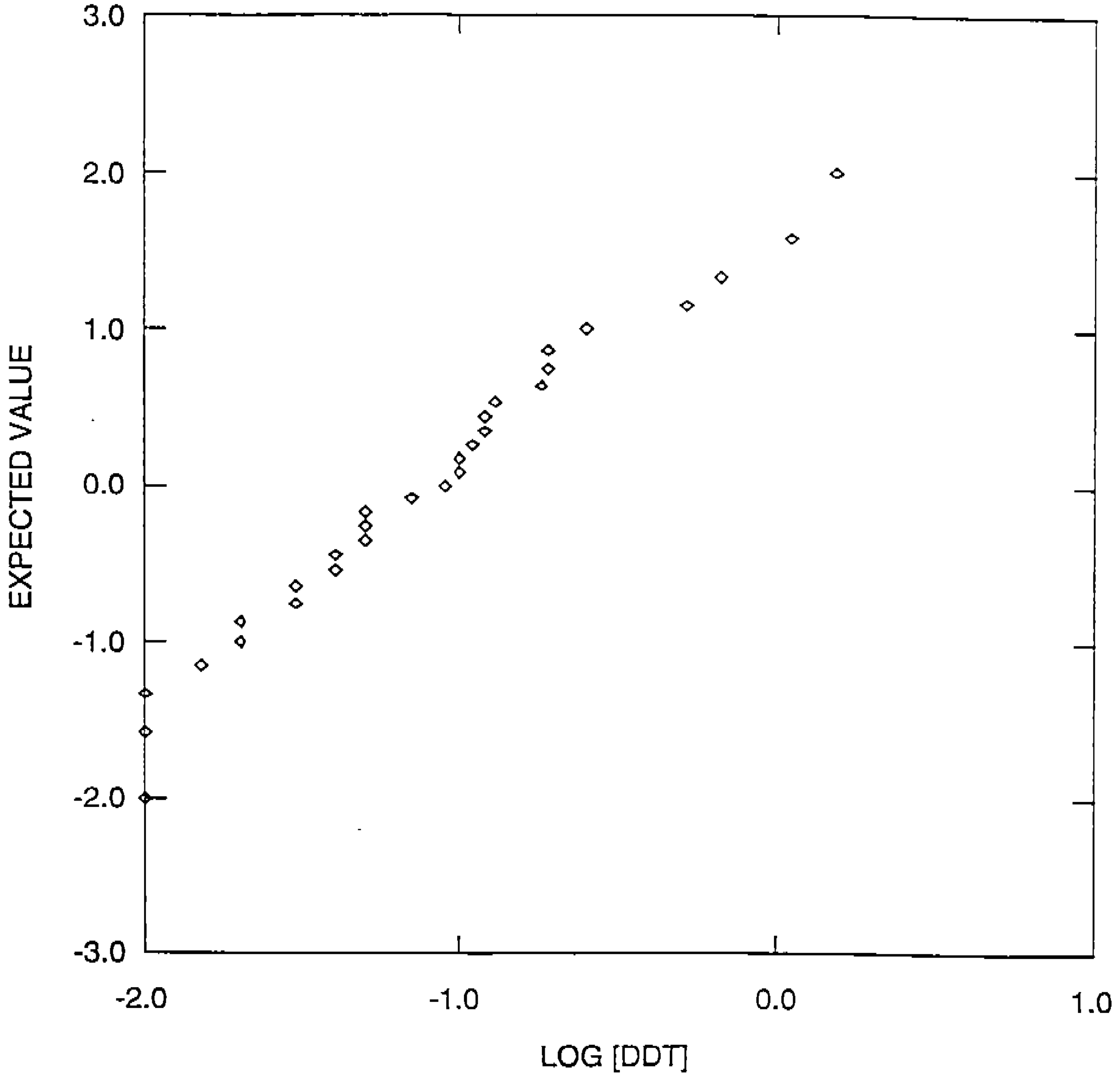

Figure 3-26 PROBABILITY PLOT FOR DDT - DETECTS ONLY

JT5100\UNFILTER\PROPLOT2.CDR (P2)

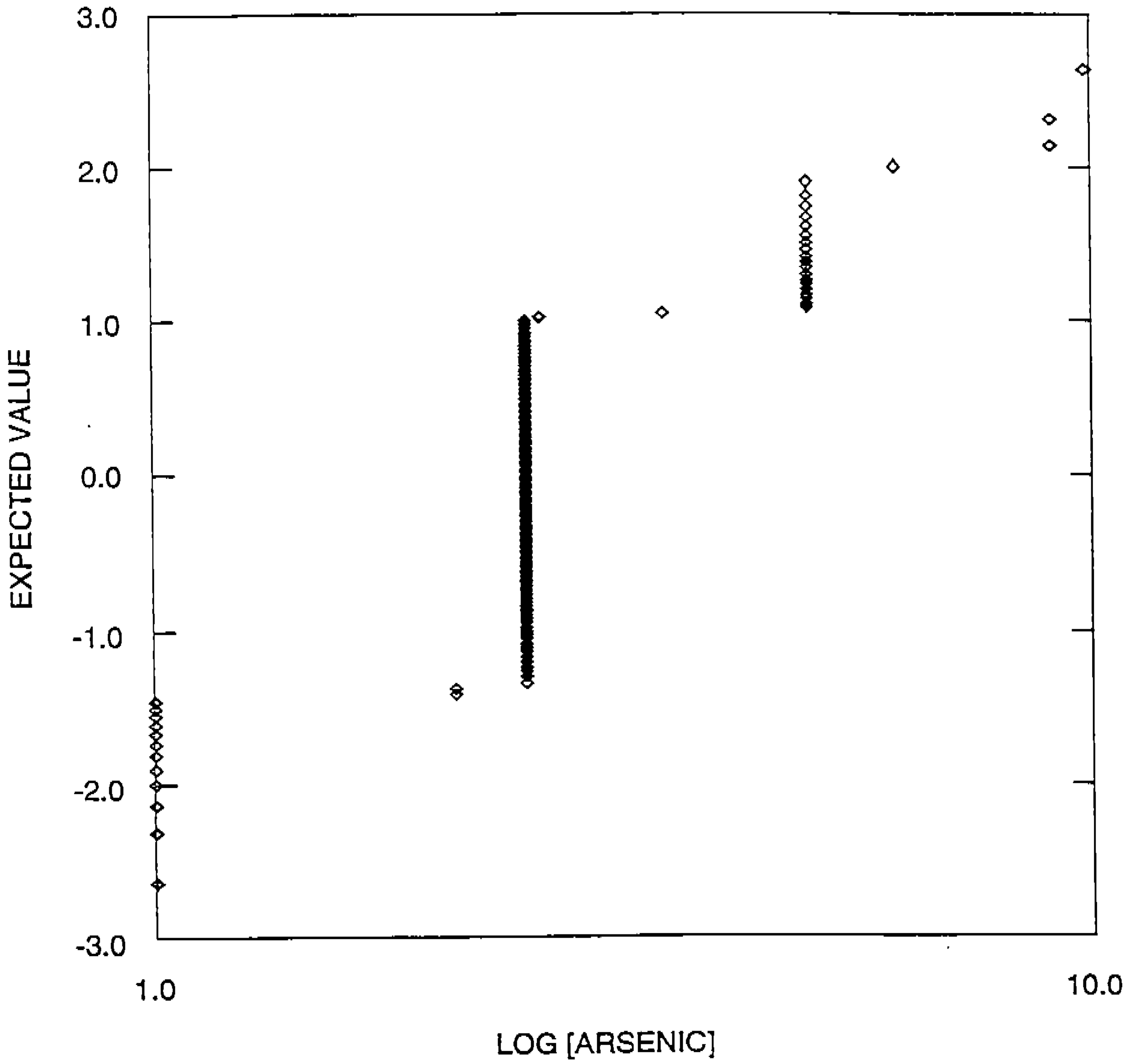

Figure 3-27 **PROBABILITY PLOT FOR ARSENIC - FILTERED GROUNDWATER**

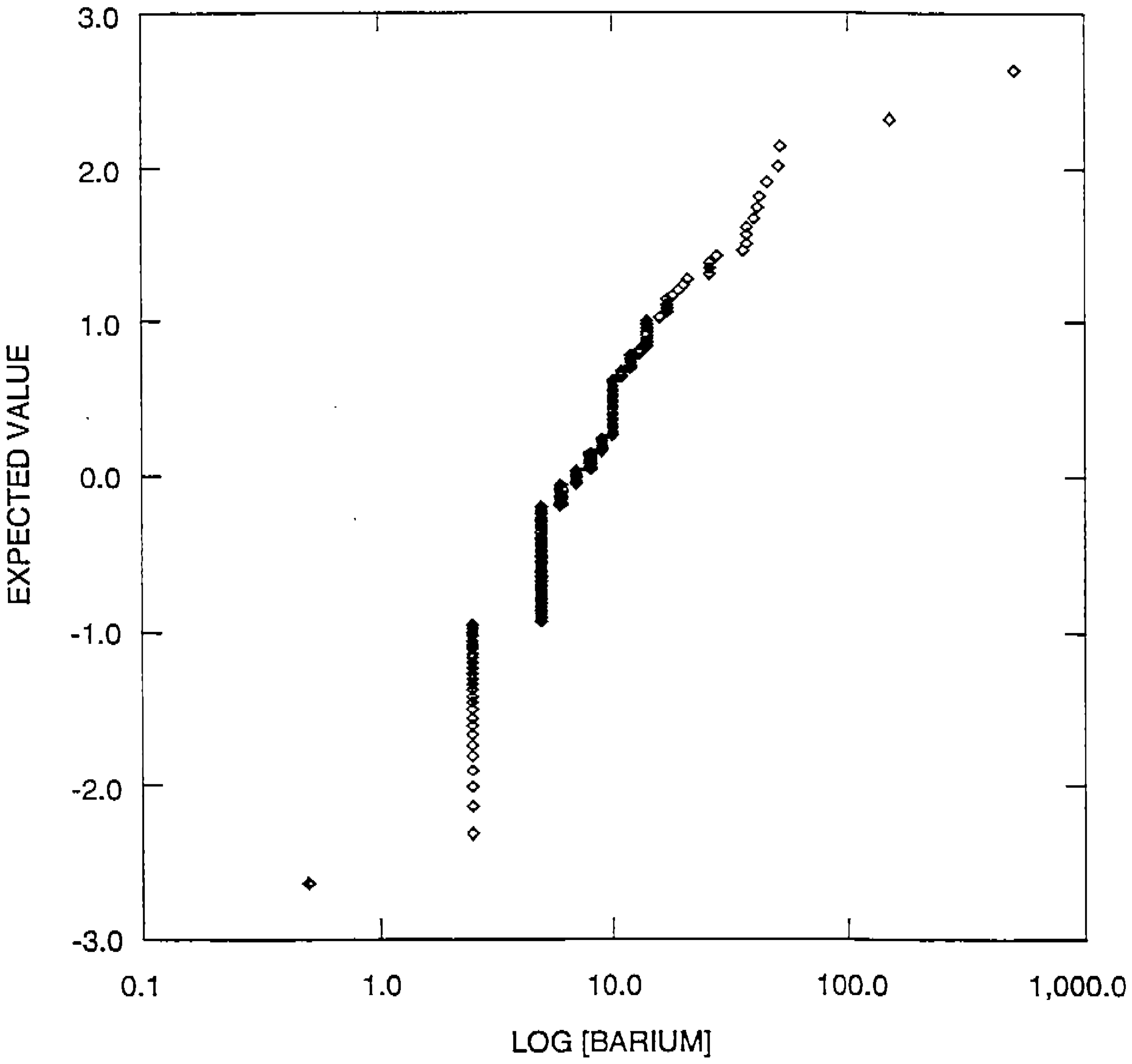

Figure 3-28 **PROBABILITY PLOT FOR BARIUM - FILTERED GROUNDWATER**

JT5100\UNFILTER\PROPLOT2.CDR (P4)

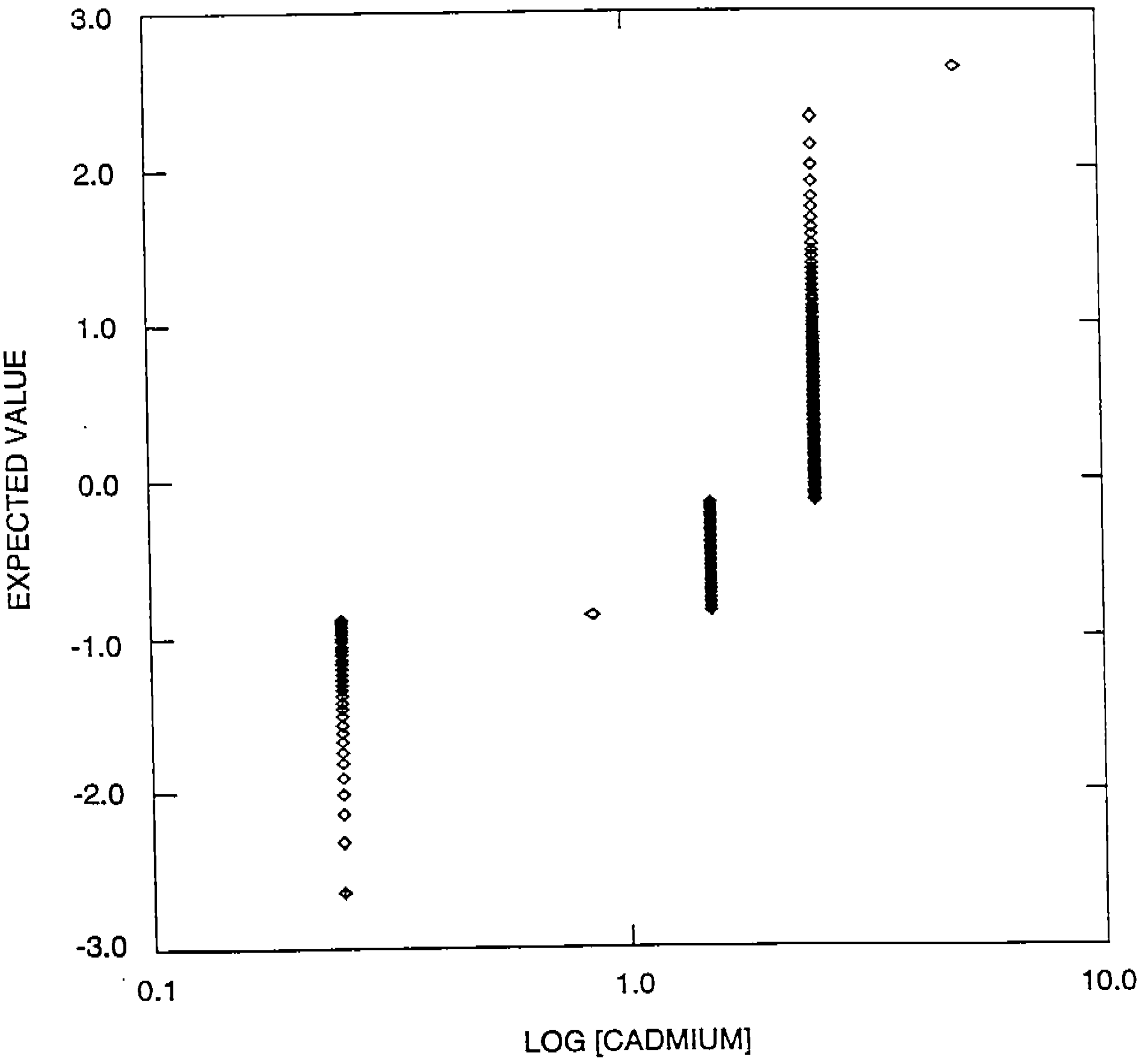

Figure 3-29 PROBABILITY PLOT FOR CADMIUM - FILTERED GROUNDWATER

JT5100\UNFILTER\PROPLOT2.CDR (P5)

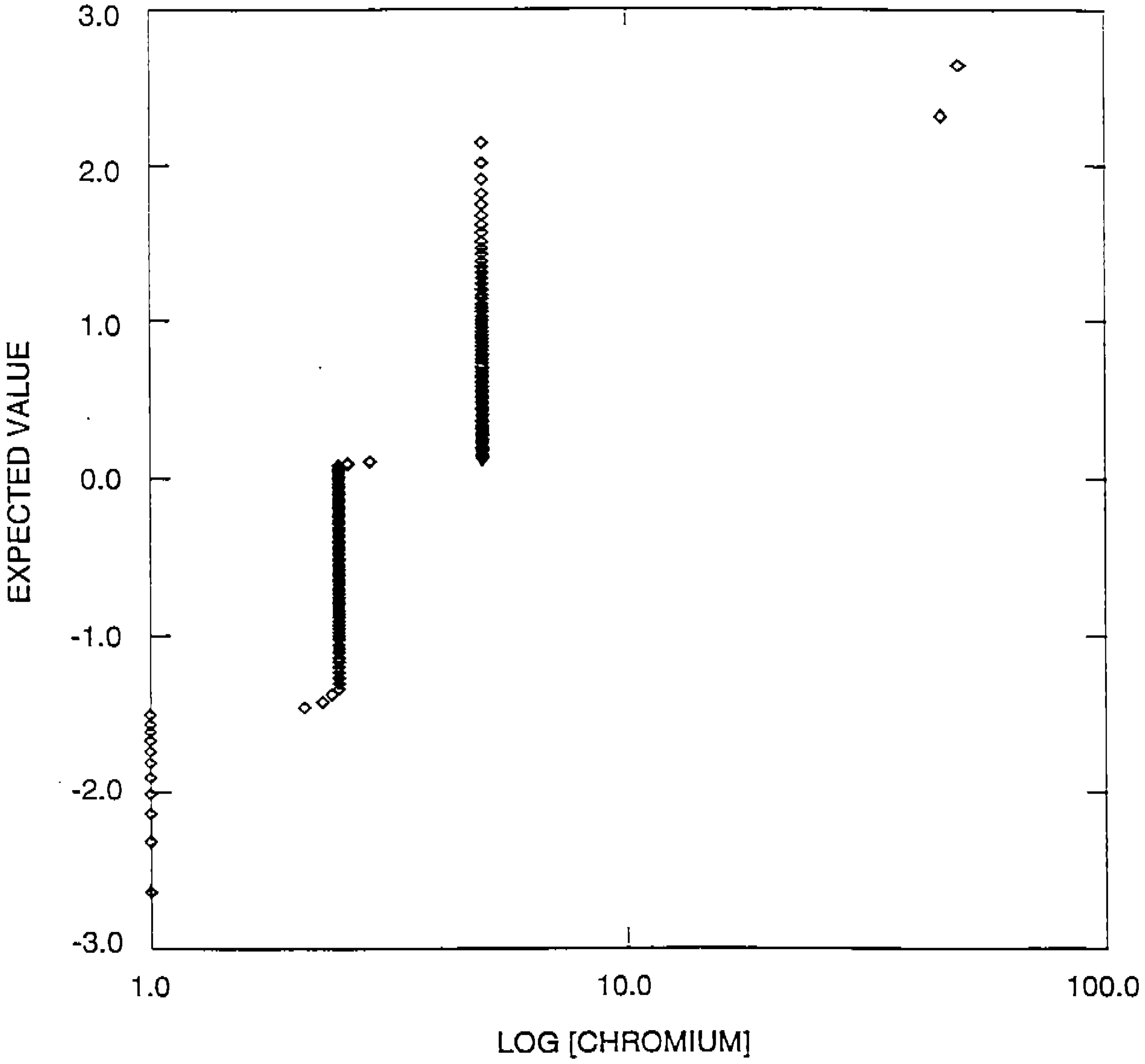

Figure 3-30 PROBABILITY PLOT FOR CHROMIUM - FILTERED GROUNDWATER

JT5100\UNFILTER\PROPLOT2.CDR (P6)

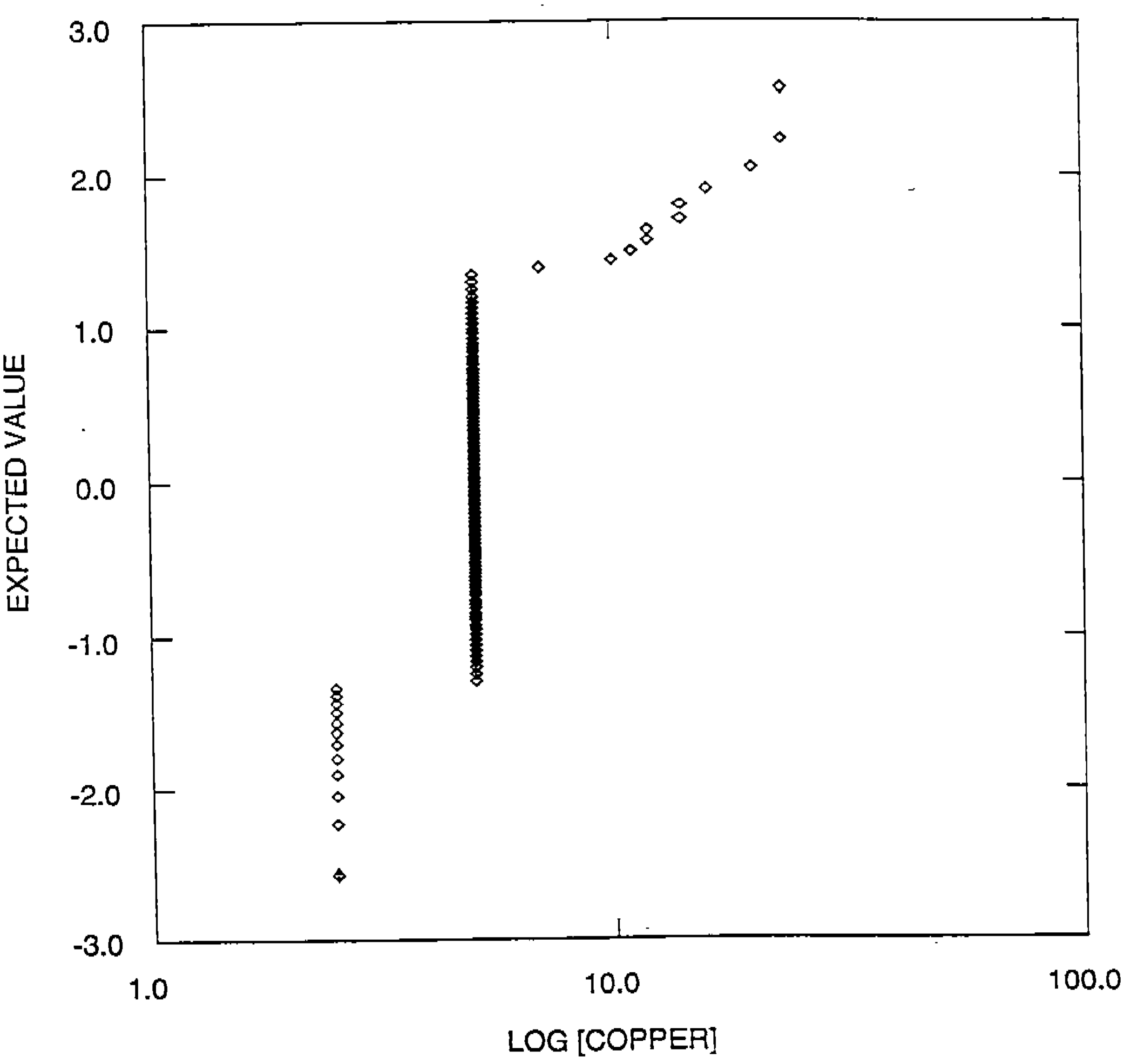

Figure 3-31 **PROBABILITY PLOT FOR COPPER - FILTERED GROUNDWATER**

JT5100\UNFILTER\PROPLOT2.CDR (P7)

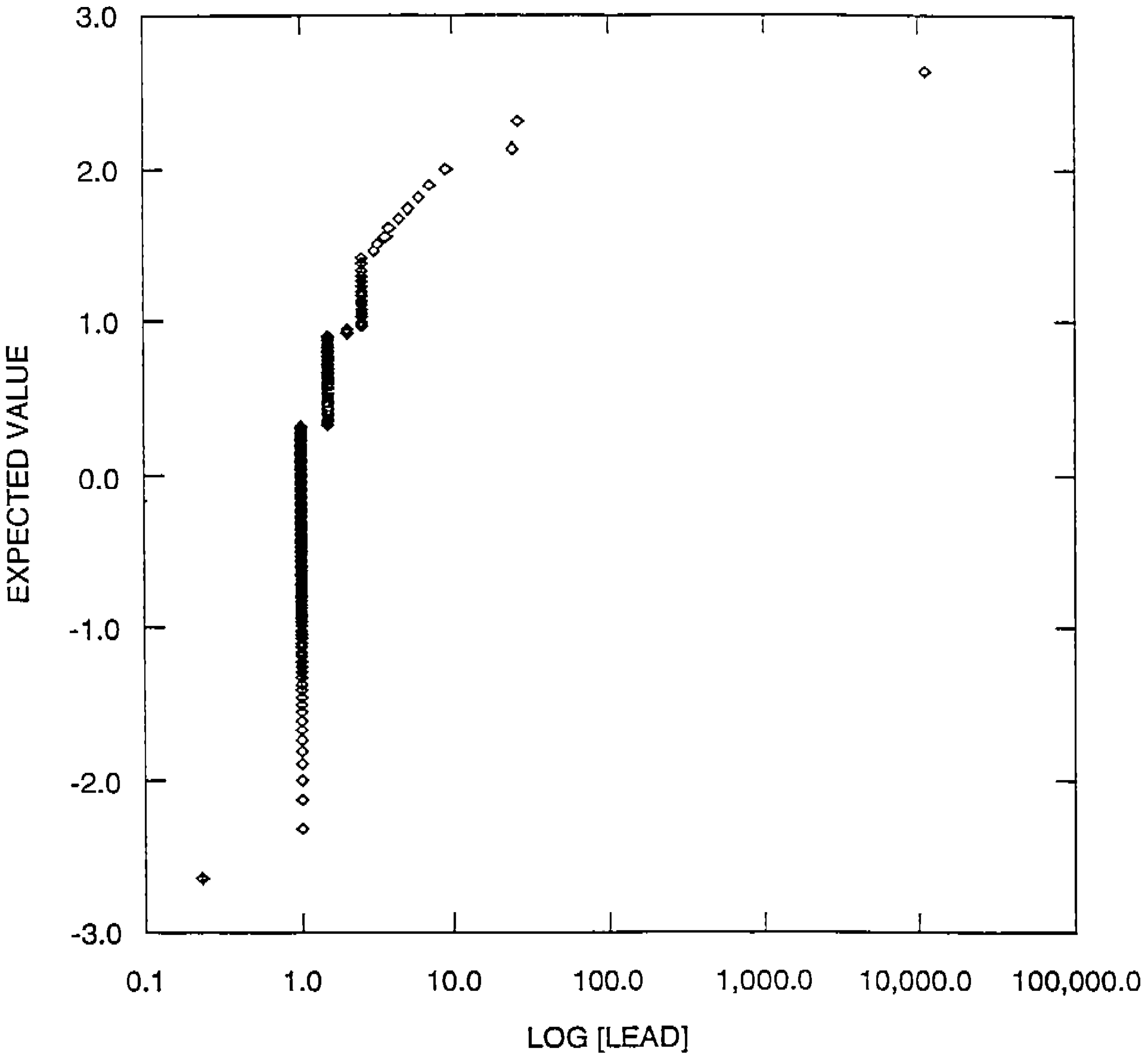

Figure 3-32 PROBABILITY PLOT FOR LEAD - FILTERED GROUNDWATER

JT5100\UNFILTER\PROPLOT2.CDR (P8)

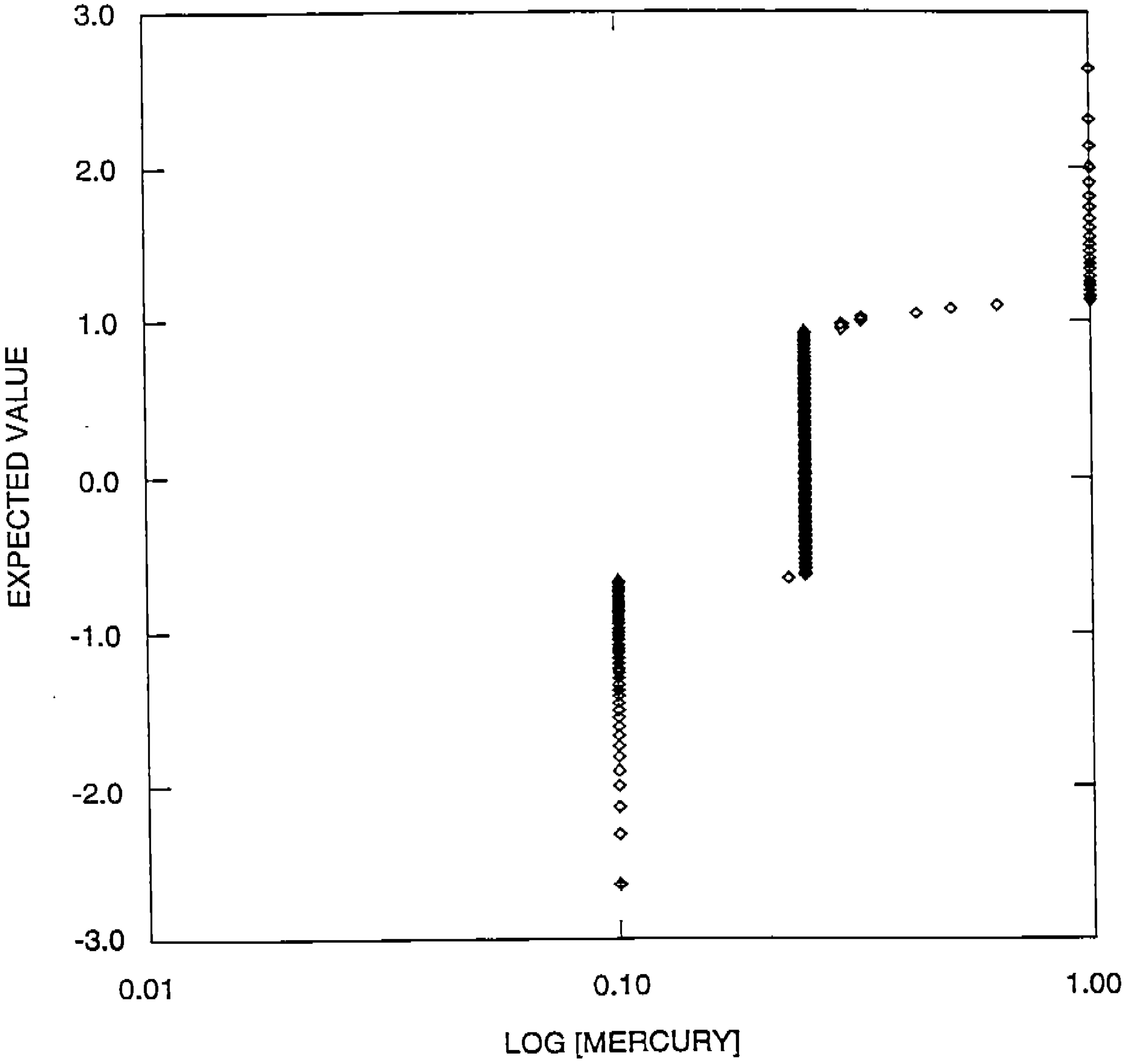

Figure 3-33 **PROBABILITY PLOT FOR MERCURY - FILTERED GROUNDWATER**

JT5100\UNFILTER\PROPLOT2.CDR (P9)

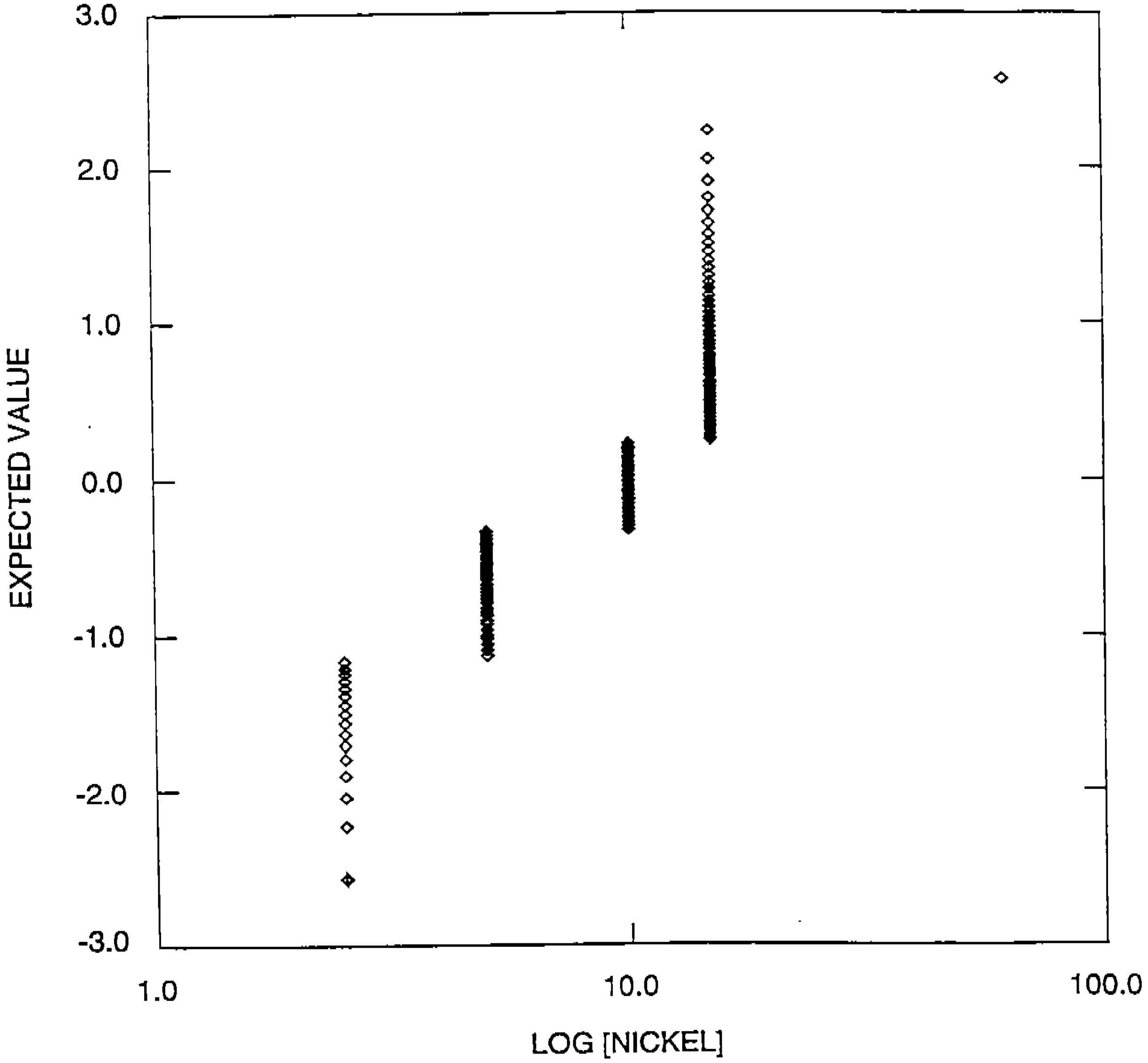

Figure 3-34 **PROBABILITY PLOT FOR NICKEL - FILTERED GROUNDWATER**

JT5100\UNFILTER\PROPLOT2.CDR (P10)

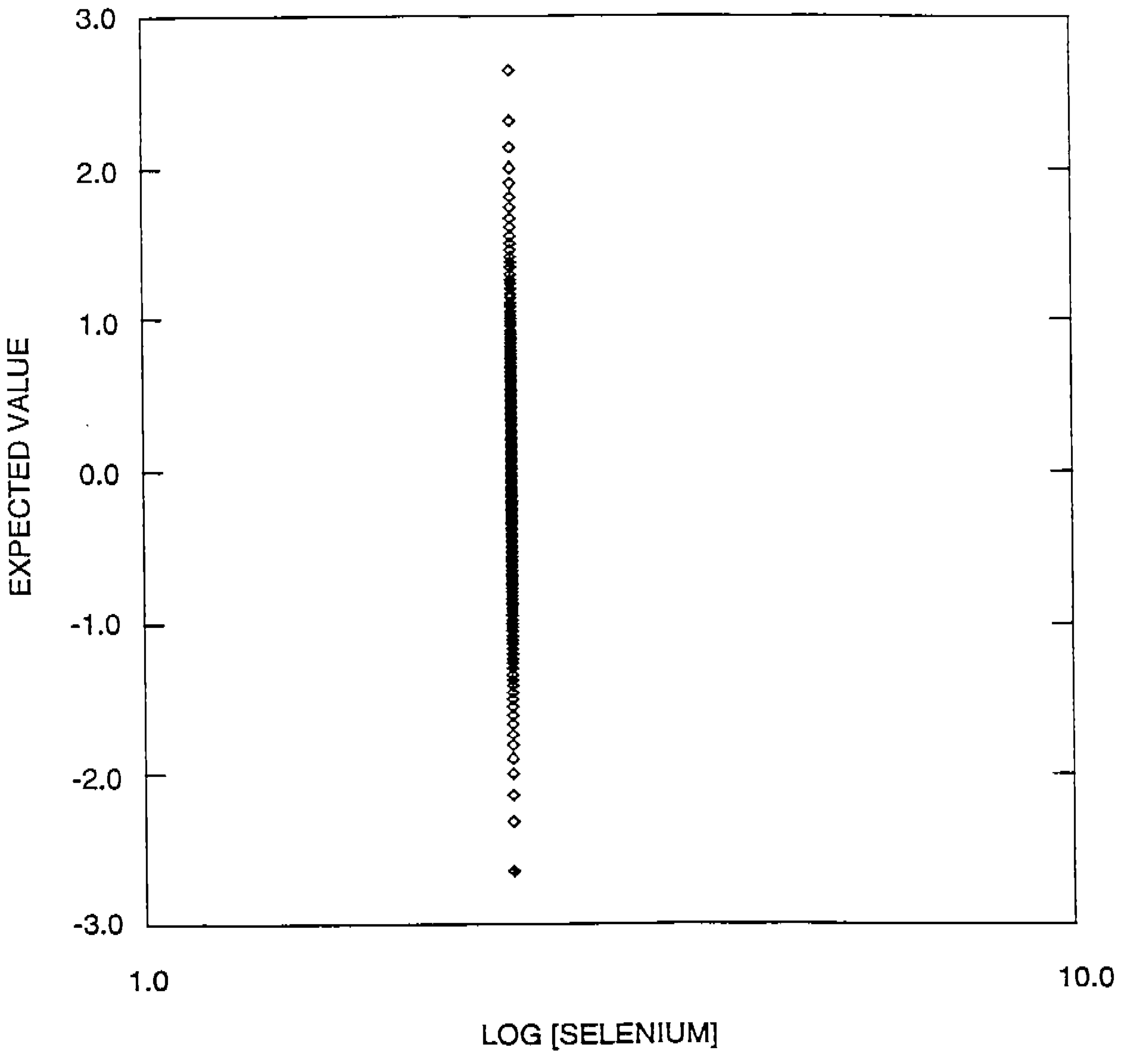

Figure 3-35 **PROBABILITY PLOT FOR SELENIUM - FILTERED GROUNDWATER**

JT5100\UNFILTER\PROPLOT2.CDR (P11)

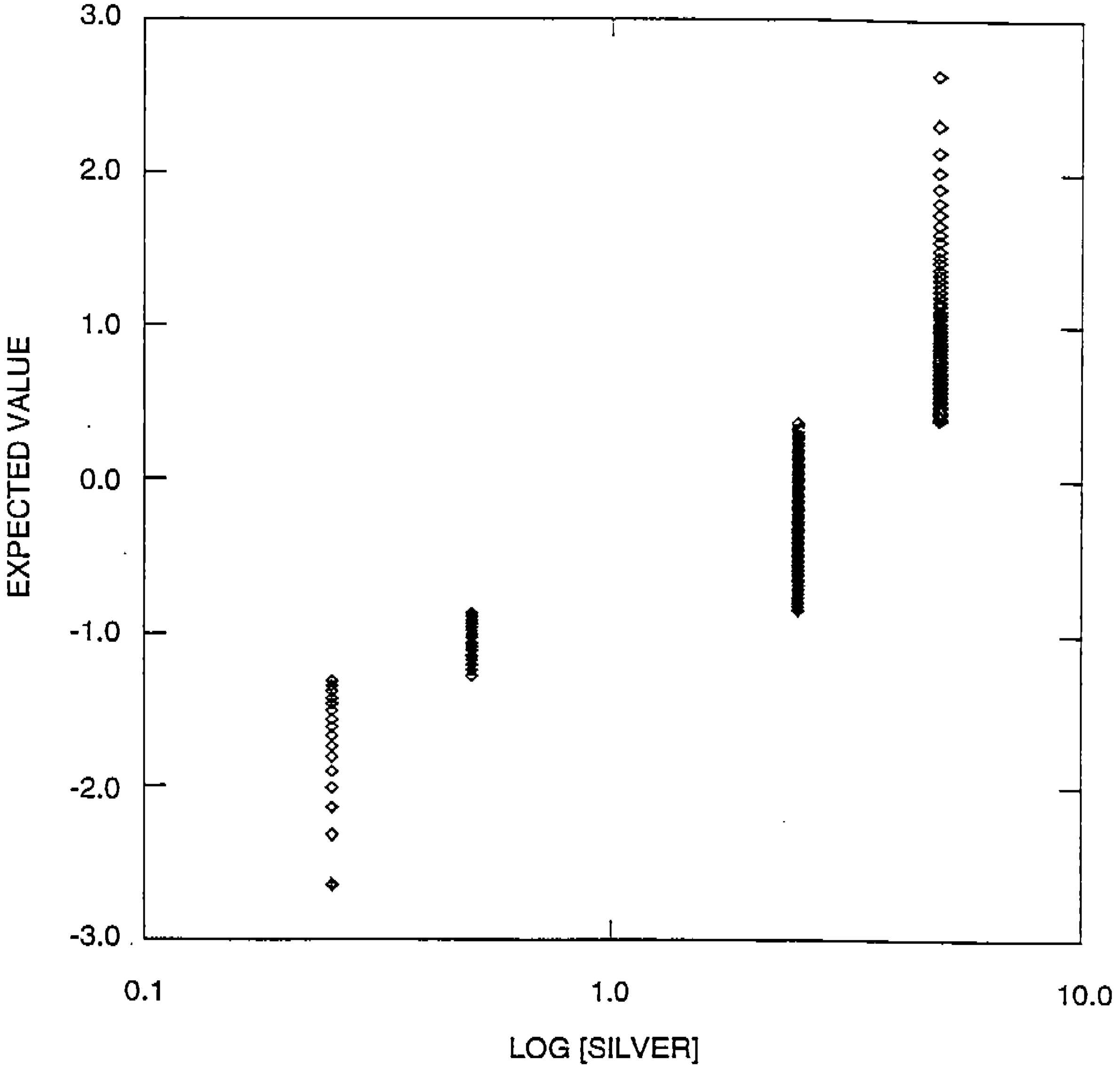

Figure 3-36 **PROBABILITY PLOT FOR SILVER - FILTERED GROUNDWATER**

JT5100\UNFILTER\PROPLOT2.CDR (P12)

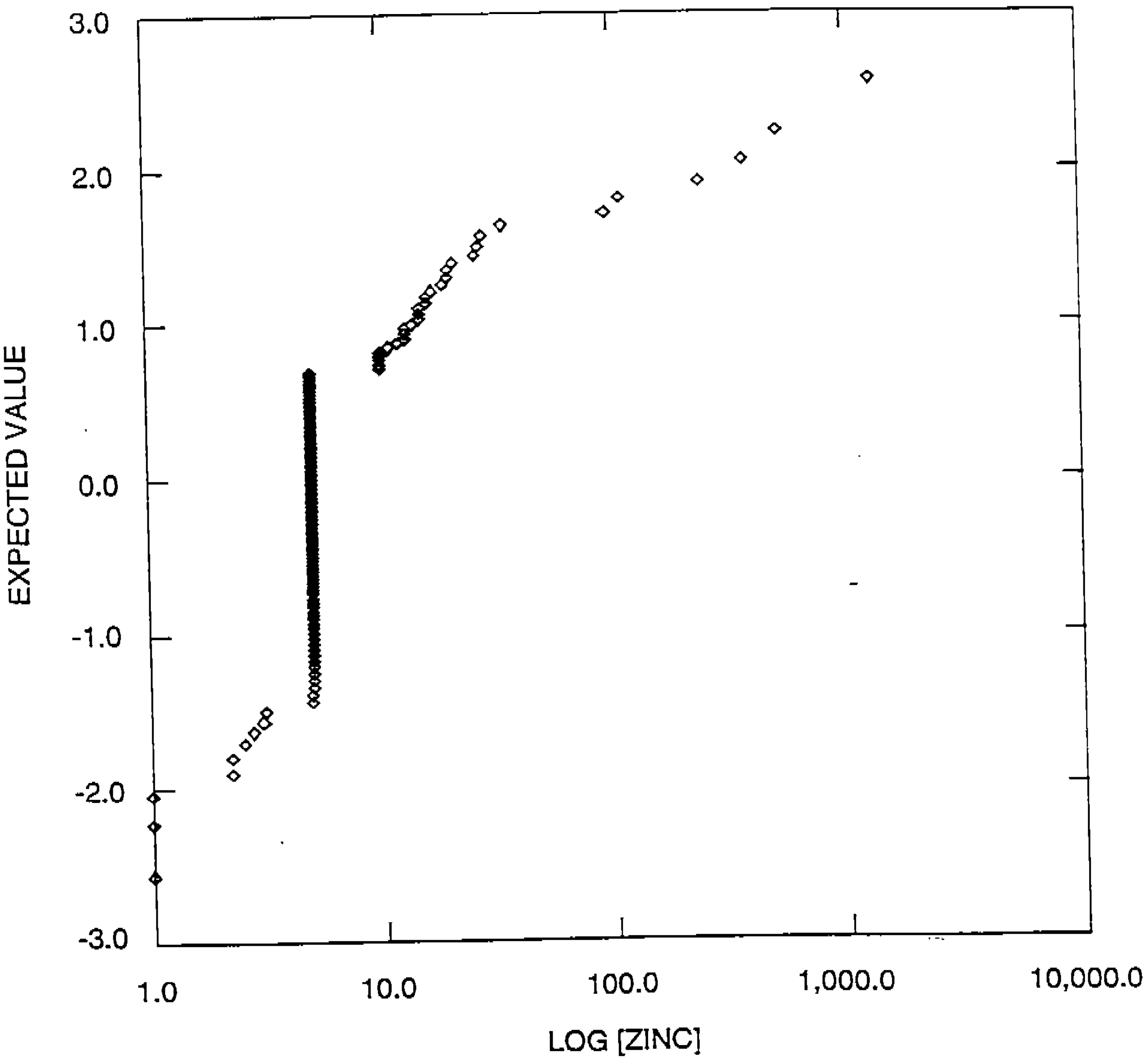

Figure 3-37 **PROBABILITY PLOT FOR ZINC - FILTERED GROUNDWATER**

JT5100\UNFILTER\PROPLOT2.CDR (P1)

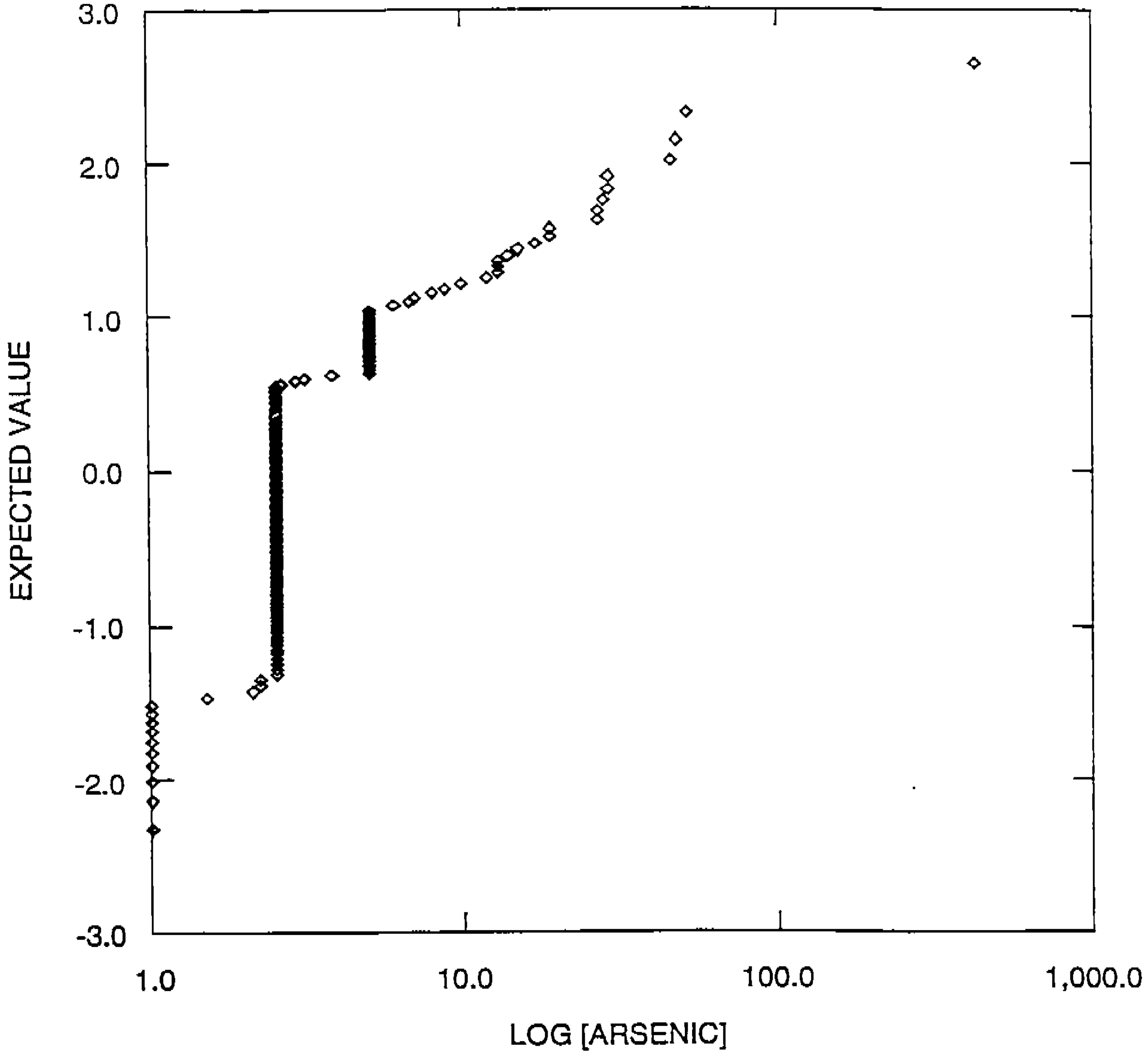

Figure 3-38 PROBABILITY PLOT FOR ARSENIC - UNFILTERED GROUNDWATER

JT5100\UNFILTER\PROPLOT2.CDR (P2)

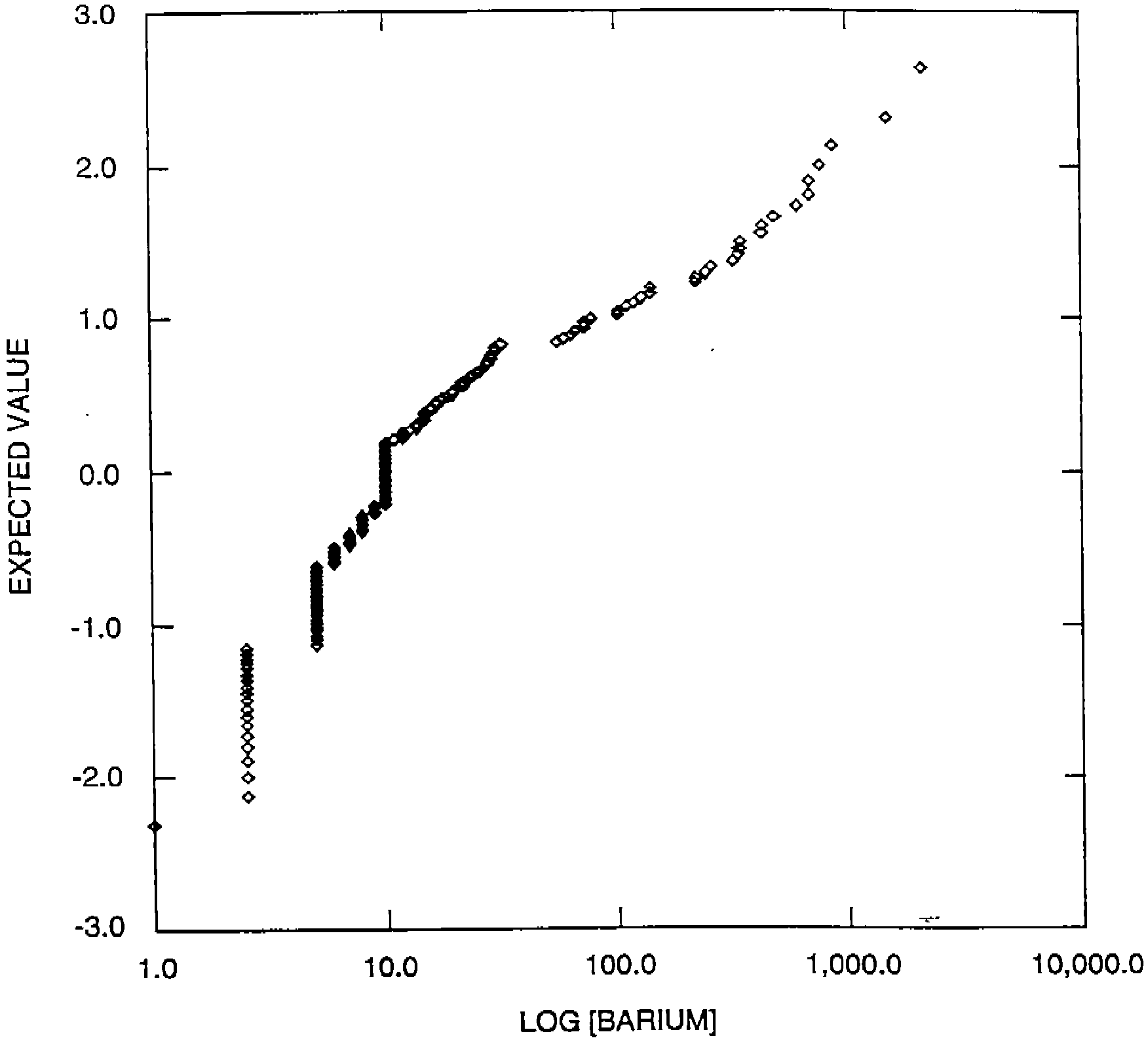

Figure 3-39 **PROBABILITY PLOT FOR BARIUM - UNFILTERED GROUNDWATER**

JT5100\UNFILTER\PROPLOT2.CDR (P3)

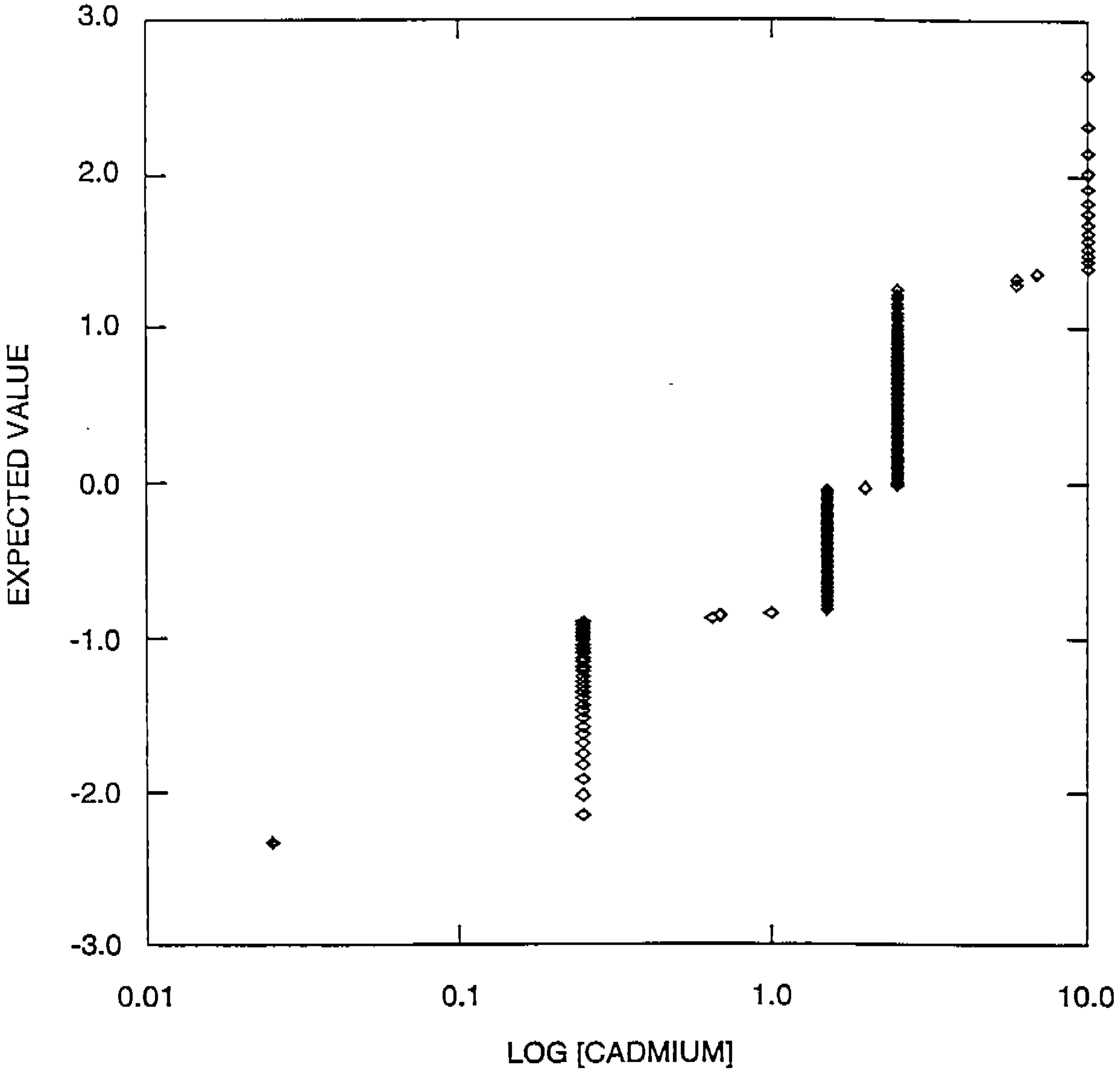

Figure 3-40 PROBABILITY PLOT FOR CADMIUM - UNFILTERED GROUNDWATER

JT5100\UNFILTER\PROPLOT2.CDR (P4)

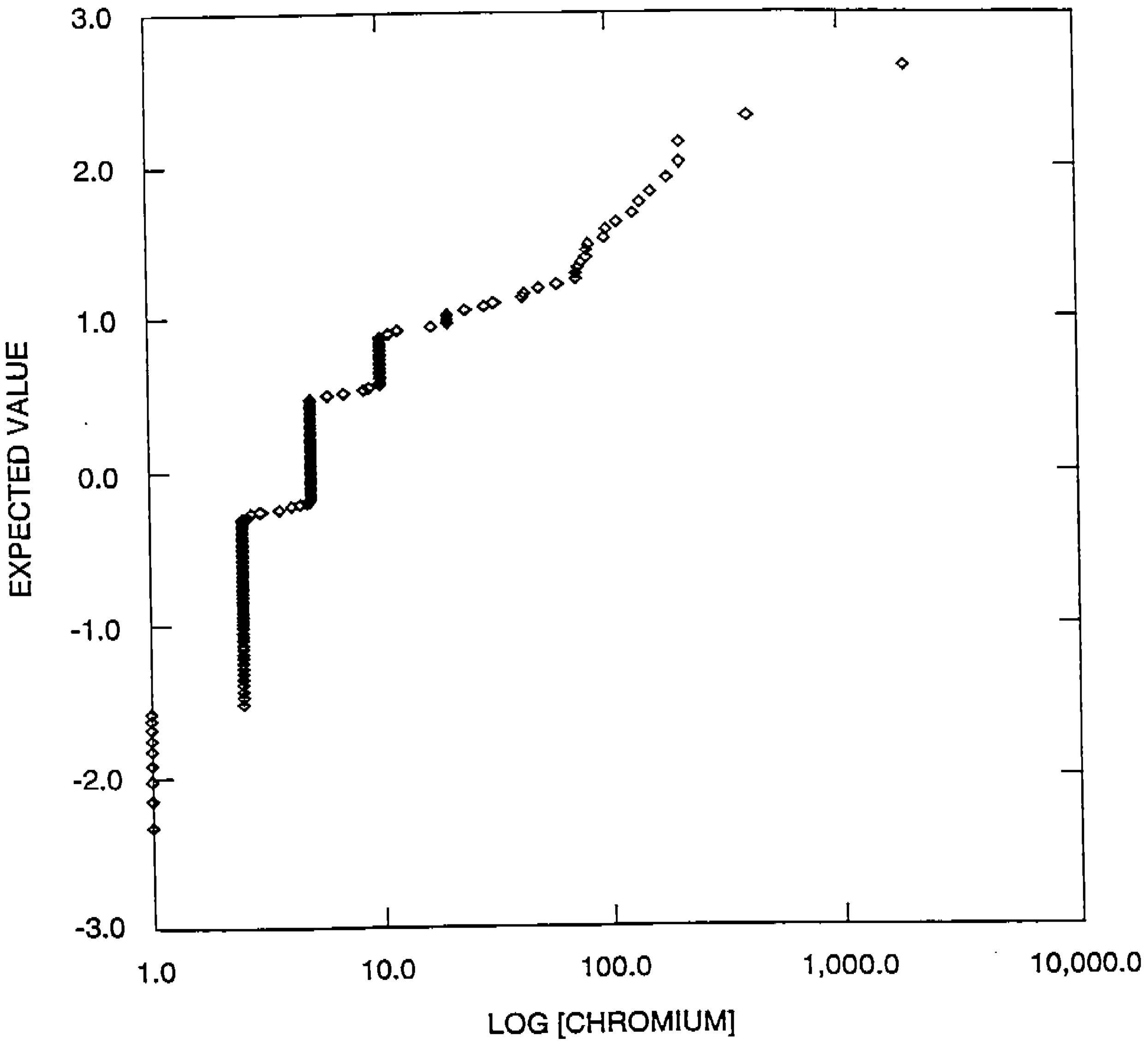

Figure 3-41 PROBABILITY PLOT FOR CHROMIUM - UNFILTERED GROUNDWATER

JT5100\UNFILTER\PROPLOT2.CDR (P5)

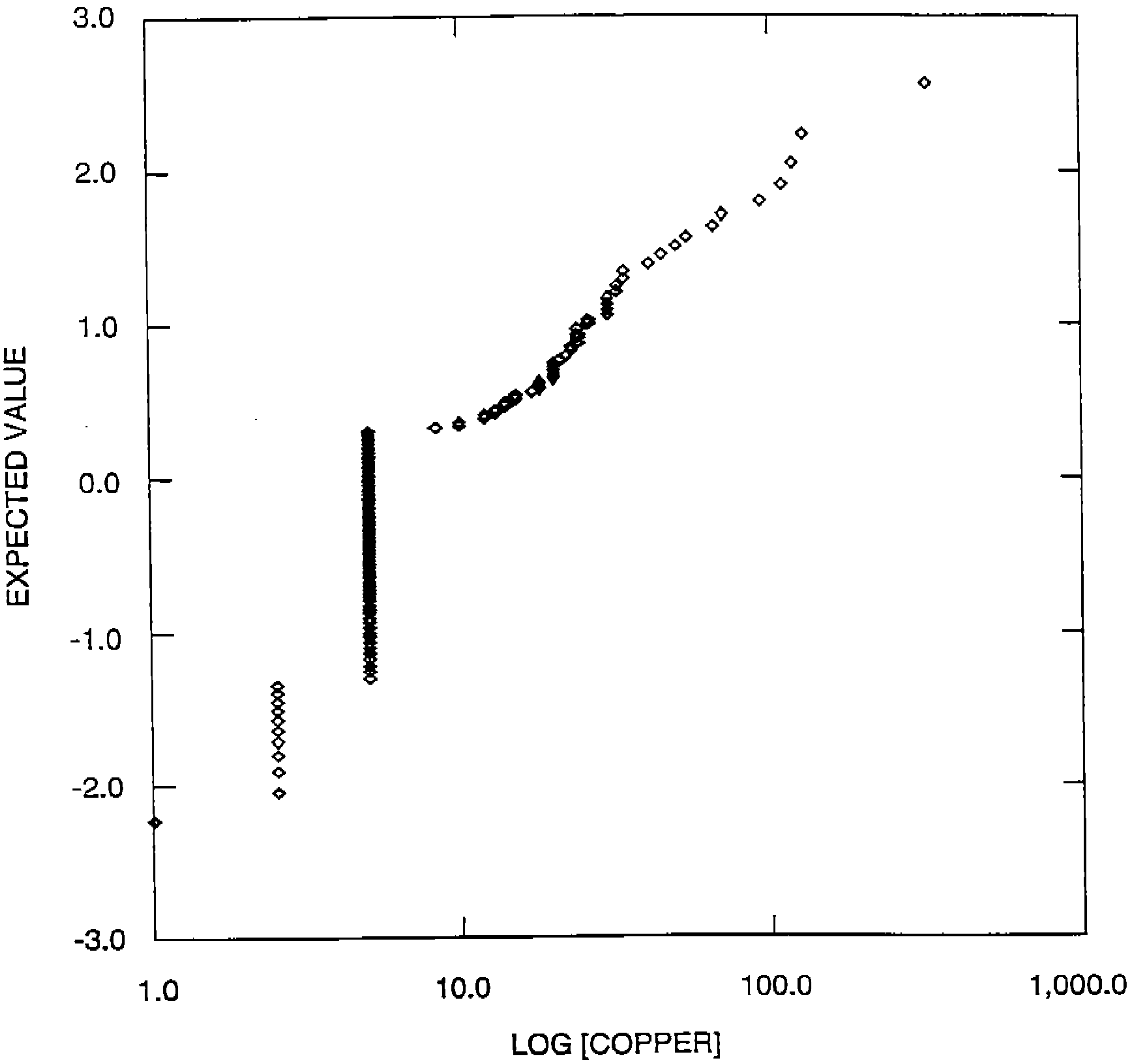

Figure 3-42 PROBABILITY PLOT FOR COPPER - UNFILTERED GROUNDWATER

JT5100\UNFILTER\PROPLOT2.CDR (P6)

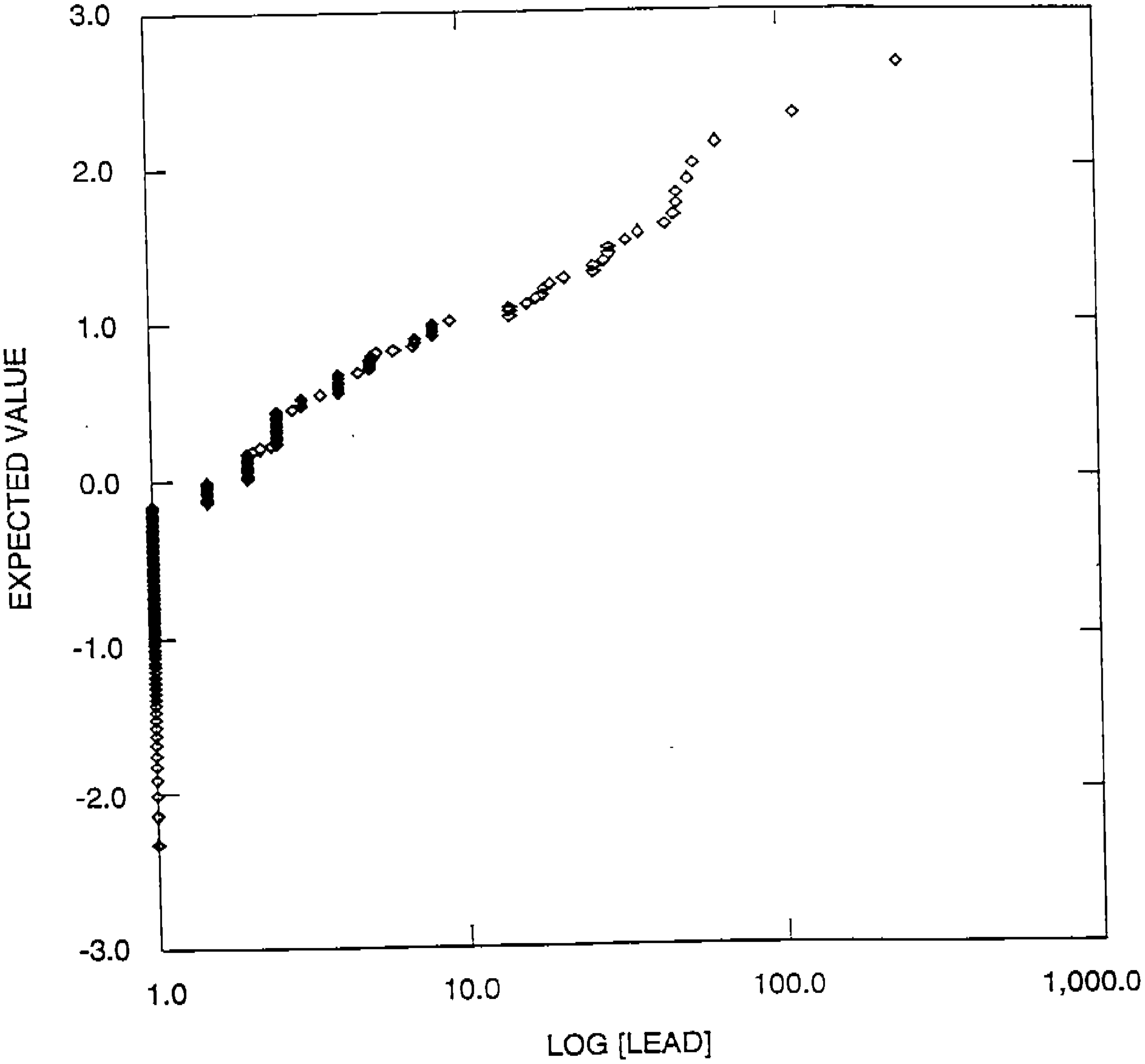

Figure 3-43 **PROBABILITY PLOT FOR LEAD - UNFILTERED GROUNDWATER**

JT5100\UNFILTER\PROPLOT2.CDR (P7)

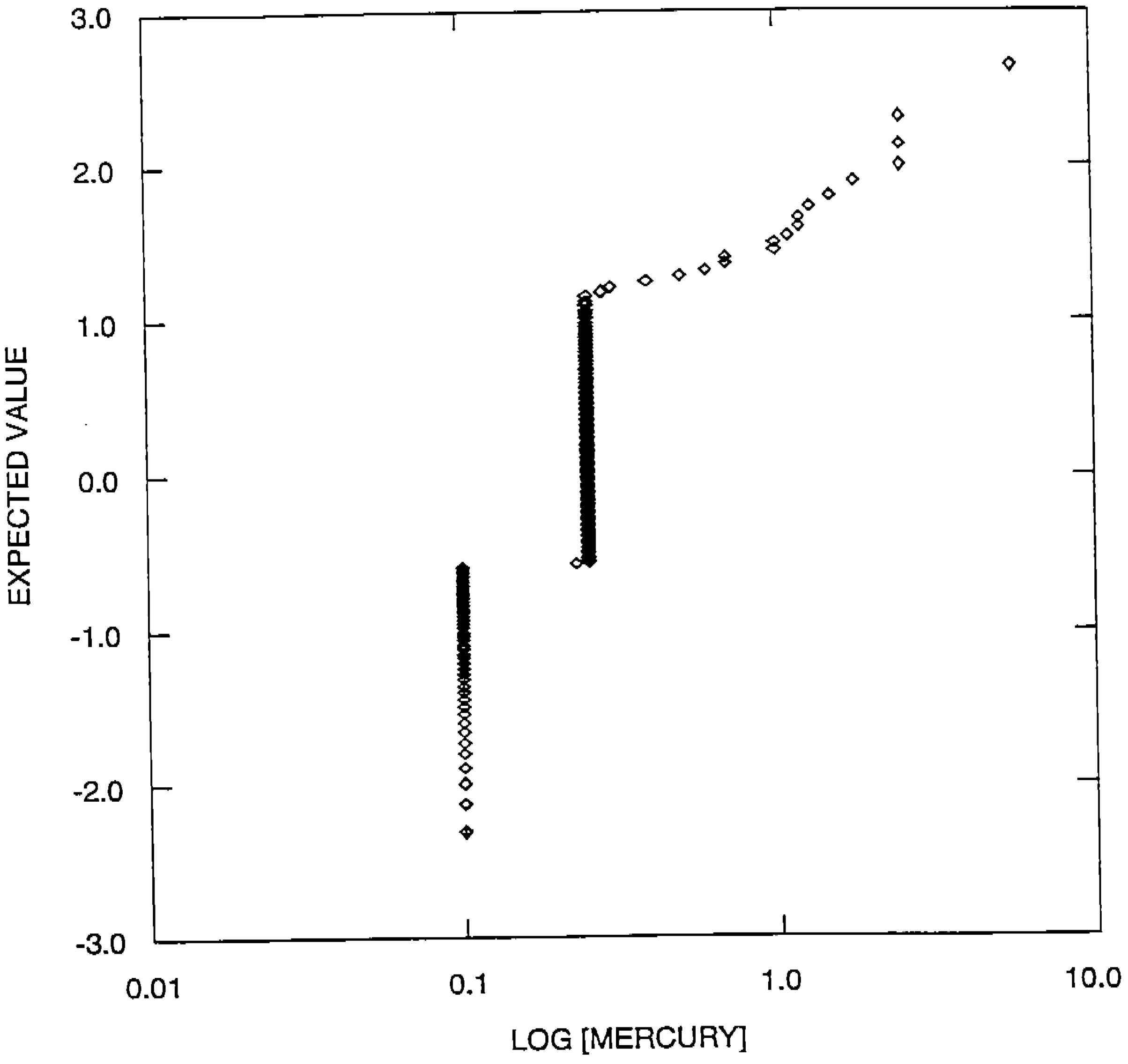

Figure 3-44 **PROBABILITY PLOT FOR MERCURY - UNFILTERED GROUNDWATER**

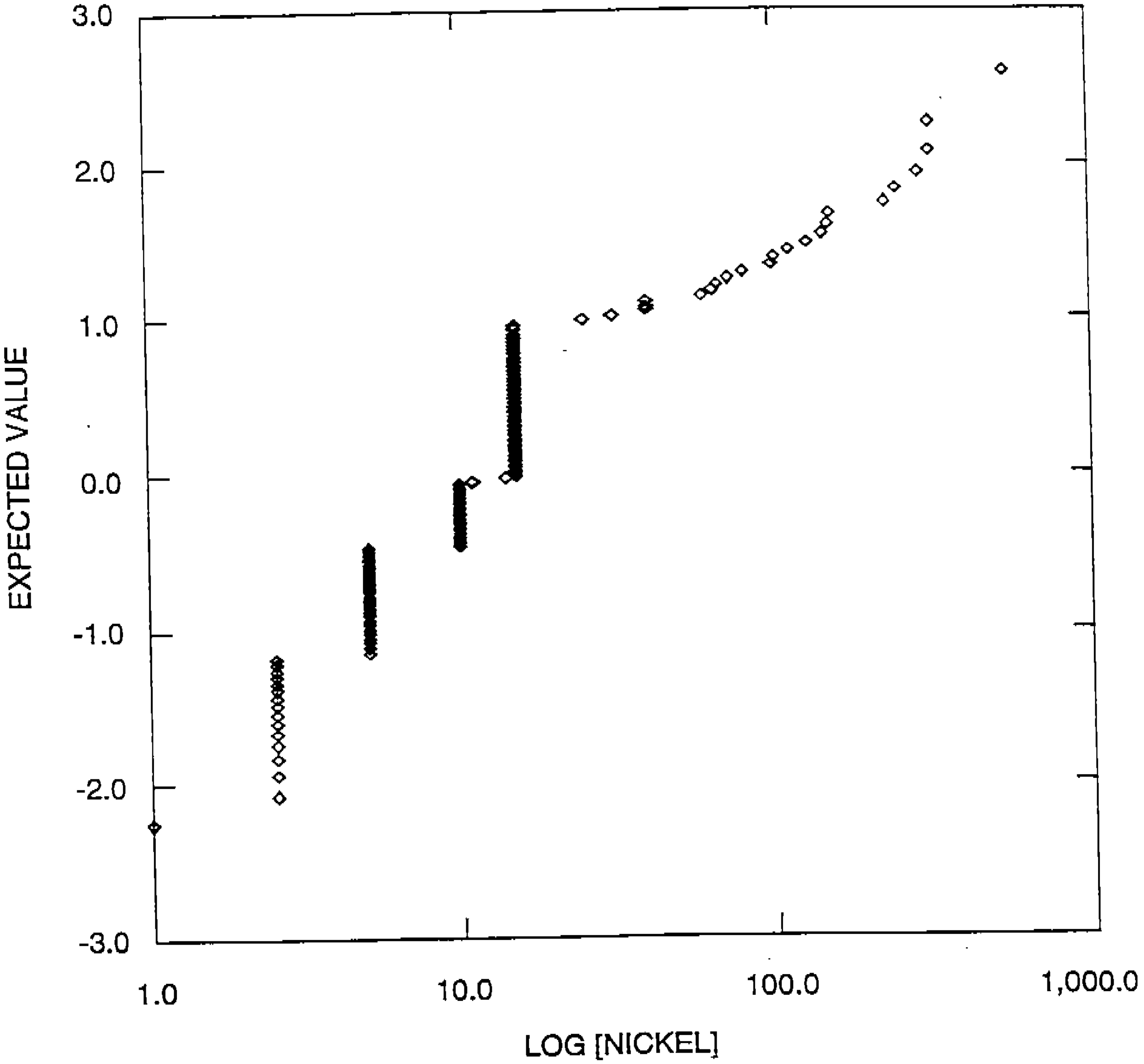

Figure 3-45 PROBABILITY PLOT FOR NICKEL - UNFILTERED GROUNDWATER

JT5100\UNFILTER\PROPLOT2.CDR (P9)

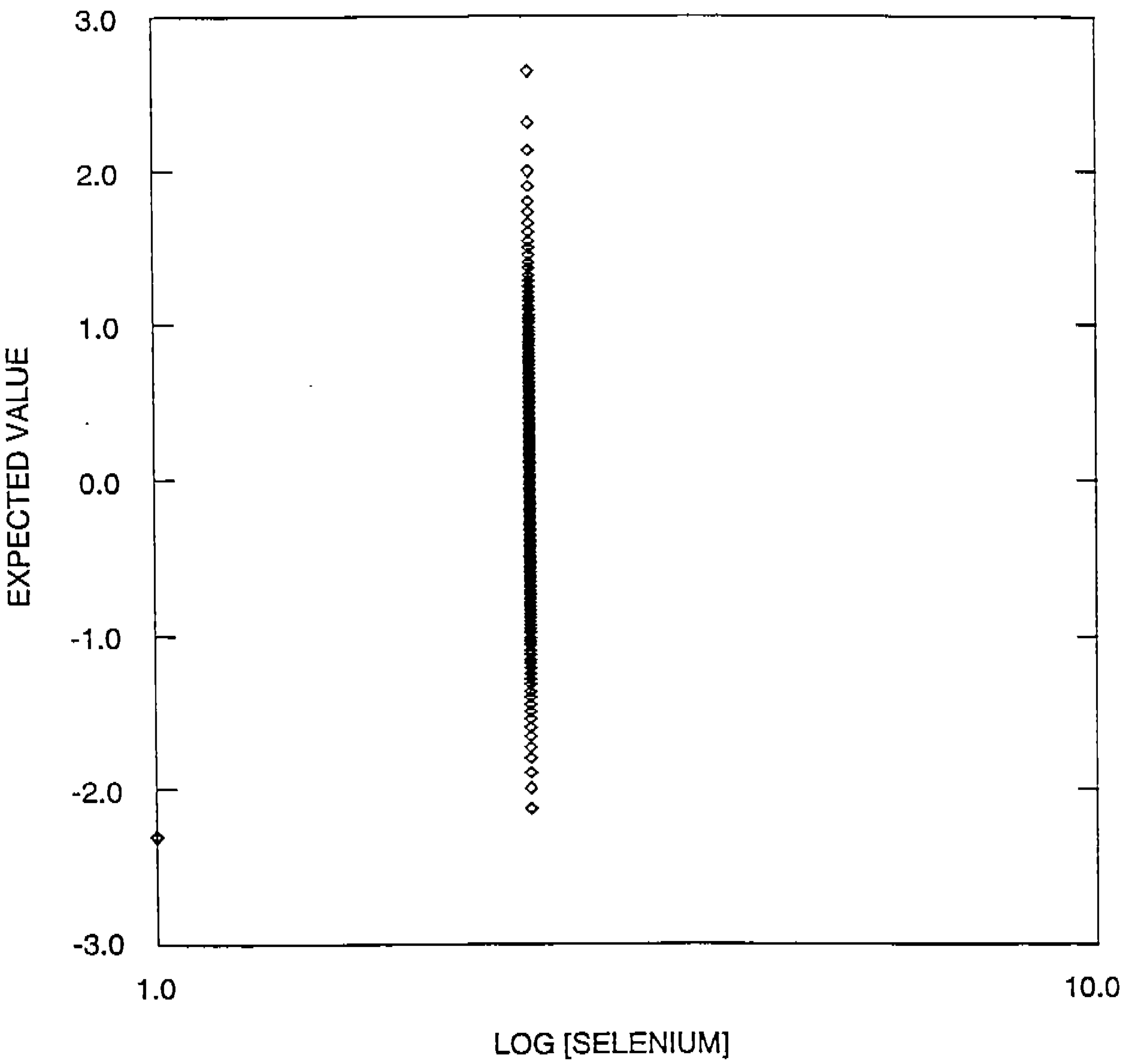

Figure 3-46 PROBABILITY PLOT FOR SELENIUM - UNFILTERED GROUNDWATER

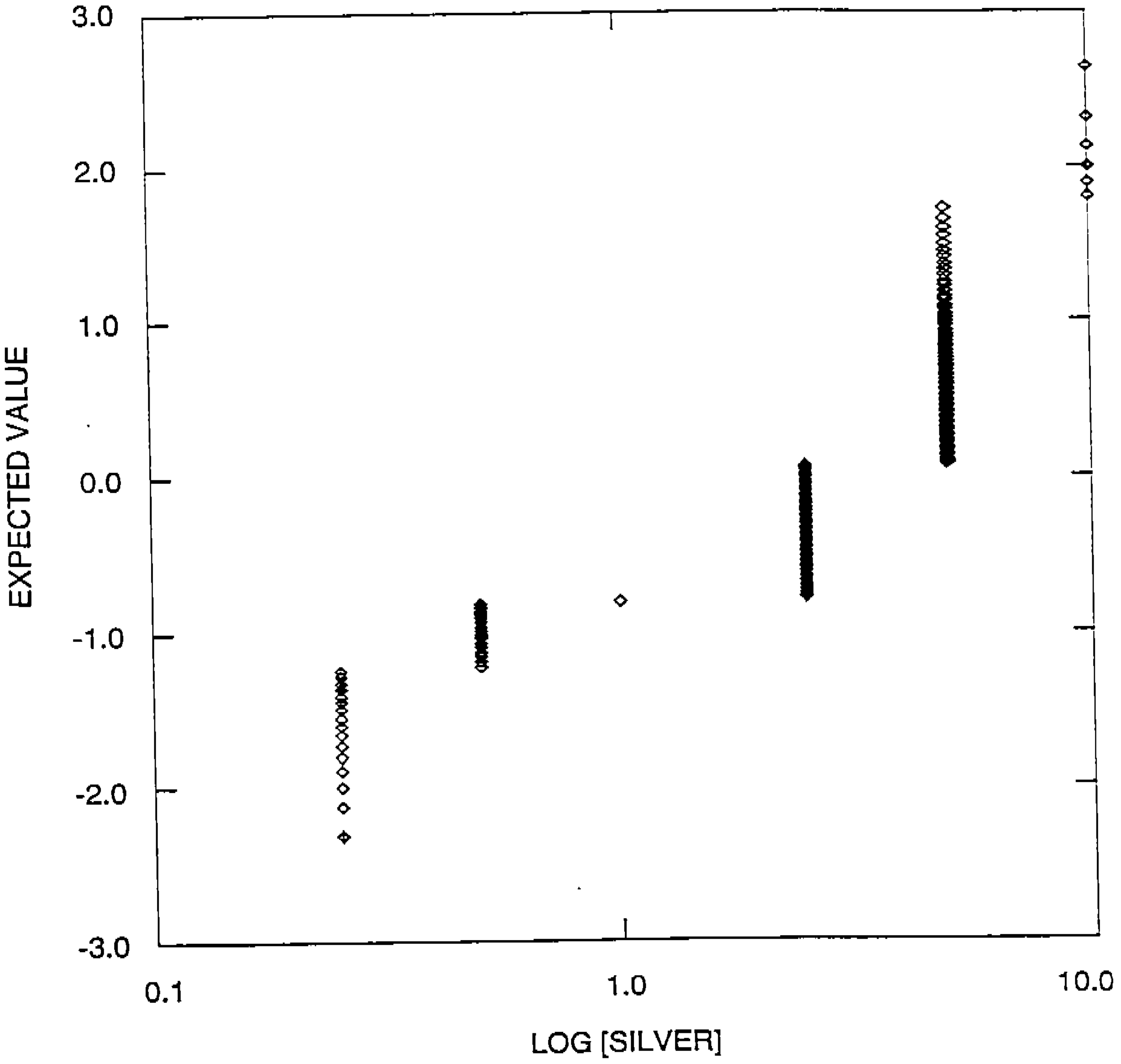

Figure 3-47 PROBABILITY PLOT FOR SILVER - UNFILTERED GROUNDWATER

JT5100\UNFILTER\PROPLOT2.CDR (P11)

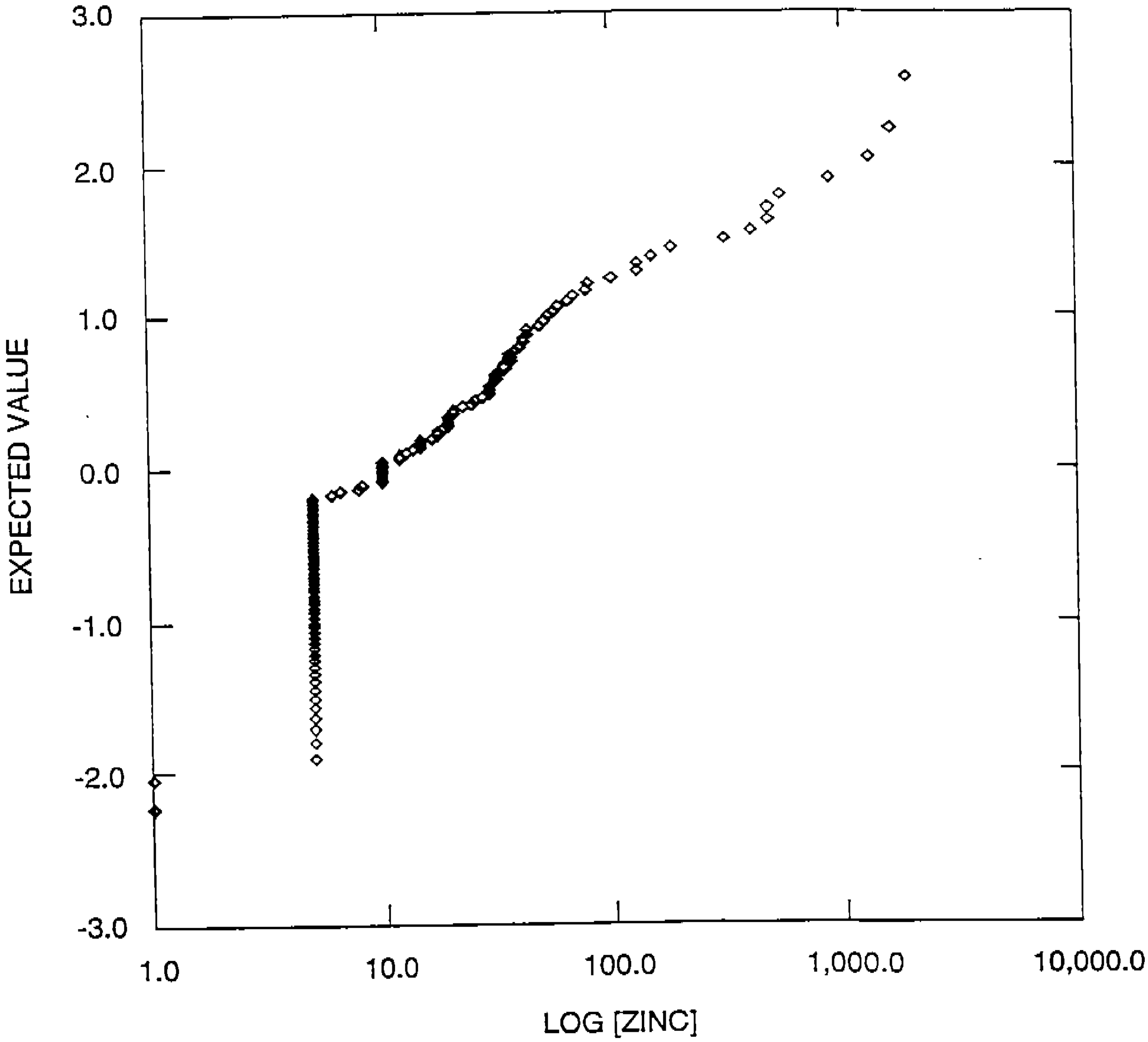

Figure 3-48 PROBABILITY PLOT FOR ZINC - UNFILTERED GROUNDWATER

4

Comparison of Elmendorf Air Force Base Background Concentrations to Fort Richardson Background Concentrations

This section compares the background study previously completed at Elmendorf Air Force Base with this background study completed for Fort Richardson.

4.1 Elmendorf Air Force Base Background Analysis

A basewide background sampling investigation was conducted by the Air Force in 1992 at Elmendorf Air Force Base (AFB) to assess background concentrations of inorganic constituents in soil (USAF 1993). This data may be utilized to assess whether concentrations of inorganic constituents detected on the base represent naturally occurring background levels or are the result of human activities (USAF 1993).

Fourteen soil borings were drilled specifically for the background study at Elmendorf AFB. Soil samples were collected from seven soil borings located on Elmendorf Moraine (identified as Qey [end moraine deposits of the Knik-Matanuska Glacier (USGS 1964)]) and seven borings south of the moraine (identified as Qay_2 [older outwash-stream deposit (USGS 1964)]). Statistical analysis of the sample analytical data indicated there were no statistically significant differences between the samples from outwash and moraine areas; thus, the samples were pooled for calculation of mean concentrations (USAF 1993). The Elmendorf background study examined the background concentrations of 23 metals. Mean concentrations of arsenic, barium, chromium, copper, lead, nickel, and zinc detected at Elmendorf AFB, the only metals with appropriate data for parametric statistical analysis in the Fort Richardson background study, are presented in Table 4-1.

4.2 Fort Richardson Background Analysis

As stated in Section 1, the background concentrations of constituents at Fort Richardson were determined utilizing existing data from previous environmental investigations completed on base. Samples included in the Fort Richardson background study were collected from the Elmendorf moraine area (Qey) and the outwash south of the moraine (Qay2). Thus, the samples included in both background studies were collected from similar geologic formations. Mean concentrations of arsenic, barium, chromium, copper, lead, nickel, and zinc detected at Fort Richardson also are presented in Table 4-1.

4.3 Discussion

The mean concentration of the seven metals statistically analyzed in both background studies are generally similar (see Table 4-1). However, variations are present, especially in the surface and rootzone concentrations of barium. Variations in background mean concentrations may be attributable to:

- Mineralogical and textural variability among glacial deposits;
- Soil origin;
- Plant uptake; and
- Differences in sample collection methodology.

Glacial debris transport and deposition homogenizes debris collected from many different mineralogical assemblages derived by erosion of bedrock and existing glacial sediments along the path of the glacier (Freeze and Cherry 1979; Ashley *et al.* 1985). Thus, small volume samples may contain sediments from numerous mineralogical origins. The varying abundances of minerals within glacial lithologic units like Qay will causes variations in the metals concentrations detected by environmental sampling analysis.

Surface soil sample variability may be attributable to soil origin. Like glacial debris, windblown dust or runoff will collect sediments from different sources. Thin, discrete layers within the soil horizons may also result from different sources, including volcanic activity. Human disturbances such as grading or lawn cultivation will further impact the metal concentration variability by redistributing sediment (Rieger *et al.* 1979).

Plant uptake may also cause variability in soil chemistry. Plants draw minerals into their tissue, which eventually are deposited on the surficial soil. This process will increase the variability of metals concentration in surficial soil by removing metals from some soils while depositing metals in other areas.

Differences in sampling methodology may also cause variability between the results from different studies. Therefore, sample means calculated from two sample populations collected with different methodologies may not be the same.

Arsenic

Arsenic mean concentrations determined at the two bases are similar (see Table 4-1).

Barium

Surface and rootzone mean concentrations of barium are approximately 30% lower at Fort Richardson compared to barium concentrations detected at Elmendorf AFB (see Table 4-1). However, barium concentrations at depths greater than 3 feet BGS are similar. The cause of the variation noted in surface and rootzone depths may be attributable to geologic variability.

Chromium

The Fort Richardson background study determined there were no statistical differences in chromium concentrations with depth. However, chromium concentrations were statistically different in the two geologic formations. In contrast, the Elmendorf background study detected statistical differences in chromium concentrations with depth (surface versus rootzone) but no difference in concentration between the two geologic formations. This variability is likely attributable to the geologic variability in glacial deposits. The mean concentrations determined by both studies, however, are similar (see Table 4-1).

Copper

The observations noted for chromium also apply to copper. The copper mean concentration in Qay2 in the Fort Richardson study is within the range of the mean concentrations detected at Elmendorf AFB (see Table 4-1). However, the Fort Richardson copper mean concentration in Qey is greater. Again, geologic variability is likely the cause of this difference.

Lead

Mean concentrations of lead are slightly higher at Fort Richardson compared to lead concentrations detected at Elmendorf AFB, although the difference is only approximately 3 mg/kg (see Table 4-1).

Nickel

Mean concentrations of nickel are slightly higher at Fort Richardson (see Table 4-1). No statistical difference in concentration was noted with depth at Fort Richardson. The Fort Richardson mean nickel concentrations closely match the rootzone and deep mean nickel concentrations at Elmendorf AFB.

Zinc

At Fort Richardson, no statistical difference was found for zinc concentrations with depth or geologic formation. At Elmendorf AFB, the mean concentration of zinc at the surface was approximately 15 mg/kg less than root-zone or deep mean concentrations. The Fort Richardson mean concentration most closely matches the root-zone and deep Elmendorf AFB concentrations (see Table 4-1).

Summary

The comparison of the seven metals detected at Elmendorf AFB and Fort Richardson indicates variability of the mean concentrations. This variability may be attributed to geologic variability in glacial deposits, soil origin (windblown dust or runoff), plant uptake (plants drawing minerals into their tissue, which is eventually deposited on the more surficial soil levels), or sampling methodology. Although the Elmendorf AFB study noted no statistical differences in the metals concentrations due to the geologic formation (thus, all samples were pooled), the Fort Richardson study did detect statistical differences due to the geologic formation in some cases. In addition, variability also may be present due to the different sampling methods (dedicated background samples versus using existing samples).

Table 4-1

COMPARISON BETWEEN ELMENDORF AFB AND FORT RICHARDSON MEAN BACKGROUND SOIL CONCENTRATIONS BACKGROUND DATA ANALYSIS FORT RICHARDSON, ALASKA

	Elmendorf AFB		Fort Richardson	
Metal	Depth Range	Mean Concentration (mg/kg)	Depth Range or Geologic Unit	Mean Concentration (mg/kg)
Arsenic	Surface	7.2	Surface	6.9
	Root Zone	6.87	Root Zone	6.7
	Deep	5.46	Deep	5.9
Barium	Surface	113.8	Surface	69.3
	Root Zone	103.3	Root Zone	68
	Deep	54.5	Deep	52.5
Chromium	Surface	19.8	Qay_2	32
	Root Zone	31.8	Qey	28.8
	Deep	31.8	—	—
Copper	Surface	14.8	Qay_1	21.9
	Root Zone	20.8	Qey	39.1
	Deep	29.5	—	—
Lead	Surface	6.93	Surface	10
	Root Zone	5.85	Deep	7
	Deep	5.3	—	—
Nickel	Surface	13	Qay_2	35.7
	Root Zone	29.6	Qey	38.3
	Deep	34.6	—	—
Zinc	Surface	36.7	All depths	52.1
	Root Zone	51.3	—	—
	Deep	51.7	—	—

Note: For the Fort Richardson study, if no statistical variation was noted in concentration with depth, the concentration is reported by geologic unit rather than by depth.

5 Summary and Conclusions

For this study, background soil and groundwater data sets were compiled for the Fort Richardson site. Soil data sets were compiled for arsenic, barium, cadmium, chromium, copper, DDD, DDE, DDT, lead, mercury, nickel, selenium, silver, and zinc; filtered and unfiltered groundwater data sets were compiled for the above metals only. The data set for unfiltered groundwater was deemed unacceptable for statistical purposes because of the presence of suspended sediments in the groundwater, as discussed in Section 3.3. The compiled background data sets were then used to estimate statistical parameters useful in site characterization and remediation.

5.1 Compilation of Background Data Sets

Background data sets for soils were constructed using the compiled data sets. For chemicals having high percentages of detects, data subsets corresponding to distinct data populations associated with the different geological units or the three designated depth intervals were identified using ANOVA. Probability plots constructed using these data were used to determine a set of corresponding upper cutoff concentrations. Values above the cutoffs were assumed to be contaminated and were eliminated from the data sets; values below the cutoffs were retained as background values.

The background data sets were checked for normality and/or lognormality and then re-examined using ANOVA for differences in concentration as a function of geological unit and/or depth. The data sets remaining after this process were used as the final background data sets in parametric UCL and UTL calculations.

For approximately half of the chemicals or metals studied, the percentages of detects were low. In these cases, the delineation of distinct populations in the different geological units and depth zones was not practical. Using probability plots of the entire compiled data set for each metal, suspected contamination values were eliminated and the resulting data sets were used as background in nonparametric calculations.

The groundwater data were not analyzed for group difference. The entire compiled data sets were culled for contamination, again using probability plots, and the resulting background data sets were used to estimate nonparametric UCLs and UTLs.

5.2 Determination of the Mean, UCL, and UTL

The compiled background data sets were used to estimate the mean, UCL, and UTL, which are statistical parameters useful in site characterization and remediation. In cases where the percentage of detects was high, the mean, parametric 95% UCL, and parametric 95% UTL were estimated. This was done for arsenic, barium, chromium, copper, lead, nickel, and zinc in soils, and for DDT, even though the percentage of nondetects for DDT was slightly above 50%. The calculation for DDT employed a correction for nondetects.

The rates of nondetect were too high for parametric calculations on the remaining soil data sets and all of the filtered groundwater data sets. It was possible, however, to estimate the median, nonparametric 95% UCL, and nonparametric 95% UTL for cadmium, DDD, DDE, mercury, and selenium in soils, and for copper and lead in the filtered groundwater. (DDT in soil was included in the nonparametric calculations for comparison with the corrected parametric estimates.)

Only one data set for one naturally occuring metal—lead in soil—clearly appears to be contaminated. The appearance of the probability plot for lead in soil indicates that the data are strongly skewed. The data and figure indicate low levels of lead contamination merging with the background distribution, a situation consistent with normal human activities at the site.

5.3 Differences by Soil Type and Depth

The data sets used in parametric calculations were also examined using ANOVA for statistically significant differences in concentration by soil type and depth. In cases where significant differences were found, the mean, UCL, and UTL were estimated for the different subgroups. Concentrations of arsenic, barium, lead, and nickel were found to decrease with depth but not by soil type. Concentrations of chromium and copper varied by soil type but not with depth. Concentrations of zinc showed no variation by either depth or soil type.

5.4 Use of Background Data in Risk Assessment

EPA risk assessment guidance (EPA 1989a) states that site-related contamination should be distinguished from naturally occurring or other non-site-related levels of chemicals or metals. Consequently, the UTLs presented in this report will be used to select chemicals of potential concern (COPCs) for quantitative evaluation in both human health and ecological risk assessments.

In future investigations, the maximum detected on-site chemical concentrations in soils and groundwater will be compared to the respective background UTLs determined in this report. Chemicals or metals will only be retained as COPCs in the risk assessment if the maximum detected on-site concentration for a particular chemical exceeds the background UTL for that chemical. This approach will be used to select COPCs in both soils and groundwater. This procedure ensures that risks are calculated only for those chemicals or metals that are present above naturally occurring or non-site-related levels.

6 References

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A Output from ANOVA on Unedited Data Sets

OUTPUT FROM ANOVA ON UNEDITED DATA SETS:

```
FRI 1/05/96 11:48:12 AM   C:\FTR\AS.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
DEPTHS$
 ROOTZONE      SUBSURFACE    SURFACE


DEP VAR:    LOGAS      N:     461  MULTIPLE R: 0.150   SQUARED MULTIPLE R: 0.022


                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO        P

DEPTHS$                0.622    2         0.311      5.248      0.006

ERROR                 27.131  458         0.059

 FRI 1/05/96 11:48:24 AM   C:\FTR\AS.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
SOILTYP$
 Qal           Qay2          Qey           Qgo


DEP VAR:    LOGAS      N:     461  MULTIPLE R: 0.270   SQUARED MULTIPLE R: 0.073


                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO        P

SOILTYP$               2.019    3         0.673     11.950      0.000

ERROR                 25.734  457         0.056


 FRI 1/05/96 11:53:00 AM   C:\FTR\BA.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
SOILTYP$
 Qay2          Qey


DEP VAR:    LOGBA      N:     314  MULTIPLE R: 0.088   SQUARED MULTIPLE R: 0.008


                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO        P

SOILTYP$               0.128    1         0.128      2.435      0.120

ERROR                 16.344  312         0.052

 FRI 1/05/96 11:53:13 AM   C:\FTR\BA.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
DEPTHS$
 ROOTZONE      SUBSURFACE    SURFACE


DEP VAR:    LOGBA      N:     314  MULTIPLE R: 0.267   SQUARED MULTIPLE R: 0.071


                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO        P

DEPTHS$                1.177    2         0.589     11.968      0.000

ERROR                 15.294  311         0.049
```

```
 FRI 1/05/96 11:54:11 AM   C:\FTR\CR.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
SOILTYP$
 Qay2         Qey

DEP VAR:   LOGCR      N:     464  MULTIPLE R: 0.190  SQUARED MULTIPLE R: 0.036

                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES  DF  MEAN-SQUARE     F-RATIO       P

SOILTYP$             0.445     1        0.445     17.234      0.000

ERROR               11.916   462        0.026

 FRI 1/05/96 11:54:29 AM   C:\FTR\CR.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
DEPTH$
 ROOTZONE     SUBSURFACE   SURFACE

DEP VAR:   LOGCR      N:     464  MULTIPLE R: 0.060  SQUARED MULTIPLE R: 0.004

                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES  DF  MEAN-SQUARE     F-RATIO       P

DEPTH$               0.045     2        0.023      0.844      0.431

ERROR               12.316   461        0.027

 FRI 1/05/96 11:55:48 AM   C:\FTR\CU.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
SOILTYP$
 Qay2         Qey

DEP VAR:   LOGCU      N:      86  MULTIPLE R: 0.361  SQUARED MULTIPLE R: 0.131

                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES  DF  MEAN-SQUARE     F-RATIO       P

SOILTYP$             0.895     1        0.895     12.614      0.001

ERROR                5.958    84        0.071

 FRI 1/05/96 11:55:57 AM   C:\FTR\CU.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
DEPTH$
 ROOTZONE     SUBSURFACE   SURFACE

DEP VAR:   LOGCU      N:      86  MULTIPLE R: 0.062  SQUARED MULTIPLE R: 0.004

                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES  DF  MEAN-SQUARE     F-RATIO       P

DEPTH$               0.026     2        0.013      0.159      0.853

ERROR                6.826    83        0.082
```

```
 FRI 1/05/96 11:58:52 AM   C:\FTR\NI.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
SOILTYP$
 Qay2          Qey

DEP VAR:   LOGNI      N:     182  MULTIPLE R: 0.092  SQUARED MULTIPLE R: 0.008

                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO       P

SOILTYP$               0.038    1        0.038       1.537      0.217

ERROR                  4.420  180        0.025

 FRI 1/05/96 11:59:08 AM   C:\FTR\NI.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
DEPTH$
 ROOTZONE     SUBSURFACE   SURFACE

DEP VAR:   LOGNI      N:     182  MULTIPLE R: 0.156  SQUARED MULTIPLE R: 0.024

                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO       P

DEPTH$                 0.109    2        0.055       2.245      0.109

ERROR                  4.348  179        0.024


 FRI 1/05/96 12:00:06 PM   C:\FTR\PB.SYS

LEVELS ENCOUNTERED DURING PROCESSING ARE:
SOILTYP$
 Qay2          Qey

DEP VAR:   LOGPB      N:     683  MULTIPLE R: 0.024  SQUARED MULTIPLE R: 0.001

                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO       P

SOILTYP$               0.033    1        0.033       0.395      0.530

ERROR                 56.781  681        0.083

 FRI 1/05/96 12:00:18 PM   C:\FTR\PB.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
DEPTH$
 ROOTZONE     SUBSURFACE   SURFACE

 DEP VAR:   LOGPB      N:     683  MULTIPLE R: 0.426  SQUARED MULTIPLE R: 0.182

                         ANALYSIS OF VARIANCE

SOURCE        SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO       P

DEPTH$                10.328    2        5.164      75.540      0.000

ERROR                 46.486  680        0.068
```

JT5904_A643

FTR 0027342

Background Data Analysis Report Fort Richardson, Alaska

April 1996

Prepared for:

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recycled paper

```
 FRI 1/05/96 12:01:16 PM   C:\FTR\ZN.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
SOILTYPS
 Qay2          Qey

DEP VAR:   LOGZN      N:       86  MULTIPLE R: 0.129  SQUARED MULTIPLE R: 0.017

                         ANALYSIS OF VARIANCE

SOURCE       SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO       P

SOILTYPS              0.330    1        0.330       1.413     0.238

ERROR                19.641   84        0.234

 FRI 1/05/96 12:01:31 PM   C:\FTR\ZN.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
DEPTHS
 ROOTZONE     SUBSURFACE   SURFACE

DEP VAR:   LOGZN      N:       86  MULTIPLE R: 0.354  SQUARED MULTIPLE R: 0.125

                         ANALYSIS OF VARIANCE

SOURCE       SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO       P

DEPTHS                2.502    2        1.251       5.943     0.004

ERROR                17.469   83        0.210
```

B

Output from ANOVA on Final Background Data Sets

OUTPUT FROM ANOVA ON FINAL BACKGROUND DATA SETS:

```
SAT 1/06/96 10:44:43 PM    C:\FTR\FAS.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
SOILTYP$
 Qay2          Qey


DEP VAR:       AS       N:      439  MULTIPLE R: 0.251  SQUARED MULTIPLE R: 0.063

                          ANALYSIS OF VARIANCE

SOURCE         SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO        P

SOILTYP$              97.889    1        97.889      29.260       0.000

ERROR               1461.983  437         3.345

 SAT 1/06/96 10:45:38 PM    C:\FTR\FAS.SYS
LEVELS ENCOUNTERED DURING PROCESSING ARE:
DEPTH$

 ROOTZONE      SUBSURFACE   SURFACE


DEP VAR:       AS       N:      445  MULTIPLE R: 0.278  SQUARED MULTIPLE R: 0.077

                          ANALYSIS OF VARIANCE

SOURCE         SUM-OF-SQUARES   DF  MEAN-SQUARE     F-RATIO        P

DEPTH$               121.273    2        60.637      18.517       0.000

ERROR               1447.375  442         3.275

 SAT 1/06/96 10:45:50 PM    C:\FTR\FAS.SYS
COL/
ROW   DEPTH$
  1  ROOTZONE
  2  SUBSURFACE
  3  SURFACE

USING LEAST SQUARES MEANS.

POST HOC TEST OF        AS


USING MODEL MSE OF        3.275 WITH     442. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:


                         1            2            3

            1          0.000
            2         -1.120        0.000
            3          0.110        1.230        0.000


TUKEY HSD MULTIPLE COMPARISONS.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:


                         1            2            3

            1          1.000
            2          0.000        1.000
            3          0.945        0.000        1.000
```