

**GUIDE FOR PREDICTING
WATER CHEMISTRY FROM
WASTE ROCK PILES**

MEND Project 1.27.1a

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FINAL REPORT

GUIDE FOR PREDICTING WATER CHEMISTRY

PHASE I

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MINE ENVIRONMENT NEUTRAL DRAINAGE PROGRAM

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EXECUTIVE SUMMARY

The Mine Environment Neutral Drainage (MEND) Program is developing tools for prediction of waste rock dump leachate quality. The first objective of this study was to evaluate a recently proposed empirical approach for predicting concentrations of metals in waste rock dump leachate primarily using pH (Morin and Hutt 1993). The method has previously been successfully applied at two mines. The second objective was to investigate refinements to the approach.

Five waste rock piles were selected for the study. Vangorda Plateau (Yukon Territory) and Sullivan (south eastern British Columbia) mines are volcanogenic massive deposits. The Cinola project, Queen Charlotte Islands, British Columbia was a previous MEND study of small test waste rock piles at a proposed sediment-hosted epithermal gold deposit mine. Mine Doyon is a gold vein deposit located between Val D'Or and Rouyn, Quebec. Eskay Creek is a stratiform and stratabound gold and silver deposit located in northwestern British Columbia. Usefulness of the datasets was limited by missing data, variable detection limits and lack of associated flow information (where applicable).

The first step involved examination of histograms for each variable and calculation of regression equations for pH and conductivity against all other parameters. The study confirmed the utility of the empirical approach. Element concentrations were generally negatively correlated with pH but positively correlated with conductivity. Geochemical evaluation of the trends using the equilibrium solution speciation model MINTEQA2 was not useful. However, evaluation of regression equations for sulphate and element concentrations showed good correspondence with predicted geochemical behaviour, consistency with site mineralogy and strong similarities between sites suggesting common mineralogical controls.

The major problems encountered with the empirical models were outliers and excessive positive skewness, variable detection limits, non-normality of residuals, departures from linearity and sub-populations. Several refined data screening methods were evaluated to address these problems, however, the effect on estimates of regression parameter is minimal. Alternatives to least squares regression and separation of data according to sub-populations can be considered.

The second step involved investigation of several multivariate techniques: multiple regression, Principal Components Analysis (PCA) and Cluster Analysis. Due to the excellent inter-correlation of many parameters, multiple regression does not increase the predictive power of bivariate regressions. PCA and Cluster Analysis have no predictive power but are useful as initial data screening tools to restrict the number of bivariate regressions required to model leachate chemistry.

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1.0 INTRODUCTION

1.1 BACKGROUND

The Mine Environment Neutral Drainage Program (MEND) Prediction Committee has recently initiated studies to develop tools and models to predict leachate quality for waste rock dumps. This follows the previous effort by MEND to develop a predictive model for acid generating tailings (RATAP). The objectives of these models will be to provide reliable long term predictions of seepage chemistry based on knowledge of the physical and chemical characteristics of the waste rock, and ambient environmental conditions, such as temperature and infiltration rates. The models should also allow prediction of seepage chemistry under various control options to evaluate these controls.

There are essentially two approaches to development of such models. The first is to use a **deterministic approach** in which the mechanisms of weathering and contaminant transport are modelled from first principles. The recent study reported by Perkins *et al.* (1995) identified several geochemical models which might form the components of this model.

The second approach is **empirical**. This approach ignores the complex source and transport interactions, and attempts to reduce the prediction of seepage chemistry to a few easily measured parameters. This approach is very attractive given the extreme mineralogical, geochemical and physical complexity of waste rock dumps, and the difficulty of adequately characterizing these variations. The purpose of this study was to investigate an empirical approach proposed by Morin and Hutt (1993, 1995) and Morin *et al.* (1995) based on studies at BHP Minerals Canada's Island Copper Mine and Noranda Minerals Inc.'s Bell Mine. Both operations are large open pit porphyry copper mines.

Morin and Hutt (1993) proposed that concentrations of metals can be predicted based solely on pH. Their method involves the following steps to developing an empirical model based on pH measurements:

1. Log transformation of metal data to reduce the variability of the data distribution.
2. Identification of major causal factors, such as pH, flow rate and temperature. For the Bell Mine Study (Morin *et al.* 1995), pH was identified as a significant factor affecting copper concentrations whilst flow rate in drainage collection ditches did not appear to be significant.
3. Determination of regression relationships between metal concentrations and pH. The relationships may be segmented to allow for obvious trend variations across the pH range. The

fit is optimized by adjusting the prediction error.

Morin *et al.* (1995) have applied their empirical model approach to:

- ! prediction of key variables from pH;
- ! analyzing short term peaks in concentrations of key parameters;
- ! evaluation of the effect of secondary minerals on water chemistry; and
- ! prediction of the long term evolution of water chemistry.

It was considered that the main limitation of the approach would be the quality of the dataset. The large datasets used by Morin were compiled over several years. To an extent, this limits the effect of data variability due to random factors such as field and laboratory error. As datasets get smaller, random scatter and the effect of anomalous results becomes more significant, potentially limiting the usefulness of the approach.

1.2 OBJECTIVES OF THE PROJECT

The objectives of the project were to:

- ! Expand the application of the approach to other types of mines and mineral deposits;
- ! Compare the relationships obtained at different sites and evaluate the geochemical significance; and
- ! Consider the application of other (multivariate) statistical methods.

1.3 SELECTION OF TEST SITES

MEND provided datasets for two mines (Doyon, Quebec and Eskay Creek, British Columbia). Additional datasets were obtained by Norecol, Dames & Moore and T.W. Higgs Associates. The sites were Cinola Waste Rock Pads, Cominco Ltd's Sullivan Mine Lower Mine Yard and Anvil Range's Vangorda Mine. Permission to use these sites was obtained from MEND, R.G. Gardiner (Cominco) and G.A. Jilson, respectively.

All chemical data have been compiled using Microsoft Excel 5. This file format can easily be converted to other formats such as other versions of Excel, Lotus or dBase.

The background information on the five sites is summarized in Table 1-1. The data sources were as follows.

1.4 PROJECT TEAM

The project team consisted of:

- ! Stephen Day, Norecol, Dames & Moore, Inc.;
- ! Tom Higgs, TW Higgs Associates; and
- ! Michael Paine, Paine, Ledge & Associates.

2.0 DATA SOURCES AND STATISTICAL OVERVIEW

2.1 VANGORDA

2.1.1 Data Sources

Water chemistry data for Vangorda was supplied by several organizations including Access Mining Consultants (Greg Jilson), Robertson Group (Linda Broughton), and Indian and Northern Affairs Whitehorse, (Wayne Kettley). Additional data on Vangorda was also extracted from the 1991 and 1992 Annual Reports filed with the Yukon Territorial Water Board.

2.1.2 Site Description and Background Information

The Vangorda site is illustrated in Figure 2-1. The deposits at Vangorda consist of sediment-hosted, stratiform, pyritic massive sulphide. The waste rock consists mainly of massive sulphide rock and phyllite. Most of the data consist of water chemistry data from V-21 which is a seepage collection ditch below the Vangorda Waste Dump. This location is a monitoring station defined by the Water Licence #IN89-002. The seepage collection ditch is fed from a series of six drains constructed through the till berms surrounding the waste dump.

The data set is a good example where oxidation readily occurring but the rate of acid generation is not high enough to overwhelm the neutralization capacity of the waste rock which is hosting the sulphides. At some point in the future, this neutralization capacity may be consumed and ARD may be produced.

2.1.3 Database Description

The water chemistry data available are from five locations at Vangorda waste dump. The raw data from Vangorda are provided in Appendix A. Data collection started at V21 in January 1991 with a requirement for monthly sampling. These data were submitted with the 1991 Annual report for the property. ICP scans were not completed on the samples collected in 1991 - only those metals required by the Licence (total Cu, Fe, Pb, Zn and As) and dissolved Zn. Limited data were available from 1992. The mine was closed in 1992. Sampling was re-started in early 1995 due to planned re-opening of the mine.

V21 is the main station for collection of the waste dump seepage. The remainder of the stations are Drains 3, 5 and 6 which feed into the sump. No samples were collected from V21 from July, 1992 to December, 1992 as no flow was registered in the seepage collection trench or the drains. Data for 1993 or 1994 were not collected for Licence compliance purposes when the mine was shutdown. Some samples were collected by Water Resources of DIAND during 1994 on both V-21 and on Drains 2, 3, 5, and 6. Data have also been collected by Water Resources on these drains in 1995.

2.1.4 Summary Statistics and Data Quality

The monitoring stations and the parameters analyzed as part of the Vangorda seepage collection program are summarized in Table 2-1. The complete analytical results from the individual monitoring stations is provided in Appendix B. A total of 42 samples were collected from the seepage associated

with the Vangorda waste dump. Thirty-three samples are from V21, nine samples are from Drain #3, three samples are from Drain 5 and seven samples are from Drain 6. Trends in pH, sulphate and zinc for V21 are shown in Figure 2-2.

The data were generated by different labs using different detection limits for some elements. Samples were collected by employees, contractors and government employees. The property was managed by a receiver during 1993 and 1994 prior to re-activation of the property in 1995. When the company was in receivership sampling was not conducted since it was not required under the terms of the Water License which designated it as being in Temporary Closure. The data are, therefore, of variable quality. No quality control information was available.

2.1.5 Conclusions

The following general conclusions can be drawn from the data:

- 1) The data consists of water chemistry from seepage associated with sulphide-bearing waste rock that currently has sufficient alkalinity to maintain neutral pH conditions.
- 2) The seepage contains elevated concentrations of sulphate and zinc. Other metals present in the seepage include Al, Ni, and Fe.
- 3) The data have been collected over a period of 4 years but not consistently as the mine was shutdown in 1993 and 1994. The analyses have been conducted using different analytical methods and detection limits.

2.2 CINOLA

2.2.1 Data Sources

The Cinola data set are appended to MEND Report 015SQ.23440-2-9271 (Norecol, Dames & Moore, Inc. 1994.) The data were supplied in CSV (comma separated value) file format.

2.2.2 Site Description and Background Information

A number of ARD assessment programs were conducted at the Cinola site between 1987 and 1992. One of these projects involved construction and monitoring of four 20- to 30-tonne on-site waste rock test pads designed to assess the kinetics of acid generation under actual field conditions for four of the main rock types encountered at the Cinola property. The material placed on each pad was as follows:

- Pad 1 Five-year weathered Silicified Skonum Sediments (20+)
- Pad 2 Silicified Skonum Sediments (30+)
- Pad 3 Argillically-Altered Skonum Sediments (30+)
- Pad 4 Brecciated Skonum Sediments (30+)

The rock contained a few percent sulphur with negligible neutralization potential. The leachate from each of these pads was collected by an underdrain system and directed to collection barrels which were sampled periodically. The monitoring intensity was greatest in 1987 and 1988 when the property was

being actively developed. Sampling was suspended between October, 1988 and July 1990 (Figure 2-3) when active development of the property was halted. Sampling and monitoring was reactivated in 1990 and continued until April, 1992 under a MEND contract.

2.2.3 Database Description

The water chemistry data was generated from analyses of the leachate from the four waste rock test pads described above. Approximately 57 leachate samples were collected from the each of four pads over a six year period from February, 1987 to April, 1992. All samples were analyzed for pH, conductivity, alkalinity, sulphate, acidity to pH 4.5, acidity to pH 8.3, SiO₂, and dissolved metals by ICP including Hg. The data are provided in Appendix B.

2.2.4 Summary Statistics and Data Quality

The monitoring program conducted for the Cinola test pads is summarized in Table 2-2. A total of 57 samples were collected from each test pad over the 5-year period, however no samples were collected in 1989 and only one sample was collected in 1990 (Figure 2-3). The data set is fairly comprehensive in that it includes a complete ICP metal data and was collected over two full year periods in 1987 and 1988. All test materials generated acid (pH<4) throughout the monitoring program.

Detection limits utilized, especially after late 1990, were high relative to the current limits used for assessment of environmental samples. No data quality control monitoring was completed. Values less than detection limits were recorded as detection limits (i.e., with no "<"). Therefore, values below detection limits could not be identified and distinguished from values at detection limits.

2.2.5 Conclusions

The following general conclusions can be drawn for the Cinola data set:

- 1) The water chemistry data provides a comprehensive data set over a time frame of five years from four different rock types. These rock-types were prone to acid generation due to their very low carbonate contents.
- 2) The data includes complete ICP metals and major anions for many of the samples.
- 3) All leachates with the exception of Pad 1 contained elevated concentrations of Fe and significant concentrations of Zn and Cu.

2.3 SULLIVAN MINE

2.3.1 Data Sources

The Sullivan data set was extracted from a report titled "Waste Characterization, Hydrogeological and Water Quality of the Lower Mine Yard Sullivan Mine" prepared by Dames & Moore. Permission to use the data was provided by R.T. Gardner of Cominco Ltd., Kimberley Operations.

2.3.2 Site Description and Background Information

Sullivan Mine is located in southeastern British Columbia near Kimberley.

The Lower Mine Yard of the Sullivan site and the relative locations of the monitoring stations are shown in Figure 2-4 and 2-5. Waste rock containing 1 to 3% total sulphur was deposited along valley sides from 1903 to the mid-1930's (Figure 2-4). The rock contains negligible neutralization potential and is strongly acid generating (Table 1-1.)

2.3.3 Database Description

Water chemistry has been monitored at 13 seepage or groundwater stations in waste dump areas (Figure 2-4) and six surface water sampling stations on Mark Creek (Figure 2-5). The samples were collected in August, 1992; March, 1993; and June, 1993. All samples were analyzed for pH, conductivity, alkalinity, sulphate, acidity and ICP dissolved metals. The same laboratory was used throughout the monitoring program.

2.3.4 Summary Statistics and Data Quality

The monitoring program for the selected groundwater and surface water stations at Sullivan is summarized in Table 2-3. The raw data is provided in Appendix C. Sixty-five samples are included in the data set. Considerable variation in pH, sulphate and dissolved metals was observed. The groundwater pH ranged from 8.47 to 1.85 with a mean of 5.4 while sulphate ranged from 9 to 14000 mg/L SO₄ with a mean of 800 mg/L. Metal concentrations exhibited similar variation. Low detection limits for the metals were consistently used. Surface water pH ranged from 8.3 to 2.53 with a mean of 6.1 while sulphate ranged from 2900 to 0.5 with a mean of 256.

Quality control monitoring included sampling blanks and for duplicates. Ion balances were less than "20% for all samples.

2.3.5 Conclusions

The data set provides comprehensive information from a spatial distribution perspective but represents a limited time frame of one year.

2.4 MINE DOYON

2.4.1 Data Sources

The Mine Doyon data set was extracted from an unpublished MEND report supplied by Natural Resources Canada, Canada Centre for Mineral and Energy Technology, (Carl Weatherell). The data were supplied in Excel 5.0 format.

2.4.2 Site Description and Background Information

Doyon gold mine is located between Val D'Or and Rouyn, Quebec. A general layout drawing for the Mine Doyon site is provided in Figure 2-6. From 1978 to 1989, the open pit mine generated 47 million tonnes of overburden and waste rock. The waste was placed in two dumps designated as the "North"

and "South" dump. Both dumps contained 20 million tonnes of waste. The south dump covers about 53 hectares and is 40 metres deep. Rock types found in the waste include intermediate tuffs, volcanoclastics, schists, diorite and alaskite, with pyrite concentrations ranging from a low of 1.5% in the diorite to 7% in the schist. The reactivity of the pyrite is accentuated by the friable nature of the sericite schist. This highly reactive sericite schist makes up 50% of the composition of the South dump. The South dump was the focus of a major MEND Prediction committee research project that has generated an extensive data set for a series of groundwater and surface water stations.

2.4.3 Database Description

The Mine Doyon Monitoring Program is summarized in Table 2-4 with the raw data provided in Appendix D. The dataset includes 16 groundwater monitoring stations in the waste dump area and three collection ditch stations downstream of the Dumps. Sample collection and analyses from these stations was intensive with 89 samples from the groundwater stations between March 1991 and December 1992, and 607 samples from the collection ditches between January 1991 to December 1992 period. The groundwater samples were analyzed for pH, Eh, conductivity, specific gravity, total dissolved solids, acidity, sulphate and metals in some cases. In many cases, the chemical composition of the samples was calculated using TDS or conductivity data based on relationships derived by Choquette et al. (1993). The data set also includes historical data from ditch monitoring stations prior to 1991, available for three sampling points (D-301, 302 and 309). Station D-301 was located in the southern portion of the eastern ditch, monitoring the leachate coming from the eastern part of the dump. Station D-302 was located in the north-west corner of the dump, approximately 100 m to the north-west of monitoring station D-510. D-309 was located in the eastern part of the south ditch. Monitoring station D-511 collects the leachate from both east and south ditches.

2.4.4 Summary Statistics and Data Quality

The data base from Mine Doyon is extensive and covers an area closely associated with the South Dump. The data set was collected over a relatively short time frame and utilized a relatively frequent schedule.

No QA/QC information was available

2.4.5 Conclusions

The data set is extensive in terms of the physical parameters but contains limited ICP metal data. The data set relies heavily on calculated values for data interpretation. The approach taken in the Mine Doyon study was similar to that proposed for this program.

2.5 ESKAY CREEK MINE

2.5.1 Site Description and Background Information

The Eskay Creek Mine is located approximately 94 km north-northwest of Stewart in northern British Columbia. The Mine is located in a very mountainous area approximately 50 km from the BC/Alaska border. The site drains to Eskay Creek which ultimately drains to the Unuk River which flows to Alaska.

The 21B deposit, which is currently being mined, is characterized by stratabound and stratiform high-grade gold and silver bearing base metals sulphide layers. Banded sulphide mineralization occurs in carbonaceous and tuffaceous mudstones of the contact unit.

2.5.2 Database Description

The water chemistry data set from Eskay used for this program consisted of 69 waste dump discharge samples (Station D-2) collected over a four year period from January 1991 to June 1995 (Table 2-5).

Approximately 70,000 tonnes of waste rock was removed from the upper portal during mine development. This rock was placed on a waste dump adjacent to the portal. The composition of dump was as follows:

Argillite	10,000 t
Massive Rhyolite	10,000 t
Brecciated Rhyolite	20,000 t
Dacite	30,000 t

Seepage run-off from the waste dump was collected and discharged to a settling pond constructed to remove sediment from mine water. A drawing showing the relative locations of the portal, waste dump and seepage collection pond is provided in Figure 2-7. Monitoring of the waste dump seepage, designated as Station D-2, indicated in 1992 that acid generation was occurring in the dump (Figure 2-8). In 1994 a portion of the waste rock dump was moved and deposited in a waste rock impoundment, referred to as Albino Lake. The Eskay Creek Mine started up in April 1995. Most of the dump was moved to the impoundment in 1995, while the remainder will be moved in 1996.

The data set includes a complete parameter list of all major anions and an ICP multi-element scan for both total and dissolved metals.

2.5.3 Summary Statistics and Data Quality

The data set is a very comprehensive from a single source of ARD. The data was generated using one lab only and the ICP metals were analyzed to low detection limits for As and Hg due to concern with leaching of these elements.

No QA/QC information was available for the data set.

2.5.4 Conclusions

The following general conclusions can be drawn from the data set for Eskay Creek.

- 1) The water chemistry data provides reasonably comprehensive information over four year period for a dump containing a mixture of different rock types. This dump include both highly reactive and non-reactive materials.
- 2) The data includes complete ICP metals and major anions.

- 3) The data set includes samples prior to the onset of acid generation.

2.6 DETECTION LIMITS

Detection limits varied considerably both between data sets and within each data set. Improvements in instrumentation and procedures have consistently reduced detection limits in recent years. Detection limits for As, Sb and Hg (if determined) also vary considerably since these elements can require separate procedures if low detection limits are required. In general the data set from Sullivan has utilized consistently low detection limits, e.g. As - 0.0001 mg/L, Cd - 0.00002 mg/L, Cu - 0.001 mg/L.

Detection limits for the Vangorda data set varied considerably since the samples were collected by different individuals and were analyzed by different labs over an extended time frame. Detection limits for several metals in the Cinola data set were increased after monitoring resumed in 1990.

3.0 APPLICATION OF THE EMPIRICAL MODELLING APPROACH

3.1 INTRODUCTION - METHODOLOGY DESCRIPTION

3.1.1 Statistical Modelling

For each site, all available water quality data were combined into a single spreadsheet file. Records with no pH or conductivity data were deleted. Parameters with $n < 10$ were also deleted. All parameters except pH were log-transformed. Finally, values less than detection limits were set to 0. These values were not included in plots and statistical analyses because values of 0 cannot be log-transformed. This approach was taken since detection limits for most data sets were extremely variable. For the Cinola data set, values less than detection limits were recorded as detection limits, so all values were used in regressions. Over 200 scatter plots of commonly detected metals and metalloids versus pH, conductivity and sulphate were then generated. The plots were examined to determine if one regression was adequate to fit the data, or whether separate regressions were required for different sites or other subsets of the data.

Required regressions, or in some cases, means, were calculated using SYSTAT statistical software (Version 5.3; Wilkinson 1990). Outliers, if present, were deleted, and the regressions recalculated. Outliers were defined as cases with absolute values of Studentized residuals > 3 . A Studentized residual is approximately equivalent to the number of SD a residual is from the mean or regression line; a more precise definition is given by Velleman and Welsch (1981). If new outliers were identified when the regression was recalculated with the first set of outliers deleted, no further data trimming was performed. To conserve time and paper, histograms of residuals were not plotted for each regression. Instead, stem-and-leaf plots were made. These plots are described in detail in Wilkinson (1990; p. 550), and are generally more informative than histograms.

SD of residuals were not calculated. Morin and Hutt (1993) calculated SD of residuals, but that is statistically incorrect. The correct statistic describing the variation of the residuals or precision of predicted values is the standard error of the estimate (S_{xy}). The standard error of the estimate accounts for the fact that two parameters (slope and intercept) must be estimated from the sample in regression, rather than the one (mean) estimated in calculating the SD. S_{xy} can be obtained by multiplying SD of residuals by $(\{n-1\}/\{n-2\})^{1/2}$. The difference between S_{xy} and SD of residuals is trivial ($< 3\%$) except for small data sets ($n < 20$).

3.1.2 Overall Comments

Figures 3-1 to 3-18 provide plots (including regression lines) and histograms of residuals for a selected subset of data. Tables 3-1 to 3-5 summarize regression statistics (intercept $\{b\}$, slope $\{m\}$, R^2 , P) for all calculated regressions for each site. In some cases, regressions were calculated for subsets of data, separated by sample site or type, or by pH range. Specific examples are discussed below and in the sections on each site. When no relationship was evident, means rather than regressions were calculated. Since values less than detection limits were usually excluded, these means are biased upwards. Slopes and intercepts in Tables 3-1 to 3-5 are based on \log_{10} transformations.

Most regressions were significant at $P < 0.05$, and usually at much lower P values. The low P and high R^2 values clearly demonstrate the success and utility of the empirical approach described by Morin and Hutt (1993). Furthermore, all slopes of significant regressions on pH were negative, and all slopes of significant relationships with conductivity and sulphate were positive, with two exceptions: slopes for Sr and U versus pH for Eskay Creek were positive. Regressions for both elements were based on small sample sizes ($n < 20$) and a restricted pH range ($\text{pH} > 6$). Uranium may behave differently from other elements due to oxidation state variability; however, the result for strontium cannot be explained as it normally shows similar behaviour to calcium.

Although the empirical approach was generally successful, there were some problems with specific regressions and the methods of Morin and Hutt (1993). These problems were:

- ! non-linearity of relationships;
- ! non-normality of residuals;
- ! large influence of extreme points;
- ! use of histograms to assess residuals; and
- ! values less than detection limits.

These problems were related, and are discussed briefly with examples below and in the sections on each site. Most of the problems can be eliminated using methods applied in this study, or by refining the methods of Morin and Hutt (1993) to conform with standard regression and statistical diagnostic procedures (e.g., Draper and Smith 1981). These refinements will be discussed and demonstrated in Chapter 4 of this report. Specific regressions in Tables 3-1 to 3-5 and from other data sets should never be applied uncritically.

Some relationships were non-linear even after log transformation. Many of these relationships could be linearized by separating sites, as done for Cinola and Mine Doyon. In other cases, relationships were linear over the lower portion of the pH range, and flat at higher pH. The relationship between dissolved As and pH for Eskay Creek demonstrates this "hockey stick" type of relationship (Figure 3-17a). A linear regression ("shaft") existed below $\text{pH} = 6$. Above $\text{pH} = 6$, there was no relationship and Figure 3-17a) shows the mean As over this range ("blade" or negative asymptote). In this example, the pH break point between the blade and shaft was visually obvious, and the same break point also applied to Mg. Relationships of As and Mg with conductivity and sulphate followed a more linear relationship (Figure 3-17a). In other cases, such as B, Cu, Fe, Ni and PO_4 versus pH for Sullivan, a break point was evident but differed among the parameters. Again, relationships with conductivity and sulphate were smoother, with no obvious break point. These hockey stick and other non-linear relationships were impossible to detect without examining plots and regression diagnostics, and often provided significant log-log relationships (Tables 3-1 to 3-5).

Many of the distributions of residuals appeared non-normal, although that was sometimes an artifact of the class intervals selected (see below). Non-linearity was one cause of non-normal distributions.

Other causes included truncation by deletion of values less than detection limits for means and blades, outliers, and cases where only a few discrete concentration values were measured. These issues are considered in the discussion of histograms.

Some regressions were highly significant, with high R^2 , only because of the influence of a few extreme observations at either end of the regression line. For example, relationships between Cu and Zn for Pads 2-4 from Cinola were strongly influenced by a few points at the lower right (i.e., pH >5) (Figures 3-4a and 3-5a). These points are arguably no different from the Pad 1 values. If these points were deleted, the slopes of the relationships for Pads 2-4 would be much steeper. Residuals from these relationships appeared bimodal or at least non-normal and asymmetric (Figures 3-4b and 3-5b). The influence of these extreme values can be removed by removing the observations at pH >5; by weighting them less than other observations; or by collecting additional observations for pH values between 3 and 5. The latter option is preferred when feasible.

Histograms were used to assess normality of residuals, following Morin and Hutt (1993). However, histograms are not suitable unless n is large (i.e., >50-100) and intervals are chosen carefully. If n is small, there are few observations in any interval. For example, the distribution of residuals from the regression of Zn on conductivity for Vangorda appears non-normal (Figure 3-2b) but that might be an artifact of the limited number of observations (#6) in each interval. In other cases, the interval chosen may bias the appearance of histograms. For example, the distribution of residuals from the Zn versus conductivity regression for Cinola Pads 2-4 appears to be shifted right, with the mode at 0.20 rather than 0 (Figure 3-7c). This apparent non-normality is an artifact of the interval selected. Each interval spans 0.20 log units (e.g., the 0 interval spans -0.10 to 0.10). Negative and positive residuals tended to be clumped towards the low end of interval ranges; the interval mid-points overestimate the mean of the values within each interval.

Biases in histograms occur in part because of the continuous distribution of predicted values versus the discrete distribution of measured values. A predicted value may be 48.87965 mg/L, but measured values may be restricted to whole numbers. Problems of continuity were greatest for means calculated for values near detection limits, since there might only be two or three possible measured values. For example, if detection limits are 1 mg/L, and measured values are whole numbers ranging from 1-5, there are only five possible values for residuals. The resulting histogram will show peaks for the intervals containing the five possible values, and no observations in other intervals. This clumped type of distribution is evident for some of the Cinola Pad 1 "regressions" which are just horizontal lines corresponding to the mean of detected values.

Most of the problems associated with histograms can be avoided by using other diagnostic plots such as box-and-whisker plots, normal probability plots, and plots of residuals versus estimates. As Figure 3-17a demonstrates, residuals from two separate relationships should not be pooled. The residuals from the shaft are relatively continuous, whereas the residuals from the blade tend to be clumped in a few intervals corresponding to a limited number of measured values near detection limits. The variances of residuals from the two parts of the hockey stick were also different.

Values less than detection limits pose special problems. Removing them or treating them as 0 may bias regressions and estimates of means. Using one-half detection limits for values less than detection limits gives a better estimate of the mean, but creates biases and problems with continuity and normality of residuals. In many cases, values less than detection limits may not be of concern environmentally, and

can safely be ignored. The shaft or linear portion of hockey stick relationships is more important, because this is the region in which high concentrations occur and need to be predicted. Finally, all values less than the Practical Quantitation Limit (PQL; usually ~ 5 times detection limits) are arguably qualitative not quantitative, and should be treated as such (Taylor 1987; see also Section 4.1). Investigators specifically interested in predicting low concentrations should use lower detection limits in the initial data set used to develop empirical models.

Finally, although regressions within mines were generally significant and successful, slopes and intercepts differed among mines for any specific set of Y and X . The significance of these differences among mines was not tested formally, but could be done as part of the next phase. Similarities and differences in slopes are discussed in Section 3.2.

3.1.3 Site Results

Vangorda

Regressions for Vangorda were generally less significant than those for other mines, partly because sample sizes were smaller. Of the measured metals, only Zn (Figure 3-1 to 3-2) and Fe were significantly correlated with all three independent variables (pH, conductivity, sulphate). As was significantly correlated with sulphate only; Cu was significantly correlated with conductivity only (Figures 3-3); Pb was not significantly correlated with any independent variable. The relatively weak relationships may reflect the fact that acidification had not progressed to where low pH and high metal concentrations are routinely or frequently measured.

Cinola

Regressions for Cinola included values less than detection limits since these were recorded as detection limits in the data set provided. No regressions were conducted for Cd and Pb because detection limits were raised in 1990 to 0.5 and 0.1 mg/l, respectively. These detection limits were well above any values measured from 1987 to 1989. Detection limits were also raised in 1990 for Co, Hg and Ni. Most concentrations from 1987-89 for Pad 1 were below the later detection limits, so no regressions were calculated for Pad 1 for these metals. However, most 1987-89 values for Pads 2-4 were above the later detection limits, so regressions were calculated for Pads 2-4.

As expected, relationships between metals and independent variables for the weathered Pad 1 were weak or non-existent, and pH were higher than in Pads 2-4 (Figures 3-4 to 3-7). Some furthering leaching may be expected at Pad 1 as some regressions were significant and some metals remained well above detection limits. The other pads had lower pH and higher metal concentrations, and the strong relationships for these pads indicated the effects of leaching at lower pH. For some metals (e.g., Mn, Mg) relationships for Pad 4 differed from those for Pads 2 and 3. This is related to the total metal content of the test materials.

Sullivan

All regressions listed in Table 3-3 for Sullivan mine were significant, most at $P < 0.001$ (Figures 3-8 to 3-9). Some of the relationships were driven by a few extreme points with high concentrations at low

pH; these extreme observations had greatest influence for the linear or shaft portion of hockey stick relationships for B, Cu, Fe, Ni and PO₄. Relationships between these five parameters and conductivity and sulphate were apparently curvilinear and log-log regressions given in Table 3-3 are suspect. Ground- and surface water samples were pooled for the regressions, as differences between the two water types (which have the same origin) were not visually obvious.

Mine Doyon

Regressions based on measured rather than calculated values for Mine Doyon seepage and borehole samples listed in Table 3-4 were all significant, usually at $P < 0.001$. Selected regressions are provided in Figure 3-10 to 3-13.

Eskay Creek

Regressions for the Eskay Creek data were all significant, usually at $P < 0.001$ (see also Figures 3-14 to 3-18). Break points for hockey stick relationships for As and Mg versus pH were evident at pH=6 (As, Figure 3-17). Despite the limited sample sizes for the shaft (n=26 for As), regressions for pH#6 were significant at $P < 0.001$. Relationships in the blade region were not significant at $P < 0.05$.

The Eskay Creek data set and regressions were used for an intensive examination of outliers. Table 3-6 summarizes the outliers observed. Primary outliers were values with absolute values of Studentized residuals > 3 . Secondary outliers were values with absolute values of Studentized residuals > 3 in regressions with the primary outliers omitted. Morin (Morin and Hutt 1993; comments on a previous draft of this report) treats outliers as "real" (i.e., valid short-term peaks or lows in metals concentrations). Some of the outliers observed, especially those which were outliers for several metals, probably were real. However, most outliers appeared to be represent measurement or data entry errors for either the Y or X variable. The frequency of real outliers versus measurement or data entry errors in empirical models will depend on the quality of the data, indicating that data quality should always be checked and improved if possible.

The sample collected February 28, 1995, with pH=13.9, was eliminated from all analyses of Eskay Creek data. This sample was probably preserved with NaOH for cyanide analyses, and inadvertently submitted for other analyses. Note that conductivity in this sample was much higher than conductivity in other samples in Table 3-6, presumably reflecting the high Na content after NaOH addition.

When samples are outliers for regressions on only one X-variable (e.g., pH), investigators should suspect that the X-variable may be in error. For example, the sample collected March 16, 1992, was an outlier (positive) for most regression of metals on pH. The pH in this sample was 10.3, > 2 pH units higher than in any other sample except the sample with pH=13.9. The pH measurement was probably a measurement error, since pH > 10 are not characteristic of natural surface or ground waters (McCutcheon et al. 1993; his list includes thermal springs with pH . 9.0-9.5).

Outliers for regressions of Sr and U on all three X-variables were similar, and reflected limited sample sizes and the large influence of a few points. For some reason, these two elements were measured only in samples with pH > 6 , so the range of the X-variables was restricted.

Some samples were outliers, often only secondary outliers, for only one or two of the 45 regressions calculated. These outliers were probably more indicative of natural variability than any specific peak or low contamination event. Studentized residuals with absolute values >3 will occur at a low frequency (#1% for the Eskay Creek regressions), even if distributions of residuals are normal with no real outliers.

Some samples were outliers for only one metal. For example, the sample collected May 31, 1995, was a positive primary outlier for all three Pb regressions. The Pb value was probably a measurement or data entry error, as there was no reason to expect only Pb to be elevated. However, the hypothesis that the sample may represent some specific heavy-metal contamination peak cannot be totally rejected because Cd and Zn measurements were also positive secondary outliers.

Finally, there were some samples which probably did represent real peak or low contamination events, as these samples were outliers for several different combinations of Y and X variables. Examples include the two samples collected May 14 and 22, 1992, which may represent peak contamination occurring over a week or more due to snow melt. No flow data were available to test this conclusion. This was a fundamental shortcoming of all the datasets.

3.1.4 Summary and Conclusions

In most cases, the empirical approach described by Morin and Hutt (1993) was successful, as regressions were significant and accounted for much of the variance of dependent variables (i.e., metals and metalloids). Most problems identified could be solved by applying standard statistical and diagnostic procedures to refine the methods of Morin and Hutt (1993). Thus, metal concentrations within any site could be predicted from easily measured and inexpensive parameters such as pH, conductivity and sulphate rather than measured directly. Costs of water quality monitoring could be lowered and/or sampling frequency increased. Although empirical relationships were significant, they probably differ among mines and even among sites or sample types within mines. Comparison of relationships for different sites is provided in Section 3.2. This issue, plus the refinement of the Morin and Hutt (1993) methods will be considered in Section 4.0.

3.2 GEOCHEMICAL MODELLING

3.2.1 Methodology

Introduction

The objective of the geochemical modelling was to ascertain whether the statistically quantified bivariate relationships could be related to actual chemical conditions within the waste rock piles being monitored. The main features to be explained are:

1. The strong negative correlations between element concentrations and pH; and
2. The strong positive correlations between conductivity and element concentrations.

In its simplest terms, the chemistry of waters in contact with mine waste rock is controlled by the chemistry of the water entering the pile and interactions with minerals contained in the rock. The

dominance of sulphate and the strong correlation of sulphate with other parameters indicates that the main chemical processes are oxidation of sulphide minerals, release of acidity and leaching of minerals along drainage pathways. Leaching occurs in proportion to the amount of acidity available and continues until the solution is buffered at a pH in equilibrium with the weathering products. Reactions are not likely to proceed to true equilibrium since percolating groundwaters are not in contact with any individual mineral grain long enough to allow development of equilibrium conditions. Nonetheless, the bulk chemistry of the waters may appear to be in equilibrium with the percolating waters if the pile is relatively consistent in mineralogical composition, and large enough to allow water chemistry to approach a chemical endpoint.

The steps used to evaluate the derived statistical relationships with respect the geochemical processes were as follows:

1. Use the equilibrium speciation model MINTEQA2 to determine whether water chemistry is potentially controlled by dissolution of minerals potentially present in the waste rock. This step was divided into an overall comparison of saturation indices for many minerals and a specific investigation of pH vs element relationships for specific hydroxide and carbonate minerals.
2. Compare bivariate relationships with expected relationships due to leaching of minerals in the absence of chemical equilibrium.

Application of MINTEQA2

MINTEQA2 (Allison et al. 1991) is a modified version of MINTEQ (Felmy et al. 1984). MINTEQA2 has a larger thermodynamic database than MINTEQ and also implements the calculations differently. The models permit calculation of geochemical equilibrium speciation using chemical analyses and mineral assemblages as inputs. The fundamental limitation of these models is that it is assumed that equilibrium is attained. No allowance is made for reaction kinetics which may preclude the formation of dissolved species and solids. Output from MINTEQA2 must be considered in this context.

A feature of MINTEQA2 is that the model allows saturation of the solution with respect to all minerals in its database for which components have been specified to be assessed. Based on the solution speciation, the model calculates the ion activity product (IAP) for each mineral. For example, the IAP for anhydrite (CaSO_4) is:

$$a_{\text{SO}_4^{2-}} \cdot a_{\text{Ca}^{2+}}$$

where a is the activity of the individual species, which is less than the concentration by the activity coefficient. The IAP is compared to the solubility product (k_{sp}) for the mineral and presented as log of the saturation index (SI):

$$\log(\text{SI}) = \log(\text{IAP}/k_{\text{sp}}).$$

If $\log(\text{SI})$ is greater than 0, the solution is said to be oversaturated with respect to a particular mineral, suggesting that the mineral is forming. If $\log(\text{SI})$ is less than 0, the solution is undersaturated,

suggesting that the mineral is dissolving.

For each model run, MINTEQA2 was allowed to calculate SIs for each mineral. Although the model allows solids to be dissolved or precipitated, this was not done. The SIs were evaluated to assess which minerals if any would be saturated and therefore controlling the overall chemistry of the solution.

Selection of Samples

Since four of the five databases indicate very strong inter-correlation between sulphate, pH and many other parameters, samples were selected for each correlation trend to represent high, intermediate and low total dissolved solids (TDS) represented by electrical conductivity. The exception was the Cinola site for which distinctive trends for the different pads were modelled separately.

Specific Limitations of MINTEQA2

In addition to the general constraints imposed by the assumption that equilibrium conditions develop, several specific limitations were encountered for this project, as described below.

- ! Absence of Aqueous Species. None of the datasets included a comprehensive analysis of all potential ions. In some cases, major cations (such as Ca^{2+} , Mg^{2+}) and anions (Cl^- , F^- , PO_4^{3-}) were not determined. This shows up as a charge imbalance. MINTEQA2 can reject excessive charge imbalances, however, this was not allowed.

Although silica has a zero charge in solution (H_4SiO_4^0), the lack of silica analyses in some databases prevents assessment of the contribution of silicates.

Analysis of trace ions was also not complete and variable between the datasets.

- ! Absence of Gas Data. No gas data were available. Therefore, partial pressures could not be reliably estimated for O_2 and CO_2 . Oxygen was not specified as a component (see "Absence of Oxidation-Reduction Data" below). Carbon dioxide was constrained at atmospheric partial pressure ($10^{-3.5}$ atm) for acidic piles. If alkalinity was measured, it was specified, and, in conjunction with constrained pH, defined the CO_2 partial pressure.
- ! Absence of Oxidation-Reduction Potential (ORP) Data. Four of the five datasets had no measures of oxidation-reduction conditions. ORP was not determined, nor were oxidation-reduction couples measured. Mine Doyon was the exception. Both Fe^{2+} and Fe^{3+} were measured in solutions. For all other sites, only total Fe was determined. This was arbitrarily entered as Fe^{3+} . Oxidation states were also assigned to Mn(III), V(III), As(V), Cr(VI) and S(VI).
- ! Interpretation of Alkalinity. Since most waters were acidic, alkalinity was not determined. For slightly acidic and alkaline waters, total alkalinity was reported as mg CaCO_3/L . MINTEQA2 allows alkalinity to be entered in this format. However, the analytical total alkalinity includes all species that can consume acid, these include not only bicarbonate and carbonate but also other aqueous species and suspended matter. This complication was ignored for this project

since the majority of waters were acidic (negligible bicarbonate alkalinity).

- ! Modelling of Adsorption Processes. MINTEQA2 allows adsorption processes to be modelled; however, no data are available to allow specific adsorption sites to be modelled.

3.2.2 Results of MINTEQA2 Modelling of Water Chemistry

Modelling runs are summarized in Tables 3-7 to 3-11. Only minerals for which log(SI) are greater than -1 are reported. All other minerals are omitted for clarity.

Vangorda

The Vangorda Mine dataset is unique for this project in that the seepage mostly has pH>7. A strong correlation was observed between TDS (conductivity) and many other parameters. Low TDS corresponded to low concentrations and higher pH. High TDS corresponded to higher concentrations of metals and lower pH. There is a distinctive grouping of the data for these two conditions. Therefore two samples were selected to represent high and low TDS conditions. The high TDS sample was dominated by sulphate and elevated heavy metal concentrations. The low TDS sample had an order of magnitude less sulphate and about the same alkalinity. Modelling results for the two samples were dissimilar, although this was partly due to the lack of a consistent dataset for the two samples.

Results for two samples were very similar (Table 3-7.) The solutions were over-saturated with respect to limonite-type minerals (jarosite, ferrihydrite, goethite, hematite and lepidocrocite). The dominant complexing anion in solution was OH⁻. Both solutions were oversaturated with respect to smithsonite (ZnCO₃). The low TDS sample was saturated with respect to several zinc hydroxides indicating that solution chemistry was being controlled by these minerals.

Cinola Gold Project

The Cinola Gold Project differs from the other sites in that different trends in conductivity vs. sulphate and other parameters were observed for Pad 1 when compared to Pads 2, 3 and 4. Pads 2 and 3 also showed distinctively different bivariate trends from Pads 1 and 4 when considering magnesium vs. conductivity and pH. Seven different sample cases were modelled to evaluate the differences between the various trends.

Results from the model runs showed very little difference between any of the cases (Table 3-8.) Oversaturation with respect to the various limonite minerals (ferrihydrite, jarosite, goethite, hematite, lepidocrocite) and manganese hydroxides and oxides was predicted. The presence of a montmorillonite-type clay was predicted by oversaturation with respect to notronite. Although significant differences in trends in bivariate space are apparent, the MINTEQA2 modelling offered no explanation for the trends.

Sullivan Mine

The Sullivan Mine dataset contains water chemistry for groundwater monitoring wells located upgradient, within and downgradient of waste rock placed on the sides of a valley. The waste rock is at least 60 years old and visibly heavily oxidized.

The data belong to a single trend in 2-dimensional space. High TDS values correspond to low pH (<4), and high concentrations of sulphate and dissolved metals. These waters originate from within the waste rock. Higher pH (between 7 and 8) waters originate from wells upgradient of the waste rock. These latter waters are not indicative of interaction with waste rock but with local unmineralized bedrock and surficial materials. Three samples were selected for modelling, representing extremely acidic (~2), very acidic (~3.5) and neutral (~7) pH.

Both the extremely and very acidic samples were indicated as being over-saturated with respect to limonite-type ferric minerals (goethite, lepidocrocite, hematite, jarosite), gypsum (anhydrite will not be stable), celestite and manganese hydroxide (MnOOH, manganite) (Table 3-9.) Weathering products of aluminosilicates were indicated as over-saturation with respect to various forms of silica (chalcedony, cristobalite, quartz and silica precipitates) and montmorillonite-type silicates (nontronite). The very high log(SI)s for nontronite indicates that this mineral in particular was not present and that some other clay mineral was probably controlling solution chemistry. Since the modelling results were very similar for the two samples despite the difference in TDS, it appeared that the strong bivariate correlations between all parameters were driven by the linkage between sulphate, acidity and leaching rather than saturation controls.

Since pH was low, there were no indications of saturation with respect to the trace heavy metal sulphates, hydroxides or carbonates (for example, Zn, Pb, Cu).

These modelling results were consistent with the strongly oxidized nature of the waste rock.

In comparison, the chemistry of upgradient groundwater appeared to be controlled by interaction with calcite and possibly dolomite. Silica concentrations appeared to be near saturation for quartz.

Mine Doyon

As with the foregoing sites, the Mine Doyon dataset showed a strong relationship between conductivity and most other parameters. Metal concentrations were also correlated with pH. Lower pH generally correlated with higher metal concentrations. The majority of samples collected from waste rock sites at Mine Doyon were very strongly acidic. Although both Fe²⁺ and Fe³⁺ were determined, Fe³⁺ is clearly dominant.

Three samples were selected representing high, medium and low TDS. The high TDS sample did not have a silica or aluminum analyses therefore saturation with respect to aluminosilicates could not be addressed.

Results for the intermediate and low TDS samples were very similar, and after allowing for missing data, the high TDS sample was also similar (Table 3-10.) Oversaturation with respect to the various

limonite minerals (ferrihydrite, jarosite, goethite, hematite, lepidocrocite) and manganese hydroxides and oxides was predicted. The high and intermediate TDS samples were predicted to be oversaturated with respect to gypsum. The intermediate and low TDS samples were predicted to be oversaturated with respect to Al(OH)SO_4 . Dissolution of silicates and precipitation of secondary silicates was indicated by the montmorillonite-type minerals nontronite.

Eskay Creek

The Eskay Creek database is the only example of data spanning a transition from high to low pH resulting from loss of buffering minerals. Unfortunately, different parameters were analyzed at various times. Silica analyses were not available for the acidic drainages.

The results for this site are very similar to the other sites (Table 3-11.) Oversaturation with respect to the various limonite minerals (ferrihydrite, jarosite, goethite, hematite, lepidocrocite) is predicted for two acidic samples.

3.2.3 Comparison of Metal pH Results for Different Sites

Regression relationships for pH vs. several metals (Fe, Al, Cu, Zn and Pb) determined for each site are compared in Figures 3-19 and 3-20. Since the regression lines were developed for defined pH ranges, line segments are shown on the individual plots. For a theoretical comparison, solubility curves for common secondary minerals are also shown. These curves were generated using MINTEQA2 from simple solutions containing only the particular ion shown. For the three carbonate minerals (malachite, smithsonite and cerussite), the atmospheric carbon dioxide partial pressure ($10^{-3.5}$) was used. Metal-pH comparisons for each metal are summarized below.

Fe-pH

The Fe-pH plot (Figure 3-19a) suggests that waters from several mines were significantly oversaturated with respect to Fe(OH)_3 . The Cinola and Sullivan relationships were similar, and low pH relationships for Doyon, Sullivan and Cinola converged. At higher pHs (in the region of oversaturation with respect to Fe(OH)_3), there was considerable variation in the regression relationships. At lower pHs, iron is probably primarily in solution as Fe^{3+} , resulting in control by Fe(OH)_3 , whereas at higher pHs, iron concentrations are low, near the detection levels and most stable as Fe^{2+} . This latter condition results in oxidative instability of water during sampling. The spread of relationships may partially reflect oxidation of the sample during collection resulting in precipitation of Fe(OH)_3 . Since the oxidation of Fe^{2+} to Fe^{3+} is slow, the effect can lead to a wide range in iron concentrations depending on conditions at the time of sampling.

Al-pH

Al-pH for the various sites were parallel (on a log scale), suggesting a common chemical control. However, several lines crossed the solubility curve for amorphous Al(OH)_3 indicating that this compound is probably not controlling chemistry. Log saturation indices for Al(OH)SO_4 were near 0 for several sites suggesting that this compound may be controlling leachate chemistry. Since it contains sulphate, the solubility curve cannot be represented on a two dimensional since sulphate concentrations

would also control solubility. This may explain the parallel relationships.

Cu-pH

Relationships for Cu varied widely though like Al had similar slopes at lower pHs (Figure 3-20a). Malachite was apparently not controlling water chemistry, and concentrations were too low to be limited by copper sulphate solubility. None of the sites were copper mines which may indicate the abundance of copper in the waste rock may have been a limiting factor.

Zn-pH

Zinc concentrations were much lower than would be generated by a zinc carbonate (smithsonite) constraint for most sites (Figure 3-20b). At lower pH, zinc sulphate is highly soluble indicating that the observed relationships are probably affected by dissolution kinetics and dilution (see below). For Vangorda, higher zinc concentrations are present at higher pH close to the smithsonite solubility curve. If the carbon dioxide concentration in the dump were greater than atmospheric (as is likely in a alkaline system), the Vangorda relationship would indicate smithsonite control. As shown in Figure 3-20b, the smithsonite solubility curve is shifted to the left if the partial pressure of CO₂ is 10⁻¹ atm.

Pb-pH

The Pb-pH relationship (Figure 3-20c) is similar to zinc. The Vangorda relationship approaches solubility control by cerussite. The control at low pH is complex, since in locally strongly acid generating conditions in the vicinity of galena, anglesite (PbSO₄) probably controls lead concentrations since it is relatively insoluble compared to zinc and copper sulphates.

3.2.3 Mineral Leaching

Introduction

The foregoing discussion indicates that modelling of solution chemistry using the equilibrium chemical speciation model MINTEQA2 provides very little insight into the source and evolution of waste rock dump leachate. The purpose of this section is to examine the strong positive correlations and temporal relationships between dissolved solids and determine whether the observed regression relationships can be related to the ideal relationships expected for leaching specific minerals present at the sites.

In this section, bivariate regression relationships for products of sulphide oxidation and acid consumption are evaluated. Sulphate is frequently measured and can be related more or less to sulphide oxidation unless soluble sulphates (e.g. gypsum) are present. Other elements are related to sulphide oxidation (eg. Fe, Mn, Co, Ni etc.) and acid consumption by carbonates and silicates (Ca, Mg, Al, K, Na, P). Considerable overlap between these groups exist due to the inclusion of siderophile and chalcophile elements in carbonates and silicates.

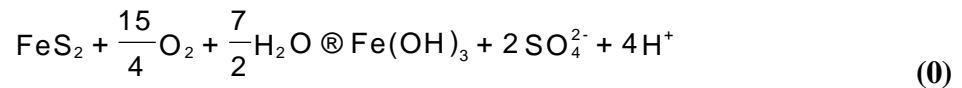
Conductivity is not considered since it is a gross parameter resulting from the overall effect of all dissolved and suspended solids. Total dissolved solids (TDS) is also not useful for this reason. Although pH is a more useful measure of a specific chemical condition, it is unreliable for comparisons

between sites since it is affected by sampling method and storage conditions. Point-of-sampling measurements of pH are preferred although field technician methods may vary widely.

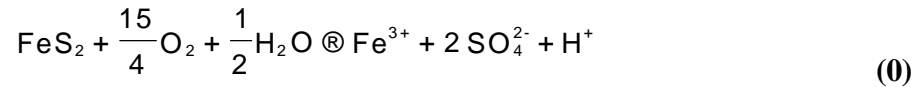
Expected Relationships

The expected relationship between sulphate and other parameters can be illustrated by considering the dissolution of calcite by acidity produced by pyrite oxidation.

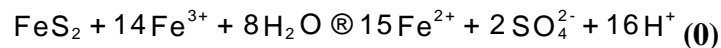
The pyrite oxidation reaction could be described by:



when iron is precipitated as Fe(OH)_3 or, at pH less than 2.3 to 2.5, the Fe^{3+} is not precipitated as Fe(OH)_3 but remains in solution:



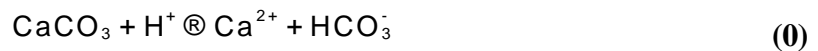
A further complication is that Fe^{3+} in solution from leaching of other minerals as well as oxidation of pyrite is also a strong oxidant:



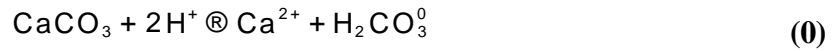
Equation 3 is more likely to represent actual conditions for a strongly sulphidic oxidizing waste rock dump.

The moles of H^+ released by these reactions varies from 1 to 16 moles per mole of pyrite, or 0.5 to 8 moles per mole of sulphate.

The H^+ will react with calcite according to:



at near neutral pH, or according to:



under acidic conditions. Either of equations 4 and 5 could be paired with equation 1, resulting in the expected relationships in solution of:

$$\text{Ca}^{2+} = 0.5 \cdot \text{SO}_4^{2-}$$

$$\log \text{Ca}^{2+} = \log(0.5) + \log \text{SO}_4^{2-}$$

at near neutral pH and

$$\text{Ca}^{2+} = 1 \cdot \text{SO}_4^{2-}$$

$$\log \text{Ca}^{2+} = \log(1) + \log \text{SO}_4^{2-}$$

as the overall conditions become more acidic. Since the overall transition to acidic conditions is gradual as different parts of the dump become acidic, the regression slope for log SO₄ vs log Ca may be greater than 1. Under strongly acidic conditions in which calcite is not sufficiently available to have a significant on overall acidic conditions, equations 3 and 5 combined would yield (in molar terms):

$$\text{Ca}^{2+} = 0.25 \cdot \text{SO}_4^{2-}$$

$$\log \text{Ca}^{2+} = \log(0.25) + \log \text{SO}_4^{2-}$$

From this example, it can be seen that under the ideal conditions indicated the slope of log-log graphs of Ca vs. SO₄ should always be 1, and that the intercept will vary. These relationships will be preserved at low and high dissolved concentrations since the volume of water the molar quantities are present in cancels from both sides of the equation. Deviations from this expected behaviour would be encountered if:

- ! the leachate is saturated with respect to calcium sulphate, in which case the slope of the log-log, sulphate vs calcium graph would be approximately -1 and the log intercept log(k_{sp}):

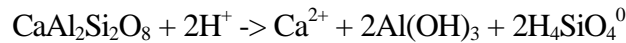
$$k_{sp} = a_{\text{SO}_4^{2-}} \cdot a_{\text{Ca}^{2+}}$$

$$\log(k_{sp}) = \log(a_{\text{SO}_4^{2-}}) + \log(a_{\text{Ca}^{2+}})$$

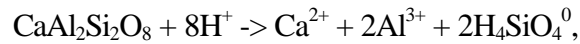
- ! the availability of calcite decreases (slope<1), or the pyrite oxidation rate slows to the point where release of calcium is due to leaching of calcite by non-acidic water (slope>1).

Figure 3-21(a) summarizes expected trends in Ca and SO₄ based on the above discussion. The Figure illustrates the predicted relationship between SO₄ and Ca in relation to progression of sulphide oxidation. For each segment, the expected correlation coefficient for the trend data is shown. Correlations are expected to be weakest early and late in the process. It should be noted that if all trends were present in a particular dataset, the correlation coefficient would be weak or statistically insignificant due to data scatter.

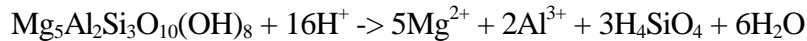
When considering elements, such as Fe and Al which are controlled by the solubility of secondary minerals, the application of this example becomes more complex. For example, Al concentrations in solution may be a result of leaching of feldspars (anorthite). At pHs greater than 4.5, aluminum concentrations in solution will be low due to the precipitation of aluminum hydroxide at the reaction site:



However, as pH drops and Al appears in solution:



similarly for chlorite, a common hydrothermal alteration product:



The expected relationships between SO₄²⁻ and Al³⁺ in combination with equation 1 would be:

$$\text{Al}^{3+} = 2\text{SO}_4^{2-} \text{ (anorthite)}$$

$$\text{Al}^{3+} = 4\text{SO}_4^{2-} \text{ (chlorite)}$$

The log-log slopes are both 1 and the intercepts are log(2) and log(4) respectively.

Figure 3-21(b) summarizes the expected relationship between SO₄ and Al according to progression of pH conditions and sulphide oxidation. The early stages controlled by Al(OH)₃ are expected to produce a weak trend. However, as pH decreases below 4.5, the abundance of aluminosilicates is expected to produce a well correlated trend with a slope of 1. This is a result of both transition to pH conditions under which Al(OH)₃ is soluble and loss of carbonate minerals produces residual acidity which reacts with aluminosilicates.

Similar conclusions can be drawn for all elements. The purpose of the next section is to test these conclusions for the five mine datasets. Regression equations for sulphate against each element determined are summarized in Table 3-12. The table provides regression slopes relative to 1 and the approximate predicted concentration (y₁₀₀) of each element at sulphate=100 mg/L. Selected scatter plots are also shown in Figures 3-22 to 3-26. These figures show slope=1 lines to allow comparison of the different sites. The following sections summarize trends for elements determined frequently.

Results

Aluminum

Aluminum follows the predicted pattern for all sites. Near-neutral pH conditions at all site correspond to lowest sulphate concentrations and poor correlation of sulphate and aluminum. This is particularly evident for Eskay Creek where the dataset spans a transition from non-acid to strongly acidic leachate. The presence of regression slopes near 1 for acidic waters at all sites correlates with the universal abundance of alumino-silicates. The closeness of y_{100} values (2 to 5 mg/L, Table 3-12) suggests a common mineralogical control, for example, $\text{Al}(\text{OH})_3$, although these y_{100} values do not correspond to any particular mineral.

Barium

Barium was determined infrequently. It occurs as barite, witherite and barian feldspars (celsian). At two sites (Vangorda and Sullivan), the regression slopes were negative. This suggests that solution chemistry was being constrained by saturation with respect to BaSO_4 which has a very low solubility (refer to Table 3-8 for Sullivan Mine). Barium is expected to be associated with these lead-zinc volcanogenic massive sulphide deposits.

Calcium

Regression relationships for calcium can be grouped into slope near 0 (Vangorda at high sulphate, and Mine Doyon), slope~1 (Cinola) and slope<1 (Sullivan and Eskay) (Figure 3-23). The slope near 0 implies saturation control by calcium sulphate. As calcite is virtually absent at Cinola and Sullivan, the trends suggest leaching of calcium silicates (probably feldspars at both sites). The waste rock in both cases is clastic sedimentary rock. At Eskay Creek, calcite was present early in monitoring as shown by pH~7 but diminishing in availability resulting in acidic conditions.

Cobalt

For all sites where cobalt was analyzed, the regression slope was near 1 and correlations with sulphate were very strong. Since cobalt commonly occurs as an impurity of pyrite and pyrrhotite, the correlation with sulphate is expected. The difference in y_{100} is probably a result of differences in the cobalt concentrations in iron sulphides at the sites.

Copper

Copper concentrations at higher pHs are constrained by the solubility of copper hydroxides and carbonates resulting in poor correlation at low sulphate concentrations (all sites) (Figure 3-24). At lower pHs, regression slopes are very close to 1 reflecting the release of copper either by oxidation of chalcopyrite or iron sulphides which contain copper as an impurity.

Iron

Iron versus sulphate has a slope very close to 1 for Cinola, Mine Doyon and Eskay Creek at high sulphate (low pH) (Figure 3-25). Sullivan showed no discernible relationship. A slope of 1 would be expected if sulphide oxidation is occurring, since iron is released with sulphur. Similar y_{100} values

would be expected for each site and are observed (20 to 30 mg/L, Table 3-12). The lack of a correlation for Sullivan may be a result of the advanced oxidation of the waste rock. At this site, iron concentrations are three orders of magnitude lower than at the other three acidic sites. This confirms that iron sulphide oxidation is not the main source of iron and sulphate in waste rock dump leachate.

Magnesium

Magnesium showed slopes near 1 for all sites and y_{100} was close to 10 mg/L for all sites except Cinola (1 mg/L) (Figure 3-26). The similarity of results suggests a common mineralogical control for example, magnesian carbonates or silicates. Since magnesian carbonates would not be expected to be present under strongly acidic conditions at Mine Doyon and Sullivan, silicates are the likely candidate. Chlorite is a common alteration product in many types of hydrothermal systems and would be expected to be readily dissolved by strongly acidic solutions. This may also explain the strong correlation with aluminum.

Manganese

Common slopes of 1 for all sites but variable y_{100} (Table 3-12) implies a very strong link to sulphide oxidation. Manganese substitutes for iron in sulphides, thereby explaining the observed correlations.

Sodium and Potassium

Sodium and potassium show confusing though in some cases similar trends (Table 3-12). Concentrations are limited for several sites regardless of the sulphate concentration suggesting a saturation control. These elements occur in Na- and K-jarosite therefore solubility may be limited by these secondary minerals.

Nickel

Nickel, like cobalt, occurs as a trace level impurity in iron sulphides. Hence, slopes are near 1 but y_{100} values are variable probably due to varying levels of nickel in pyrite and pyrrhotite.

Lead

Lead generally shows a very weak correlation with sulphate because lead sulphate is highly insoluble. Four of the sites are large waste dumps and lead sulphate saturation control is very likely in conjunction with lead mineralization at Vangorda, Sullivan, Mine Doyon and Eskay Creek. A slope of 1 was obtained for Cinola probably due to very low lead concentrations in the waste material.

Zinc

For Sullivan and Mine Doyon where conditions are strongly acidic and zinc mineralization occurs, slopes of 1 were obtained presumably due to oxidation of sphalerite by ferric iron. The slopes much greater than 1 for Vangorda and Eskay Creek may represent increasing leaching of zinc due to decreasing pH conditions within the waste. At Eskay Creek, the transition to acidic conditions occurred. At Cinola, zinc concentrations are very low and zinc in leachate may represent leaching of

zinc hosted by silicates.

3.2.4 Conclusions

The strong bivariate statistical relationships observed between dissolved concentrations of elements, sulphate and pH are not easily linked to primary or secondary mineral control. Modelling of whole solution chemistry using MINTEQA2 indicated that secondary iron minerals are commonly over-saturated which implies formation of the minerals. However, use of the model was restricted by the absence of specific data for iron oxidation state forms (ferric and ferrous) as well as gas data.

Comparison of pH-metal regression equations with solubility curves for common minerals was also not useful. The regression equations did not mimic the solubility curves. For iron and aluminum, the solutions appeared to be strongly over-saturated with respect to $\text{Fe}(\text{OH})_3$ and $\text{Al}(\text{OH})_3$, respectively. In the case of iron, the assumption that the iron in solution is present principally in the ferric form is probably incorrect.

The investigation of the very strong correlation of element concentrations and sulphate indicated that solution chemistry is a result of varying degrees of leaching and dilution of the resulting leachates. The log ratio of element to sulphate is preserved allowing mineralogical controls to be evaluated. The results showed excellent agreement with expected behaviour for many elements and very strong similarities between sites.

4.0 REFINEMENTS OF THE EMPIRICAL MODELLING APPROACH

This section discusses refinements to the basic bivariate regression approach described by Morin and Hutt (1993) and used in Section 3.0. Analyses were conducted on selected subsets of the data to illustrate specific techniques. References are provided for other techniques discussed but not illustrated in detail. These other techniques should be used only by experienced investigators. Sections 4.1 and 4.2.1 are intended primarily for investigators specifically interested in developing empirical models to predict metal concentrations from easily measured variables such as pH or conductivity. Sections 4.2.2 and 4.2.3 are intended for investigators interested in exploratory and other analyses as well as prediction. All analyses were conducted using SYSTAT Versions 5.03 (Wilkinson 1990) and 6.0 (Wilkinson and Hill 1994a,b).

General statistical texts such as Snedecor and Cochran (1980) and Sokal and Rohlf (1981) include chapters on linear regression and other methods discussed in this section. Draper and Smith (1981) is the standard reference on linear regression; Hocking (1983) and associated discussion papers in *Technometrics* 15(3) provide a good review of regression methods and diagnostics and their application. Hirsch et al. (1993) review the application of statistics, including regression, to hydrological data. Prairie et al. (1995) discuss problems with empirical models based on limnological field data. They provide methods for interpreting empirical models, and determining underlying structural or functional relationships among variables. This report, and Section 4.1, was primarily concerned with prediction, but interpretation of empirical models through comparison with expected relationships is the obvious next step in modelling acid mine data.

Tabachnik and Fidell (1989) review multivariate statistics, and provide example analyses using the statistical software packages BMD, SAS, SPSS and SYSTAT. Multivariate analyses are often used in chemometrics, or the application of statistical and mathematical methods to chemical data, because most chemical data (e.g., ICP metal scans) are multivariate. Brereton (1990) provides a good introduction to multivariate methods in chemometrics, and includes calculations and algorithms suitable for spreadsheet programs. His examples focus on experimental and laboratory data, and the methods and approaches may not always be applicable to exploratory analyses of observational data collected in the field. Meloun et al. (1992) review exploratory chemometric methods which are generally suitable for data such as those in this report. Brown et al. (1992) review recent developments in chemometrics and associated software.

4.1 BIVARIATE RELATIONSHIPS

4.1.1 Data Screening and Analysis of Residuals

Data screening in Task 2 (Section 3.0) was restricted to visual examination of bivariate scatter plots. Analysis of residuals was restricted to examination of frequency histograms. As recommended in Section 3.0, data screening and analysis of residuals should be expanded to include standard screening and diagnostic procedures described in Draper and Smith (1981), Hocking (1983), Tabachnik and Fidell (1989) and Wilkinson and Hill (1994a,b). Some of these procedures are described below, using examples from the five site datasets.

Data screening and analysis of residuals includes evaluating:

- ! goodness of fit
- ! normality of residuals
- ! equality of variance (homoscedasticity)
- ! the influence of extreme observations, including outliers

A good empirical model should fit the underlying statistical model (e.g., linear regression) used, and the residuals should be normally distributed. The variance of residuals should be similar across the entire range of the independent (X) variable. The model should not depend on a few extreme observations, and outliers should be identified and evaluated.

This section recommends a graphical approach to data screening and analysis of residuals. Specific graphical procedures illustrated are:

- ! scatter plot matrices (SPLOM or casement plots)
- ! smoothing functions (other than linear)
- ! normal probability plots of residuals
- ! plots of residuals vs predicted values
- ! box plots of residuals

Tests for normality and outliers are also discussed briefly. Procedures are illustrated using data from Eskay Creek Mine and the Mine Doyon historical data set.

The Eskay Creek example data set consisted of three variables: Mg, pH and sulphate. These variables were chosen because all three were measured for 48 of 52 samples, and because no values of Mg were below detection limits. Also, previous analyses had indicated that the relationship between Mg and pH was non-linear. One obvious outlier, with pH=13.9, was eliminated from analyses (see Section 3.1.3), to provide a data set of 47 observations.

The Mine Doyon historical example data set consisted of four variables: Fe (= $\text{Fe}^{2+} + \text{Fe}^{3+}$), pH, acidity and sulphate. Five observations with missing values or values below detection limits for one or more variables were excluded, leaving 104 observations for analyses. These data have been used by others for empirical models (e.g., Choquette et al. 1993). Fe was a useful independent (Y) variable because it was detected in most samples. These data were also used to illustrate multiple regression in Section 4.2.1.

Eskay Creek Example

Figure 4-1 provides a scatter plot matrix (SPLOM) for pH, sulphate and Mg concentrations from the Eskay Creek data set. Figures 4-2 and 4-3 provide residual diagnostic plots for regressions of Mg on sulphate and pH, respectively. The regression of Mg on sulphate is used as an example of a reasonably good linear regression model; the regression of Mg on pH is used as an example of a poor model.

In Figure 4-1, frequency distributions of the three variables are provided along the diagonal of the SPLOM. These histograms are useful for assessing the shape of the distribution, and identifying extreme values. Scatter plots are provided below the diagonal. These scatter plots can be used to evaluate the fit of the data to linear or other regression models. A smoothed line has been fitted to the points in each plot to assist in evaluating the fit to a linear model. A LOWESS (Locally Weighted Scatter-plot Smoothing) function was used; details of the function are given in Hirsch et al. (1993). Other smoothing functions are available, but the LOWESS function is more robust than most (Wilkinson and Hill 1994a).

The LOWESS smoothing function removes point-to-point fluctuations of the Y variable to provide general trends. If a linear regression is a good fit, the smoothed line will approximate a straight line, as it did in the plot of Mg versus sulphate. If the linear regression is a poor fit, the smoothed line will be non-linear, as it was in the plot of Mg versus pH. In Section 3.0, this relationship was treated as a segmented relationship with a linear relationship to the left at lower pH and no relationship at higher pH. In Figure 4-1, the relationship at higher pH seems to be linear but in the opposite direction of the relationship at lower pH. Over the entire pH range, the relationship was U-shaped. However, analyses in Section 3.0 indicated that there was no significant relationship between Mg and pH at $\text{pH} > 6$. Smoothed lines are reliable as indicators of the goodness of fit to linear or other models, but are less reliable as indicators of specific alternative models. For example, although the LOWESS smoothed line suggests a quadratic relationship between Mg and pH, a quadratic model (i.e., with pH and pH^2 as X -variables) is a poorer fit than the segmented model used in Section 3.0.

The non-linear relationships for Mg and pH reflects the following seasonal and leaching effects:

- ! under neutral pH conditions (monitoring from early 1991 to mid-1993), slightly lower pH (between 6 and 7) and lower magnesium concentrations coincided with rapid infiltration at the tail of the snow melt event, and higher pH occurred in the summer, fall and winter due to greater contact between acidic water and neutralizing minerals;
- ! strongly acidic conditions from 1994 onwards and enhanced leaching of magnesium containing minerals.

Figure 4-2 provides the frequency histogram (top left) for the residuals from the relationship between Mg and sulphate. The curve corresponds to a normal distribution with the same mean and variance as the actual distribution (bars). The mode of the observed values is shifted slightly left of the mode for the normal curve, and there were more observations than expected at both tails of the distribution (i.e., the frequency distribution had "heavy tails"). Heavy tails were apparent in distributions of residuals from most regressions in this project, and are considered in more detail below. Nevertheless, the distribution of residuals from the Eskay Creek Mg versus sulphate regression was closer to normal than most others presented.

Figure 4-2 also provides normal probability plots (bottom left) and box plots (bottom right), which can be used to assess normality and identify potential outliers. The normal probability plot plots expected values from the normal distribution against the observed values. If the observed values are normally distributed, the plotted points will form a straight line. In Figure 4-2, the points form a straight line in the middle of the plot. However, the plot flattened to the left and right, indicative of the heavy tails.

Box plots are constructed and interpreted as follows (Wilkinson and Hill 1994a; Hirsch et al. 1993):

- ! The vertical line in the middle of the box is the median. The box encompasses roughly 50% of the data (the interquartile range).
- ! The length of the box is called the H spread; a step is defined as 1.5 times the H spread. The horizontal lines or whiskers extending from the box encompass all points ± 1 step from the box.
- ! Asterisks denote outside values or observations between 1 and 2 steps from the box. Open circles denote far-outside values or observations >2 steps from the box.

For a normal distribution, and also for symmetrical non-normal distributions, the median will be in the centre of the box. For residuals, the median will also be 0 or the mean. The whiskers at both ends of the box will be of equal length. There should be few or no outside values, as the expected frequency of outside values in a normal distribution is less than 1%. There should be no far-outside values, except in data sets much larger than any reviewed in this report, as the expected frequency of far-outside values in a normal distribution is less than 0.0003% (1 in 300,000). For the purposes of this report, and most data sets, far-outside values can be considered outliers.

The box plot in Figure 4-2 conforms reasonably well to that expected from a symmetrical distribution with heavy tails. The median is .0 and in the centre of the box. However, there were three outside values and five far-outside values, many more than expected with 47 observations.

Box plots are particularly useful for indicating the presence of multiple outliers, which may not be revealed by examination of Studentized residuals for single samples. For the Mg versus sulphate regression, only one primary and one secondary outlier were identified (Table 3-6). Had we persisted in deleting secondary, tertiary, etc. outliers based on Studentized residuals, most of the outside and far-outside values may have been deleted, but that would depend on the criterion for deletion. This tedious step-wise deletion might never begin, if no Studentized residuals greater than the criterion selected were identified initially, or might end only when a large proportion of the data had been deleted (e.g., the 8 outside and far-outside values, or $>15\%$ of the data). When box plots identify multiple outliers, such as those arising from heavy tails, alternative regression methods which reduce the influence of the outliers should be considered (Section 4.1.3) instead of wholesale deletion of observations.

The final plot in Figure 4-2 is a plot of residuals versus predicted values (top right). These plots are useful for evaluating goodness of fit and equality of variance. There will be some systematic relationship between residuals and predicted values if relationships are curvilinear (see discussion of Mg versus pH regression). In Figure 4-2, there is no relationship, confirming the linear relationship in Figure 4-1. However, the residuals should also be spread evenly across the plot, centred around 0 on

the Y-axis (the mean). The points were centred around 0, but the vertical spread (variance) increased at both ends of the plot, again indicating heavy tails.

In summary, the residual diagnostics for the Mg versus sulphate relationship indicated that the linear log-log model was appropriate but that the distribution of residuals had heavy tails. When heavy tails are present, investigators should immediately suspect that variance may not be equal along the Y or X axis (Snee 1983), which will often be the case for chemical data. Note that the largest departures from the LOWESS line (effectively, the linear regression) in Figure 4-1 tend to occur at the ends of the line rather than in the middle. In general, variances of chemical concentrations increase as values approach detection limits (Taylor 1987), which can explain the greater departures at the left end of the Mg versus sulphate regression. Variance of Y may also increase at high values, since samples have to be diluted several times for ICP analyses, increasing measurement error (Shawn Heier, ZENON Laboratories, Burnaby, B.C.; pers. comm.). There may also be increases in variance or decreases in precision of measurements of X at either end of the scale, especially for pH meters.

Heavy tails will not substantially affect regression parameters (slope, intercept) if distributions of residuals are symmetrical (i.e., with a similar number of positive and negative outliers). However, heavy tails will lead to non-normal distributions, and affect conclusions based on using probabilities from the normal distribution (e.g., the probability of exceeding some water quality criterion).

Figure 4-3 provides residual diagnostic plots for the linear regression of Mg on pH. Since the relationship was not linear over the entire pH range, the diagnostic plots should reveal various "pathologies" and did. The LOWESS smoothed line in the SPLOM (Figure 4-1) clearly identifies the departure from linearity. The histogram, normal probability plot and box plot in Figure 4-3 do not reveal any pathologies, because the distribution of residuals from the linear regression was relatively symmetrical, if not normal. However, the LOWESS smoothed line in Figure 4-3 clearly identified the U-shaped or parabolic relationship between residuals and predicted values. Remember that there should be no systematic relationship between residuals and observed values if relationships are linear. The presence of a parabolic relationship indicates that the linear model overestimates Mg values in the mid-range and underestimates Mg values at the extremes.

Mine Doyon Example

Figure 4-4 provides the SPLOM for Fe and the independent variables in the Mine Doyon historical data set. Linear, rather than LOWESS, functions were fit. Fe concentrations were strongly correlated with the three independent variables (bottom row of plots). Relationships between Fe and sulphate or acidity were tighter (less scatter) than the relationship between Fe and pH. Conductivity, sulphate and acidity were better predictors of most metal concentrations than pH. The relationships between Fe and the predictor variables generally fit the linear model, but there were a few points well below the fitted line for each relationship, especially at the upper end of the Fe range.

Figure 4-5 provides the residual diagnostic plots for the relationship between Fe and pH. The frequency distribution was unimodal, but skewed left, with the left tail stretched beyond the normal distribution, and the right tail truncated. The normal probability plot was not linear, indicating some departure from normality. The points below the line in Figure 4-4 stretch the left end of the probability plot, indicating some left skew. The central part of the plot was reasonably linear, but the right end

terminated abruptly, reflecting truncation of the frequency distribution. The box plot revealed the asymmetric distribution evident from the frequency histogram, and indicated that one outside value and two far-outside values or outliers were present. The spread of the residuals increased at higher predicted values, because of the outside and far-outside values.

Collectively, the diagnostic plots for Fe versus pH indicated that the linear model was a reasonable fit to most points, but that there were two outliers, and that the frequency distribution of residuals was truncated at the right. The truncation probably indicated that there was an upper limit to Fe concentrations, regardless of pH, imposed by solubility. The distribution of Fe values in Figure 4-4 was also truncated, as maximum values were >10,000 mg/L, indicating iron mineral solubility control.

Regressions of Fe on acidity and sulphate were also approximately linear, although the same outliers were present (Figure 4-4). When those outliers were eliminated, new outliers were generated as the variance of residuals was reduced. Continual generation of new outliers after removal of old outliers was common for many of the relationships between metals and conductivity, sulphate and acidity. Outliers were more frequent from regressions on conductivity, sulphate and acidity than for regressions on pH, because prediction errors were smaller, not because absolute deviations were larger. A point 0.1 log units from the fitted line might be an outlier for a regression of Fe on sulphate, but not for a regression of Fe on pH. Thus, the outliers were not a problem, except when they may have affected statistical tests (see following sections).

Statistical Tests for Normality and Outliers

The graphical methods presented above for screening data and analyzing residuals are subjective, with no firm "accept/reject" criteria. Formal tests for normality and outliers are potentially less subjective alternatives to the graphical methods.

Lilliefors' Test, which is a modification of the Kolmogorov-Smirnov (KS) One-sample Test, is the best test for normality, especially for small sample sizes (Sokal and Rohlf 1981). KS One-sample Tests may only be used if the data have been standardized. Based on Lilliefors' Test, the distributions of residuals for all regressions discussed in Section 4.0 were significantly non-normal ($P < 0.05$), largely because of heavy tails. With large sample sizes ($n > 50$), Lilliefors' and other tests will often detect significant departures from normality which have little or no effect on linear regressions and statistical tests. A lower P -value (e.g., 0.01 rather than 0.05) can always be used for rejection of normality, but that will not address the central problem with formal tests. As sample sizes increase, the tests are more likely to detect departures from normality, yet those departures are less likely to affect linear and other regression models than at smaller sample sizes. Also, tests for normality are not useful for suggesting possible transformations, identifying outliers, and revealing other systematic departures from normality (e.g., heavy tails). For those reasons, tests of normality are not recommended.

Grubbs (1969) reviews statistical tests for identifying outliers. He first discusses his own test, which compares the difference between a suspected outlier and the mean to the standard deviation (SD; the prediction error would be used for residuals). That test is similar to the method used by SYSTAT to calculate Studentized residuals, except that the SD or prediction error used by SYSTAT is calculated excluding the suspected outlier. The SYSTAT approach can be extended to multivariate analyses, with the suspected outlier compared to the remainder of the sample using multivariate tests

(Tabachnick and Fidell 1989, pp. 96-104). Grubbs (1969) also discusses a test developed by Dixon (1953), which uses differences between the suspected outlier and various other observations. Dixon's Test can be used for rapid screening, without the need to use a computer or even a calculator. Effectively, the test replaces the SD with the trimmed or untrimmed range. The method used to identify outside and far-outside values in a box plot represents another approach, using the interquartile range (H spread), rather than SD. Finally, Grubbs (1969) considers tests for simultaneous rejection of more than one outlier. These tests are preferable to stepwise tests of single outliers which may simply lead to generation of new outliers, but usually identify the same observations identified as outside or far-outside values in box plots.

Tests for outliers suffer from the same problems as tests for normality. As sample sizes increase, the tests are more likely to detect significant outliers, but those outliers are likely to have less effect on regression models. Furthermore, the tests do not indicate any potential solutions such as using a transformation. Grubbs (1969) provides the same advice for treating outliers as do Tabachnick and Fidell (1989) and others relying mostly on graphical methods:

- ! search for a specific cause for the outlier (e.g., analytical or data entry error)
- ! if no specific cause is found, compare results from analyses conducted with and without the outlier and/or conduct analyses using some of the alternatives described in Section 4.1.3

Conclusions and Recommendations

This report recommends that graphical procedures, rather than formal tests, be used for screening data and analyzing residuals from empirical models. That recommendation is consistent with other sources such as Green (1979), Tabachnick et al. (1989) and Hirsch et al. (1993). Formal tests are self-defeating with large sample sizes, and do not indicate any potential solutions to problems with non-normality and outliers. Any approach to data screening and analysis of residuals, and the ultimate decision to accept or reject a specific model, will necessarily be subjective. For that reason, investigators should always explore alternatives (e.g., analysis with and without outliers) and report any deletions of outliers and apparent problems with the model chosen.

4.1.2 Analysis of Subpopulations

There are two general cases in which investigators may be interested in comparing regressions among subpopulations. In the first case, subpopulations are discrete and identifiable *a priori*, such as different sampling sites within a mine or even different mines. In the second case, subpopulations represent different ranges of the independent or *X*-variable, and may or may not be obvious *a priori*. Relationships for the second type of cases are referred to as segmented models.

Comparison of Discrete Subpopulations (e.g., Sites)

Analysis of covariance (ANCOVA) is the appropriate method for comparison of discrete subpopulations. The following discussion assumes that readers are familiar with ANCOVA (Snedecor and Cochran 1980; Sokal and Rohlf 1981; Tabachnick and Fidell 1989). ANCOVA is actually a form of multiple regression, in which additional dummy variables are used to test for differences in slope and intercept among subpopulations.

In ANCOVA conducted for this section, equality of slopes was tested first, then equality of intercepts was only tested if slopes were not significantly different ($P < 0.05$). In model terminology, a model including X , categorical variable SITE (comparison of intercepts) and $\text{SITE} \times X$ (comparison of slopes) was first tested. If $\text{SITE} \times X$ was not significant, it was dropped from the model. The SITE and $\text{SITE} \times X$ terms can be tested simultaneously, which is effectively a test of the null hypothesis that the regressions do not differ. However, we used the sequential approach because we were specifically interested in whether slopes or intercepts differed. We suspected that intercepts would differ because of differences in mineral content of source rock or soils. However, it is reasonable to expect slopes, which are rates of change of metal concentrations with changing pH or other independent variables, to be similar among sites.

Cinola Example

Use of ANCOVA was illustrated using the Cinola data, with Pad 1 excluded. Section 3.0 indicated that regressions for Pad 1 were different from those for other pads; the Principal Components Analyses (PCA) described in Section 4.2.2 confirmed that Pad 1 was clearly different from Pads 2-4. Fe concentrations were used as the dependent variable because Fe was measured and detected in most samples from Pads 2-4. pH and conductivity were used as independent variables. After deletion of observations with missing or non-detect values for any of the four variables, there were 157 observations in the data set.

Even after deletion of some outliers, both elevations and slopes of Fe versus pH relationships differed significantly among pads ($P < 0.05$). Regressions for Pads 2 and 4 were similar and slopes and elevations were not significantly different ($P > 0.05$). However, the slope for Pad 3 was lower than slopes for Pads 2 and 4. The relationships for the three pads converged at low pH, a phenomenon evident in other data sets (see Mine Doyon example). The shallower slope for Pad 3 is partly an artifact of the limited range of pH, the independent variable. Slopes will usually be depressed and correlations lower when the range of the covariate is narrow. As a result, the difference in slopes among pads may be an artifact of differences in ranges of the covariate, a common problem with ANCOVA.

Relationships between Fe and conductivity for the three pads are shown in Figure 4-6b. Regression lines were similar among pads but several points from Pads 2 and 4 lay below the regression lines. These apparent outliers could be deleted, which would probably remove any differences among pads. However, there are >10 points well below the lines in Figure 4-6b, and wholesale deletion of points without any rationale is not recommended. Based on analyses presented in Section 4.2.2, it was expected that the outliers in Figure 4-6b were observations from early in the monitoring program when

the pads first underwent weathering. Figure 4-6c, which excludes observations made prior to June, 1987, confirmed this hypothesis. There was one obvious outlier from Pad 2, which is arguably an analytical or data entry error since it was the lowest Fe value recorded and the only value <1 mg/L. However, this sample was also a negative outlier for several other metals, suggesting that it might represent a valid low-contamination event or some systematic analytical error for all metals.

Intercepts differed significantly among pads even after the one obvious outlier was deleted (Table 4-1).

There were other suspected outliers, mostly resulting from heavy tails (see below), which may have affected the test for equality of intercepts. However, these outliers also inflated error variance (MSE), reducing the power of the test for equality of intercepts. The test for equality of intercepts is too powerful. The variance or sums-of-squares (SS) explained by the PAD term (difference in intercepts) is unimportant compared to the variance explained by conductivity. The differences among intercepts were small, and only significant because error variance was also small. Pooling data from the three pads would result in little change in the accuracy and precision of predictions. If the PAD term is dropped (i.e., the pads pooled), R^2 for the pooled regression would decrease from 0.932 to 0.928, which is an unimportant reduction. In terms of multiple regression, addition of the dummy variables used to test for differences in intercept did not substantially improve the fit of the model.

Figures 4-7 provides diagnostic plots for the residuals from the pooled regression. There were six far-outside values (outliers), evident from the normal probability and box plots, and indicating the presence of heavy tails. However, the regressions lines for each pad, and for all pads pooled were linear with little scatter (Figure 4-6c). The outliers were also partly a function of the tight fit of the regression through the remainder of the points. More than 50% of the residuals lay within ± 0.1 log units of the mean (0), indicating that >50% of observed values were within 25% of predicted values (antilog $0.1=1.26$). Furthermore, the outliers were symmetrically distributed and would have little effect on predicted values. In general, the pooled regression was one of the best (least biased and most precise) presented in this report.

Other Examples

There were significant differences among regressions of Fe on pH among the Mine Doyon data sets (Figure 4-8; the seepage observations at the upper left obscure observations from the other data sets) and between surface and groundwater samples from Sullivan mine. Some of these differences may be attributable to artifacts, such as differences in width of pH ranges among subpopulations (e.g., as in the Cinola and Mine Doyon data sets). Similar results were obtained for regressions of Cu and Zn on pH (e.g., as in Cinola and Mine Doyon), although sample sizes were smaller because fewer values were above detection limits and/or measured (the distinction was not always clear in the original data sets). In most cases, slopes differed among subpopulations, and regressions converged at low pH, as they did in Figures 4-6a and 4-8.

Regressions of Fe, Cu and Zn on conductivity or sulphate were less likely to differ among subpopulations, although heavy tails and other outliers render probabilities from ANCOVA suspect. Even when there were significant differences among subpopulations, they were often trivial, as in the Cinola example. Therefore, pooling of conductivity and sulphate regressions within mines may be justified in many cases. However, some "detective" work, similar to that conducted for the Cinola data set, may be required to remove outliers and other irregularities, and to homogenize regressions.

Segmented Models

As discussed in Section 3.0, non-linear regression (NLR) packages can be used to generate segmented models. In Section 3.0, there were several relationships between metals and predictor variables (especially pH), in which the relationship was linear over some portion of the dependent variable range, but flat over the remaining portion. The flat portion usually represented values near or below detection limits. In some cases, the flat portion can be ignored because low metal concentrations are not of concern, and a linear model fit to the remainder of the data. If the values near or below detection limits are of concern, they should generally be measured by using different or improved analytical methods, rather than estimated. However, it can be useful to objectively estimate the point (i.e., pH value) at which the relationship becomes flat, rather than choose that point visually. For example, one might use that point as a critical value for determining whether to intensify monitoring of metals. There are models in the toxicological literature, referred to as linear plateau models, which can be used for that purpose (Cox 1987). Wilkinson and Hill (1994b) provide instructions for fitting these models in SYSTAT. These models can also be fit to cases in which metal concentrations reach an upper plateau, set by solubility.

Wilkinson and Hill (1994b) provide instructions for fitting other segmented models, such as two or more separate linear regressions. They concluded that NLR is subject to the same problems as simple linear regression (lack-of-fit, non-normality and heteroscedasticity of residuals, outliers), and several additional problems (e.g., failure to converge on a unique solution). Anyone fitting segmented models should be experienced with NLR, and aware of its pathologies.

Conclusions and Recommendations

Regressions of metal concentrations on predictor variables, especially pH, are likely to differ among subpopulations. In some cases, as in the regressions of Fe on conductivity for the Cinola data, those differences may be small and can be ignored if there are advantages to a more general model based on pooling subpopulations. Nevertheless, differences among subpopulations should be assessed, and will often limit the generality of specific models. Finally, our initial hypothesis that intercepts, but not slopes, would differ can probably be rejected. Instead, slopes generally differed but regressions, especially on pH, converged. The convergence may be attributable to an upper limit set by solubility or to some other factor.

4.1.3 Alternatives to Least-Squares Regression (LSR)

The analyses in this report were based on standard LSR techniques. LSR fits lines by minimizing the sum of the squares of deviations from regressions. LSR has some advantages, primarily in statistical testing and calculating distributions and probabilities of expected values, because of its relationship with the normal distribution. However, conducting statistical tests and estimating probability distributions are not always objectives of empirical modelling. Furthermore, if data do not meet the assumptions of LSR and other parametric analyses, probability distributions derived from LSR will be suspect. No relationship in this project produced a normal distribution of residuals and dealing with heavy tails and other outliers was always a problem. Furthermore, the objective of many empirical models is simply to accurately predict metal concentrations; outliers and non-normal distributions may bias predictions made by LSR, especially if the data and residuals are not carefully screened.

This section discusses some alternatives to LSR, and specifically how these alternatives could be used to address treatment of outliers and values less than detection limits.

Alternatives Based on Other Distributions

LSR is based on the normal distribution and linear relationships. In this study, log transformations were used to linearize relationships and normalize the distribution of residuals. However, if NLR is used, there is no reason to linearize the relationship, although the residuals may not be normally distributed. More generally, regressions based on other distributions such as the Poisson or logistic (Generalized Linear Models or GLIM), or on the log likelihood function (Maximum Likelihood Estimation or MLE), can be used. These alternatives may have advantages in analyses of biological or sociological data. However, most chemical concentrations are log-normally distributed, and log-log relationships are usually linear.

Log-log relationships based on LSR are usually adequate for developing empirical models for mine water quality data. However, regressions based on alternative distributions can be superior for treating data sets with values less than detection limits (DL). Distributions with values less than detection limits are referred to as left-censored, because values at the left (low) end are censored (unknown or unmeasurable). A special form of MLE regression, Tobit regression, can be used to estimate models for left-censored data when there are relatively few (i.e., <20%) censored values (Hirsch et al. 1993, pp. 17.50-17.51; Slymen and de Peyster 1994). Tobit regression basically estimates the distribution of censored values from the distribution of uncensored values; the distributions of uncensored values are usually assumed to be log-normal. Hirsch et al. (1993) caution that Tobit regression is regarded as experimental, at least in the field of hydrology (applications in toxicology are more common).

Hirsch et al. (1993) also note that if values <DL are common (>20%), variables such as metal concentrations can be treated as categorical (i.e., <DL; \$DL) and analyzed using logistic regression. The approach can be extended to use more categories (e.g., <DL; <10DL; \$10DL), or categories based on other separators (e.g., Practical Quantitation Limits; water quality criteria; toxicological endpoints such as LC50). Logistic regression using categories can be useful for reducing or eliminating problems with outliers. For example, suppose that an investigator wants to use an empirical model to predict the probability of exceeding a water quality criterion for Cu at various pH. If outliers are present, predicted frequencies of exceedances based on a linear log-log regression may be suspect. A logistic model based on two categories (# the criterion; > the criterion) should provide a better estimate of the probability of exceedances. With the categorical approach, outliers will usually no longer be outliers - we do not care how much above or below the criterion they are. LSR is designed for predicting a continuous distribution of Cu values but we are interested only in the frequency of two discrete categories.

Alternatives Based on Other Loss Functions or Trimming

In LSR, outliers have strong influence on regressions because LSR minimizes the sum of the squares of deviations from the regression line. In statistical terms, the squares of the deviations are used as a loss function. Since many outliers are arguably analytical or data entry errors, or reflect increased analytical variance at one or both ends of the chemical concentration scale, it is not clear that they should influence regressions so strongly. The only advantage to using the squares of the deviations as a loss

function is that various statistics calculated can be related to the normal distribution. If outliers are present, residuals are likely to be non-normally distributed, and that advantage is reduced or eliminated.

An obvious alternative is to minimize the sum of the absolute values of deviations, rather than the sum of their squares. More generally, the sum of any function of the deviations can be minimized, provided that absolute values are used when both positive and negative values are possible. For example, the sum of the inverse of the squares of the deviations could be minimized to severely reduce the influence of large deviations. A less extreme alternative would be to use the deviations to some power between -2 and 2 as a loss function. More complex functions can also be used as loss functions. Wilkinson and Hill (1994b) describe several robust estimation procedures which use complex loss functions to reduce the influence of outliers. One common robust method, effective when distributions of residuals from LSR have heavy tails, is to weight values by the inverse of their variance. Variance can be estimated from the data, or one can use the measurement error estimated independently during calibration of the analytical method.

Removing outliers is the most extreme method of removing their influence. Before removing outliers, the original data (e.g., analytical reports) should be inspected to ensure that the outliers are not data entry errors. Large numbers of outliers should not be removed, unless there is a logical reason to do so (e.g., as in removal of early data from the Cinola data set). In review projects such as this one, it is often difficult or impossible to check original data, and systematic trimming may be justified. Trimmed regression techniques calculate a regression based on all data, then recalculate the regression after removing the $p\%$ of the residuals with the largest absolute values. Usually p is $\approx 5\%$; removing a higher percentage of the data is not recommended unless there is a rationale.

Conclusions and Recommendations

The recommended approach to regression depends on the objective of the analysis and the nature of the data. If continuous probability distributions are required, then LSR or GLIM should be used. However, Tobit and logistic regression should be used if separation of concentrations into two or more categories adequately addresses objectives. If the primary objective is to accurately predict metal concentrations, or if data violate the assumptions of parametric analyses, then altering the loss function or trimming can be justified and may remove biases introduced by outliers in LSR. Those alternatives could have been used in this study, as outliers were frequent. However, if outliers are symmetrically distributed about regression lines, their net influence on regression parameters will be minimal, and LSR and alternatives will produce similar results. In this study, most regressions fell into one of two classes:

! outliers were relatively few and symmetrically distributed around the regression line (e.g., Figure 4-2 and Figure 4-6c, after deletion of the most obvious outlier; most regressions on conductivity and sulphate);

or

! pathologies were extensive (e.g., relationship between Mg and pH for Eskay Creek in Figure 4-1; many regressions on pH)

In the first case, LSR and alternatives will provide similar regressions, and the alternatives serve mostly to increase confidence in the robustness of the empirical models. In the second case, no technique will be suitable, and the situation cannot easily be addressed.

4.1.4 Overall Conclusions and Recommendations

Based on Section 3.0, and further analyses in this section, the major problems with empirical models are:

- ! outliers and heavy tails
- ! values less than detection limits
- ! non-normality of residuals
- ! departures from linearity
- ! heterogeneity of regressions (i.e., differences among subpopulations)

The data screening and residual diagnostics outlined in Section 4.1.1 identify these problems more readily than the simpler techniques used in Section 3.0. In many cases, these problems do not affect estimates of regression parameters (m, b) and can probably be ignored. Most remaining problems can be addressed using alternatives to LSR such as those recommended in Section 4.1.3, or by calculating separate regressions for different subpopulations. Regardless of the approach adopted, and the final model (if any) chosen, deviations from standard LSR regression and any remaining potential problems should be reported. Finally, any predictive model should be validated by testing it on other data sets (Hocking 1983; Snee 1983). For example, the regression of Fe on conductivity for Pads 2-4 for the Cinola Gold Project appears acceptable but should be validated using more recent data. If the recommendations in this section are adopted, empirical models can be developed which will provide accurate predictions of metal concentrations from less costly predictor variables.

4.2 MULTIVARIATE TECHNIQUES

Multivariate techniques discussed in this section include multiple regression, ordination (especially Principal Components Analysis) and, cluster analysis. The discussion assumes that readers are familiar with multivariate analyses. Readers unfamiliar with multivariate analyses should consult Tabachnick and Fidell (1989).

4.2.1 Multiple Regression

Multiple regression uses more than one independent or X -variable. In this study, metal concentrations were highly correlated with several independent variables (pH, conductivity, sulphate, acidity), and it is reasonable to ask if multiple regression improves the predictive power of regressions (i.e., reduces the difference between predicted and observed values). Adding independent variables will almost always increase R^2 . However, continued addition of independent variables provides ever diminishing returns in terms of improving predictive power, and may introduce problems with robustness and residuals.

Thus, the objective of multiple regression is to derive a model which minimizes the number of independent variables while maximizing R^2 (=minimizing residual or error variance) (Tabachnick and Fidell 1989).

There are many ways to optimize multiple regressions; stepwise regression with forward and backward stepping was used for this study. The stepwise procedure in SYSTAT is described in detail by Wilkinson and Hill (1994a). Forward stepping begins by first entering the independent variable with the highest correlation with the dependent variable. Additional variables are added sequentially if they meet several criteria (usually if partial correlations are significant at some specified P). Backward stepping begins with all variables in the model, and removes them sequentially until there are no more partial correlations which are not significant at some specified P . For this study, we used $P=0.5$, the default option in SYSTAT. Lower P may be more appropriate when correlations among independent variables are as high as in this study (Wilkinson and Hill 1994b).

Alternatives to stepwise regression include: setwise regression, in which models based on different subsets of independent variables are compared; hierarchical regression, in which independent variables are sequentially added and tested in an order specified by the investigator; and standard multiple regression, in which all independent variables are entered simultaneously, and those which meet some criterion (e.g., P -value for partial correlation) retained (Tabachnick and Fidell 1989). Because choices of procedures and criteria for entry and removal of variables are arbitrary, there is no "best" model. In this project, the primary objective was to determine if multiple regressions could generally improve predictive power without introducing other problems; the specifics of the final model were of less interest.

The first example chosen was the Mine Doyon historical data. Fe was the dependent variable; acidity, sulphate and pH were the independent variables. Figure 4-4 provides the SPLOM for these variables; Table 4-2 provides the correlation matrix. Section 4.1.1 and Figure 4-4 indicated that the major problem with linear regressions of Fe on all three variables was the presence of several observations well below fitted lines, especially at the upper end of the pH range.

Table 4-2 indicates that the three independent variables, and especially acidity and sulphate, were highly correlated. Fe was more strongly correlated with acidity and sulphate than with pH. Forward and backward stepping indicated that the "best" model included both sulphate and acidity. However, R^2 for the model with both sulphate and acidity was 0.760, not markedly greater than R^2 for the bivariate models with either sulphate (0.741) or acidity (0.751). If $P=0.05$, instead of $P=0.15$, had been used as the criterion for entry and removal, the bivariate regression of Fe on acidity would be the "best" model. Thus, multiple regression offered little improvement in predictive power. Furthermore, when independent variables are as highly correlated as they were in this study, estimates of slopes for each variable are suspect and have broad confidence limits. This problem is called variance inflation (Hocking 1983).

The relationship between observed versus predicted values for the multiple regression of Fe on acidity and sulphate (Figure 4-9) was virtually identical to plots of Fe versus either independent variable (Figure 4-4). There were still many outliers (far-outside values) and outside values, as the residual diagnostics in Figure 4-10 indicate. Bivariate and multiple regression models fit 90% of the data well, but cannot account for the remaining 10% of the data below fitted lines. There is no obvious

explanation for the occurrence of these anomalous values, nor any obvious solution to deal with them. Multiple regression was obviously not effective at removing them.

Similar results were obtained when the Mine Doyon seepage data were analyzed. Conductivity was added to pH, acidity and sulphate as independent variables; Fe was used as the dependent variable. The best model included acidity and conductivity; conductivity and sulphate were highly correlated so only one was necessary in the model; pH was a poor predictor because the pH range was narrow. Interestingly, plots of observed versus predicted values for any multivariate model looked like Figure 4-9. The models were good fits to most of the data, but there were several negative outliers and outside values, especially at the upper end of the Fe range. Thus, the negative outliers and outside values for both the seepage and historical data appear to reflect some systematic cause. In the seepage data, both Fe^{2+} and Fe^{3+} , as well as total Fe, values were provided. The negative outliers for regressions using total Fe were also negative outliers for regressions using Fe^{3+} , but not Fe^{2+} . Thus, the outliers suggest some analytical problems or natural events associated with Fe^{3+} .

In summary, multiple regressions did not substantially improve bivariate regressions because potential predictor variables such as pH, conductivity and sulphate were highly correlated. Multiple regressions did not remove any problems with non-linearity, outliers, and non-normality of residuals identified in bivariate regressions.

4.2.2 Principal Components Analysis (PCA)

Factor analyses and other multivariate data reduction and pattern recognition techniques summarize relationships among variables (metal concentrations) and among samples (Gauch 1982). Principal Components Analysis (PCA) is the simplest and most commonly used form of factor analysis (FA), and is usually adequate for most chemometric analyses. Tabachnick and Fidell (1989) provide a good general review of PCA and FA; Zitko (1994) reviews the application of PCA to observational field data, providing examples. PCA combines original variables into derived variables, or Principal Components (PC; also referred to as factors), which reflect the major axes or patterns of variance among the original variables. The PC are weighted linear combinations of the original variables. The first PC (PC1) identifies the major axis or pattern of variance or factor; PC2 identifies the minor axis (the largest axis of variance perpendicular to the major axis); subsequent PC identify axes of variance perpendicular to preceding axes. Because PC are perpendicular, they are independent and uncorrelated. In most chemical data sets, there are few independent axes or patterns of variance among many variables. PCA is an effective way to summarize those patterns, and reduce a large number of variables (e.g. concentrations of individual metals) to one or a few variables (PC) for further analyses.

Figure 4-11 illustrates PCA for the two-variable case. The first PC, or major axis, is a regression line which minimizes distances of points from the line in both the Y (vertical) and X (horizontal) directions. PC2, or the minor axis, lies perpendicular to the major axis. PCA effectively rotates the original axis, producing two new axes or variables (PC1, PC2) which are uncorrelated. The position of any point along any PC axis is referred to as a PC score; these scores are usually scaled to mean=0. For example, the point furthest right on the graph in Figure 4-11 would have the highest PC1 score, but an intermediate, slightly negative PC2 score. Plots of samples on PC axes can be used to examine differences among groups of samples.

In the two-variable case, PCA has little advantage over bivariate plots and regression. However, when many variables are present, PCA can reduce multi-dimensional plots which cannot even be imagined, to two- or three-dimensional plots. PCA have no predictive power, at least in the context of this project, although PC scores can be used in place of dependent or independent variables. However, PCA is useful for screening the data, as illustrated in this section.

PCA has some disadvantages and restrictions, because it is a form of multivariate parametric analysis (Tabachnick and Fidell 1989). Specifically, relationships among variables should be linear, and residuals should conform to a multivariate normal distribution. Obviously, based on previous sections, data in this project will rarely meet the requirements of linearity and multivariate normality. However, the requirements for PCA can be relaxed considerably when it is used as an exploratory tool.

For biological and sociological analyses, PCA is also not robust when the number of samples or observations is less than 5-10 times the number of variables, and therefore can only be conducted on large data sets (usually $n > 50$) (Green 1979; Tabachnick and Fidell 1989). For chemometric analyses, that sample size requirement can be relaxed further, provided that emphasis is only on the first one or two PC (Brown et al. 1992). In fact, chemometricians will often analyze data sets with more variables than observations by transposing the data matrix, and looking at patterns of correlation among the observations, rather than among the variables, and plots of the variables, rather than observations.

Two data sets from Cinola, and one from Sullivan Mine, were used for PCA. The first (=large) Cinola data set consisted of Fe, Ca, pH, conductivity and sulphate, and contained 209 observations. The second (=small) Cinola data set consisted of Ca and six metals (Al, As, Cu, Fe, Mn, Pb, Zn). All seven variables were measured in 104 samples, although some values less than detection limits were recorded as detection limits. The Sullivan data set consisted of 8 metal (Ba, Cd, Cu, Fe, Ni, Pb, Sr, Zn) concentrations for 63 samples. There were 9-15 values below detection limits for all metals except Ba, Sr and Zn, and these were set at one-half detection limits. Sr and Ba were used in the analyses because there was one (Ba) or no (Sr) values less than detection limits. No values for Zn were recorded as below detection limits, but 9 values were at detection limits (0.005 mg/L).

Large Cinola Data Set

Table 4-3 provides the correlation matrix for the five variables in the large Cinola data set. All correlations were high. Table 4-4 provides loadings of the five variables on the first two PC. Loadings are correlations between the original variables and PC scores. The first PC accounted for 82% of total variance; the second accounted for 15%. Thus, two PC were adequate to account for 97% of the total variance and reduced the original five variables to two factors. PC1 was negatively correlated with pH, and positively correlated with the other four variables. This is clearly an acid drainage axis, reflecting leaching of metals and ions at low pH. The second PC (PC2) was positively correlated with Ca and pH, reflecting the tendency for pH to be higher in natural hard waters.

Figure 4-12a plots PC2 versus PC1 scores. Pad 1 was clearly distinct from the other pads, with most points located in the two left quadrants of the plot (high pH, low values of other variables). Samples from the remaining pads were largely located below the diagonal, although there were a few points above the diagonal. The separation between Pad 1 and most Pads 2-4 samples, plus the presence of a few Pads 2-4 samples in the clump of Pad 1 samples, suggested that the pattern of PC scores was related to the time course of weathering. Specifically, we suspected that the time course of weathering began at the lower left of the plot, below the diagonal, and moved counter-clockwise. Pad 1 had

already undergone some weathering prior to the initiation of sampling. If so, the few Pad 2-4 samples above the diagonal should represent later samples.

Figures 4-12b plots PC1 scores versus time. Seasonal cycles are obvious, especially in 1987-89. PC1 scores have not decreased substantially in Pads 2-4 from 1987 to 1993, and have not converged on Pad 1 scores. However, scores from Pads 2-4 did diverge over time, as the three pads were not separated in 1987-89 but were in 1991-93. The Pad 2-4 samples above the diagonal in Figure 4-12a were obviously not later samples. Instead, they were earlier samples (i.e., the samples in early 1987 in Figure 4-12b with low PC1 scores).

PC2 scores showed no obvious seasonal cycles, did not differ much among pads, and decreased over time as samples became softer and more acidic (Figure 4-12c). There are a few Pad 2-4 samples at the upper left of the plot, indicating natural conditions of relatively high pH and Ca.

If all Pad 2-4 samples prior to June, 1987, are deleted ($n=18$) from the data set, the diagonal in Figure 4-12a effectively separates Pad 1 from Pads 2-4. Thus, the PCA revealed differences among pads which were obvious from bivariate analyses, but also revealed some time trends and other patterns which were less obvious. As illustrated in Section 4.1.2, deletion of the early Pad 2-4 observations substantially improved the fit of regressions of Fe on conductivity.

Small Cinola Data Set

Table 4-5 provides the correlation matrix for the seven metals. All correlations were positive, and ranging from 0.541 (Fe-Mn) to 0.955 (Fe-Cu). The first PC accounted for 82% of total variance and was positively correlated with the six metals and Ca (Table 4-6). PC2 accounted for 12% of total variance, and was positively correlated with Ca and Mn and weakly negatively correlated with all other metals except Zn. Thus, the first two PC accounted for 94% of the variance for the seven original variables. PC1 was an acid drainage axis, reflecting leaching of metals and ions at low pH (see discussion of correlations with pH and other predictor variables below). PC2 was similar to PC2 from the analyses of the large Cinola data set, reflecting the tendency for pH to be higher in natural hard waters. However, there is no obvious reason why Mn concentrations should have been correlated with hardness (i.e., Ca).

Figure 4-13a plots PC2 versus PC1, and was similar to the same plot for the larger Cinola data set (Figure 4-12a). Pad 1 samples, plus a few samples from other pads, lay above the diagonal; most samples from Pads 2-4 lay below the diagonal. Figure 4-13b indicates that the few Pads 2-4 samples above the diagonal were collected in early 1987, prior to weathering or leaching. The seasonal cycles evident in the larger data set (Figure 4-12b) were also evident in the smaller data set (Figure 4-13b). Figure 4-13c indicates that PC2 scores decreased over time, and seasonal trends were obvious only for Pad 1 samples from 1987-89. As in the larger data set, the decrease in PC2 scores over time suggests that natural harder water was becoming softer as leaching proceeded.

Table 4-7 provides correlations between the two PC and the predictor variables pH, conductivity and sulphate; Figure 4-14 provides the SPLOM. PC1 was highly correlated with the predictor variables, reflecting the increased metal concentrations in acid mine drainage. The relationship between PC1 and pH was non-linear, with a steep slope at low pH (most Pads 2-4 samples), and a shallower slope at higher pH (Pad 1 samples plus a few early Pads 2-4 samples). Relationships between PC1 and conductivity or sulphate, and between PC2 and pH, appeared more linear, but there were still

statistically significant differences in relationships among pads.

In summary, PCA for the small Cinola data set indicated that concentrations of the six most frequently measured and detected metals and Ca were strongly positively correlated. A few selected metals which can be reliably measured and detected in most samples could be analyzed in the future, with little loss of information. PC1 could be used as a single surrogate metals for *post hoc* comparisons of trends and spatial differences for all or most metals. PC2 could also be used as an indicator of trends in hardness, but that would be no more efficient than simply analyzing Ca or hardness. Both the large and small data sets revealed the same trends despite the differences in sample sizes and variables analyzed, indicating that the PC analyses were robust. The few variables in the large data set were representative of a larger suite of variables, or conversely, the subset of samples in the smaller data set were representative of the larger set of samples from which they were obtained.

Sullivan Data Set

Table 4-8 provides the correlation matrix for the 8 metals in the Sullivan data set. Correlations among all metals except Ba were positive; Ba was negatively correlated with all other metals except Sr. Correlations were generally weaker than for the small Cinola data set because of the large number of values below detection limits. The first PC accounted for 63% of the total variance and was positively correlated with all metals except Ba (Table 4-9). Correlations of PC1 with Cd, Cu, Ni and Zn were stronger than correlations with Pb, Sr and Fe. PC2 accounted for 16% of the variance, and was positively correlated with Ba and Sr. Thus, two PC accounted for 79% of the variance among the 8 metals.

Figure 4-15 plots PC2 against PC1, with surface and groundwater samples indicated by different symbols. The two sample types overlapped along PC1, but were separated along PC2. Specifically, PC2 scores were generally higher in the groundwater samples, indicating some enrichment of Ba and Sr relative to other metals (i.e., PC1). The variance or scatter among along the PC2 axis decreased as PC1 scores increased (ignoring the apparent outlier at the lower right), but that may be an artifact of the large number of values less than detection limits. There was a lower limit to PC1 scores (-1) which represents samples in which all or most metals except Ba and Sr were not detected; the distribution of PC1 scores was truncated at the left tail. In contrast, PC2 scores did not have a truncated distribution because they depend on Ba and Sr concentrations, which, with one exception, were all above detection limits. Thus, there may be some hidden relationships between the two PC, and two groups of metals, on the left of the graph.

As expected, PC1 was negatively correlated with pH, and positively correlated with conductivity and sulphate (Table 4-10). The relationships between PC1 and these predictor variables were reasonably linear, with some flattening at high pH and low conductivity and sulphate (Figure 4-16). The flattening was due to the truncated distribution of PC1 scores, especially for the surface samples. Thus, we would conclude that values less than detection limits might create problems for analyses of surface samples. Relationships between PC2 and the predictor variables, especially pH, departed from linear. These relationships were not examined in detail, but the difference in PC2 scores for the two sample types (Figure 4-16) suggests that the relationships should be examined separately for surface and groundwater.

The PCA for the Sullivan data set was not as robust as that for the small Cinola data set, because of the smaller sample size and the large number of values less than detection limits (–20% for most variables). The two sample types, groundwater and surface, were each represented by several different sites sampled at three different times. There may have been some differences among sites or times which could not be examined. Nevertheless, the PCA was adequate to:

- ! indicate that Ba and Sr behave differently than other metals, especially in groundwater samples. Barium concentrations are limited by saturation by barium sulphate (barium and sulphate concentrations are roughly negatively correlated). Strontium originates from leaching of calcium silicates which are not leached at the same rate as heavy metal sulphides.
- ! suggest that values less than detection limits would pose problems for analyses of surface samples.
- ! identify one or two outliers among the groundwater samples.

4.2.3 Cluster Analyses

Cluster analyses are reviewed by Gauch (1982), and are usually used to classify samples rather than variables. For example, cluster analyses could be used on the Cinola data to determine if samples were grouped on the basis of site (i.e., pad) and/or time. When there are a large number of samples, cluster diagrams for samples can be unwieldy and difficult to interpret. Therefore, we prefer PCA and plots of factor scores for examining relationships among samples. Readers interested in using cluster analyses for screening samples, especially when groupings are not known a priori, should use *k*-means clustering rather than the standard hierarchical methods (Hendrickson and Horwitz 1984; Wilkinson and Hill 1994b). However, standard hierarchical cluster analyses can be suitable for examining the relationships among variables (see below).

There are many different cluster methods, most of which have been developed for classification of biological data (community or taxonomic data) (Rohlf 1993). There are two key elements to most methods: the distance measure and the linkage method. For most chemical data sets, Pearson R^2 is adequate as a distance measure. Since R^2 measures similarity, not distance, $1-R^2$ is used as a distance measure. $1-R^2$ is used rather than $1-R$ unless the signs of the correlations, as well as their magnitude, are of interest. Other distance measures are scale-dependent, and should not be used unless the data are standardized (subtract mean; divide by SD).

Cluster analysis proceeds hierarchically by grouping the two most similar cases (samples or variables), treating that group as a single case, recalculating the distance between that group and other cases, then grouping the next most similar cases or groups. The distance between groups can be calculated in several ways; the method used is referred to as the linkage method. We used the average linkage method, which defines the distance between groups as the average of the distances between all pairs of cases in different groups.

Figure 4-17 provides the cluster diagram for the six metals, Ca, pH, conductivity and sulphate in the small Cinola data set used for PCA in Section 4.2.2. Cluster diagrams usually reveal similar associations of variables to those evident from loadings of the same variables in PCA, because both

analyses are based on correlation matrices. For example, Figure 4-17 identifies the association between Ca and Mn identified on PC2 from the PCA. However, the cluster analyses also identified two different groups of metals (Cu, Fe, As versus Zn, Al) which were not evident from the PCA. Conductivity and sulphate were more closely associated with five of the metals (Cu, Fe, As, Zn, Al) than was pH, indicating that the former were better predictors of most metal concentrations.

Cluster analysis is often redundant when PCA are conducted, although the cluster analyses revealed two groups of metals not identified in the PCA. However, cluster analyses of variables, conducted in the absence of PCA, can be used to identify relationships among the variables and reduce the number analyzed. For example, the cluster diagram in Figure 4-17 could be used to justify:

- ! analyzing a subset of metals (e.g., one of Cu, Fe, As; either Al or Zn; either Mn or Ca).
- ! using either conductivity or sulphate, rather than both or pH, as predictor variables.

4.2.4 Conclusions and Recommendations

Multiple regression, PCA and cluster analyses are probably adequate multivariate techniques for most chemical data sets. Only multiple regressions offer predictive power, and their predictive power was not substantially greater than that of bivariate regressions. In this study, the primary predictor variables, pH, conductivity and sulphate, were highly correlated and therefore redundant. Other less correlated predictor variables might increase predictive power, but only if they are less expensive to measure than the predicted variables (metal concentrations). Temperature, time (date) and oxidative reductive potential (ORP) are the most obvious predictor variables which could be added at little cost.

PCA and cluster analysis have no predictive power, but are valuable exploratory tools. Subsets of variables can be selected for further analyses; differences among sites and times can be efficiently examined; other patterns in the data can be identified; the PC can be used as surrogate variables for *post hoc* analyses. In this project, a more efficient and effective approach would have been to screen the dependent and independent variables in each data set first, using PCA. Then a subset of metals and predictors could have been chosen for further analyses, based on the PCA. Data sets could be subdivided into subpopulations in some systematic way, based on the separation of samples by ordination. In hindsight, we could have restricted bivariate analyses to Fe and a few other commonly detected metals and/or metals of concern such as Al, As, Cu and Zn.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL CONCLUSIONS

The two datasets used by Morin and Hutt (1993, 1995) and Morin et al. (1995) had the following characteristics which favoured the approach proposed:

- ! a large number of samples (in the order of 1000);
- ! frequent and uniform sampling schedule; and
- ! represented several years of monitoring.

These characteristics resulted in datasets for which random variability was controlled (due to the large numbers of samples), large data gaps were not present, and metal concentrations were significantly elevated above detection levels. A further consequence of the latter point is that leachate chemistry was likely to be controlled by dissolution of identifiable secondary minerals. Saturation with respect to copper hydroxides and sulphate was apparent for one site.

In contrast, the datasets evaluated for this project were small (less than 100 samples) and frequently had large data gaps and variable detection limits. In all cases, the waste piles were much smaller than the large dumps typical of large open pit porphyry copper deposits.

It is concluded based on this study that the approach proposed by Morin and others is valuable for large datasets but less reliable predictive relationships are likely to be obtained for small datasets. However, as noted below, comparison of sulphate with metal concentrations can lead to an understanding of minerals involved in oxidation and leaching.

5.2 STATISTICAL CONCLUSIONS

- (1) Concentrations of many metals can be predicted from conductivity and sulphate using simple bivariate regressions. pH is a poorer predictor than conductivity or sulphate. Other predictors such as temperature and ORP may also be useful, and inexpensive to measure.
- (2) Regression relationships for pH and conductivity are likely to differ among sites and times, and most will be site-specific. Therefore, they cannot be applied uncritically to new or unmonitored sites. However, they can be used to reduce monitoring costs and/or increase sampling frequency. For example, metal concentrations could be predicted from continuous or frequent conductivity records, although the predictions should be verified periodically by metal analyses.
- (3) Multivariate techniques such as PCA can be used to screen the data and identify relationships among the variables. Information from the screening can be used to select variables for further analyses, using LSR or alternatives. Residual diagnostics and other tools should be used to identify any problems with regressions. Problems with regressions should be solved logically (i.e., through good "detective" work) rather than by arbitrarily trimming data sets. However,

investigators should not hesitate to use robust alternatives to LSR or trimming as a final step in refining relationships. The desired result should be a subset of useable, robust and accurate predictive empirical models, rather than the "all possible regressions" provided in Section 3.0.

5.3 GEOCHEMICAL CONCLUSIONS

- (1) Geochemical evaluation of the data indicates that the strong correlation of many variables in the datasets is due to the link between sulphur oxidation, release of acid and leaching along drainage pathways.
- (2) Modelling using MINTEQA2 indicates that the water chemistry is largely controlled by limonite-type minerals. Other significant relationships were not identified. Evaluation of other metal-pH relationships indicated that most waters are undersaturated with respect to metal hydroxides and carbonates. Adjustment of the partial pressure of CO₂ indicated zinc carbonate control for one site. Modelling was severely limited by the lack of data for partial pressures of gases (particularly CO₂ and O₂) and speciation of oxidation states of metals (particularly Fe²⁺/Fe³⁺).
- (3) Comparison of sulphate with element concentrations on log-log plots indicate extremely strong correlations even with small datasets. The relationships can be related to predicted mineral leaching and show strong similarities between sites in some cases.

5.4 RECOMMENDATIONS

5.4.1 Monitoring

Based on this study, it is recommended that the approach proposed by Morin and others be applied to datasets having characteristics similar to those described in Section 5.1. The utility of the approach is enhanced if sampling is conducted following a routine schedule by trained personnel using well-defined protocols. Detection limits should not fluctuate widely and the same laboratory should be used throughout the monitoring program. Routine quality control (QC) is often missing and should include as a minimum field duplicates and blanks. Ion balances should be checked routinely to ensure analyses are complete and to monitor laboratory performance. QC is probably less important for large datasets since infrequent laboratory errors are less significant. However, thorough QC is essential for small datasets and assists with understanding data variability.

Flow data should also be collected particularly to evaluate outlying data points.

Most datasets currently available are probably not adequate for the approach proposed by Morin and Hutt (1993).

5.4.2 Chemical Modelling

The next step in this type of modelling should be to develop a better understanding of the mineralogical controls on dump leachate chemistry as has been started for this project. The current datasets do not contain sufficient chemical data to allow modelling of results without making several assumptions. Monitoring of at least the following parameters is recommended:

- ! concentrations of all major cations and anions (including SO_4^{2-} , F, Cl, PO_4^{3-} , SiO_2) in waters;
- ! concentrations of oxidation states of common forms of metals (particularly, Fe and Mn);
- ! total dissolved inorganic carbon, rather than total alkalinity to reduce assumptions on forms of alkalinity;
- ! partial pressure of gases in pore spaces; and
- ! types of secondary minerals present.

NORECOL, DAMES & MOORE, INC.

per:

Stephen J. Day, P.Geo.
Senior Geochemist
Project Manager

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TABLES

TABLE 1-1
SUMMARY OF BACKGROUND INFORMATION

Site	Size of Pile(s) (m³)	Lithology	Sulphur %	Relative Degree of Oxidation	Constructed Started (year)	Duration of Dumping (years)	General Seepage Characteristics	Climatic Factors Controlling Water Chemistry	Internal Factors Controlling Water Chemistry
Vangorda		Phyllite and Massive Pyrite	0.5 to 13%	Slight	1990	1.5-2	Neutral pH, elevated sulfate and zinc	Long cold winters, spring melt, thunder showers in short summer	Localized acid generation neutralized internally by carbonates
Cinola	4 piles each 18	Silicified and brecciated clastic sediments		Moderate	1987(one pile 1982)	1 day	Strongly acidic with elevated sulfate, iron, zinc, copper and arsenic	Mild wet winters, drier summer, flushing by heavy rain in fall	Sulphide oxidation, negligible buffering by reaction with silicates
Sullivan	2,500,000 in 2 piles	Mineralized clastic sediments, massive sulphides		High	1903	~ 30	Strongly acidic with elevated sulfate, iron, zinc, copper and arsenic	Cool winters, spring melt, thunder showers in summer, rain in fall	Sulphide oxidation, leaching of acid salts Negilible buffering
Mine Doyon	28,000,000 in 2 piles	Schists, diorite, volcanis sediments, alaskite		Moderate	1978	11	Strongly acidic with elevated sulfate, iron,	Cool winters, spring melt, thunder showers in summer, rain in fall	Sulphide oxidation, leaching of acid salts Negilible buffering
Eskay Creek	40,000	Massive and brecciated rhyolite, argillite and basalt	0.2 to 6%	High	1991	4	pH less 3, high copper and zinc	Long moderate winters, high snow accumulation, high run-off, rain in fall	Formation of jarosite caused lateral and vertical movement of water inflow. Waste deposited in valley bottom

TABLE 2-1
DESCRIPTION OF VANGORDA SEEPAGE SAMPLES

Station	Description	Period of Sampling	Number of Samples	Sampling Frequency	Parameters Analyzed
V-21	Vangorda waste dump collector ditch	Jan7/91 - May9/95	28	Monthly Monthly to Aug/92 Monthly	Compliance monitoring started in 1991 with monitoring of pH, temp., cond., suspended solids, alkalinity, sulphate and total metals As, Cu, Pb and Zn. Monitoring continued in 1992 with the addition of ICP metal scans for total metals for some of the samples Monitoring re-started in Jan. 1995 with complete analyses including some ICP metal scans for total metals
Drain 2	Drain through till berm from zone containing phyllite waste	May4/94 - May9/95	3	Random during Site Visits	Complete set of physical parameters, anions and ICP total metals
Drain 3	Drain through till berm from zone containing phyllite waste - main source of seepage to Station V-21	May4/94 - Jun10/95	5	Random during Site Visits	Complete set of physical parameters, anions and ICP total metals, included extractable metals on two samples in 1994
Drain 5	Drain through till berm from zone containing sulphide waste	Aug9/94 - Jun9/95	2	Random during Site Visits	Complete set of physical parameters, anions and ICP total metals, included extractable metals on on sample in 1994
Drain 6	Drain through the waste dump till berm from zone containing sulphides	Aug9/94 - Jun25/95	4	Random during Site Visits	Complete set of physical parameters, anions and ICP total metals, included extractable metals on two samples in 1994 and dissolved metals on one sample in 1995

TABLE 2-2
DESCRIPTION OF CINOLA TEST PAD LEACHATE SAMPLES

Station	Description	Period of Sampling	Number of Samples	Sampling Frequency	Parameters Analyzed
Pad 1	20 tonnes of five-year weathered silicified skonum sediments	Feb/87 - Dec/87	24	Weekly to Biweekly	pH, cond., Alk., sulphate, acidity, SiO ₂ , P and ICP Total Metals
		Jan/88 - Sept/88	20	Weekly to Biweekly	
		Sept/90	1	Random	
		Mar/91 - Dec/91	8	Monthly	
		Jan/92 - May/92	4	Monthly	
Pad 2	30 tonnes of silicified Skonum sediments	Feb/87 - Dec/87	24	Weekly to Biweekly	
		Jan/88 - Sept/88	20	Weekly to Biweekly	
		Sept/90	1	Random	
		Mar/91 - Dec/91	8	Monthly	
		Jan/92 - May/92	4	Monthly	
Pad 3	30 tonnes of argillically-altered Skonum sediments	Feb/87 - Dec/87	24	Weekly to Biweekly	
		Jan/88 - Sept/88	20	Weekly to Biweekly	
		Sept/90	1	Random	
		Mar/91 - Dec/91	8	Monthly	
		Jan/92 - May/92	4	Monthly	
Pad 4	30 tonnes of brecciated Skonum sediments	Feb/87 - Dec/87	24	Weekly to Biweekly	
		Jan/88 - Sept/88	20	Weekly to Biweekly	
		Sept/90	1	Random	
		Mar/91 - Dec/91	8	Monthly	
		Jan/92 - May/92	4	Monthly	

**TABLE 2-3
DESCRIPTION OF SULLIVAN GROUNDWATER AND SEEPAGE SAMPLES**

Stations	Period of Sampling	Number of Samples	Sampling Frequency	QA/QC Samples	Parameters Analyzed
Groundwater					
92AA2	Aug1/92-Jun1/93	2	See Note	1	pH, cond., Alk., sulphate, acidity, phosphate, SiO ₂ , and ICP dissolved metals
92BB	Aug1/92-Jun1/93	3			
92CC2	Aug1/92-Jun1/93	3			
92DD	Aug1/92-Jun1/93	3			
HE0047	Aug1/92	1			
92EE2	Mar1/93-Jun1/93	2			
92Q	Aug1/92-Jun1/93	3			
92S	Aug1/92-Jun1/93	3		1	
92T2	Aug1/92-Jun1/93	3			
92V	Aug1/92-Jun1/93	3			
92W	Aug1/92-Jun1/93	3			
92X1	Aug1/92-Jun1/93	3			
92Y	Aug1/92-Jun1/93	3			
Total Groundwater		35			
Seepage					
MY11	Aug1/92-Jun1/93	3	See Note	1	pH, cond., Alk., sulphate, acidity, phosphate, SiO ₂ , and ICP dissolved metals
MY12	Aug1/92-Jun1/93	3			
MY13A	Aug1/92-Jun1/93	3			
MY13B	Aug1/92-Jun1/93	3			
MY14	Aug1/92-Jun1/93	2			
MY14N	Mar1/93	1			
MY15	Aug1/92-Jun1/93	3			
MY16	Aug1/92-Jun1/93	3			
MY17	Aug1/92-Jun1/93	3			
MY18	Aug1/92-Jun1/93	3			
Total Seepage		27			

Note: Sampling was conducted on a schedule that involved collection during three site visits

**TABLE 2-4
DESCRIPTION OF MINE DOYON SAMPLES**

Station	Description	Period of Sampling	Number of Samples	Sampling Frequency	Parameters Analyzed	
Ditch Monitoring Stations						
Station 510	Collection Ditch	Apr13/92-Nov1/92	142	Daily to Weekly Flow Dependent	Measured - pH, Eh, conductivity and total dissolved solids Calculated - acidity, Al, Fe, Fe2+/Fe3+, Mg, SO4	
		Jan22/91-Dec30/92	93	Weekly	Measured - physical parameters and metals until Jul10/91 Measured pH, TDS and Cond Jul16/91 to May27/92 Measured pH, Fe and TDS to Dec 30/92 plus calculated physical parameters, no pH data after Jun3/92	
Station 511	Collection Ditch	Apr15/92-Nov11/92	116	Daily to Weekly Flow Dependent	Measured - pH, Eh, conductivity and total dissolved solids Calculated - acidity, Al, Fe, Fe2+/Fe3+, Mg, SO4	
		Jan22/91-Dec30/92	92	Weekly	Measured - physical parameters and metals until Jul10/91 Measured pH, TDS and Cond Jul16/91 to May27/92 Measured pH, Fe and TDS to Dec 30/92 plus calculated physical parameters, no pH data after Jun3/92	
Station 512	Collection Ditch	Apr13/92-Nov13/92	92	Daily to Weekly Flow Dependent	Measured - pH, Eh, conductivity and total dissolved solids Calculated - acidity, Al, Fe, Fe2+/Fe3+, Mg, SO4	
		Apr 9/91-Dec22/92	72	Weekly when Flowing	Measured - physical parameters and metals until Jul10/91 Measured pH, TDS and Cond Jul16/91 to May27/92 Measured pH, Fe and TDS to Dec 30/92 plus calculated physical parameters, no pH data after Jun3/92	
Groundwater Monitoring Stations						
BH-91-01	Rock	Apr8/91-Aug15/92	7	Quarterly	pH, Eh, Cond, SG, TDS acidity, sulphate and metals with some calculated values	
BH-91-01	Soil	Apr8/91-Aug15/92	7	Quarterly		
BH-91-02	Rock	Mar26/91-Jun17/92	6	Quarterly		
BH-91-02	Soil	Mar26/91-Jun17/92	6	Quarterly		
BH-91-03	Rock	Mar27/91-Jun17/92	6	Quarterly		
BH-91-03	Soil	Mar27/91-Aug15/92	7	Quarterly		
BH-91-04	Rock	Mar26/91-Aug15/92	7	Quarterly		
BH-91-04	Soil	Mar26/91-Aug15/92	7	Quarterly		
BH-91-06	Rock	Mar26/91-Aug15/92	7	Quarterly		
BH-91-06	Soil	Oct30/91	1	Selected		
BH-91-101	Rock	Mar27/91 - Oct30/91	3	Quarterly		
BH-91-102	Rock	Apr24/91-Aug15/92	6	Quarterly		
BH-91-103	Rock	Apr24/91-Oct10/91	4	Quarterly		
BH-91-104	Rock	Mar26/91-Aug15/92	7	Quarterly		
BH-91-105	Rock	Mar28/91-Aug15/92	7	Quarterly		
BH-91-105	Soil	Apr25/91	1	Selected		
Historical Monitoring Data						
D-301	East	Apr30/86-Nov11/89	31	Monthly		pH, Acidity, Fe and SO4
D-302		Apr30/86-Nov11/90	48			
D-309	South	Jun17/86-Nov22/89	30			

**TABLE 2-5
DESCRIPTION OF ESKAY CREEK WASTE DUMP SEEPAGE SAMPLES**

Station	Description	Period of Sampling	Number of Samples	Sampling Frequency	Parameters Analyzed
D-2	Exploration Waste Dump Seepage	Jan/91 - Dec/91	25	Biweekly	pH, cond., Alk., sulphate, acidity, TSS, turbidity, TDS, hard, Cl, Fl, SO4 total PO4, ortho-PO4, dissolved PO4, NH3, NO3, NO2 Total & Dissolved Metals via ICP
		Jan/92 - Dec/92	27	Biweekly	
		Jan/93 - Feb/93	2	Random	
		Jan/94 - Dec/94	11	Monthly	
		Feb/95 - Jun/95	4	Monthly	

**TABLE 3-1
VANGORDA PLATEAU MINE REGRESSION LIST**

Y-Variable	X-Variable	Mean	Intercept	Slope	n	r²	P	
As	Conductivity		-1.382	0.042	19	0.009	0.702	
Cu	Conductivity		-5.118	1.030	22	0.382	0.002	*
Fe	Conductivity		-6.013	2.042	23	0.807	0.000	*
Pb	Conductivity		-2.690	0.496	22	0.086	0.185	
SO4	Conductivity		-0.887	1.182	26	0.863	0.000	*
Zn	Conductivity		-5.369	2.078	27	0.624	0.000	*
As	pH		-1.619	0.048	16	0.024	0.568	
Cu	pH		2.191	-0.593	19	0.193	0.060	
Fe	pH		10.050	-1.380	20	0.765	0.000	*
Pb	pH		0.754	-0.281	20	0.055	0.318	
SO4	pH		7.218	-0.624	23	0.513	0.000	*
Zn	pH		9.853	-1.247	23	0.37	0.002	*
As	SO4		-2.137	0.365	20	0.39	0.003	*
Cu	SO4		-2.936	0.422	29	0.031	0.358	
Fe	SO4		-3.116	1.205	29	0.414	0.000	*
Pb	SO4		-1.318	0.063	27	0.002	0.841	
Zn	SO4		-4.436	2.010	33	0.796	0.000	*

Notes

1. * in last column indicates that the r² is significant (p<0.05)

**TABLE 3-2
CINOLA REGRESSION LIST**

Pad	Y-Variable	X-Variable	Mean	Intercept	Slope	n	r ²	P <0.05	*
1	Al	All x	0.586			33			
1	Cu	All x	-2.654			33			
1	P	All x	-1.949			11			*
1	Zn	All x	-0.992			33			
1	Al	Conductivity		0.124	0.251	28	0.029	0.388	
2-4	Al	Conductivity		-4.947	1.957	84	0.819	0.000	*
2-4	As	Conductivity		-10.554	3.086	83	0.872	0.000	*
1	Ca	Conductivity		-3.183	1.870	52	0.843	0.000	*
2-4	Ca	Conductivity		-3.409	1.538	154	0.789	0.000	*
2-4	Co	Conductivity		-5.453	1.513	79	0.775	0.000	*
2-4	Cu	Conductivity		-6.772	1.868	84	0.84	0.000	*
2-4	Fe	Conductivity		-4.320	2.010	148	0.819	0.000	*
2-4	Hg	Conductivity		-4.179	0.864	44	0.418	0.000	*
1	K	Conductivity		-1.050	0.373	9	0.845	0.000	*
1	Mg	Conductivity		-2.973	1.475	12	0.921	0.000	*
2-3	Mg	Conductivity		-3.235	1.331	24	0.928	0.000	*
4	Mg	Conductivity		-4.874	1.654	11	0.977	0.000	*
1	Mn	Conductivity		-3.755	1.526	27	0.737	0.000	*
2-3	Mn	Conductivity		-6.289	2.001	53	0.931	0.000	*
4	Mn	Conductivity		-8.868	2.604	25	0.9	0.000	*
2-4	Ni	Conductivity		-6.338	1.670	77	0.79	0.000	*
1	P	Conductivity		-6.541	1.911	11	0.369	0.047	*
2-4	P	Conductivity		-10.657	3.310	31	0.916	0.000	*
1	SO4	Conductivity		-0.935	1.242	53	0.951	0.000	*
2-4	SO4	Conductivity		-2.832	1.778	153	0.97	0.000	*
2-4	Zn	Conductivity		-7.161	2.161	85	0.892	0.000	*
2-4	Al	pH		4.067	-0.922	86	0.438	0.000	*
2-4	As	pH		2.964	-0.481	86	0.342	0.000	*
2-4	Co	pH		0.631	-0.359	80	0.131	0.001	*
1	Cu	pH		-1.040	-0.365	30	0.426	0.000	*
2-4	Cu	pH		1.679	-0.820	86	0.392	0.000	*
2-4	Fe	pH		5.947	-1.309	156	0.684	0.000	*
1	Mg	pH		2.332	-0.535	12	0.06	0.442	
2-3	Mg	pH		5.232	-1.674	24	0.889	0.000	*
4	Mg	pH		4.695	-1.756	11	0.928	0.000	*
2-4	Na	pH		1.563	-0.393	33	0.204	0.008	*
2-4	Ni	pH		0.364	-0.391	77	0.131	0.001	*
2-4	P	pH		2.208	-0.414	30	0.094	0.100	*
2-4	Zn	pH		1.822	-0.629	86	0.208	0.000	*
1	Al	SO4		0.303	0.207	31	0.031	0.346	
2-4	Al	SO4		-1.927	1.134	91	0.908	0.000	*
2-4	As	SO4		-5.630	1.742	92	0.87	0.000	*
1	Ca	SO4		-1.610	1.425	53	0.788	0.000	*
2-4	Ca	SO4		-0.856	0.837	154	0.782	0.000	*
2-4	Co	SO4		-2.953	0.817	88	0.726	0.000	*
2-4	Cu	SO4		-3.804	1.062	92	0.897	0.000	*
2-4	Fe	SO4		-1.417	1.213	159	0.803	0.000	*
2-4	Hg	SO4		-2.578	0.421	53	0.395	0.000	*
1	K	SO4		-0.732	0.275	9	0.8	0.001	*
1	Mg	SO4		-1.662	1.057	12	0.929	0.000	*
2-3	Mg	SO4		-1.517	0.890	24	0.935	0.000	*
4	Mg	SO4		-2.730	1.154	11	0.954	0.000	*
1	Mn	SO4		-2.847	1.330	30	0.85	0.000	*
2-3	Mn	SO4		-3.385	1.196	58	0.953	0.000	*
4	Mn	SO4		-4.177	1.328	28	0.868	0.000	*
2-4	Ni	SO4		-3.747	0.962	86	0.839	0.000	*
1	P	SO4		-4.212	1.086	11	0.343	0.058	
2-4	P	SO4		-4.226	1.520	31	0.887	0.000	*
2-4	Zn	SO4		-3.771	1.237	94	0.93	0.000	*

Notes

- * in last column indicates that the r² is significant (p<0.05)

**TABLE 3-3
SULLIVAN MINE REGRESSION LIST**

Y-Variable	X-Variable	Mean	Intercept	Slope	n	r ²	P <0.05	*
Al	Conductivity		-5.067	1.997	40	0.783	0.000	*
Ba	Conductivity		-2.525	0.317	64	0.237	0.000	*
Cd	Conductivity		-6.338	1.612	56	0.697	0.000	*
Co	Conductivity		-5.586	1.443	18	0.963	0.000	*
Cu	Conductivity		-5.563	1.459	51	0.607	0.000	*
Fe	Conductivity		-2.516	0.820	51	0.254	0.000	*
K	Conductivity		-1.122	0.508	63	0.583	0.000	*
Mg	Conductivity		-1.907	1.195	62	0.985	0.000	*
Mn	Conductivity		-4.620	1.656	56	0.62	0.000	*
Na	Conductivity		-0.374	0.423	63	0.353	0.000	*
Ni	Conductivity		-4.239	1.052	50	0.827	0.000	*
Pb	Conductivity		-3.546	0.563	49	0.218	0.001	*
SIO2	Conductivity		0.029	0.489	65	0.715	0.000	*
Sr	Conductivity		-2.707	0.629	64	0.772	0.000	*
Zn	Conductivity		-4.793	1.859	65	0.616	0.000	*
Al	pH		4.121	-0.699	41	0.75	0.000	*
B	pH <= 3		8.616	-3.474	8	0.823	0.002	
B	pH > 3	-1.74			28			
Cd	pH		1.104	-0.536	56	0.68	0.000	*
Co	pH		1.204	-0.533	19	0.369	0.006	*
Cu	pH		1.267	-0.519	50	0.745	0.000	*
Cu	pH <= 6		3.213	-1.002	30	0.676	<0.001	
Cu	pH > 6	-2.45			22			
Fe	pH		1.886	-0.398	51	0.403	0.000	*
Fe	pH <= 4		8.293	-2.356	16	0.862	<0.001	
Fe	pH > 4	-0.81			36			
Mg	pH		2.669	-0.237	64	0.268	0.000	*
Mn	pH		2.914	-0.539	56	0.499	0.000	*
Ni	pH		0.832	-0.378	50	0.684	0.000	*
Ni	pH <= 6		1.111	-0.471	29	0.344	0.001	
Ni	pH > 6	-1.94			22			
PO4	pH <= 4		3.504	-1.038	10	0.607	0.008	
PO4	pH > 4	-0.23			5			
Pb	pH		-0.468	-0.297	48	0.464	0.000	*
SIO2	pH		2.220	-0.153	65	0.533	0.000	*
SO4	pH		4.199	-0.360	65	0.397	0.000	*
Zn	pH		4.325	-0.720	65	0.702	0.000	*
Al	SO4		-2.313	1.226	40	0.75	0.000	*
Ba	SO4		-1.996	0.151	64	0.134	0.000	*
Cd	SO4		-4.411	1.115	56	0.773	0.000	*
Co	SO4		-3.080	0.762	18	0.885	0.000	*
Cu	SO4		-3.599	0.922	51	0.618	0.000	*
K	SO4		-0.281	0.236	64	0.356	0.000	*
Mg	SO4		-0.267	0.724	62	0.883	0.000	*
Mn	SO4		-2.248	0.987	56	0.564	0.000	*
Na	SO4		0.280	0.226	63	0.251	0.000	*
Ni	SO4		-2.747	0.637	50	0.668	0.000	*
Pb	SO4		-2.933	0.418	49	0.291	0.000	*
SIO2	SO4		0.712	0.297	65	0.655	0.000	*
Sr	SO4		-1.824	0.374	63	0.713	0.000	*

**TABLE 3-4
DOYON MINE REGRESSION LIST**

Y-Variable	X-Variable	Mean	Intercept	Slope	n	r ²	P <0.05	*	Location Mine-site
Al	Conductivity		-4.525	1.789	46	0.751	0.000	*	Doyon Borehole
Al	Conductivity		-3.023	1.479	56	0.914	0.000	*	Doyon SP
Cu	Conductivity		-9.287	2.435	14	0.896	0.000	*	Doyon Borehole
Cu	Conductivity		-4.361	1.361	27	0.958	0.000	*	Doyon SP
Fe	Conductivity		-4.935	2.002	50	0.829	0.000	*	Doyon Borehole
Fe	Conductivity		-0.381	1.008	72	0.748	0.000	*	Doyon SP
Mg	Conductivity		-2.249	1.305	51	0.958	0.000	*	Doyon Borehole
Mg	Conductivity		-2.599	1.361	70	0.786	0.000	*	Doyon SP
Mn	Conductivity		-3.022	1.239	50	0.912	0.000	*	Doyon Borehole
Mn	Conductivity		-4.421	1.510	70	0.894	0.000	*	Doyon SP
Ni	Conductivity		-4.407	1.253	20	0.585	0.000	*	Doyon Borehole
Ni	Conductivity		-4.471	1.233	35	0.88	0.000	*	Doyon SP
Pb	Conductivity		-2.334	0.544	24	0.824	0.000	*	Doyon Borehole
Pb	Conductivity		-3.368	0.760	34	0.273	0.002	*	Doyon SP
SO4	Conductivity		-1.841	1.475	49	0.984	0.000	*	Doyon Borehole
SO4	Conductivity		-1.594	1.425	72	0.864	0.000	*	Doyon SP
Zn	Conductivity		-5.711	1.604	23	0.968	0.000	*	Doyon Borehole
Zn	Conductivity		-4.925	1.411	35	0.951	0.000	*	Doyon SP
Al	pH		5.698	-0.820	47	0.797	0.000	*	Doyon Borehole
Al	pH		5.903	-1.111	57	0.257	0.000	*	Doyon SP
Cu	pH		3.788	-0.862	14	0.889	0.000	*	Doyon Borehole
Cu	pH		6.021	-1.973	27	0.623	0.000	*	Doyon SP
Fe	pH		6.503	-0.923	52	0.805	0.000	*	Doyon Borehole
Fe	pH		5.912	-0.839	73	0.229	0.000	*	Doyon SP
Mg	pH		4.844	-0.492	51	0.738	0.000	*	Doyon Borehole
Mg	pH		4.806	-0.653	71	0.085	0.013	*	Doyon SP
Mn	pH		3.479	-0.404	51	0.516	0.000	*	Doyon Borehole
Mn	pH		4.409	-0.999	71	0.182	0.000	*	Doyon SP
Ni	pH		1.908	-0.315	21	0.248	0.022	*	Doyon Borehole
Ni	pH		4.184	-1.481	36	0.56	0.000	*	Doyon SP
Pb	pH		0.594	-0.191	25	0.73	0.000	*	Doyon Borehole
Pb	pH		2.755	-1.270	34	0.345	0.000	*	Doyon SP
SO4	pH		6.120	-0.534	50	0.785	0.000	*	Doyon Borehole
SO4	pH		7.192	-1.138	73	0.256	0.000	*	Doyon SP
Zn	pH		2.879	-0.555	25	0.776	0.000	*	Doyon Borehole
Zn	pH		4.582	-1.515	36	0.479	0.000	*	Doyon SP
Al	SO4		-3.720	1.528	45	0.866	0.000	*	Doyon Borehole
Al	SO4		-1.101	0.977	56	0.933	0.000	*	Doyon SP
Cu	SO4		-5.931	1.579	14	0.918	0.000	*	Doyon Borehole
Cu	SO4		-2.008	0.768	28	0.972	0.000	*	Doyon SP
Fe	SO4		-3.281	1.545	48	0.854	0.000	*	Doyon Borehole
Fe	SO4		0.774	0.700	71	0.819	0.000	*	Doyon SP
Mg	SO4		-0.463	0.852	49	0.953	0.000	*	Doyon Borehole
Mg	SO4		-0.935	0.922	69	0.807	0.000	*	Doyon SP
Mn	SO4		-0.487	0.620	48	0.832	0.000	*	Doyon Borehole
Mn	SO4		-2.494	1.006	70	0.936	0.000	*	Doyon SP
Ni	SO4		-2.074	0.666	21	0.409	0.002	*	Doyon Borehole
Ni	SO4		-2.377	0.703	36	0.916	0.000	*	Doyon SP
Pb	SO4		-1.414	0.315	25	0.831	0.000	*	Doyon Borehole
Pb	SO4		-1.999	0.416	34	0.264	0.002	*	Doyon SP
Zn	SO4		-3.315	0.998	23	0.953	0.000	*	Doyon Borehole
Zn	SO4		-2.469	0.792	36	0.951	0.000	*	Doyon SP
Fe	pH		9.451	-2.368	105	0.64	0.000	*	Historical

**TABLE 3-5
ESKAY CREEK REGRESSION LIST**

Y-variable	X-variable	Mean	Intercept	Slope	n	r ²	P <0.05	*
Al	Conductivity		-7.680	2.424	38	0.681	0.000	*
As	Conductivity		-9.330	2.405	38	0.522	0.000	*
Ba	Conductivity		-3.646	0.968	17	0.554	0.000	*
Ca	Conductivity		-0.556	0.820	37	0.934	0.000	*
Cd	Conductivity		-9.239	2.253	36	0.685	0.000	*
Co	Conductivity		-7.767	1.924	35	0.741	0.000	*
Cu	Conductivity		-10.251	2.910	38	0.690	0.000	*
Fe	Conductivity		-9.858	3.267	37	0.810	0.000	*
Mg	Conductivity		-1.465	1.044	37	0.925	0.000	*
Mn	Conductivity		-3.189	1.136	22	0.375	0.002	*
Ni	Conductivity		-8.354	2.277	36	0.704	0.000	*
Pb	Conductivity		-4.299	0.713	36	0.226	0.003	*
Sr	Conductivity		-2.989	0.991	16	0.908	0.000	*
U	Conductivity		-9.958	2.504	16	0.484	0.003	*
Zn	Conductivity		-9.200	2.825	36	0.643	0.000	*
Al	pH		3.423	-0.687	48	0.903	0.000	*
As	pH		1.734	-0.675	49	0.674	0.000	*
As	pH<=6		3.742	-1.246	26	0.800	0.000	*
As	pH>6	-3.206			20			
Ba	pH		-1.646	0.097	17	0.159	0.113	
Ca	pH		2.540	-0.116	48	0.427	0.000	*
Cd	pH		0.767	-0.586	43	0.858	0.000	*
Co	pH		0.751	-0.504	40	0.876	0.000	*
Cu	pH		2.968	-0.811	47	0.912	0.000	*
Fe	pH		4.469	-0.812	47	0.933	0.000	*
Mg	pH		2.684	-0.176	46	0.586	0.000	*
Mg	pH<=6		3.394	-0.389	24	0.658	0.000	*
Mg	pH>6	1.438			23			
Mn	pH		1.400	-0.221	32	0.519	0.000	*
Ni	pH		1.917	-0.612	44	0.886	0.000	*
Pb	pH		-0.841	-0.243	46	0.491	0.000	*
Sr	pH		-2.610	0.340	16	0.680	0.000	*
U	pH		-8.763	0.816	16	0.455	0.004	*
Zn	pH		3.028	-0.704	44	0.760	0.000	*
Al	SO4		-5.574	2.063	49	0.781	0.000	*
As	SO4		-7.488	2.153	49	0.578	0.000	*
Ba	SO4		-2.799	0.869	16	0.627	0.000	*
Ca	SO4		0.419	0.569	48	0.864	0.000	*
Cd	SO4		-7.464	1.934	42	0.878	0.000	*
Co	SO4		-6.408	1.698	39	0.935	0.000	*
Cu	SO4		-7.755	2.460	48	0.803	0.000	*
Fe	SO4		-6.637	2.592	47	0.877	0.000	*
Mg	SO4		-0.430	0.813	46	0.940	0.000	*
Mn	SO4		-2.474	1.071	33	0.621	0.000	*
Ni	SO4		-6.300	1.902	45	0.822	0.000	*
Pb	SO4		-3.836	0.654	46	0.302	0.000	*
Sr	SO4		-1.994	0.810	16	0.768	0.000	*
U	SO4		-5.981	1.294	16	0.237	0.056	
Zn	SO4		-6.925	2.364	44	0.794	0.000	*

TABLE 3-6
LIST OF OUTLIERS - ESKAY CREEK

Date	Cond	pH	SO4	Al			As				Ba			Cd			Ca			Co			Cu			Fe			Pb			Mg				Mn			Ni			Sr			U			Zn							
				S	C	p	S	C	pS	pB	S	C	p	S	C	p	S	C	p	S	C	p	S	C	p	S	C	p	S	C	pS	pB	S	C	p	S	C	p	S	C	p	S	C	p	S	C	p								
09/25/91	431	6.21	67																																																				
10/05/91	681	7.26	116																																																				
01/01/92	630	7.97	79																																																				
02/28/92	613	6.77	276																																																				
03/16/92	1280	10.30	213																																																				
04/12/92	832	7.29	236																																																				
05/14/92	312	6.23	80																																																				
05/22/92	295	6.48	81																																																				
11/24/92	#N/A	6.55	499																																																				
06/26/94	5650	2.86	3580																																																				
08/30/94	481	4.78	231																																																				
09/20/94	10600	1.89	4980																																																				
09/30/94	152	5.47	58																																																				
02/28/95	77000	13.90	945	<i>Omitted from all regressions</i>																																																			
05/31/95	1600	5.31	1050																																																				

Primary outlier
 Secondary outlier
 X-variables (columns): S=SO4; C=conductivity; p=pH; pS=pH(shaft); pB=pH(blade)
 Date format is mm/dd/yy.

TABLE 3-7
VANGORDA MINE
SATURATION INDICES

Mineral	Log(SI)		Chemical Formula
	HIGH TDS	LOW TDS	
Anhydrite	-0.138	NA	CaSO4
Bixbyite	<-1	38.899	Mn2O3
Brochantite	<-1	-0.198	AlO(OH)
Cu(OH)2	NA	-0.779	Cu(OH)2
Calcite	-0.903	NA	CaCO3
Chalcedony	0.038	NA	SiO2
Cerrusite	<-1	0.184	PbCO3
Cupricferite	NA	19.440	CuFe2O4
Fe(OH)2.7Cl.3	<-1	8.653	Fe(OH)2.7Cl.3
Ferrihydrite	3.487	4.293	Fe(OH)3
Goethite	7.317	8.122	FeO(OH)
Gypsum	0.228	NA	CaSO4.2H2O
Jarosite (H)	5.370	0.172	HFe3(SO4)2(OH)6
Jarosite (K)	11.764	7.996	KFe3(SO4)2(OH)6
Jarosite (Na)	8.323	4.400	NaFe3(SO4)2(OH)6
Hydcerrusite	<-1	-0.271	Pb(CO3)2(OH)2
Ni(OH)2	<-1	-0.369	Ni(OH)2
Lepidocrocite	7.008	7.813	FeOOH
Malachite	NA	-0.195	Cu(CO3)OH
Mag-Ferrite	<-1	11.087	MgFe2O4
Maghemite	10.372	11.983	Fe2O3
Magnesite	0.046	NA	MgCO3
Manganite	<-1	19.678	MnO(OH)
Otavite	-0.127	NA	CdCO3
Quartz	0.583	NA	SiO2
Silica	-0.474	NA	SiO2 - A, G1
Silica	-0.803	NA	SiO2 - A,PT
Smithsonite	0.046	1.297	ZnCo3
Tenorite	NA	0.241	CuO
ZnCO3, 1H2O	<-1	1.726	ZnCO3, 1H2O
Zn(OH)2 (a)	<-1	0.691	Zn(OH)2 (a)
Zn(OH)2 (c)	<-1	0.941	Zn(OH)2 (c)
Zn(OH)2(b)	<-1	1.391	Zn(OH)2(b)
Zn(OH)2(g)	<-1	1.431	Zn(OH)2(g)
Zn(OH)2(e)	<-1	1.641	Zn(OH)2(e)
Zn2(OH)3Cl	NA	-0.824	Zn2(OH)3Cl
Zn5(OH)8Cl2	NA	3.394	Zn5(OH)8Cl2
Zn2(OH)2SO4	<-1	0.112	Zn2(OH)2SO4
Zn4(OH)6SO4	<-1	5.494	Zn4(OH)6SO4
ZnO (Active)	<-1	1.831	ZnO (Active)
Zincite	<-1	1.152	ZnO
Pb(OH)2 (c)	<-1	-0.154	Pb(OH)2 (c)
ZnCO3, 1H2O	0.474	<-1	ZnCO3, 1H2O
ZnSiO3	2.453	NA	ZnSiO3
pH	6.400	7.500	

Note:

1. Only minerals with at least one log(SI)>-1 are shown. Value ommitted if log(SI)<-1

**TABLE 3-8
CINOLA PROJECT
SATURATION INDICES**

Mineral	Log SI							Chemical Formula
	Pad 1			Pad 2	Pad 3	Pad 4		
	High TDS	Mid TDS	Low TDS	Mid TDS	Low TDS	High TDS	High TDS	
AlOHSO4	0.512	0.637	-0.139	-0.594	<-1	-0.358	<-1	AlOHSO4
Alunite	3.146	3.353	1.901	<-1	NA	<-1	<-1	KAl3(SO4)2(OH)6
Anhydrite	<-1	<-1	<-1	<-1	<-1	-0.837	<-1	CaSO4
Barite	1.113	0.752	0.266	0.927	0.578	1.256	0.443	BaSO4
Bixbyite	13.084	11.733	12.653	5.110	5.841	3.127	2.303	Mn2O3
Chalcedony	0.402	-0.267	-0.268	0.801	0.158	<-1	0.883	SiO2
Cristobalite	0.500	-0.169	-0.170	0.899	0.257	1.268	0.981	SiO2
Cupricferite	1.552	0.955	0.741	-0.583	0.354	<-1	<-1	CuFe2O4
Diaspore	-0.056	0.248	0.228	<-1	<-1	<-1	<-1	AlO(OH)
FeAsO4.2W	<-1	<-1	<-1	<-1	<-1	<-1	<-1	FeAsO4.2W
Ferrihydrite	-0.688	<-1	<-1	<-1	-0.767	<-1	<-1	Fe(OH)3
Goethite	3.140	2.762	2.621	2.667	3.062	1.974	2.438	FeO(OH)
Gypsum	<-1	<-1	<-1	<-1	<-1	-0.471	<-1	CaSO4.2H2O
Hematite	11.216	10.459	10.176	10.269	11.059	8.884	9.812	Fe2O3
Jarosite (H)	1.583	0.091	<-1	5.464	4.573	6.006	5.602	KFe3(SO4)2(OH)6
Jarosite (K)	4.522	2.682	0.864	6.740	6.147	6.872	6.457	KFe3(SO4)2(OH)6
Jarosite (Na)	1.373	-0.298	<-1	4.073	3.146	4.613	3.931	KFe3(SO4)2(OH)6
Kaolinite	1.842	1.120	1.079	<-1	<-1	<-1	<-1	Al2Si2O5(OH)4
Lepidocrocite	2.832	2.453	2.312	2.358	2.753	1.666	2.130	FeO-OH
Maghemite	2.019	1.263	0.980	1.073	1.862	-0.312	0.616	Fe2O3
Manganite	6.777	6.095	6.555	2.783	3.149	1.797	1.380	MnO(OH)
Montmorillonite	0.772	<-1	<-1	<-1	<-1	<-1	<-1	NaAlMgSi4O10(OH)2.nH2O
Na - Nontronite	13.347	10.176	9.924	12.236	10.831	11.847	11.656	NaFe2+3(AlSi)O10(OH2).nH2O
K - Nontronite	14.180	10.953	10.701	12.910	11.624	12.372	12.284	NaFe2+3(AlSi)O10(OH2).nH2O
Ca - Nontronite	20.383	17.355	16.987	19.269	17.924	18.831	18.681	NaFe2+3(AlSi)O10(OH2).nH2O
Mg - Nontronite	20.058	16.853	16.613	18.982	17.596	18.497	18.343	NaFe2+3(AlSi)O10(OH2).nH2O
Pyrophyllite	3.935	1.875	1.833	<-1	<-1	<-1	<-1	AlSi2O5(OH)
Quartz	0.947	0.278	0.277	1.346	0.704	1.715	1.428	SiO2
Silica	-0.110	-0.779	-0.780	0.289	-0.353	0.658	0.371	SiO2 - A, G1
Silica	-0.439	-1.108	<-1	-0.039	-0.682	0.329	0.043	SiO2 - A,PT
pH	3.800	3.900	4.000	2.600	2.900	2.200	2.200	

Note:

1. Only minerals with at least one log(SI)>-1 are shown. Value omitted if log(SI)<-1

TABLE 3-9
SULLIVAN MINE
SATURATION INDICES

Mineral	Log SI			Chemical Formula
	High TDS	Mid TDS	Low TDS	
Aragonite	<-1	<-1	-0.153	CaCO3
AlOHSO4	0.887	-0.022	<-1	AlOHSO4
Alunite	<-1	0.320	<-1	KAl3(SO4)2(OH)6
Anhydrite	0.428	<-1	<-1	CaSO4
Barite	0.774	0.504	<-1	BaSO4
Bixbyite	8.194	11.106	<-1	Mn2O3
Calcite	<-1	<-1	0.043	CaCO3
Celestite	0.502	<-1	<-1	SrSO4
Chalcedony	1.631	0.901	0.186	SiO2
Cristobalite	1.730	1.000	0.284	SiO2
Cupricferite	<-1	-0.040	<-1	CuFe2O4
Dolomite	<-1	<-1	-0.232	CaMg(CO3)2
Epsomite	-0.733	<-1	<-1	MgSO4
Goethite	0.797	2.209	<-1	FeO(OH)
Gypsum	0.758	-0.742	<-1	CaSO4.2H2O
Hematite	6.548	9.354	<-1	Fe2O3
Jarosite (H)	4.683	1.048	<-1	HFe(SO4)2(OH)6
Jarosite (K)	5.553	3.892	<-1	KFe(SO4)2(OH)6
Jarosite (Na)	2.649	<-1	<-1	NaFe(SO4)2(OH)6
Kaolinite	<-1	-0.477	<-1	Al2Si2O5(OH)4
Lepidocrocite	0.489	1.901	<-1	FeOOH
Maghemite	<-1	0.158	<-1	Fe2O3
Magnesite	<-1	<-1	-0.757	MgCO3
Manganite	4.316	5.781	<-1	MnO(OH)
Montmorillonite	<-1	-0.363	<-1	NaAlMgSi4O10(OH)2.nH2O
Na - Nontronite	11.008	12.922	<-1	NaFe2+3(AlSi)O10(OH2).nH2O
K - Nontronite	11.760	13.572	<-1	KFe2+3(AlSi)O10(OH2).nH2O
Ca - Nontronite	18.233	19.785	<-1	CaFe2+3(AlSi)O10(OH2).nH2O
Mg - Nontronite	18.135	19.485	<-1	MgFe2+3(AlSi)O10(OH2).nH2O
Otavite	<-1	<-1	0.096	CdCO3
Pyrophyllite	-0.573	2.615	<-1	AlSi2O5(OH)
Quartz	2.176	1.447	0.731	SiO2
Silica	1.119	0.390	-0.326	SiO2 - A, G1
Silica	0.791	0.061	-0.655	SiO2 - A,PT
Strengite	2.311	0.671	12.247	Fe PO4.2H2O
pH	2.130	3.420	6.810	

Note:

1. Only minerals with at least one log(SI)>-1 are shown. Value omitted if log(SI)<-1

TABLE 3-10
MINE DOYON
SATURATION INDICES

Mineral	Log SI			Chemical Formula
	High TDS	Mid TDS	Low TDS	
AlOHSO4	NA	0.809	0.278	AlOHSO4
Anglesite	<-1	-0.498	-0.925	PbSO4
Anhydrite	0.361	-0.106	-0.678	CaSO4
Bixbyite	6.121	5.847	5.456	Mn2O3
Chalcedony	NA	1.059	0.777	SiO2
Cristobalite	NA	1.157	0.875	SiO2
Cupricferite	<-1	0.535	1.229	CuFe2O3
Epsomite	-0.839	<-1	<-1	MgSO4.7H2O
Ferrihydrite	<-1	<-1	-0.750	Fe(OH)3
Goethite	1.086	2.657	3.081	FeO(OH)
Gypsum	0.710	0.250	-0.313	CaSO4.2H2O
Hematite	7.116	10.255	11.098	Fe2O3
Jarosite (H)	5.537	8.335	8.154	KFe3(SO4)2(OH)6
Jarosite (K)	8.071	8.586	8.608	KFe3(SO4)2(OH)6
Jarosite (Na)	3.881	8.730	6.573	KFe3(SO4)2(OH)6
Lepidocrocite	0.777	2.349	2.772	FeO-OH
Maghemite	<-1	1.059	1.902	Fe2O3
Magnetite	1.025	4.220	4.165	Fe3O4
Melanterite	-0.488	<-1	<-1	FeSO4.7H2O
Manganite	3.284	3.149	2.955	MnO(OH)
Na - Nontronite	NA	13.731	12.959	NaFe2+3(AlSi)O10(OH2).nH2O
K - Nontronite	NA	13.478	13.425	NaFe2+3(AlSi)O10(OH2).nH2O
Ca - Nontronite	NA	20.224	20.128	NaFe2+3(AlSi)O10(OH2).nH2O
Mg - Nontronite	NA	20.080	19.939	NaFe2+3(AlSi)O10(OH2).nH2O
Quartz	NA	1.604	1.322	SiO2
Silica	NA	0.547	0.265	SiO2 - A, G1
Silica	NA	0.218	-0.063	SiO2 - A,PT
pH	2.210	2.290	2.390	

Note:

1. Only minerals with at least one log(SI)>-1 are shown. Value omitted if log(SI)<-1

**TABLE 3-11
ESKAY CREEK MINE
SATURATION INDICES**

Mineral	Log SI			Chemical Formula
	High TDS	Mid TDS	Low TDS	
Al4(OH)10SO4	<-1	<-1	0.854	Al4(OH)10SO4
AlOHSO4	0.323	-0.760	<-1	AlOHSO4
Alunite	<-1	1.658	0.842	KAl3(SO4)2(OH)6
Anhydrite	-0.118	<-1	<-1	CaSO4
Ba (ASO4)2	NA	NA	5.625	Ba (ASO4)2
Barite	NA	NA	0.607	BaSO4
Bixbyite	NA	NA	31.331	Mn2O3
Boehmite	NA	NA	0.519	AlO(OH)
Chalcedony	NA	NA	-0.575	SiO2
Cristobalite	NA	NA	-0.476	SiO2
Cupricferite	1.666	7.314	10.887	CuFe2O4
Diaspore	<-1	-0.026	2.360	AlO(OH)
FeOH)2.7Cl.3	4.851	6.749	6.187	FeOH)2.7Cl.3
FeAsO4.2W	-0.697	<-1	<-1	FeAsO4.2W
Ferrihydrite	<-1	1.364	1.486	Fe(OH)3
Gibbsite	<-1	<-1	0.534	Al(OH)3
Goethite	2.808	<-1	5.314	FeO(OH)
Gypsum	0.246	-0.737	<-1	CaSO4.2H2O
Halloysite	NA	NA	1.288	Al2Si2O3(OH)4
Hematite	10.553	<-1	15.564	Fe2O3
Jarosite (H)	7.565	5.135	<-1	KFe3(SO4)2(OH)6
Jarosite (K)	10.251	9.098	<-1	KFe3(SO4)2(OH)6
Jarosite (Na)	6.871	5.761	<-1	KFe3(SO4)2(OH)6
Kaolinite	NA	NA	4.728	Al2Si2O5(OH)4
Leonhardite	NA	NA	8.124	Ca2Al4Si8(OH)
Lepidocrocite	2.500	4.884	5.006	FeO-OH
Mag-Ferrite	<-1	-0.999	4.091	MgFe2O4
Maghemite	1.357	6.124	6.367	Fe2O3
Manganite	NA	NA	15.894	MnO(OH)
Microcline	NA	NA	-0.555	KAlSi2O3
Muscovite	NA	NA	5.623	KAlSi3O10(OH)2
Montmorillonite	NA	NA	5.029	NaAlMgSi4O10(OH)2.nH2O
Na - Nontronite	NA	NA	16.178	NaFe2+3(AlSi)O10(OH2).nH2O
K - Nontronite	NA	NA	17.018	NaFe2+3(AlSi)O10(OH2).nH2O
Ca - Nontronite	NA	NA	23.066	NaFe2+3(AlSi)O10(OH2).nH2O
Mg - Nontronite	NA	NA	22.766	NaFe2+3(AlSi)O10(OH2).nH2O
Pyrophyllite	NA	NA	4.869	AlSi2O5(OH)
Quartz	NA	NA	-0.029	SiO2
V2O3	NA	NA	-0.882	V2O3
ZnSiO3	NA	NA	-0.420	ZnSiO3
pH	2.200	4.500	8.000	

Note:

1. Only minerals with at least one log(SI)>-1 are shown. Value omitted if log(SI)<-1
NA - Relevant parameters not analyzed.

**TABLE 3-12
SUMMARY OF REGRESSIONS FOR SULPHATE (X) VS ELEMENTS (Y)**

Element	Sites									
	Vangorda		Cinola		Sullivan		Doyon		Eskay	
	Slope	SO4=100	Slope	SO4=100	Slope	SO4=100	Slope	SO4=100	Slope	SO4=100
Ag	DL	DL	DL	DL	DL	DL	NA	NA	NC	NC
Al	NC	NC	1	3	1	4	1	5	1	2
As	DL	DL	>>1	0.009	DL	DL	NA	NA	1	PC
B	ID	ID	DL	DL	NC	NC	NA	NA	DL	DL
Ba	-1	0.5	DL	DL	<-1	PC	NA	NA	ID	ID
Be	ID	ID	DL	DL	DL	DI	NA	NA	DL	DL
Ca	0	400	1	3	<1	20	0	500	<1	30
Cd	NC	NC	1	0.0007	1	0.01	ID	ID	>1	0.001
Co	1	0.06	1	0.02	1	0.01	NA	NA	1	0.006
Cr	DL	DL	1	0.003	DL	DL	NA	NA	DL	DL
Cu	NC	NC	1	0.03	~1	0.02	1	0.1	>1	0.02
Fe	NC	NC	1	20	NC	NC	1	30	1	20
Hg	ID	ID	DL	DL	NA	NA	NA	NA	NA	NA
K	0	10	DL	DL	<1	PC	NC	NC	0	10
Mg	1	10	1	1	1	7	1	6	~<1	20
Mn	1	2	>1	0.04	1	1	1	0.3	1	0.5
Mo	ID	ID	DL	DL	NA	NA	NA	NA	DL	DL
Na	0	10	0	3	<1	PC	NC	NC	<1	3
Ni	>1	0	1	0.01	1	0.03	1	0.02	1	0.1
P	DL	DL	>1	0.05	1	0.01	NA	NA	NC	NC
Pb	NC	NC	1	0.00008	NC	NC	<1	PC	PC	PC
Sb	DL	DL	1	0.0002	DL	DL	NA	NA	NC	NC
Se	DL	DL	1	0.001	NA	NA	NA	NA	DL	DL
SiO2	0	36	<1	6	<1	PC	<1	4	ID	ID
Sn	NA	NA	DL	DL	DL	DL	NA	NA	NA	NA
Sr	0	1	<1	0.02	<1	0.07	NA	NA	1	0.4
Ti	DL	DL	DL	DL	DL	DL	NA	NA	NA	NA
U	ID	ID	NA	NA	NA	NA	NA	NA	ID	ID
V	DL	DL	DL	DL	DL	DL	NA	NA	ID	ID
Zn	>>1	PC	<1	PC	1	5	1	0.04	>>1	PC

Notes.

1. NC - No correlation, PC - Very poor correlation, not quantified, NA - Not analyzed, ID - Insufficient data, DL - Detecti

TABLE 4-1
CINOLA PADS 2-4; EARLY DATA DELETED - ANOVA TABLE FOR COMPARISON OF INTERCEPTS
OF FE VERSUS CONDUCTIVITY REGRESSIONS

Source	d.f.	SS	MS	<i>F</i>	<i>P</i>
Conductivity	1	53.341	53.341	1529.11	<<0.001
PAD (Diff. in intercepts among pads)	2	0.221	0.111	3.17	0.045
Error (Residual)	128	4.465	0.035		

COND = conductivity; d.f. = degrees of freedom; MS = mean square; SS = sum-of-squares

TABLE 4-2
MINE DOYON HISTORICAL DATA - CORRELATION (PEARSON R) MATRIX
FOR VARIABLES USED IN MULTIPLE REGRESSION

	pH	Acidity	Sulphate
Fe (Fe ⁺⁺ + Fe ⁺⁺⁺)	-0.747	0.867	0.861
pH	1.000		
Acidity	-0.837	1.000	
Sulphate	-0.811	0.966	1.000

TABLE 4-3
LARGE CINOLA DATA SET - CORRELATION (PEARSON *R*) MATRIX

	pH	Conductivity	Sulphate	Ca
pH	1.000			
Conductivity	-0.766	1.000		
Sulphate	-0.747	0.958	1.000	
Ca	-0.347	0.787	0.820	1.000
Fe	-0.893	0.916	0.896	0.572

TABLE 4-4
LARGE CINOLA DATA SET - LOADINGS OF ORIGINAL VARIABLES ON
FIRST TWO PRINCIPAL COMPONENTS (PC)

Variable	Loadings (<i>R</i>)	
	PC1	PC2
Conductivity	0.981	0.071
Sulphate	0.978	0.121
Fe	0.951	-0.248
pH	-0.834	0.517
Ca	0.773	0.619

NOTE: IR120.500 shown in bold.

TABLE 4-5
SMALL CINOLA DATA SET - CORRELATION (PEARSON *R*) MATRIX

	Al	As	Ca	Cu	Fe	Mn
Al	1.000					
As	0.827	1.000				
Ca	0.620	0.708	1.000			
Cu	0.876	0.941	0.632	1.000		
Fe	0.791	0.946	0.577	0.955	1.000	
Mn	0.745	0.669	0.932	0.657	0.541	1.000
Zn	0.919	0.883	0.809	0.894	0.808	0.868

TABLE 4-6
 SMALL CINOLA DATA SET - LOADINGS OF ORIGINAL VARIABLES ON
 FIRST TWO PRINCIPAL COMPONENTS (PC)

Variable	Loadings (<i>R</i>)	
	PC1	PC2
Zn	0.975	0.079
As	0.945	-0.221
cu	0.943	-0.288
Al	0.914	-0.100
Fe	0.891	-0.399
Mn	0.847	0.514
Ca	0.825	0.504

NOTE: |*R* 120.500 shown in bold.

TABLE 4-7
SMALL CINOLA DATA SET - CORRELATION (PEARSON *R*) MATRIX
FOR PC1 AND PREDICTOR VARIABLES

	pH	Conductivity	Sulphate
PC1	-0.73 1	0.936	0.979
PC2	0.585	-0.064	0.050
pH	1.000		
Conductivity	-0.727	1.000	
Sulphate	-0.679	0.956	1.000

TABLE 4-8
SULLIVAN DATA SET - CORRELATION (PEARSON *R*) MATRIX

	Ba	Cd	cu	Fe	Ni	Pb	Sr
Ba	1.000						
Cd	-0.241	1.000					
Cu	-0.350	0.889	1.000				
Fe	-0.174	0.467	0.650	1.000			
Ni	-0.358	0.872	0.873	0.511	1.000		
Pb	-0.219	0.697	0.713	0.467	0.648	1.000	
Sr	0.257	0.631	0.495	0.220	0.624	0.318	1.000
Zn	-0.226	0.939	0.847	0.440	0.809	0.647	0.542

TABLE 4-9
 SULLIVAN DATA SET - LOADINGS OF ORIGINAL VARIABLES ON
 FIRST TWO PRINCIPAL COMPONENTS (PC)

Variable	Loadings (<i>R</i>)	
	PC1	PC2
Cd	0.954	0.086
Cu	0.952	-0.115
Ni	0.931	-0.019
Zn	0.920	0.102
Pb	0.774	-0.118
Sr	0.631	0.677
Fe	0.623	-0.197
Ba	-0.304	0.857

NOTE: IR110.500 shown in bold.

TABLE 4-10
SULLIVAN DATA SET - CORRELATION (PEARSON *R*) MATRIX
FOR PC1 AND PREDICTOR VARIABLES

	pH	Conductivity	Sulphate
PC1	-0.863	0.791	0.816
pH	1.000		
Conductivity	-0.543	1.000	
Sulphate	-0.586	0.923	1.000

FIGURES

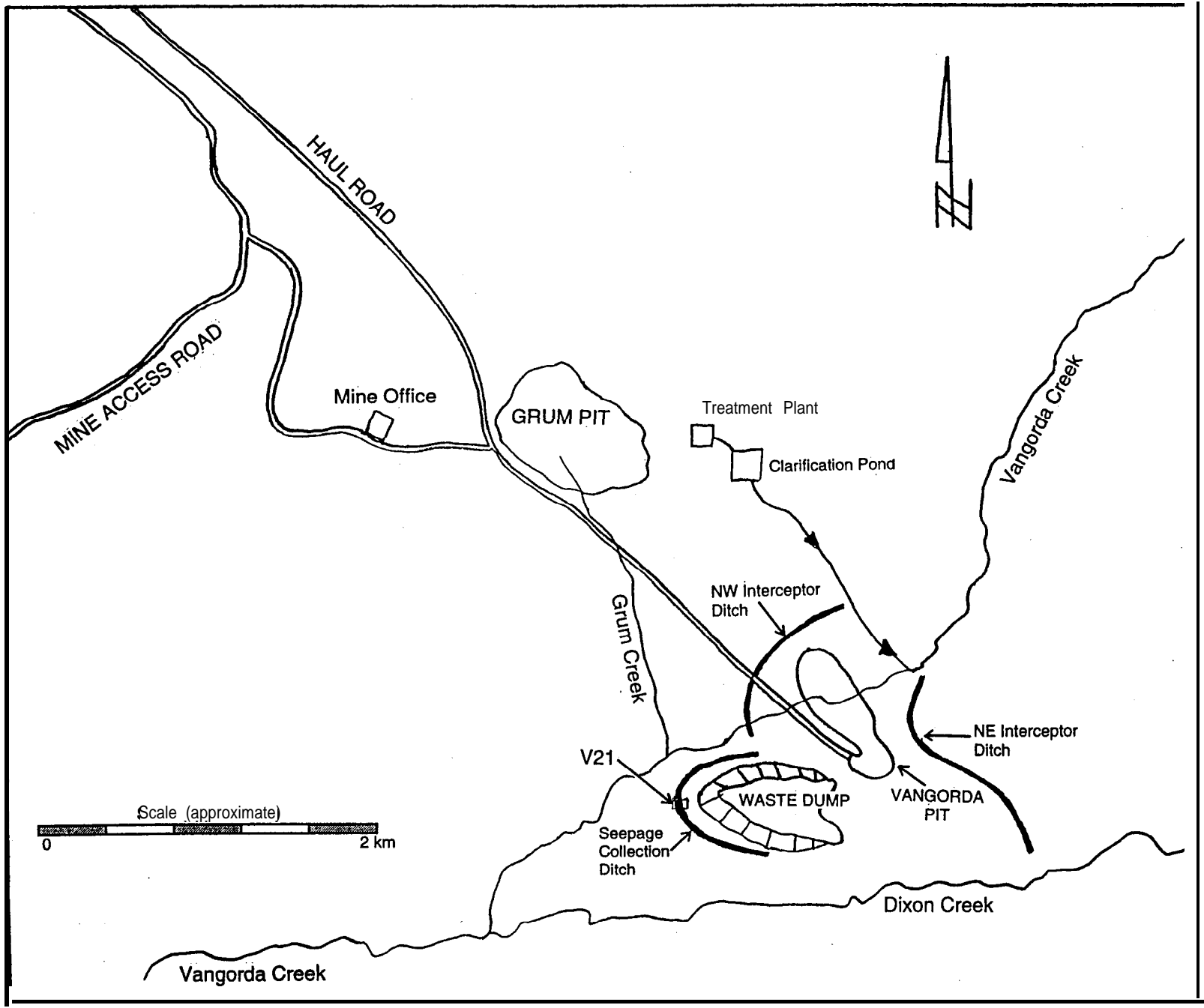
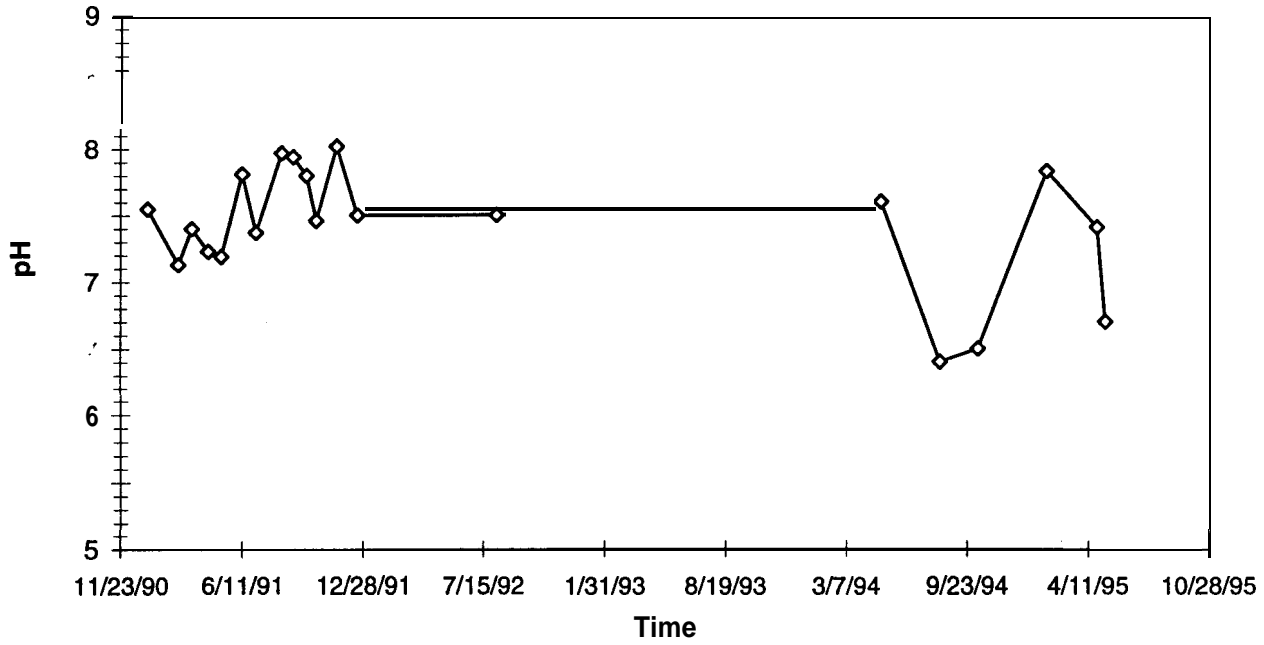


Figure 2-1
Vangorda Mine
Site Plan

a) pH vs. Time



b) SO4 and Zn in mg/L

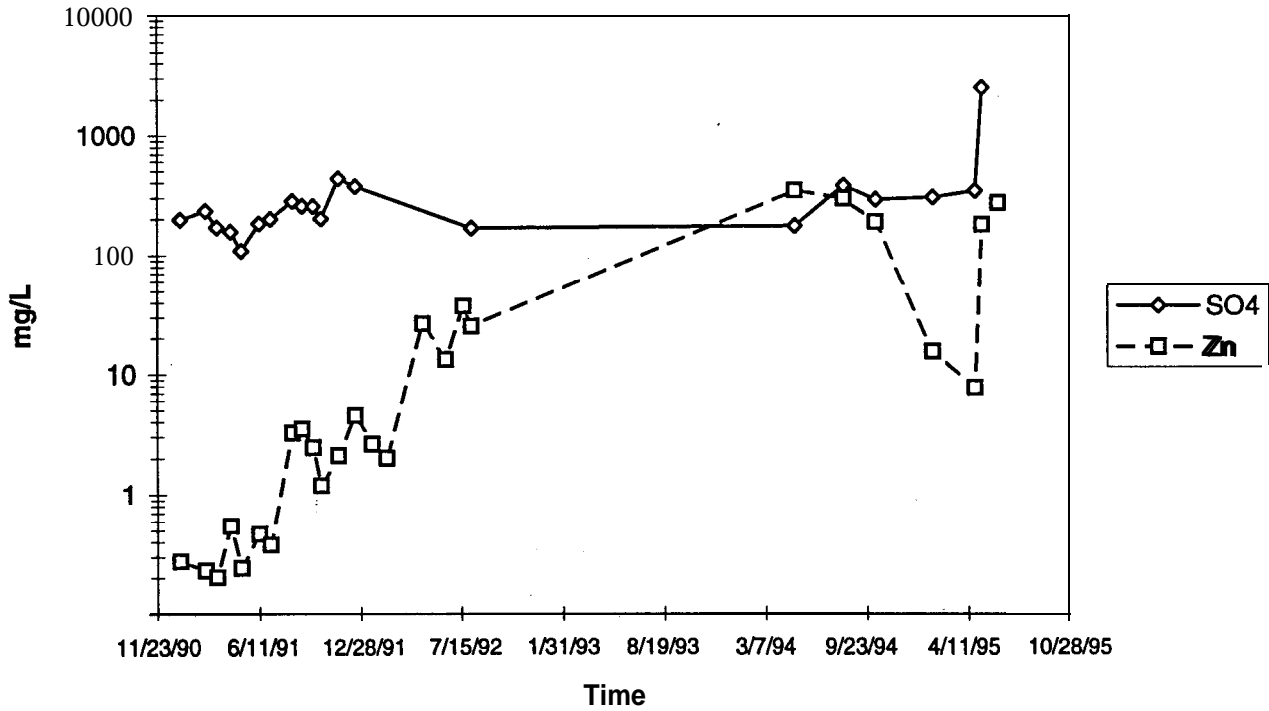
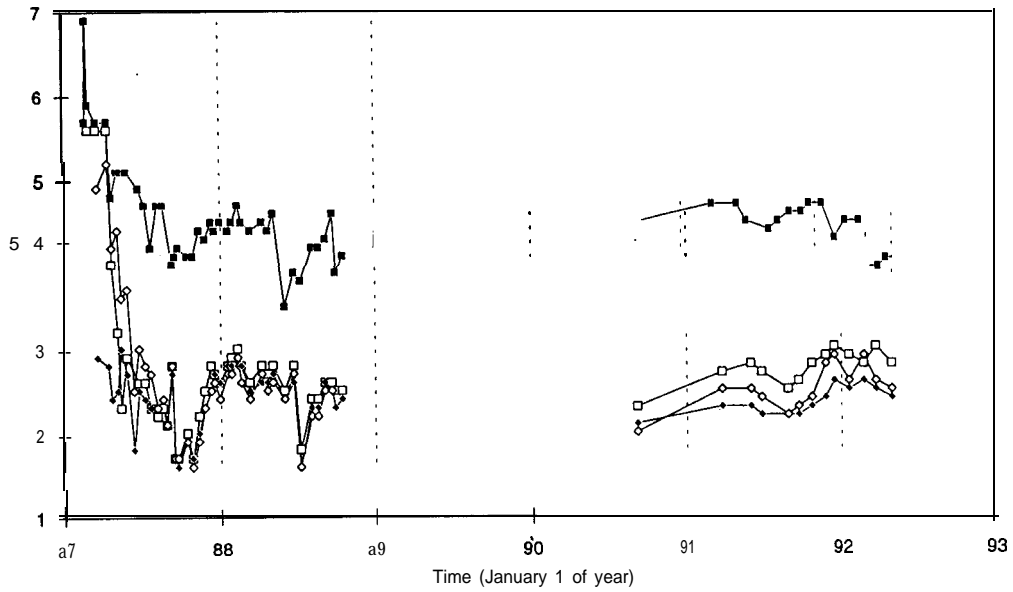
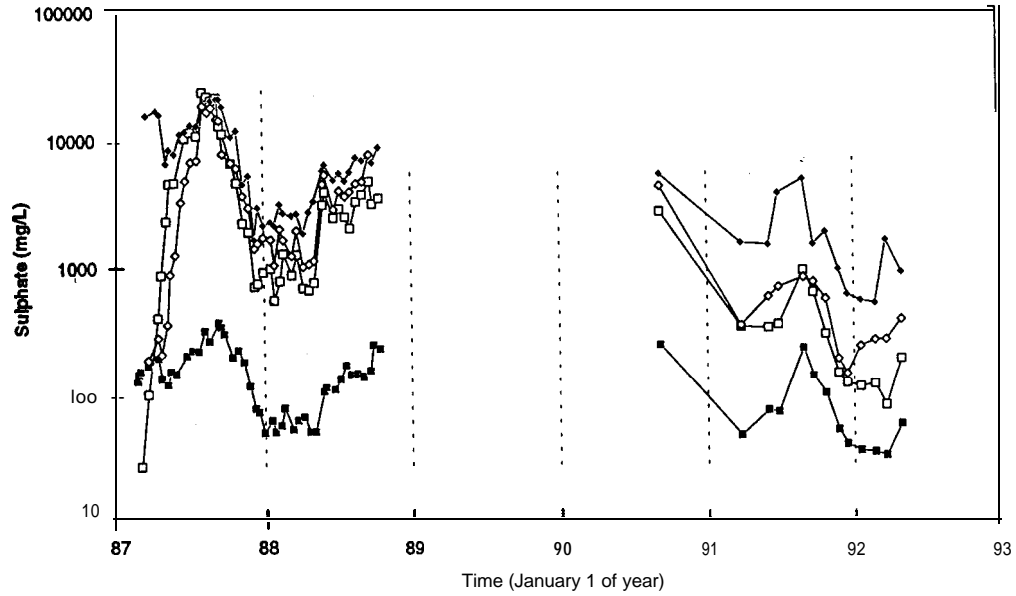


Figure 2-2
Vangorda Mine
Measurements over Time



legend

- Pad 1, Silicified,
5-year
weathered
- Pad 2, Silicified
- Pad 3,
argillally-
Altered
- ◇ Pad 4,
Brecciated



Legend

- Pad 1, Silicified,
5-year
weathered
- Pad 2, Silicified
- Pad 3,
argillally-
Altered
- ◇ Pad 4,
Brecciated

Figure 2-3
Cinola Project
Measurements over Time

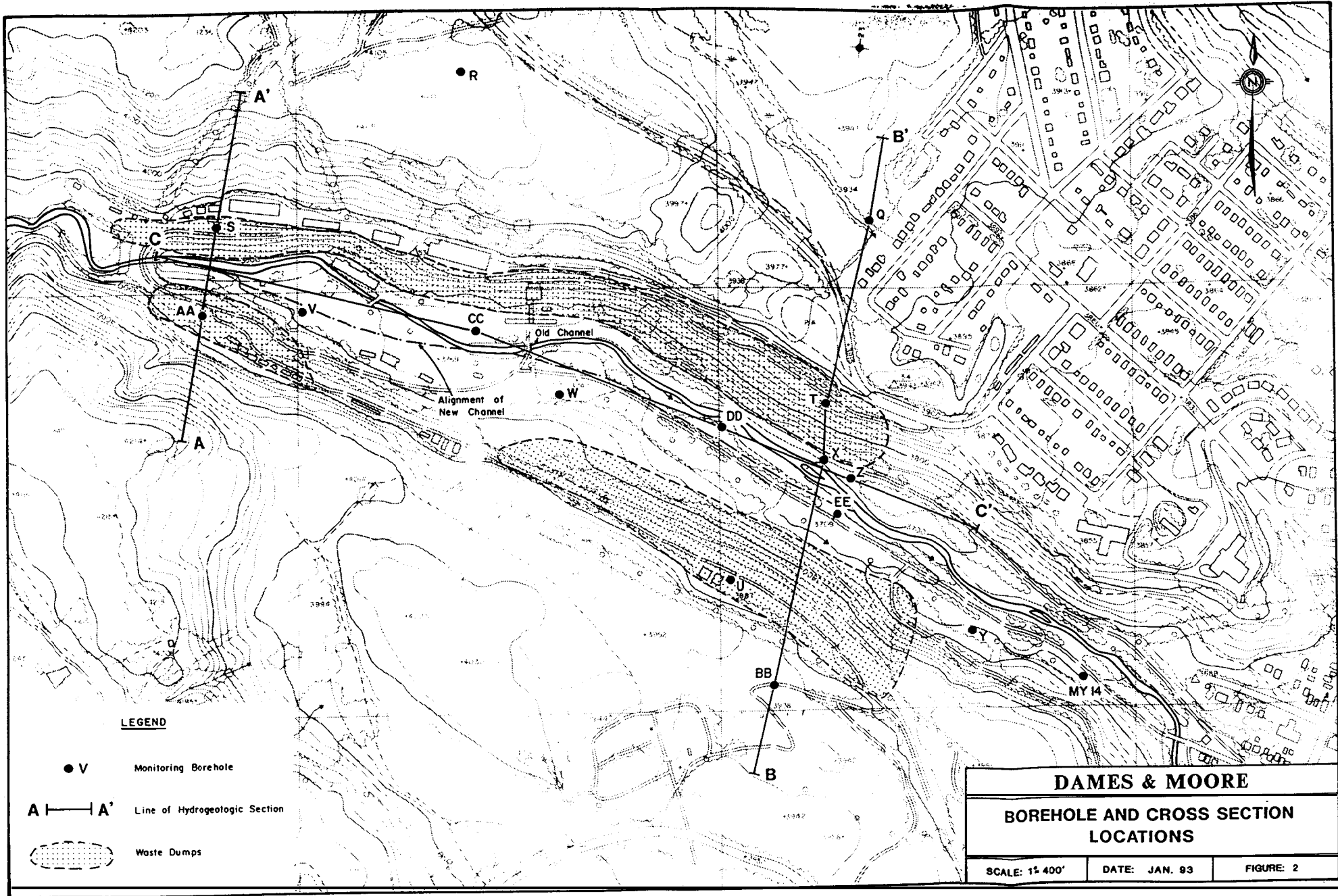


Figure 2-4
 Sullivan Mine Lower Mine Yard
 Groundwater Sampling Locations

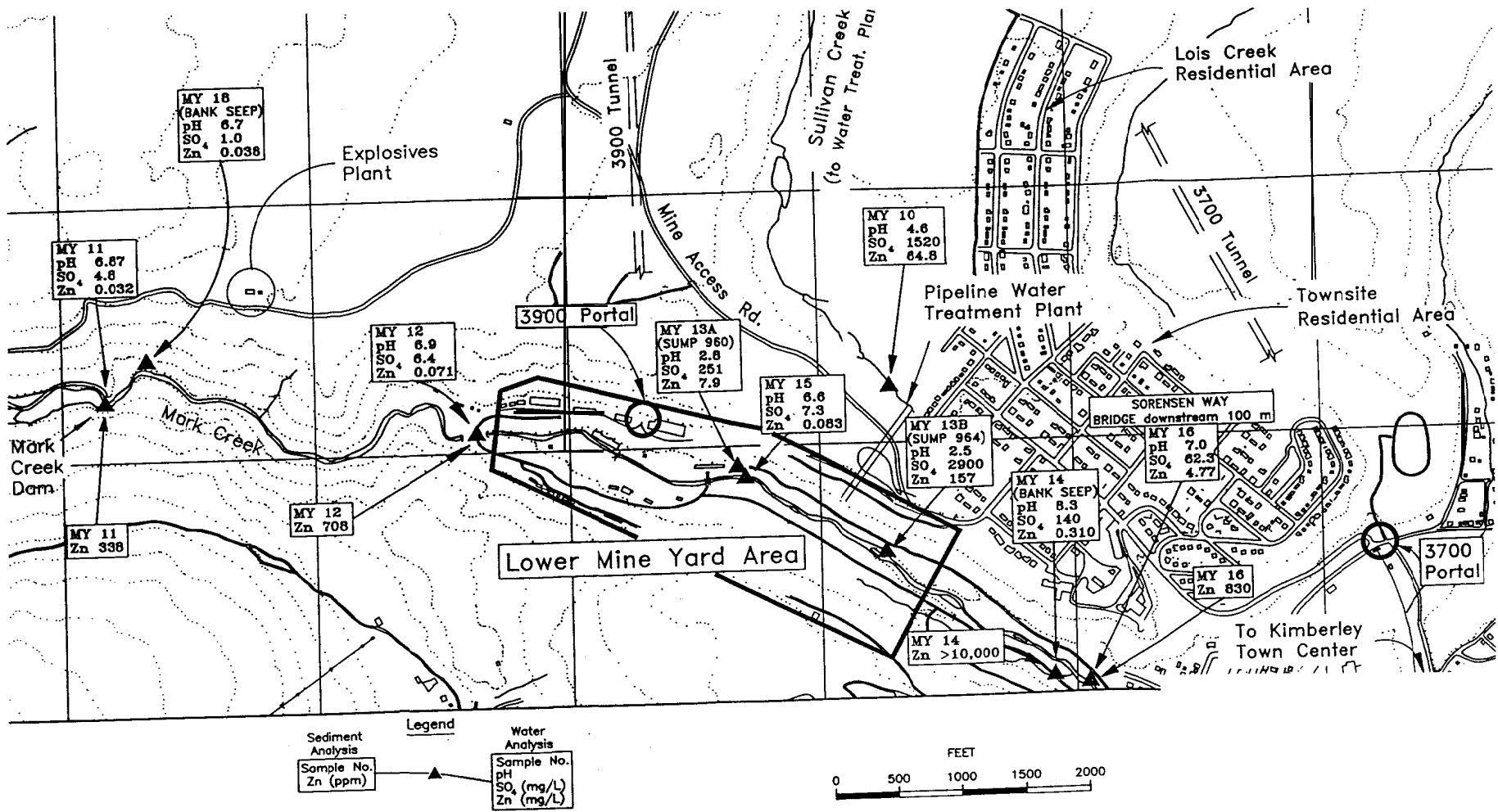


Figure 2-5
Sullivan Mine Lower Mine Yard
Surface Water Sampling Stations

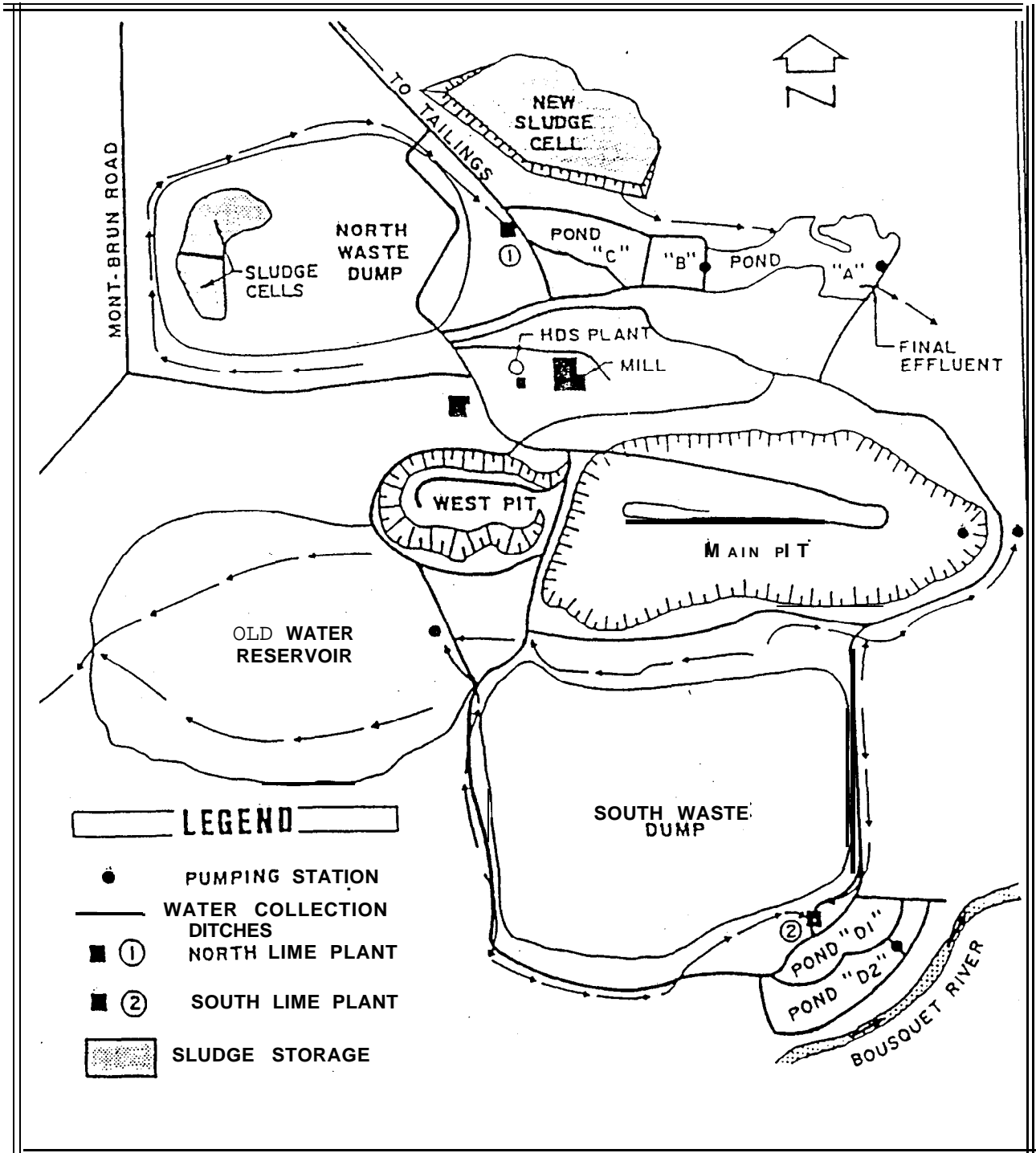


Figure 2-6
 Mine Doyon
 Site Plan

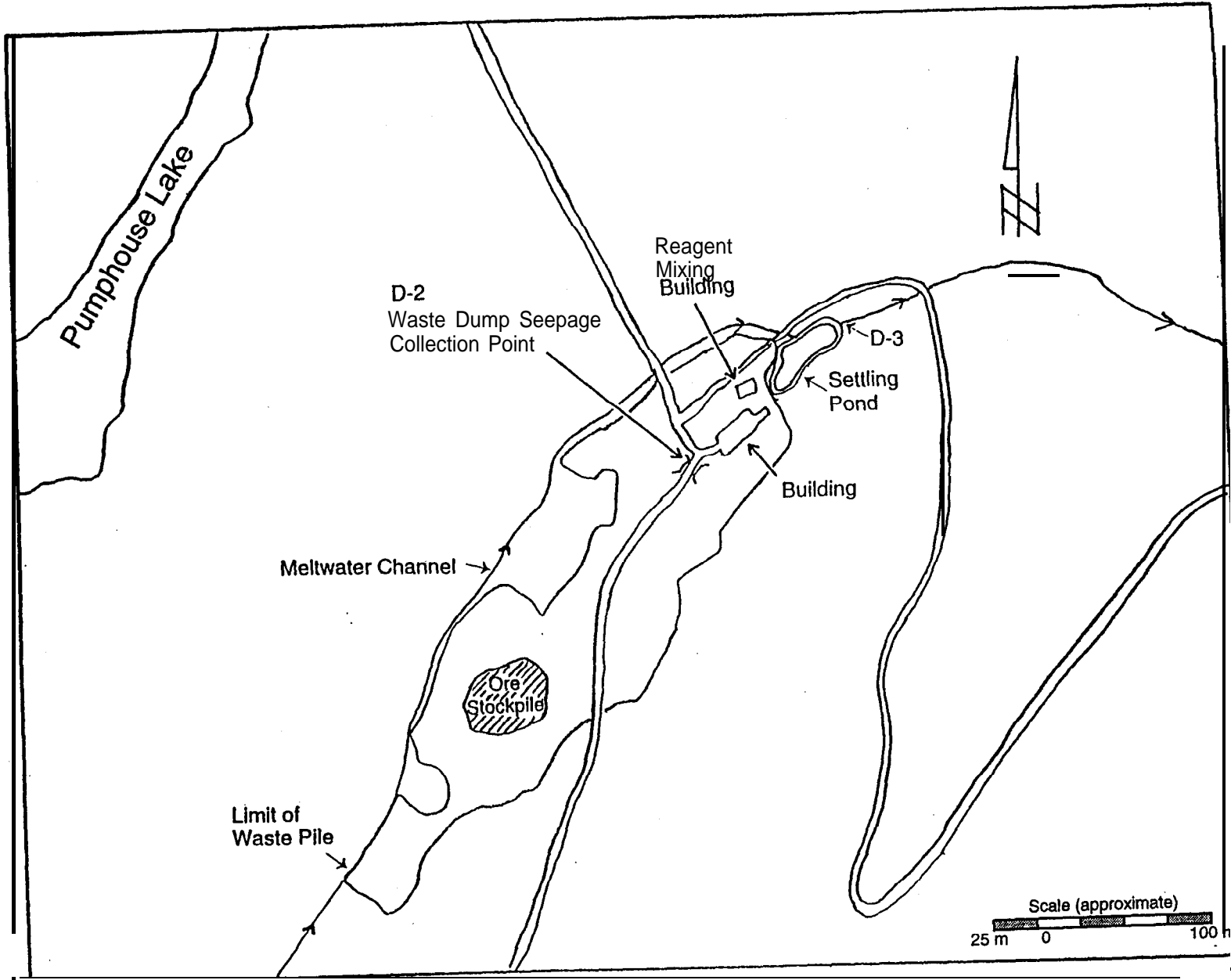
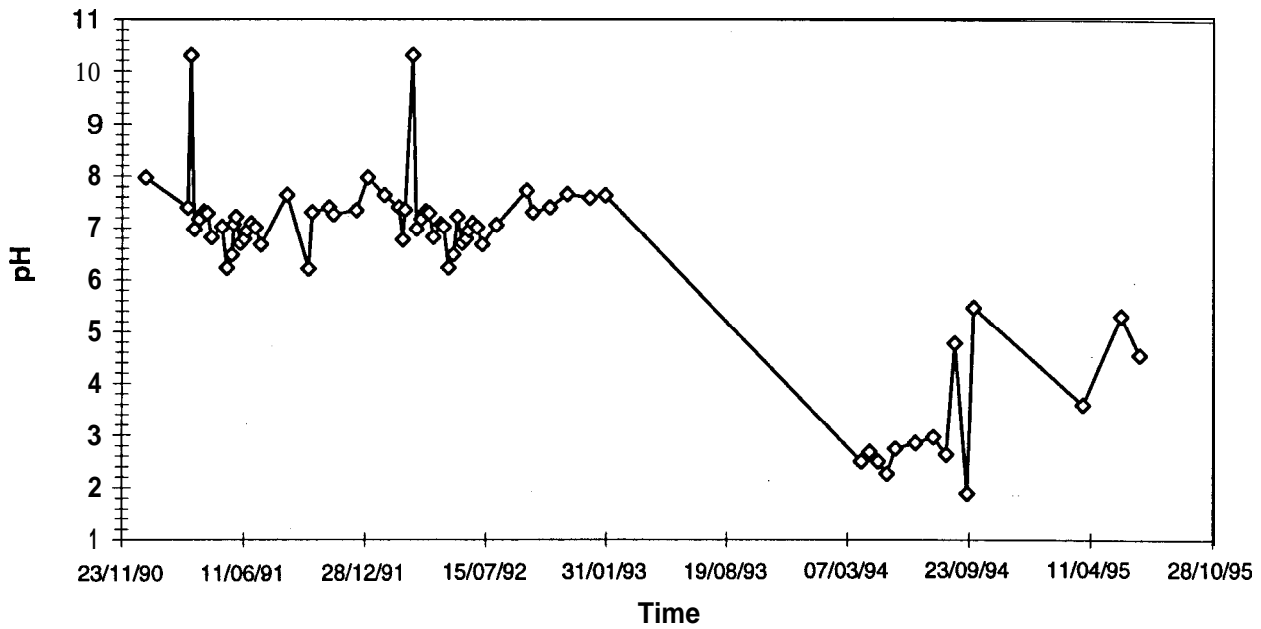


Figure 2-7
Eskay Creek Mine
Site Plan

a) pH vs. Time



b) Selected Parameters in mg/L

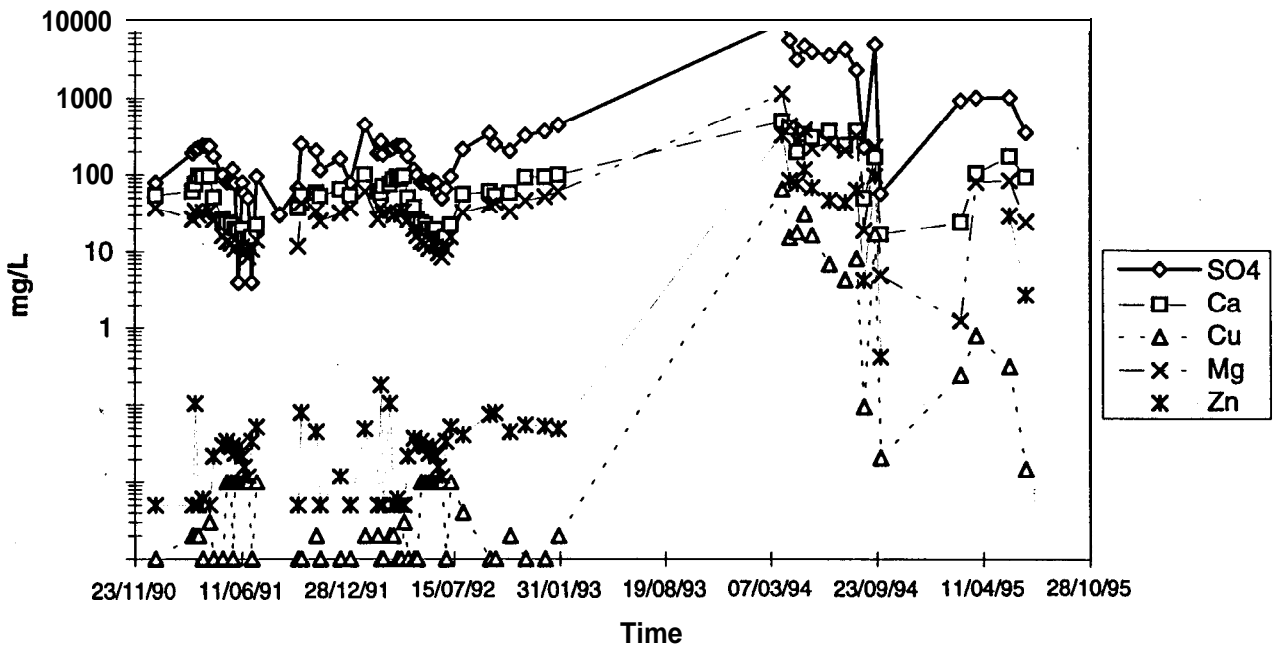
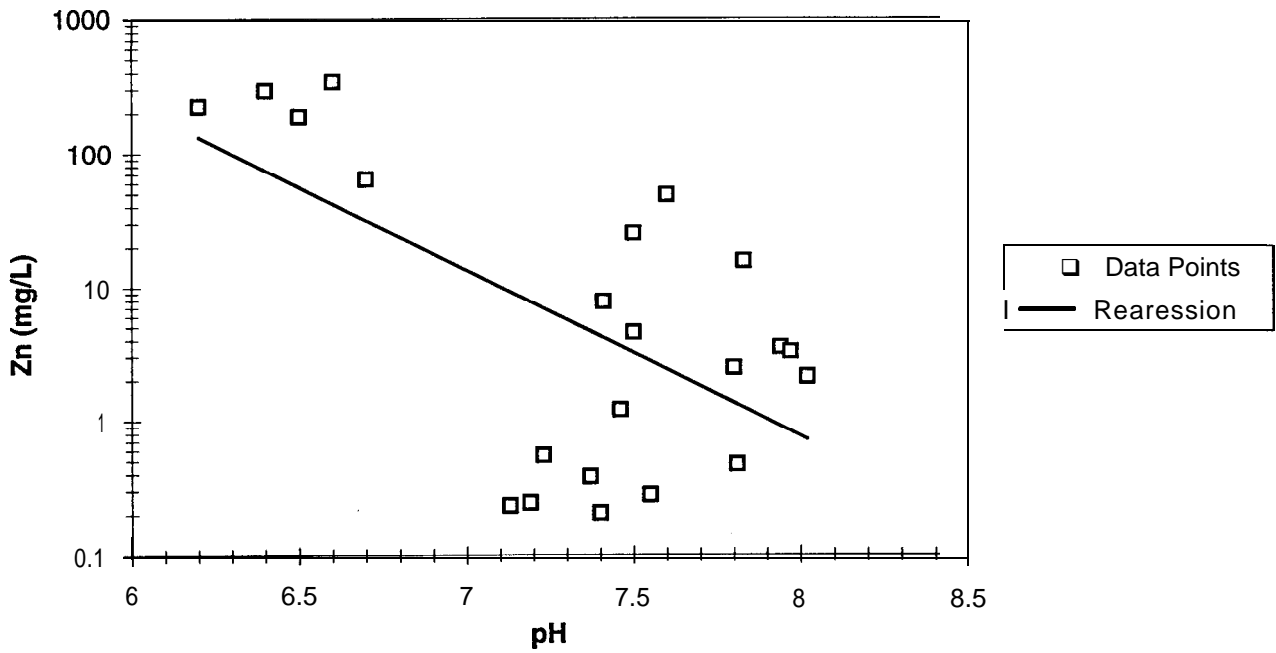


Figure 2-8
Eskay Creek Mine
Measurements over Time

a) Data Plot and Regression



b) Histogram of Residuals

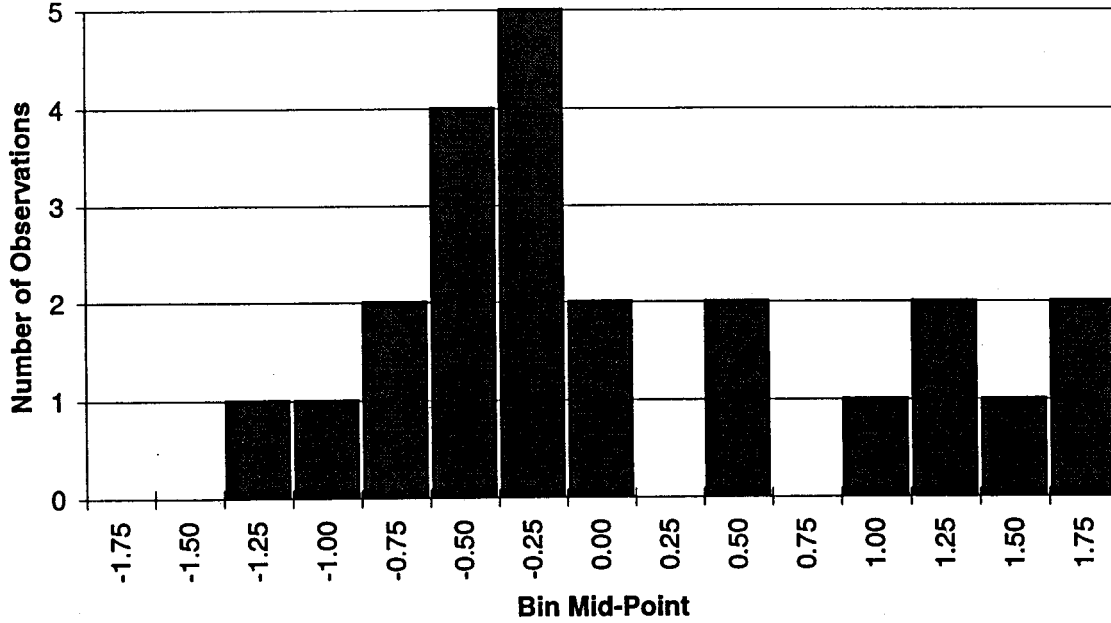
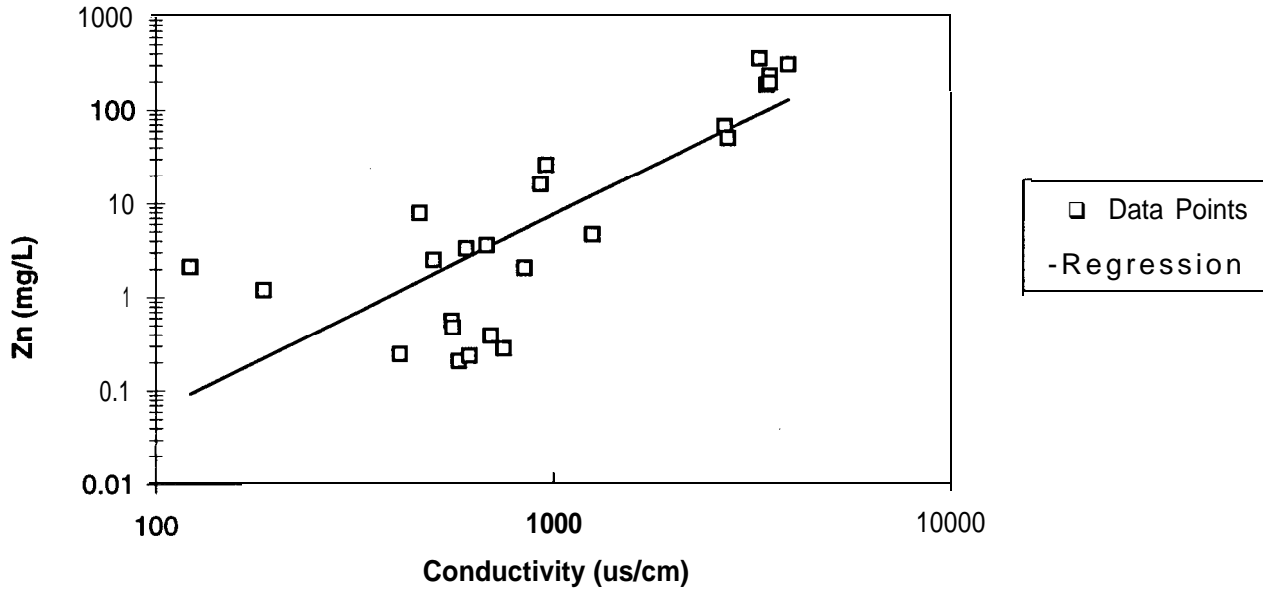


Figure 3-1
Vangorda Mine
Zn vs pH

a) Data Plot and Regression



b) Histogram of Residuals

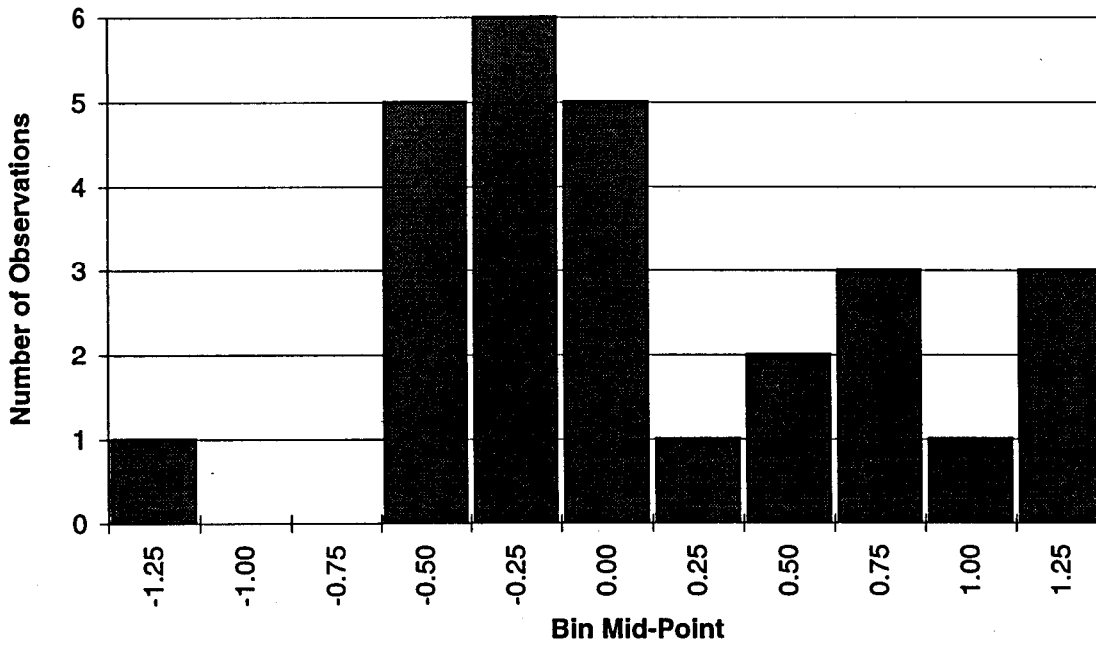
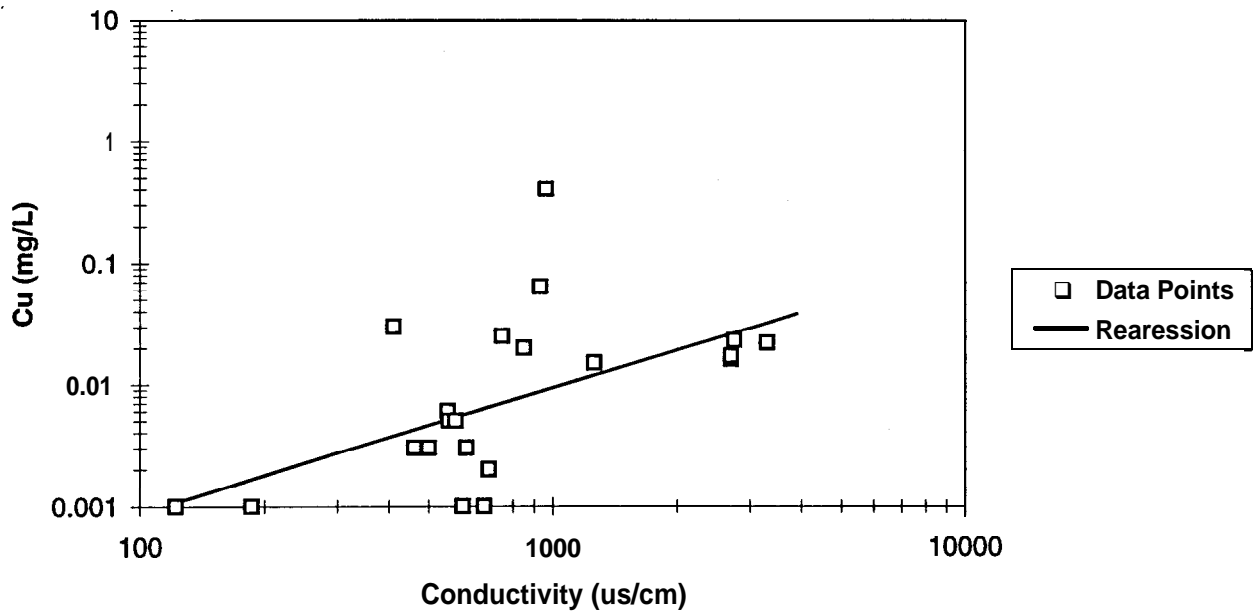


Figure 3-2
Vangorda Mine
Zn vs Conductivity

a) Data Plot and Regression



b) Histogram of Residuals

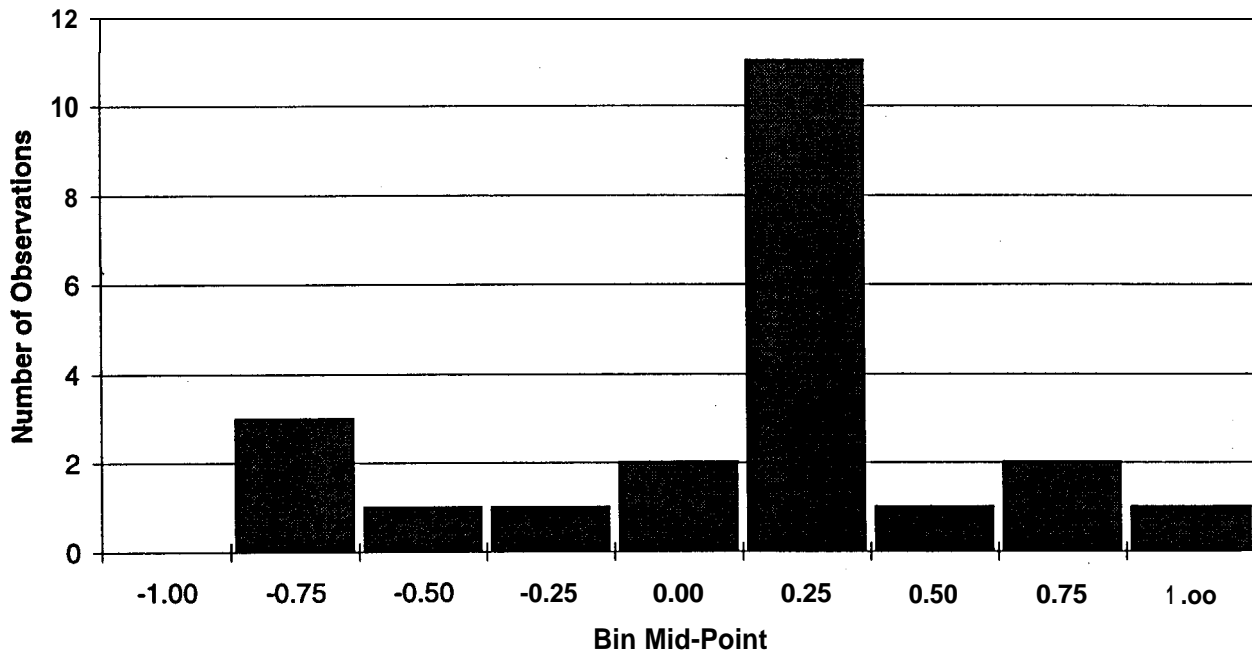
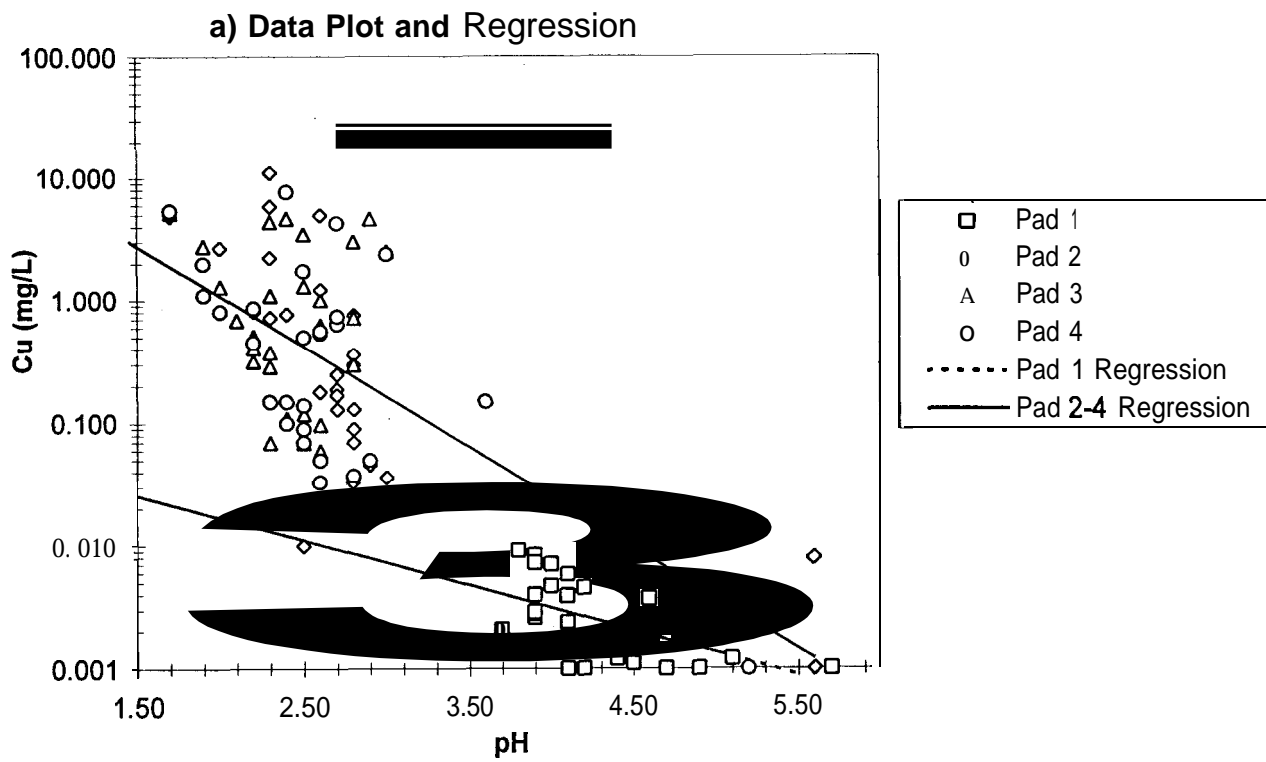
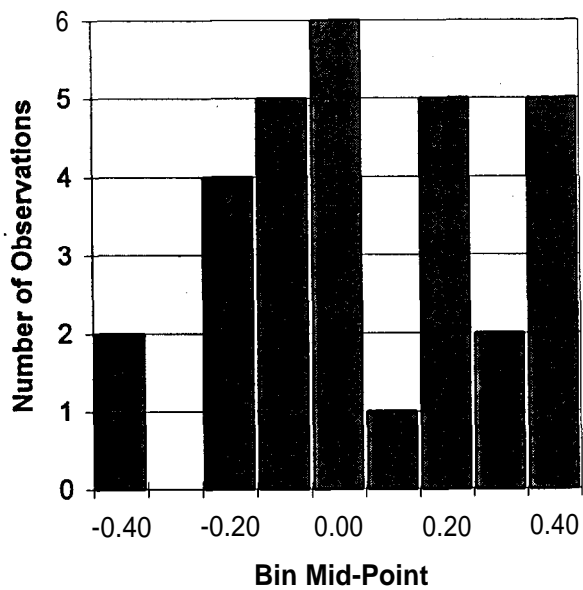


Figure 3-3
Vangorda Mine
Cu vs Conductivity



b) Histogram of Pad 1 Residuals



c) Histogram of Pads 2 through 4 Residuals

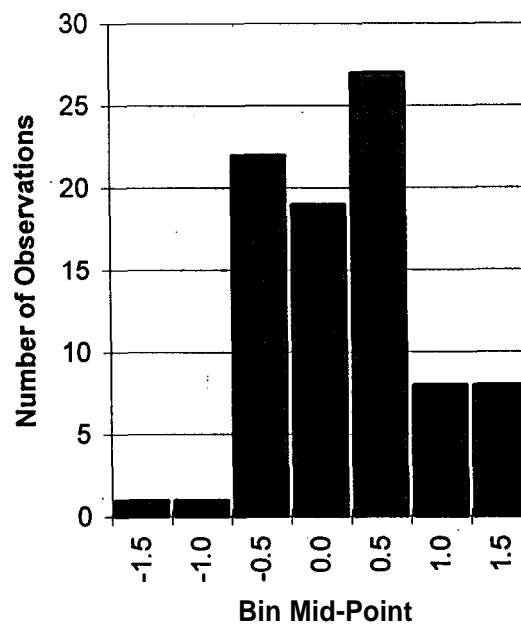
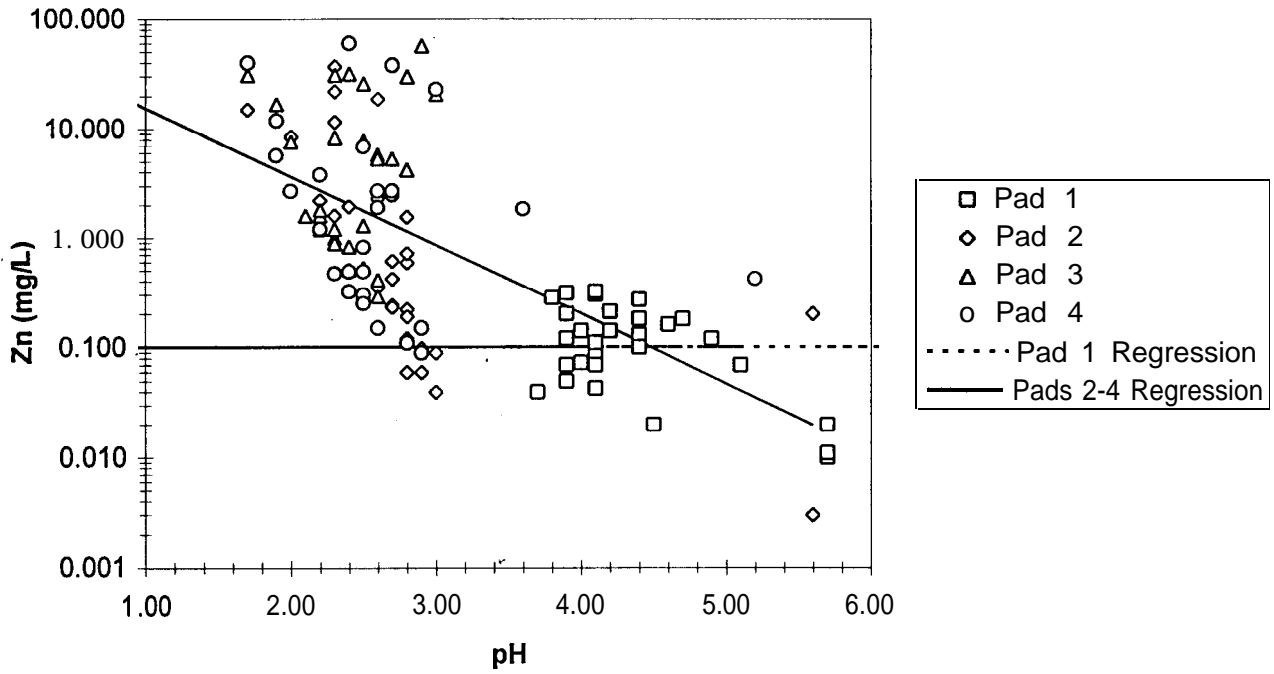
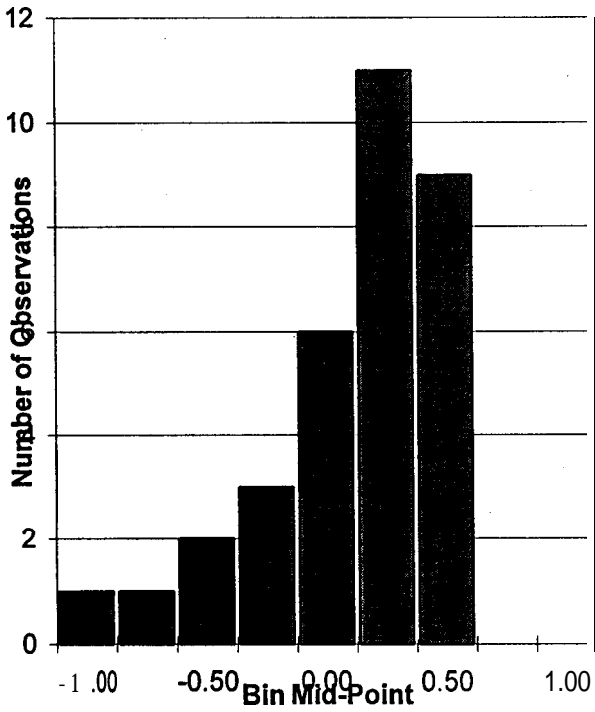


Figure 3-4
Cinola Project
Cu vs pH

a) Data Plots and Regressions



b) Histogram of Pad 1 Residuals



c) Histogram Pads 2 through 4 Residuals

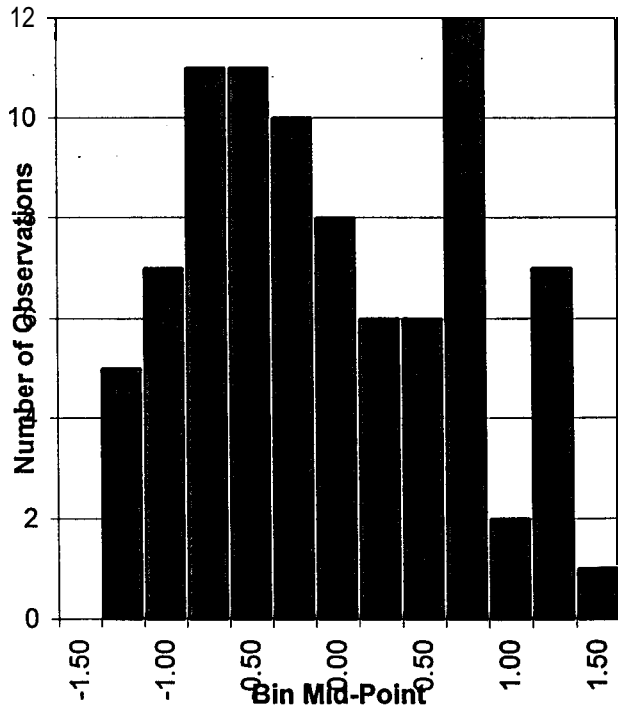
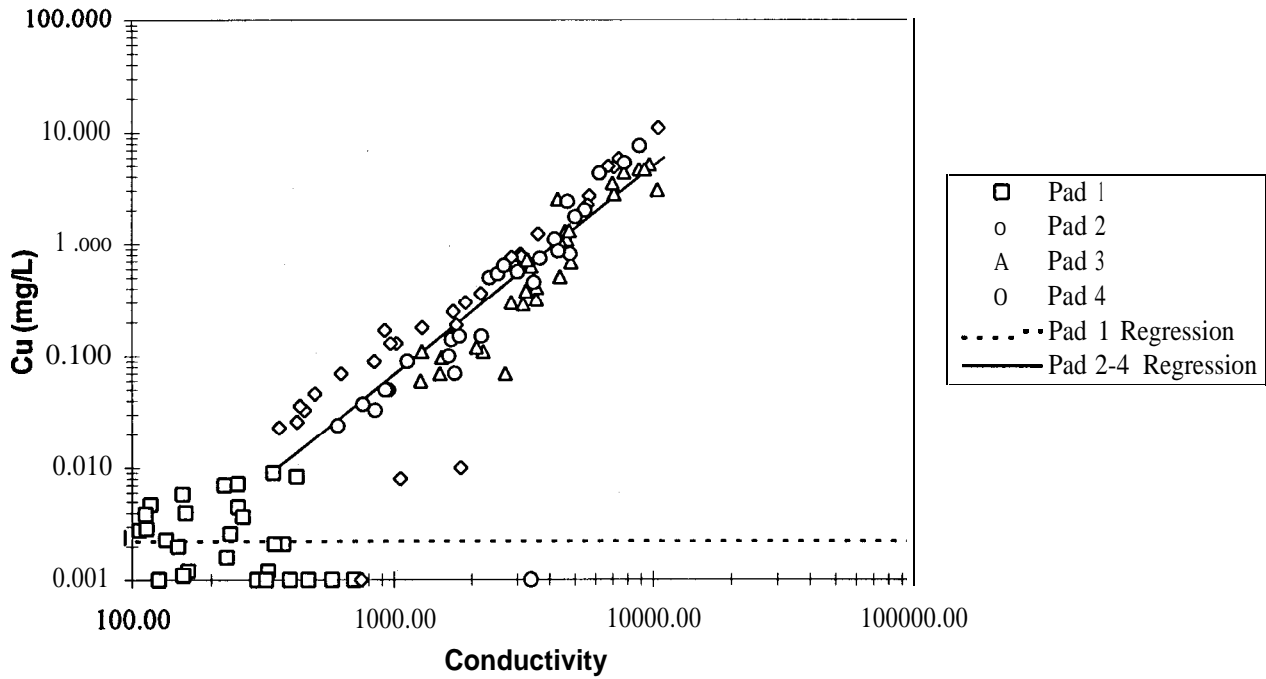
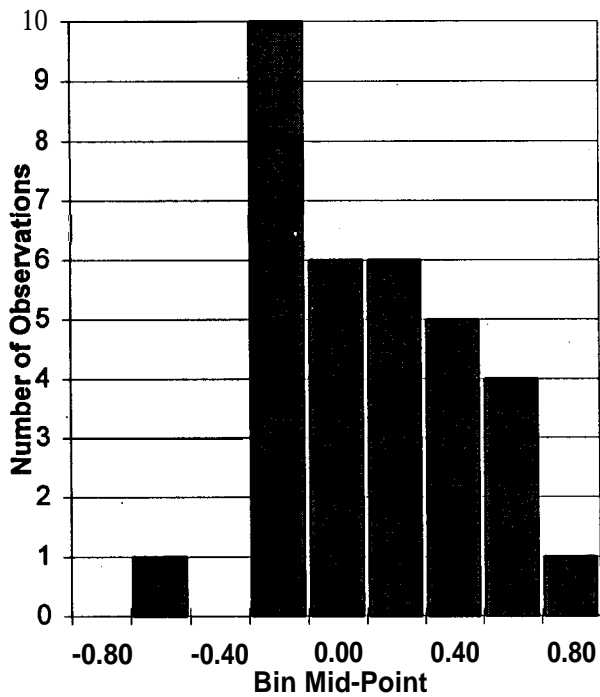


Figure 3-5
Cinola Project
Zn vs pH

a) Data Plots and Regression



b) Histogram of Pad 1 Residuals



c) Histogram of Pads 2 through 4 Residuals

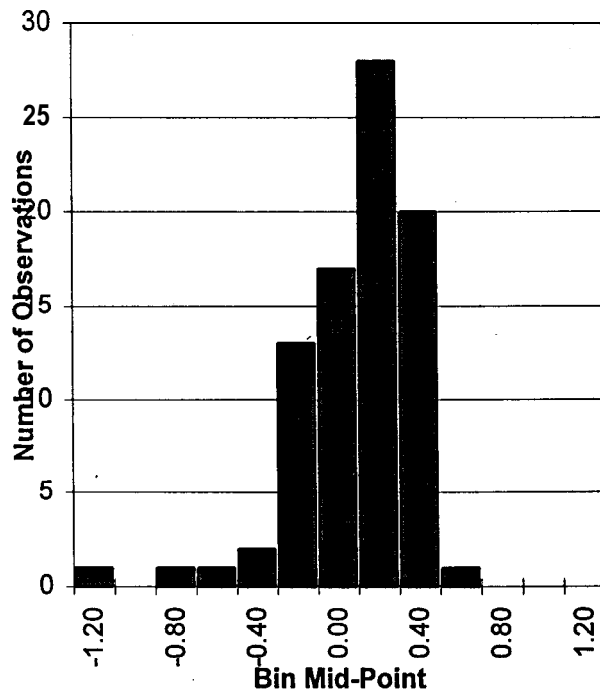
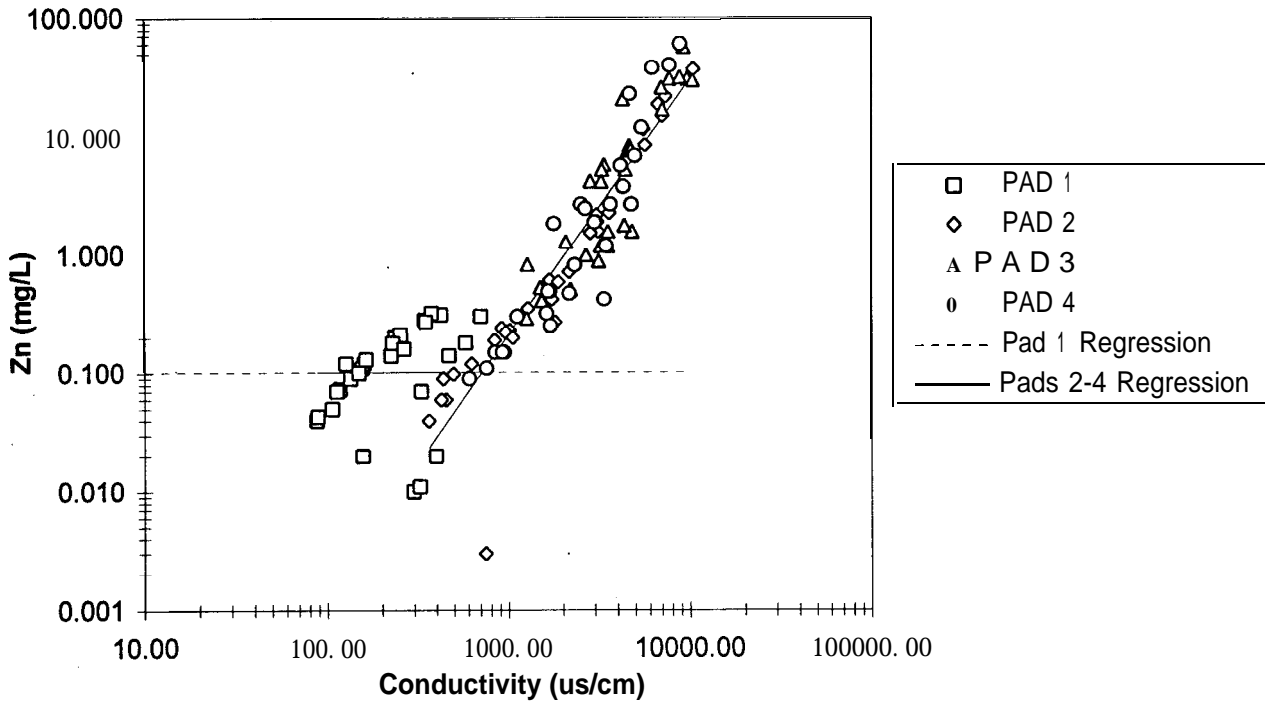
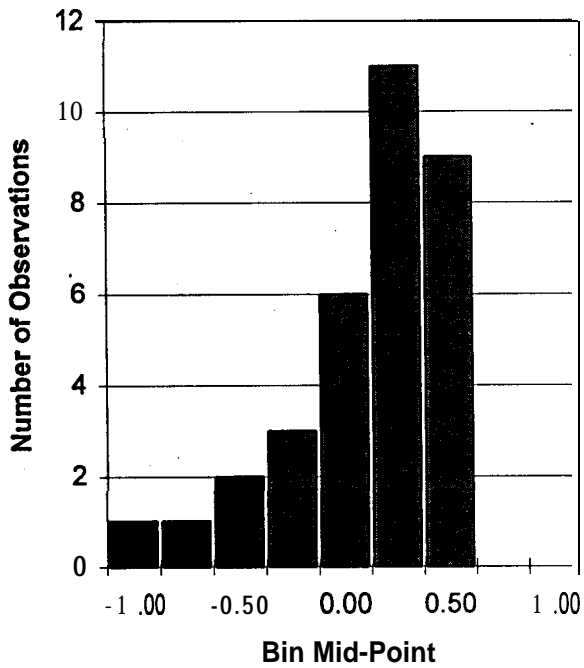


Figure 3-6
Cinola Project
Cu vs Conductivity

a) Data Points and Regressions



a) Histogram of Pad 1 Residuals



b) Histogram of Pad 2 through 4 Residuals

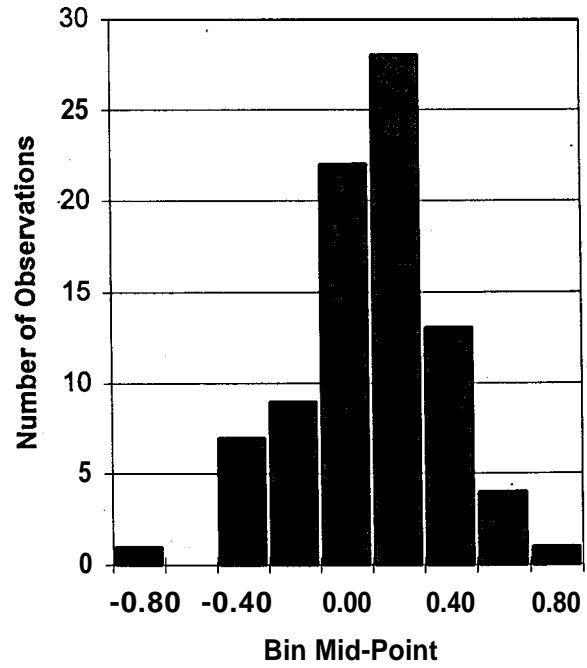
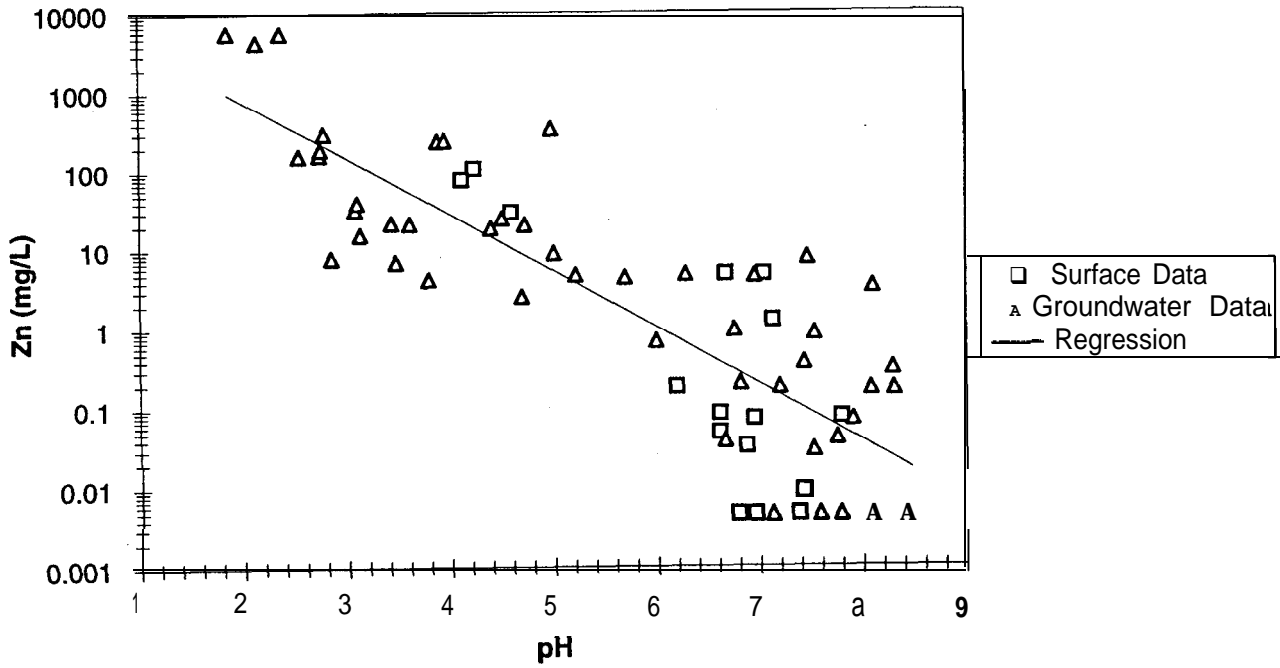


Figure 3-7
Cinola Project
Zn vs Conductivity

a) Data Plot and Regression



b) Histogram of Residuals

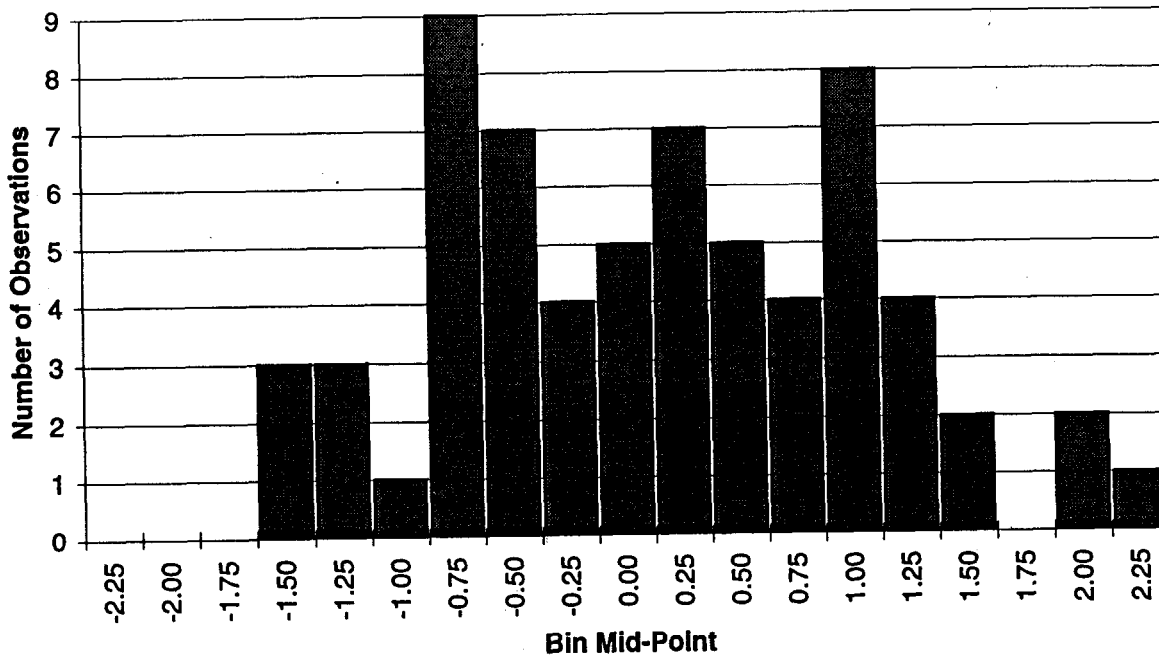
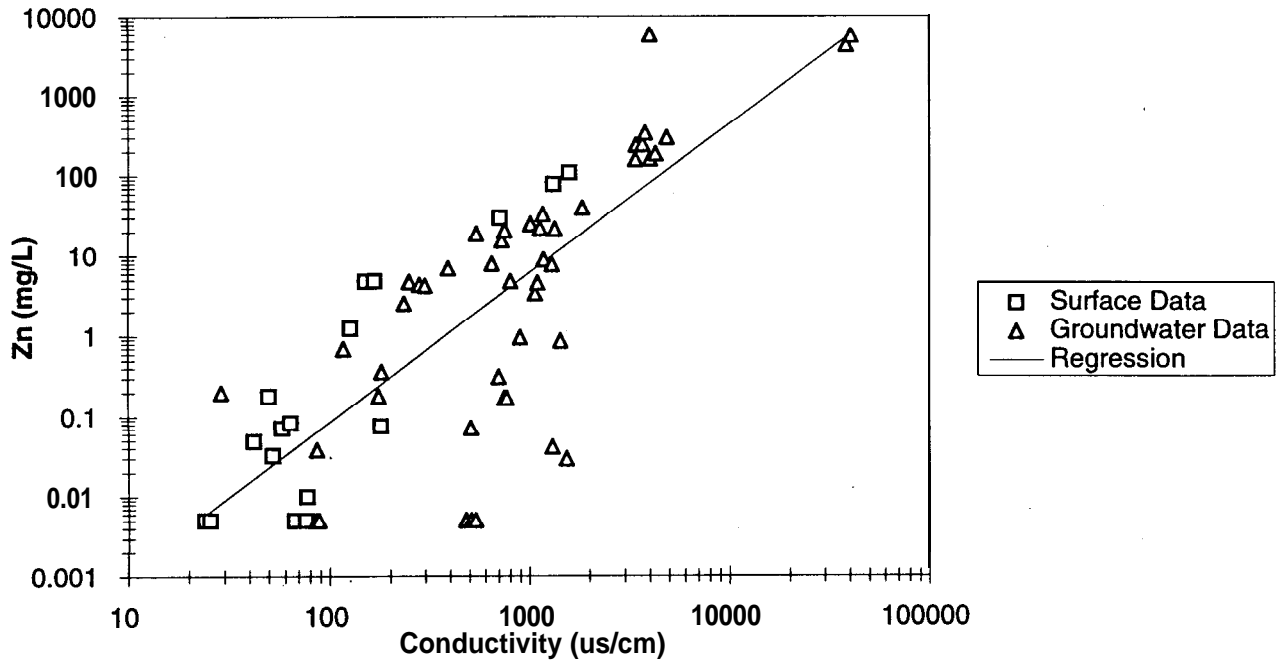


Figure 3-8
Sullivan Mine
Zn vs pH

a) Data Plot and Regression



b) Histogram of Residuals

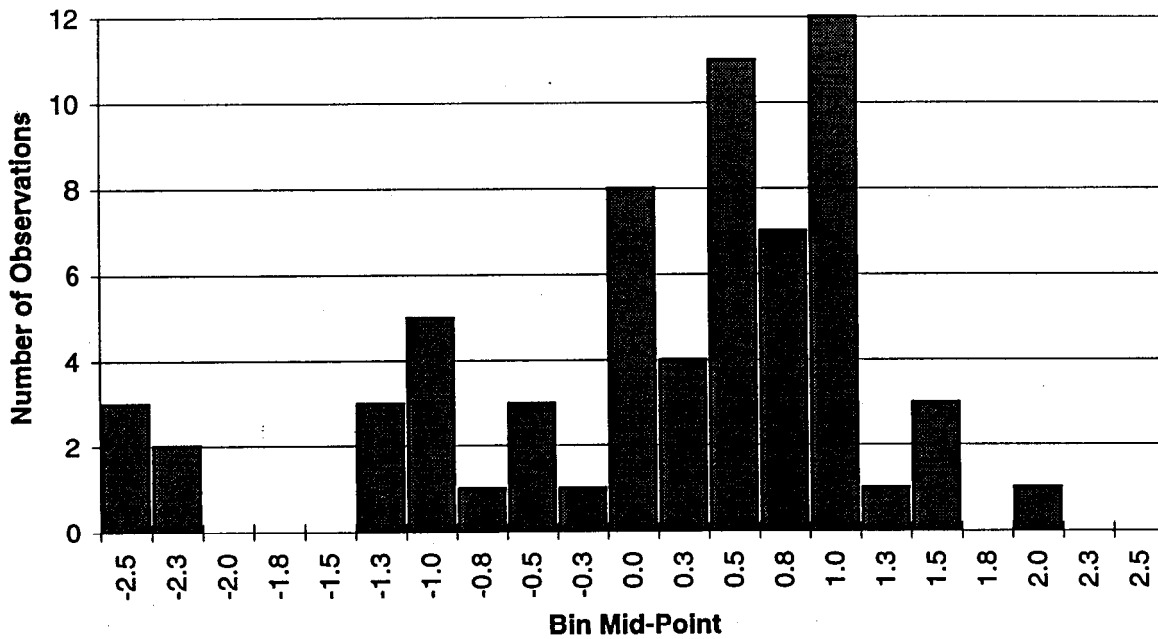
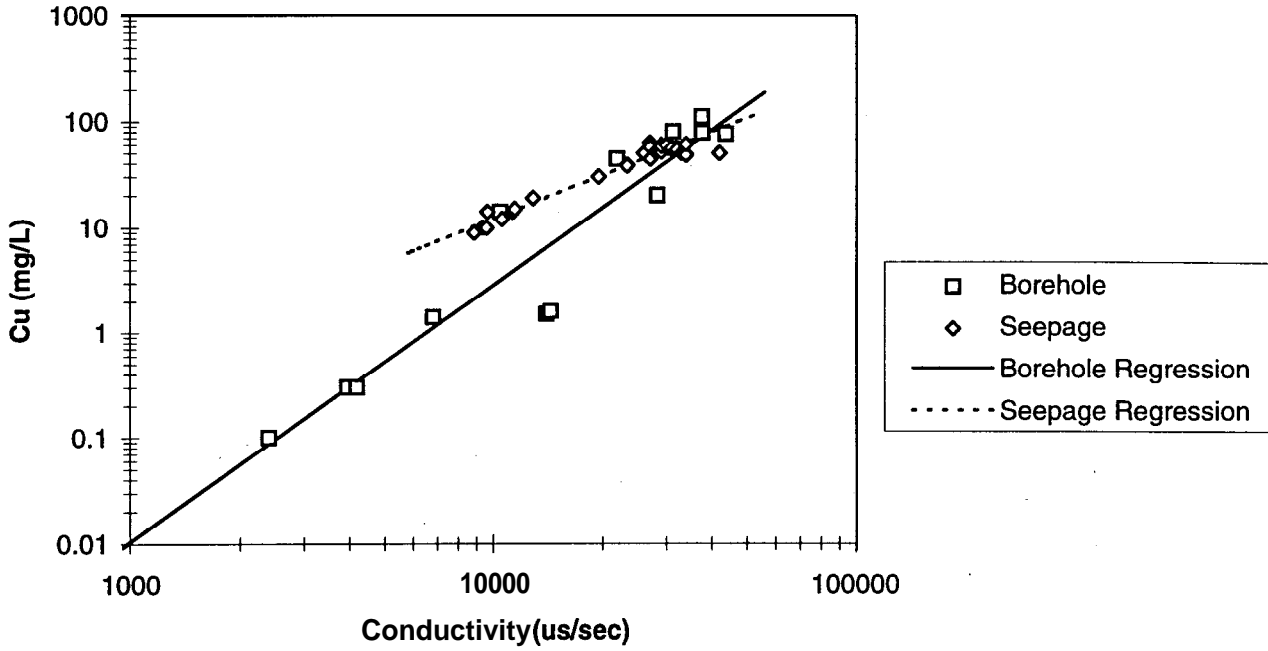
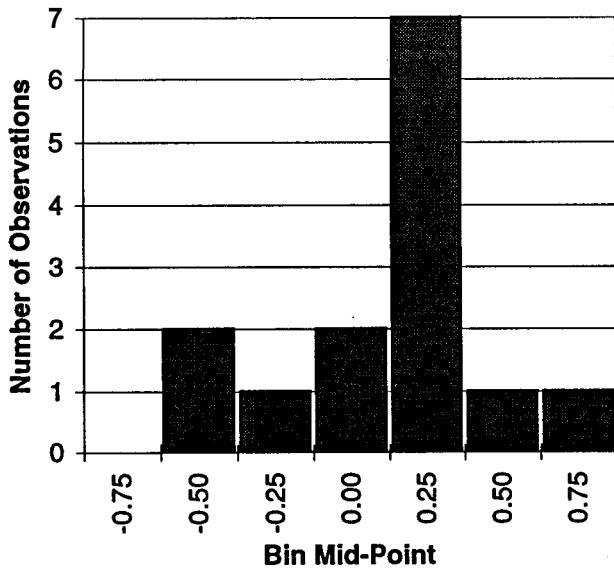


Figure 3-9
Sullivan Mine
Zn vs Conductivity

a) Data Plot and Regressions



b) Histogram of Borehole Residuals



c) Histogram of Seepage Residuals

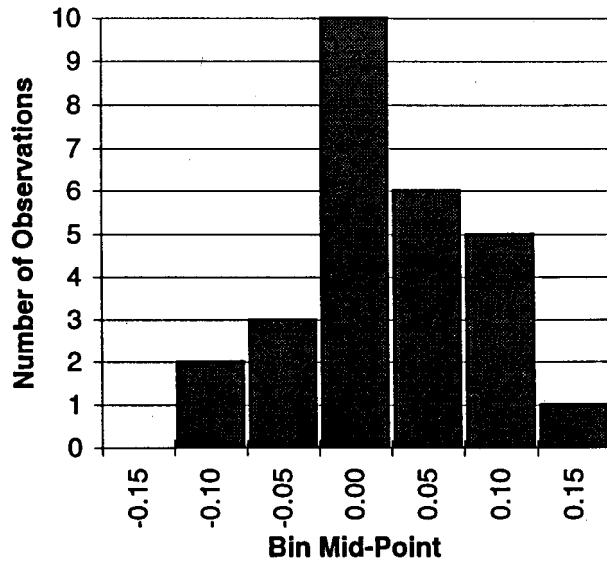
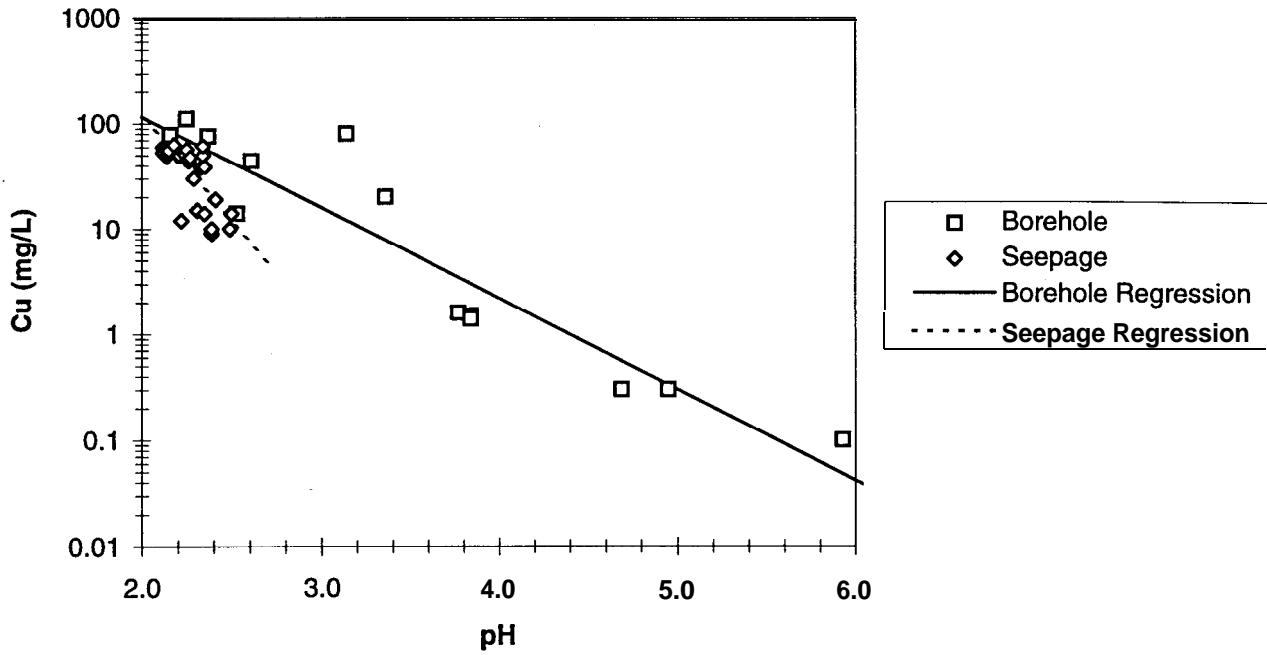
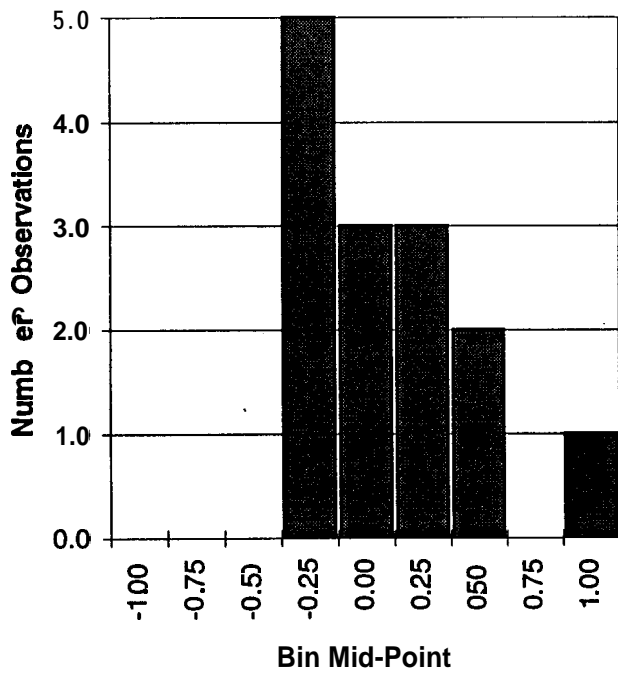


Figure 3-10
Doyon Mine
Cu vs Conductivity

a) Data Plot and Regressions



b) Histogram of Borehole Residuals



c) Histogram of Seepage Residuals

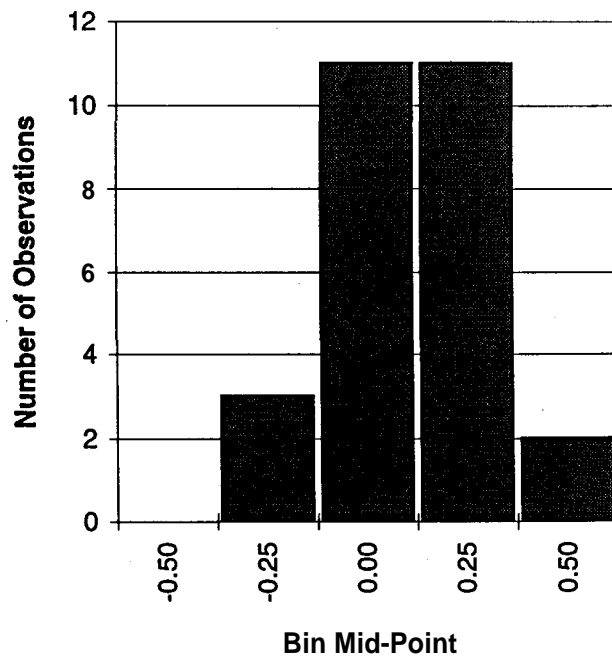
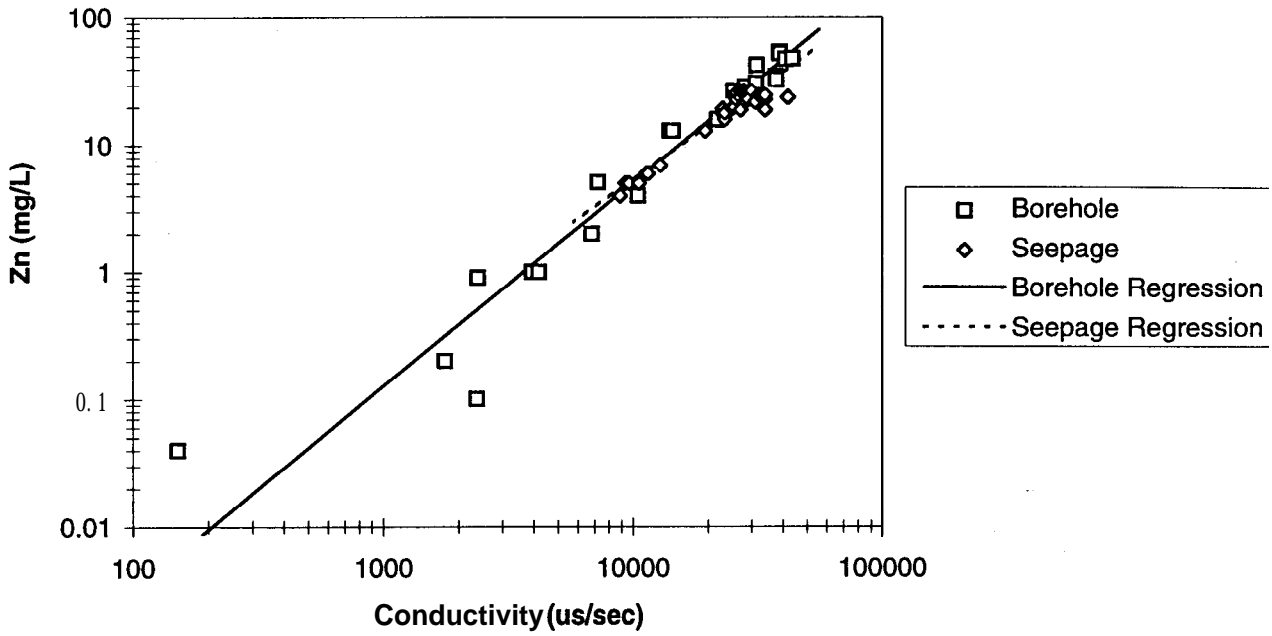
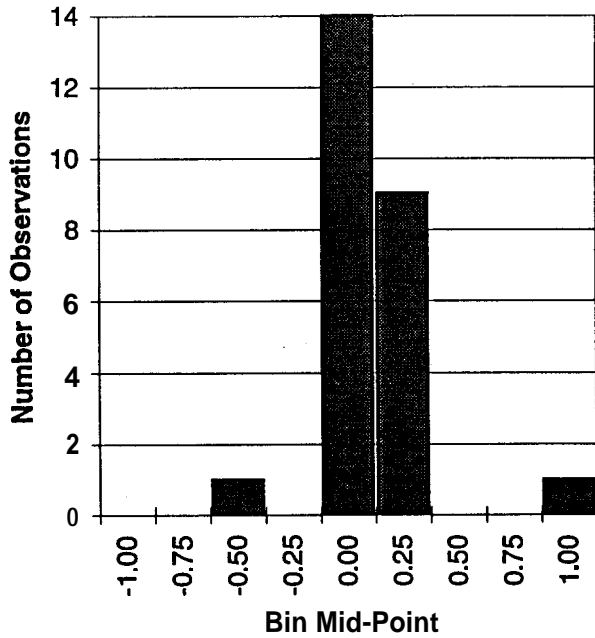


Figure 3-11
Doyon Mine
Cu vs pH

a) Data Plot and Regressions



b) Histogram of Borehole Residuals



c) Histogram of Seepage Residuals

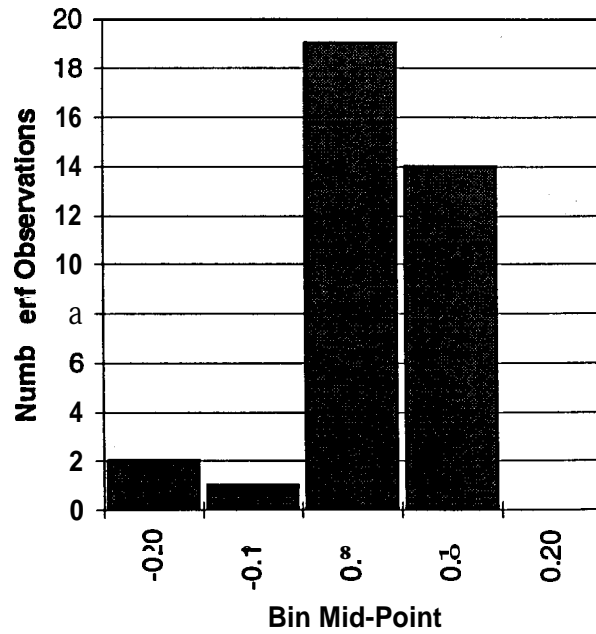
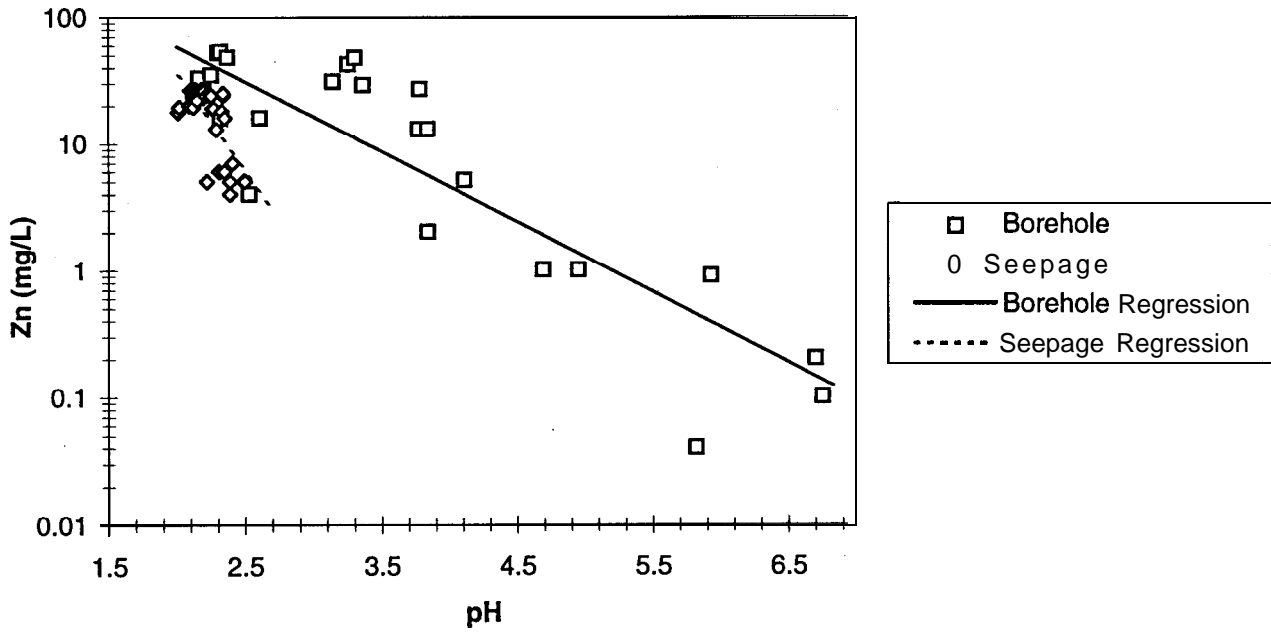
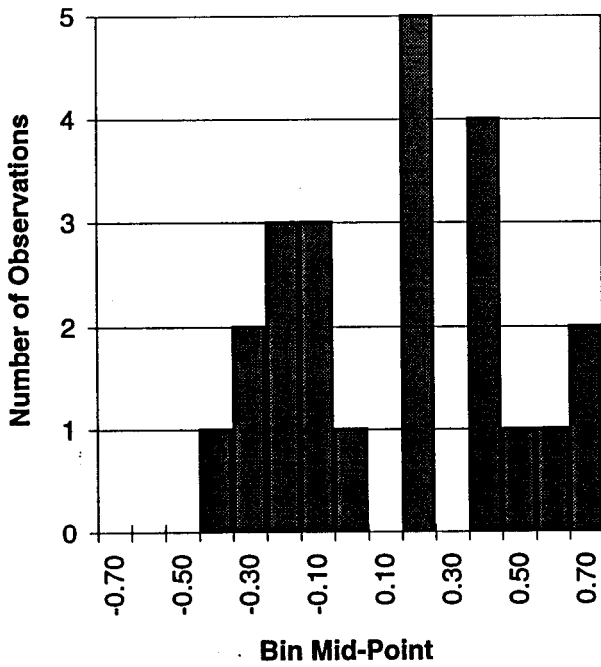


Figure 3-12
Doyon Mine
Zn vs Conductivity

a) Data Plot and Regressions



b) Histogram of Borehole Residuals



c) Histogram of Seepage Residuals

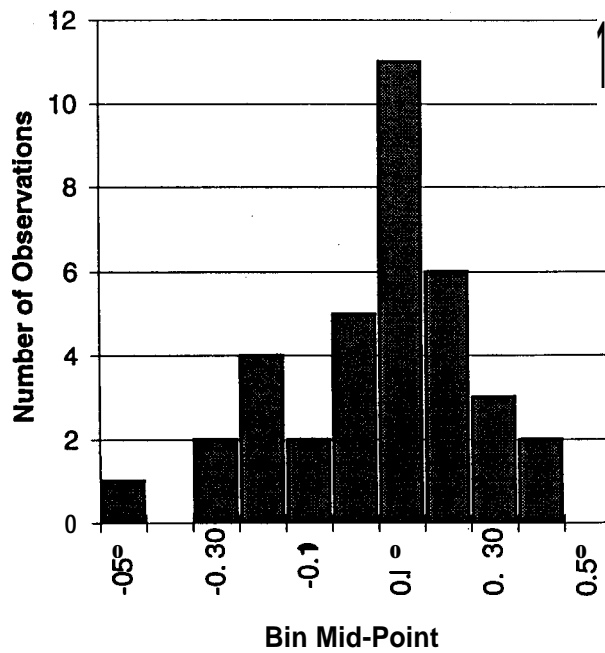
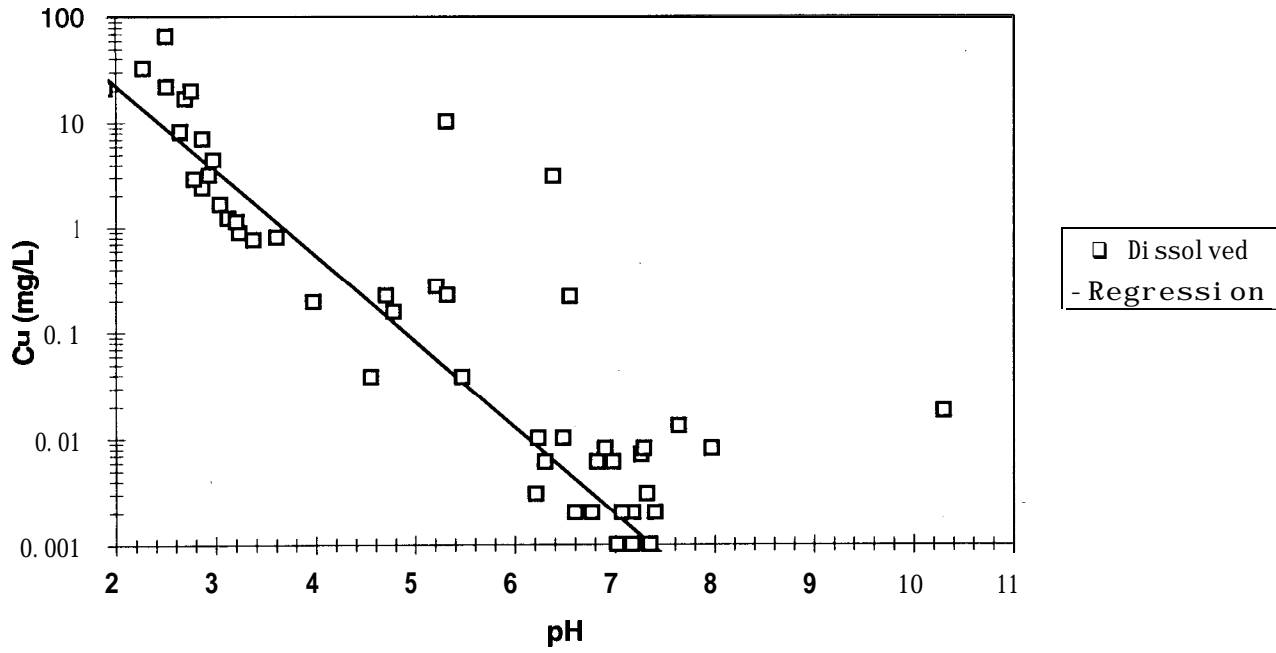


Figure 3-13
Doyon Mine
Zn vs pH

a) Data Plot and Regression



b) Histogram of Residuals

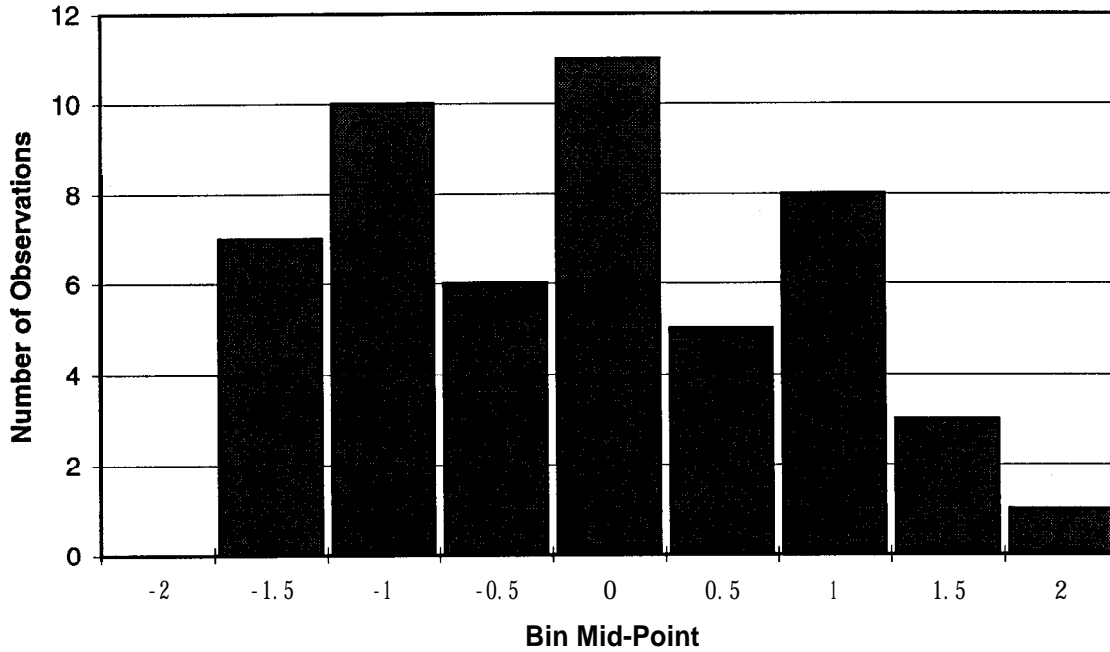
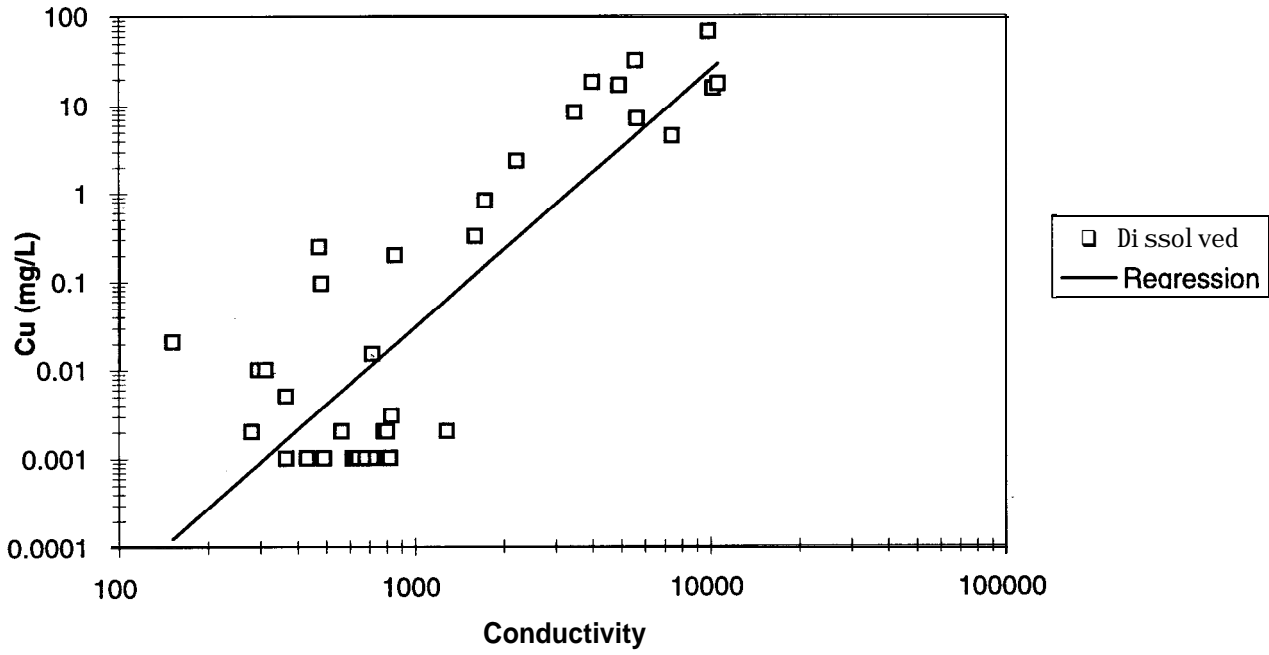


Figure 3-1 4
Eskay Creek Mine
Cu vs pH

a) Data Plot and Regression



b) Histogram of Residuals

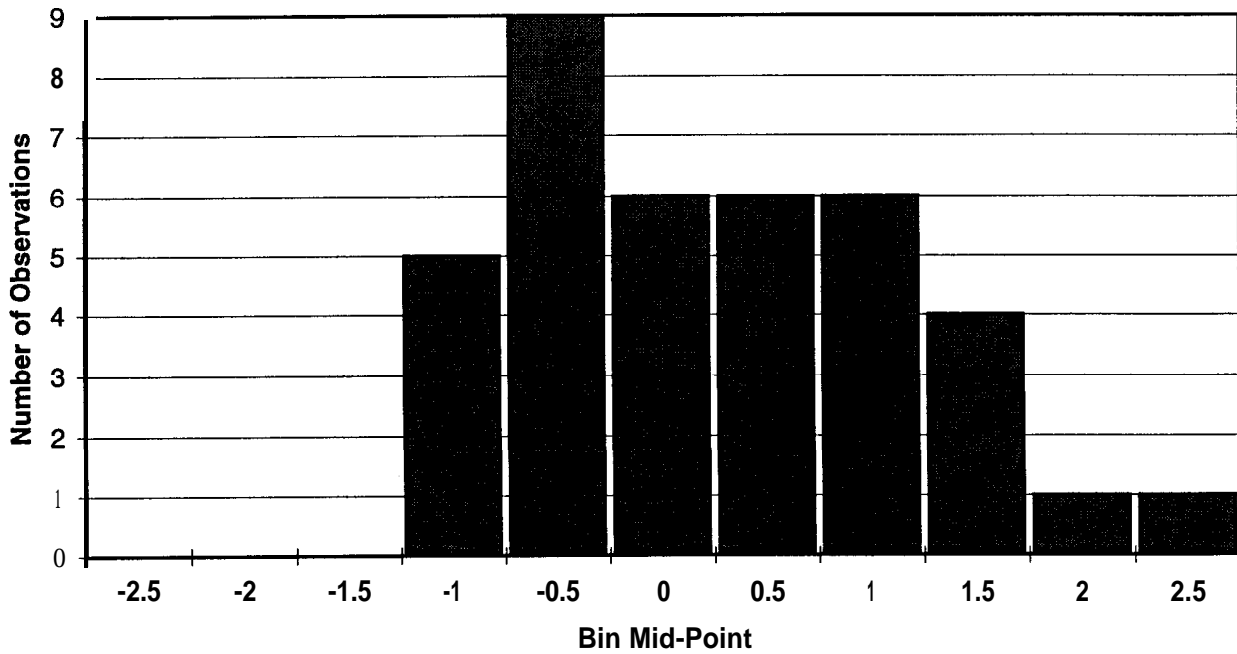
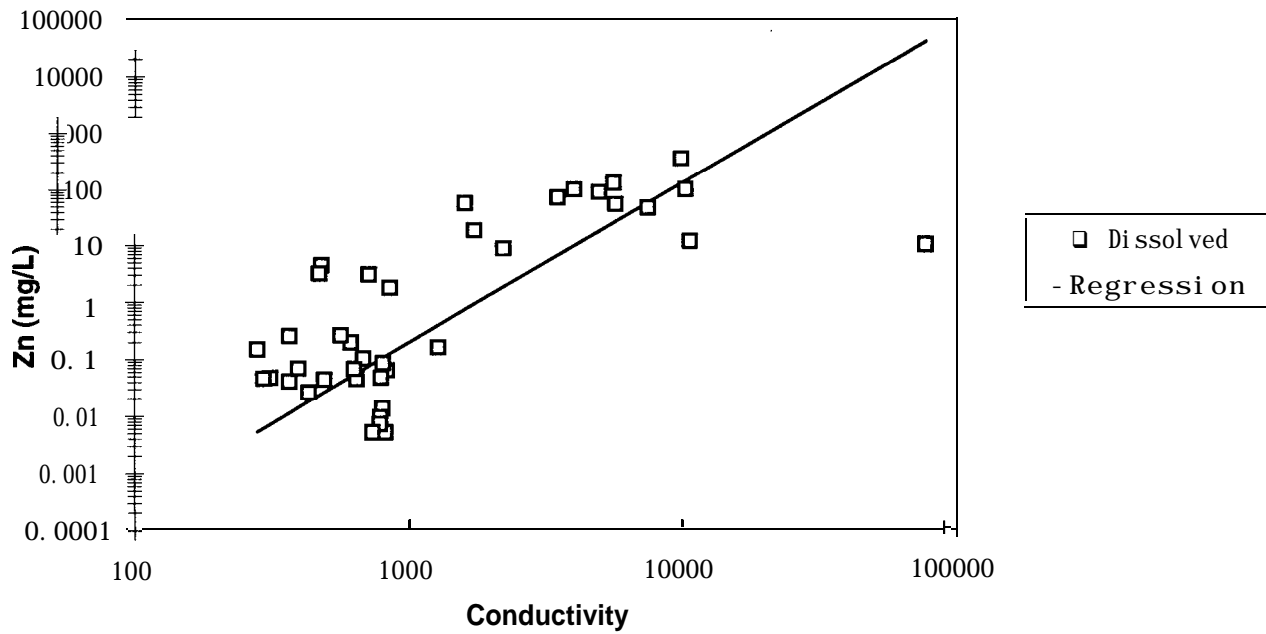


Figure 3-I 5
Eskay Creek Mine
Cu vs Conductivity

a) Data Plot and Regression



b) Histogram of Residuals

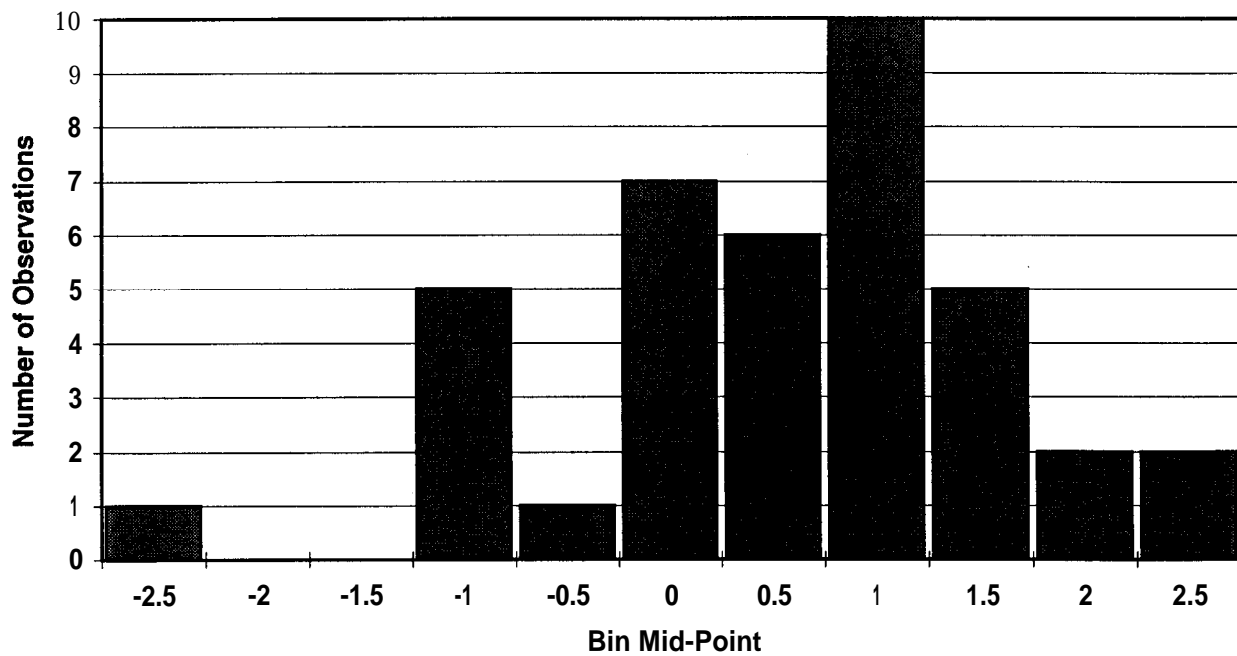
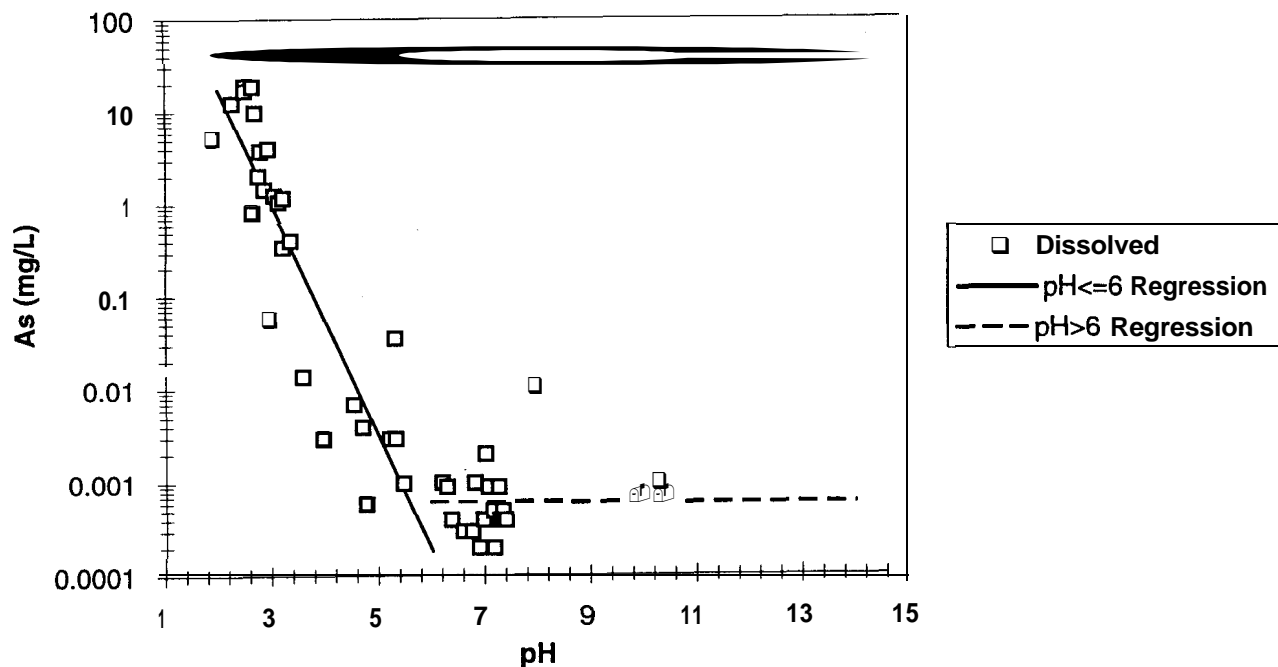


Figure 3-1 6
Eskay Creek Mine
Zn vs Conductivity

a) Data Plot and Regression



b) Histogram of Combined Residuals

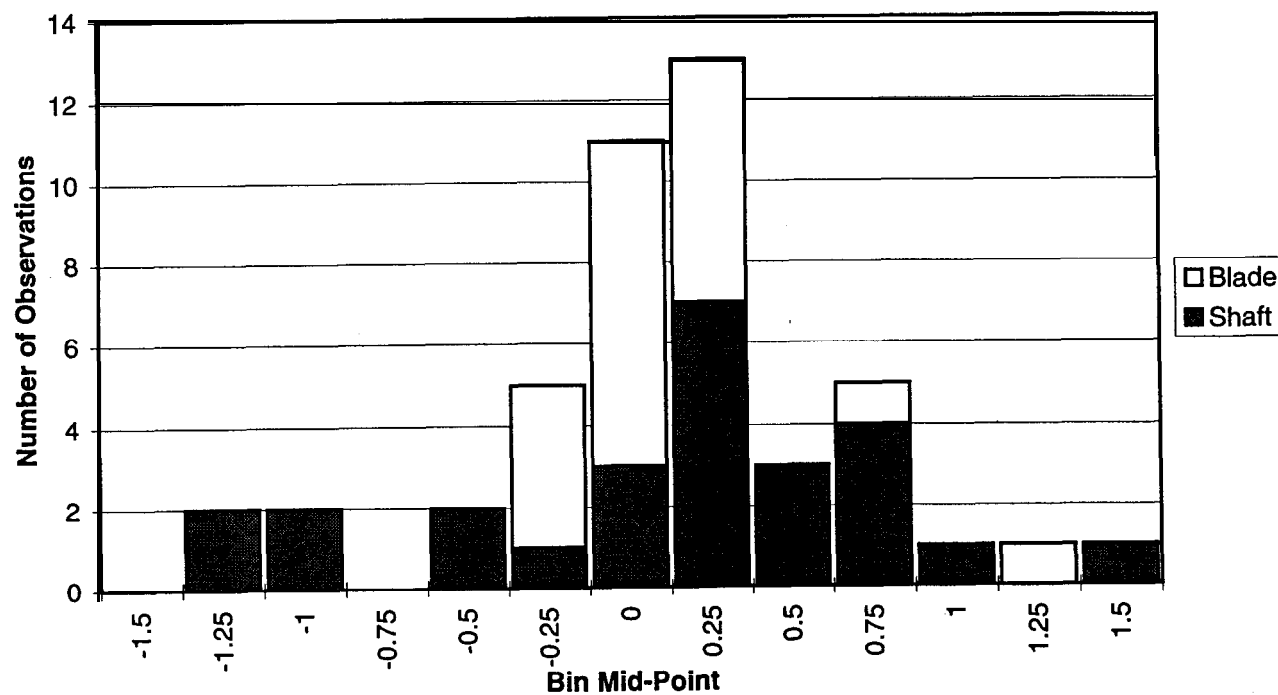
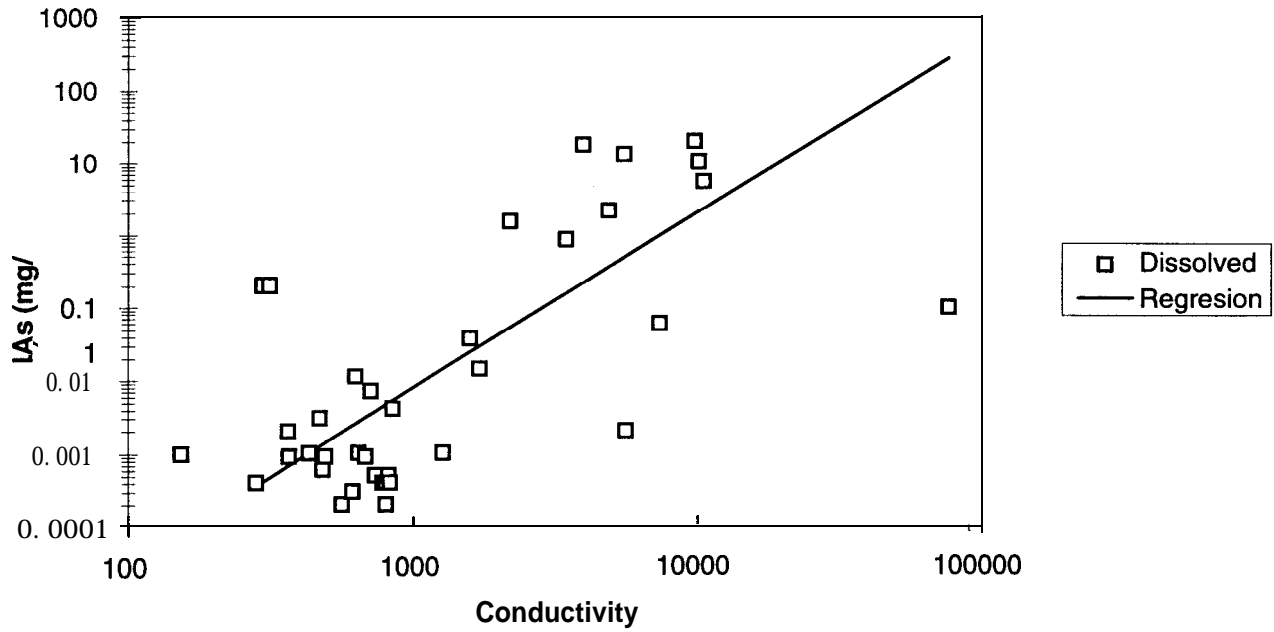


Figure 3-17
Eskay Creek Mine
As vs pH

a) Data Plot and Regression



b) Histogram of Residuals

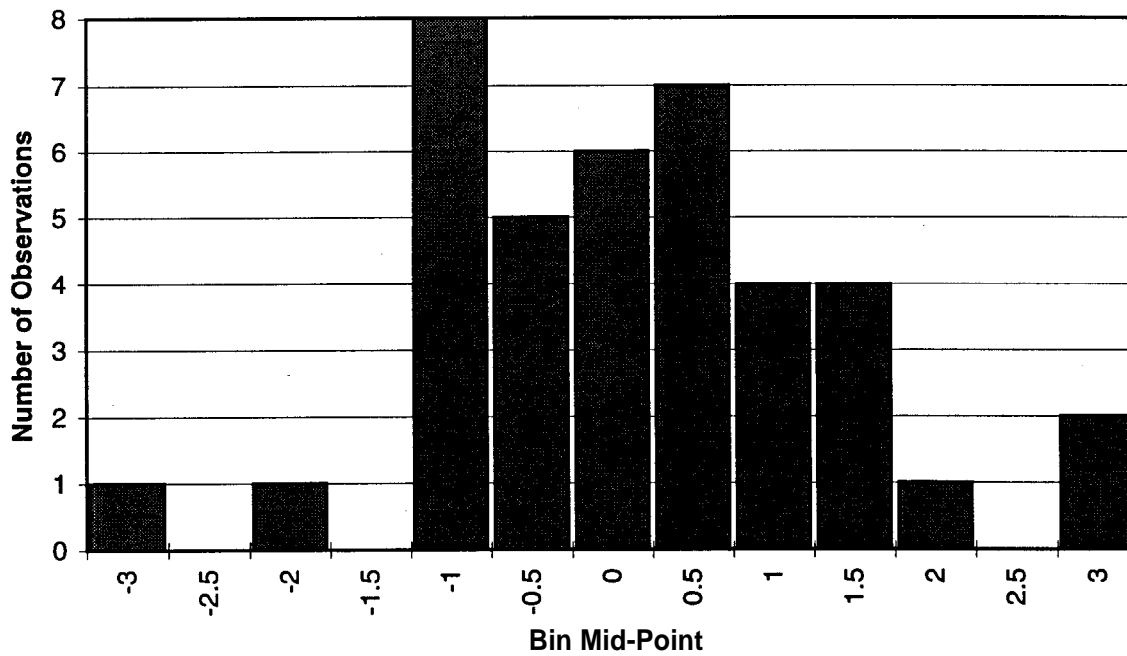
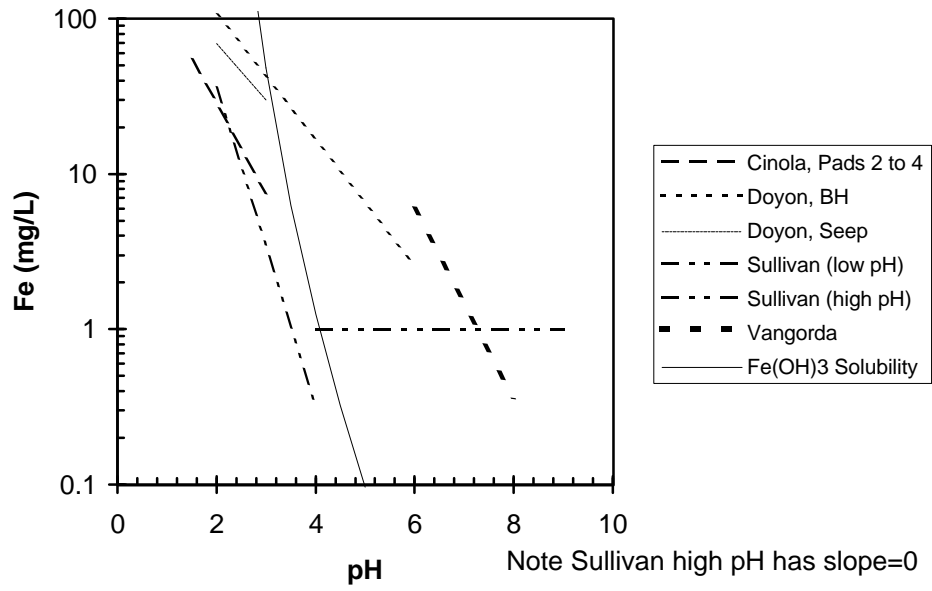


Figure 3-18
Eskay Creek Mine
As vs Conductivity

a) Iron



b) Aluminum

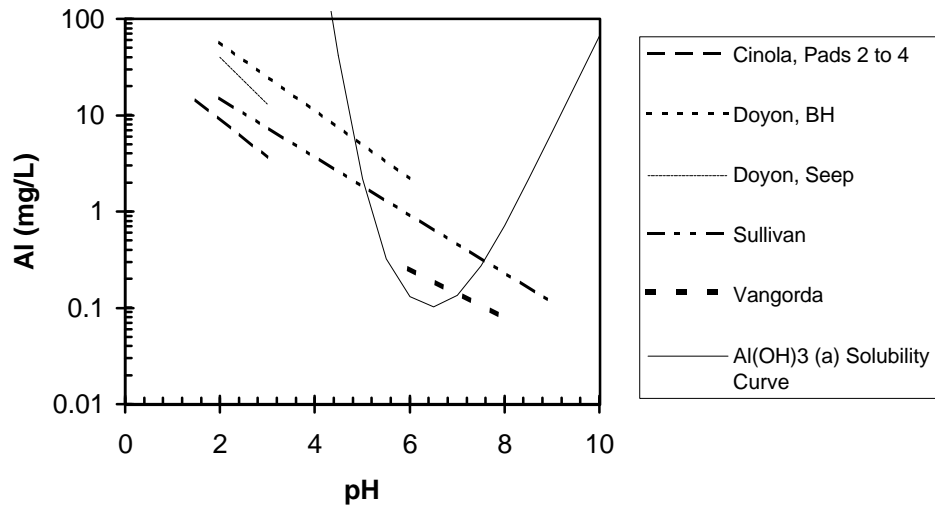


Figure 3-19
Comparison of pH vs Fe and Al Relationships

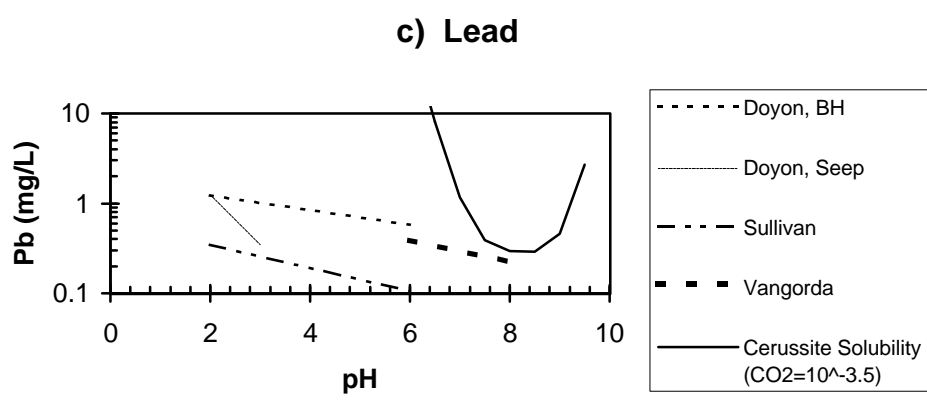
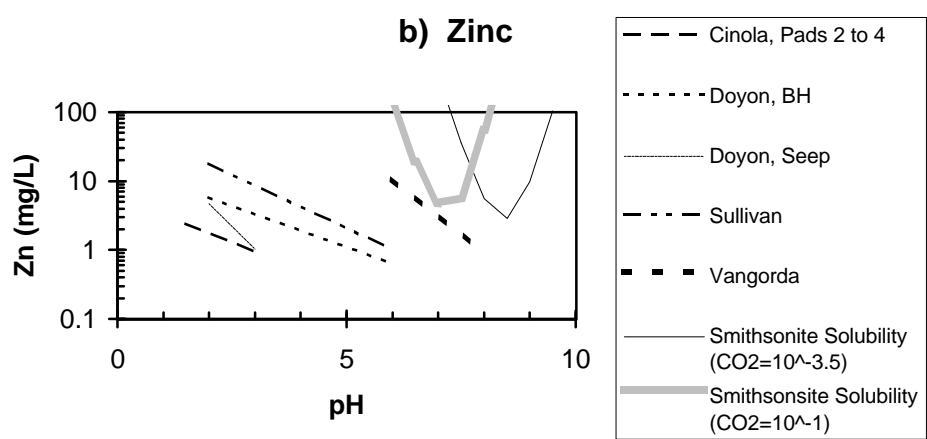
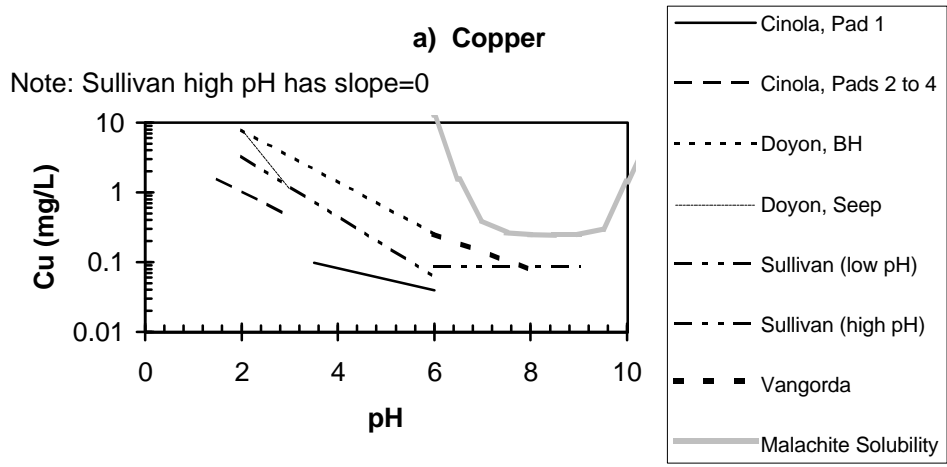
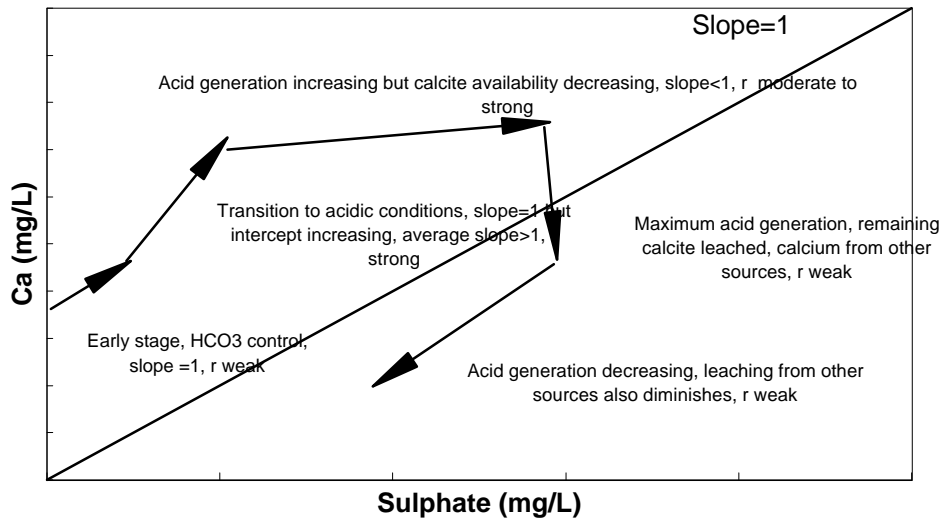
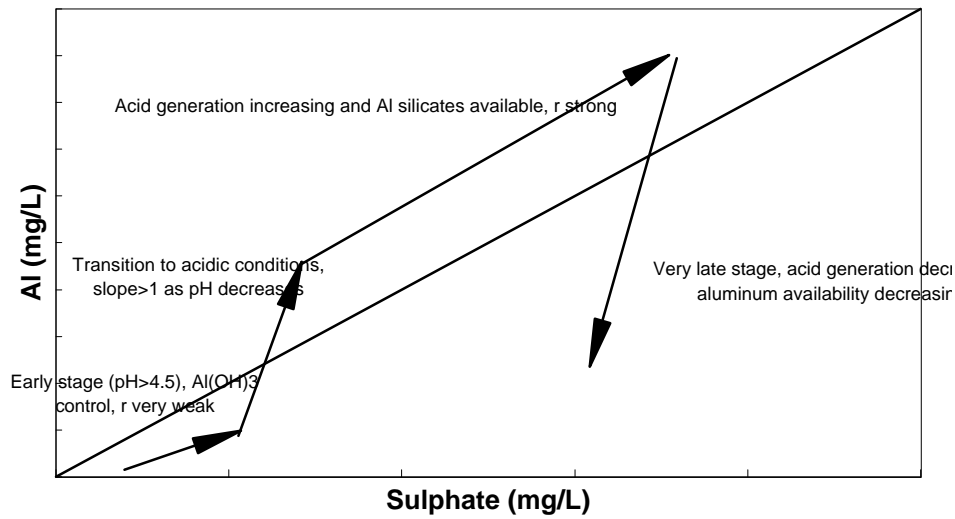


Figure 3-20
Comparison of pH vs Cu, Zn and Pb Relationships

(a) SO₄ vs Ca with primarily calcite dissolution



(b) SO₄ vs Al



Note: r is the correlation coefficient

Figure 3-21
Predicted Relationships
Sulphate vs Ca and Al.

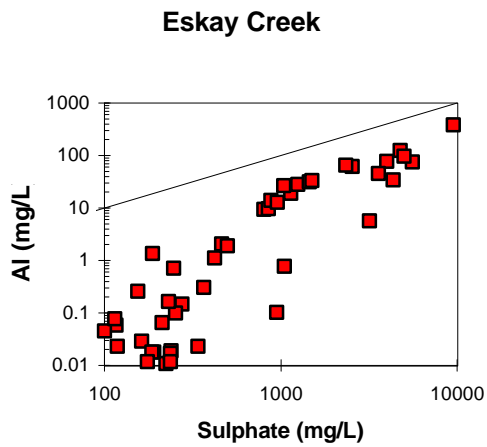
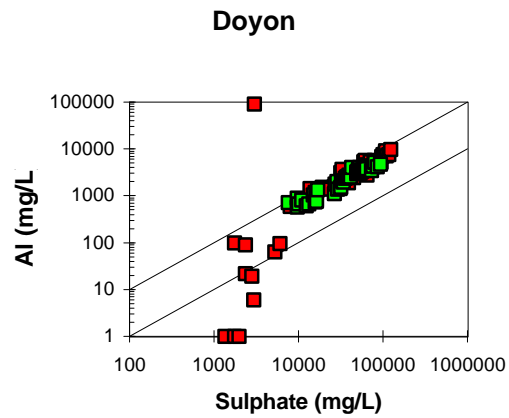
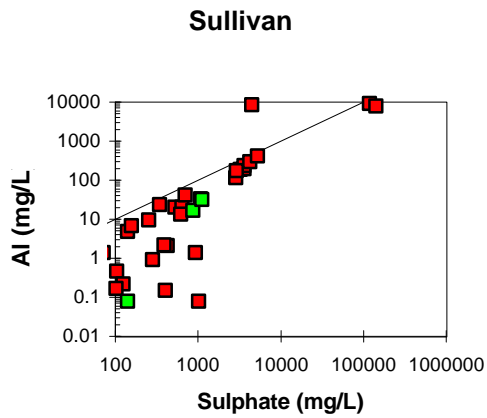
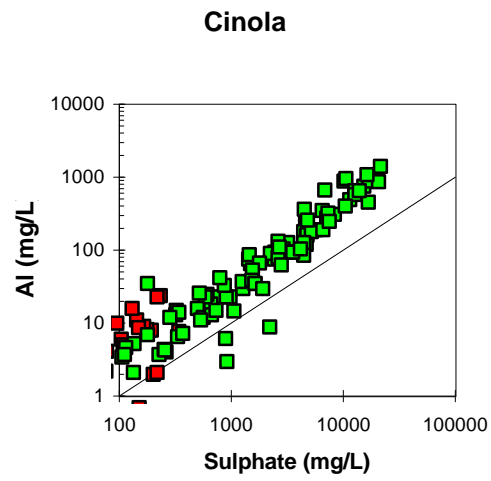
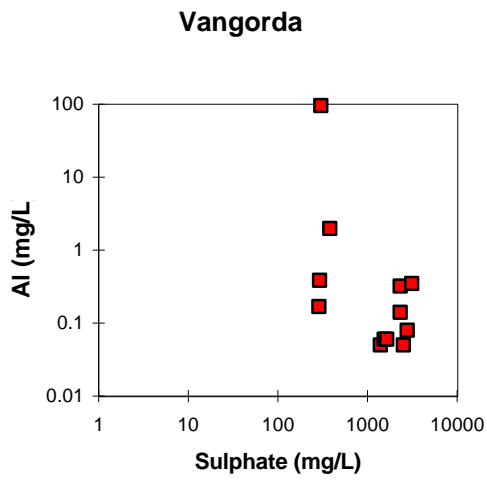
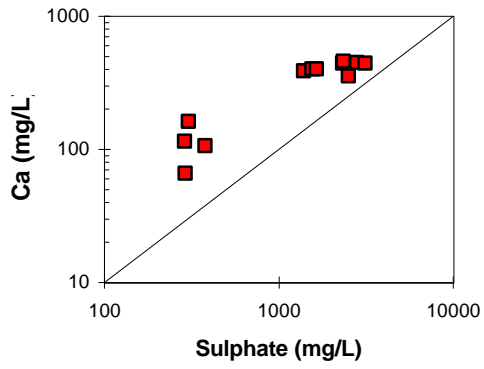
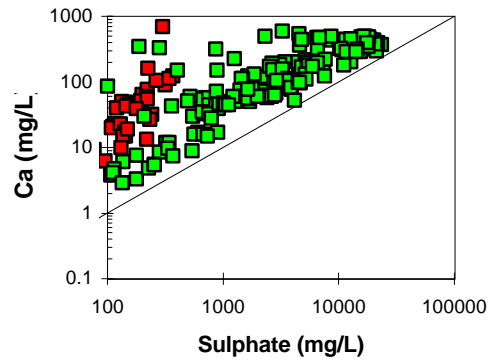


Figure 3-22
Sulphate vs. Aluminum

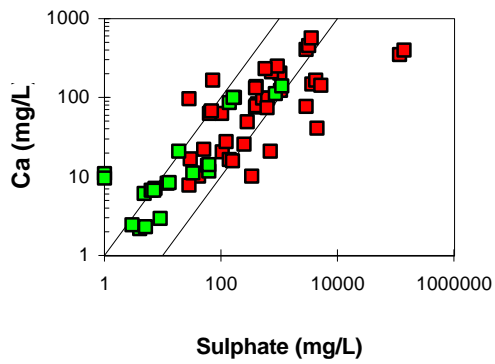
Vangorda



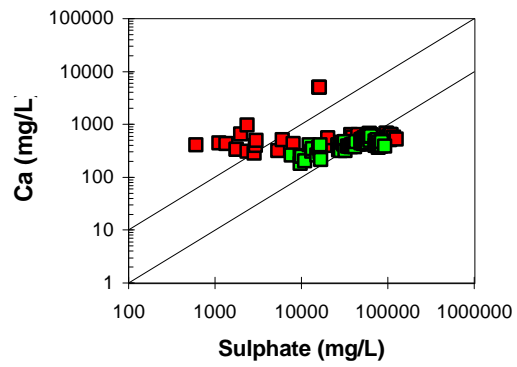
Cinola



Sullivan



Doyon



Eskay Creek

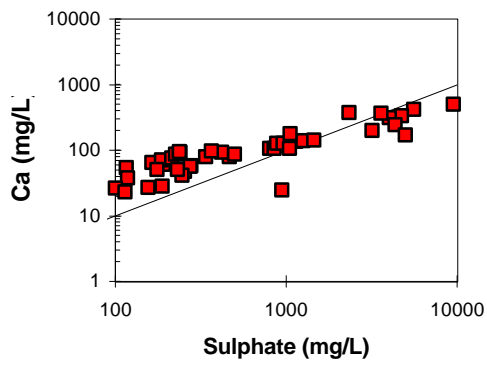
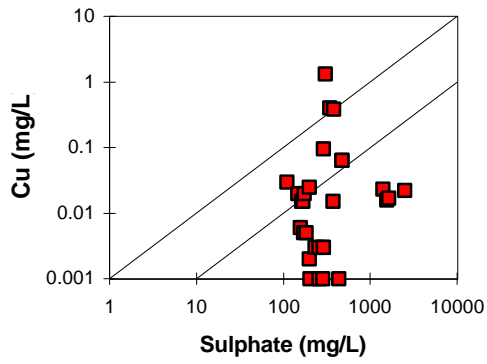
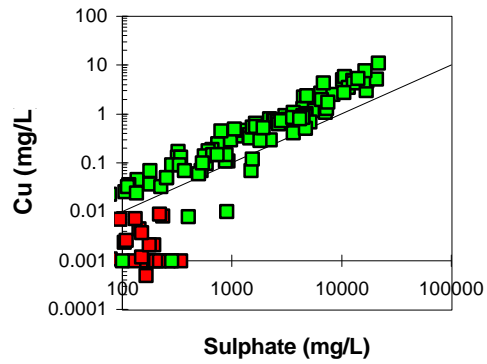


Figure 3-23
Sulphate vs Calcium

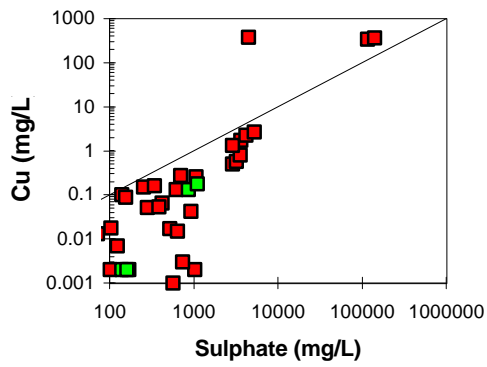
Vangorda



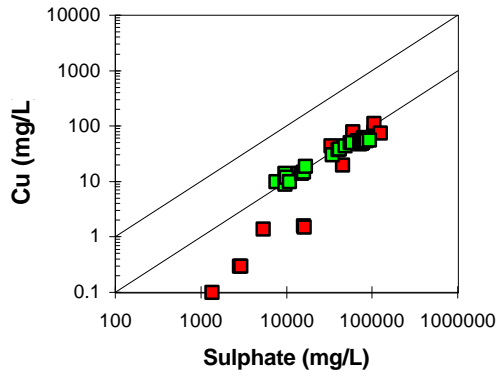
Cinola



Sullivan



Doyon



Eskay Creek

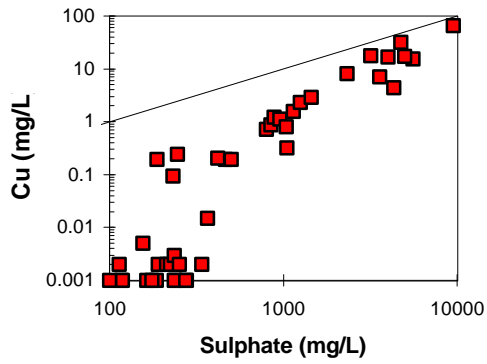
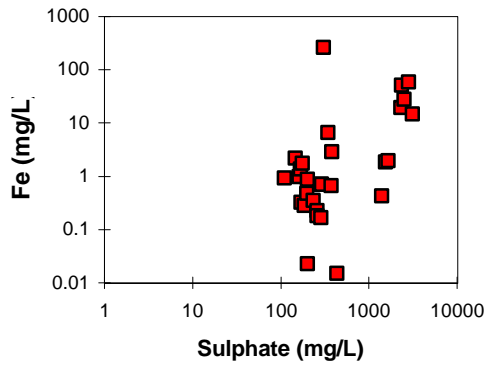
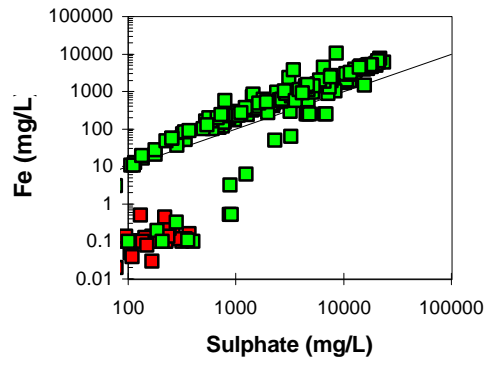


Figure 3-24
Sulphate vs. Copper

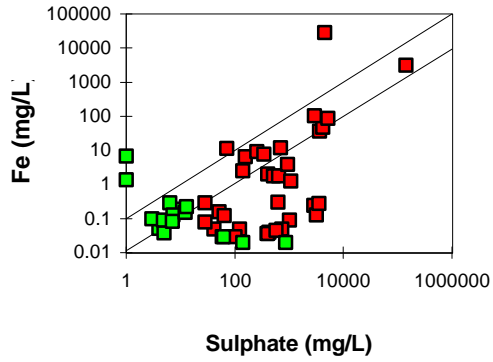
Vangorda



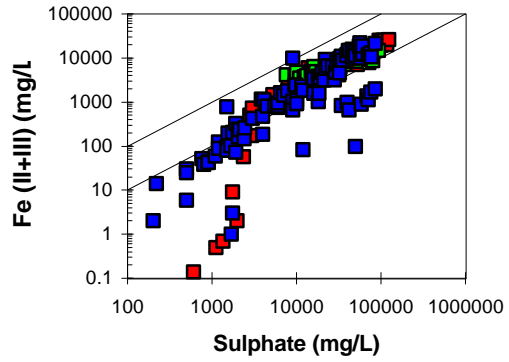
Cinola



Sullivan



Doyon



Eskay Creek

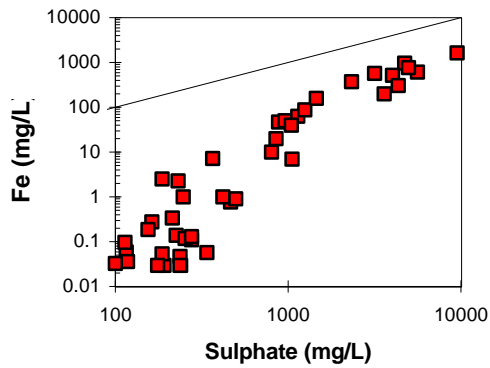
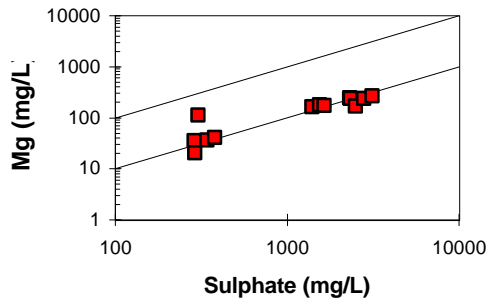
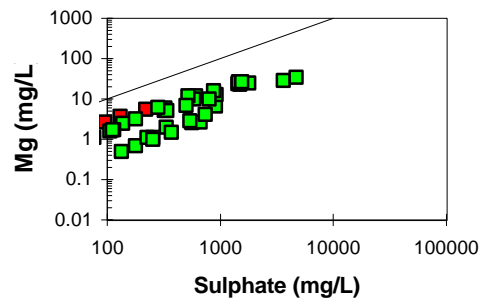


Figure 3-25
Sulphate vs. Iron

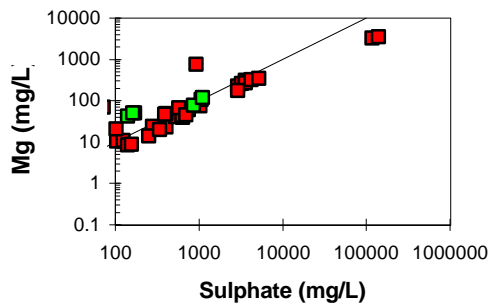
Vangorda



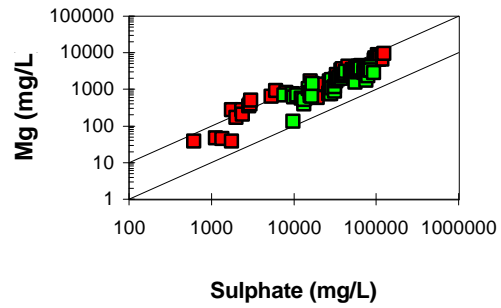
Cinola



Sullivan



Doyon



Eskay Creek

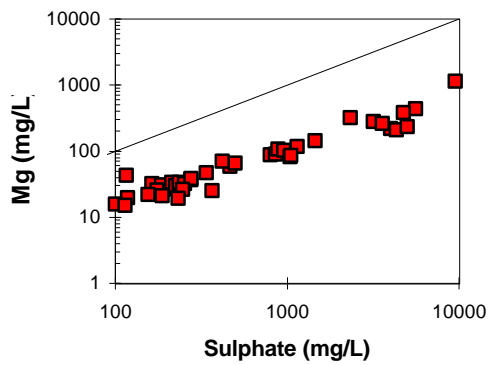


Figure 3-26
Sulphate vs. Magnesium

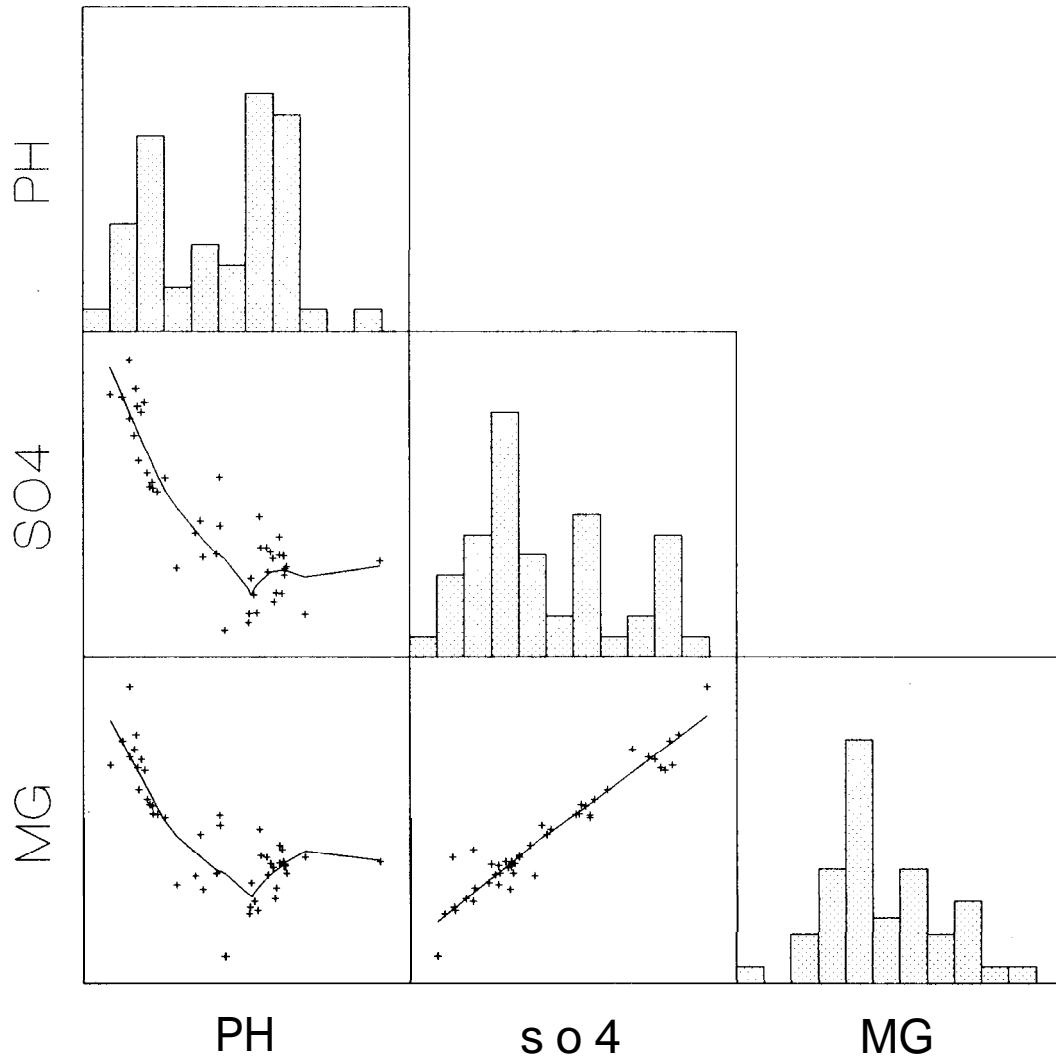


Figure 4-1
 Eskay Creek Mine
 SPLOM: pH, sulphate, Mg

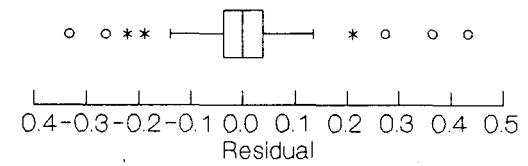
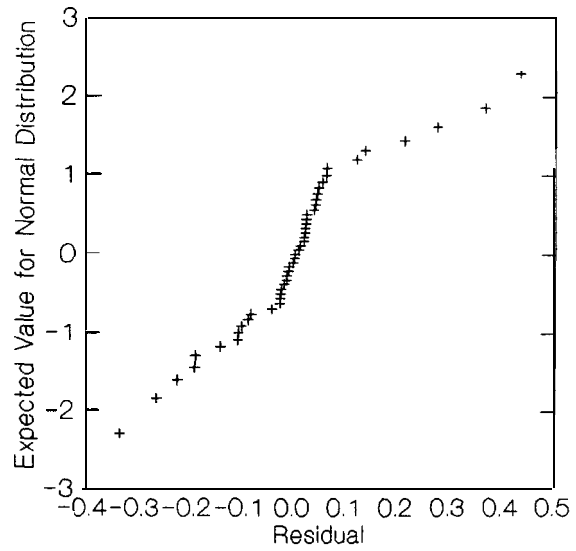
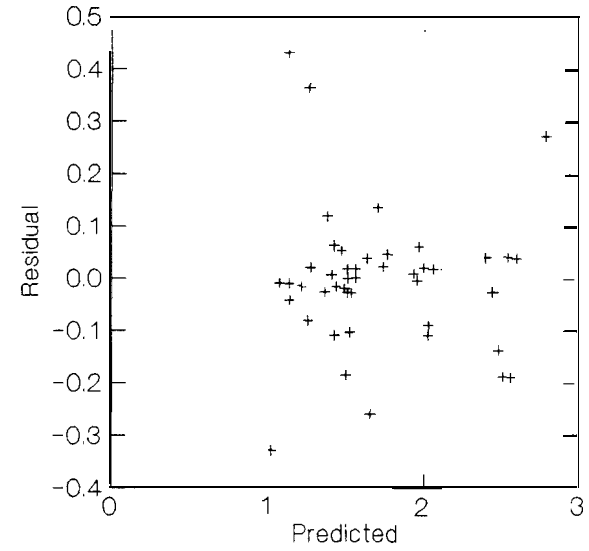
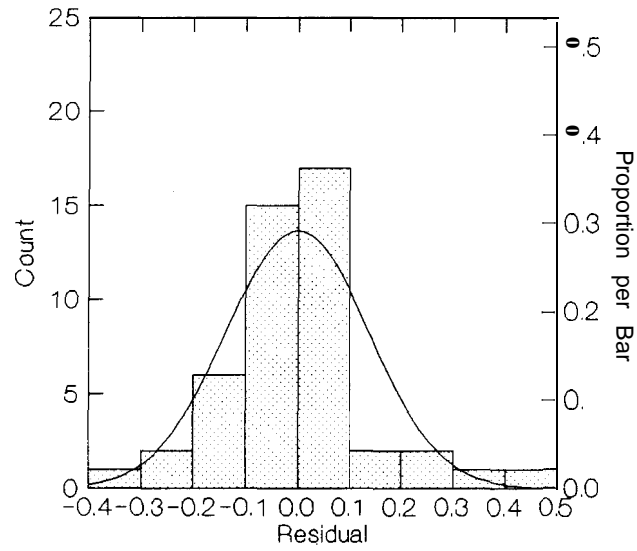


Figure 4-2
Eskay Creek Mine
Mg vs sulphate: residual plots

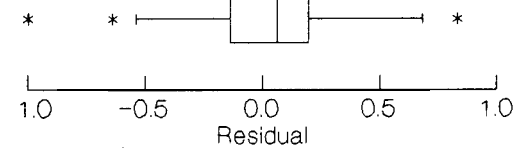
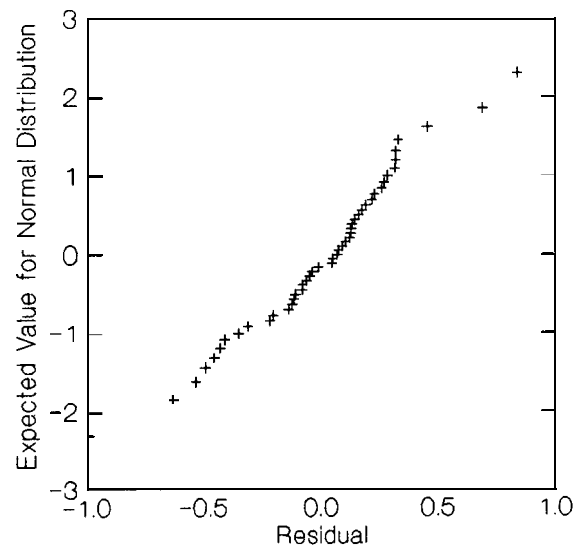
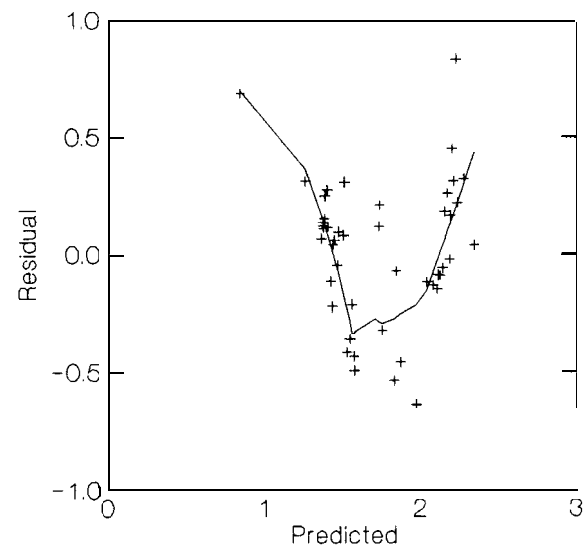
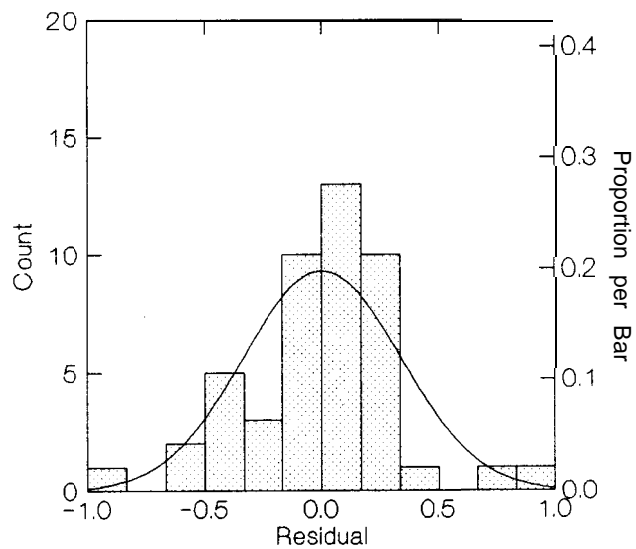


Figure 4-3
 Eskay Creek Mine
 Mg vs pH: residual plots

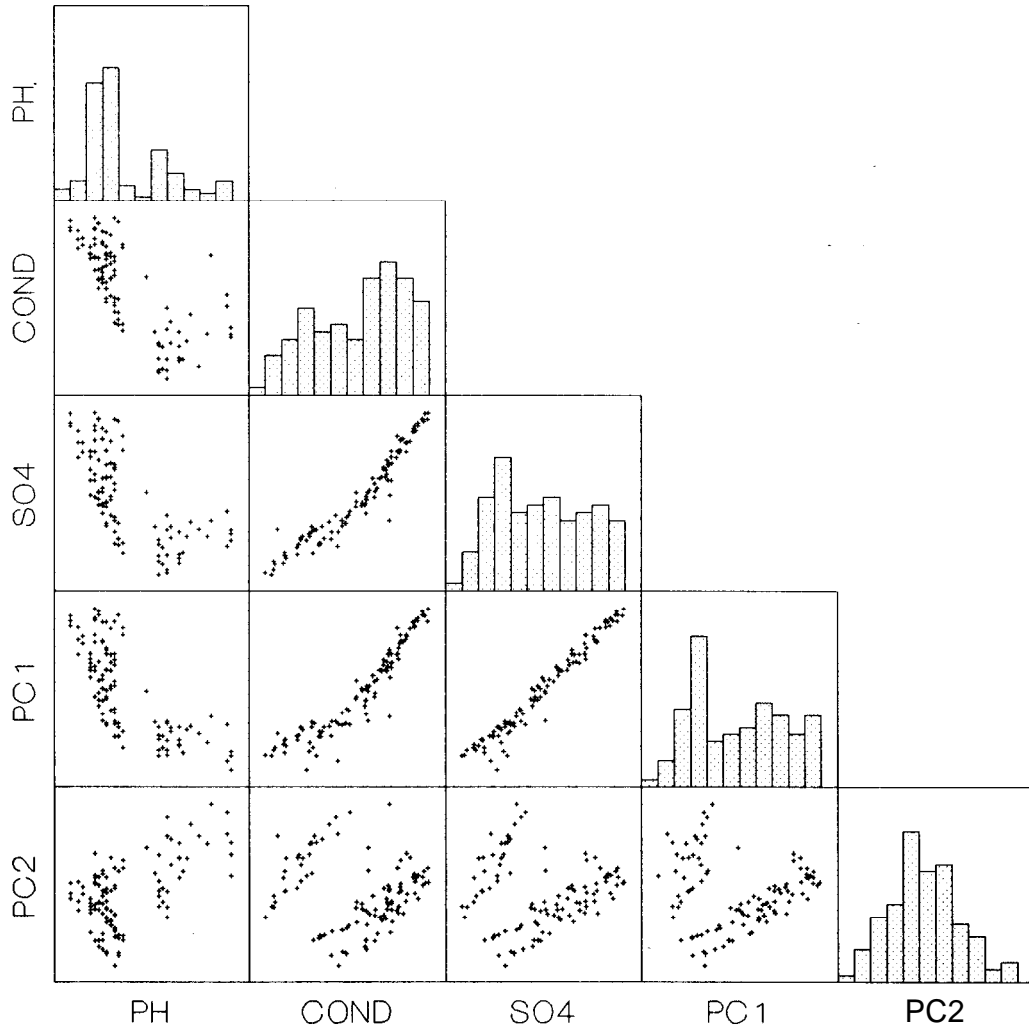


Figure 4-4
Cinola Gold Project
Small data set
SPLOM: pH, conductivity, sulphate, PC1, PC2

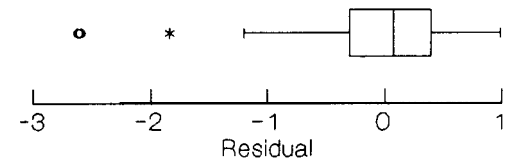
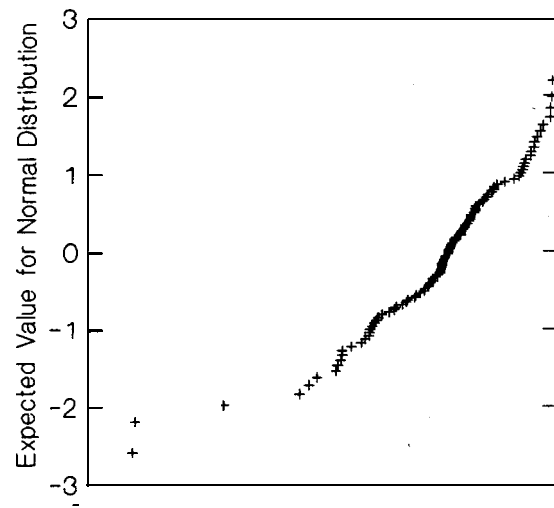
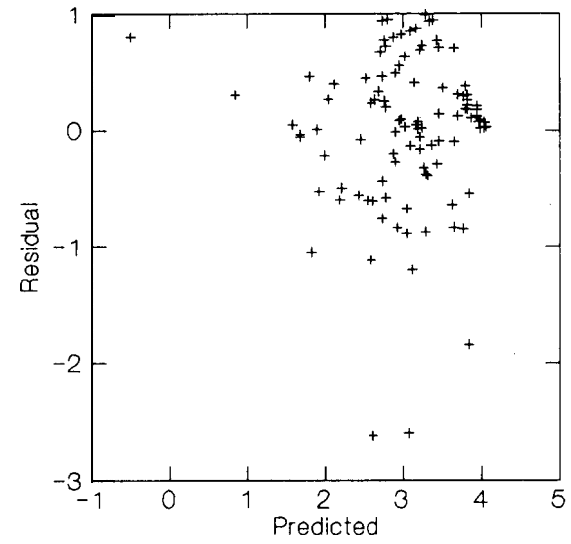
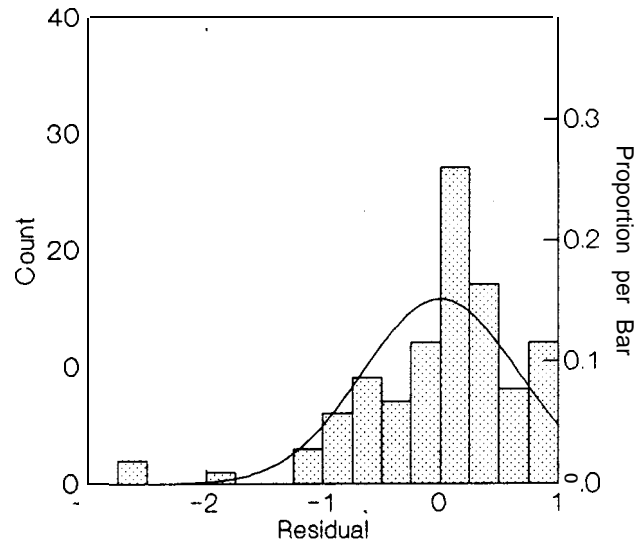


Figure 4-5
 Mine Doyon historical data
 Fe vs pH: residual plots

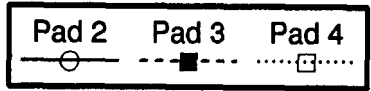
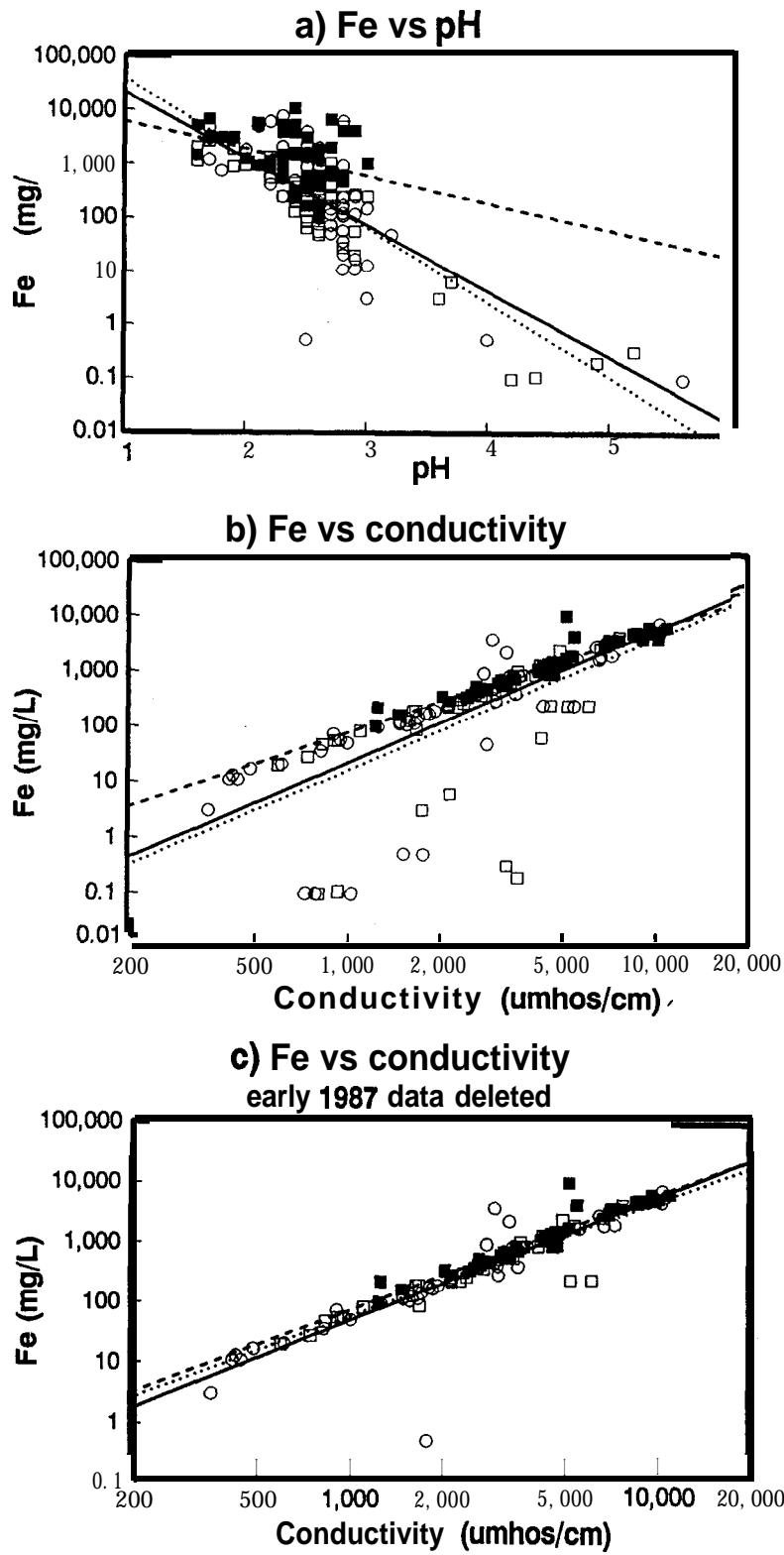


Figure 4-6
Cinola Gold Project (Pads 2-4)
Fe vs pH, conductivity

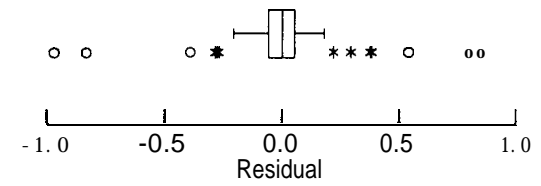
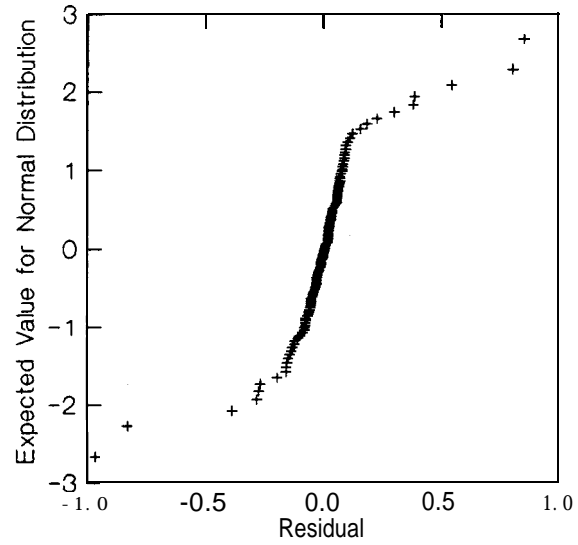
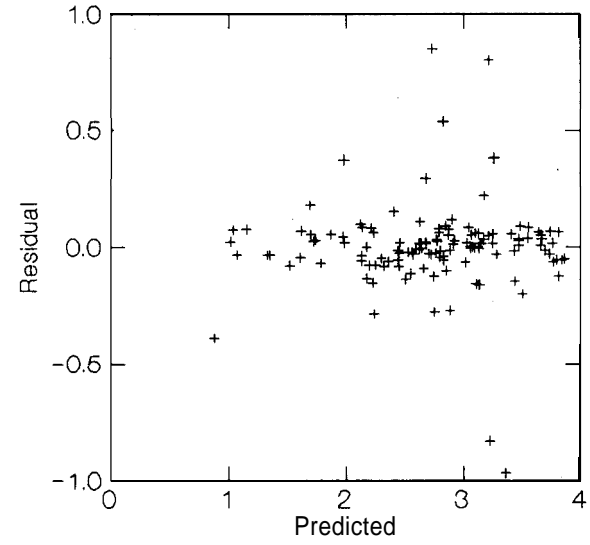
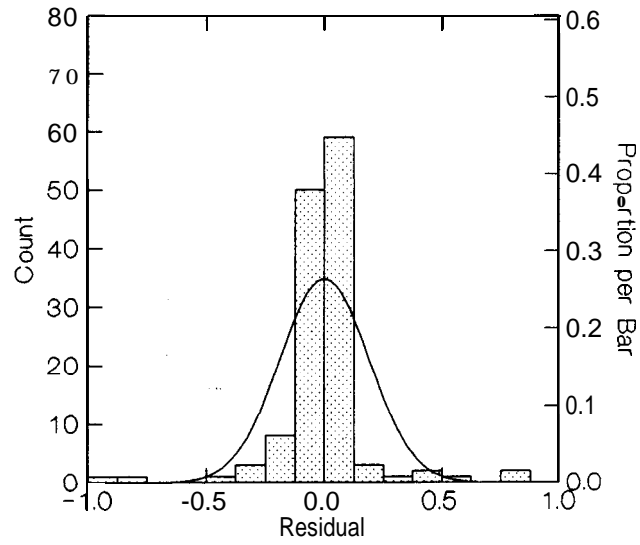


Figure 4-7
 Cinola Gold Project (Pads 2-4)
 Early data and one outlier deleted
 Fe vs conductivity: residual plots

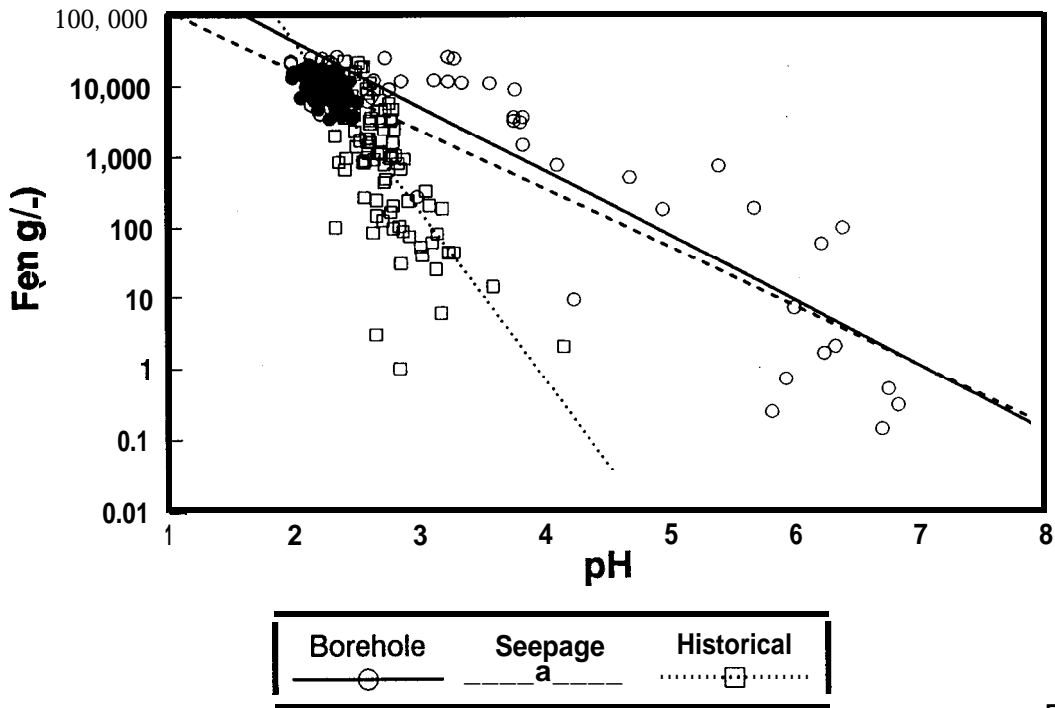


Figure 4-8
 Mine Doyon
 Fe vs pH

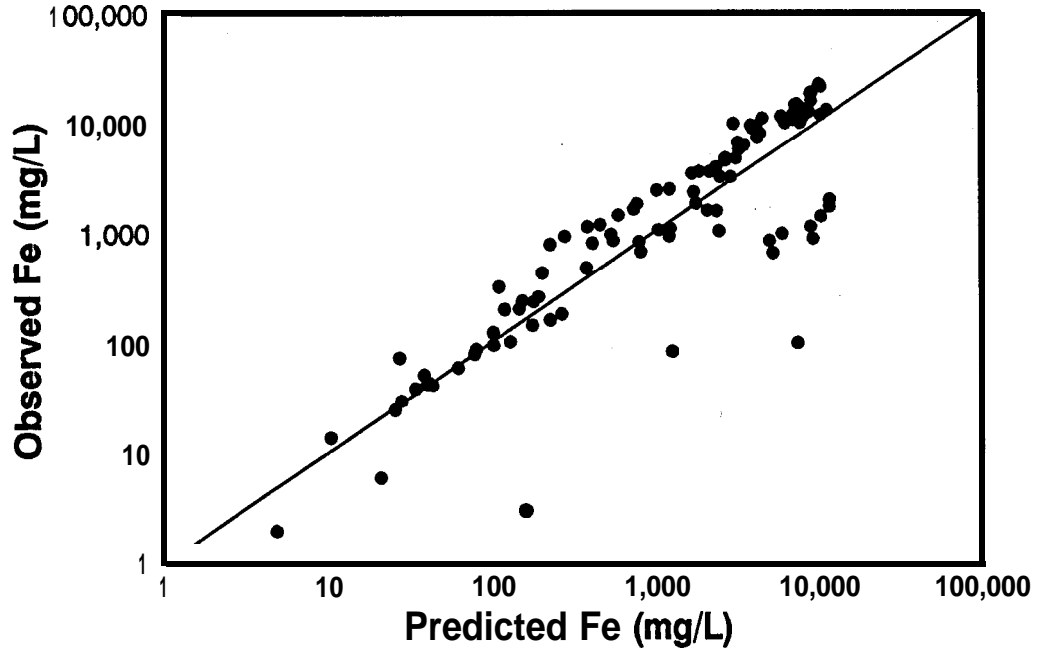


Figure 4-9
 Mine Doyon historical data
 Multiple regression: observed Fe vs predicted Fe

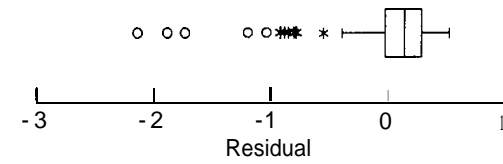
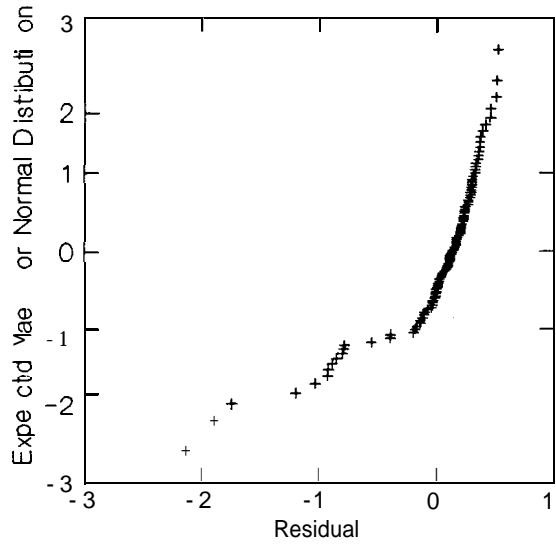
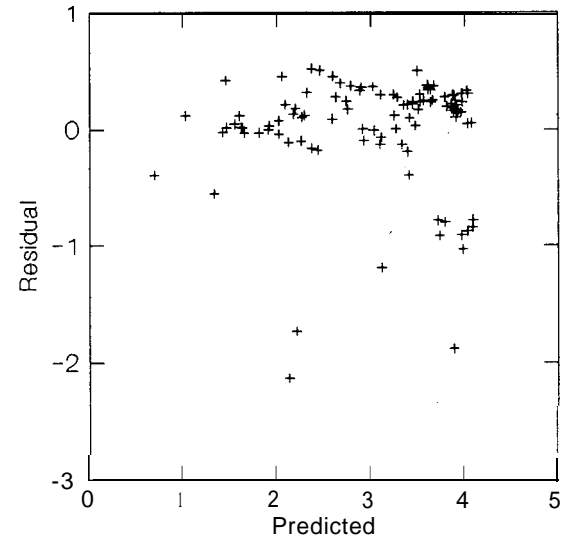
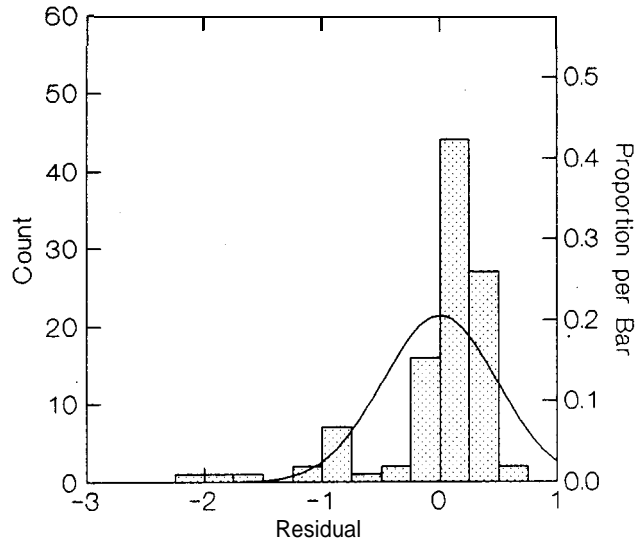


Figure 4-1 0
 Mine Doyon historical data
 Multiple regression: residual plots

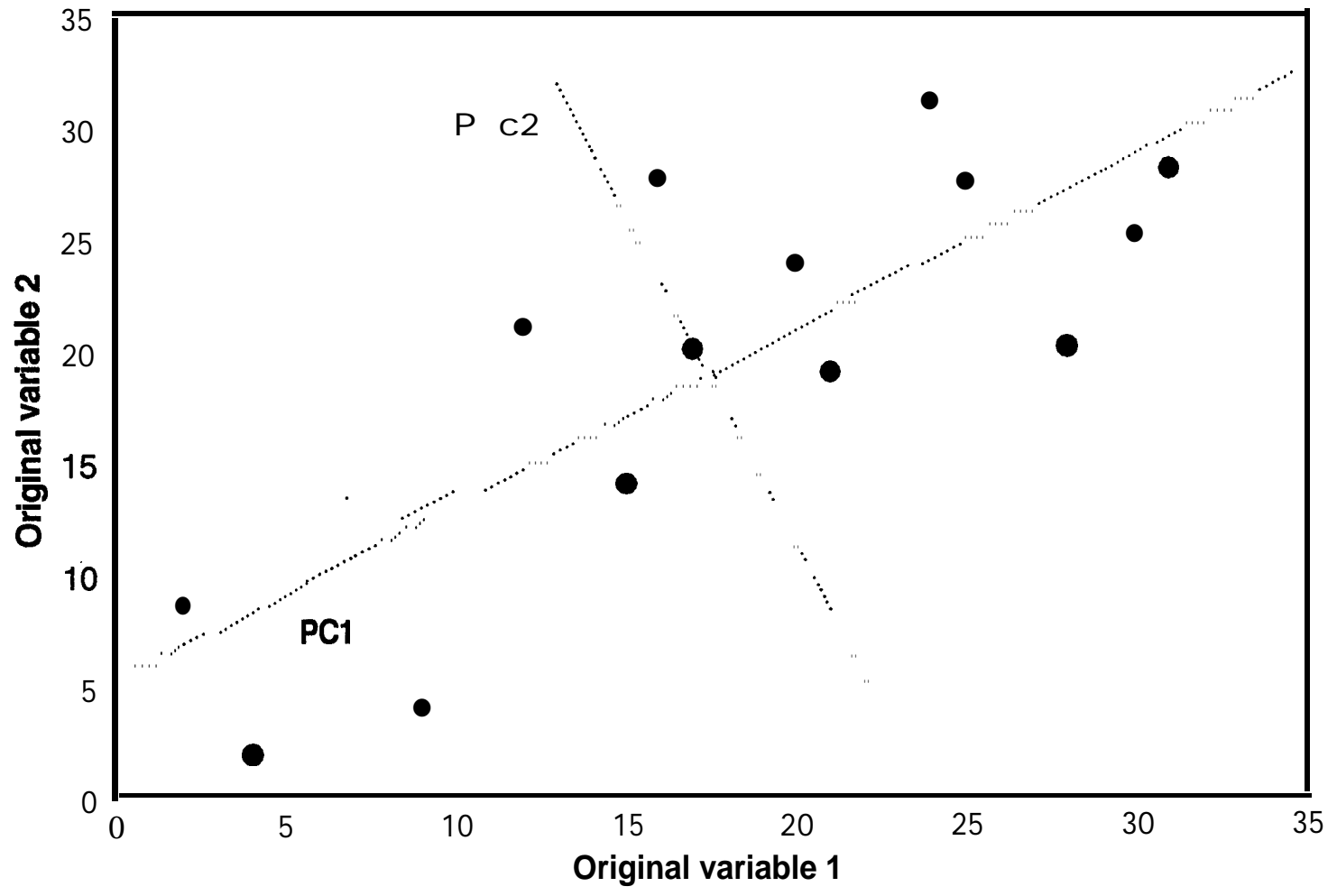


Figure 4-I 1
Principal Components (PC)

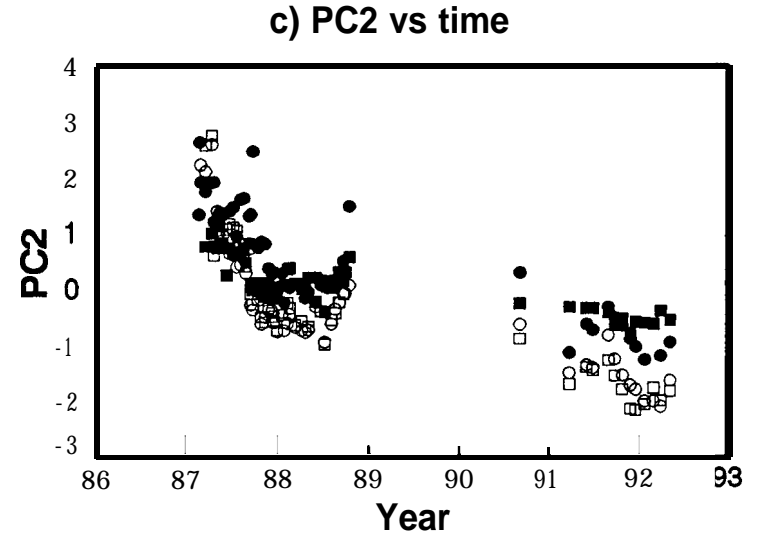
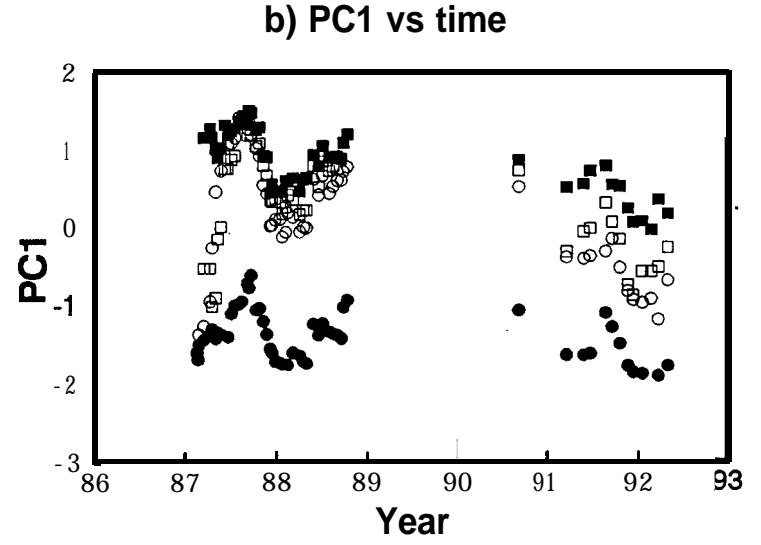
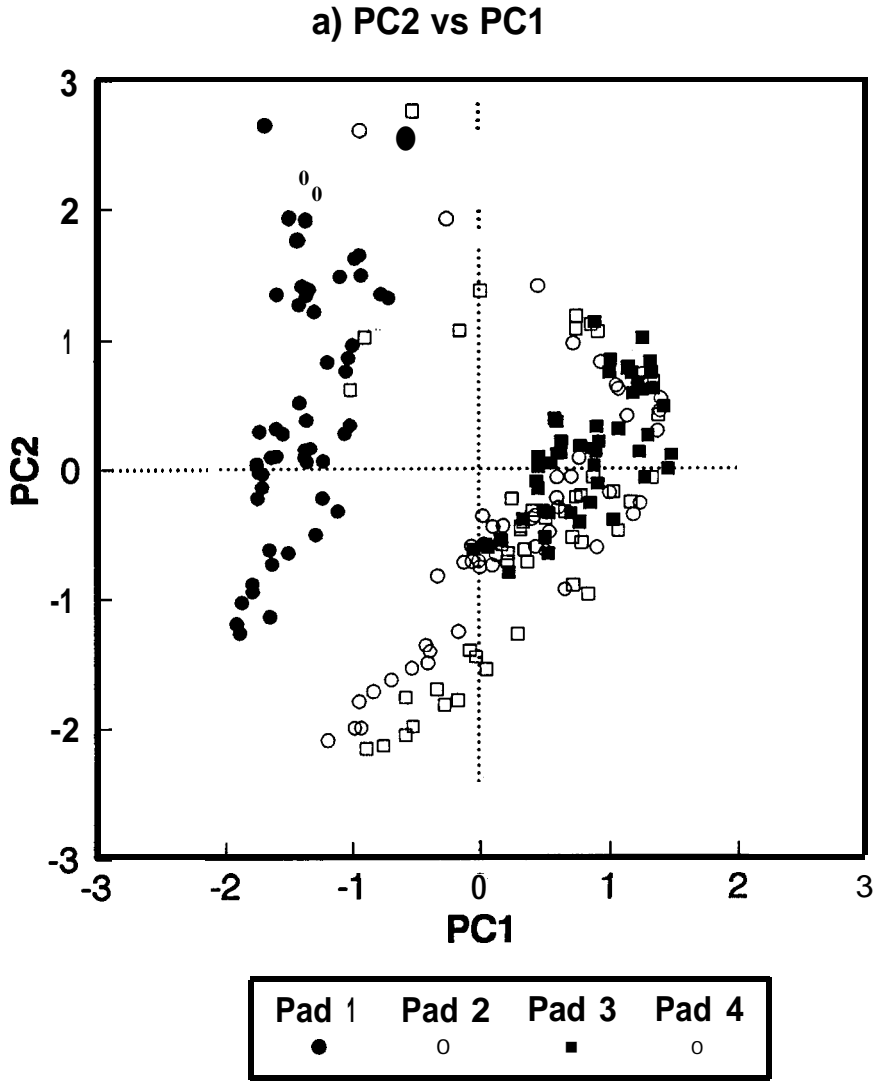


Figure 4-I 2
 Cinola Gold Project
 PC plots for large data set

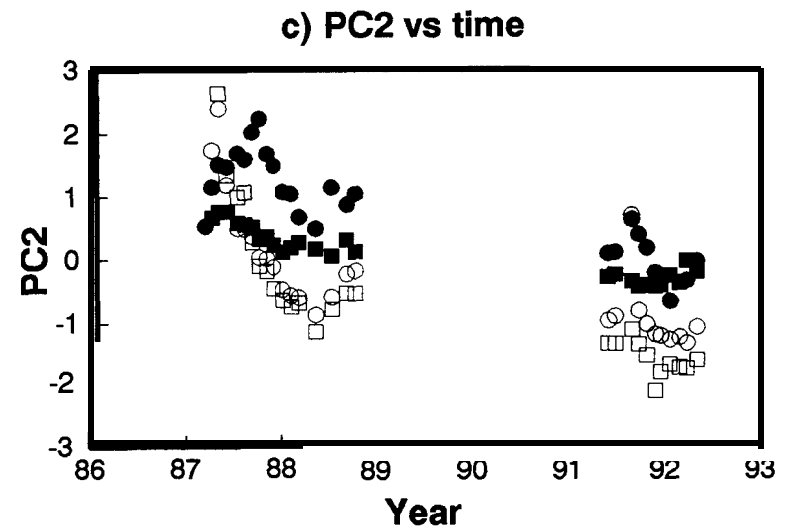
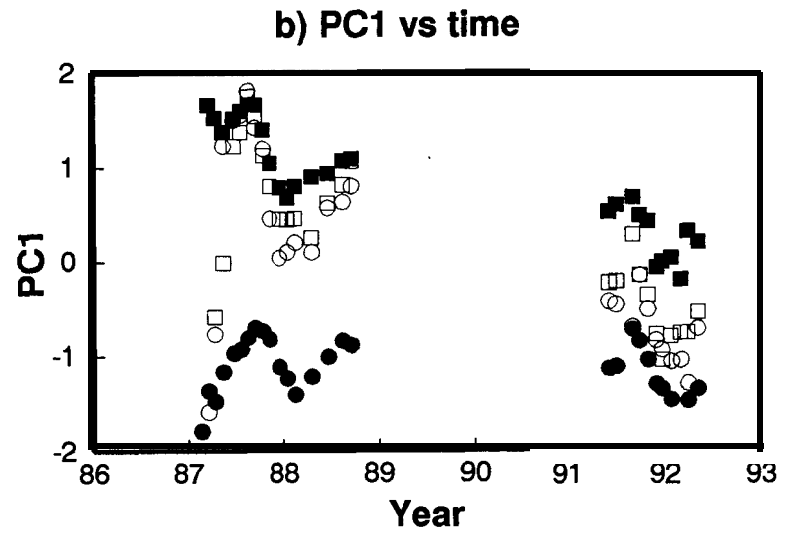
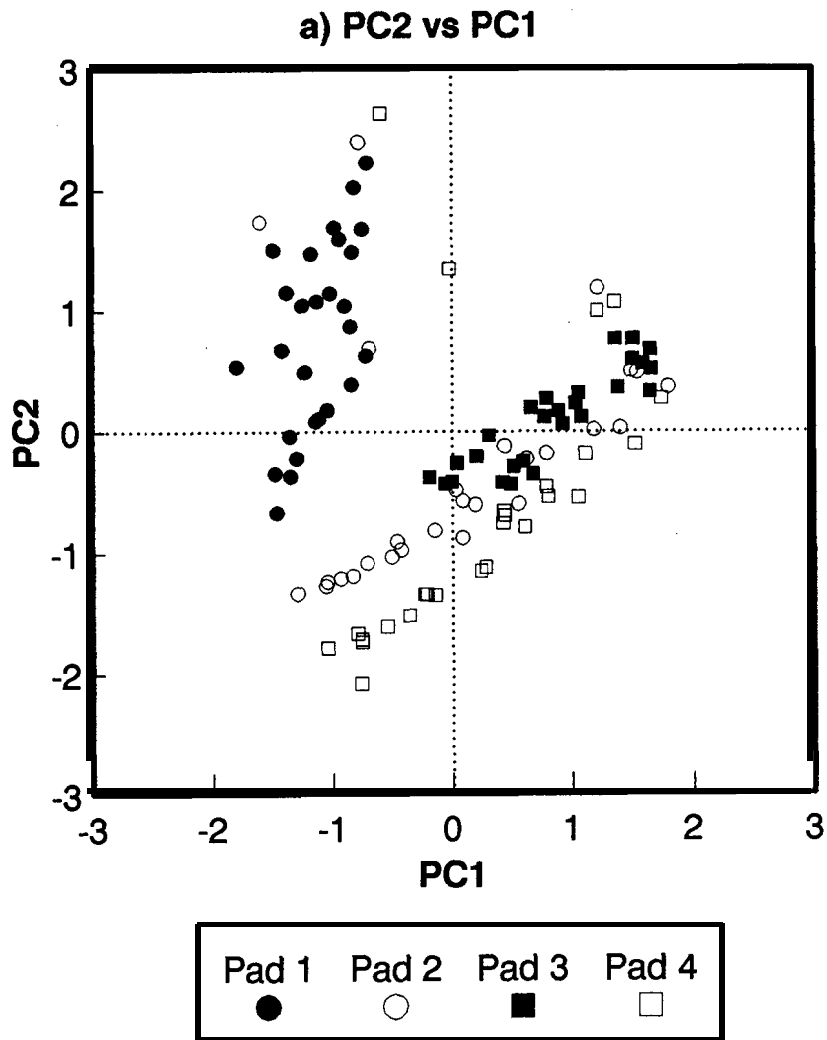


Figure 4-13
Cinola Gold Project
PC plots for small data set

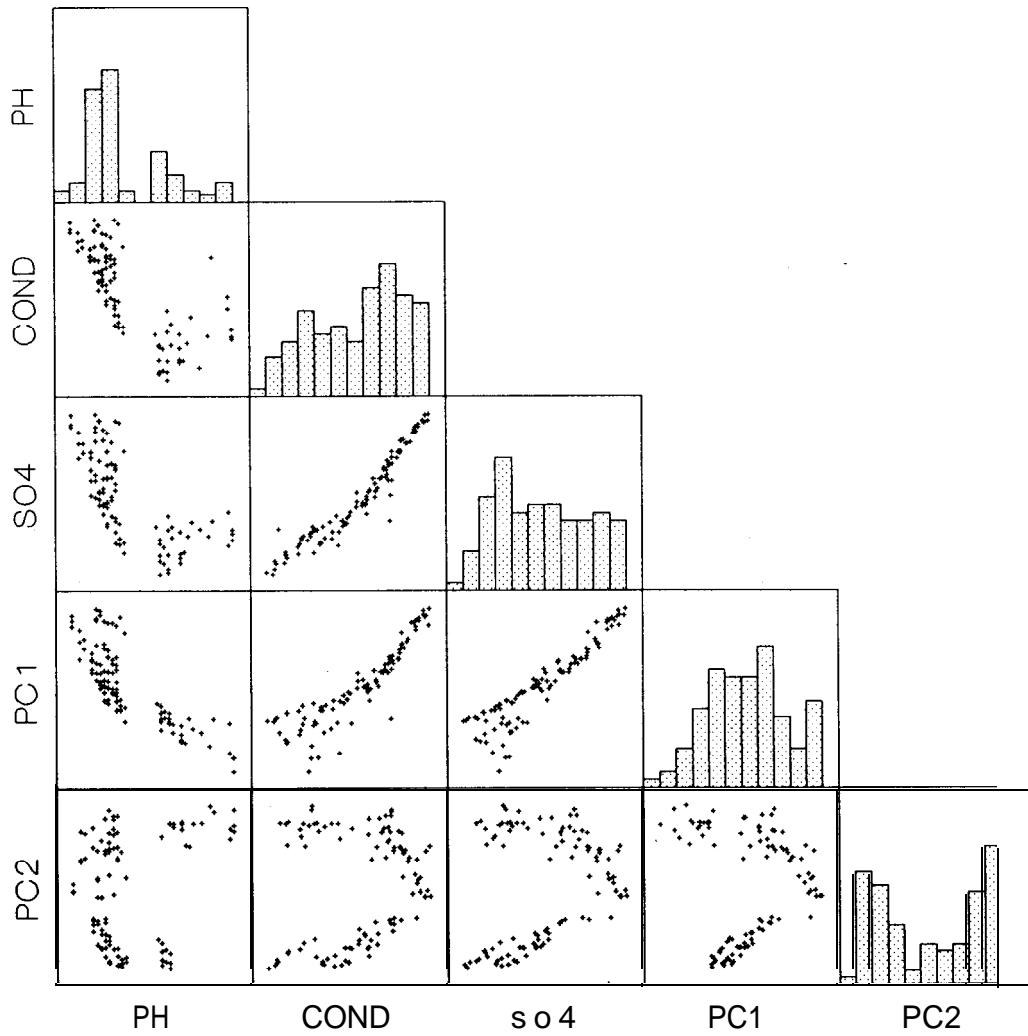


Figure 4-14
 Cinola Gold Project
 Small data set
 SPLOM: pH, conductivity, sulphate, PC1, PC2

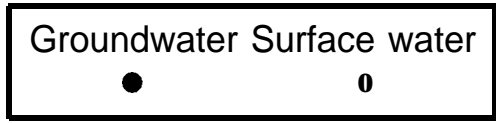
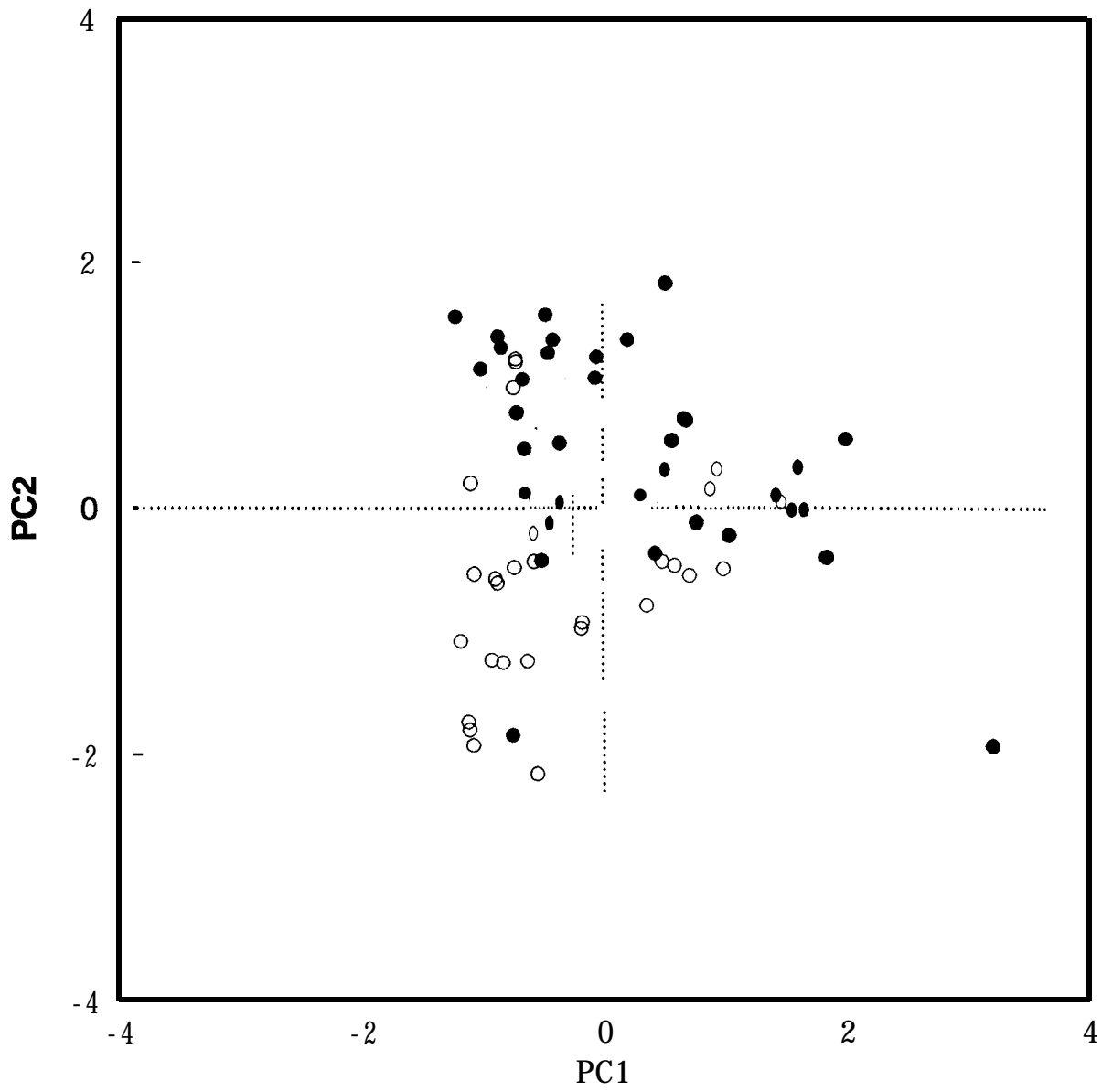


Figure 4-15
Sullivan Mine
PC2 vs PC1

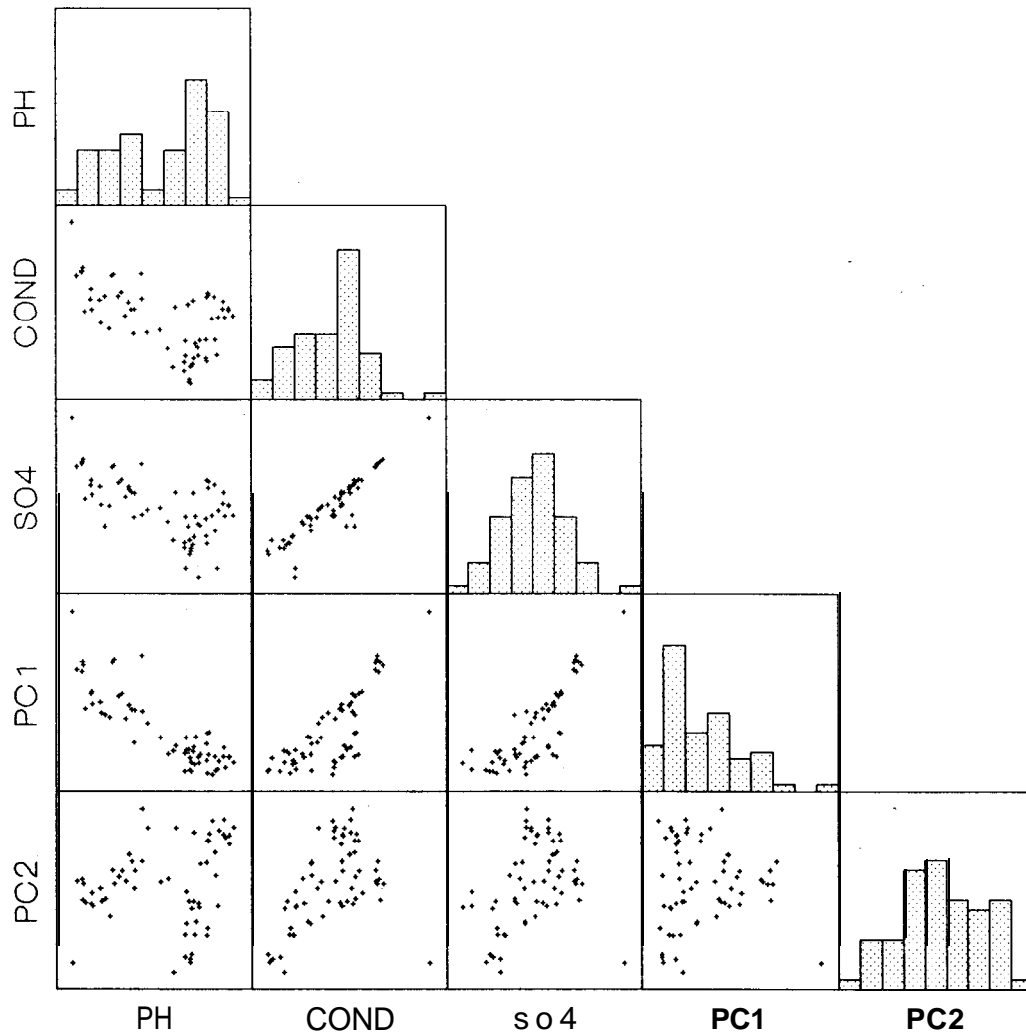


Figure 4-16
 Sullivan Mine
 SPLOM: pH, conductivity, sulphate, PC1, PC2

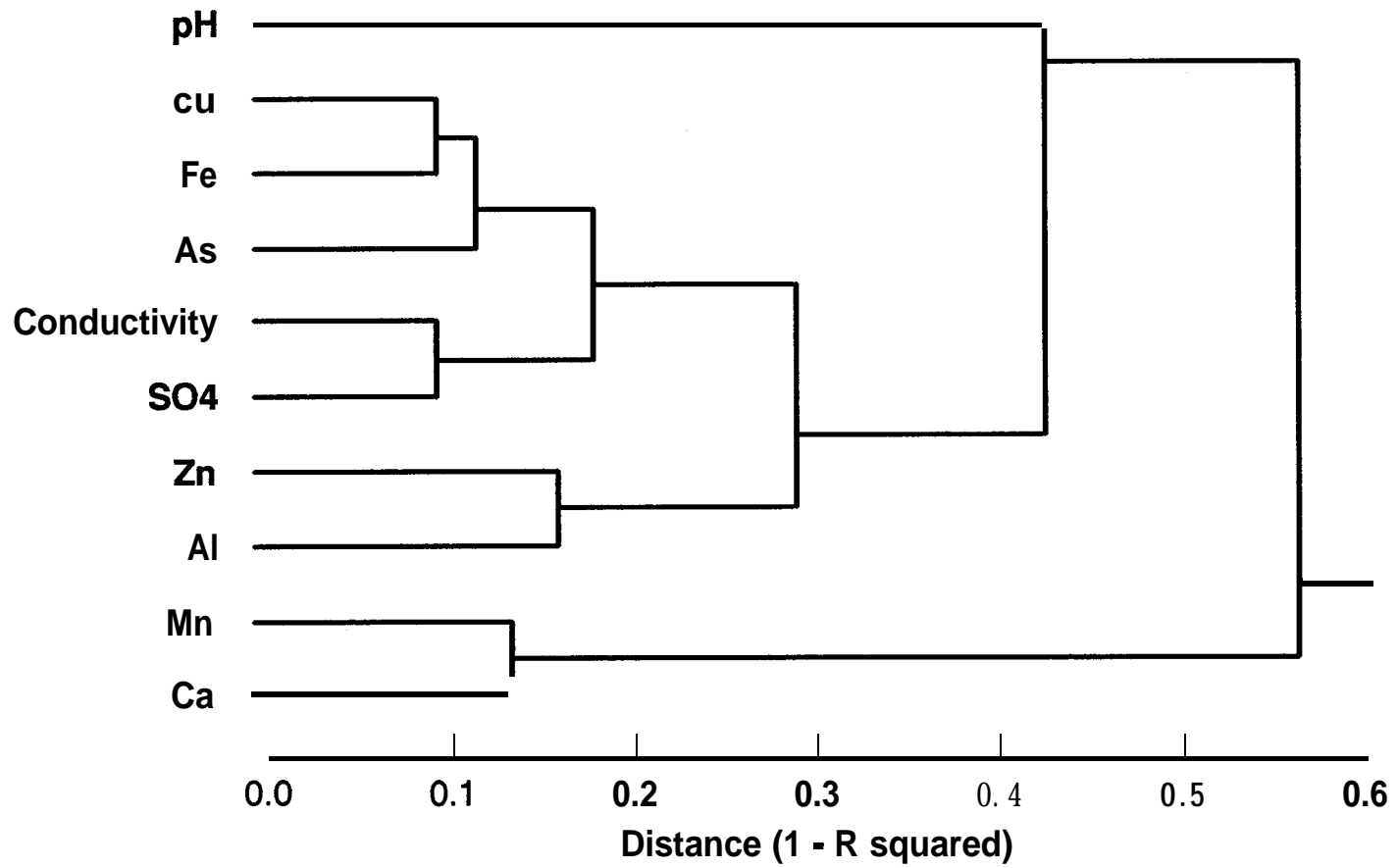


Figure 4-I 7
Cinola Gold Project
Small data set
Cluster diagram

APPENDIX A
RAW DATA - VANGORDA

DATE	SITE	pH	TEMP C	COND uS/cm	COLOUR TCU	TURBIDIT FTU	SUS. mg/L	DISS. mg/L	FLOW L/s	ALK mg/L
05/04/94	Drain 2	7.6		2750	8	4	7	2400		256
05/09/95	Drain 2	6.7		2700	5	18	8	2870		242
05/09/95	Drain 2	6.7		2700	5	18	8	2840		261
05/04/94	Drain 3	6.6		3300	15	240	46	3950		77
08/09/94	Drain 3	6.4		3900	5	128	27	5270	0.05	163
08/09/94	Drain 3									
10/11/94	Drain 3	6.5		3500			45	3930	0.08	186
10/11/94	Drain 3								0.08	
05/09/95	Drain 3	6.2		3500	15	370	44	4070	0.083	126
06/10/95	Drain 3									
01/07/91	V21	7.55	0.0	753			26			195.0
02/26/91	V21	7.13	1.0	617			5			163.0
03/20/91	V21	7.40	2.0	580			5			157.0
04/16/91	V21	7.23	2.5	556			16			164.0
05/07/91	V21	7.19	3.5	410			56			108.0
06/11/91	V21	7.81	2.0	560			15			122.0
07/03/91	V21	7.37	17.0	699			11			139.0
08/15/91	V21	7.97	16.0	605			5			149.0
09/03/91	V21	7.94	8.0	682			5			157.0
09/25/91	V21	7.80	6.1	500			8			157.0
10/11/91	V21	7.46	2.0	186			5			156.0
11/14/91	V21	8.02	1.0	122			41			244.0
12/18/91	V21	7.50	0.0	1260			24			277.0
01/20/92	V21						20			
01/20/92	V21						20			
02/18/92	V21			850			47			
03/18/92	V21						40			
04/30/92	V21						94			
06/15/92	V21						5			
07/20/92	V21						7700			
08/05/92	V21	7.5		963			90			103
01/31/95	V21									
01/31/95	V21			932			134			133.0
02/01/95	V21	7.83	1.4	932			134			133
04/25/95	V21			461			9			81.6
04/25/95	V21	7.41	8.2	461			9		18	61.6
05/09/95	V21			3440			97			182.0

Max	8.02	17.00	3900.00	15.00	370.00	7700.00	5270.00	18.00	277.00
Min	8.20	0.00	122.00	5.00	4.00	5.00	2400.00	0.05	61.60
Mean	7.30	4.71	1404.41	8.83	129.67	266.85	3618.57	3.66	161.28
Count	23	15	27	6	6	33	7	5	26

DATE	SITE	NH3 mg/L	HARD CaCO3	Al mg/L	As mg/L	AU mg/L	B mg/L	Ba mg/L	Be mg/L	Bi mg/L
05/04/94	Drain 2	2.80		0.05	<0.02			0.0394	0.0006	<0.02
05/09/95	Drain 2	2.60	1790	0.06	<0.02			0.0364	<0.0002	<0.02
05/09/95	Drain 2	2.60	1780	0.06	<0.02			0.0361	<0.0002	<0.02
05/04/94	Drain 3	6.20		0.05	0.07			0.0217	0.0016	<0.02
08/09/94	Drain 3	6.40	2390	0.35	<0.02			0.0090	<0.0002	<0.02
08/09/94	Drain 3		2720	0.38	<0.02			0.0086	<0.0002	<0.02
10/11/94	Drain 3	5.60	2260	0.14	<0.02			0.0176	<0.0002	<0.02
10/11/94	Drain 3		2510	0.15	<0.02			0.0176	<0.0002	<0.02
05/09/95	Drain 3	8.30		0.08	0.30			0.0166	<0.0002	<0.02
06/10/95	Drain 3			2.37	<0.02	<0.01		0.148	<0.001	<0.04
01/07/91	V21	1.15			0.050					
02/26/91	V21	1.20	321.0		0.050					
03/20/91	V21	0.71			0.050					
04/16/91	V21	0.79			0.050					
05/07/91	V21	0.59			0.050					
06/11/91	V21	1.53			0.050					
07/03/91	V21	1.00			0.080					
08/15/91	V21	3.77			0.080					
09/03/91	V21	6.42			0.050					
09/25/91	V21	5.89			0.050					
10/11/91	V21	4.20			0.060					
11/14/91	V21	6.10			0.080					
12/18/91	V21	10.00			0.050					
01/20/92	V21	18	310		<0.05					
01/20/92	V21	19	311		<0.05					
02/18/92	V21	10.5			0.06					
03/18/92	V21	13.0			<0.04					
04/30/92	V21	4.70		2.00	<0.04			0.36	<0.0002	<0.02
06/15/92	V21	14.0		0.17	<0.04			0.09	<0.0002	<0.02
07/20/92	V21	29.6	872	96.4	1.00		0.040	4.11	<0.001	<0.02
08/05/92	V21	6.09								
01/31/95	V21				0.06					
01/31/95	V21	1.83			0.07					
02/01/95	V21	1.83			0.07					
04/25/95	V21	0.590	250	0.39	0.0274		<0.04	0.033	<0.001	co.02
04/25/95	v21	0.59	250		0.0274					
05/09/95	v21	8.36	2150	0.32	0.0019		<0.04	0.020	<0.001	<0.02
	Max	29.80	2720.00	96.40	1.00	0.00	0.04	4.11	0.00	0.00
	Min	0.59	250.00	0.05	0.00	0.00	0.00	0.01	0.00	0.00
	Mean	8.24	1378.00	8.86	0.07	0.00	0.01	0.33	0.00	0.00
	Count	33	13	15	36	1	3	15	15	15

DATE	SITE	Ca mg/L	Cd mg/L	Cl mg/L	Cr mg/L	Co mg/L	Cu mg/L	F mg/L	Fe mg/L	Hg mg/L
05/04/94	Drain 2	389	0.0632	<30	0.003	0.531	0.023	<50	0.429	
05/09/95	Drain 2	404	0.0941	<10	0.004	0.615	0.016	<20	1.85	
05/09/95	Drain 2	402	0.0940	<10	0.005	0.614	0.017	<20	1.99	
05/04/94	Drain 3	359	0.175	<30	0.004	3.27	0.022	<50	28.3	
08/09/94	Drain 3	446	0.0504	<10	<0.001	3.27	<0.002	<20	14.7	
08/09/94	Drain 3	511	0.0510		<0.001	3.81	<0.002		16.9	
10/11/94	Drain 3	447	0.0339	<10	0.004	2.34	<0.002	<20	19.7	
10/11/94	Drain 3	498	0.0351		0.004	2.60	<0.002		20.3	
05/09/95	Drain 3	450	0.0479	<10	0.009	2.51	<0.002	<20	59.1	
06/10/95	Drain 3	494.0	0.076		<0.005	2.298	<0.002		112.3	<0.03
01/07/91	V21						0.025		0.477	
02/26/91	V21						0.003		0.359	
03/20/91	V21						0.005		0.325	
04/16/91	V21						0.006			
05/07/91	V21						0.030		0.925	
06/11/91	V21						0.005		0.286	
07/03/91	V21						0.002		0.896	
08/15/91	V21						0.001		0.168	
09/03/91	V21						0.001		0.183	
09/25/91	V21						0.003		0.231	
10/11/91	V21						0.001		0.023	
11/14/91	V21						0.001		0.015	
12/18/91	V21						0.015		0.668	
01/20/92	V21						0.015		0.993	
01/20/92	V21						0.015		1.39	
02/18/92	V21						0.020		1.79	
03/18/92	V21						0.020		2.20	
04/30/92	V21	107	0.120		0.006	0.437	0.386		2.90	4.000
06/15/92	V21	115	0.0598		<0.001	0.320	0.095		0.717	
07/20/92	V21	163	0.200		0.590	0.197	1.33		268	
08/05/92	V21			4.4			0.403		6.61	
01/31/95	V21						0.059			
01/31/95	V21						0.064			
02/01/95	V21						0.064			
04/25/95	V21	66.3	0.002		0.003	0.109	0.003		0.70	
04/25/95	V21						0.003		0.7	
05/09/95	V21	460	0.054		<0.002	2.21	<0.002		51.2	

Max	511.00	0.20	4.40	0.59	3.81	1.33	0.00	268.00	4.00
Min	88.30	0.00	0.00	0.00	0.11	0.00	0.00	0.02	0.00
Mean	354.09	0.08	0.55	0.04	1.68	0.07	0.00	18.71	2.00
Count	15	15	8	15	15	37	7	33	2

DATE	SITE	so4 mg/L	La mg/L	Li mg/L	Mg mg/L	Mn mg/L	MO mg/L	Ni mg/L	P mg/L	Pb mg/L
05/04/94	Drain 2	1390		0.033	164	17.5	<0.005	1.59	<0.05	0.020
05/09/95	Drain 2	1540		0.036	179	20.6	<0.005	2.05	<0.06	0.05
05/09/95	Drain 2	1640		0.036	178	20.5	<0.005	2.04	<0.06	0.05
05/04/94	Drain 3	2500		0.078	173	56.2	<0.005	5.10	<0.05	0.097
08/09/94	Drain 3	3120		0.070	270	72.3	<0.005	5.52	<0.06	<0.01
08/09/94	Drain 3			0.0711	3071	82.5	<0.005	6.46	<0.06	<0.01
10/11/94	Drain 3	2310		0.062	245	48.8	<0.005	3.98	<0.06	<0.01
10/11/94	Drain 3			0.063	274	54.1	<0.005	4.37	<0.06	<0.01
05/09/95	Drain 3	2790		0.053	244	63.2	<0.005	4.41	<0.06	0.1
06/10/95	Drain 3		<.005		339.90	76.11	0.002	3.937	2.32	<0.02
01/07/91	V21	198.0								0.276
02/26/91	V21	233.0								0.028
03/20/91	V21	170.0								0.024
04/16/91	V21	157.0								0.300
05/07/91	V21	109.0								0.042
06/11/91	V21	183.0								0.004
07/03/91	V21	200.0								0.034
08/15/91	V21	282.0								0.020
09/03/91	V21	256.0								0.009
09/25/91	v21	255.0								0.022
10/11/91	v21	201.0								0.005
11/14/91	v21	431.0								0.039
12/18/91	v21	371.01								0.153
01/20/92	v21	162								0.236
01/20/92	v21	167								0.267
02/18/92	V21	175								0.236
03/18/92	V21	146								0.174
04/30/92	V21	377		<0.5	41.4	7.05	0.01	0.194	<0.2	0.288
06/15/92	V21	288		<0.5	35.8	3.21	<0.003	0.141	<0.2	0.030
07/20/92	v21	3021			113	8.41	0.054	0.623	3.03	14.6
08/05/92	V21	340			36.94	6.73	<0.01	0.19	0.04	0.310
01/31/95	V21					5.61				0.66
01/31/95	V21	472				5.56				0.67
02/01/95	v21	472								0.6701
04/25/95	v21	289			20.6	2.45	<0.004	0.22	<0.04	co. 0g
04/25/95	v21	289								<0.0g
05/09/95	v21	2330			243	56.4	<0.004	3.82	0.40	<0.0g
	Max	3120.00	0.00	0.08	339.90	82.50	0.05	6.46	3.03	14.60
	Min	109.00	0.00	0.00	20.60	2.45	0.00	0.14	0.00	0.00
	Mean	731.67	0.00	0.05	179.04	33.73	0.00	2.79	0.36	0.52
	Count	33	1	11	16	18	16	16	16	37

DATE	SITE	K mg/L	S mg/L	Sb mg/L	Se mg/L	Si mg/L	Sn mg/L	Sr mg/L	Ag mg/L	Na mg/L
05/04/94	Drain 2	17	371	<0.02	<0.02	5.77	<0.01	1.39	<0.001	12.5
05/09/95	Drain 2	11	525	0.04	<0.02	6.04	<0.01	1.31	<0.001	11.0
05/09/95	Drain 2	11	524	0.05	<0.02	5.99	<0.01	1.29	<0.001	10.9
05/04/94	Drain 3	17	568	<0.02	<0.02	5.97	<0.01	1.24	<0.001	7.60
08/09/94	Drain 3	12	880	<0.02	<0.02	5.90	<0.01	1.53	0.001~	15.7
08/09/94	Drain 3	16	950	<0.02	<0.02	6.10	<0.01	1.55	0.001	15.8
10/11/94	Drain 3	13	700	<0.02	<0.02	6.64	<0.01	1.36	0.002	11.8
10/11/94	Drain 3	13	750	0.03	<0.02	6.67	<0.01	1.421	0.003	14.5
05/09/95	Drain3	12	780	<0.02	<0.02	8.371	<0.01	1.37	<0.001	12.2
06/10/95	Drain 3				<0.02	5.861		1.9361	<0.003	15
01/07/91	V21									
02/26/91	V21									
03/20/91	V21									
04/16/91	V21									
05/07/91	V21									
06/11/91	V21									
07/03/91	v21									
08/15/91	v21									
09/03/91	v21									
09/25/91	v21									
10/11/91	v21									
11/14/91	v21									
12/18/91	V21									
01/20/92	v21									
01/20/92	V21									
02/18/92	v21									
03/18/92	v21									
04/30/92	V21	8.1		<0.02		<06.9		0.62	<0.01	7.1
06/15/92	V21	7.3			<0.02	4.6		0.98	<0.01	9.5
07/20/92	V21	19.7	112	0.073	<0.03	16.3	<0.02	1.68	0.02	12.8
08/05/92	V21	8		<0.06	<0.06			0.553	<0.01	7.34
01/31/95	V21									
01/31/95	V21									
02/01/95	V21									
04/25/95	v21	1.51	62.5	<0.02	<0.03	2.0	<0.02	0.221	<0.03	1.2
04/25/95	v21									
05/09/95	V21	13.0	790	<0.02	<0.0005	7.5	0.06	1.60	<0.03	11.4
	Max.	19.70	950.00	0.07	0.00	16.30	0.06	1.94	0.02	15.80
	Min	1.50	62.50	0.00	0.00	2.00	0.00	0.22	0.00	1.20
	Mean	11.97	584.38	0.01	0.00	6.71	0.01	1.25	0.00	11.15
	Count	15	12	14	16	15	12	18	16	16

DATE	SITE	Te mg/L	Ti mg/L	Th mg/L	Tl mg/L	U mg/L	V mg/L	W mg/L	Zn mg/L	Zr mg/L
05/04/94	Drain 2		0.011	<0.01		<0.06	0.003		48.5	0.005
05/09/95	Drain 2		0.005	<0.01		<0.07	<0.002		64.2	0.001
05/09/95	Drain 2		0.005	<0.01		<0.07	<0.002		63.9	<0.001
05/04/94	Drain 3		0.0096	<0.01		<0.06	0.004		342	0.019
08/09/94	Drain 3		0.002	<0.01		<0.07	0.003		294	<0.001
08/09/94	Drain 3		0.002	<0.01		<0.07	<0.002		338	<0.001
10/11/94	Drain 3		0.001	<0.01		<0.07	<0.002		188	0.003
10/11/94	Drain 3		0.001	<0.01		<0.07	0.005		193	0.004
05/09/95	Drain 3		0.006	<0.01		<0.07	<0.002		224	<0.001
06/10/95	Drain 3		0.005				<.005	<.02	270.3	
01/07/91	V21								0.276	
02/26/91	v21								0.231	
03/20/91	v21								0.203	
04/16/91	V21								0.546	
05/07/91	V21								0.242	
06/11/91	V21								0.467	
07/03/91	V21								0.379	
08/15/91	V21								3.230	
09/03/91	V21								3.480	
09/25/91	V21								2.450	
10/11/91	V21								1.190	
11/14/91	V21								2.100	
12/18/91	v21								4.500	
01/20/92	v21								2.52	
01/20/92	V21								2.60	
02/18/92	V21								2.00	
03/18/92	V21								0.939	
04/30/92	V21		0.05	<0.005		<0.02	<0.001		26.3	<0.01
06/15/92	V21		<0.01	<0.005		<0.02	<0.001		13.2	<0.01
07/20/92	V21	<0.02	0.361		<0.003		0.230		37.1	0.107
08/05/92	V21		0.11				<0.01		25.1	
01/31/95	V21								15.5	
01/31/95	v21								15.5	
02/01/95	v21								15.5	
04/25/95	v21	<0.02	0.012		<0.03		<0.003		7.71	<0.003
04/25/95	v21								7.71	
05/09/95	v21	0.06	0.015		<0.03		<0.003		179	0.008

Max	0.06	0.36	0.00	0.00	0.00	0.23	0.00	342.00	0.11
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Mean	0.02	0.04	0.00	0.00	0.00	0.02	0.00	64.75	0.01
Count	3	16	11	3	11	16	1	37	14

DATE	SITE	NO3 mg/L	NO2 mg/L	Hydroxide CaCl/CaCO3	Carbonate CaCO3	Bicarbonate CaCO3
05/04/94	Drain 2	<5	<50		<5	256
05/09/95	Drain 2	<2	<20			
05/09/95	Drain 2	<2	<20			
05/04/94	Drain 3	<5	<50			<5 77
08/09/94	Drain 3	10	<20			
08/09/94	Drain 3					
10/11/94	Drain 3	8	<20	<5	<5	185
10/11/94	Drain 3					
05/09/95	Drain 3	<2	<20			
06/10/95	Drain 3					
01/07/91	v21					1
02/26/91	V21					
03/20/91	v21					
04/16/91	v21					
05/07/91	v21					
06/11/91	v21					
07/03/91	V21					
08/15/91	V21					
09/03/91	v21					
09/25/91	v21					
10/11/91	V21					
11/14/91	v21					
12/18/91	v21					
01/20/92	v21					
01/20/92	V21					
02/18/92	v21					
03/18/92	v21					
04/30/92	v21					
06/15/92	v21					
07/20/92	V21					
08/05/92	V21	8.65	0.758			
01/31/95	V21					
01/31/95	V21					
02/01/95	V21					
04/25/95	V21					
04/25/95	V21					
05/09/95	V21					

Max	10.00	0.78	0.00	0.00	258.00
Min	0.00	0.00	0.00	0.00	77.W
Mean	3.33	0.09	0.00	0.00	173.00
Count	8	8	1	3	3

APPENDIX B
RAW DATA • CINOLA

ALLPAD.XLS

PAD	YEAR	PH	COND	ALK	SO4	ACID 4	ACID 8	SIO2	HG	P	AG	AL	AS
P01	87.1425	5.7	300	2	127	0	0	0	0	0	0	0.03	0.001
P01	87.1507	6.9	345	2	143	0	0	0	0	0	0	0	0
P01	87.1616	5.9	335	2	150	0	0	0	0	0	0	0	0
P01	87.2137	5.7	325	4	167	0	0	0	0	0	0	0.64	0.001
P01	87.2822	5.7	400	3	193	0	0	0	0.05	0	0	0.05	0.001
P01	87.3041	4.8	310	2	133	0	7	0	0.05	0	0	0	0
P01	87.3425	5.1	285	2	120	0	7	0	0	0	0	0	0
P01	87.3644	5.1	330	1	150	0	7	0	0.05	0	0	0.7	0.001
P01	87.4	5.1	320	9	145	0	0	0	0	0	0	0	0
P01	87.4754	4.9	127	0	200	0	16	0	0	0	0	2	0.002
P01	87.5137	4.7	430	0	220	0	16	0	0	0	0	0	0
P01	87.5519	4.2	470	0	218	7	30	0	0	0	0	2.1	0.003
P01	87.5956	4.7	570	0	315	0	26	0	0	0	0	0	0
P01	87.6284	4.7	580	0	262	1	33	0	0.05	0	0	4	0.001
P01	87.6885	4	700	0	367	19	53	0	0	0	0	0	0
P01	87.7049	4.1	705	0	340	26	60	0	0.05	0	0	7.7	0.001
P01	87.7268	4.2	550	0	300	42	69	0	0	0	0	0	0
P01	87.7842	4.1	378	0	194	12	58	0	0.05	0	0	8	0.001
P01	87.8197	4.1	422	0	219	19	61	0	0	0	0	0	0
P01	87.8607	4.4	350	0	177	2	55	0	0.05	0	0	8.1	0.001
P01	87.8989	4.3	255	0	115	11	50	0	0	0	0	0	0
P01	87.9372	4.5	192	0	76	0	35	0	0	0	0	0	0
P01	87.959	4.4	230	0	72	2	34	0	0.05	0	0	5.1	0.001
P01	87.9945	4.5	150	0	49	0	28	0	0	0	0	0	0
P01	88.0464	4.4	164	0	61	0	31	0	0.05	0	0	4	0.001
P01	88.071	4.5	150	0	50	0	24	0	0.05	0	0	0	0
P01	88.10931	4.71	1431	0	56	0	291	0	0	0	0	0	0
P01	88.1311	4.5	157	0	77	0	29	0	0.05	0	0	4.1	0.001
P01	88.1885	4.4	186	0	52	9	31	0	0	0	0	0	0
P01	88.224	0	0	0	61	0	0	0	0.05	0	0	4.2	0.001
P01	88.265	4.5	158	0	65	0	28	0	0	0	0	0	0
P01	88.3033	4.4	150	0	50	1	25	0	0.05	0.007	0	3.2	0.001
P01	88.3388	4.6	150	0	50	0	25	0	0	0.003	0	0	0
P01	88.40161			0	0	0	1041	0	0	0.051	0	6	0.0011
P01	88.4153	3.5	238	0	111	36	61	0	0	0.033	0	0	0
P01	88.474	3.9	237	0	108	10	54	0	0.05	0.003	0	5	0.001
P01	88.5151	3.8	283	0	1291	38	79	0	0	0.011	0	0	0
P01	88.5534	0	0	0	165	0	0	0	0.05	0	0	9	0.039
P01	88.589	4.2	288	0	141	14	62	0	0	0.01	0	0	0
P01	88.6301	4.2	254	0	142	13	68	0	0.05	0.01	0	11	0.002
P01	88.674	4.3	292	0	135	10	58	0	0	0.013	0	0	0
P01	88.7205	4.6	265	0	149	0	58	0	0.05	0.027	0	8.6	0.002
P01	88.7425	3.9	400	0	240	20	129	0	0	0.062	0	0	0
P01	88.7863	4.1	327	0	224	18	107	0	0	0.008	0	0	0
P01	90.6822	3.9	424	0	233	43	141	0	0	0	0	24	0.001
P01	91.2274	4.1	135	0	45	8	40	0	0	0	0	6	0.001
P01	91.41641	4.11	156	0	70	7	56	5	0	0	0.11	7.91	0.001
P01	91.4849	3.9	160	0	68	20	59	6	0	0	0.1	8.4	0.003
P01	91.6547	3.8	346	1	218	35	140	14	0	0	0.1	23	0.001
P01	91.7232	3.9	253	1	130	30	100	12	0	0	0.1	16	0.001
P01	91.808	4	225	1	95	9	74	6	0	0	0.1	10	0.001
P01	91.896	4	118	1	49	8	43	3	0	0	0.1	6.1	0.001
P01	91.95341	4.11	1131	1	38	51	341	3	0	0	0.11	5.21	0.001
P01	92.04931	4.11	89	1	34	4	28	4	0	0	0.11	3	0.001
P01	92.1475	3.7	88	1	33	12	28	3	0	0	0.1	3	0.001
P01	92.224	3.9	107	1	31	5	28	5	0	0	0.1	3.1	0.001
P01	92.3279	3.9	114	1	54	8	36	1	0	0	0.1	4.4	0.001
P02	87.1616	5.6	810	3	27	0	0	0	0	0	0	0	0
P02	87.2137	5.6	750	3	1001	0	0	0	0	0	0	0.03	0.001

ALLPAD.XLS

PAD	YEAR	PH	COND	ALK	SO4	ACID 4	ACID 8	SIO2	HG	P	AG	AL	AS
P02	87.2822	5.6	1060	4	400	0	0	0	0	0	0	0.37	0.001
P02	87.3041	4	1570	0	866	49	119	0	0.05	0	0	0	0
P02	87.3425	3.2	2930	0	2308	360	1245	0	0	0	0	0	0
P02	87.3644	2.3	5600	0	4500	2380	3910	0	0.05	0	0	362	1.5
P02	87.4	2.9	4450	0	4579	3120	4320	0	0	0	0	0	0
P02	87.4754	2.6	6730	0	10182	6360	9960	0	0.06	0	0	886	14.4
P02	87.5137	2.6	6850	0	11305	7840	11200	0	0	0	0	0	0
P02	87.5519	2.3	7400	0	10605	9250	12500	0	0	0	0	954	17.5
P02	87.5956	2.2	9900	0	23331	15800	24000	0	0	0	0	0	0
P02	87.6284	2.3	10500	0	21589	15450	21589	0	0.36	0	0	1420	62
P02	87.653	2.1	10500	0	20032	9900	21800	0	0	0	0	0	0
P02	87.6885	2.8	10800	0	21000	17900	23300	0	0	0	0	0	0
P02	87.7049	1.7	7100	0	12654	10909	13818	0	0.26	0	0	660	22
P02	87.7268	1.7	6600	0	10989	9200	11500	0	0	0	0	0	0
P02	87.7842	2	5700	0	6462	5500	7700	0	0.21	0	0	351	11
P02	87.8197	1.7	4500	0	4530	3650	5200	0	0	0	0	0	0
P02	87.8607	2.2	3100	0	2200	1600	2475	0	0.06	0	0	8.9	1.6
P02	87.8989	2.5	2720	0	1879	1338	1850	0	0	0	0	0	0
P02	87.9372	2.8	1600	0	700	434	576	0	0	0	0	0	0
P02	87.959	2.7	1700	0	742	465	692	0	0	0	0	23	0.16
P02	87.9945	2.6	1850	0	909	600	925	0	0	0	0	0	0
P02	88.0464	2.8	1900	0	970	660	1120	0	0.05	0	0	23	0.32
P02	88.071	2.9	1520	0	546	380	440	0	0	0	0	0	0
P02	88.1093	3	1600	0	775	460	700	0	0	0	0	0	0
P02	88.1311	2.8	2180	0	1268	750	1225	0	0.05	0	0	30	0.6
P02	88.1885	2.6	1980	0	860	600	950	0	0	0	0	0	0
P02	88.224	0	0	0	1250	0	0	0	0.05	0	0	37	0.92
P02	88.265	2.8	1525	0	680	452	583	0	0	0	0	0	0
P02	88.3033	2.7	1750	0	656	520	710	0	0.05	0.75	0	18.5	5
P02	88.3388	2.8	1750	0	753	515	700	0	0	0.74	0	0	0
P02	88.4016	0	0	0	3050	0	0	0	0.05	0	0	105	7
P02	88.4153	2.5	3470	0	3812	2760	3540	0	0	18.5	0	0	0
P02	88.474	2.8	2860	0	2400	2420	3120	0	0.05	9.5	0	75	2.5
P02	88.5151	1.8	3260	0	2840	2300	3290	0	0	11	0	0	0
P02	88.5534	0	0	0	2450	0	0	0	0.08	0	0	95	2.8
P02	88.589	2.4	2860	0	2000	1620	2270	0	0	5.5	0	0	0
P02	88.6301	2.4	3120	0	3200	2360	3050	0	0.05	8.8	0	128	2.2
P02	88.674	2.6	3730	0	3660	2760	3900	0	0	14	0	0	0
P02	88.7205	2.6	3620	0	4600	3200	4450	0	0.08	20	0	240	3.7
P02	88.7425	2.5	3390	0	3100	2725	3980	0	0	15.8	0	0	0
P02	88.7863	2.5	3040	0	3400	2310	4100	0	0	10.5	0	0	0
P02	90.6822	2.3	3150	0	2622	1790	2514	0	0	0	0	132	1.6
P02	91.2274	2.7	924	0	322	253	336	0	0	0	0	15	0.015
P02	91.4164	2.8	973	0	317	235	330	16	0	0	0.1	13	0.02
P02	91.4849	2.7	1024	0	338	260	351	20	0	0	0.1	14	0.009
P02	91.6548	2.5	1820	1	900	650	890	42	0	0	0.1	23	0.001
P02	91.7232	2.6	1289	1	603	420	550	35	0	0	0.1	25	0.1
P02	91.808	2.8	841	1	281	195	294	15	0	0	0.1	12	0.026
P02	91.896	2.9	498	1	136	98	121	8	0	0	0.1	5.2	0.008
P02	91.9534	3	437	1	114	73	112	9	0	0	0.1	4.6	0.004
P02	92.0493	2.9	426	1	106	67	111	12	0	0	0.1	3.4	0.003
P02	92.1475	2.8	454	1	111	74	105	9	0	0	0.1	3.7	0.002
P02	92.224	3	364	1	76	54	77	7	0	0	0.1	2.2	0.001
P02	92.3279	2.8	627	1	178	118	172	15	0	0	0.1	6.9	0.009
P03	87.2137	2.9	9300	0	15320	5148	13365	0	0.07	0	0	750	16
P03	87.2822	2.8	10400	0	16700	6855	12901	0	0.06	0	0	455	8
P03	87.3041	2.4	6180	0	15851	4050	5500	0	0.06	0	0	0	0
P03	87.3425	2.5	4950	0	6462	3560	6060	0	0	0	0	0	0
P03	87.3644	3	4300	0	8333	5420	7320	0	0.06	0	0	312	10.9

ALLPAD.XLS

PAD	YEAR	PH	COND	ALK	SO4	ACID 4	ACID 8	SIO2	HG	P	AG	AL	AS
P03	87.4	2.7	5550	0	7687	5235	7110	0	0	0	0	0	0
P03	87.4426	1.8	7000	0	10982	6550	10550	0	0	0	0	0	0
P03	87.4754	2.5	7000	0	11455	7850	11450	0	0.09	0	0	498	17.2
P03	87.5137	2.4	7200	0	12920	8740	12400	0	0	0	0	0	0
P03	87.5519	2.3	7750	0	12727	10400	13900	0	0	0	0	585	26.9
P03	87.5956	2.3	8650	0	18786	12500	18400	0	0	0	0	0	0
P03	87.6284	2.4	8850	0	17009	11200	17700	0	0.63	0	0	890	38
P03	87.653	2.1	10300	0	20032	10400	21100	0	0	0	0	0	0
P03	87.6885	2.7	11100	0	20667	17300	23000	0	0	0	0	0	0
P03	87.7049	1.7	9700	0	20646	17455	21636	0	0.54	0	0	860	49
P03	87.7268	1.6	9600	0	17982	14800	18400	0	0	0	0	0	0
P03	87.7842	1.9	7100	0	10462	7800	10400	0	0.23	0	0	404	17
P03	87.8197	1.7	7100	0	11560	7000	10900	0	0	0	0	0	0
P03	87.8607	2	4600	0	4444	2975	4050	0	0.08	0	0	179	4.4
P03	87.8989	2.3	4800	0	5152	3450	5050	0	0	0	0	0	0
P03	87.9372	2.5	2500	0	1633	1088	1452	0	0	0	0	0	0
P03	87.959	2.7	3300	0	2900	1640	2560	0	0.05	0	0	104	1.6
P03	87.9945	2.6	2750	0	2121	1360	1800	0	0	0	0	0	0
P03	88.0464	2.8	2850	0	2242	1260	1980	0	0.05	0	0	90	1.3
P03	88.071	2.8	2940	0	2121	1200	1860	0	0	0	0	0	0
P03	88.1093	2.8	3200	0	3100	1500	2400	0	0	0	0	0	0
P03	88.1311	2.8	3280	0	2641	1300	2350	0	0.05	0	0	98	1.7
P03	88.1885	2.5	3400	0	2520	1650	2450	0	0	0	0	0	0
P03	88.224	0	0	0	2600	0	0	0	0.05	0	0	80	1.5
P03	88.265	2.6	2600	0	1840	1200	1580	0	0	0	0	0	0
P03	88.3033	2.6	3400	0	2667	1755	2535	0	0.05	9.4	0	111	9
P03	88.3388	2.7	3620	0	3260	2000	2900	0	0	11.6	0	0	0
P03	88.4016	0	0	0	5650	0	0	0	0.08	0	0	191	12
P03	88.4153	2.4	5010	0	6238	4700	6140	0	0	37	0	0	0
P03	88.474	2.6	4450	0	4750	4100	5590	0	0.07	25.9	0	160	3.5
P03	88.5151	1.6	4900	0	5350	4340	5690	0	0	24	0	0	0
P03	88.5534	0	0	0	4700	0	0	0	0.05	0	0	164	5
P03	88.589	2.3	4860	0	5490	4200	5430	0	0	23	0	0	0
P03	88.6301	2.3	4670	0	7100	4600	6100	0	0.08	27	0	275	4.5
P03	88.674	2.6	5280	0	6750	5000	7100	0	0	31	0	0	0
P03	88.7205	2.5	4760	0	7300	4720	6750	0	0.08	41	0	320	6.5
P03	88.7425	2.3	5590	0	6500	5140	6880	0	0	48	0	0	0
P03	88.7863	2.4	5270	0	8500	5635	7825	0	0	43	0	0	0
P03	90.6822	2.1	4840	0	5148	3800	4940	0	0	0	0	180	6
P03	91.2274	2.3	2700	0	1480	1500	1785	0	0	0	0	66	1.9
P03	91.4164	2.3	3250	0	1428	1910	2630	38	0	0	0.1	75	1.9
P03	91.4849	2.2	3570	0	3610	2390	3250	61	0	0	0.1	95	2.1
P03	91.6547	2.2	4390	1	4660	3180	4100	80	0	0	0.1	120	4.3
P03	91.7232	2.2	3560	1	1445	2160	2820	48	0	0	0.1	86	1.8
P03	91.808	2.3	3170	1	1790	1750	2464	41	0	0	0.1	67	1.9
P03	91.896	2.4	2220	1	918	923	1118	21	0	0	0.1	3	0.71
P03	91.9534	2.6	1534	1	583	510	750	22	0	0	0.1	23	0.3
P03	92.0493	2.5	1509	1	520	540	702	29	0	0	0.1	26	0.34
P03	92.1475	2.6	1269	1	495	346	494	17	0	0	0.1	16	0.092
P03	92.224	2.5	2090	1	1540	555	708	5	0	0	0.1	53	0.39
P03	92.3279	2.4	1285	1	870	380	442	25	0	0	0.1	33	0.7
P04	87.2137	4.9	3700	3	186	0	0	0	0	0	0	0	0
P04	87.2822	5.2	3400	3	280	0	0	0	0.05	0	0	0.31	0.03
P04	87.3041	4.2	830	0	207	32	202	0	0.05	0	0	0	0
P04	87.3425	4.4	960	0	357	1	76	0	0	0	0	0	0
P04	87.3644	3.6	1800	0	883	25	400	0	0.05	0	0	6.2	0.01
P04	87.4	3.7	2220	0	1243	85	565	0	0	0	0	0	0
P04	87.4426	2.5	4400	0	3230	500	1050	0	0	0	0	0	0
P04	87.4754	3	4700	0	4773	1660	3540	0	0.05	0	0	257	2.1

ALLPAD.XLS

PAD	YEAR	PH	COND	ALK	SO4	ACID 4	ACID 8	SIO2	HG	P	AG	AL	AS
P04	87.5137	2.8	5350	0	6622	3440	5350	0	0	0	0	0	0
P04	87.5519	2.7	6250	0	6818	4250	6600	0	0	0	0	666	1.2
P04	87.5956	2.3	8800	0	18180	11500	18300	0	0	0	0	0	0
P04	87.6284	2.4	8900	0	16335	11300	18600	0	0.18	0	0	1090	77
P04	87.653	2.1	9980	0	17528	9200	18200	0	0	0	0	0	0
P04	87.6885	2.8	9210	0	14333	13400	17300	0	0	0	0	0	0
P04	87.7049	1.7	7800	0	13986	11400	14300	0	0.31	0	0	650	59
P04	87.7268	1.7	6800	0	7659	7900	9909	0	0	0	0	0	0
P04	87.7842	1.9	5480	0	6539	5000	6400	0	0.16	0	0	191	18
P04	87.8197	1.6	5500	0	5940	5050	6850	0	0	0	0	0	0
P04	87.8607	1.9	4200	0	3600	2575	3300	0	0	0	0	94	7.3
P04	87.8989	2.3	3780	0	2909	2225	3200	0	0	0	0	0	0
P04	87.9372	2.5	2410	0	1400	976	1264	0	0	0	0	0	0
P04	87.9591	2.61	2530	0	1533	9621	15121	0	0.05	0	0	39	2.7
P04	87.99451	2.4	2680	0	1697	1320	1700	0	0	0	0	0	0
P04	88.0464	2.7	2680	0	1636	1200	1700	0	0.05	0	0	35	3
P04	88.071	2.7	2210	0	1030	710	1060	0	0.06	0	0	0	0
P04	88.1093	2.9	2180	0	1980	760	1160	0	0	0	0	0	0
P04	88.1311	2.6	3020	0	1627	1200	2000	0	0.05	0	0	35	4
P04	88.1885	2.4	2800	0	1220	1125	1575	0	0	0	0	0	0
P04	88.224	0	0	0	1915	0	0	0	0.05	0	0	30	2.9
P04	88.265	2.7	2200	0	1000	814	964	0	0	0	0	0	0
P04	88.3033	2.5	2350	0	1050	835	1050	0	0.05	2.94	0	14.8	19
P04	88.3388	2.6	2460	0	1110	860	1120	0	0	3.7	0	0	0
P04	88.4016	0	0	0	4400	0	0	0	0.15	0	0	85	19
P04	88.4153	2.4	4620	0	5198	4100	5240	0	0	4.4	0	0	0
P04	88.474	2.7	3680	0	2800	2950	3680	0	0.11	20.5	0	63	8.3
P04	88.5151	1.6	4430	0	3900	3420	4520	0	0	2.4	0	0	0
P04	88.55341	0	0	0	3550	0	0	0	0.14	0	0	9.4	12
P04	88.589	2.2	4270	0	3840	3300	4300	0	0	24	0	0	0
P04	88.8301	2.2	4330	0	4450	3950	5030	0	0.181	30	0	1281	12
P04	88.674	2.5	4780	0	4600	4080	5450	0	0	41	0	0	0
P04	88.7205	2.5	5030	0	7490	5750	7600	0	0.491	20	0	250	29
P04	90.6822	2	4810	0	4154	3395	4195	0	0	0	0	105	7.6
P04	91.2274	2.5	1129	0	332	310	354	0	0	0	0	6.5	0.2
P04	91.4164	2.5	1676	0	560	610	780	18	0	0	0.1	12	0.26
P04	91.4849	2.4	1713	0	665	628	816	21	0	0	0.1	13	0.27
P04	91.6547	2.2	3490	1	790	1790	2190	42	0	0	0.1	42	2.2
P04	91.7233	2.3	2190	1	730	790	950	22	0	0	0.1	15	0.6
P04	91.808	2.4	1638	1	535	549	664	16	0	0	0.1	11	0.29
P04	91.896	2.8	761	1	178	158	185	7	0	0	0.1	35	0.042
P04	91.9534	2.9	611	1	134	108	144	7	0	0	0.1	2.1	0.021
P04	92.0493	2.6	849	1	225	203	294	17	0	0	0.1	3.7	0.054
P04	92.1475	2.9	930	1	252	238	284	11	0	0	0.1	4.4	0.042
P04	92.224	2.6	956	1	253	148	286	11	0	0	0.1	4.3	0.051
P04	92.3279	2.5	1723	1	366	740	944	14	0	0	0.1	7.3	0.11

ALLPAD.XLS

PAD	YEAR	B	BA	BE	CA	CD	CO	CR	CU	K	MG	FE	MN
P01	87.1425	0	0	0	22.5	5E-04	0.002	0.001	0.001	0	0	0.1	0.09
P01	87.1507	0	0	0	49	0	0	0	0	0	0	0.1	0
P01	87.1616	0	0	0	46	0	0	0	0	0	0	0.1	0
P01	87.2137	0	0	0	45	0.001	0.002	0.001	0.001	0	0	0.14	0.47
P01	87.2822	0	0	0	53	0.001	0.006	0.001	0.001	0	0	0.1	0.61
P01	87.3041	0	0	0	50	0	0	0	0	0	0	0.1	0
P01	87.3425	0	0	0	40	0	0	0	0	0	0	0.1	0
P01	87.3644	0	0	0	46	0.002	0.008	0.001	0.001	0	0	0.1	0.91
P01	87.4	0	0	0	43	0	0	0	0	0	0	0.1	0
P01	87.4754	0	0	0	65	0.006	0.021	0.002	0.001	0	0	0.1	1.39
P01	87.5137	0	0	0	78	0	0	0	0	0	0	0.1	0
P01	87.5519	0	0	0	60	0.01	0.022	0.001	0.001	0	0	0.15	1.43
P01	87.5956	0	0	0	90	0	0	0	0	0	0	0.1	0
P01	87.6284	0	0	0	105	0.011	0.036	0.001	0.001	0	0	0.191	2.5
P01	87.6885	0	0	0	123	0	0	0	0	0	0	0.16	0
P01	87.7049	0	0	0	112	0.016	0.05	0.001	0.001	0	0	0.121	3.81
P01	87.7268	0	0	0	705	0	0	0	0	0	0	0.12	0
P01	87.7842	0	0	0	51	0.013	0.04	0.001	0.002	0	0	0.16	2.7
P01	87.8197	0	0	0	55	0	0	0	0	0	0	0.1	0
P01	87.8607	0	0	0	39	0.011	0.034	0.001	0.002	0	0	0.1	1.8
P01	87.8989	0	0	0	23	0	0	0	0	0	0	0.1	0
P01	87.9372	0	0	0	17	0	0	0	0	0	0	0.1	0
P01	87.959	0	0	0	16	0.006	0.017	0.003	0.002	0	0	0.02	0.74
P01	87.9945	0	0	0	11	0	0	0	0	0	0	0.1	0
P01	88.0464	0	0	0	15	0.004	0.015	0.001	0.001	0	0	0.01	0.51
P01	88.071	0	0	0	8	0	0	0	0	0	0	0.1	0
P01	88.1093	0	0	0	8	0	0	0	0	0	0	0	0
P01	88.1311	0	0	0	9.3	0.012	0.012	0.001	0.001	0	0	0.02	0.47
P01	88.1885	0	0	0	15	0	0	0	0	0	0	0.1	0
P01	88.224	0	0	0	0	0.004	0.02	0.001	0.002	0	0	0.04	0.47
P01	88.265	0	0	0	13	0	0	0	0	0	0	0.1	0
P01	88.3033	0	0	0	10	0.0041	0.0111	0.001	0.0021	0	0	0.081	0.4
P01	88.3388	0	0	0	10	0	0	0	0	0	0	0.1	0
P01	88.4016	0	0	0	0	2E-04	0.05	0.001	0.002	0	0	0.05	0.73
P01	88.4153	0	0	0	21	0	0	0	0	0	0	0.1	0
P01	88.474	0	0	0	20	0.017	0.028	0.001	0.003	0	0	0.04	1.06
P01	88.5151	0	0	0	23	0	0	0	0	0	0	0.1	0
P01	88.5534	0	0	0	0	0.008	0.1	0.029	5E-04	0	0	0.03	1.21
P01	88.589	0	0	0	17	0	0	0	0	0	0	0.1	0
P01	88.6301	0	0	0	15	0.01	0.035	0.001	0.005	0	0	0.13	1.61
P01	88.674	0	0	0	15	0	0	0	0	0	0	0.1	0
P01	88.7205	0	0	0	19	0.012	0.033	0.025	0.0041	0	0	0.081	1.581
P01	88.7425	0	0	0	32	0	0	0	0	0	0	0.22	0
P01	88.7863	0	0	0	163	0	0	0	0	0	0	0.11	0
P01	90.6822	0	0	0	27	0	0	0	0.0081	0	0	0.141	0
P01	91.2274	0	0	0	4	0	0	0	0.002	0	1.5	1.3	0
P01	91.4164	1	0.06	0.04	6.1	0.05	0.05	0.04	0.006	0	2.4	0.1	0.39
P01	91.4849	1	0.05	0.04	6.1	0.05	0.05	0.04	0.004	0.55	2.4	0.07	0.4
P01	91.6547	1	0.12	0.04	13.3	0.05	0.07	0.04	0.009	1.4	5.6	0.45	1.7
P01	91.7232	1	0.05	0.04	10	0.05	0.05	0.04	0.007	0.78	3.7	0.5	1.1
P01	91.808	1	0.05	0.04	6.31	0.051	0.051	0.041	0.0071	0.641	2.71	0.141	0.611
P01	91.896	1	0.05	0.05	4.6	0.05	0.05	0.04	0.005	0.5	1	0.07	0.18
P01	91.9534	1	0.05	0.05	3.5	0.05	0.05	0.04	0.004	0.53	0.9	0.09	0.16
P01	92.0493	1	0.05	0.05	2.9	0.05	0.05	0.04	0.002	0.5	0.7	0.29	0.1
P01	92.1475	1	0.05	0.05	2.6	0.05	0.05	0.04	0.002	0.5	0.9	0	0.11
P01	92.224	1	0.05	0.05	3.2	0.05	0.05	0.04	0.003	0.5	0.9	0.05	0.13
P01	92.3279	1	0.05	0.05	4.4	0.05	0.05	0.04	0.003	0.5	1.5	0.05	0.23
P02	87.1616	0	0	0	128	0	0	0	0	0	0	0.1	0
P02	87.2137	0	0	0	86	0.0051	0.14	0.001	0.001	0	0	0.1	0.811

ALLPAD.XLS

PAD	YEAR	B	BA	BE	CA	CD	/CO	/CR	CU	K	MG	FF	MN
P02	87.2822	0	0	0	151	0.005	0.14	0.001	0.008	0	0	0.1	5.9
P02	87.3041	0	0	0	320	0	0	0	0	0	0	0.53	0
P02	87.3425	0	0	0	500	0	0	0	0	0	0	50	0
P02	87.3644	0	0	0	548	0.07	2.44	0.001	2.241	0	0	250	38.4
P02	87.4	0	0	0	360	0	0	0	0	0	0	250	0
P02	87.4754	0	0	0	325	0.1	2.9	0.8	5	0	0	1750	43
P02	87.5137	0	0	0	310	0	0	0	0	0	0	2000	0
P02	87.5519	0	0	0	310	0.11	3.6	0.8	5.9	0	0	2060	51
P02	87.5956	0	0	0	370	0	0	0	0	0	0	6100	0
P02	87.6284	0	0	0	400	0.24	5.8	0.82	11.1	0	0	7660	69
P02	87.653	0	0	0	315	0	0	0	0	0	0	4950	0
P02	87.6885	0	0	0	300	0	0	0	0	0	0	6150	0
P02	87.7049	0	0	0	205	0.15	2.6	0.36	4.9	0	0	3190	24
P02	87.7268	0	0	0	180	0	0	0	0	0	0	2950	0
P02	87.7842	0	0	0	175	0.06	1.31	0.221	2.71	0	0	1800	15
P02	87.8197	0	0	0	125	0	0	0	0	0	0	1200	0
P02	87.8607	0	0	0	87	0.013	0.31	0.06	0.81	0	0	425	3.8
P02	87.8989	0	0	0	80	0	0	0	0	0	0	450	0
P02	87.9372	0	0	0	58	0	0	0	0	0	0	110	0
P02	87.959	0	0	0	45	0.008	0.09	0.029	0.25	0	0	119	0.96
P02	87.9945	0	0	0	39	0	0	0	0	0	0	180	0
P02	88.0464	0	0	0	50	0.009	0.09	0.028	0.31	0	0	175	0.92
P02	88.071	0	0	0	30	0	0	0	0	0	0	118	0
P02	88.1093	0	0	0	32	0	0	0	0	0	0	150	0
P02	88.1311	0	0	0	50	0.022	0.24	0.029	0.36	0	0	245	1.18
P02	88.1885	0	0	0	45	0	0	0	0	0	0	200	0
P02	88.224	0	0	0	0	0.007	0.15	0.037	0.471	0	0	355	1.31
P02	88.265	0	0	0	33	0	0	0	0	0	0	125	0
P02	88.3033	0	0	0	35	0.004	0.09	0.025	0.19	0	0	150	0.8
P02	88.3388	0	0	0	33	0	0	0	0	0	0	150	0
P02	88.4016	0	0	0	0	0.006	0.39	0.131	0.931	0	0	950	3.71
P02	88.4153	0	0	0	85	0	0	0	0	0	0	875	0
P02	88.474	0	0	0	58	0.022	0.32	0.12	0.76	0	0	950	3.1
P02	88.5151	0	0	0	68	0	0	0	0	0	0	750	0
P02	88.5534	0	0	0	0	0.013	0.591	0.121	0.761	0	0	5301	3.3
P02	88.589	0	0	0	60	0	0	0	0	0	0	500	0
P02	88.6301	0	0	0	80	0.018	0.31	0.07	0.77	0	0	303	4.4
P02	88.674	0	0	0	85	0	0	0	0	0	0	850	0
P02	88.7205	0	0	0	98	0.021	0.57	0.11	1.23	0	0	415	6.4
P02	88.7425	0	0	0	150	0	0	0	0	0	0	2350	0
P02	88.7863	0	0	0	205	0	0	0	0	0	0	3875	0
P02	90.6822	0	0	0	61	0	0	0	0.721	0	0	552	0
P02	91.2274	0	0	0	11	0	0	0	0.17	0	6	75	0
P02	91.4164	1	0.05	0.04	12	0.05	0.14	0.04	0.13	0.5	5.1	59	0.43
P02	91.4849	1	0.05	0.04	12	0.05	0.13	0.04	0.131	0.51	5.1	52	0.431
P02	91.6548	1	0.1	0.04	17	0.05	0.1	0.05	0.01	1.2	6.8	0.52	1.7
P02	91.7232	1	0.05	0.04	17	0.05	0.24	0.07	0.18	0.5	12	101	0.92
P02	91.808	1	0.05	0.04	8.6	0.05	0.08	0.04	0.09	0.2	6.2	37	0.42
P02	91.896	1	0.05	0.05	6.1	0.05	0.05	0.04	0.046	0.5	2.5	17	0.17
P02	91.9534	1	0.05	0.05	4.8	0.05	0.05	0.04	0.036	0.5	1.7	13	0.15
P02	92.0493	1	0.05	0.05	3.8	0.05	0.05	0.04	0.026	0.5	1.6	11	0.13
P02	92.1475	1	0.05	0.05	4.2	0.05	0.05	0.04	0.033	0.5	1.7	11	0.13
P02	92.224	1	0.05	0.05	2.6	0.05	0.05	0.004	0.023	0.5	1.1	3.1	0.08
P02	92.3279	1	0.05	0.05	7.6	0.05	0.1	0.04	0.07	0.5	3.2	21	0.24
P03	87.2137	0	0	0	290	0.07	7.1	0.19	4.69	0	0	4050	35
P03	87.2822	0	0	0	470	0.06	4.5	0.17	3.05	0	0	4115	52
P03	87.3041	0	0	0	489	0	0	0	0	0	0	1500	0
P03	87.3425	0	0	0	473	0	0	0	0	0	0	1575	0
P03	87.3644	0	0	0	470	0.11	3.07	0.261	2.53	0	0	1037	31

ALLPAD.XLS

PAD	YEAR	B	BA	BE	CA	CD	CO	CR	CU	K	MG	FE	MN
P03	87.4	0	0	0	438	0	0	0	0	0	0	2000	0
P03	87.4426	0	0	0	450	0	0	0	0	0	0	3000	0
P03	87.4754	0	0	0	450	0.17	3.5	0.4	3.5	0	0	3000	37
P03	87.51371	0	0	0	450	0	0	0	0	0	0	3800	0
P03	87.5519	0	0	0	460	0.18	4.4	0.4	4.4	0	0	3920	43
P03	87.5956	0	0	0	450	0	0	0	0	0	0	5200	0
P03	87.6284	0	0	0	504	0.37	4.5	0.34	4.7	0	0	5280	44
P03	87.6531	0	0	0	4401	0	0	0	0	0	0	5600	0
P03	87.6885	0	0	0	395	0	0	0	0	0	0	6600	0
P03	87.7049	0	0	0	380	0.21	4.5	0.36	5.2	0	0	6570	42
P03	87.7268	0	0	0	350	0	0	0	0	0	0	5150	0
P03	87.7842	0	0	0	325	0.06	2.5	0.23	2.8	0	0	3050	26
P03	87.8197	0	0	0	290	0	0	0	0	0	0	3250	0
P03	87.8607	0	0	0	203	0.012	1.05	0.13	1.3	0	0	1250	12
P03	87.8989	0	0	0	215	0	0	0	0	0	0	1350	0
P03	87.9372	0	0	0	125	0	0	0	0	0	0	350	0
P03	87.959	0	0	0	1201	0.0061	0.71	0.07	0.72	0	0	620	7.7
P03	87.9945	0	0	0	99	0	0	0	0	0	0	440	0
P03	88.0464	0	0	0	114	0.0081	0.091	0.028	0.3	0	0	502	6.6
P03	88.071	0	0	0	120	0	0	0	0	0	0	478	0
P03	88.1093	0	0	0	185	0	0	0	0	0	0	640	0
P03	88.1311	0	0	0	193	0.014	1.21	0.09	0.72	0	0	575	6.9
P03	88.1885	0	0	0	175	0	0	0	0	0	0	600	0
P03	88.224	0	0	0	0	0.005	0.51	0.06	0.72	0	0	613	5
P03	88.265	0	0	0	133	0	0	0	0	0	0	390	0
P03	88.3033	0	0	0	155	0.005	0.781	0.091	0.631	0	0	625	9
P03	88.3388	0	0	0	160	0	0	0	0	0	0	750	0
P03	88.4016	0	0	0	0	0.02	0.95	0.23	1.18	0	0	1610	10.9
P03	88.4153	0	0	0	218	0	0	0	0	0	0	1600	0
P03	88.474	0	0	0	168	0.026	0.77	0.19	1.01	0	0	1325	8.2
P03	88.5151	0	0	0	198	0	0	0	0	0	0	1475	0
P03	88.5534	0	0	0	0	0.021	0.13	0.17	0.94	0	0	600	8.4
P03	88.589	0	0	0	180	0	0	0	0	0	0	1450	0
P03	88.6301	0	0	0	200	0.032	1.11	0.14	1.1	0	0	900	14
P03	88.674	0	0	0	210	0	0	0	0	0	0	1850	0
P03	88.7205	0	0	0	170	0.0311	1.091	0.161	1.31	0	0	1350	13
P03	88.7425	0	0	0	325	0	0	0	0	0	0	4475	0
P03	88.7863	0	0	0	500	0	0	0	0	0	0	10500	0
P03	90.6822	0	0	0	132	0	0	0	0.691	0	0	959	0
P03	91.2274	0	0	0	1141	0	0	0	0.071	0	23	550	0
P03	91.4164	1	0.05	0.04	113	0.05	1.39	0.05	0.38	0.5	24	721	2.4
P03	91.4849	1	0.05	0.04	112	0.05	1.9	0.041	0.41	0.5	29	896	3.1
P03	91.65471	1	0.051	0.041	96	0.051	2.4	0.111	0.511	0.5	35	11501	3.9
P03	91.7232	1	0.05	0.04	76	0.05	1.4	0.07	0.32	0.5	27	843	2.5
P03	91.808	1	0.05	0.04	79	0.05	0.05	0.04	0.29	0.5	25	638	2.2
P03	91.896	0.5	0.05	0.05	47	0.05	0.45	0.04	0.11	0.5	13	302	1.1
P03	91.9534	1	0.05	0.05	55	0.05	0.05	0.04	0.098	0.5	10	167	0.88
P03	92.0493	1	0.05	0.05	61	0.05	0.45	0.04	0.07	0.5	12	167	1.1
P03	92.1475	1	0.05	0.05	51	0.05	0.34	0.04	0.06	0.5	6.9	104	0.58
P03	92.224	1	0.05	0.05	79	0.05	0.54	0.04	0.12	0.5	27	364	2.7
P03	92.3279	1	0.05	0.05	73	0.05	1.2	0.04	0.11	0.5	16	229	1.6
P04	87.2137	0	0	0	347	0	0	0	0	0	0	0.2	0
P04	87.2822	0	0	0	332	0.007	0.13	0.001	0.001	0	0	0.33	6
P04	87.3041	0	0	0	30	0	0	0	0	0	0	0.1	0
P04	87.3425	0	0	0	43	0	0	0	0	0	0	0.11	0
P04	87.3644	0	0	0	150	0.03	0.59	0.003	0.15	0	0	3.2	4.98
P04	87.41	0	0	0	2271	0	0	0	0	0	0	6.41	0
P04	87.4426	0	0	0	600	0	0	0	0	0	0	65	0
P04	87.47541	0	0	0	4501	0.21	4	0.1	2.4	0	0	250	26

ALLPAD.XLS

PAD	YEAR	B	BA	BE	CA	CD	CO	CR	CU	K	MG	FE	MN
P04	87.5137	0	0	0	475	0	0	0	0	0	0	250	C
P04	87.5519	0	0	0	475	0.51	5.8	0.2	4.3	0	0	250	37
P04	87.5956	0	0	0	490	0	0	0	0	0	0	4700	C
P04	87.6284	0	0	0	500	0.34	6.5	0.37	7.7	0	0	5120	28
P04	87.653	0	0	0	400	0	0	0	0	0	0	5150	C
P04	87.6885	0	0	0	320	0	0	0	0	0	0	4900	C
P04	87.7049	0	0	0	290	0.19	3.9	0.27	5.4	0	0	4420	13
P04	87.7268	0	0	0	220	0	0	0	0	0	0	2650	C
P04	87.7842	0	0	0	200	0.07	1.3	0.11	2	0	0	1850	6
P04	87.8197	0	0	0	175	0	0	0	0	0	0	2050	C
P04	87.8607	0	0	0	106	0.012	0.57	0.06	1.1	0	0	900	2.8
P04	87.8989	0	0	0	105	0	0	0	0	0	0	900	C
P04	87.9372	0	0	0	75	0	0	0	0	0	0	325	C
P04	87.959	0	0	0	60	0.013	0.26	0.05	0.54	0	0	350	1.3
P04	87.9945	0	0	0	50	0	0	0	0	0	0	440	C
P04	88.0464	0	0	0	56	0.01	0.29	0.042	0.64	0	0	412	1.19
P04	88.071	0	0	0	46	0	0	0	0	0	0	270	C
P04	88.10931	0	0	0	60	0	0	0	0	0	0	270	C
P04	88.1311 88.1885	0	0	0	78	0.023	0.49	0.031	0.56	0	0	500	1.09
P04	-----	-	-	-	-	0	0	0	0	0	0	375	C
P04	88.224	0	0	0	0	0.003	0.18	0.028	0.52	0	0	528	0.77
P04	88.265	0	0	0	48	0	0	0	0	0	0	235	C
P04	88.3033	0	0	0	45	0.004	0.121	0.0181	0.5	0	0	2361	0.51
P04	88.3388	0	0	0	45	0	0	0	0	0	0	2751	C
P04	88.4016	0	0	0	0	0.032	0.45	0.1	0.92	0	0	1450	2.2
P04	88.4153	0	0	0	110	0	0	0	0	0	0	1450	C
P04	88.474	0	0	0	63	0.019	0.35	0.09	0.74	0	0	1050	1.87
P04	88.5151	0	0	0	78	0	0	0	0	0	0	1150	C
P04	88.5534	0	0	0	0	0.017	0.67	0.1	0.86	0	0	590	2.2
P04	88.589	0	0	0	82	0	0	0	0	0	0	1125	C
P04	88.6301	0	0	0	100	0.016	0.36	0.07	0.86	0	0	1350	3.1
P04	88.674	0	0	0	98	0	0	0	0	0	0	1550	C
P04	88.7205	0	0	0	125	0.015	0.79	0.12	1.74	0	0	2500	4.7
P04	90.6822	0	0	0	53	0	0	0	0.81	0	0	946	C
P04	91.22741	0	0	0	9.71	0	0	0	0.091	0	2	84	C
P04	91.4164	1	0.05	0.04	16	0.05	0.4	0.04	0.14	0.5	2.6	198	0.24
P04	91.4849	1	0.05	0.04	16	0.05	0.44	0.04	0.15	0.5	2.7	198	0.25
P04	91.6547	1	0.05	0.04	28	0.05	1.2	0.04	0.45	0.5	10	570	0.95
P04	91.7233	1	0.05	0.04	15	0.05	0.4	0.06	0.15	0.5	4.2	248	0.35
P04	91.808	1	0.05	0.04	8.9	0.05	0.24	0.04	0.1	0.5	2.9	131	0.23
P04	91.896	1	0.05	0.05	3.3	0.05	0.05	0.04	0.037	0.5	0.7	28	0.05
P04	91.9534	1	0.05	0.05	2.9	0.05	0.05	0.04	0.024	0.5	0.5	20	0.06
P04	92.0493	1	0.05	0.05	4.9	0.05	0.05	0.04	0.033	0.5	1.1	49	0.05
P04	92.1475	1	0.05	0.05	5.6	0.05	0.19	0.04	0.05	0.5	1.1	57	0.05
P04	92.2241	1	0.05	0.05	5.4	0.05	0.19	0.04	0.05	0.5	1	56	0.05
P04	92.3279	1	0.05	0.05	7.5	0.05	0.42	0.04	0.07	0.5	1.5	90	0.13

ALLPAD.XLS

PAD	YEAR	MO	NA	NI	PB	SB	/SE	SN	SR	TI	V	ZN
P01	87.1425	0	0	0.003	0.002	0.002	0	0	0	0	0	0.01
P01	87.1507	0	0	0	0	0	0	0	0	0	0	0
P01	87.16161	0	0	0	0	0	0	0	0	0	0	0
P01	87.2137	0	0	0.007	0.001	0.002	0	0	0	0	0	0.011
P01	87.2822	0	0	0.01	0.004	0.002	0	0	0	0	0	0.02
P01	87.3041	0	0	0	0	0	0	0	0	0	0	0
P01	87.3425	0	0	0	0	0	0	0	0	0	0	0
P01	87.3644	0	0	0.016	0.001	0.002	0	0	0	0	0	0.07
P01	87.4	0	0	0	0	0	0	0	0	0	0	0
P01	87.4754	0	0	0.03	0.001	0.002	0	0	0	0	0	0.12
P01	87.5137	0	0	0	0	0	0	0	0	0	0	0
P01	87.5519	0	0	0.02	0.001	0.002	0	0	0	0	0	0.14
P01	87.5956	0	0	0	0	0	0	0	0	0	0	0
P01	87.6284	0	0	0.029	0.001	0.002	0	0	0	0	0	0.18
P01	87.6885	0	0	0	0	0	0	0	0	0	0	0
P01	87.7049	0	0	0.041	0.001	0.002	0	0	0	0	0	0.3
P01	87.7268	0	0	0	0	0	0	0	0	0	0	0
P01	87.7842	0	0	0.037	0.001	0.002	0	0	0	0	0	0.32
P01	87.8197	0	0	0	0	0	0	0	0	0	0	0
P01	87.8607	0	0	0.04	0.001	0.002	0	0	0	0	0	0.27
P01	87.8989	0	0	0	0	0	0	0	0	0	0	0
P01	87.9372	0	0	0	0	0	0	0	0	0	0	0
P01	87.959	0	0	0.0161	0.001	0.0021	0	0	0	0	0	0.181
P01	87.9945	0	0	0	0	0	0	0	0	0	0	0
P01	88.0464	0	0	0.014	0.001	0.002	0	0	0	0	0	0.13
P01	88.071	0	0	0	0	0	0	0	0	0	0	0
P01	88.1093	0	0	0	0	0	0	0	0	0	0	0
P01	88.1311	0	0	0.014	0.001	0.002	0	0	0	0	0	0.02
P01	88.1885	0	0	0	0	0	0	0	0	0	0	0
P01	88.224	0	0	0.014	0.001	0.002	0	0	0	0	0	0.15
P01	88.265	0	0	0	0	0	0	0	0	0	0	0
P01	88.3033	0	0	0.021	0.001	0.0021	0	0	0	0	0	0.1
P01	88.3388	0	0	0	0	0	0	0	0	0	0	0
P01	88.4016	0	0	0.018	0.001	0.002	0	0	0	0	0	0.16
P01	88.4153	0	0	0	0	0	0	0	0	0	0	0
P01	88.474	0	0	0.023	0.001	0.002	0	0	0	0	0	0.2
P01	88.5151	0	0	0	0	0	0	0	0	0	0	0
P01	88.5534	0	0	0.025	0.001	0.002	0	0	0	0	0	0.22
P01	88.589	0	0	0	0	0	0	0	0	0	0	0
P01	88.6301	0	0	0.031	0.001	0.002	0	0	0	0	0	0.21
P01	88.6741	0	0	0	0	0	0	0	0	0	0	0
P01	88.72051	0	0	0.0291	0.001	0.0021	0	0	0	0	0	0.16
P01	88.7425	0	0	0	0	0	0	0	0	0	0	0
P01	88.7863	0	0	0	0	0	0	0	0	0	0	0
P01	90.6822	0	0	0	0	0	0	0	0	0	0	0.31
P01	91.2274	0	0	0	0	0	0.001	0	0	0	0	0.09
P01	91.4164	0.041	2.7	0.051	0.1	0.1	0.001	0.51	0.041	0.2	0.051	0.111
P01	91.4849	0.04	2.8	0.05	0.1	0.1	0.001	0.5	0.04	0.2	0.05	0.12
P01	91.6547	0.04	3.6	0.05	0.1	0.1	0.003	0.5	0.08	0.2	0.05	0.28
P01	91.7232	0.04	2.7	0.07	0.1	0.1	0.002	0.5	0.06	0.2	0.05	0.2
P01	91.808	0.04	1.5	0.05	0.1	0.1	0.001	0.5	0.04	0.2	0.05	0.14
P01	91.896	0.041	1.91	0.04	0.1	0.1	0.001	0.51	0.041	0.21	0.051	0.0731
P01	91.95341	0.041	4.31	0.041	0.1	0.1	0.001	0.5	0.041	0.21	0.051	0.07
P01	92.0493	0.04	1.9	0.04	0.1	0.1	0.001	0.5	0.04	0.2	0.05	0.043
P01	92.1475	0.04	3.6	0.04	0.1	0.1	0.001	0.5	0.04	0.2	0.05	0.04
P01	92.224	0.04	3.7	0.04	0.1	0.1	0.001	0.5	0.04	0.2	0.05	0.05
P01	92.3279	0.04	3.1	0.04	0.1	0.1	0.004	0.5	0.04	0.2	0.05	0.07
P02	87.1616	0	0	0	0	0	0	0	0	0	0	0
P02	87.2137	0	0	0.006	0.001	0.011	0	0	0	0	0	0.003

ALLPAD.XLS

PAD	YEAR	MO	NA	NI	PB	SB	SE	SN	SR	TI	V	ZN
P02	87.2822	0	0	0.1	0.0061	0.007	0	0	0	0	0	0.2
P02	87.3041	0	0	0	0	0	0	0	0	0	0	0
P02	87.3425	0	0	0	0	0	0	0	0	0	0	0
P02	87.3644	0	0	0	0.003	0.026	0	0	0	0	0	11.6
P02	87.4	0	0	0	0	0	0	0	0	0	0	0
P02	87.4754	0	0	1.69	0.01	0.19	0	0	0	0	0	18.8
P02	87.5137	0	0	0	0	0	0	0	0	0	0	0
P02	87.5519	0	0	1.91	0.015	0.14	0	0	0	0	0	22
P02	87.5956	0	0	0	0	0	0	0	0	0	0	0
P02	87.6284	0	0	3.1	0.031	0.31	0	0	0	0	0	37
P02	87.653	0	0	0	0	0	0	0	0	0	0	0
P02	87.6885	0	0	0	0	0	0	0	0	0	0	0
P02	87.7049	0	0	1.1	0.011	0.12	0	0	0	0	0	15
P02	87.7268	0	0	0	0	0	0	0	0	0	0	0
P02	87.7842	0	0	0.751	0.0041	0.111	0	0	0	0	0	8.5
P02	87.8197	0	0	0	0	0	0	0	0	0	0	0
P02	87.8607	0	0	0.16	0.001	0.007	0	0	0	0	0	2.2
P02	87.8989	0	0	0	0	0	0	0	0	0	0	0
P02	87.9372	0	0	0	0	0	0	0	0	0	0	0
P02	87.959	0	0	0.05	0.001	0.002	0	0	0	0	0	0.61
P02	87.9945	0	0	0	0	0	0	0	0	0	0	0
P02	88.0464	0	0	0.05	0.005	0.004	0	0	0	0	0	0.59
P02	88.071	0	0	0	0	0	0	0	0	0	0	0
P02	88.10931	0	0	0	0	0	0	0	0	0	0	0
P02	88.1311	0	0	0.051	0.001	0.0021	0	0	0	0	0	0.72
P02	88.1885	0	0	0	0	0	0	0	0	0	0	0
P02	88.224	0	0	0.06	0.001	0.006	0	0	0	0	0	0.9
P02	88.265	0	0	0	0	0	0	0	0	0	0	0
P02	88.3033	0	0	0.15	0.001	0.002	0	0	0	0	0	0.42
P02	88.3388	0	0	0	0	0	0	0	0	0	0	0
P02	88.4016	0	0	0.14	0.003	0.012	0	0	0	0	0	1.91
P02	88.4153	0	0	0	0	0	0	0	0	0	0	0
P02	88.474	0	0	0.14	0.003	0.009	0	0	0	0	0	1.55
P02	88.5151	0	0	0	0	0	0	0	0	0	0	0
P02	88.5534	0	0	0.45	0.019	0.008	0	0	0	0	0	1.6
P02	88.589	0	0	0	0	0	0	0	0	0	0	0
P02	88.6301	0	0	0.27	0.002	0.006	0	0	0	0	0	1.94
P02	88.6741	0	0	0	0	0	0	0	0	0	0	0
P02	88.7205	0	0	0.33	0.004	0.008	0	0	0	0	0	2.3
P02	88.7425	0	0	0	0	0	0	0	0	0	0	0
P02	88.7863	0	0	0	0	0	0	0	0	0	0	0
P02	90.6822	0	0	0	0	0	0	0	0	0	0	1.6
P02	91.2274	0	0	0	0	0	0.004	0	0	0	0	0.24
P02	91.4164	0.041	3.6	0.051	0.1	0.1	0.006	0.5	0.041	0.2	0.051	0.22
P02	91.4849	0.04	3.7	0.05	0.1	0.1	0.005	0.05	0.04	0.2	0.05	0.23
P02	91.6548	0.04	3.6	0.06	0.1	0.1	0.004	0.5	0.08	0.2	0.05	0.27
P02	91.7232	0.04	3.9	0.1	0.1	0.1	0.01	0.5	0.07	0.2	0.05	0.35
P02	91.808	0.04	2.4	0.05	0.1	0.1	0.004	0.5	0.04	0.2	0.05	0.19
P02	91.896	0.04	1.7	0.04	0.1	0.1	0.002	0.5	0.04	0.2	0.05	0.098
P02	91.9534	0.04	3.9	0.04	0.1	0.1	0.002	0.5	0.04	0.2	0.05	0.09
P02	92.0493	0.04	1.8	0.04	0.1	0.1	0.002	0.5	0.04	0.2	0.05	0.06
P02	92.1475	0.04	3.1	0.04	0.1	0.1	0.001	0.5	0.04	0.2	0.05	0.06
P02	92.224	0.04	3.3	0.04	0.1	0.1	0.001	0.5	0.04	0.2	0.05	0.04
P02	92.3279	0.041	3.5	0.041	0.1	0.1	0.005	0.51	0.04	0.2	0.05	0.12
P03	87.2137	0	0	5.8	0.012	0.158	0	0	0	0	0	57
P03	87.2822	0	0	3.8	0.006	0.041	0	0	0	0	0	30
P03	87.3041	0	0	0	0	0	0	0	0	0	0	0
P03	87.3425	0	0	0	0	0	0	0	0	0	0	0
P03	87.3644	0	0	0	0.005	0.045	0	0	0	0	0	20.8

ALLPAD.XLS

PAD	YEAR	MO	NA	NI	PB	SB	SE	SN	SR	TI	V	ZN
P03	87.4	0	0	0	0	0	0	0	0	0	0	0
P03	87.4426	0	0	0	0	0	0	0	0	0	0	0
P03	87.4754	0	0	3.09	0.14	0.062	0	0	0	0	0	2.6
P03	87.5137	0	0	0	0	0	0	0	0	0	0	0
P03	87.5519	0	0	3.55	0.011	0.03	0	0	0	0	0	31
P03	87.5956	0	0	0	0	0	0	0	0	0	0	0
P03	87.6284	0	0	3.8	0.021	0.05	0	0	0	0	0	32
P03	87.653	0	0	0	0	0	0	0	0	0	0	0
P03	87.6885	0	0	0	0	0	0	0	0	0	0	0
P03	87.7049	0	0	3.6	0.024	0.05	0	0	0	0	0	31
P03	87.7268	0	0	0	0	0	0	0	0	0	0	0
P03	87.7842	0	0	2.1	0.008	0.04	0	0	0	0	0	17
P03	87.8197	0	0	0	0	0	0	0	0	0	0	0
P03	87.8607	0	0	0.93	0.004	0.01	0	0	0	0	0	7.7
P03	87.8989	0	0	0	0	0	0	0	0	0	0	0
P03	87.9372	0	0	0	0	0	0	0	0	0	0	0
P03	87.959	0	0	0.59	0.002	0.006	0	0	0	0	0	5.3
P03	87.9945	0	0	0	0	0	0	0	0	0	0	0
P03	88.0464	0	0	0.49	0.002	0.008	0	0	0	0	0	4.24
P03	88.071	0	0	0	0	0	0	0	0	0	0	0
P03	88.1093	0	0	0	0	0	0	0	0	0	0	0
P03	88.1311	0	0	0.5	0.002	0.005	0	0	0	0	0	4.2
P03	88.1885	0	0	0	0	0	0	0	0	0	0	0
P03	88.2241	0	0	0.44	0.002	0.006	0	0	0	0	0	3.7
P03	88.265	0	0	0	0	0	0	0	0	0	0	0
P03	88.3033	0	0	0.62	0.002	0.012	0	0	0	0	0	5.8
P03	88.3388	0	0	0	0	0	0	0	0	0	0	0
P03	88.4016	0	0	0.72	0.004	0.01	0	0	0	0	0	6.8
P03	88.4153	0	0	0	0	0	0	0	0	0	0	0
P03	88.474	0	0	0.6	0.003	0.006	0	0	0	0	0	5.3
P03	88.5151	0	0	0	0	0	0	0	0	0	0	0
P03	88.5534	0	0	0.35	0.0141	0.0061	0	0	0	0	0	5.2
P03	88.589	0	0	0	0	0	0	0	0	0	0	0
P03	88.6301	0	0	0.98	0.005	0.009	0	0	0	0	0	8.4
P03	88.674	0	0	0	0	0	0	0	0	0	0	0
P03	88.7205	0	0	0.89	0.006	0.006	0	0	0	0	0	7.8
P03	88.7425	0	0	0	0	0	0	0	0	0	0	0
P03	88.7863	0	0	0	0	0	0	0	0	0	0	0
P03	90.6822	0	0	0	0	0	0	0	0	0	0	1.6
P03	91.2274	0	0	0	0	0	0.03	0	0	0	0	1
P03	91.4164	0.04	4.5	0.14	0.1	0.1	0.064	0.5	0.15	0.2	0.05	1.2
P03	91.4849	0.04	7	0.18	0.1	0.1	0.062	0.5	0.17	0.2	0.05	1.6
P03	91.6547	0.04	11	0.31	0.1	0.1	0.087	0.5	0.19	0.2	0.2	1.8
P03	91.7232	0.04	8.5	0.21	0.1	0.1	0.052	0.5	0.15	0.2	0.15	1.2
P03	91.808	0.04	7	0.19	0.1	0.1	0.046	0.5	0.11	0.2	0.05	0.89
P03	91.896	0.04	3.4	0.09	0.1	0.1	0.019	0.5	0.04	0.2	0.05	0.51
P03	91.9534	0.04	4.2	0.06	0.1	0.1	0.009	0.5	0.07	0.2	0.05	0.41
P03	92.0493	0.041	3.8	0.08	0.1	0.1	0.009	0.5	0.07	0.2	0.05	0.53
P03	92.1475	0.04	4.6	0.04	0.1	0.1	0.004	0.5	0.06	0.2	0.05	0.29
P03	92.224	0.04	7.1	0.14	0.1	0.1	0.023	0.5	0.1	0.2	0.09	1.3
P03	92.3279	0.04	5.4	0.07	0.1	0.1	0.008	0.5	0.1	0.2	0.07	0.83
P04	87.2137	0	0	0	0	0	0	0	0	0	0	0
P04	87.2822	0	0	0.15	0.002	0.004	0	0	0	0	0	0.42
P04	87.3041	0	0	0	0	0	0	0	0	0	0	0
P04	87.3425	0	0	0	0	0	0	0	0	0	0	0
P04	87.3644	0	0	0	0.001	0.003	0	0	0	0	0	1.85
P04	87.4	0	0	0	0	0	0	0	0	0	0	0
P04	87.4426	0	0	0	0	0	0	0	0	0	0	0
P04	87.47541	0	0	2.881	0.0091	0.008	0	0	0	0	0	2.3

ALLPAD.XLS

PAD	YEAR	MO	NA	NI	PB	SB	SE	SN	SR	TI	V	ZN
P04	87.5137	0	0	0	0	0	0	0	0	0	0	0
P04	87.5519	0	0	3.81	0.011	0.007	0	0	0	0	0	38
P04	87.5956	0	0	0	0	0	0	0	0	0	0	0
P04	87.6284	0	0	4.4	0.021	0.23	0	0	0	0	0	60
P04	87.653	0	0	0	0	0	0	0	0	0	0	0
P04	87.6885	0	0	0	0	0	0	0	0	0	0	0
P04	87.7049	0	0	2.6	0.018	0.18	0	0	0	0	0	40
P04	87.7268	0	0	0	0	0	0	0	0	0	0	0
P04	87.7842	0	0	0.87	0.004	0.09	0	0	0	0	0	12
P04	87.8197	0	0	0	0	0	0	0	0	0	0	0
N/A	87.8607	0	0	0.381	0.0021	0.0321	0	0	0	0	0	5.71
P04	87.8989	0	0	0	0	0	0	0	0	0	0	0
P04	87.9372	0	0	0	0	0	0	0	0	0	0	0
P04	87.959	0	0	0.19	0.0011	0.013	0	0	0	0	0	2.71
P04	87.9945	0	0	0	0	0	0	0	0	0	0	0
P04	88.0464	0	0	0.17	0.001	0.03	0	0	0	0	0	2.49
P04	88.071	0	0	0	0	0	0	0	0	0	0	0
P04	88.1093	0	0	0	0	0	0	0	0	0	0	0
P04	88.1311	0	0	0.13	0.001	0.0171	0	0	0	0	0	1.9
P04	88.1885	0	0	0	0	0	0	0	0	0	0	0
P04	88.224	0	0	0.13	0.001	0.022	0	0	0	0	0	1.7
P04	88.285	0	0	0	0	0	0	0	0	0	0	0
P04	88.3033	0	0	0.07	0.001	0.01	0	0	0	0	0	0.821
P04	88.33881	0	0	0	0	0	0	0	0	0	0	0
P04	88.40161	0	0	0.22	0.0041	0.03	0	0	0	0	0	3.51
P04	88.4153	0	0	0	0	0	0	0	0	0	0	0
P04	88.474	0	0	0.2	0.002	0.022	0	0	0	0	0	2.7
P04	88.5151	0	0	0	0	0	0	0	0	0	0	0
P04	88.5534	0	0	0.62	0.049	0.031	0	0	0	0	0	3.4
P04	88.589	0	0	0	0	0	0	0	0	0	0	0
P04	88.6301	0	0	0.34	0.004	0.028	0	0	0	0	0	3.8
P04	88.674	0	0	0	0	0	0	0	0	0	0	0
P04	88.7205	0	0	0.62	0.0071	0.043	0	0	0	0	0	6.9
P04	90.6822	0	0	0	0	0	0	0	0	0	0	2.7
P04	91.2274	0	0	0	0	0	0.009	0	0	0	0	0.3
P04	91.4164	0.04	1.7	0.05	0.1	0.1	0.037	0.5	0.05	0.2	0.05	0.49
P04	91.4849	0.04	2.2	0.05	0.1	0.1	0.044	0.5	0.05	0.2	0.05	0.49
P04	91.6547	0.04	5.4	0.05	0.1	0.1	0.12	0.5	0.14	0.2	0.05	1.2
P04	91.7233	0.04	2.5	0.1	0.1	0.1	0.038	0.5	0.06	0.2	0.05	0.47
P04	91.808	0.04	1.5	0.05	0.1	0.06	0.029	0.5	0.04	0.2	0.05	0.32
P04	91.896	0.04	1.6	0.04	0.1	0.1	0.005	0.5	0.04	0.2	0.05	0.11
P04	91.9534	0.04	4.1	0.04	0.1	0.1	0.003	0.5	0.04	0.2	0.05	0.09
P04	92.0493	0.04	1.8	0.041	0.1	0.1	0.0091	0.5	0.041	0.21	0.051	0.151
P04	92.1475	0.04	3.8	0.04	0.1	0.1	0.008	0.5	0.04	0.2	0.05	0.15
P04	92.224	0.04	4	0.04	0.1	0.1	0.014	0.5	0.04	0.2	0.05	0.15
P04	92.3279	0.04	2.6	0.04	0.1	0.1	0.031	0.5	0.04	0.2	0.05	0.25

APPENDIX C
RAW DATA - SULLIVAN

TABLE 3
SELECTED ANALYTICAL RESULTS FOR WELLS COLLARED WITHIN LOWER MINE YARD WASTE ROCK DUMPS

Site	Date	As	Cd	Ca	cu	Fe	Pb	Mg	Ag	Zn	pH	Total Acidity	Total Alkalinity	Sulphate
92AA2	Aug-92	0.002	0.006	22.1	0.005	0.16	0.005	6.8	0.02	0.36	7.43	4.4	42.1	51.1
92AA2	Jun-93	<0.001	0.005	16.7	0.002	<0.03	0.002	4.9	co.03	0.18	7.19	14.7	44.4	30.
92S	Aug-92	<0.001	21.2	40.7	378.	29000.	0.02	4210.		5840.	1.85	99400.	0.	4450.
92S	Mar-93	1.	15.6	350.	348.	35500.	0.01	3320.	<0.03	4350.	2.13	102000.		117000.
92S	Jun-93	0.011	22.3	404.	362.	3160.	0.011	3550.	3.	5690.	2.36	89700.	2.5	140000.
92T2	Aug-92	<0.001	0.023	204.	0.002	0.09	0.003	76.4	0.02	7.69	7.47	27.	303.	1020.
92T2	Mar-93	<0.001	0.013	139.	<0.001	0.036	<0.001	50.2	<0.03	3.32	8.1		266.	400.
92T2	Jun-93	<0.001	0.019	134.	<0.001	<0.03	<0.001	47.7	co.03	4.53	6.95	103.	260.	390.

Notes:

1. All metal concentrations in **mg/L**. Metals determined on 0.45 um filtered water. Other parameters on unfiltered water.
2. "-" indicates no analysis.

TABLE 4
SELECTED ANALYTICAL RESULTS FOR WELLS DOWNGRADIENT OF LOWER MINE YARD WASTE ROCK DUMPS

Site	Date	As	Cd	Ca	CU	Fe	Pb	Mg	Ag	Zn	pH	Total Acidity	Total Alkalinity	Sulphate
92CC2	Aug-92	<0.001	0.01	27.8	0.007	0.05	<0.001	10.9	0.02	4.33	5.69	16.	6.	123.
92CC2	Mar-93	<0.001	0.005	13.9	0.009	0.03	0.003	6.22	<0.03	2.52	4.69		2.	59.
92CC2	Jun-93	<0.001	0.016	20.5	0.018	<0.03	0.002	10.7	<0.03	4.7	5.21	27.6	5.9	104.
92DD	Aug-92	<0.001	0.002	10.1	0.003	0.05	<0.001	3.73	0.02	0.69	5.99	32.	10.9	40.9
92DD	Mar-93	<0.001	0.002	7.77	0.004	0.079	0.003	2.92	<0.03	0.94	6.75		32.	28.
92DD	Jun-93	0.001	0.0007	2.04	0.007	0.033	0.001	0.8	<0.03	0.2	6.81	5.5	13.8	9.
92EE2	Aug-92	0.001	0.041	83.9	0.065	0.04	0.003	42.3	0.02	29.6	4.59	68.	0.1	420.
92EE2	Mar-93	<0.001	0.045	76.	0.053	0.036	0.006	34.7	<0.03	20.6	4.72		2.	388.
92EE2	Jun-93	<0.001	0.025	49.4	0.051	co.03	0.002	24.6	<0.03	18.7	4.39	73.	2.5	280.
92V	Aug-92	<0.001	1.96	573.	0.8	0.28	2.23	315.	0.02	338.	4.98	46.	0.	3580.
92V	Mar-93	0.022	1.42	459.	0.58	0.13	1.31	264.	<0.03	242.	3.94	1170.		3200.
92V	Jun-93	0.005 1	1.27	408.	0.5	0.24	1.22	229.	<0.03	238.	3.87	947.	2.5	2870.
92W	Aug-92	<0.001	0.019	167.	0.013	11.6	0.004	69.3	0.02	8.89	5.	66.	0.1	71.6
92W	Mar-93	<0.001	0.0001	79.1	<0.001	2.04	0.002	23.3	co.03	4.78	6.28		35.	400.
92w	Jun-93	<0.001	0.037	99.3	0.015	1.76	0.028	40.5	<0.03	24.7	4.5	170.	2.5	640.
92w	Jun-93	<0.001	0.036	99.4	0.017	1.76	0.032	40.6	<0.03	24.6	4.5	194.	2.5	520.
92X1	Aug-92	0.02	0.67	144.	2.65	88.7	0.014	356.	0.02	296.	2.77	2570.	0.	5202.
92X1	Mar-93	0.01	0.43	149.	1.71	37.1	0.015	277.	0.038	160.	2.73	2920.		3600.
92x1	Jun-93	0.011	0.48	166.	2.3	47.1	0.14	324.	<0.03	186.	2.74	2380.	2.5	4200.
92Y	Aug-92	<0.001	0.077	124.	0.26	1.29	0.13	107.	0.02	39.2	3.09	338.	0.	1060.
92Y	Mar-93	<0.001	0.043	97.4	0.13	0.29	0.001	74.5	<0.03	21.4	3.6	213.		28.
92Y	Jun-93	<0.001	0.063	75.	0.13	0.31	0.077	44.2	co.03	21.8	3.42	184.	2.5	620.
93HH	Jun-93	0.044	0.44	452.	1.99	176.	0.16	368.	0.3	222.	2.47	2050.	2.5	4800.
93II	Jun-93	0.01	0.7	152.	1.5	0.34	0.036	277.	0.049	410.	3.55	2470.	2.5	3800.
93JJ	Jun-93	0.0005	0.06	68.1	0.11	0.015	0.005	37.5	0.05	32.2	4.3	138.	2.5	420.
93KK	Jun-93	0.01	0.32	174.	0.9	0.41	0.045	174.	0.015	144.	3.49	959.	2.5	2260.
93KK	Jun-93	0.01	0.33	175.	0.93	0.41	0.04	175.	0.015	145.	3.59	1090.	2.5	2390.

Notes:

1. All metal concentrations in mg/L. Metals determined on 0.45 um filtered water. Other parameters on unfiltered water.
2. "-" indicates no analysis.

TABLE 5
SELECTED ANALYTICAL RESULTS FOR WATER (DISOM SEEPS AND SUMPS - SOLVED METALS)

Site	Date	As	Cd	Ca	CU	Fe	Pb	Mg	Ag	Zn	pH	Total Acidity	Total Alkalinity	Sulphate
MY13A	Aug-92	0.001	0.02	25.8	0.15	9.22	0.17	14.1	0.02	7.89	2.84	164.	0.	251.
MY13A	Mar-93	<0.001	0.014	16.4	0.1	2.55	0.091	8.66	<0.03	4.22	3.78	59.		140.
MY13A	Jun-93	<0.001	0.022	15.8	0.087	6.48	0.099	8.86	<0.03	6.96	3.46	75.6	2.5	156.
MY13B	Aug-92	0.002	0.35	76.8	1.31	103.	0.2	178.	0.02	157.	2.53	240.	0.	2900.
MY13B	Mar-93	<0.001	0.067	21.	0.28	11.8	0.13	45.4	<0.03	32.5	3.07	317.		700.
MY13B	Jun-93	<0.001	0.036	10.2	0.16	7.69	0.12	20.6	<0.03	15.5	3.12	229.	2.5	340.
MY14	Aug-92	<0.001	0.0005	86.9	0.002	0.02	<0.001	43.4	0.02	0.31	8.29	0.	242.	140.
MY14N	Mar-93	<0.001	0.0003	20.9	<0.001	<0.03	<0.001	6.94	<0.03	0.075	7.79		68.	19.
MY14	Jun-93	<0.001	0.0007	100.	0.002	<0.03	0.001	51.4	<0.03	0.17	8.3	2.5	269.	160.
MY14	Jun-93	<0.001	0.0007	101.	0.002	<0.03	0.001	51.5	<0.03	0.17	8.08	8.5	270.	170.
MY18	Aug-92	0.006	0.0005	10.9	0.008	6.85	0.001	2.72	0.02	0.038	6.66	6.	46.2	1.
MY18	Mar-93	0.001	0.0001	9.65	<0.001	1.39	<0.001	3.1	<0.03	0.005	7.86		44.	1.
MY18	Jun-93	0.001	0.0001	9.32	0.002	2.13	0.001	2.46	<0.03	0.005	7.14	11.1	44.4	0.5

Notes:

1. All metal concentrations in mg/L. Metals determined on 0.45 µm filtered water. Other parameters on unfiltered water.
2. "-" indicates no analysis.

TABLE 6
SELECTED ANALYTICAL RESULTS FOR MARK CREEK WATER (DISSOLVED METALS)

Site	Date	As	Cd	Ca	CU	Fe	Pb	Mg	Ag	Zn	pH	Total Acidity	Total Alkalinity	Sulphate
MY11	Aug-92	<0.001	0.0005	6.14	0.002	0.09	40.001	1.54	0.02	0.032	6.87	4.	25.2	4.8
MY11	Mar-93	<0.001	0.0001	6.74	<0.001	0.083	<0.001	2.26	<0.03	0.005	7.46		27.	7.
MY11	Jun-93	<0.001	0.0001	2.31	<0.001	0.039	<0.001	0.59	<0.03	0.048	6.61	2.5	9.9	5.
MY12	Aug-92	0.001	0.0005	6.7	0.005	0.29	0.005	1.66	0.02	0.071	6.94	4.	24.2	6.4
MY12	Mar-93	<0.001	0.0005	8.45	<0.001	0.22	0.005	2.52	<0.03	0.01	7.44		32.	13.
MY12	Jun-93	<0.001	0.0001	2.44	<0.001	0.1	0.002	0.68	<0.03	0.005	6.82	2.5	9.9	3.
MY15	Aug-92	<0.001	0.0005	7.1	0.002	0.13	0.005	1.95	0.02	0.083	6.61	8.	22.1	7.3
MY15	Mar-93	<0.001	0.0003	8.32	<0.001	0.15	0.004	2.7	<0.03	0.005	6.98		30.	12.
MY15	Jun-93	<0.001	0.0001	2.19	<0.001	0.052	0.002	0.62	<0.03	0.005	6.86	2.5	10.9	4.
MY16	Aug-92	<0.001	0.008	11.7	0.013	0.03	0.004	6.22	0.02	4.77	7.04	14.	73.6	62.3
MY16	Mar-93	<0.001	0.002	11.2	0.001	0.03	<0.001	4.68	<0.03	1.23	7.13		27.	33.
MY16	Jun-93	<0.001	0.0004	2.96	0.006	0.19	0.004	0.85	<0.03	0.18	6.19	10.	10.	9.

Notes:

1. All metal concentrations in **mg/L**. Metals determined on 0.45 **um** filtered water. Other parameters on unfiltered water.
2. "-" indicates no analysis.

APPENDIX D
RAW DATA - DOYON

HISTORICAL DATA FROM 1986 TO 1990

	Date (m/d/y)	Acidity (mg/l)	Fe (mg/l)	SO4 (mg/l)	pH
STATION D-391 (EAST)	04/29/86	23000	9365	34000	2.34
STATION D-391 (EAST)	05/26/86	33759	10050	46600	2.29
STATION D-391 (EAST)	06/16/86	40450	10600	46000	2.36
STATION D-301 (EAST)	07/28/86	42756	11300	57000	2.27
STATION D-361 (EAST)	08/25/86	40000	9860	9000	2.36
STATION D-361 (EAST)	09/29/86	43759	12290	58000	2.26
STATION D-301 (EAST)	1 1/18/86	41700	100	50000	2.35
STATION D-361 (EAST)	04/12/87	26000	1026	58000	2.16
STATION D-301 (EAST)	05/04/87	35500	974	40000	2.44
STATION D-301 (EAST)	06/01/87	15625	3960	16000	2.51
STATION D-361 (EAST)	07/20/87	46166	14669	41630	2.37
STATION D-361 (EAST)	08/17/87	58350	13200	75000	2.36
STATION D-361 (EAST)	09/16/87	30535	839	33900	2.36
STATION D-361 (EAST)	10/20/87	53400	11900	70000	2.36
STATION D-301 (EAST)	11/19/87	56500	2000	85000	2.35
STATION D-361 (EAST)	01/11/88	525	60	1500	3.16
STATION D-361 (EAST)	04/25/88		6300		2.47
STATION D-301 (EAST)	05/08/88	62500	22500	56000	2.43
STATION D-361 (EAST)	05/09/88	46750	16700	60000	2.56
STATION D-361 (EAST)	05/10/88	46900	14700	41000	2.51
STATION D-361 (EAST)	05/11/88	61250	16000	46000	2.52
STATION D-361 (EAST)	05/12/88	27500	8050	30000	2.61
STATION D-301 (EAST)	06/21/88	46256	21500	85000	2.54
STATION D-301 (EAST)	07/19/88	53756	19000	55000	2.56
STATION D-361 (EAST)	08/21/88	61250	1717	76000	2.55
STATION D-361 (EAST)	10/26/88	15000	3200	28000	2.79
STATION D-301 (EAST)	04/24/89	25750	7400	30000	2.49
STATION D-361 (EAST)	06/05/89	12670	3570	19000	2.64
STATION D-361 (EAST)	07/09/89	45000	14000	49000	2.31
STATION D-361 (EAST)	10/30/89	42840	11500	50000	2.36
STATION D-361 (EAST)	1 1/21/89	22050	5770	22000	2.76
STATION D-362	04/29/86	32	2	200	4.16
STATION D-362	05/26/86	155	6	500	3.19
STATION D-362	06/16/86	650	66	1200	2.69
STATION D-362	07/28/86	1300	145	2400	2.66
STATION D-362	08/25/86	63	74	1900	2.94
STATION D-362	09/29/86	800	96	1500	2.61
STATION D-362	1 1/18/86	468	60	1100	3.12
STATION D-302	02/02/87			4000	
STATION D-362	04/12/87	1650 101	163 14	220	3.20 3.66
STATION D-302	05/04/87			500	
STATION D-362	06/01/87	217 251	25 30	500	3.15 2.67
STATION D-302	07/20/87	952	124	1200	2.73
STATION D-302	08/17/87	1070	103	1650	2.96
STATION D-362	09/16/87	2622	776	1500	2.74
STATION D-362	10/20/87	1403	3	1750	2.67
STATION D-362	11/19/87	1065	1	1700	2.66
STATION D-362	12/07/87	1464	235	2100	2.93
STATION D-362	01/11/88	525	60	1500	3.16

HISTORICAL DATA FROM 1986 TO 1990

	Date (m/d/y)	Acidity (mg/l)	Fe (mg/l)	SO4 (mg/l)	pH
STATION D-392	04/25/88		3300		2.63
STATION D-392	05/08/88	235	39	800	3.94
STATION D-392	05/09/88	300	52	750	3.03
STATION D-392	05/10/88	312	42	900	3.25
STATION D-392	05/11/88	288	44	900	3.25
STATION D-392	05/12/88	275	43	900	3.29
STATION D-392	06/21/88	1188	239	2050	2.68
STATION D-392	07/19/88	1465	261	2450	2.58
STATION D-392	08/21/88	1250	203	1750	3.10
STATION D-392	09/05/88	13500	2319	11500	2.51
STATION D-392	10/26/88	1000	201	1550	2.81
STATION D-302	11/22/88	750	323	1900	3.07
STATION D-392	12/12/88	5150	1820	7880	2.66
STATION D-302	01/16/89	6750	2430	9750	2.82
STATION D-392	07/01/89	1357	430	3000	2.74
STATION D-392	03/13/89	15000	3210	21000	2.72
STATION D-392	04/24/89	4050	1180	3830	2.71
STATION D-392	05/15/89	3600	960	6000	2.79
STATION D-392	06/05/89	3000	800	4500	2.85
STATION D-392	07/09/89	35750	11500	39000	2.31
STATION D-392	10/30/89	20475	6630	23500	2.41
STATION D-392	11/21/89	9135	2480	9500	2.74
STATION D-302	04/09/90	2200	162	2040	2.79
STATION D-392	05/07/90	2900	1130	4100	2.69
STATION D-392	06/11/90	28750	10750	77500	2.36
STATION D-302	07/08/90	3750	1442	7000	2.61
STATION D-302	08/26/90	21250	9475	32000	2.37
STATION D-302	09/16/90	5600	1633	6500	2.63
STATION D-302	10/08/90	6700	822	6000	2.58
STATION D-302	11/18/90	11950	3570	15500	2.43
STATION D-309 (SOUTH)	06/16/86	13750	1850	12000	2.62
STATION D-309 (SOUTH)	07/28/86	16400	1030	18250	2.86
STATION D-309 (SOUTH)	08/25/86	14000	1600	16000	2.62
STATION D-309 (SOUTH)	09/29/86	9000	1093	10000	2.72
STATION D-309 (SOUTH)	11/18/86	6700	930	10000	2.99
STATION D-309 (SOUTH)	04/12/87	8000	84	12000	2.65
STATION D-309 (SOUTH)	05/04/87	7470	1054	9000	2.83
STATION D-309 (SOUTH)	06/01/87	2875	477	4000	2.75
STATION D-309 (SOUTH)	07/20/87	5019	672	9050	2.87
STATION D-309 (SOUTH)	08/17/87	15302	1580	18500	2.81
STATION D-309 (SOUTH)	09/16/87	4060	844	5500	2.57
STATION D-309 (SOUTH)	10/20/87	857	921	10000	2.66
STATION D-309 (SOUTH)	04/25/88		3000		2.63
STATION D-309 (SOUTH)	05/08/88	26250	11050	34000	2.63
STATION D-309 (SOUTH)	05/09/88	30000	9300	22000	2.66
STATION D-309 (SOUTH)	05/10/88	17500	4770	20000	2.75
STATION D-309 (SOUTH)	05/11/88	21250	6340	26500	2.71
STATION D-309 (SOUTH)	05/12/88	10000	3430	16000	2.66
STATION D-S09 (SOUTH)	06/21/88	20695	8910	35000	2.66

HISTORICAL DATA FROM 1986 TO 1990

	Date (m/d/y)	Acidity (mg/l)	Fe (mg/l)	SO4 (mg/l)	pH
STATION D-309 (SOUTH)	07/19/88	16383	4740	29000	2.81
STATION D-399 (SOUTH)	08/21/88	52500	883	58000	2.59
STATION D-399 (SOUTH)	09/05/88	27750	653	42000	2.43
STATION D-399 (SOUTH)	10/26/88	55000	1400	68000	2.52
STATION D-399 (SOUTH)	11/22/88	12000	4540	32000	2.59
STATION D-399 (SOUTH)	04/24/89	41250	13000	57000	2.31
STATION D-399 (SOUTH)	05/15/89	43000	1130	70000	2.81
STATION D-399 (SOUTH)	06/05/89	40125	10100	57000	2.41
STATION D-399 (SOUTH)	07/09/89	53750	17500	77500	2.21
STATION D-399 (SOUTH)	10/30/89	47250	12700	60000	2.27
STATION D-399 (SOUTH)	11/21/89	37800	11900	50000	2.29

Borehole Samples

Soil	Date	pH	EH mV	Cond. μ S	SG g/cc	TDS mg/l	Acidity meq/1000	Al mg/l	Ca mg/l	Cd mg/l	Cu tot mg/l	Fe ++ mg/l	Fe +++ mg/l	K mg/l	Mg mg/l	Mn mg/l	Na mg/l	Ni mg/l	Pb mg/l	Si mg/l	SO4 = mg/l	Zn mg/l	
BH-91-04 Soil	03/25/87	4.11	290	7218	-	10318	2448	97	812	0.12	-	787434	323	10.38	929	211	42.6	7.1	0.3	-	5999	8.1	
BH-91-04 Soil	04/23/87	4.06	170	4195	-	4807	599	8	402	-	0.3	176	188	7	8.13	408	81	a7	1	0.33	25	2934	1
BH-91-04 Soil	06/12/87	8.88	nd	3325	-	3710	327	1	343	-	-	181	108	73	8.18	-	280	a4	ao	-	-	1751	-
BH-91-04 Soil	08/29/87	5.4	-	4500	-	-	1350	91360	500	-	-	720	375	345	28	520	62	37	-	-	-	3000	-
BH-91-04 Soil	10/29/87	4.88	190	4232	1.0043	4688	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-04 Soil	06/17/82	6.1	182	4872	1.0060	4800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-04 Soil	08/14/88	4.88	217	4594	1.005	8010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-01 Soil	04/07/87	3.64	262	6619	-	4677	3358	63	310	1.4	1483	1438	<0.1	18.8	663	88	80	1	0.33	12	5269	2	
BH-91-01 Soil	04/23/87	4.69	20.	3953	-	10060	1432	19	288	0.3	500	445	55	20.8	357	23	22	1	0.27	12	2812	1	
BH-91-01 Soil	08/11/87	3	320	3966	-	5205	1623	69	308	-	-	266	141	125	16.88	280	21	20	-	-	2341	-	
BH-91-01 Soil	08/29/87	3.82	-	10000	-	-	6000	600	430	-	-	3100	1173	-	1925	21	820	59	17	-	-	8000	-
BH-91-01 Soil	10/29/87	2.78	395	9491	1.0143	14975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-01 Soil	08/17/82	a.42	321	13722	1.0260	27700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-01 Soil	08/14/88	3.44	273	18621	1.0400	48040	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-02 Soil	03/25/87	22	409	30650	-	109015	65195	4522	847	1.23	-	1wol	8282	8012	0.41	4217	279	109.1	1.25	1.3	-	03611	25.8
BH-91-02 Soil	04/23/87	2.18	417	31071	-	112595	66425	4413	538	-	55	17878	7905	9970	0.41	4335	254	18	13	1.35	95	88746	23
BH-91-02 Soil	08/11/87	2.02	417	all 22	-	-	107775	64844	3974	609	-	15899	8109	7790	0.80	4012	241	6	-	-	-	65367	-
BH-91-02 Soil	08/29/87	248	-	32000	-	-	48000	4200	810	-	-	13800	8800	K00	21	3900	250	10	-	-	-	77500	-
BH-91-02 Soil	10/29/87	2.31	392	31071	1.0634	95695	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-02 Soil	08/18/88	2.37	401	33973	1.1400	117410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-06 Soil	10/30/91	272	264	44612	1.187	191545	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-03 Soil	03/26/87	2.3	399	36830	-	-	106180	8828	645	1.59	-	21027	11887	10060	0.3	7827	405	645	8.1	2	-	108228	52.5
BH-91-03 Soil	04/23/87	2.16	417	37721	-	173180	108006	7287	872	-	78	26104	11271	13923	0.15	8727	319	5	24	1.73	66	104004	33
BH-91-03 Soil	08/11/87	2	392	a8800	-	188695	102780	7261	814	-	-	20942	9996	10348	<0.1	8732	320	1	-	-	-	100043	-
BH-91-03 Soil	08/29/87	2.22	-	40000	-	-	89000	7600	870	-	-	-1Moo	11300	8100	10	8800	340	1	-	-	-	100000	-
BH-91-03 Soil	10/29/87	2.00	404	35788	1.117	134255	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-03 Soil	08/18/88	2.37	401	36424	1.1400	180620	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-03 Soil	08/14/88	2.22	393	39028	1.143	190850	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-91-105 Soil	04/24/87	8.83	337	319	-	225	14	<1	78	-	<0.1	0.3	<0.1	0.3	8.6	18	02	5	<0.1	0.24	<0.1	63	<0.1
Mean	as	280.89	20599.79	0.46	66350.92	39146.12	8246.35	275.48	0.14	4.88	2323.72	4082.10	3643.07	6.30	2544.75	101.83	36.99	1.88	0.27	724	42492.59	4.04	
Maximum	6.83	417.00	44612.00	1.10	191545.00	108006.00	91360.00	847.00	1.59	78.00	25194.00	11887.00	13923.00	26.00	8797.00	405.00	645.00	24.00	2 m	95.00	106926.00	52.50	
Minimum	2 m	om	319.00	om	0.00	14m	om	om	om	0.00	0.30	om	0.00	om	om	om	om	om	om	om	om	63.00	om
Standard Deviation	1.34	139.30	15050.21	0.63	70720.94	42209.23	21009.17	280.30	0.41	17.10	9375.53	4675.00	4692.96	8.81	2926.36	132.53	117.33	5.03	0.55	20.99	43212.75	122.7	
Number of Samples	29	28	29	28	28	28	17	17	29	22	29	17	20	20	27	20	22	29	22	29	29	17	29

Seepage		lab	Acidity mg/l	Al mg/l	Ca mg/l	Cd mg/l	Cl mg/l	Cond μS	Cu mg/l	Fetot mg/l	Fe ++ mg/l	Fe +++ mg/l	K mg/l	TDS mg/l	Mg mg/l	Mn tot mg/l	Na mg/l
Station 510	01/21/87	2	47500	nd	451	0.12	55	28000	51	17400	6000	11400	36	11800	3200	221	5.4
Station 510	01/23/87	2	50000	nd	473	0.12	55	26000	50	8400	6000	2400	29	98000	1600	225	5.4
Station 510	01/29/87	2	50000	nd	450	0.03	55	33000	50	14900	5200	9700	31	98000	3000	188	5.4
Station 510	02/04/87	2	53700	nd	487	0.05		42000	50	12600	7200	5400	36	1E+05	3400	219	8
Station 510	02/12/87	2	58700	nd	491	0.05		30000	59	18700	6900	11800	49	1E+05	3400	263	8.5
Station 510	02/20/87	2	60000	4300	410	0.05		34000	49	11100	7000	4100	49	1E+05	1800	259	8.3
Station 510	02/25/87	2	53750	4300	509	0.05		29000	51	9300	6800	2500	47	1E+05	3400	245	7.4
Station 510	03/04/87	2	57500	4200	480	0.05		32000	54	20000	5900	14000	49	1E+05	3400	252	6.9
Station 510	03/10/87	1	61859	4264	643	1.29		27928	na	16877	6110	10767	0.26	1E+05	3686	268	1.27
Station 510	03/17/87	1	53365	3886	616	1.27		27927	na	16816	5706	11110	0.21	1E+05	3585	242	1.04
Station 510	03/24/87	1	61957	4074	618	1.31		28532	na	17715	6413	11302	0.15	1E+05	3737	249	0.95
Station 510	04/01/87	1	54396	3062	567	1.18		25026	na	15524	4646	10878	0.15	91610	2878	186	1.17
Station 510	04/08/87	1	34923	1979	386	na		19525	30	10582	2346	8236	0.12	58700	1938	120	599
Station 510	04/14/87	1	43360	2507	419	na		23370	38	12240	4182	8058	0.15	70995	2448	152	510
Station 510	04/21/87	1	42183	2507	379	na		23358	39	11233	4284	6949	0.15	69605	2652	144	510
Station 510	04/28/87	1	51649	2996	444	na		27082	44	13693	4539	9154	0.12	82255	2881	173	382
Station 510	05/06/87	1	52238	3195	519			27686		13974	3009	10965	<0.1	86455	3009	186	5
Station 510	05/12/87	1	62784	3731	590			30709		16474	3927	12546	<0.1	1E+05	3621	218	7
Station 510	05/19/87	1	61803	3609	598			30830		16537	3672	12865	<0.1	1E+05	3595	222	5
Station 510	05/26/87	1	63274	3550	584			31192		16294	4182	12112	0.22	1E+05	3595	222	3
Station 510	06/02/87	1	59105	3430	572			30466		15988	4182	11806	<0.1	99335	3468	212	6
Station 510	06/09/87	1	65236	3852	617			31313		17302	3723	13579	<0.1	1E+05	3825	234	2
Station 510	06/15/87	1	61312	3550	584			31434		16473	4794	11679	0.19	1E+05	3799	231	5
Station 510	07/02/87	2	50250	3450				39950		14500							
Station 510	07/09/87	2	52500	3400	470			29500		14000	4200	9800		1E+05	3100	200	
Station 510	07/15/87	2						42500						1E+05			
Station 510	07/22/87	2						42500						1E+05			
Station 510	07/29/87	2						32000						2E+05			
Station 510	08/06/87	2						37000						23700			
Station 510	08/13/87	2		3720	590			23000		15200	5000	10200		93600	3400	220	
Station 510	08/20/87	2						28000						1E+05			
Station 510	08/26/87	2						30000						1E+05			
Station 510	09/03/87	2						47000						97000			
Station 510	09/10/87	2	50000		650			43000			5000	12600		98200	3800	250	
Station 510	09/17/87	2						43500						88000			
Station 510	09/24/87	2						39000						93000			
Station 510	10/06/87	2						35000						78600			
Station 510	10/15/87	2						36000						89900			
Station 510	10/22/87	2	25000		560			30000			4800	9200		1E+05	3100	210	
Station 510	10/28/87	2						49000						83400			
Station 510	11/06/87	2			520			34000			4800	9900		93300	3100	220	
Station 510	11/12/87	2						35000						94900			
Station 510	11/18/87	2						37000						90800			
Station 510	11/25/87	2						35000						86900			
Station 510	12/03/87	2						32000						65100			
Station 510	12/10/87	2						28000						98100			

Seepage

		lab	Acidity mg/l	Al mg/l	Ca mg/l	Cd mg/l	Cl mg/l	Cond μS	Cu mg/l	Fetot mg/l	Fe ++ mg/l	Fe +++ mg/l	K mg/l	TDS mg/l	Mg mg/l	Mntot mg/l	Na mg/l
Station 510	12/17/87	2						43000						95400			
Station 510	12/23/87	2						44000						1E+05			
Station 510	12/29/87	2						38000						98200			
Station 510	01/07/88	2						48000						1E+05			
Station 510	01/14/88	2						42000						1E+05			
Station 510	01/29/88	2						39000						1E+05			
Station 510	gelé/frozen																
Station 510	03/30/88	2						31000						1E+05			
Station 510	04/07/88	2						23000						91000			
Station 510	04/13/88	2						33000						1E+05			
Station 510	04/21/88	2						17000						22000			
Station 510	04/29/88	2						52000						87000			
Station 510	05/06/88	2						24000						91000			
Station 510	05/12/88	2						20000						54000			
Station 510	05/20/88	2						40000						98000			
Station 510	05/26/88	2						37000						1E+05			
Station 510	06/02/88								13700					1E+05			
Station 510	06/10/88								13100					1E+05			
Station 510	06/16/88	2							15300					1E+05			
Station 510	06/22/88	2							14200					1E+05			
Station 510	06/29/88	2							15800					1E+05			
Station 510	07/06/88	2							15400					92000			
Station 510	07/15/88	2							15600					1E+05			
Station 510	07/20/88	2							14400					1E+05			
Station 510	07/27/88	2							14100					1E+05			
Station 510	08/03/88	2							14700					1E+05			
Station 510	08/11/88	2							14400					1E+05			
Station 510	08/18/88	2							16400					1E+05			
Station 510	08/24/88	2							15100					1E+05			
Station 510	08/31/88	2							13500					91700			
Station 510	09/07/88	2							13900					95000			
Station 510	09/14/88								13300					95700			
Station 510	09/23/88								14100					1E+05			
Station 510	09/28/88								12700					81000			
Station 510	10/07/88								15100					1E+05			
Station 510	10/13/88								14000					92000			
Station 510	10/19/88								13400					96000			
Station 510	10/25/88								14000					92000			
Station 510	11/04/88	2							12500					93000			
Station 510	11/09/88	2							15000					98000			
Station 510	11/16/88	2							14200					86000			
Station 510	11/23/88	2							14100					96600			
Station 510	11/30/88	2							15700					1E+05			
Station 510	12/07/88								17000					1E+05			
Station 510	12/14/88								15900					1E+05			
Station 510	12/21/88								16300					1E+05			

Seepages

		lab	Acidity mg/l	Al mg/l	Ca mg/l	Cd mg/l	Cl mg/l	Cond μS	Cu mg/l	Fetot mg/l	Fe ++ mg/l	Fe +++ mg/l	K mg/l	TDS mg/l	Mg mg/l	Mntot mg/l	Na mg/l
Station 510	12/29/88								15900					1E+05			
Station 511	01/21/87	2	58750		373	0.09	55	27000	57	16600	1700	14900	33	1E+05	3100	255	6.9
Station 511	01/23/87	2	60000		389	0.08	55	27000	63	17800	1800	16000	35	1E+05	3400	282	6
Station 511	01/29/87	2	57500		388	0.08	55	34000	61	16200	1400	14800	37	11800	4000	274	6.3
Station 511	02/04/87	2	53800		400	0.05		34000	48	8000	1680	6320	43	1E+05	2900	205	8.8
Station 511	02/12/87	2	62750		406	0.05		29000	60	18000	1860	16000	40	1E+05	4200	254	8.5
Station 511	02/20/87	2	60000	5700	464	0.05		28300	53	9700	2000	9700	47	1E+05	2400	275	8.3
Station 511	03/25/87	2	65000	5200	399	0.05		29000	58	8700	1800	6900	62	1E+05	3700	267	8
Station 511	03/04/87	2	57500	4800	390	0.05		31000	56	15000	1780	13000	56	1E+05	2900	247	7.7
Station 511	03/10/87	1	61269	4222	532	1.16		25994	na	14605	1767	12838	0.62	1E+05	3964	235	17.2
Station 511	03/17/87	1	53365	4032	489	1.01		22971	na	12665	909	11756	0.3	89790	3131	186	108.1
Station 511	03/24/87	1	60484	4328	506	1.17		25631	na	15211	1666	13545	0.26	1E+05	3611	195	91.9
Station 511	04/01/87	1	51549	3438	523	1.01		22971	na	13130	1313	11817	0.62	88565	2979	166	107.1
Station 511	04/08/87	1	19620	1030	266	na		11304	14	5087	21	5066	0.45	31385	1045	48	4
Station 511	04/14/87	1	14617	802	208	na		9333	10	3519	52	3467	0.71	22870	714	39	11
Station 511	04/21/87	1	15941	882	186	na		9636	14	3876	135	3741	0.66	24250	765	42	6
Station 511	04/28/87	1	21484	1346	215	na		12876	19	4883	304	4579	0.66	34180	1479	61	16
Station 511	05/06/87	1	28057	1768	334			16370		6222	48	6174	<0.1	46700	1708	97	4
Station 511	05/12/87	1	37278	2346	391			19537		8109	82	8027	<0.1	58825	2142	129	6
Station 511	05/19/87	1	40711	2736	417			21037		8938	156	8782	<0.1	68145	2448	145	4
Station 511	05/26/87	1	38847	2624	412			21061		8428	158	8270	0.32	64445	2320	152	8
Station 511	06/02/87	1	29920	1994	324			17216		6069	95	5974	0.27	48755	1887	111	6
Station 511	06/09/87	1	55181	3790	454			26719		11628	360	11268	0.22	89685	3493	200	4
Station 511	06/15/87	1	52729	3550	433			26598		10837	476	10361	0.32	87785	3442	191	3
Station 511	07/02/87	2	60000							14200							
Station 511	07/09/87	2	52500	4000	470			26500		11300	1520	9780		98900	3200	200	
Station 511	07/15/87	2						38500						1E+05			
Station 511	07/22/87	2						40500						2E+05			
Station 511	07/29/87	2						31000						3E+05			
Station 511	08/06/87	2						37000						28000			
Station 511	08/13/87	na															
Station 511	08/20/87	2						30000						1E+05			
Station 511	08/26/87	2						30000						1E+05			
Station 511	09/03/87	2						41000						91500			
Station 511	09/10/87	2	43000		460			38000		10400	6060	4340		92900	3100	190	
Station 511	09/17/87	2						37000						80100			
Station 511	09/24/87	2						26000						53600			
Station 511	10/06/87	2						25000						56400			
Station 511	10/15/87	2						23000						53500			
Station 511	10/22/87	2	15000	2500	380			27000		7200	600	6600		65400	2000	140	
Station 511	10/28/87	2						24000						34200			
Station 511	11/06/87	2			320			20000			540	6360		49400	1700	110	
Station 511	11/12/87	2						22000						55900			
Station 511	11/18/87	2						22000						51400			
Station 511	11/25/87	2						19000						40600			
Station 511	12/03/87	2						22000						41000			

Seepages

		lab	Acidity mg/l	Al mg/l	Ca mg/l	Cd mg/l	Cl mg/l	Cond μS	Cu mg/l	Fe tot mg/l	Fe ++ mg/l	Fe +++ mg/l	K mg/l	TDS mg/l	Mg mg/l	Mn tot mg/l	Na mg/l
Station 511	12/10/87	2						20000						66900			
Station 511	12/17/87	2						30000						61100			
Station 511	12/23/87	2						35000						86000			
Station 511	12/29/87	2						34000						1E+05			
Station 511	01/07/88	gelé/frozen															
Station 511	01/14/88	gelé/frozen															
Station 511	01/29/88	2						39000						1E+05			
Station 511		gelé/frozen															
Station 511	03/30/88	2						23000						93000			
Station 511	04/07/88	2						23000						92000			
Station 511	04/13/88	2						22000						74000			
Station 511	04/21/88	2						5800						11000			
Station 511	04/29/88	2						26000						36000			
Station 511	05/06/88	2						13000						38000			
Station 511	05/12/88	2						7800						17000			
Station 511	05/20/88	2						21000						43000			
Station 511	05/26/88	2						26000						73000			
Station 511	06/02/88	2							7810					90000			
Station 511	06/10/88	2							7050					64000			
Station 511	06/16/88	2							11400					93000			
Station 511	06/22/88	2							5660					50000			
Station 511	06/29/88	2							9900					82000			
Station 511	07/06/88	2							5830					49000			
Station 511	07/15/88	2							12500					96000			
Station 511	07/20/88	2							9840					85000			
Station 511	07/27/88	2							10700					96000			
Station 511	08/03/88	2							9540					92000			
Station 511	08/11/88	2							12700					1E+05			
Station 511	08/18/88	2							15000					1E+05			
Station 511	08/24/88	2							11400					1E+05			
Station 511	08/31/88	2							8220					69700			
Station 511	09/07/88	2							10600					88000			
Station 511	09/14/88								8000					79200			
Station 511	09/23/88								9160					76000			
Station 511	09/28/88								6030					48000			
Station 511	10/07/88								9950					80000			
Station 511	10/13/88								7179					57000			
Station 511	10/19/88								6250					49000			
Station 511	10/25/88								8090					65000			
Station 511	11/04/88	2							5400					50000			
Station 511	11/09/88	2							7520					58000			
Station 511	11/16/88	2							7970					61000			
Station 511	11/23/88	2							7780					60300			
Station 511	11/30/88	2							10900					83000			
Station 511	12/07/88								10300					69000			
Station 511	12/14/88								11300					93000			

Seepages

		lab	Acidii mg/l	Al mg/l	Ca mg/l	Cd mg/l	Cl mg/l	Cond µS	Cu mg/l	Fetot mg/l	Fe ++ mg/l	Fe +++ mg/l	K mg/l	TDS mg/l	Mg mg/l	Mn tot mg/l	Na mg/l
Station 511	12/21/88									13000				93000			
Station 511	12/29/88									14400				1E+05			
Station 512	04/08/87	1	19963	949	361	na	11473	15	6413	99	6314	0.12	33960	841	54	6	
Station 512	04/14/87	1	14617	571	257	na	8862	9	4067	110	3957	0.25	22685	135	34	11	
Station 512	04/21/87	1	14224	716	263	na	9575	10	4220	149	4071	0.15	24615	714	38	5	
Station 512	04/28/87	1	16284	682	247	na	10567	12	4768	162	4606	0.15	27035	637	42	5	
Station 512	05/06/87	1	17756	733	366		10301		4845	32	4813	<0.1	27680	688	46	11	
Station 512	05/12/87	1	14224	615	409		9612		3799	28	3771	<0.1	23500	586	40	21	
Station 512	05/19/87	1	17658	766	4121		11679		4539	38	4501	0.14	28760	663	47	15	
Station 512	05/26/87	1	31147	1379	456		16092		8479	55	8424	<0.1	49470	1122	74	4	
Station 512	06/02/87	1	18639	813	306		11522		4692	39	4653	0.14	28785	688	48	7	
Station 512	06/09/87	1	33746	1546	479		15862		8759	115	8644	<0.1	53750	1198	81	3	
Station 512	06/15/87	1	15451	681	349		9660		4003	128	3875	0.22	24535	535	42	7	
Station 512	07/02/87	2	28750	1430			25500		7980								
Station 512	07/09/87	2	20000	1100	410		13000		5600	244	5360		57000	780	58		
Station 512	07/15/87	2					39500						35900				
Station 512	07/22/87	2					22500						59400				
Station 512	07/29/87	2					16000						1E+05				
Station 512	08/06/87	2					18000						7050				
Station 512	08/13/87	2			420		30000		7200	164	7000		44500	890	65		
Station 512	08/20/87	2					14000						46140				
Station 512	08/27/87	2					15000						48500				
Station 512	09/03/87	2					21000						38400				
Station 512	09/10/87	2	9500		310		13000		3500	2100	1400		20200	410	35		
Station 512	09/17/87	2					17000						27000				
Station 512	09/24/87	2					18000						37400				
Station 512	10/06/87	2					15000						31200				
Station 512	10/15/87	2					24000						36500				
Station 512	10/22/87	2			400		20000		6400	200	6200		45000	790	61		
Station 512	10/28/87	2					20000						27000				
Station 512	11/06/87	2			380		19000		6900	160	6740		38800	760	60		
Station 512	11/12/87	2					17000						48900				
Station 512	11/18/87	2					18000						41200				
Station 512	11/25/87	2					13000						29700				
Station 512	12/03/87	non-d	sponible														
Station 512	12/10/87	2					15000						48100				
Station 512	12/17/87	2					21000						44700				

Mean	43193.5	2435	437.1	0.289	55	26531	31.22	11443	2459	8587	12.06	80080	2417	162.7	46.41
Maximum	65236	5700	650	1.31	55	52000	63	20000	7200	16000	62	3E+05	4200	282	599
Minimum	9500	0	186	0	55	5800	0	3500	21	1400	0	7050	135	34	0.95
Standard Deviation	17535.6	1547	107.8	0.477	0	9903	23.43	4178	2359	3637	19.58	35478	1184	81.04	128.2
Number of Readings	68	59	71	36	6	152	36	132	71	71	57	212	71	71	57

Seepages

		Ni	Pb	Si	SO4 =	Zn	pH	Eh
		mg/l	mg/l	mg/l	mg/l	mg/l		mV
Station 510	01/21/87	9.1	0.5		77500	25	2.24	
Station 510	01/23/87	8.4	0.5		55000	26	2.2	
Station 510	01/29/87	8.2	0.5		58000	24	2.34	
Station 510	02/04/87	8.9	0.05		71250	24	2.21	
Station 510	02/12/87	11	0.5		85000	27	2.14	
Station 510	02/20/87	9.2	4.1		75000	23	2.14	
Station 510	02/25/87	10	1.3		75000	25	2.15	
Station 510	03/04/87	11	1.9		85000	25	2.15	
Station 510	03/10/87	11.6	1.2	na	61556	27.1	2.13	434
Station 510	03/17/87	12	1.1	na	60696	25	2.14	435
Station 510	03/24/87	12.4	1.2	na	62939	26.5	2.1	435
Station 510	04/01/87	10.1	1.1	na	53462	19.4	2.02	441
Station 510	04/08/87	6	0.76	51	34097	13	2.29	451
Station 510	04/14/87	8	0.89	58	39730	18	2.33	429
Station 510	04/21/87	8	0.8	56	41347	16	2.35	435
Station 510	04/28/87	9	0.93	63	48627	19	2.26	435
Station 510	05/06/87				49051		2.33	424
Station 510	05/12/87				58886		2.33	422
Station 510	05/19/87				62918		2.35	421
Station 510	05/26/87				59997		2.38	421
Station 510	06/02/87				56170		2.37	420
Station 510	06/09/87				63577		2.37	423
Station 510	06/15/87				56540		2.37	417
Station 510	07/02/87				72500		2.21	
Station 510	07/09/87						2.24	
Station 510	07/15/87						2.27	
Station 510	07/22/87						2.16	
Station 510	07/29/87						2.16	
Station 510	08/06/87						2.13	
Station 510	08/13/87				60000		2.23	
Station 510	08/20/87						2.27	
Station 510	08/26/87						2.19	
Station 510	09/03/87						2.22	
Station 510	09/10/87				58000		2.26	
Station 510	09/17/87						2.25	
Station 510	09/24/87						2.24	
Station 510	10/06/87						2.24	
Station 510	10/15/87						2.21	
Station 510	10/22/87				58000		2.23	
Station 510	10/28/87						2.41	
Station 510	11/06/87				55000		2.17	
Station 510	11/12/87						2.28	
Station 510	11/18/87						2.2	
Station 510	11/25/87						2.34	
Station 510	12/03/87						2.29	
Station 510	12/10/87						2.32	

Seepages

		Ni mg/l	Pb mg/l	Si mg/l	SO4 = mg/l	Zn mg/l	pH	Eh mV
Station 510	12/17/87						2.35	
Station 510	12/23/87						2.26	
Station 510	12/29/87						2.16	
Station 510	01/07/88						na	
Station 510	01/14/88						2.44	
Station 510	01/29/88						2.23	
Station 510	gelé/froze							
Station 510	03/30/88						2.34	
Station 510	04/07/88						2.2	
Station 510	04/13/88						2.2	
Station 510	04/21/88						2.7	
Station 510	04/29/88						2.2	
Station 510	05/06/88						2.2	
Station 510	05/12/88						2.4	
Station 510	05/20/88						2.2	
Station 510	05/26/88						2.2	
Station 510	06/02/88							
Station 510	06/10/88							
Station 510	06/16/88							
Station 510	06/22/88							
Station 510	06/29/88							
Station 510	07/06/88							
Station 510	07/15/88							
Station 510	07/20/88							
Station 510	07/27/88							
Station 510	08/03/88							
Station 510	08/11/88							
Station 510	08/18/88							
Station 510	08/24/88							
Station 510	08/31/88							
Station 510	09/07/88							
Station 510	09/14/88							
Station 510	09/23/88							
Station 510	09/28/88							
Station 510	10/07/88							
Station 510	10/13/88							
Station 510	10/19/88							
Station 510	10/25/88							
Station 510	11/04/88							
Station 510	11/09/88							
Station 510	11/16/88							
Station 510	11/23/88							
Station 510	11/30/88							
Station 510	12/07/88							
Station 510	12/14/88							
Station 510	12/21/88							

Seepages

		Ni	Pb	Si	SO4 =	Zn	pH	Eh
		mg/l	mg/l	mg/l	mg/l	mg/l		mV
Station 511	12/10/87						2.49	
Station 511	12/17/87						2.3	
Station 511	12/23/87						2.38	
Station 511	12/29/87						2.23	
Station 511	01/07/88							
Station 511	01/14/88							
Station 511	01/29/88						2.3	
Station 511								
Station 511	03/30/88						2.46	
Station 511	04/07/88						2.15	
Station 511	04/13/88						2.2	
Station 511	04/21/88						2.7	
Station 511	04/29/88						2.1	
Station 511	05/06/88						2.4	
Station 511	05/12/88						2.7	
Station 511	05/20/88						2.4	
Station 511	05/26/88						2.3	
Station 511	06/02/88							
Station 511	06/10/88							
Station 511	06/16/88							
Station 511	06/22/88							
Station 511	06/29/88							
Station 511	07/06/88							
Station 511	07/15/88							
Station 511	07/20/88							
Station 511	07/27/88							
Station 511	08/03/88							
Station 511	08/11/88							
Station 511	08/18/88							
Station 511	08/24/88							
Station 511	08/31/88							
Station 511	09/07/88							
Station 511	09/14/88							
Station 511	09/23/88							
Station 511	09/28/88							
Station 511	10/07/88							
Station 511	10/13/88							
Station 511	10/19/88							
Station 511	10/25/88							
Station 511	11/04/88							
Station 511	11/09/88							
Station 511	11/16/88							
Station 511	11/23/88							
Station 511	11/30/88							
Station 511	12/07/88							
Station 511	12/14/88							

Seepages

		Ni	Pb	Si	SO4 =	Zn	pH	Eh
		mg/l	mg/l	mg/l	mg/l	mg/l		mV
Station 511	12/21/88							
Station 511	12/29/88							
Station 512	04/08/87	3	0.48	33	15917	6	2.31	520
Station 512	04/14/87	2	0.45	28	9654	4	2.39	514
Station 512	04/21/87	2	0.45	30	7564	5	2.39	506
Station 512	04/28/87	3	0.45	31	9938	5	2.22	511
Station 512	05/06/87				15719		2.41	652
Station 512	05/12/87				12345		2.4	675
Station 512	05/19/87				16336		2.42	645
Station 512	05/26/87				28928		2.32	658
Station 512	06/02/87				16336		2.41	653
Station 512	06/09/87				31356		2.27	569
Station 512	06/15/87				13291		2.39	601
Station 512	07/02/87				31000		2.13	
Station 512	07/09/87				26500		2.22	
Station 512	07/15/87						2.22	
Station 512	07/22/87						2.04	
Station 512	07/29/87						2.09	
Station 512	08/06/87						2.05	
Station 512	08/13/87				31000		2.11	
Station 512	08/20/87						2.22	
Station 512	08/27/87						2.1	
Station 512	09/03/87						2.12	
Station 512	09/10/87				13250		2.31	
Station 512	09/17/87						2.12	
Station 512	09/24/87						2.12	
Station 512	10/06/87						2.1	
Station 512	10/15/87						2.13	
Station 512	10/22/87				26500		2.18	
Station 512	10/28/87						2.39	
Station 512	11/06/87				28000		2.08	
Station 512	11/12/87						2.14	
Station 512	11/18/87						2.24	
Station 512	11/25/87						2.39	
Station 512	12/03/87							
Station 512	12/10/87						2.24	
Station 512	12/17/87						2.3	

Mean	8.834	1.014	24.1	47434	18.87	2.234	507.9
Maximum	12.8	4.3	83	92500	27.1	2.7	675
Minimum	2	0.05	07564		4	0	417
Standard Deviation	3.394	0.917	21.89	23380	7.784	0.228	84.25
Number of Readings	38	38	20	73	36	153	41

APPENDIX E
RAW DATA - ESKAY

Eskay

Date	Cond umhos/cm	TDS	Hardness CaCO3	pH	TSS	Turb. NTU	Acidity CaCO3	Alkalinity CaCO3	Chloride Cl	Fluoride F	Sulphate SO4
08/21/91	395			7.64				127			30.6
09/25/91	431	370		6.21	20	26.3	143	68.1	3.2		67.2
10/05/91	681	347		7.26	7.3	7.9	239	82.5	4.8		116
12/13/91	802	690		7.34	13	26.2	297	129	4.2		163
01/01/92	630	501		7.97	211	93.4	292	259	0.7		78.8
02/22/92	784	533		7.4	11	12.2	266	169	4.2	0.05	191
02/28/92	613	441	298	6.77	4	4.5		39.8	3.1	0.04	276
03/03/92	737	567		7.35	5	4.6	309	186	3.9	0.05	186
03/16/92	1280	1020		10.3	480	381	333	315	4.1	0.08	213
03/22/92	790	597		6.98	53	142	324	160	5.1	0.06	224
03/30/92	821	763		7.17	7	10.9	374	161	5.2	0.06	239
03/31/92	803	631	396	7.18	5	1.7	82.4	82.4	2.9	0.04	338
04/06/92	787	608		7.32	6	8.95	352	177	1.5	0.06	236
04/12/92	832	625		7.29	155	204	383	160	5.8	0.06	236
04/19/92	644	390		6.82	65	62.3	239	57.7	19.7	0.06	175
04/30/92	563	430	253	6.9	11	3.5	40.8	40.8	1.5	0.04	253
05/01/92	491	393		7.07	22	23.9	178	54.3	12.5	0.06	118
05/06/92	366	293		7.02	11	36.1	134	34.4	6.9	0.07	100
05/14/92	312	190		6.23	9	27.7	117	34.9	3.8	0.05	79.9
05/22/92	295	185		6.48	13	23.2	110	30.9	2.5	0.07	81
06/01/92	366	255	158	6.3	3	3.8	19.4	19.4	0.5	0.04	155
07/01/92	280	195	120	6.38	4	2.08		18.6	<0.5	0.03	114
08/06/92				6.6	3						275
09/27/92			159	3.97	10						187
10/20/92	472			5.21	9			6.4			246
11/20/92	854	683		4.7	22		63.2	63.2			463
11/24/92			487	6.55	25						499
11/27/92			526	5.32	25						420
12/01/92			626	3.37	76						798
12/04/92			638	3.23	89						851
12/08/92			762	3.12	124						882
12/11/92			749	3.2	130						956
12/15/92			831	3.04	79						1140
12/16/92	2210	1700	915	2.86	51	1070	<1.0	<1.0	1.3	0.32	1250
12/18/92			951	2.78	17						1450
01/05/93			1130	2.93	268						1500
01/08/93			1420	2.64	490						2540
03/29/94	9860	7300	5970	2.5	250	2.5	6880	<1.0	2.1	0.13	9520
04/12/94	10200	8360	2860	2.69	357	2.69	2970	<1.0	3	0.1	5580
04/26/94	4000	3540	1660	2.5	166	2.5	2480	<1	2.5	0.07	3170
05/10/94	5570	5010	2450	2.27	60	2.27	2960	<1.0	2.3	0.1	4740
05/24/94	4920	4420	1690	2.75	48	2.75	1910	<1.0	1.5	0.11	4000
06/26/94	5650	5460	2020	2.86	87	2.86	1300	<1.0	1.8	0.07	3580
07/26/94	7430	6100	1490	2.97	67	2.97	1750	<1.0	4.5	0.11	4320
08/16/94	3480	2260	2280	2.64	7	2.64	863	<1.0	2.4	0.9	2330
08/30/94	481	367	206	4.78	54	4.78	29.9	1.4	0.6	0.08	231
09/20/94	10600	8380	1410	1.89	153	1.89	3240	<1.0	2.5	0.18	4980
09/30/94	152	99	63.8	5.47	8	5.47	7.1	4.4	<0.5	0.03	58.4
02/28/95	77000	61200	61.9	13.9	766	13.9	<1.0	56400	67	0.4	945
03/29/95	1730	1670	606	3.6	216	3.6	251	<1.0	3.1	0.61	1040
05/31/95	1600	1110	805	5.31	49000	5.31	132	11.9	7.2	0.07	1050
06/30/95	715	526	346	4.55	23	4.55	16.3	1.5	4.6	0.08	366

Max	77000	61200	5970	13.9	49000	1070	666	56400	67	0.9	9520
Min	152	99	61.9	1.89	3	1.7	0	0	0	0.03	30.6
Avg	4015.7	3373.9	1073.1	5.3	1054.6	60.5	607.9	1472.4	5.5	0.1	1212.3
Count	40	36	32	52	51	37	36	40	37	33	52

Eskay

Date	Ammonia	Nitrate	Nitrite	0-Phos	T. Diss. P	T. Phos.	TCN	Total Metals			
	N	N	N	P	P	Al		Sb	As	Be	
08/21/91								7.9	0.048	0.016	<.005
09/25/91	1.28	16.4	1.56	0.03	0.044	0.072		1.43	0.049	0.0024	<.005
10/05/91	3.27	36.4	1.05	0.015	0.026	0.031	0.02	0.24	0.071	0.0012	<.005
12/13/91	3.14	29.8	0.97	0.001	0.007	0.021	0.022	0.22	0.057	0.0013	<.005
01/01/92	1.64	7.6	0.44	0.01	0.013	0.27	0.001	3.36	0.42	0.02	<.005
02/22/92	2.61	14.6	0.16	0.008	0.008	0.66	0.011	0.176	0.028	0.0005	<.005
02/28/92	1.38	2.83	0.002	0.008	0.004	0.025	0.003	0.25	0.0001	0.0007	<.005
03/03/92	2.07	13.2	0.23	0.005	0.013	0.014	0.007	0.113	0.029	0.0005	<.005
03/16/92	1.82	12.8	0.12	0.003	0.035	0.171	0.14	1.36	0.034	0.012	<.005
03/22/92	2.16	12.2	0.34	0.015	0.019	0.109	0.02	0.78	0.047	0.0078	<.005
03/30/92	2.22	14.1	0.057	0.003	0.011	0.02	0.019	0.022	0.033	0.0015	<.005
03/31/92	0.53	4.26	0.034	0.005	0.008	0.009	0.004	0.1	0.0108	0.0004	<.005
04/06/92	0.167	11.9	0.062	0.006	0.012	0.02	0.013	0.23	0.0085	0.0007	<.005
04/12/92	2.33	16	0.077	0.024	0.065	0.1	0.028	0.824	0.058	0.011	<.005
04/19/92	2.76	13.8	0.119	0.01	0.06	0.205	0.017	1.02	0.032	0.0031	<.005
04/30/92	0.976	2.43	0.012	0.003	0.006	0.018	0.003	0.52	0.012	0.0009	<.005
05/01/92	3.17	11.9	0.18	0.045	0.14	0.18	0.013	0.591	0.0268	0.001	<.005
05/06/92	2.13	10.7	0.189	0.051	0.07	0.07	0.005	0.841	0.017	0.0018	<.005
05/14/92	2.47	8.45	0.11	0.019	0.036	0.105	0.007	2.29	0.0136	0.2	<.005
05/22/92	1.76	7.38	0.093	0.036	0.046	0.11	0.003	0.69	0.026	0.2	<.005
06/01/92	<0.005	1.1	<0.001	0.005	0.007	0.013	0.005	0.5	0.0147	0.001	<.005
07/01/92	0.62	1.12	<0.001	0.003	0.006	0.007	<0.001	0.185	0.0117	0.0004	<.005
08/06/92					<0.30	<0.30		<0.20	0.0082	0.0005	<.005
09/27/92					<0.30	<0.30		1.39	0.0045		<.005
10/20/92					<0.30	<0.30		1.23	0.0081	0.0474	<.005
11/20/92					<0.30	<0.30		2.96	0.0081		<.005
11/24/92					<0.30	<0.30		3.24	0.0074	0.168	<.005
11/27/92					<0.30	<0.30		3.4	0.0069	0.133	<.005
12/01/92					<0.30	<0.30		9.9	0.0158	1.02	<.005
12/04/92					<0.30	0.36		10.2	0.0181	1.49	<.005
12/08/92					0.3	0.55		14	0.0197	1.71	<.005
12/11/92					0.34	0.56		12.9	0.0211	2.03	<.005
12/15/92					0.4	0.65		19.9	0.0245	2.44	<.005
12/16/92	0.68	2.22	0.015	0.038	0.037	3.01		28.8	0.0478	3.63	0.005
12/18/92					1.46	1.78		31.8	0.0793	5.07	0.006
01/05/93						1.79		33.5	0.0612	4.18	0.006
01/08/93						6.79		63	0.429	20.6	0.01
03/29/94	1.76	<1.00						386	0.059	36.8	
04/12/94	1.24	0.488						84.1	0.0616	13.4	
04/26/94	0.41	0.007						102	0.03	24.7	
05/10/94	0.618	0.536						129	0.018	13.4	
05/24/94	0.8	<0.125						107	0.0027	2.57	
06/26/94	1.15	0.097						47	0.0037	0.266	
07/26/94	0.845	0.242						34.3	0.0013	0.058	
08/16/94	1.37	0.029						68.8	0.0098	0.84	
08/30/94	0.16	1.16						2.13	0.0273	0.0169	
09/20/94	0.625	0.355						116	0.046	13.8	
09/30/94	0.027	0.157						0.373	0.0058	0.0188	
02/28/95	0.91	0.131						2.75	0.329	0.0965	
03/29/95	0.728	0.291						27.9	0.0364	0.544	
05/31/95	2.23	0.026						158	3.89	18.3	
06/30/95	0.26	0.147						1.3	0.0175	0.0143	

Max	3.27	36.4	1.56	0.051	1.46	6.79	0.14	366	3.69	36.6	0.01
Min	0	0	0	0.001	0	0	0	0	0.0001	0.0004	0
Avg	1.4	6.9	0.3	0.0	0.1	0.5	0.0	29.4	0.1	3.4	0.0
Count	37	37	22	22	34	36	20	52	52	50	37

Eskay

Date	Total Metals										
	Bi	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn
08/21/91	<.1	0.1	0.0004	48.8	0.011	0.007	0.013	9.5	0.07	12.1	2.74
09/25/91	<.1	<.1	0.0002	37.7	0.002	0.002	0.003	1.47	0.037	11.8	0.856
10/05/91	<.1	<.1	0.0012	54.2	0.001	0.002	0.007	0.59	0.041	43.2	0.749
12/13/91	<.1	<.1	0.0002	66.1	0.001	0.002	0.001	1.69	0.003	33	2.08
01/01/92	<.1	0.1	0.0002	58.8	0.002	0.001	0.008	0.635	0.104	37.2	0.332
02/22/92	0.1	0.1	0.0002	61.6	0.001	0.002	0.002	0.72	0.001	26.7	1.82
02/28/92	0.1	0.1	0.001	58.8	<0.001	0.003	0.002	0.307	0.009	37.3	1.05
03/03/92	0.1	0.1	0.0002	71.4	0.001	0.004	0.001	0.67	0.001	31.2	2.45
03/16/92	0.1	0.1	0.0015	78	0.007	0.004	0.018	9.07	0.07	36.2	2.58
03/22/92	0.1	0.1	0.0013	86.5	0.006	0.003	0.006	20	0.042	30.3	2.29
03/30/92	0.1	0.1	0.0002	108	0.001	0.003	0.001	1.1	0.004	38.7	2.33
03/31/92	<0.10	<0.10	0.0007	80.6	<0.001	<0.001	0.002	0.107	0.001	47.3	0.431
04/06/92	<.1	<.1	0.0002	91.7	0.001	0.001	0.003	0.999	0.008	32	1.94
04/12/92	<.1	0.1	0.0006	95.9	0.004	0.004	0.008	40	0.054	34	1.91
04/19/92	<.1	0.1	0.0004	51.7	0.003	0.002	0.006	1.12	0.039	28	0.807
04/30/92	<0.10	<0.10	0.001	48.2	<0.001	<0.001	0.008	1.29	0.011	32.4	0.776
05/01/92	<.1	0.1	0.0002	38	0.001	0.002	0.002	0.457	0.016	19.9	0.67
05/06/92	<.1	0.1	0.0003	29.9	0.001	0.001	0.001	0.19	0.014	17.4	0.483
05/14/92	<.1	<.1	0.01	24	0.015	0.015	0.01	0.401	0.05	14.1	0.432
05/22/92	<.1	<.1	0.01	22.8	0.015	0.015	0.01	0.309	0.05	12.7	0.388
06/01/92	<0.10	<0.10	<0.0002	28.3	<0.001	0.002	0.006	0.37	0.015	22.8	0.627
07/01/92	<0.10	<0.10	0.0008	23	<0.001	0.002	3	0.233	0.014	15.5	0.416
08/06/92	<0.10		<0.010	59.5	<0.015	<0.015	0.002	0.298	0.004	43.1	0.448
09/27/92	<0.10		<0.010	29	<0.015	<0.015	0.194	4.6	0.094	21.3	1.55
10/20/92	<0.10		0.017	43.2	<0.015	0.017	0.272	2.88	0.095	28.3	2.16
11/20/92	<0.10		<0.010	80.4	<0.015	0.017	0.221	10.8	0.018	60	2.39
11/24/92	0.1		0.013	87.5	<0.015	<0.015	0.216	10.2	0.015	66.2	2.52
11/27/92	<0.10		0.013	95	<0.015	<0.015	0.225	9.25	0.013	70.7	2.67
12/01/92	0.12		0.026	108	<0.015	0.051	0.759	40.1	0.02	89.8	4.48
12/04/92	0.13		0.029	107	<0.015	0.051	0.892	48	0.021	89.7	4.54
12/08/92	0.18		0.038	132	<0.015	0.073	1.22	67.2	0.02	108	5.77
12/11/92	0.16		0.031	130	<0.015	0.058	1.13	70.4	0.026	104	5.44
12/15/92	0.18		0.049	141	<0.015	0.088	1.65	97.1	0.024	123	7.2
12/16/92	0.2	<0.10	0.07	143	0.024	0.126	2.36	144	0.026		8.97
12/18/92	0.22		0.088	144	0.025	0.144	2.87	182	0.027	146	9.53
01/05/93	0.31		0.085	185		0.143	3.14	150		165	11.8
01/08/93	0.42		0.197	195		0.301	8.07	601		235	16.7
03/29/94			1.42	502		2.04	66.5	2070	0.095	1150	
04/12/94			0.406	435		0.588	16.8	701	0.03	469	
04/26/94			0.44	231		0.553	21.7	733	0.002	1.11	
05/10/94			0.604	351		0.676	32.6	1030	0.096	394	
05/24/94			0.393	350		0.495	19.8	629	0.119	270	
06/26/94			0.221	402		0.397	7.05	209	0.001	269	
07/26/94			0.142	246		0.335	4.41	304	0.02	212	
08/16/94			0.278	389		0.528	8.23	519	0.036	346	
08/30/94			0.024	50.5		0.025	0.155	8.65	0.094	19.3	
09/20/94			0.63	192		0.454	21	914	0.186	274	
09/30/94			0.0016	17.7		0.002	0.038	2.34	0.005	5.05	
02/28/95			<0.25	42		<0.001	<0.25	<0.75	1.4	<1.25	
03/29/95			0.0583	108		0.056	0.807	111	0.22	84	
05/31/95			0.245	267		0.214	10.1	845	42.5	321	
06/30/95			0.0085	99.1		0.027	0.036	9.07	0.029	25.9	
Max	0.42	0.1	1.42	502	0.025	2.04	66.5	2070	42.5	1150	16.7
Min	0	0	0	17.7	0	0	0	0	0.001	0	0.332
Avg	0.1	0.1	0.1	127.4	0.0	0.1	4.5	164.9	0.9	113.6	3.1
Count	37	23	52	52	35	52	52	52	50	51	37

Eskay

Date	Total Metals										
	Hg	Mo	Ni	Se	Si	Ag	Sr	U	V	Zn	Al
08/21/91	0.0015	0.008	0.01	0.0017	11.1	0.0017	0.363	0.00025	0.03	0.066	
09/25/91	0.00016	0.003	0.005	0.005	4.33	0.0002	0.34	0.0016	0.03	0.025	0.164
10/05/91	0.00003	0.003	0.009	0.0025	3.02	0.0013	0.79	0.00035	0.03	0.099	0.059
12/13/91	0.00005	0.004	0.004	0.0005	2.84	0.0001	0.847	0.0058	0.03	0.013	0.029
01/01/92	0.00021	0.015	0.005	0.0005	8.59	0.0006	1.1	0.0131	0.03	0.064	0.037
02/22/92	0.00108	0.003	0.002	0.0005	2.59	0.0005	0.687	0.0027	0.03	0.007	0.018
02/28/92	0.00001	0.001	0.011	0.0005	2.2	0.0001	0.701	0.00067	0.03	0.188	0.15
03/03/92	0.00001	0.004	0.002	0.0005	3.05	0.0001	0.794	0.0018	0.03	0.005	0.018
03/16/92	0.00041	0.005	0.007	0.0005	5.21	0.0011	0.931	0.0002	0.03	0.153	0.066
03/22/92	0.00001	0.006	0.005	0.0005	4.12	0.0006	0.806	0.0018	0.03	0.045	0.011
03/30/92	0.00001	0.003	0.003	0.0005	3.43	0.0001	0.992	0.0025	0.03	0.005	0.019
03/31/92		<0.001	0.005			<0.0001				0.081	0.023
04/06/92	0.00005	0.006	0.004	0.0005	3.27	0.0001	0.829	0.0029	0.03	0.009	0.017
04/12/92	0.00001	0.005	0.004	0.0005	4.32	0.001	0.892	0.0038	0.03	0.061	0.012
04/19/92	0.00005	0.004	0.005	0.0005	3.37	0.0003	0.624	0.004	0.03	0.043	0.012
04/30/92		<0.001	0.008			<0.0001				0.251	0.099
05/01/92	0.00003	0.002	0.004	0.0005	2.61	0.0001	0.455	0.0005	0.03	0.042	0.023
05/06/92	0.00004	0.001	0.004	0.0005	2.77	0.0001	0.369	0.00039	0.03	0.039	0.046
05/14/92	0.00002	0.03	0.02	0.2	5.03	0.015	0.308	0.0003	0.03	0.045	0.2
05/22/92	0.00005	0.03	0.02	0.2	2.27	0.015	0.288	0.0003	0.03	0.044	0.2
06/01/92		<0.001	0.012			<0.0001				0.245	0.26
07/01/92		<0.001	0.008			<0.0001				0.144	0.078
08/06/92		<0.030	0.02			<0.015				0.142	<0.20
09/27/92		<0.030	0.048			<0.015				2.32	1.38
10/20/92		<0.030	0.092			<0.015				3.08	0.72
11/20/92		<0.030	0.143			<0.015				1.72	2.07
11/24/92		<0.030	0.153			<0.015				1.68	1.9
11/27/92		<0.030	0.154			<0.015				1.7	1.12
12/01/92		<0.030	0.428			<0.015				3.38	9.44
12/04/92		<0.030	0.463			<0.015				3.54	9.84
12/08/92		<0.030	0.619			<0.015				4.65	14
12/11/92		<0.030	0.599			<0.015				4.26	12.8
12/15/92		<0.030	0.826			<0.015				5.98	19
12/16/92		0.002	1.13			0.0005				8.41	28.1
12/18/92		<0.030	1.28			<0.015				9.97	31.6
01/05/93						<0.015					33.5
01/08/93						0.034					61.4
03/29/94	0.00037		16			0.005				333	386
04/12/94	0.00017		4.1			0.0016				93.4	75.8
04/26/94	0.00012		4.32			0.002				93.1	5.7
05/10/94	0.00019		5.72			0.0025				122	125
05/24/94	0.00008		4.01			0.002				83.5	78.5
06/26/94	0.00005		2.59			0.0005				51.2	45.1
07/26/94	0.00005		2.03			<0.0001				44.4	34.3
08/16/94	0.00005		3.15			0.0038				66.6	65.7
08/30/94	0.00044		0.039			0.0006				4.29	0.168
09/20/94	0.00017		3.46			<0.0001				11.3	96.4
09/30/94	0.00005		0.007			<0.0001				0.425	0.06
02/28/95	0.00005		0.5			<0.37				9.75	0.103
03/29/95	0.00009		0.105			0.0006				17.6	26.5
05/31/95	0.0155		1.01			0.216				52.7	0.772
06/30/95	0.00005		0.05			<0.0001				2.93	0.31

Max	0.0155	0.03	16	0.2	11.1	0.216	1.1	0.0131	0.03	333	386
Min	0.00001	0	0.002	0.0005	2.1	0	0.288	0.0002	0.03	0.005	0
Avg	0.0	0.0	1.1	0.0	4.1	0.0	0.7	0.0	0.0	20.8	22.9
Count	33	35	50	18	1a	52	1a	1a	1a	50	51

Eskay

Date	Dissolved Metals										
	Sb	As	Ba	Be	Bi	B	Cd	Ca	Cr	Co	Cu
08/21/91							0.0004				
09/25/91	0.049	0.0013	0.128	0.005	0.1	0.1	0.0002	37.4	0.001	0.001	0.001
10/05/91	0.015	0.0009	0.078	0.005	0.1	0.1	0.0002	54.1	0.001	0.001	0.001
12/13/91	0.055	0.0004	0.21	0.005	0.1	0.1	0.0002	64.9	0.001	0.001	0.001
01/01/92	0.33	0.011	0.057	0.005	0.1	0.1	0.0002	54.2	0.001	0.001	0.001
02/22/92	0.027	0.0004	0.17	0.005	0.1	0.1	0.0002	61.5	0.001	0.002	0.002
02/28/92	0.0001	0.0003	0.063	0.005	0.1	0.1	0.0008	58.1	0.001	0.003	0.001
03/03/92	0.029	0.0005	0.2	0.005	0.1	0.1	0.0002	71.3	0.001	0.002	0.001
03/16/92	0.018	0.001	0.215	0.005	0.1	0.1	0.0015	76	0.002	0.003	0.002
03/22/92	0.047	0.0004	0.195	0.005	0.1	0.1	0.0013	86.5	0.001	0.003	0.002
03/30/92	0.0173	0.0005	0.191	0.005	0.1	0.1	0.0002	94.2	0.001	0.003	0.001
03/31/92	0.0106	0.0002			<0.10	<0.10	0.0006	80.5	<0.001	<0.001	0.002
04/06/92	0.0085	0.0004	0.17	0.005	0.1	0.1	0.0002	89.1	0.001	0.001	0.001
04/12/92	0.0179	0.0004	0.135	0.005	0.1	0.1	0.0006	95.9	0.001	0.001	0.003
04/19/92	0.032	0.0013	0.099	0.005	0.1	0.1	0.0004	51.1	0.001	0.001	0.001
04/30/92	0.011	0.0002			<0.10	<0.10	0.0004	48	<0.001	<0.001	0.002
05/01/92	0.025	0.0009	0.082	0.005	0.1	0.1	0.0002	38	0.001	0.001	0.001
05/06/92	0.017	0.0015	0.066	0.005	0.1	0.1	0.0003	26.8	0.001	0.001	0.001
05/14/92	0.0118	0.2	0.063	0.005	0.1	0.1	0.01	24	0.015	0.015	0.01
05/22/92	0.018	0.2	0.061	0.005	0.1	0.1	0.01	22.7	0.015	0.015	0.01
06/01/92	0.0147	0.0009			<0.10	<0.10	<0.0002	27	<0.001	0.002	0.005
07/01/92	0.0098	0.0004			<0.10	<0.10	0.0006	23	<0.001	0.001	0.002
08/06/92	0.0079	0.0003			<0.10		<0.010	57.5	<0.015	<0.015	0.001
09/27/92	0.0016	0.003			<0.10		<0.010	28.4	<0.015	<0.015	0.192
10/20/92	0.0051	0.0031			<0.10		<0.010	41.3	<0.015	<0.015	0.243
11/20/92	0.0021	0.0042			<0.10		<0.010	79	<0.015	0.017	0.196
11/24/92	0.0028	<0.0001			<0.10		<0.010	86.7	<0.015	<0.015	0.196
11/27/92	0.0028	0.0027			<0.10		<0.010	94.3	<0.015	<0.015	0.207
12/01/92	0.0033	0.409			0.12		0.021	106	<0.015	0.051	0.726
12/04/92	0.003	0.346			0.13		0.022	107	<0.015	0.051	0.869
12/08/92	0.0057	1.09			0.18		0.033	129	<0.015	0.073	1.21
12/11/92	0.0116	1.21			0.16		0.029	129	<0.015	0.058	1.12
12/15/92	0.0075	1.29			0.16		0.035	137	<0.015	0.08	1.58
12/16/92	0.0072	1.5			0.2	<0.10	0.057	141	0.021	0.126	2.32
12/18/92	0.02	3.86			0.22		0.084	143	0.023	0.132	2.87
01/05/93	0.041	4.13			0.28		0.085		0.026		
01/08/93	0.289	18.9			0.42		0.194		0.089		
03/29/94	0.025	19.2					1.42	502		2.04	65.9
04/12/94	0.0348	10					0.372	419		0.548	15.4
04/26/94	0.0078	17.1					0.374	201		0.466	18
05/10/94	0.0153	12.6					0.586	340		0.664	31.5
05/24/94	0.0007	2.09					0.325	311		0.41	16.6
06/26/94	0.0034	0.0017					0.197	371		0.379	6.98
07/26/94	0.0007	0.058					0.142	246		0.335	4.41
08/16/94	0.0098	0.84					0.247	376		0.513	8.23
08/30/94	0.0006	0.0006					0.0004	50.5		0.023	0.094
09/20/94	0.0049	5.36					0.502	173		0.395	17.3
09/30/94	0.0041	0.0011					0.0015	17.2		0.001	0.021
02/28/95	0.101	0.0965					<0.0002	24.8		<0.001	<0.25
03/29/95	0.0329	0.0135					0.0563	107		0.055	0.807
05/31/95	0.173	0.0356					0.143	179		0.062	0.321
06/30/95	0.015	0.0069					0.01	96.8		0.027	0.015

Max	0.33	19.2	0.215	0.005	0.42	0.1	1.42	502	0.069	2.04	65.9
Min	0.0001	0	0.057	0.005	0	0	0	17.2	0	0	0
Avg	0.0	2.0	0.1	0.0	0.1	0.1	0.1	120.0	0.0	0.1	4.0
Count	51	51	17	17	36	22	52	49	36	49	49

Eskay

Dissolved Metals											
Date	Fe	Pb	Mg	Mn	Mo	Ni	K	Se	Si	Ag	Na
08/21/91											
09/25/91	0.158	0.002	11.8	0.856	0.002	0.001	6.96	0.0005	2.39	0.0001	14.9
10/05/91	0.059	0.004	43.2	0.749	0.002	0.006	8.61	0.0005	2.63	0.0001	16.8
12/13/91	0.276	0.001	32.1	2	0.004	0.004	9.3	0.0005	2.62	0.0001	31.9
01/01/92	0.03	0.001	37.2	0.061	0.014	0.004	8.99	0.0005	3.89	0.0001	26.1
02/22/92	0.03	0.001	26.7	1.81	0.003	0.002	7.5	0.0005	2.58	0.0005	24.2
02/28/92	0.112	0.005	37	1.04	<0.001	0.011			1.97	0.0001	11
03/03/92	0.053	0.001	31.1	2.44	0.004	0.002	8.3	0.0005	3.01	0.0001	29
03/16/92	0.34	0.006	34	2.47	0.003	0.004	7.99	0.0005	3.08	0.0001	27.4
03/22/92	0.138	0.001	30	2.29	0.004	0.002	8.34	0.0005	3.04	0.0001	29.1
03/30/92	0.03	0.001	33	1.82	0.003	0.002	7.79	0.0005	2.86	0.0001	29.1
03/31/92	0.058	<0.001	47.3	0.431	<0.001	0.005					
04/06/92	0.047	0.001	30.7	1.77	0.002	0.002	7.66	0.0005	2.81	0.0001	26.8
04/12/92	0.03	0.001	34	0.292	0.003	0.001	8.25	0.0005	2.78	0.0001	27.8
04/19/92	0.03	0.002	26.2	0.478	0.004	0.004	9.63	0.0005	1.9	0.0002	30.5
04/30/92	0.117	0.002	32.4	0.541	<0.001	0.003			2.13		9.47
05/01/92	0.036	0.002	19.8	0.484	0.002	0.004	7.51	0.0005	1.83	0.0001	20.4
05/06/92	0.033	0.005	16	0.43	0.001	0.004	6.13	0.0005	1.48	0.0001	15
05/14/92	0.042	0.050	13.5	0.392	0.03	0.02	4.9	0.2	1.45	0.015	12.2
05/22/92	0.034	0.050	12.7	0.373	0.03	0.02	4.65	0.2	1.35	0.015	11.1
06/01/92	0.186	0.010	22.1	0.604	<0.001	0.012					4.45
07/01/92	0.098	0.009	15.2	0.409	<0.001	<0.001					3.03
08/06/92	0.13	0.001	38.4	0.431	<0.030	<0.020					10.9
09/27/92	2.52	0.070	21.3	1.53	<0.030	0.048					3.4
10/20/92	0.999	0.060	26.8	2.06	<0.030	0.082					4.1
11/20/92	0.78	0.005	58.7	2.33	<0.030	0.143					7.6
11/24/92	0.9	0.002	65.7	2.51	<0.030	0.153					8.5
11/27/92	1.01	0.002	70.5	2.67	<0.030	0.152					9.4
12/01/92	10.1	0.017	87.8	4.33	<0.030	0.428					10.3
12/04/92	19.9	0.017	89.7	4.44	<0.030	0.463					10.4
12/08/92	46.9	0.018	107	5.76	<0.030	0.619					12.2
12/11/92	50.7	0.019	104	5.42	<0.030	0.599					12
12/15/92	63.4	0.022	119	6.91	<0.030	0.79					13.3
12/16/92	87.2	0.026			0.001	1.1					
12/18/92	156	0.027	144	9.51	<0.030	1.27					13.4
01/05/93											16.7
01/08/93											16.6
03/29/94	1630	0.055	1150			16	20			0.0034	30
04/12/94	618	0.026	439			3.78	9.7			0.0011	18
04/26/94	579	0.069	280			3.66	2.7			0.0012	13.4
05/10/94	983	0.094	388			5.56	3.3			0.0017	12.1
05/24/94	511	0.062	223			3.33	2			0.0009	15.2
06/26/94	198	0.001	265			2.27	3.7			0.0005	27.6
07/26/94	304	0.020	212			2.03	2.7			<0.0001	101
08/16/94	376	0.036	326			3	3.7			0.0019	49.3
08/30/94	2.28	0.021	19.3			0.027	2.2			<0.0001	2
09/20/94	775	0.150	237			3	2			<0.0001	5
09/30/94	1.25	0.001	5.04			0.006	2			<0.0001	<2.0
02/28/95	<0.75	1.250	<1.25			<0.50	50			<0.37	
03/29/95	39.5	0.140	82.6								
05/31/95	7.02	3.550	87			0.189	13.3			0.0046	8.8
06/30/95	7.12	0.005	25.3			0.049	2.7			<0.0001	4.5

Max	1630	3.55	1150	9.51	0.03	16	50	0.2	3.89	0.015	101
Min	0	0	0	0.061	0	0	2	0.0005	1.35	0	0
Avg	132.1	0.1	109.5	2.1	0.0	1.0	6.1	0.0	2.4	0.0	17.6
Count	49	49	46	33	34	46	30	16	16	31	47

Eskay

Date	Dissolved Metals			
	Sr	U	V	Zn
08/21/91				
09/25/91	0.34	0.0008	0.03	0.005
10/05/91	0.786	0.0003	0.03	0.079
12/13/91	0.819	0.0044	0.03	0.012
01/01/92	1.1	0.0131	0.03	0.005
02/22/92	0.687	0.0024	0.03	0.005
02/28/92	0.69	0.00056	0.03	0.011
03/03/92	0.79	0.0013	0.03	0.005
03/16/92	0.897	0.00009	0.03	0.104
03/22/92	0.8	0.0009	0.03	0.005
03/30/92	0.85	0.0021	0.03	0.006
03/31/92				0.005
04/06/92	0.814	0.0026	0.03	0.005
04/12/92	0.875	0.0031	0.03	0.005
04/19/92	0.616	0.001	0.03	0.022
04/30/92				0.003
05/01/92	0.455	0.00015	0.03	0.037
05/06/92	0.342	0.00022	0.03	0.03
05/14/92	0.292	0.00025	0.03	0.034
05/22/92	0.288	0.0002	0.03	0.029
06/01/92				0.012
07/01/92				<0.001
08/06/92				<0.02
09/27/92				0.048
10/20/92				0.082
11/20/92				0.143
11/24/92				0.153
11/27/92				0.152
12/01/92				0.428
12/04/92				0.448
12/08/92				0.619
12/11/92				0.599
12/15/92				0.79
12/16/92				1.1
12/18/92				1.27
01/05/93				
01/08/93				
03/29/94				333
04/12/94				86.2
04/26/94				78.2
05/10/94				119
05/24/94				69.3
06/26/94				47.6
07/26/94				44.4
08/16/94				64.3
08/30/94				4.29
09/20/94				98.3
09/30/94				0.424
02/28/95				
03/29/95				
05/31/95				30.2
06/30/95				2.82

Max	1.1	0.0131	0.03	333
Min	0.288	0.00009	0.03	0
Avg	0.7	0.0	0.0	20.9
Count	17	17	17	47