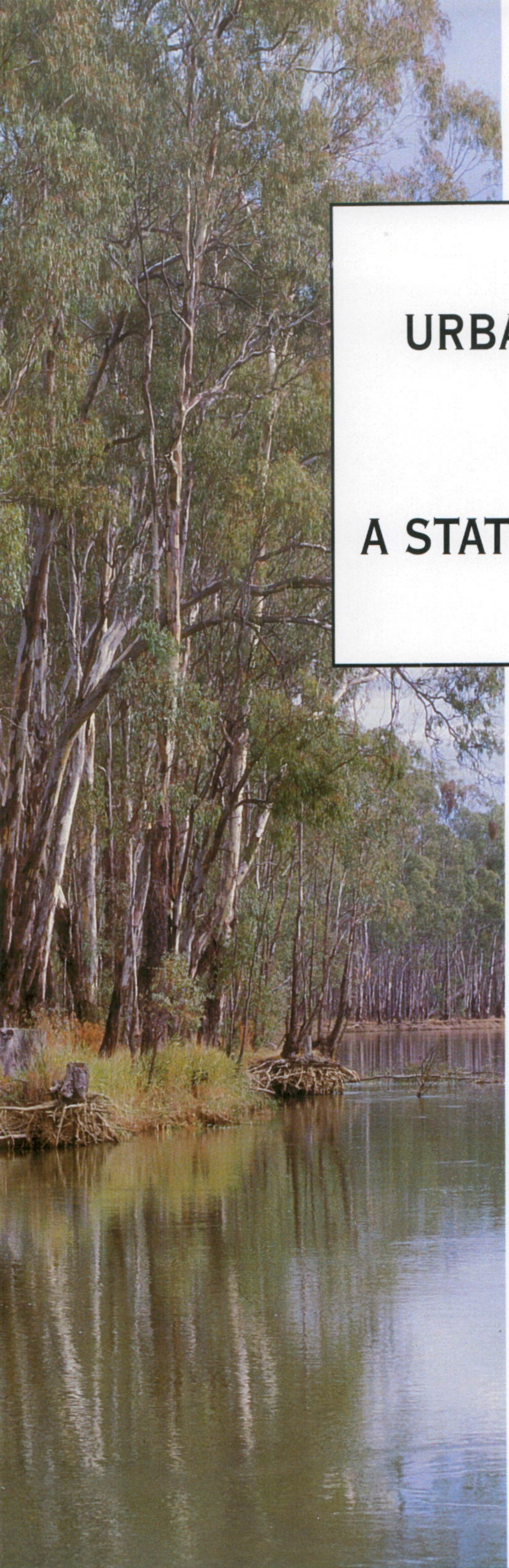

# URBAN STORMWATER QUALITY: A STATISTICAL OVERVIEW

Hugh P. Duncan

Report 99/3
February 1999

COOPERATIVE RESEARCH CENTRE FOR
CATCHMENT HYDROLOGY

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# PREFACE

The Cooperative Research Centre for Catchment Hydrology (CRCCH) commenced in July 1992. Its Urban Hydrology research program initially comprised two main projects. Project C1 investigated methods for estimating runoff and pollution loads from urban catchments over a range of time and space scales. Project C2 brought together several studies aimed at improving design and management procedures for urban waterways.

The Urban Hydrology research program was restructured in 1996 to reflect the evolving emphasis of the program. Project U1 addresses gross pollutant management and the behaviour of urban pollution control ponds, and develops the work of the old Project C2. Project U2 investigates the sources, movement, and modelling of pollutants in urban areas, and extends the work of the old Project C1.

This report was prepared for Projects C1 and U2 by Hugh Duncan, seconded to the CRCCH from Melbourne Water. It describes the analysis of stormwater quality data from over 500 Australian and overseas studies. The report summarises stormwater concentrations of 21 water quality parameters, and examines the relationships between contaminant concentrations and physical and climatic catchment characteristics.

Tom McMahon
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# ABSTRACT

This report presents a statistical overview of urban stormwater quality, obtained by analysing the results of many investigations reported in the literature. The objective is to assess the broad scale behaviour of urban runoff quality, and its interactions with land use and other catchment characteristics. A data management system that permits consistent and objective comparison between studies is described.

Information on each water quality parameter includes a brief description of the contaminant, its likely sources and possible effects, the statistical distribution of concentration data, means and standard deviations for each land use with sufficient data, and significant relationships with catchment characteristics. Correlations between water quality parameters are also investigated.

Concentrations are approximately log-normally distributed for all water quality parameters investigated except pH, which is approximately normally distributed. Concentrations of suspended solids, total nitrogen, and total phosphorus are on average highest for agricultural catchments, intermediate for urban catchments, and lowest for forested catchments. Concentrations of total lead, BOD, COD, total coliforms, fecal coliforms, and fecal streptococci are higher on average from high urban catchments than from all low urban catchments taken as a single group.

Roads are a major source of most contaminants in urban runoff. This is due to their lower elevation as well as their vehicular traffic. Concentrations from roofs are substantially lower on average than concentrations from roads and all high urban zonings, for all parameters tested except zinc. Within urban areas, residential zonings tend to produce lower concentrations of metals and organic carbon, and higher concentrations of phosphorus and microbiological measures than the other urban zonings, but the explanatory power is low.

Urban sites with higher mean annual rainfall produce lower stormwater concentrations, on average, for most metal and non-metal parameters, but not for the microbiological measures. For suspended solids, which shows the strongest effect, increasing the mean annual rainfall by 500 mm approximately halves the most likely concentration in runoff. Sites with higher population density produce higher stormwater concentrations, on average, for total nitrogen, BOD, and fecal coliforms, and perhaps for COD and total coliforms, but not for metals.

Correlations between water quality parameters over many measurement sites are often low. As a result, there are only a few cases where one quality parameter can provide a good estimate of another parameter. No single quality parameter can provide a good estimate of a range of other parameters.

The explanatory power of all normally reported catchment characteristics is low, which implies that one or more important explanatory variables are yet to be recognised. Possible contenders include geological age of catchment rocks and soils, and short term rainfall intensity. A higher level of detail in modelling may also be helpful, but would be difficult to apply in practice.

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# URBAN STORMWATER QUALITY:

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## 1. INTRODUCTION

Pollution from urban catchments is a major problem in waterways. In Australia, this problem is compounded by extensive city and suburban development and by the large variability of flows. Urban runoff can contain nutrients at similar concentrations to treated sewage, as well as significant levels of suspended solids, heavy metals, and pathogens. Some pollutants have long-term adverse effects on urban waterways and the habitat of aquatic life, while others can cause acute or chronic toxicity. More accurate assessment of pollutant loads entering urban waterways is needed for improving urban stormwater design and management.

To help address this need, this report presents a statistical overview of observed urban runoff water quality. The study was carried out by analysing the results of many investigations reported in the literature. The objective was to assess the broad scale behaviour of runoff quality, and its interactions with land use and other catchment characteristics.

### 1.1 Report Layout

Following this Introduction, Section 2 describes the data management system developed to handle the wide range of experimental design and level of detail encountered in the urban runoff quality literature.

Section 3 presents information about each single water quality parameter in turn. Information includes a brief description of the contaminant, its likely sources and possible effects, the statistical distribution of concentration data, means and standard deviations for each land use with sufficient data, and significant relationships with catchment characteristics.

Section 4 looks at correlations between the concentrations of the various water quality parameters.

Section 5 provides a general discussion of land use effects, catchment characteristics, and explanatory power.

Section 6 summarises the conclusions.

The Appendices include an abbreviated tabulation of data, descriptive statistics of every water quality parameter for each land use observed, and a table of regression coefficients for significant relationships between concentration and catchment characteristics.

## 2. DATA MANAGEMENT

The data collated for this study have been obtained from reports of many investigations noted in the literature. These reports vary greatly in scope, structure, objectives, and detail, ranging from isolated measurements taken more than 40 years ago (Akerlindh 1950; Palmer 1950; Wilkinson 1954; Shigorin 1956), to the large centrally coordinated Nationwide Urban Runoff Program implemented by the United States Environmental Protection Agency (Athayde et al. 1983; Torno 1984). Urban and partly urban catchments were the main target of the literature search, but non-urban catchments used for comparison or control have also been retained.

One record in the data file is the average behaviour of one experimental condition at one site in the source document. Thus, for example, the six roofs of Thomas & Greene (1993) at Armidale in Australia form six records, and the separately tabulated results for summer and autumn storms at Viborg in Denmark (Hvitved-Jacobsen et al. 1987) form two records. This means that separate records are not always fully independent. Altogether, 508 data records have been collated, although not all parameters are available at all sites.

The majority of data points represent the mean event mean concentration of several runoff events, although other measures of central tendency have also been used. The 81 NURP sites use median event mean concentrations, and geometric means have also very occasionally been used. For the purposes of this overview, they are all accepted as locally appropriate measures of central tendency. The event mean concentration of a single event is the total load of a specified contaminant during the event divided by the total flow volume of the event.

The number of events measured, the number of samples taken, and the measurement techniques used vary widely between studies. It follows that the accuracy of the average behaviour data used here must also vary widely. But due to the difficulty and subjectivity of assessing the relative accuracy, no attempt has been made to apply weighting factors to the data.

## 2.1 Water Quality Variables

Twenty-one water quality parameters have been analysed. They are suspended solids, total phosphorus, total nitrogen, chemical oxygen demand, biochemical oxygen demand, oil & grease, total organic carbon, pH, turbidity, lead, zinc, copper, cadmium, chromium, nickel, iron, manganese, mercury, total coliforms, fecal coliforms, and fecal streptococci. All parameters are recorded as concentrations in milligrams per litre except for pH (pH units), turbidity (NTU), and the three microbiological measures (organisms per 100 mL).

## 2.2 Catchment Characteristics

Catchment information collated includes catchment area (ha), impervious (%), urban (%), residential (%), industrial (%), commercial (%), institutional (%), urban open space (%), other urban (%), agricultural (%), forest (%), other rural (%), population density (people/ha), roads (%), traffic density (vehicles/day), roofs (%), affected by Mt. St. Helens eruption (yes/no), and mean annual rainfall (mm).

## 2.3 Data File Structure

Because of the wide range of sources and levels of detail, a major challenge of the present study has been to prepare the available data in a manner which is internally consistent, yet captures as much information as possible from the original reports. Land use is sometimes expressed in numeric form in the source document, but often a qualitative verbal description is given (e.g. '...a predominantly residential catchment...', '...an urban road...', etc.). The descriptive information almost always permits allocation into one of three classes - high, medium, or low - and so a three-class structure has been adopted for the land use categories. The cut points for allocating numeric percentages to the three classes are set at one third and two thirds of total catchment area.

The final data structure and analysis protocol evolved from these practical considerations. Contaminant concentrations, catchment area, percent impervious, population density, traffic density, and mean annual rainfall are treated as continuous variables, since they are recorded in numeric form. The remainder are treated as grouping variables, since they can take only two or three distinct states.

The three-class structure for grouping variables has become an integral part of the analysis procedure. Thus we have a major data division into high urban, medium urban, and low urban catchments.

***High urban*** is by far the largest group, since it was the main objective of the literature review and data collection program. It is subdivided into residential, industrial, commercial, and other high urban subgroups. Again the three-way structure applies. To be classed as residential, an urban catchment must comprise at least two thirds residential area (or be described as 'residential', 'substantially residential', or some similar expression), and similarly for the other subgroups. If no single urban use falls in the top third, or if no further breakdown is given, the catchment is classed as other high urban. The institutional and urban open space categories are too small to permit separate analysis, so they also are included as other high urban.

***Medium urban*** is a very small group. Occasionally a large study has measured several catchments with a continuous gradation of urbanisation, but more commonly the land uses chosen are widely separated - high urban test catchments and low urban controls. Although basic statistics are presented, no further analysis has been carried out for the medium urban group. It is treated as a buffer to clearly separate the high urban and low urban groups.

***Low urban*** is a group of intermediate size. Rural catchments were not a primary data collection objective, and those included are often control catchments set up as part of an urban study. It is subdivided into agricultural, forest, and other low urban subgroups, using the same three-way structure as previously. Agricultural use is not further subdivided into type of agriculture, due to the small sample size. Forest may include woodland and scrubland - the essential feature is lack of development rather than size of trees. The term 'low urban' is used rather than 'rural', to emphasise that under the adopted data structure this group could include up to 33% urban area (although in practice that is very rarely the case).

Catchment descriptors which measure actual surface use (roads, roofs) apply at a different scale from those which measure more general zonings (residential, agricultural, etc.), and both types may apply simultaneously. Residential roofs or high urban roads are both legitimate land use categories. Initial review of the data shows that the actual surface use has a far greater effect on runoff quality than the broader zoning. Therefore roads and roofs have been accorded major group status. They have been separated from the remaining records *before* the division into high, medium, and low urban use. The usual two-thirds criterion applies. Note that areas classed as roads may not all be actual running lanes - shoulders, median strips, and embankments may also be included.

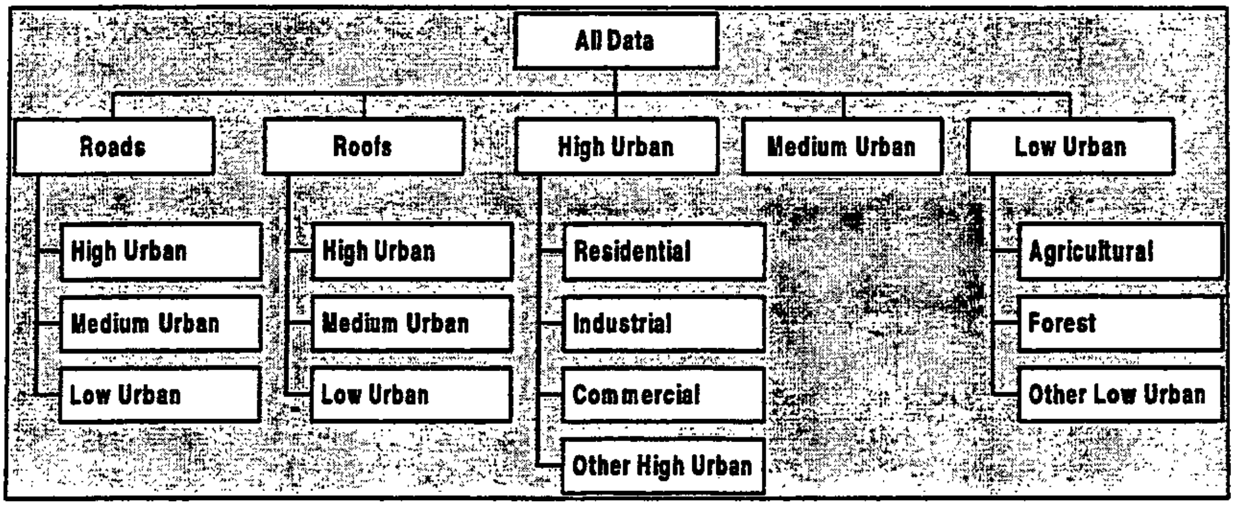

Figure 1. Land Use Groups

Thus in the final analysis there are five major land use groups, as shown in Figure 1:

- roads,
- roofs,
- high urban (excluding roads and roofs),
- medium urban (excluding roads and roofs), and
- low urban (excluding roads and roofs).

Roads and roofs may be further subdivided, depending on sample size. High urban and low urban are subdivided as described above. Medium urban is not subdivided, and takes little part in the detailed analysis. The data used in this study are tabulated in an abbreviated form in Appendix A.

Mean annual rainfall has been obtained either from the source document, from other studies at the same location, or from a data file of worldwide rainfall data. Mean annual runoff has not been used as it is rarely quoted in the published reports.

## 3. STATISTICS OF SINGLE PARAMETERS

In this section the statistics of each single water quality parameter are presented in turn. General results and trends are discussed in the following sections. The land use groups used are those described in Section 2, although groups may be combined where sample sizes are small. Issues that apply to many water quality parameters are discussed more fully under the first parameter (suspended solids), and treated more briefly for the other parameters.

Two main measures are used here to assess the relationship between two parameters. The **coefficient of determination** (**$R^2$**) measures the fraction of the variation in one parameter which can be explained by the other. A value of zero means they are completely independent, while a value of one means that either parameter can be completely determined from the other. The **statistical significance** assesses the probability that an apparent relationship is really present, or whether it could have occurred by chance in our data sample. It depends on the sample size as well as the association between the sample points. A confidence level of 95% is very commonly used as a standard. Throughout this report, 'significant' means statistically significant at the 95% confidence level, and 'highly significant' means statistically significant at the 99% confidence level. A change or trend which requires discussion but is not statistically significant is referred to as a tendency or an apparent trend.

The reliability and usefulness of any statistic depend in part on the sample size, with smaller samples giving less reliable results. Because of this, subgroups with less than four sample points have been omitted from the bar graphs and summary tables in this section. This is a very low cutoff, suitable for a general overview but too small for many statistical tests. The sample size is shown on both bar graphs and summary tables, and should be noted before drawing conclusions from the information presented.

### 3.1 Suspended Solids

Suspended solids is the material that can be removed from a water sample by filtration under standard conditions. Nonfiltrable residue is an older term of identical meaning. The greatest mass of suspended solids in urban runoff typically occurs in the 1 - 50 μm particle size range (Collins & Ridgway 1980; Ellis et al. 1981; Roberts et al. 1988) although much larger particles may be observed. The largest sizes are likely to be under-recorded, due to limitations in sampling techniques (Ellis 1979).

Deposition of suspended solids can block pipes, change flow conditions in open channels, and disrupt the habitat of aquatic invertebrates and fish. Turbidity associated with fine suspended solids will reduce light penetration. Equally important is the association between suspended solids and many other contaminants, including hydrocarbons, heavy metals, and phosphorus (Walesh 1986; Preul & Ruszkowski 1987; Urbonas 1991). Suspended solids has frequently been used as a generic or indicator measure of urban runoff pollution.

Sources of suspended solids include wet and dry atmospheric deposition, wear of roads and vehicles, construction and demolition operations, vegetation, and erosion of pervious areas by wind and water (Pitt 1979; James & Shivalingaiah 1986; Sriananthakumar & Codner 1992).

Altogether 362 records were obtained for suspended solids, including 247 records from high urban areas other than roads and roofs. The observed range extends from 2.8 mg/L for a rural stream in Minnesota to 14,541 mg/L from urban cobblestone streets in Leningrad in 1948-50.

Suspended solids concentrations from all land uses closely follow the log-normal distribution (Figure 2). Log-normality of runoff quality data has frequently been noted (Mance & Harman 1978; Torno 1984; Driscoll 1986; Marsalek 1991). Even so, the goodness of fit is striking, particularly since the points plotted are raw data, not residuals after processing. It will be seen subsequently that the log-normal distribution provides a moderate to very good fit to all quality parameters tested except pH. Because of this, all graphs (except for pH) are presented on a log scale, and T-tests between land use groups are carried out in the log domain. Summary statistics for each water quality parameter are shown in both transformed and untransformed coordinates.

Basic statistics describing the concentrations of suspended solids from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 3.

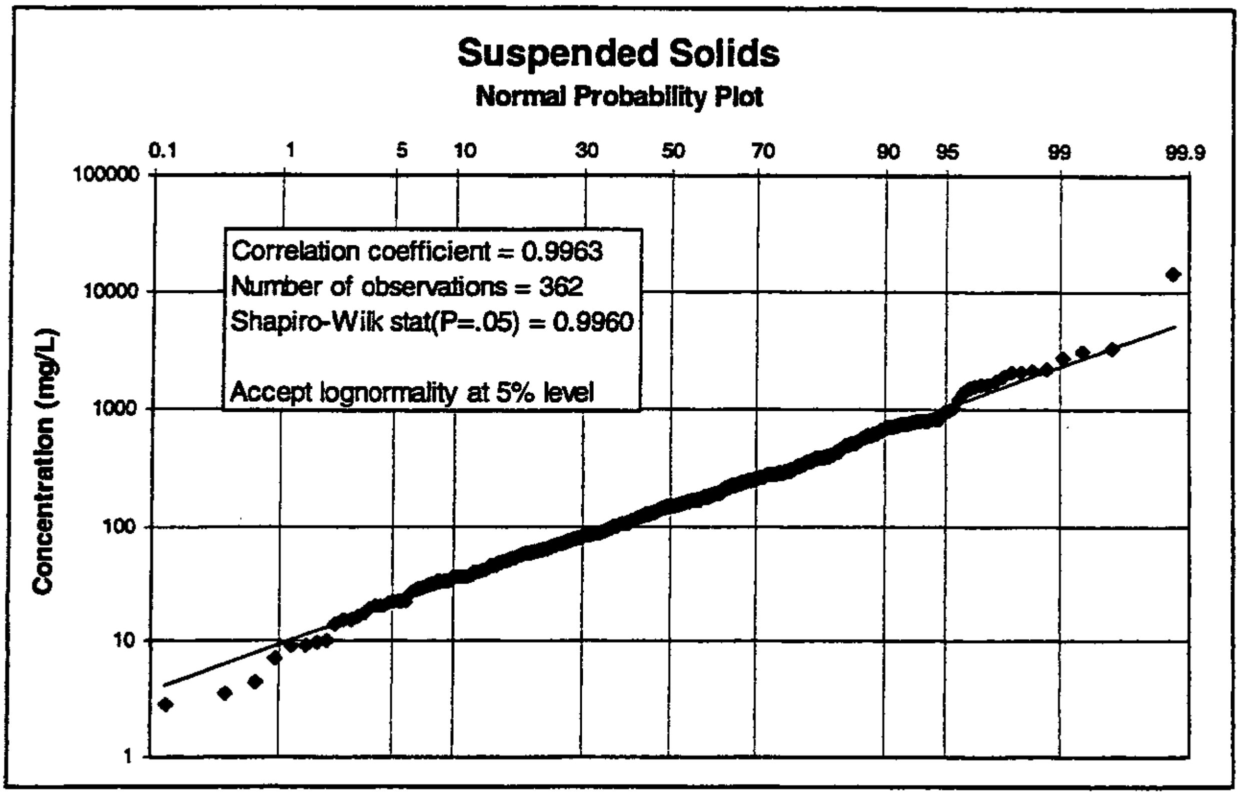

Figure 2. Suspended Solids Normal Probability Plot

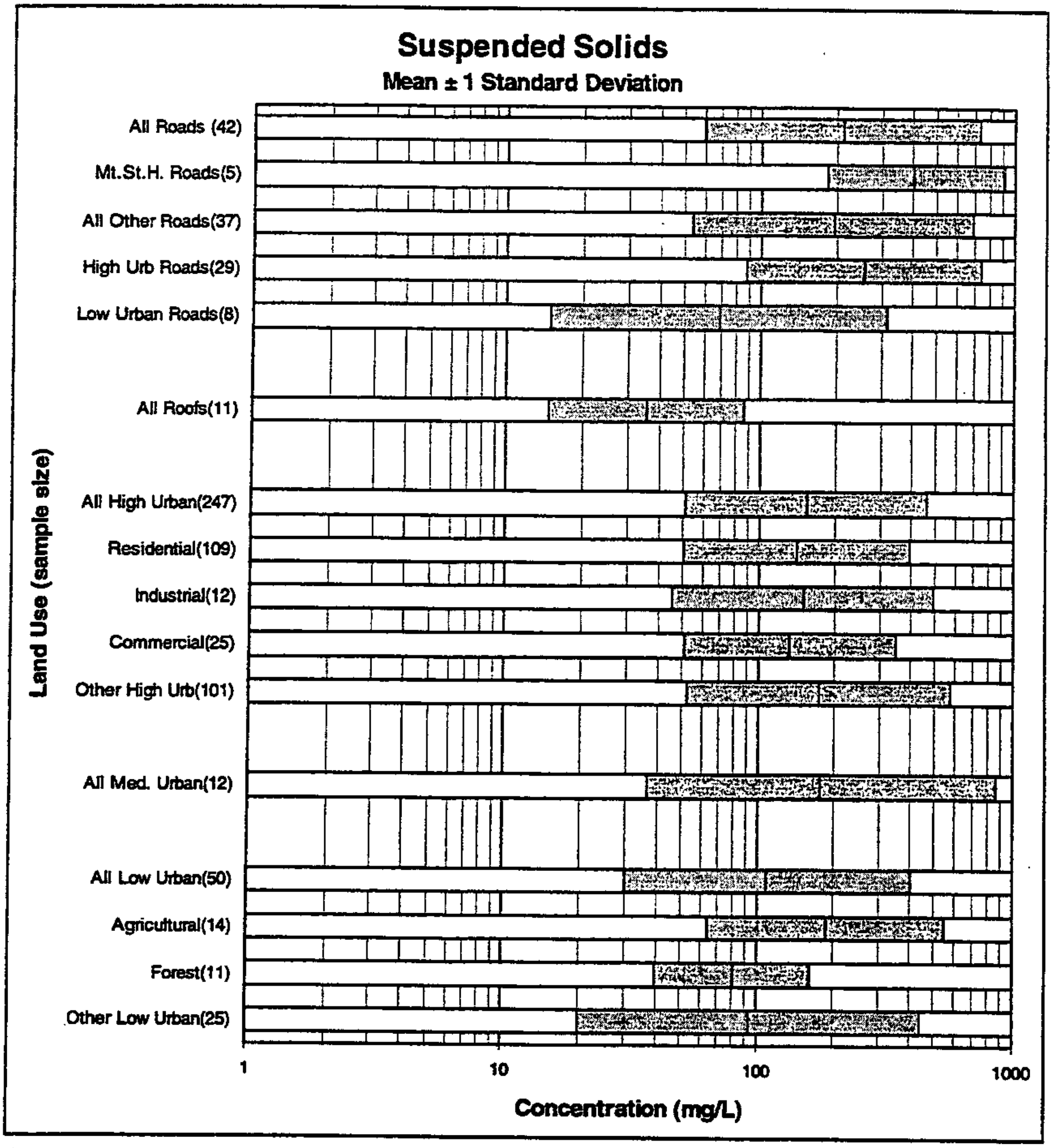

Figure 3. Suspended Solids Concentration vs Land Use

### 3.1.1 Roads

Within the roads group of land uses, the five sites affected by the eruption of Mt. St. Helens produced the highest suspended solids concentrations. Deposition of up to 20 mm of volcanic ash was recorded at these sites (Asplund et al. 1982). This highlights the unpredictable effect of unusual and unexpected events, but for most practical purposes these records can be treated as outliers. Accordingly, they have been excluded from the remainder of the analysis.

Concentrations from all other roads (37 records) are significantly related to mean annual rainfall. The higher the annual rainfall, the lower the concentration of suspended solids (Figure 4). The size of the effect is substantial - increasing the annual rainfall by 500 mm approximately halves the most likely concentration of suspended solids. As a result, the average loads from two sites of different annual rainfall differ by much less than would otherwise be expected. This seems to suggest some measure of source limitation for suspended solids.

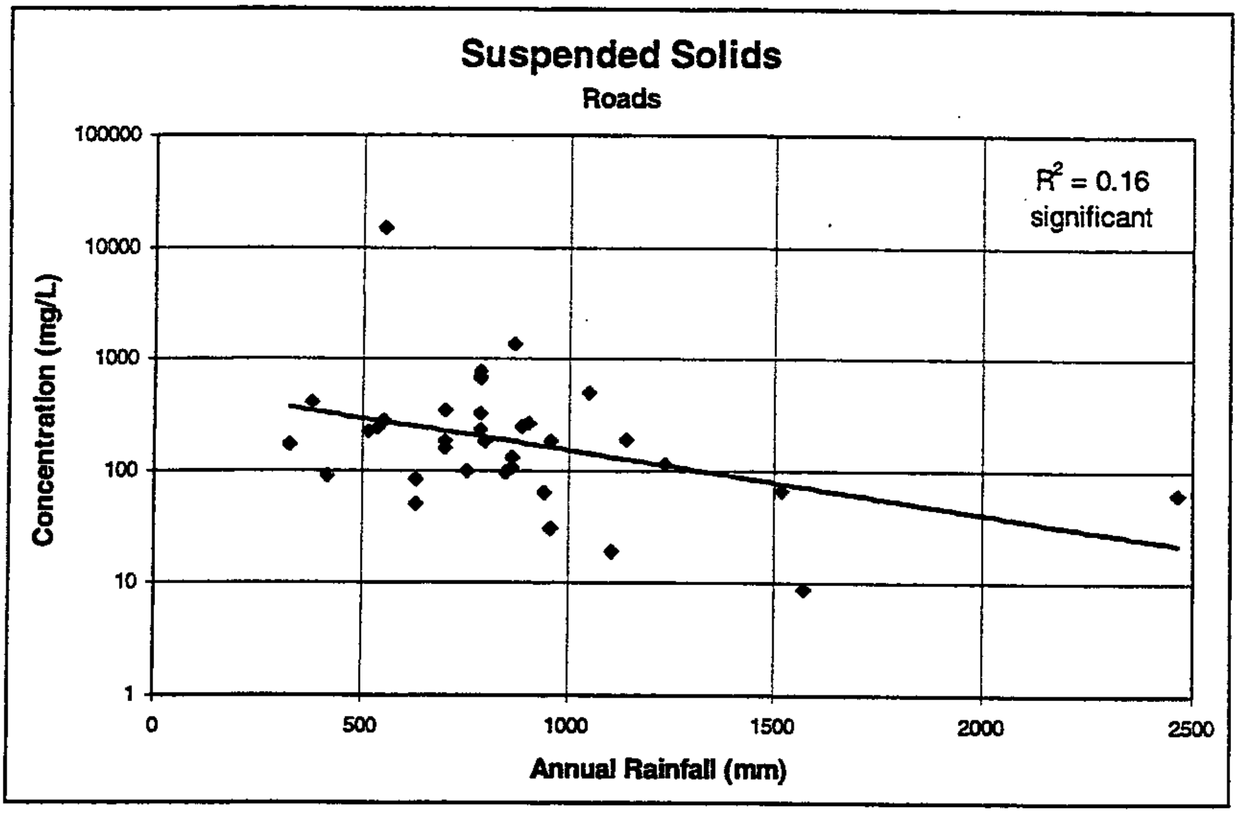

Figure 4. Suspended Solids Concentration (Roads) vs Annual Rainfall

Note that comparing two locations with different annual rainfall is not the same as comparing two rainfall events at the one site. In the first case, the vegetation, soils, drainage pattern, and other physical factors have developed over a long period under that rainfall regime. As will be seen, lower contaminant concentrations from impervious areas under higher annual rainfall is a very common result. In the second case, all the long term site-dependent factors remain the same, but short term factors such as time of year, antecedent dry period, and rainfall intensity will differ. In this case, higher rainfall intensity typically leads to somewhat higher suspended solids concentrations, giving much higher total loads (Driver & Troutman 1989).

No significant relationships were found between suspended solids concentration and percent impervious or vehicles per day.

On the bar graphs in Figure 3, the average concentration from low urban roads is considerably lower than that from high urban roads, and a T-test (in the log domain) shows that the difference is highly significant. But if the fitted rainfall effect is subtracted from the data, the difference between high urban and low urban roads is much reduced, and is only just significant. So we can say that the concentrations of suspended solids from low urban roads are lower than from high urban roads, but partly because the urban areas in this sample tend to be located away from the areas of highest rainfall.

### 3.1.2 Roofs

The roofs group cannot be further subdivided for suspended solids, due to the small sample size (11 records). As it happens, all the roof samples are from high urban roofs, yet the mean concentration is only one seventh of that from high urban roads, and one quarter of that from all high urban sites excluding roads and roofs. Both differences are statistically highly significant. All roof concentrations fall in the lower half of the observed range from all land uses.

Of all the sources of suspended solids, only wet and dry atmospheric deposition will apply equally to roofs and to surfaces at lower elevation. All other sources are likely to be at their maximum below roof level. Dry weather redistribution by wind also tends to concentrate dense particulate contaminants at lower elevations. This elevation effect explains the lower concentrations of suspended solids in roof runoff, and also contributes to the higher concentrations in road runoff. It seems likely that urban roads are major contributors to pollutant load not just because of their vehicular traffic, but also because they are usually low. The same effect may be a factor contributing to the lower contamination of rural roads compared with urban roads. Urban roads are often at the lowest elevation in a local area, whereas rural roads generally are not.

### 3.1.3 High Urban

The high urban group excluding roads and roofs (247 records) has been subdivided into residential, industrial, commercial, and other high urban subgroups. There are no significant differences between any of the subgroups, despite the large sample size (Figure 3). It seems that the similarities between the various subgroups of high urban land use far outweigh the differences, when analysed in this way. The NURP study (Athayde et al. 1983) reached the same conclusion. In their analysis of 81 US catchments, which comprise about one fifth of the data used here, they found no significant differences for suspended solids between residential, mixed, commercial, industrial, or open/non-urban sites.

Suspended solids concentrations from high urban areas are significantly correlated with mean annual rainfall (Figure 5), and the relationship is very similar to that described above for the roads group. Increasing the annual rainfall by 500 mm more than halves the most likely concentration of suspended solids. No significant relationships were detected between suspended solids concentration and catchment area, percent impervious, or population density.

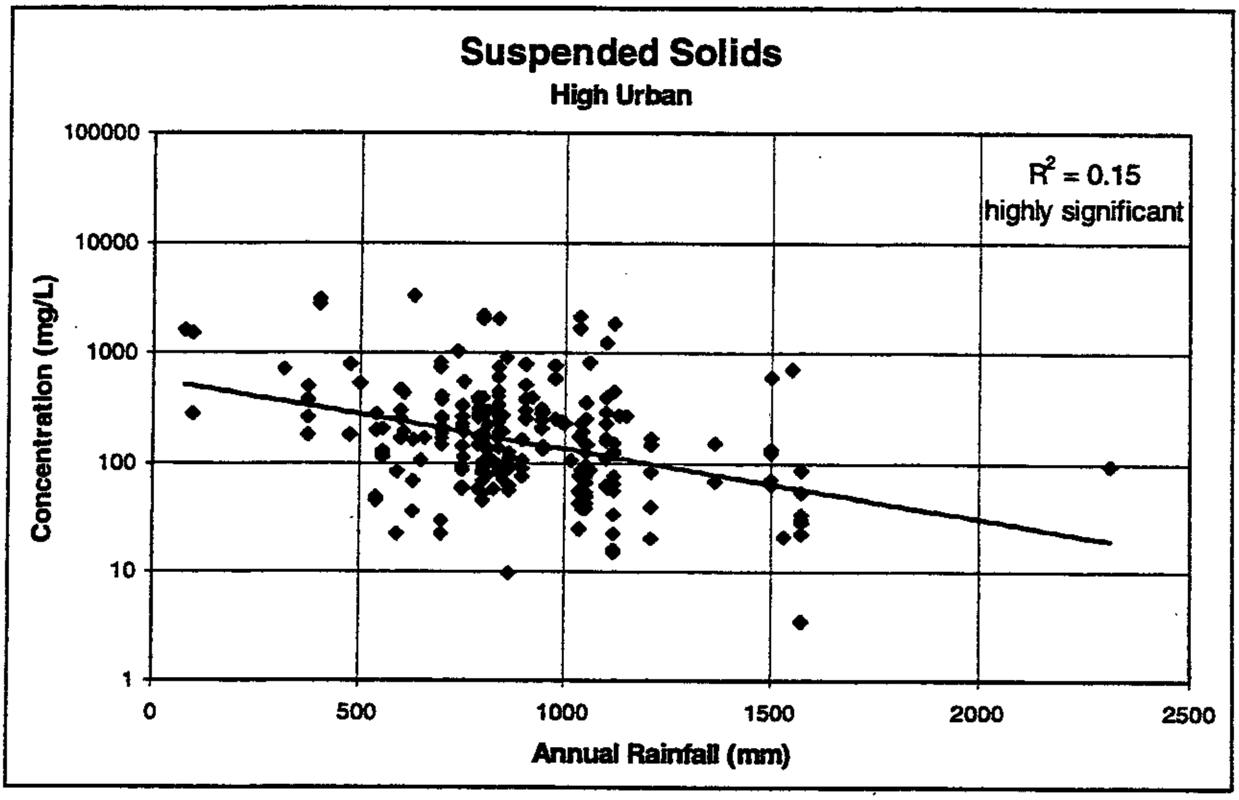

Figure 5. Suspended Solids Concentration (High Urban) vs Annual Rainfall

### 3.1.4 Medium Urban

The medium urban group (12 records) is characterised by small sample size and high variability. No further division into subgroups is possible, since percent urban lies between 34% and

66%, so that no single land use can achieve the 67% needed for inclusion in any subgroup. Because of this, the medium urban group is not analysed in any detail.

### 3.1.5 Low Urban

The low urban group (50 records) is subdivided into agricultural, forest, and other low urban subgroups. Mean suspended solids concentration from the agricultural subgroup is more than twice that from the forest subgroup, which is a statistically significant difference. The other low urban subgroup exhibits a very wide range of values, presumably because this group contains records for which the detailed land use is not stated (but could be all forest, or all agricultural) as well as sites known to be of mixed land use.

All three low urban subgroups (and the group as a whole) show a tendency for concentration to increase with increasing annual rainfall, in contrast to the roads and high urban groups (Figure 6). Although not significantly different from zero, the gradient is significantly different from that of the roads and high urban groups, suggesting that different processes are involved. It is likely that erosion is an important process in the low urban (mainly pervious) areas, while some degree of source limitation applies in the roads and high urban (mainly impervious) areas. The higher concentration from agricultural areas, compared with undisturbed forest areas, is compatible with the erosion hypothesis.

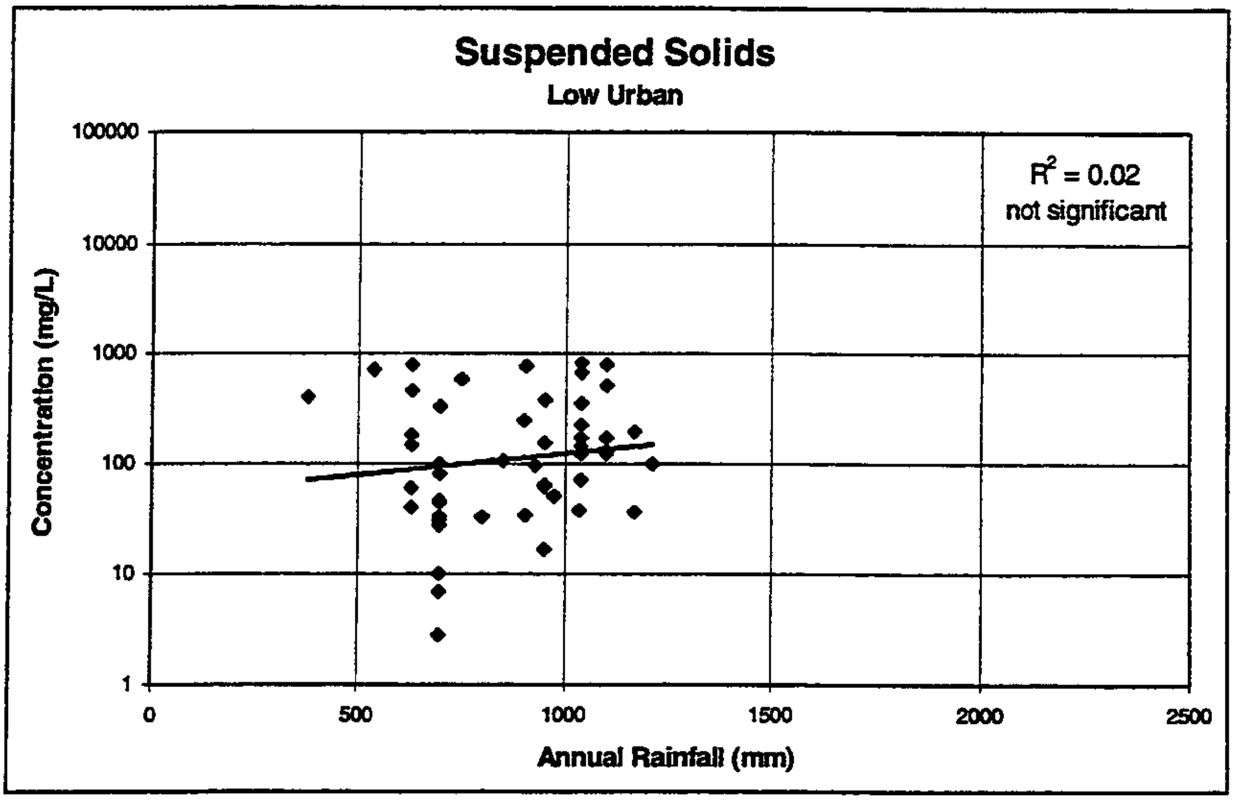

Figure 6. Suspended Solids Concentration (Low Urban) vs Annual Rainfall

No significant relationships have been found between low urban suspended solids concentrations and percent impervious, population density, or catchment area, using this analysis approach.

### 3.1.6 Summary

Within an urban area, roofs produce the lowest concentrations of suspended solids on average, followed by high urban sites excluding roads and roofs, followed by high urban roads, which give the highest average concentrations. Low urban roads give lower concentrations than high urban roads. This gradation appears to be related to relative local elevation.

Suspended solids concentration in runoff increases as forested land changes to agricultural land, and also as forest land becomes urbanised. High urban and agricultural sites produce similar concentrations, on average, although the underlying processes appear to be different. Suspended solids concentrations from roads and high urban areas (both largely impervious) decrease on average as annual rainfall increases, while concentrations from low urban areas do not.

No significant differences were found between the four subgroups of high urban land use - residential, industrial, commercial, and other high urban.

Summary statistics are listed in Table 1 for the distinct land use subgroups identified. Two subgroups are treated as distinct if they belong to different major groups, if their means are significantly different (in the log domain), or if other identified processes appear to be different. The arithmetic means in log coordinates correspond to the geometric means in untransformed coordinates. And since the data are log-normally distributed, the geometric means tend to be similar to the medians.

Table 1. Suspended Solids Summary Statistics

| Subgroup | Sample | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | size | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| High urban roads | 29 | 2.41 | 0.46 | 779 | 257 | 232 |
| Low urban roads | 8 | 1.84 | 0.66 | 229 | 69 | 64 |
| Roofs | 11 | 1.55 | 0.38 | 47 | 35 | 41 |
| High urban | 247 | 2.19 | 0.48 | 294 | 155 | 152 |
| Agricultural | 14 | 2.27 | 0.47 | 311 | 186 | 133 |
| Forest | 11 | 1.90 | 0.30 | 99 | 79 | 71 |

## 3.2 Total Phosphorus

Total phosphorus in runoff is the sum of dissolved and particulate phosphorus. Each of these fractions can be subdivided into reactive, acid-hydrolysable, and organically bound phosphorus, according to its chemical availability. Reactive phosphorus is readily available, while organic phosphorus is released only by powerful oxidising agents (Eaton et al. 1995). It is a common but not universal practice to quote concentrations in terms of the mass of phosphorus only, rather than the mass of the compound in which it occurs. Orthophosphate, in particular, may be expressed in either form, and great care is required in the interpretation of published data. This report uses concentrations of phosphorus only.

Phosphorus is an essential nutrient, and may be the limiting nutrient at a site. Where phosphorus is limiting, an increase may cause excessive and unbalanced growth of plants and algae leading to oxygen depletion (eutrophication). Sources of phosphorus include atmospheric deposition (Nicholls & Cox 1978; Jassby et al. 1994), tree leaves (Kluesener & Lee 1974; Dorney 1986; Allison & Chiew 1997), domestic and agricultural fertilisers, industrial wastes, detergents and lubricants (Makepeace et al. 1995).

A total of 306 records were obtained, including 206 from high urban areas excluding roads and roofs. The observed range runs from 0.01 mg/L for an urban catchment at Shrimptons Creek in Sydney to 4.7 mg/L for the agricultural Pequea 3 catchment in Virginia.

Total phosphorus concentrations from all land uses closely follow the log-normal distribution (Figure 7). Basic statistics describing the concentrations of total phosphorus from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 8.

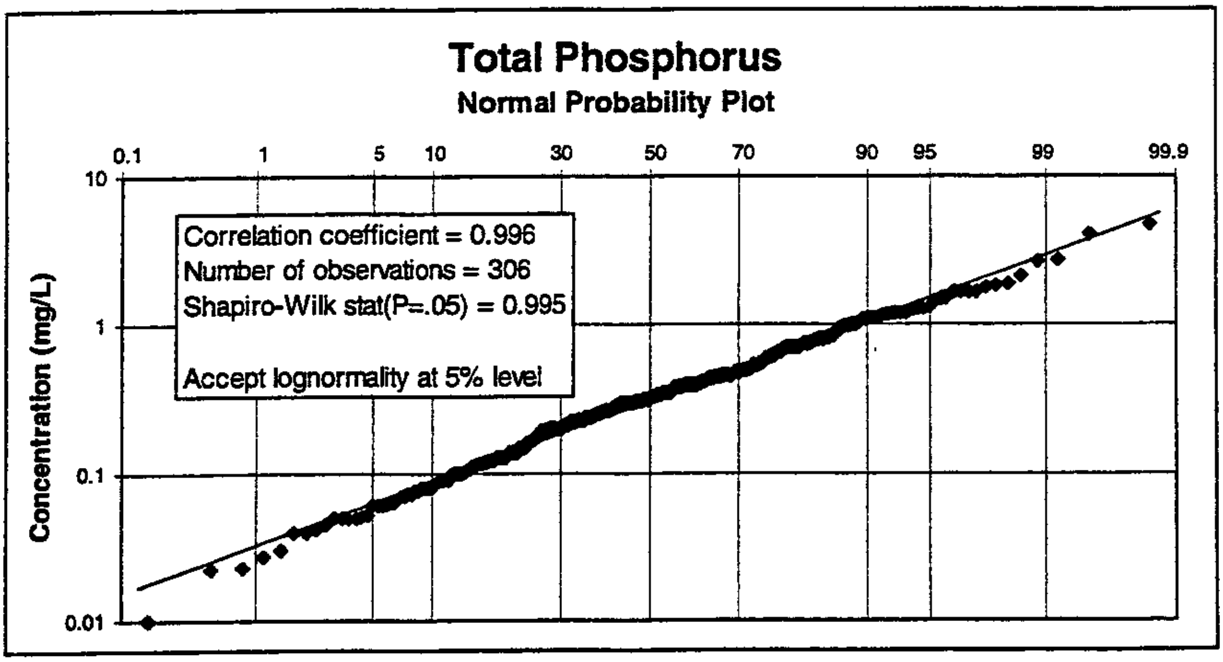

Figure 7. Total Phosphorus Normal Probability Plot

### 3.2.1 Roads

No significant differences in total phosphorus concentration were detected between the three subgroups (high urban, low urban, and Mt. St. Helens) of the roads group. Even so, the Mt. St. Helens subgroup has been excluded from further analysis, so that all quality parameters are treated consistently.

For the remaining roads, there is a highly significant relationship with traffic density (Figure 9). Interestingly, the relationship is negative - higher traffic density is associated with lower total phosphorus concentration. Perhaps there tends to be more vegetation per square metre of road area bordering lower volume routes, which supplies phosphorus to the ground surface in the form of leaves and other plant litter. Mechanical breakup of plant debris by traffic movement will lead to the rapid release of phosphorus (Cowen & Lee 1973).

No significant relationship with mean annual rainfall was detected in this group.

### 3.2.2 Roofs

The roofs group for total phosphorus is small (6 records), and as all roofs are classed as high urban, no further separation is possible. The mean concentration from roofs is about half of that from roads and about one third of that from high urban areas excluding roads and roofs. All roof concentrations fall in the lower half of the observed range from all land uses.

### 3.2.3 High Urban

In the high urban group (206 records), mean total phosphorus concentration from residential areas is significantly higher than from all other high urban areas combined, although the actual increase in mean event mean concentration is quite small. No significant differences were found between industrial, commercial, and other high urban uses. Again, this appears to be consistent with the results of the NURP study, as shown graphically by Athayde et al. (1983).

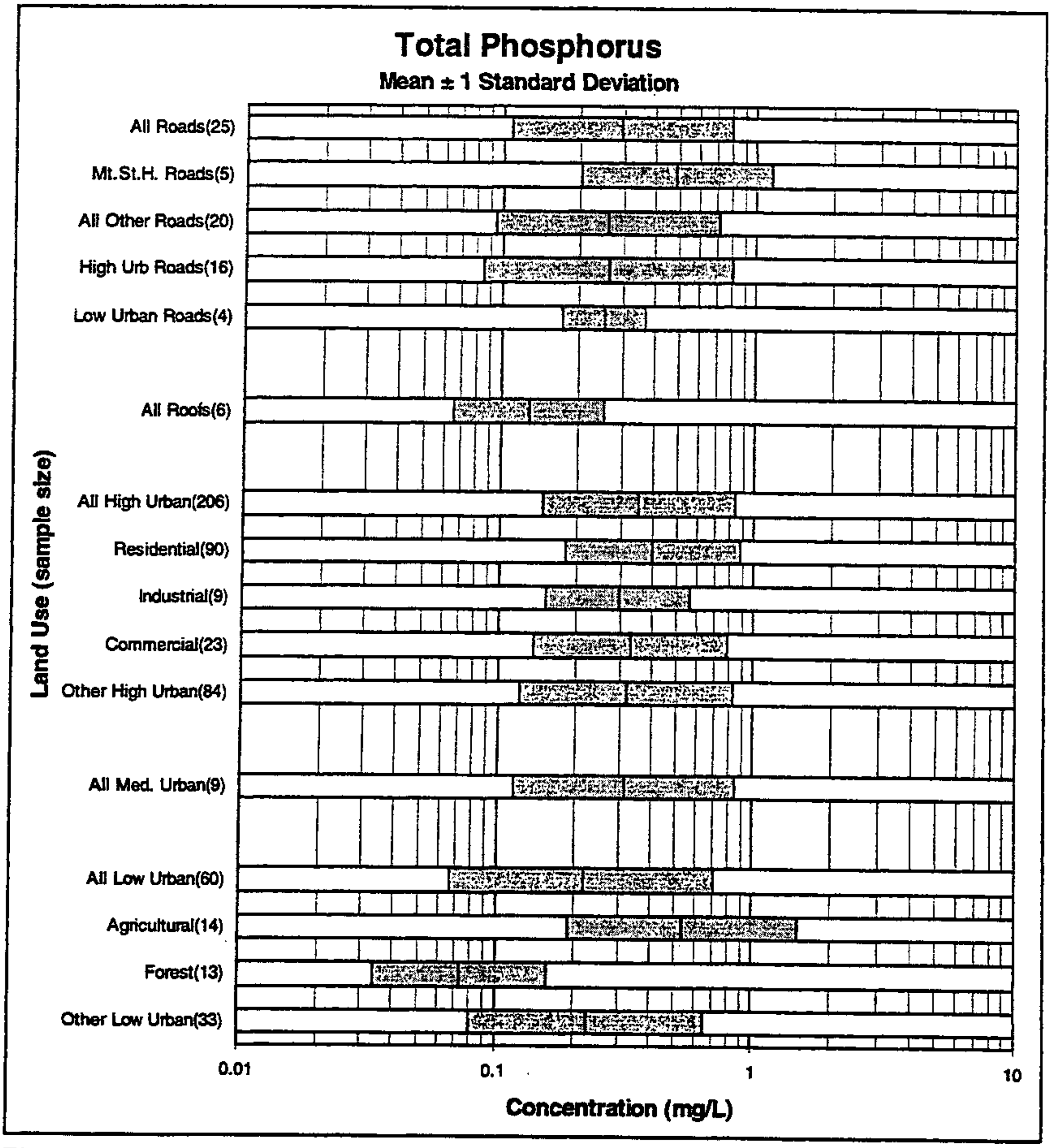

Figure 8. Total Phosphorus Concentration vs Land Use

Higher total phosphorus concentrations from residential areas could simply reflect the use of fertilisers on gardens. Alternatively, residential areas may provide the optimum mix of source material (vegetation) and impervious area (which allows fast runoff and minimises adsorption of phosphorus onto fixed soil particles).

No significant relationships were found between total phosphorus concentration and mean annual rainfall, catchment area, impervious percent, or population density.

### 3.2.4 Low Urban

In the low urban group (60 records), the difference between forested and agricultural catchments is very marked (Figure 8). Mean total phosphorus concentration from forest areas is only one seventh of that from agricultural areas, and less than one quarter of that from the high urban group. Both differences are highly significant. High concentrations from agricultural areas are presumably related to erosion and fertiliser use. Agricultural concentrations are not significantly higher than residential concentrations. They are, however, significantly higher than concentrations from other high urban areas.

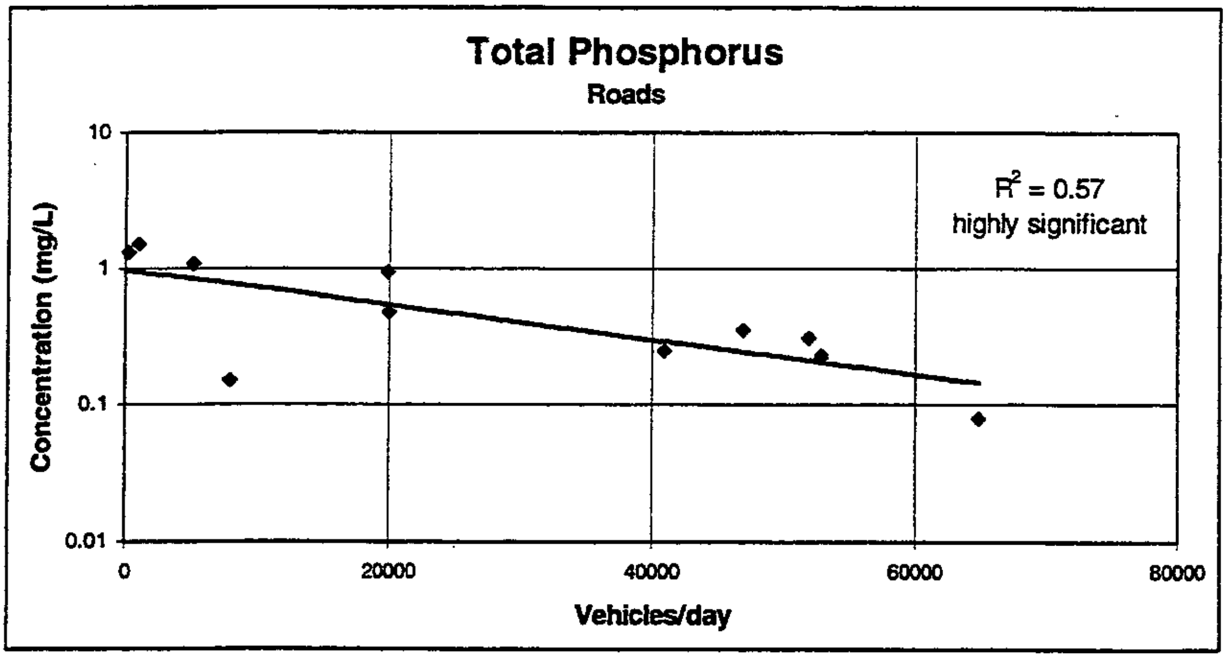

Figure 9. Total Phosphorus Concentration (Roads) vs Traffic Density

### 3.2.5 Summary

In an urban area, roofs produce the lowest concentrations of total phosphorus on average, and residential areas produce the highest concentrations. All other urban land uses, including roads, fall between these limits. On roads, total phosphorus concentrations decrease as traffic density increases. These effects may be related to the presence of vegetation as a source of phosphorus.

Total phosphorus concentrations from the forest subgroup are significantly lower than those from the agricultural subgroup and the high urban group. Agricultural concentrations are significantly higher than all urban subgroups except residential.

No strong relationships between total phosphorus concentrations and annual rainfall were detected for any group or subgroup analysed.

Summary statistics are listed in Table 2 for the distinct land use subgroups identified.

Table 2. Total Phosphorus Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 20 | -0.59 | 0.44 | 0.42 | 0.26 | 0.24 |
| Roofs | 6 | -0.89 | 0.29 | 0.15 | 0.13 | 0.14 |
| Residential | 90 | -0.40 | 0.34 | 0.56 | 0.40 | 0.39 |
| Non-resid. high urban | 116 | -0.50 | 0.40 | 0.46 | 0.32 | 0.36 |
| Agricultural | 14 | -0.27 | 0.45 | 0.90 | 0.54 | 0.51 |
| Forest | 13 | -1.14 | 0.34 | 0.095 | 0.072 | 0.070 |

## 3.3 Total Nitrogen

Total nitrogen in runoff is the sum of several forms. Organic nitrogen plus ammonia nitrogen comprise total kjeldahl nitrogen. Nitrite plus nitrate comprise oxidised nitrogen. Total kjeldahl nitrogen and oxidised nitrogen together make up total nitrogen. Nitrogen can be converted between these forms, and also nitrogen gas, by chemical and biological action (Eaton et al. 1995). It is a common but not universal practice to quote concentrations in terms of the mass of nitrogen only, rather than the mass of the compound in which it occurs. Nitrite and nitrate, in particular, may be expressed in either form. This report uses concentrations of nitrogen only.

Nitrogen is an essential nutrient, and may be the limiting nutrient at a site. In such cases, increased nitrogen levels may stimulate further growth and lead to eutrophication of the water body. Nitrite and nitrate in drinking water contribute to the illness known as methemoglobinemia, or blue baby syndrome.

Sources of nitrogen in storm water include fertilisers, industrial cleaning operations, feed lots, animal droppings, combustion of fossil fuels (Makepeace et al. 1995), windblown pollen, spores, bacteria, and dust (McKee 1962), fallen leaves, and other plant debris. Rainfall is consistently the major source of nitrogen in urban runoff (Duncan 1995), and inorganic nitrogen concentrations in rainfall often exceed a threshold level for algal blooms (Weibel et al. 1966).

Altogether 212 records were obtained for total nitrogen, including 139 records from high urban areas excluding roads and roofs. The observed range extends from 0.194 mg/L for the largely forested Tieton River in Washington state to 56.6 mg/L for an urban road in Washington state affected by the eruption of Mt. St. Helens.

Total nitrogen concentrations from all land uses approximately follow the log-normal distribution (Figure 10). Although log-normality is rejected by the rigorous Shapiro-Wilk test, the fit still appears to be reasonable. Since consistency of method is important when comparing behaviour, total nitrogen concentrations are analysed in the log domain the same as the other quality parameters. Basic statistics describing the concentrations of total nitrogen from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 11.

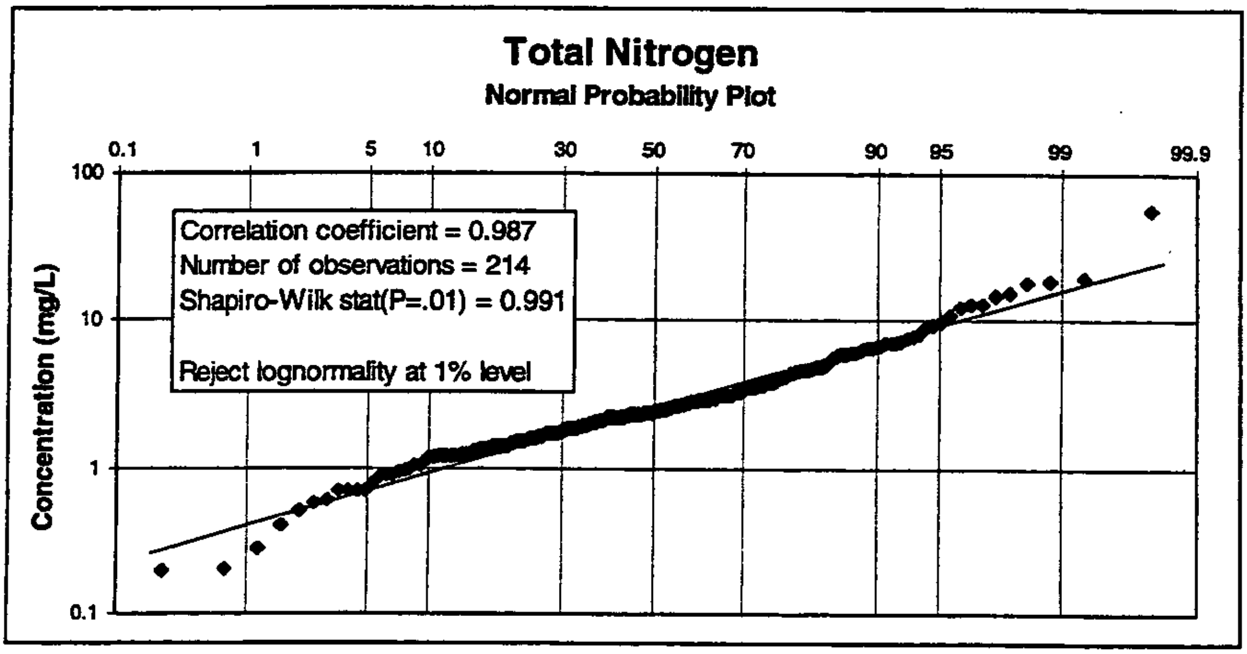

Figure 10. Total Nitrogen Normal Probability Plot

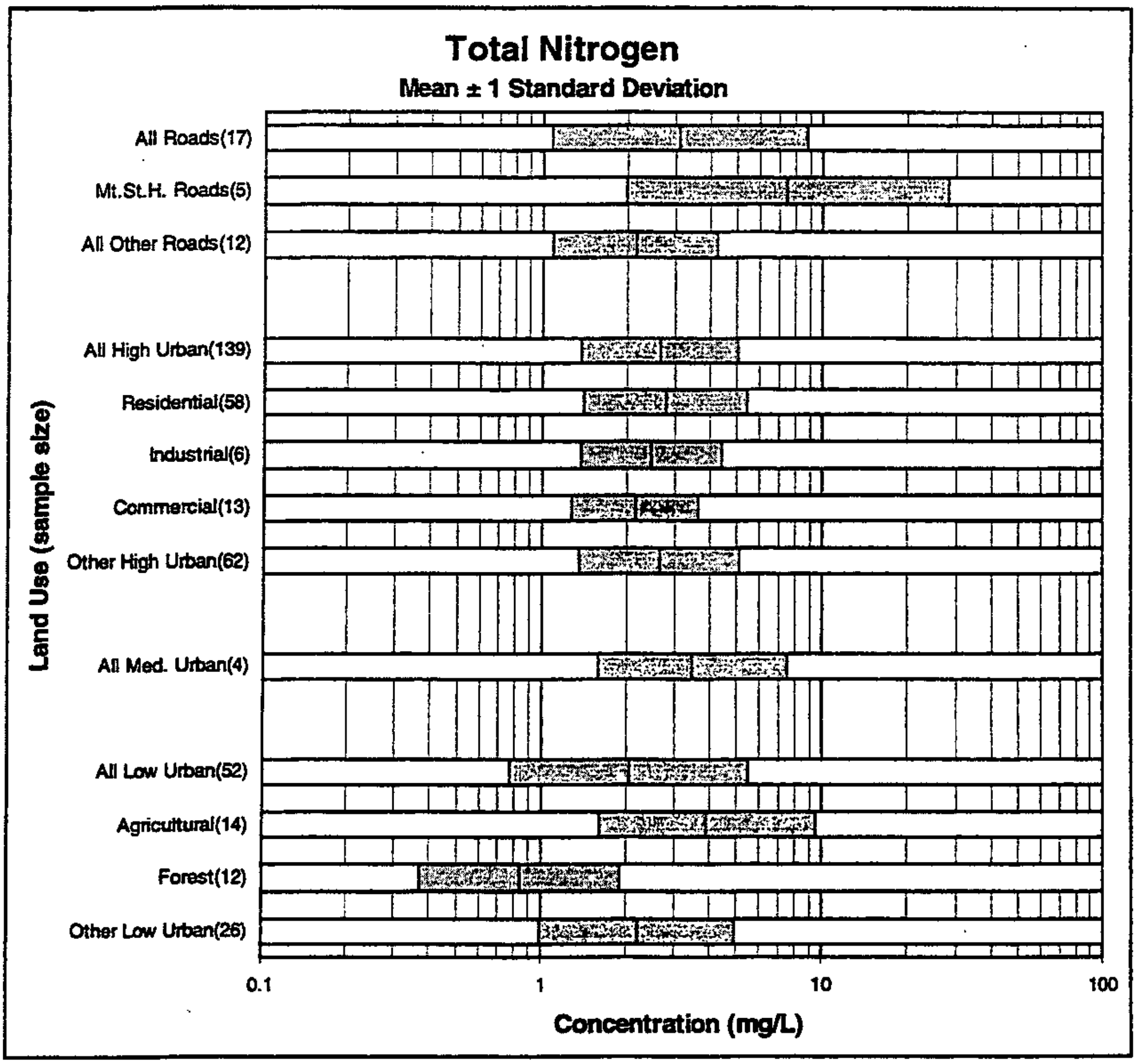

Figure 11. Total Nitrogen Concentration vs Land Use

### 3.3.1 Roads

There are no significant differences in total nitrogen concentrations between subgroups in the roads group of land uses. The high mean and standard deviation for the Mt. St. Helens subgroup in Figure 11 are due to a single very high reading. Either including or excluding this point, the mean is not significantly different from that for all other roads. With the Mt. St. Helens subgroup excluded, the all other roads subgroup contains 11 high urban roads and only one low urban road, so it can not be usefully subdivided any further.

A tendency for total nitrogen concentration from roads to decrease with increasing annual rainfall is not significant (Figure 12), but the regression line is almost identical to that described below for high urban land use excluding roads and roofs.

### 3.3.2 Roofs

With only two records, both from the same urban area, roofs data for total nitrogen carry little statistical weight. Informally, we can note that both concentrations fall in the upper half of the observed range from all land uses. For suspended solids, all eleven roof runoff concentrations fall in the lower half of the observed range.

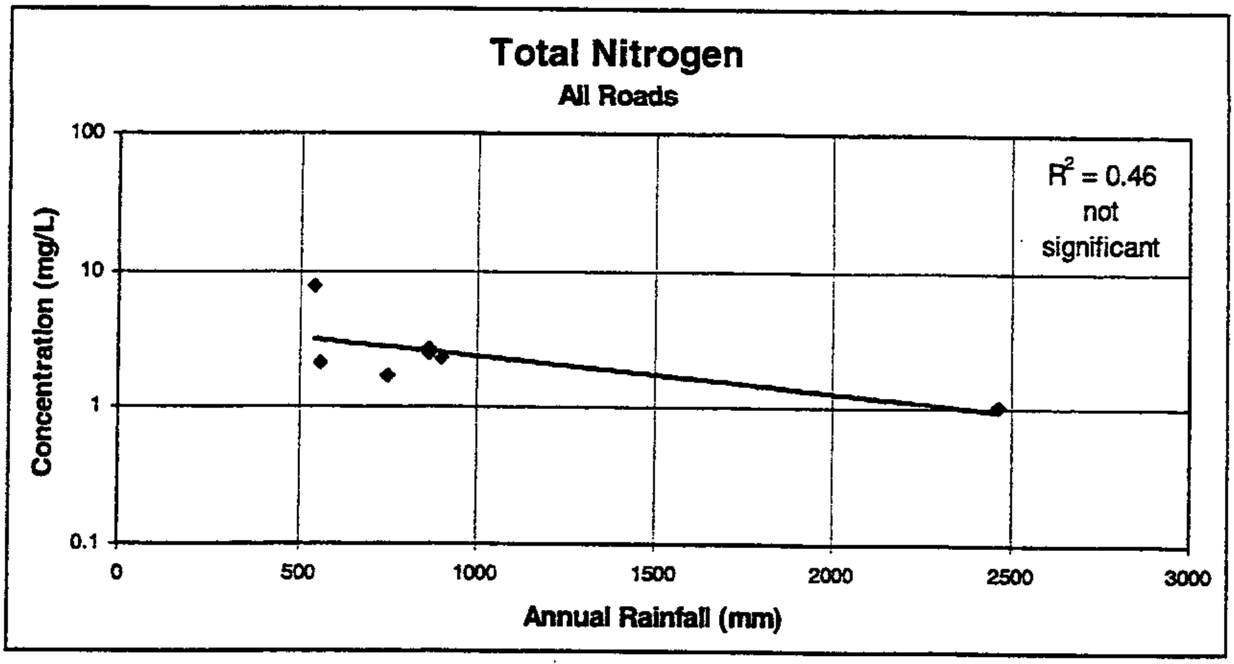

Figure 12. Total Nitrogen Concentration (Roads) vs Annual Rainfall

### 3.3.3 High Urban

There are no significant differences in total nitrogen concentrations between any subgroups of the high urban group (139 records). The NURP study (Athayde et al. 1983) did not analyse total nitrogen, but for total kjeldahl nitrogen they found somewhat higher median concentrations from residential sites than from mixed or commercial sites. The median concentration in high urban runoff (2.5 mg/L) is not much higher than the typical concentration in urban rainfall (1 to 2 mg/L) quoted by Duncan (1995). The nitrogen in rainfall may be brought in from distant sources, or it may be derived locally and stripped from the atmosphere close to ground level. Either way, the rainfall itself (not just the runoff it generates) evidently plays a major role in mobilising nitrogen in urban runoff.

Total nitrogen concentrations from high urban areas are significantly correlated with mean annual rainfall (Figure 13). The regression line is almost identical to that for the roads group. Increasing the annual rainfall by 500 mm reduces the most likely concentration by about 30%. Total nitrogen is also correlated with population density (Figure 14), with higher population density giving higher total nitrogen concentration. Unfortunately the sample size is much reduced, since population information is less readily available than rainfall data.

No significant relationships were detected in the high urban group between total nitrogen concentration and catchment area or percent impervious.

### 3.3.4 Low Urban

The low urban group comprises 52 records, with all three subgroups well represented. Mean total nitrogen concentration from the forest subgroup is about one fifth of that from the agricultural subgroup, and about one third of that from the high urban group. Both differences are highly significant. Mean agricultural and high urban concentrations are not significantly different.

The low urban group shows a negative correlation with annual rainfall - the higher the rainfall the lower the concentration of total nitrogen (Figure 15). The relationship is highly significant, although arguably not very robust, since it depends largely on a small number of records with high rainfall. This behaviour is similar to that of the roads and high urban groups, but quite different from that of suspended solids in the low urban situation. Perhaps the relationship with annual rainfall reflects an atmospheric process, rather than a runoff process, since it is so similar for all land uses.

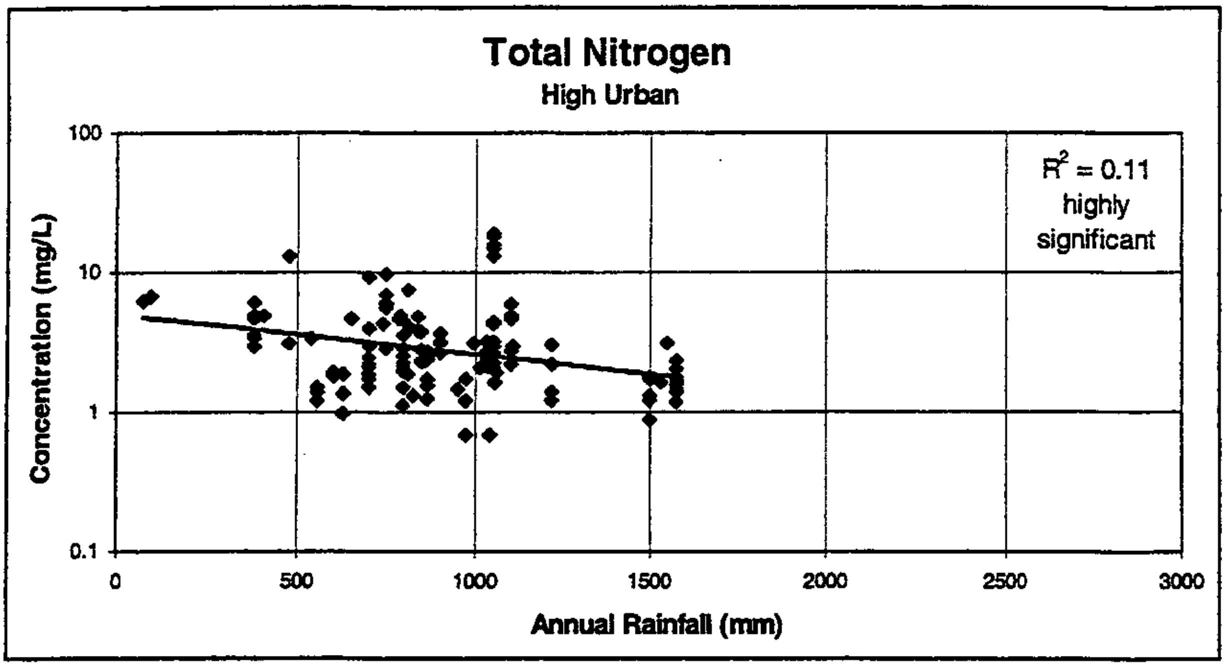

Figure 13. Total Nitrogen Concentration (High Urban) vs Annual Rainfall

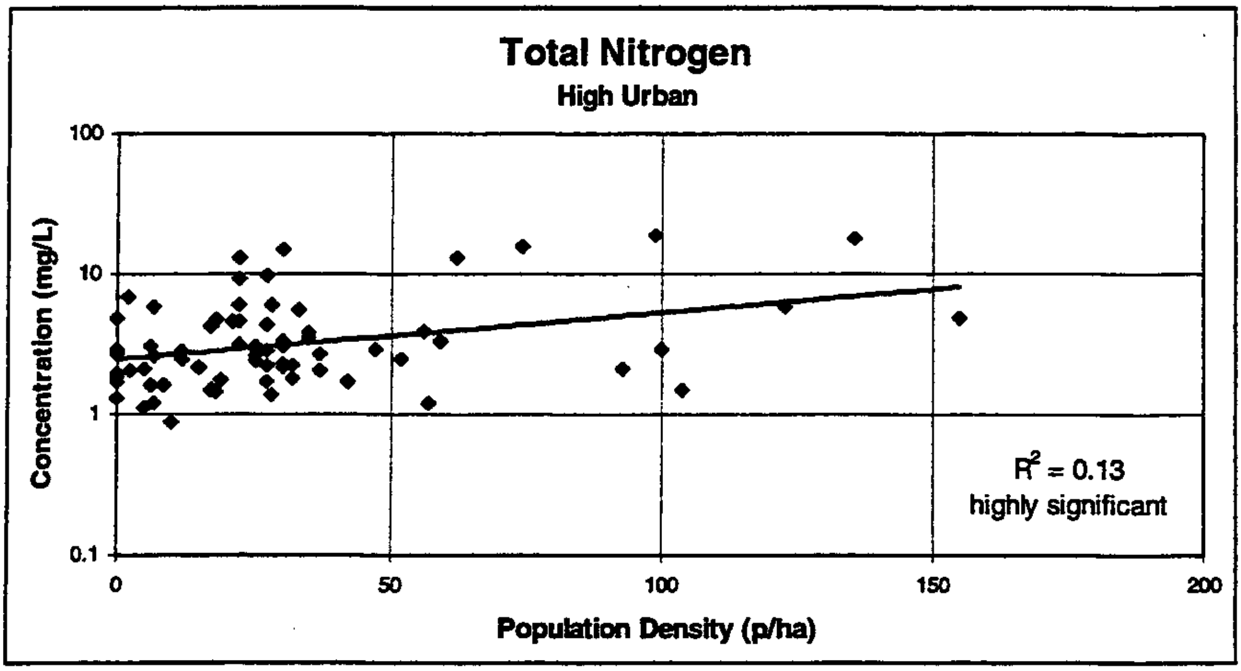

Figure 14. Total Nitrogen Concentration (High Urban) vs Population Density

### 3.3.5 Summary

No significant differences in total nitrogen concentrations were found between the three land use groups with adequate sample size for analysis - roads, high urban, and low urban. Nor were any significant differences found between the four subgroups of high urban land use - residential, industrial, commercial, and other high urban.

Total nitrogen concentrations from the forest subgroup are significantly lower than those from the agricultural subgroup and the high urban group.

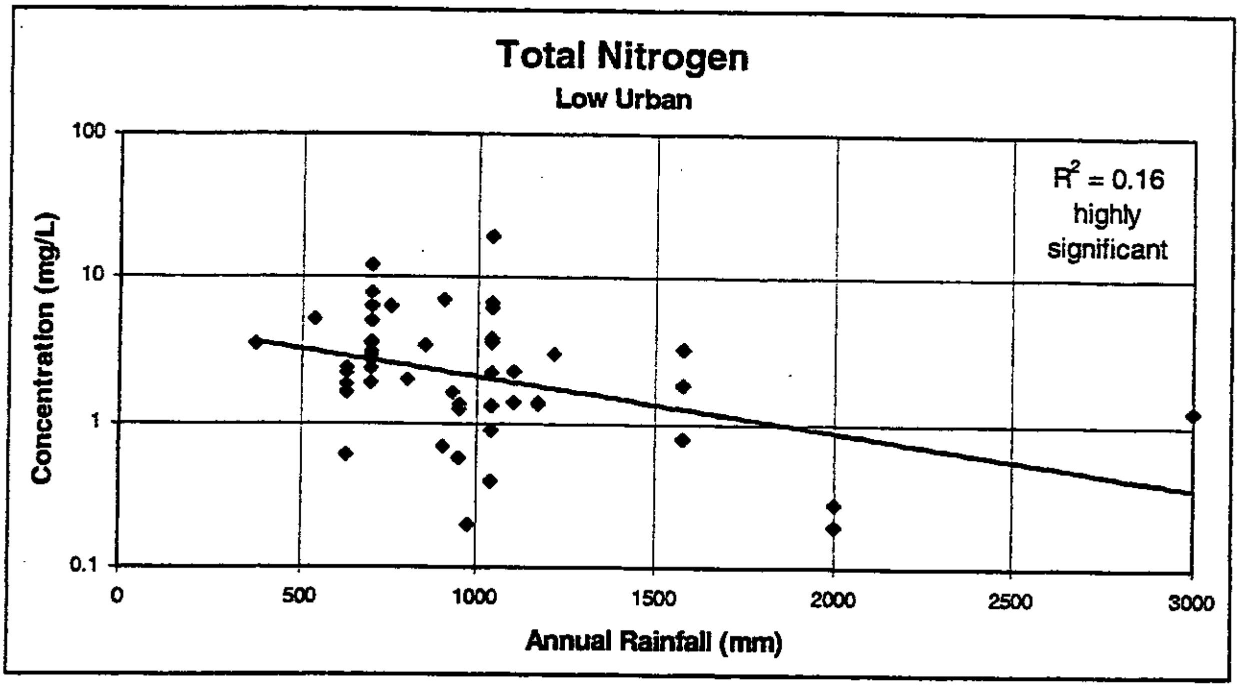

Figure 15. Total Nitrogen Concentration (Low Urban) vs Annual Rainfall

Total nitrogen concentrations from roads, high urban areas, and low urban areas all decrease on average as annual rainfall increases. The relationships are strikingly similar for all three land uses.

Summary statistics are listed in Table 3 for the distinct land use subgroups identified.

Table 3. Total Nitrogen Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 12 | 0.33 | 0.30 | 2.7 | 2.1 | 2.2 |
| High urban | 139 | 0.42 | 0.28 | 3.4 | 2.6 | 2.5 |
| Agricultural | 14 | 0.59 | 0.39 | 5.3 | 3.9 | 4.4 |
| Forest | 12 | -0.08 | 0.36 | 1.1 | 0.83 | 0.95 |

## 3.4 Chemical Oxygen Demand

Chemical oxygen demand, or COD, is a measure of the oxygen uptake of organic matter in a sample under the action of a strong chemical oxidant. For samples from a given source, COD can be related empirically to BOD, organic carbon, or organic matter (Eaton et al. 1995).

A total of 224 records were obtained for COD, including 165 records from high urban areas other than roads and roofs. The observed range extends from 5 mg/L for an urban catchment in Zhuhai, China, to 1031 mg/L for a commercial area in Burnaby, Canada.

COD concentrations from all land uses follow the log-normal distribution (Figure 16). Basic statistics describing the concentrations of COD from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 17.

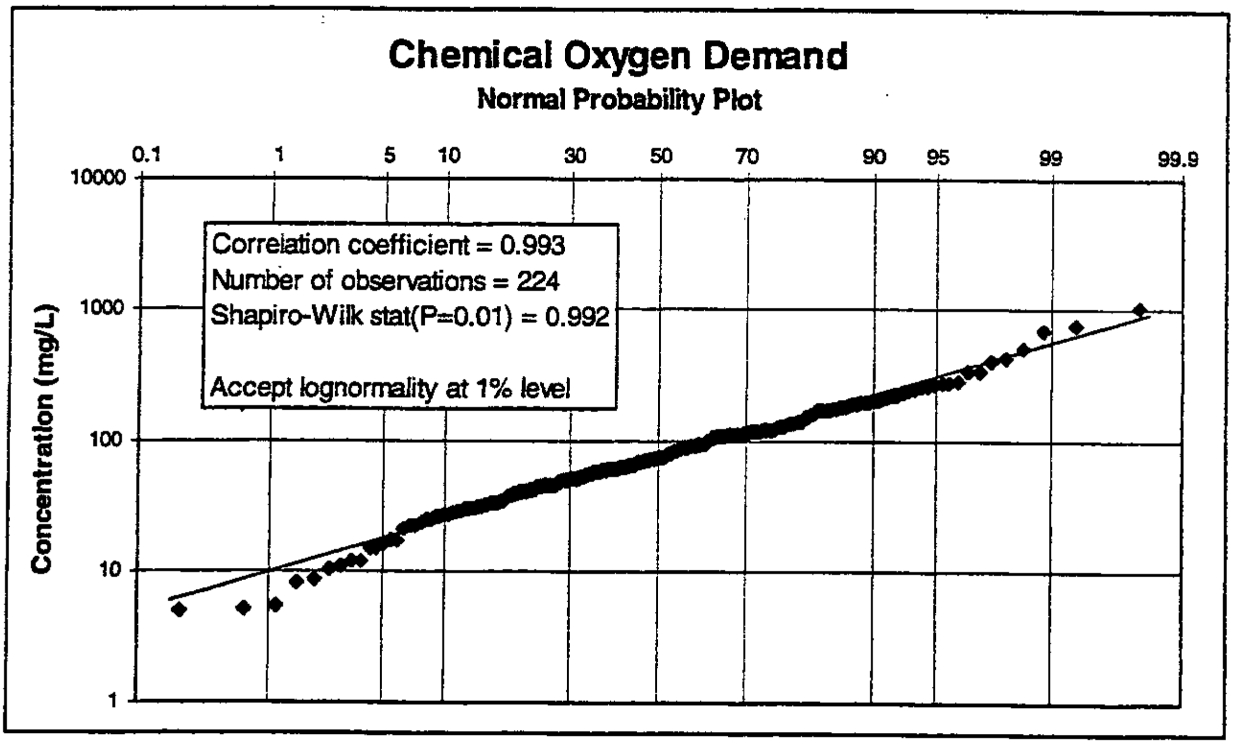

Figure 16. Chemical Oxygen Demand Normal Probability Plot

### 3.4.1 Roads

There are no significant differences in COD concentrations between the three roads subgroups. As usual, the Mt. St. Helens subgroup is excluded from analysis, to provide consistency across all water quality parameters. The mean COD concentration from both high urban and low urban roads is almost identical to that from all high urban areas excluding roads and roofs. There is a significant negative relationship between COD from roads and mean annual rainfall - higher annual rainfall is associated with lower mean concentration (Figure 18).

### 3.4.2 High Urban

The mean COD concentration from industrial areas is about twice that from all other high urban areas and all roads (Figure 17). However the industrial sample size is small, which decreases the importance of the observation. There are no other significant differences in the high urban or roads groups. The characteristic negative relationship with mean annual rainfall is again present (Figure 19), and is virtually identical to the relationship found in the roads group. No relationships were found with either percent impervious or population density.

### 3.4.3 Low Urban

The mean COD concentration from all low urban areas is about half of that from all high urban areas and roads, which is a highly significant difference, although no significant differences were found between the subgroups of low urban land use. The relationship with annual rainfall, while not itself significant, is very similar in gradient to the significant relationships found in the roads and high urban groups.

### 3.4.4 Summary

Elevated COD concentration in runoff appears to be associated with all kinds of roads and high urban land use, with a further increase in the case of industrial use. The lack of any difference between high urban and low urban roads suggests that a major source must be associated with the roads themselves, rather than the surrounding areas.

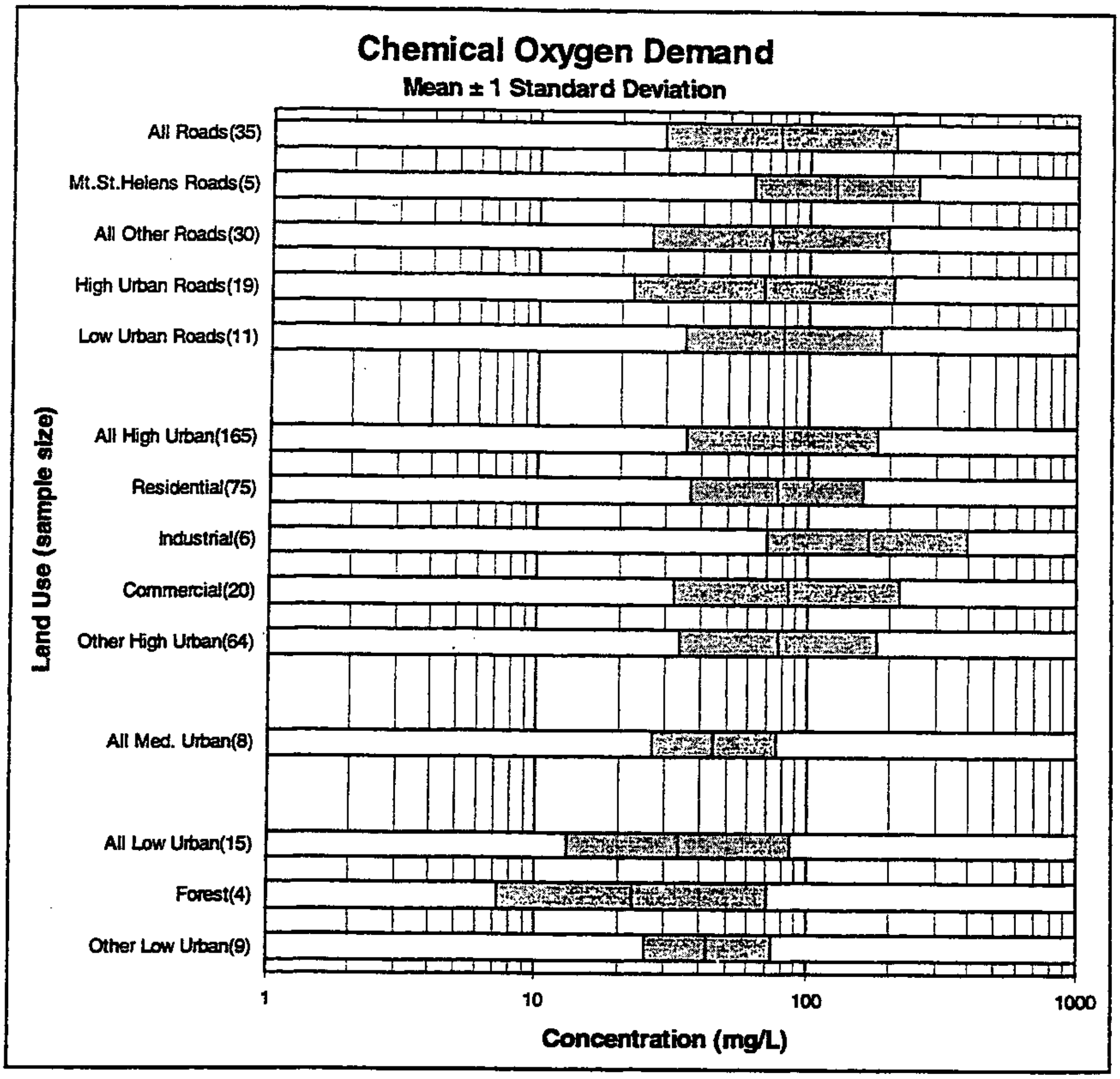

Figure 17. Chemical Oxygen Demand vs Land Use

Summary statistics are listed in Table 4 for the distinct land use subgroups identified.

Table 4. Chemical Oxygen Demand Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 30 | 1.86 | 0.44 | 109 | 72 | 99 |
| Industrial | 6 | 2.22 | 0.38 | 223 | 166 | 178 |
| Non-ind. high urban | 159 | 1.89 | 0.35 | 108 | 78 | 73 |
| Low urban | 15 | 1.53 | 0.41 | 47 | 34 | 36 |

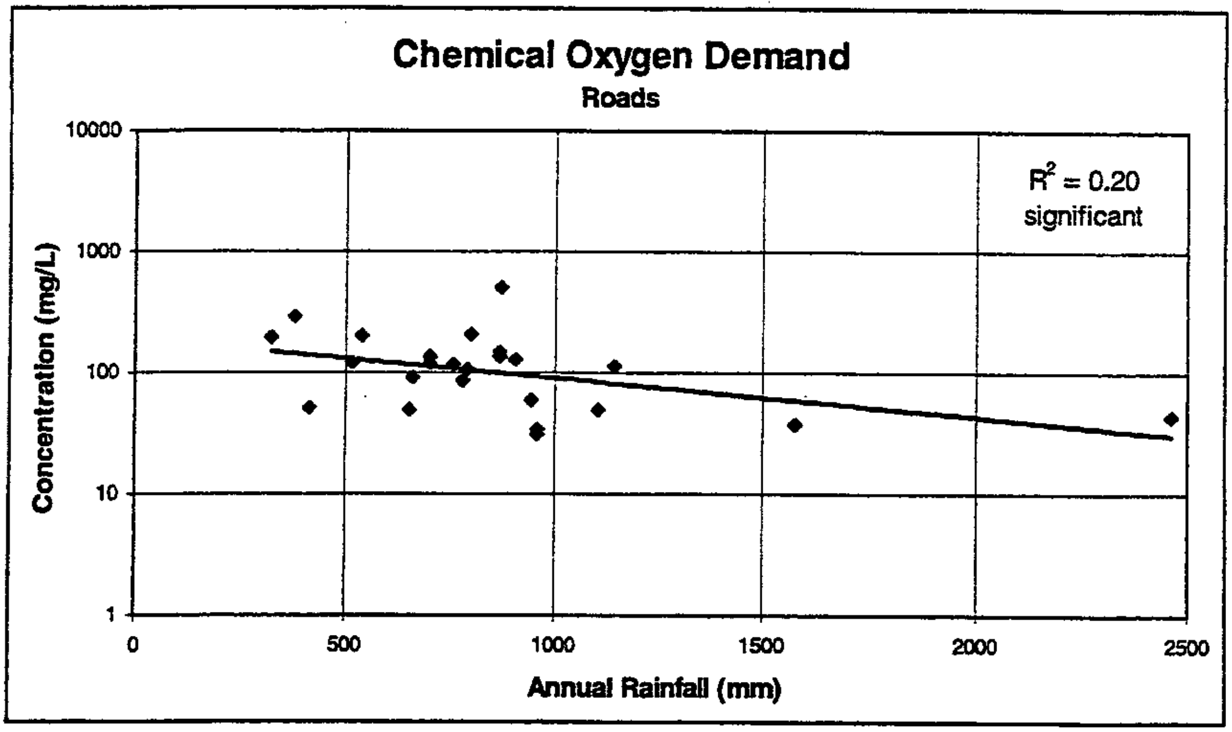

Figure 18. Chemical Oxygen Demand (Roads) vs Annual Rainfall

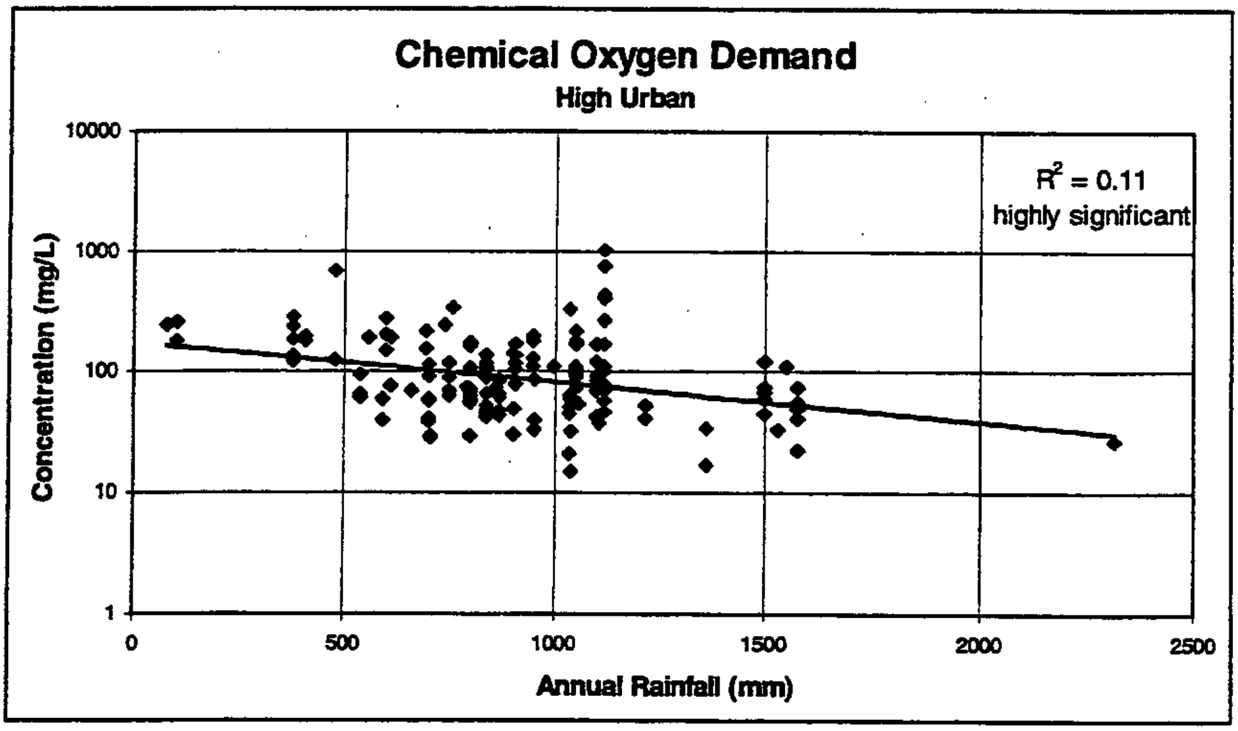

Figure 19. Chemical Oxygen Demand (High Urban) vs Annual Rainfall

## 3.5 Biochemical Oxygen Demand

Biochemical oxygen demand, or BOD, is an empirical measure of the relative oxygen requirements of polluted waters. A five day test is standard, although other durations have also been used. The oxygen demand arises from the biochemical degradation of organic material, the oxidation of inorganic material such as sulphides and ferrous iron, and possibly the oxidation of reduced forms of nitrogen (Eaton et al. 1995).

A total of 154 records were obtained for BOD, including 127 records from high urban areas other than roads and roofs. The observed range extends from 1.1 mg/L for a forested catchment near Asheville, North Carolina, to 146 mg/L for an urban catchment in Detroit, Michigan.

BOD concentrations from all land uses approximately follow the log-normal distribution (Figure 20). Basic statistics describing the concentrations of BOD from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 21.

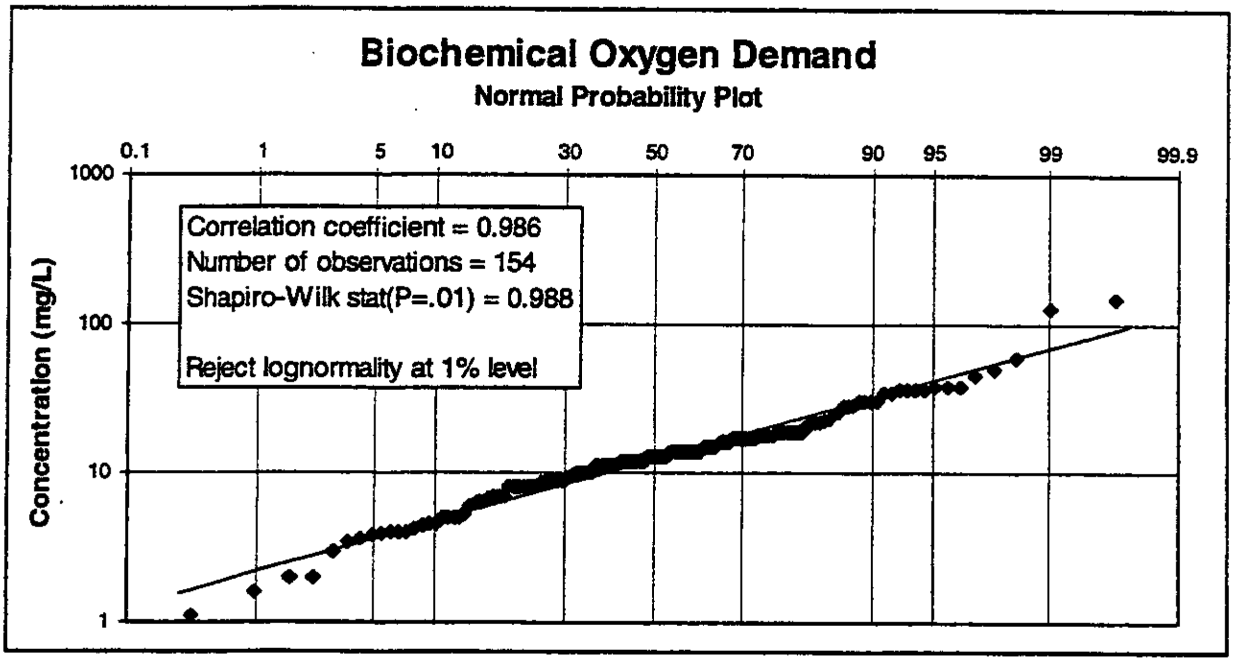

Figure 20. Biochemical Oxygen Demand Normal Probability Plot

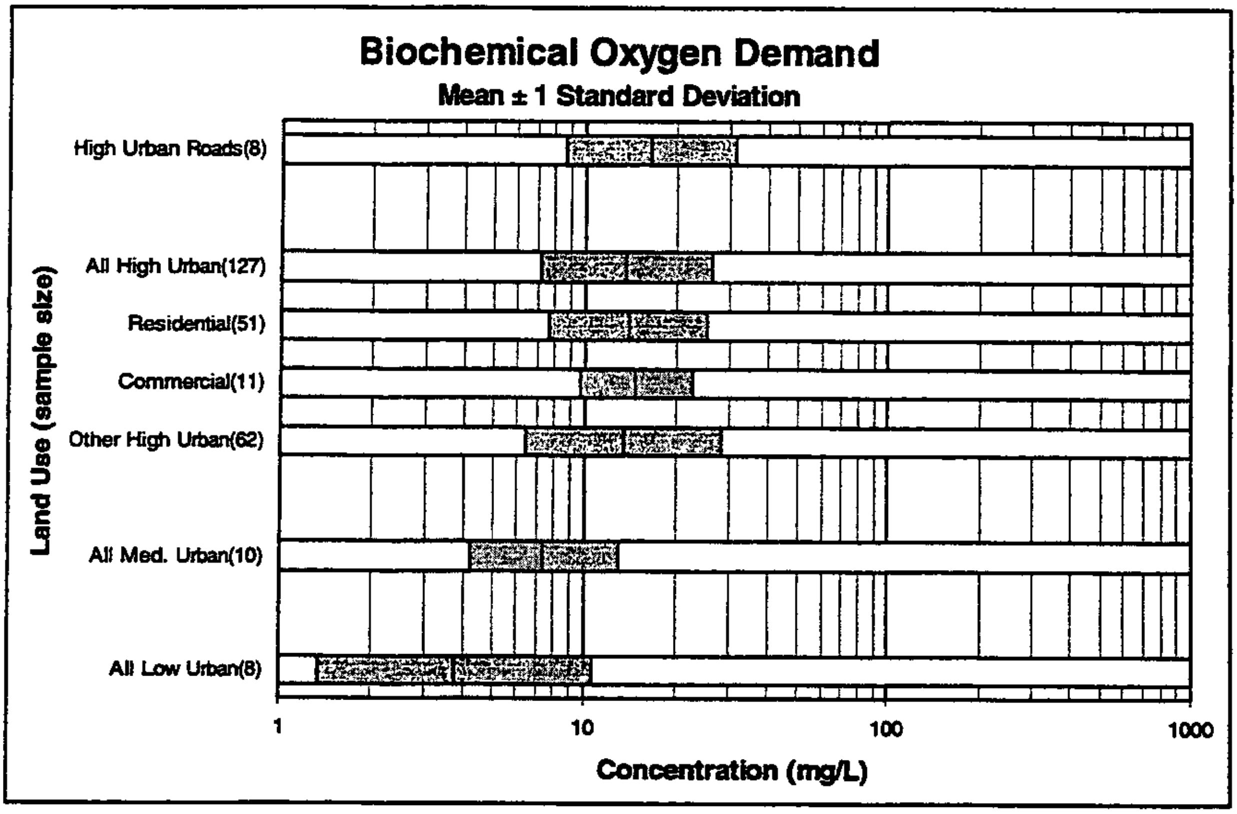

Figure 21. Biochemical Oxygen Demand vs Land Use

### 3.5.1 High Urban

There are no significant differences between any subgroups of high urban land use excluding roads and roofs. A relationship between BOD concentration and population density is highly significant, but arguably not very robust, as it depends to a large extent on just three readings (Figure 22). Higher population density is associated with higher BOD. No significant relationships were found between BOD and mean annual rainfall or percent impervious.

### 3.5.2 Summary

The mean BOD concentration from high urban roads is similar to that from all high urban areas excluding roads and roofs. The mean BOD from all low urban areas is less than one third of that from high urban areas or roads, which is a highly significant difference. Medium urban areas, which in this case have a larger sample size than low urban areas, occupy an intermediate position.

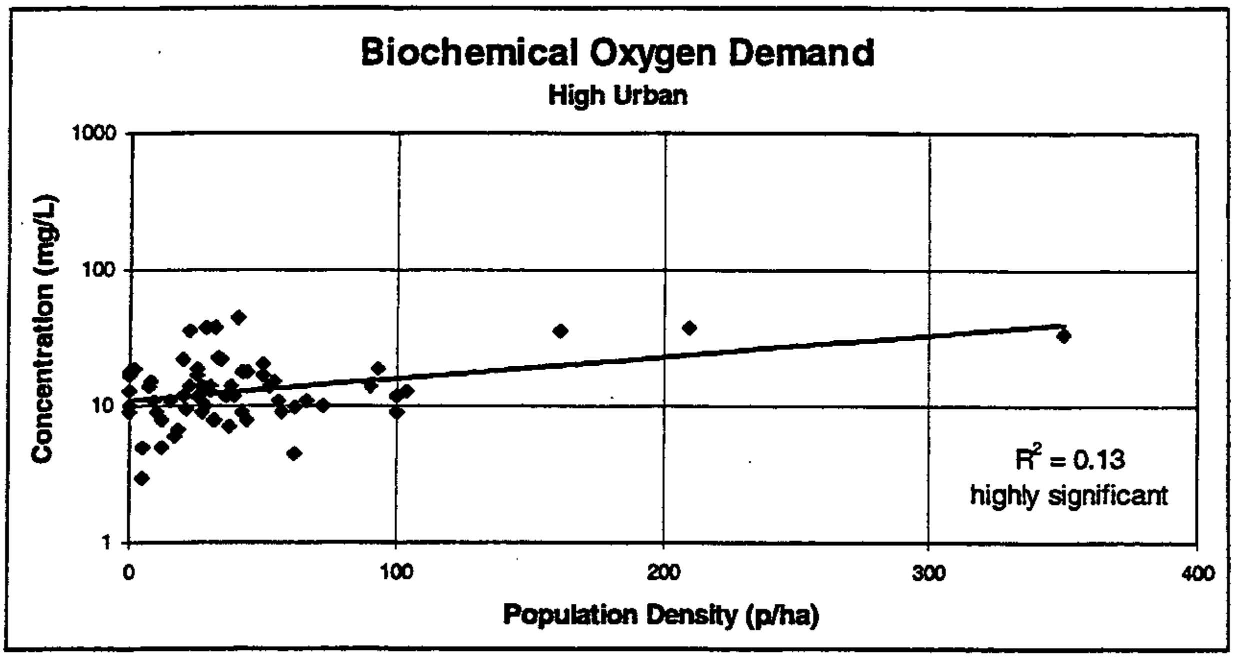

Figure 22. Biochemical Oxygen Demand (High Urban) vs Population Density

Mean BOD concentration increases with increasing urbanisation, although the type of urbanisation (land use subgroup) does not appear to be important. Associated with this is an increase in BOD with increasing population density.

Summary statistics are listed in Table 5 for the distinct land use subgroups identified.

Table 5. Biochemical Oxygen Demand Summary Statistics

| Subgroup | Sample | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | size | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| High urban roads | 8 | 1.22 | 0.28 | 20 | 17 | 16 |
| High urban | 127 | 1.14 | 0.28 | 18 | 14 | 14 |
| Low urban | 8 | 0.58 | 0.45 | 6.2 | 3.8 | 3.0 |

## 3.6 Oil & Grease

Oil & grease is a composite of possibly thousands of organic chemicals with different properties and toxicities (Makepeace et al. 1995). It is defined as any material soluble in an organic extracting solvent, but no solvent is completely selective for oils and greases only, and four different solvents have been preferred over the period covered by the collated data (Eaton et al. 1995). Oil & grease concentrations should therefore be treated as indicative measures, rather than analytically exact determinations.

Sources of oil & grease include food processing and preparation, operation and maintenance of vehicles and machinery, and natural compounds leached from vegetation and plant litter.

A total of 41 records were obtained for oil & grease, including 33 records from high urban areas other than roads and roofs. The observed range extends from 0.5 mg/L for a forested catchment near Asheville, North Carolina, to 200 mg/L for motorway runoff in London, England.

Oil & grease concentrations from all land uses closely follow the log-normal distribution (Figure 23). Basic statistics describing the concentrations of oil & grease from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 24.

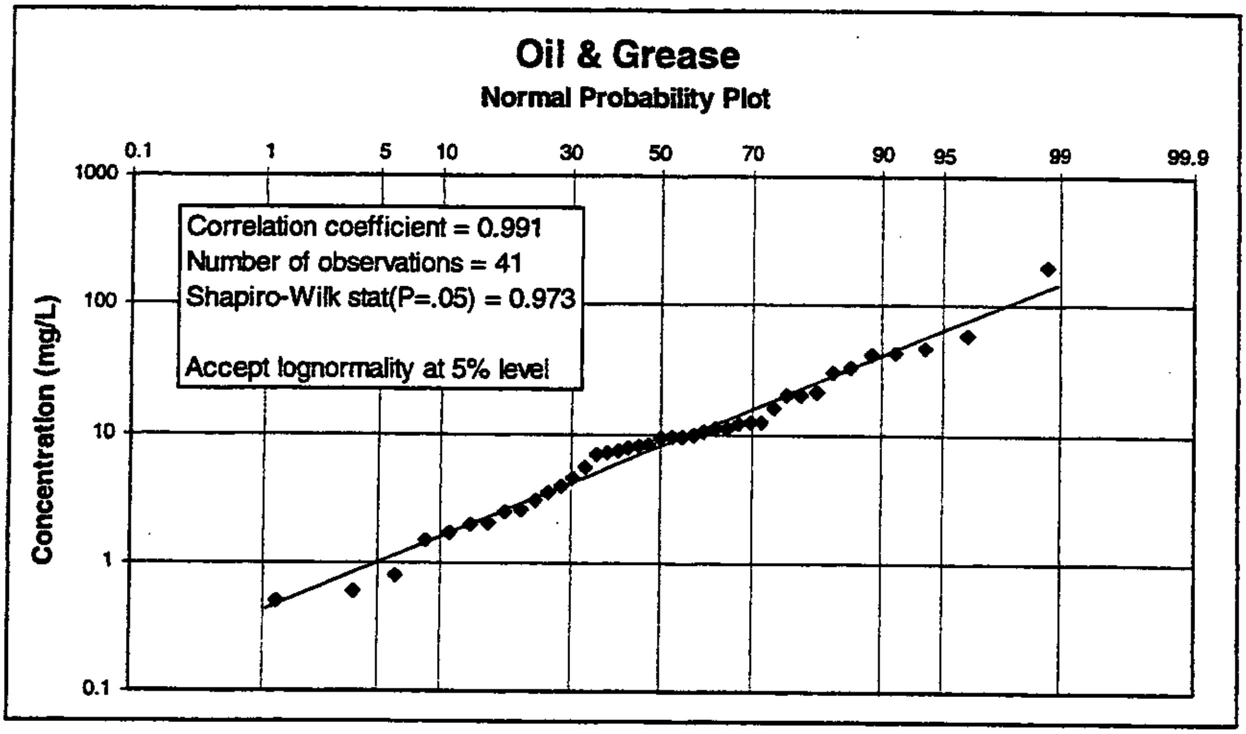

Figure 23. Oil & Grease Normal Probability Plot

### 3.6.1 Roads

With only two high urban roads and three low urban roads, the sample is too small for formal comparisons to be useful. It can be noted, however, that the two high urban roads produced the two highest oil & grease concentrations in the data set, and hence had the highest mean of any group or subgroup. This may be related to higher traffic density and lower speeds in built up areas, rather than to any direct effect of the surrounding land use.

### 3.6.2 High Urban

No significant concentration differences were found between the subgroups of high urban land use, or between all high urban land use and all roads taken as a single group. Nor were any significant relationships found between oil & grease concentration and mean annual rainfall or percent impervious. This does not mean that the relationships are definitely absent. It means only that we could not detect them with confidence in this sample of data. Significant effects become increasingly difficult to detect as sample sizes become smaller. Because of this, the lack of a significant effect is not necessarily noted in the text.

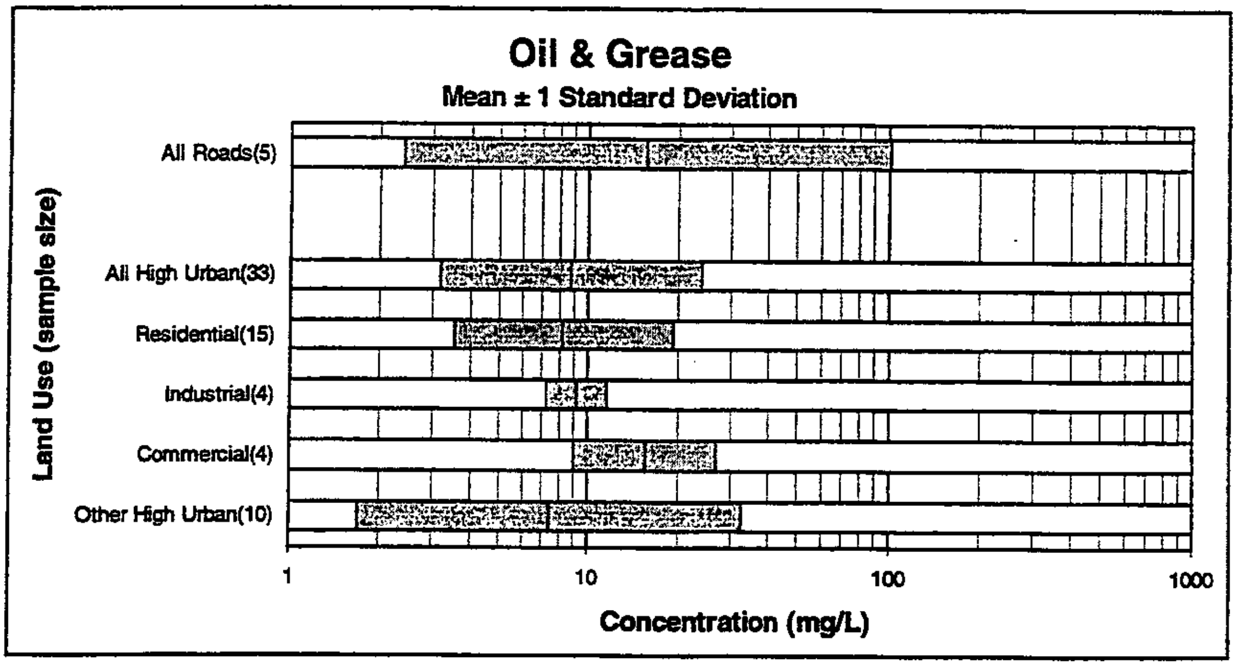

Figure 24. Oil & Grease Concentration vs Land Use

### 3.6.3 Low Urban

As with the roads group, there are too few data in the low urban and medium urban categories for formal comparisons. But again an apparent effect can be informally noted, since the two low urban sites account for the two lowest oil & grease concentrations in the data set.

### 3.6.4 Summary

Statistical analysis of oil & grease concentrations is hampered by lack of data in all groups other than high urban. Even so, there is an apparent trend from low urban (low concentration) through high urban to high urban roads (high concentration). Given the known sources and likely pathways of this contaminant, the apparent trend probably indicates a real effect rather than a chance occurrence in the data.

Summary statistics are listed in Table 6 for the distinct land use subgroups identified.

Table 6. Oil & Grease Summary Statistics

| Subgroup | Sample | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | size | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 5 | 1.19 | 0.82 | 55 | 15 | 7.0 |
| High urban | 33 | 0.94 | 0.44 | 13 | 8.7 | 9.5 |

## 3.7 Total Organic Carbon

Total organic carbon is a measure of all carbon atoms covalently bonded in organic molecules (Eaton et al. 1995). To a large extent it reflects the level of natural organic substances, or humic materials, in the water sample (World Health Organization 1984).

A total of 29 records were obtained for total organic carbon, including 23 records from high urban areas excluding roads and roofs. The observed range extends from 4.2 mg/L from a tributary of the Stamford Canal in Singapore, to 110 mg/L from urban streets in San Jose.

Total organic carbon concentrations from all land uses follow the log-normal distribution (Figure 25). Basic statistics describing the concentrations of total organic carbon from various land uses (in log coördinates) are tabulated in Appendix B, while means and standard deviations are shown as bar graphs in Figure 26.

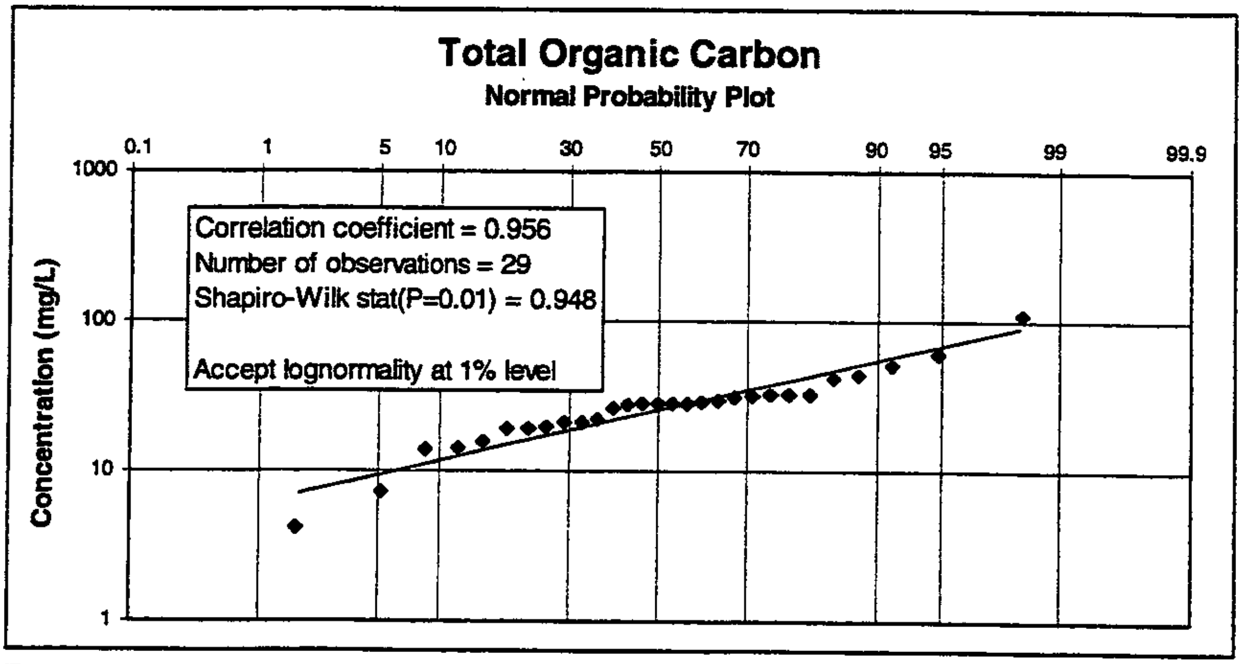

Figure 25. Total Organic Carbon Normal Probability Plot

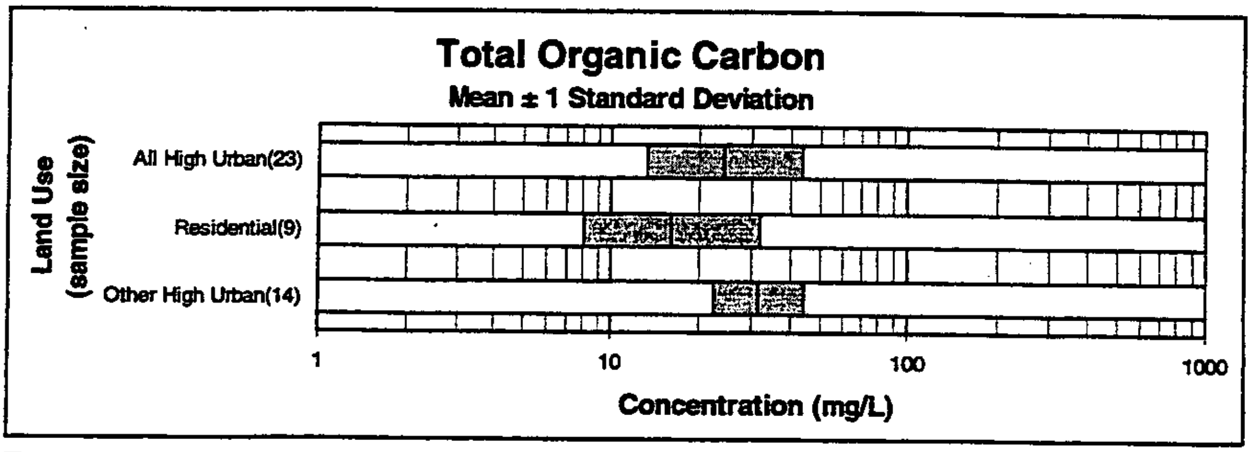

Figure 26. Total Organic Carbon Concentration vs Land Use

### 3.7.1 Roads

Although the sample is too small to carry much weight, we can note informally that the three recorded concentrations from roads all fall in the upper half of the observed range from all land uses.

### 3.7.2 High Urban

In the high urban group, total organic carbon concentration from residential areas is typically about half of that from other high urban areas (Figure 26), which is a significant difference. There is a highly significant relationship between total organic carbon concentration and mean annual rainfall, with higher rainfall giving lower concentrations (Figure 27). Increasing the annual rainfall by 500 mm almost halves the most likely concentration of total organic carbon.

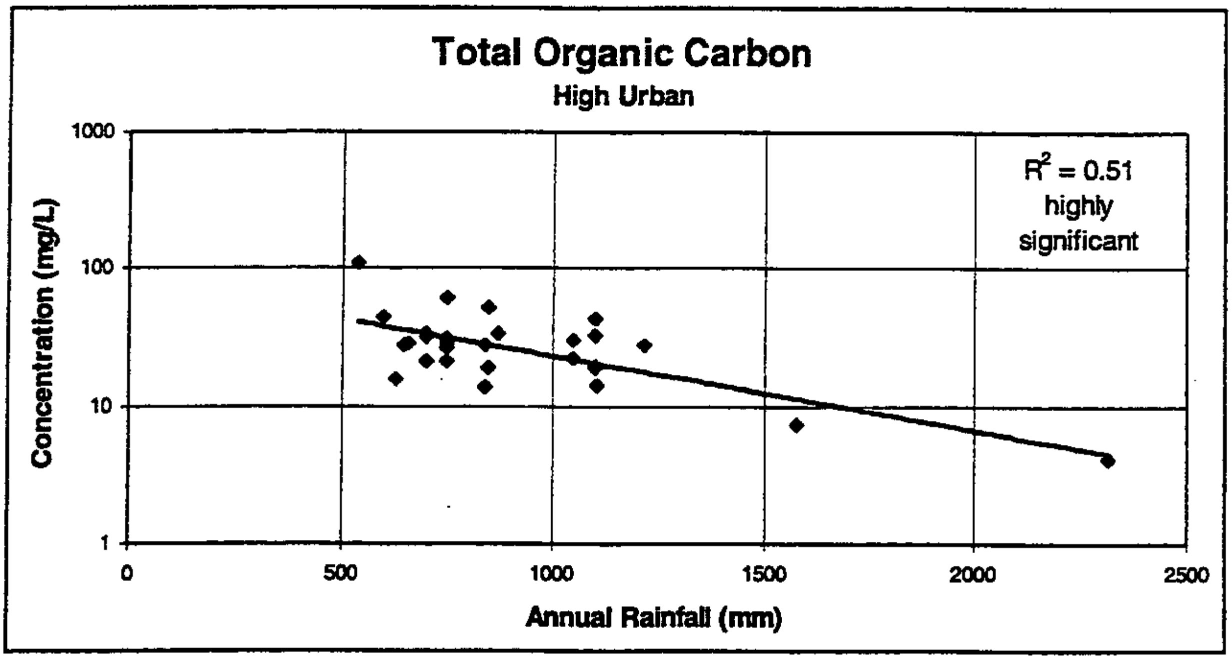

Figure 27. Total Organic Carbon Concentration (High Urban) vs Annual Rainfall

### 3.7.3 Summary

Summary statistics are listed in Table 7 for the distinct land use subgroups identified.

Table 7. Total Organic Carbon Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Residential | 9 | 1.20 | 0.30 | 19 | 16 | 19 |
| Other high urban | 14 | 1.50 | 0.15 | 33 | 32 | 30 |

## 3.8 pH

The pH of a solution is a measure of hydrogen ion activity, which in very dilute solution is approximately the same as hydrogen ion concentration. The number quoted is actually the negative base 10 logarithm of the hydrogen ion activity. A pH of 7.0 is neutral at normal temperatures, lower pH is acidic, and higher pH is basic (Eaton et al. 1995). The pH of most raw water sources lies within the range 6.5 to 8.5 (World Health Organization 1984).

The importance of pH in water quality lies mainly in its effect on other quality parameters, and on chemical reactions in solution. Its effect on solubility of a wide range of metallic contaminants is of particular significance.

A total of 76 records were obtained for pH, including 48 records from high urban areas other than roads and roofs. The observed range extends from 4.1 for a tarred sawmill roof in Washington state to 8.3 for an urban drain in Sydney, Australia.

The pH of runoff from all land uses other than roofs closely follows the normal distribution (Figure 28). It is the only quality parameter in this study which is not approximately log-normal. Interestingly, pH is itself a log-based index. Basic statistics describing the pH of runoff from various land uses are tabulated in Appendix B, while means and standard deviations are shown as bar graphs in Figure 29.

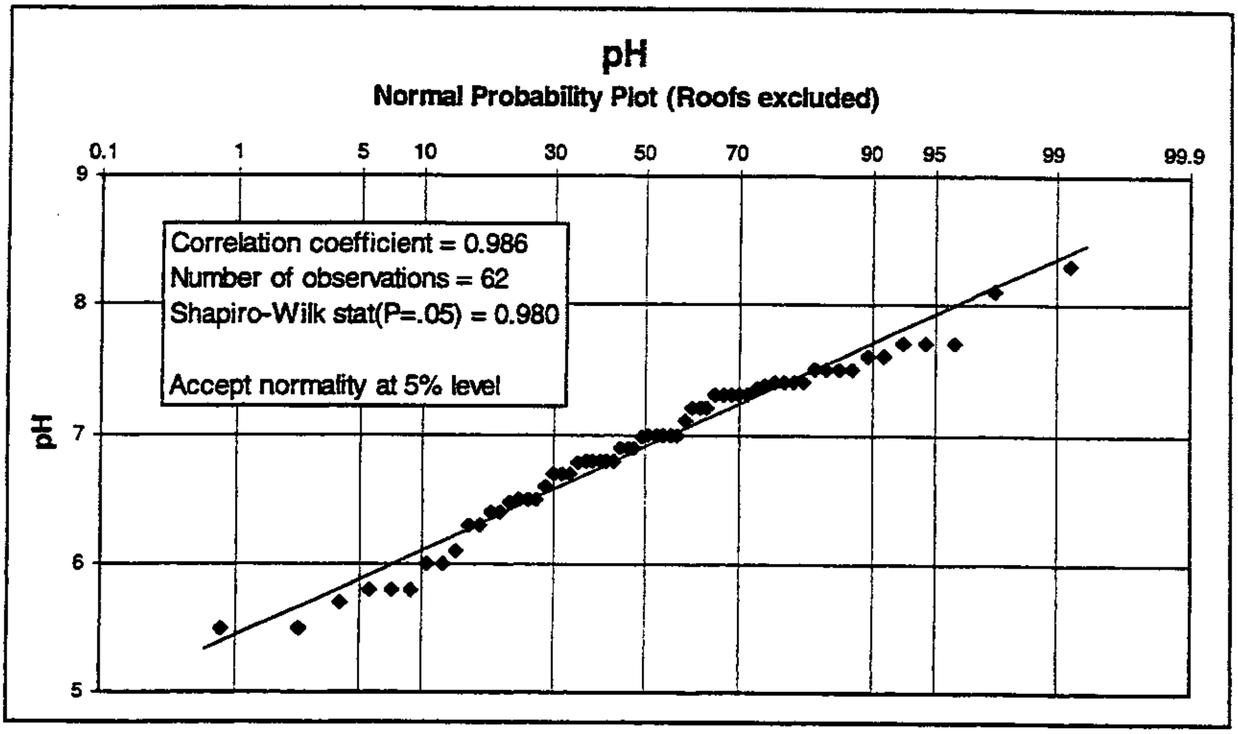

Figure 28. pH Normal Probability Plot

### 3.8.1 Roofs

The mean pH of roof runoff is more than a full unit lower (i.e. more acidic) than that of any other land use in this study. The lowest readings of all (average pH 4.2) come from three tarred paper or tarred felt roofs.

### 3.8.2 High Urban

There are no significant differences in pH between any of the subgroups of high urban land use. Nor, for that matter, between roads or low urban land use and any subgroup of high urban. All of these land uses exhibit mean pH close to the neutral value of seven. No significant relationship was found between pH and mean annual rainfall in the high urban group.

### 3.8.3 Summary

The only notable effect of land use is for roof runoff, which has a mean pH significantly lower than that of any other land use, but somewhat higher than that of rainfall. The pH of rainfall (sampled before striking a roof or the ground) averaged 5.0 at the 42 sites in this study where it was measured. The effect is evidently related to the type of roofing material, since tarred roofs show distinctive behaviour, but an effect of contact time may also be present. Roof catchments in this study are typically much smaller than ground level catchments, and this is reflected in correspondingly shorter times of concentration.

Summary statistics are listed in Table 8 for the distinct land use subgroups identified.

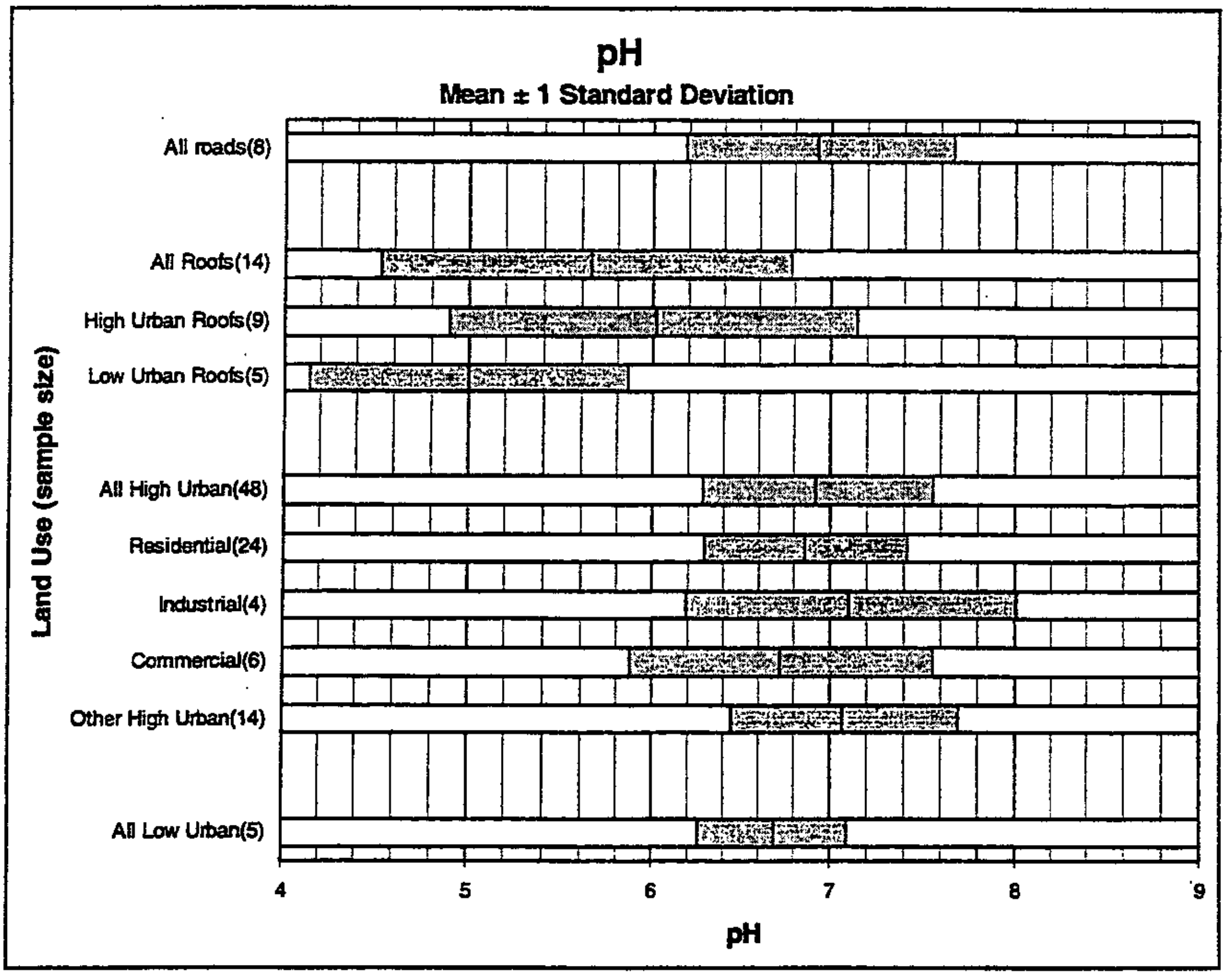

Figure 29. pH vs Land Use

Table 8. pH Summary Statistics

| Subgroup | Sample size | Untransformed Data (mg/L) | | |
|---|---|---|---|---|
| | | Mean | Std. Dev. | Median |
| Roads | 8 | 6.9 | 0.7 | 7.0 |
| Roofs | 14 | 5.7 | 1.1 | 5.9 |
| High urban | 48 | 6.9 | 0.6 | 7.0 |
| Low urban | 5 | 6.7 | 0.4 | 6.7 |

## 3.9 Turbidity

Turbidity is the cloudiness in water caused by the presence of suspended matter such as clay, silt, colloidal organic particles, plankton, and other microscopic organisms (World Health Organization 1984). It affects light penetration into a water body, and interferes with disinfection in situations where water treatment is required.

Turbidity is measured by the scattering or extinguishment of light passing through the sample. Measurements using the nephelometric method are based on light scattering, and are expressed in Nephelometric Turbidity Units (NTU). Formazin Turbidity Units (FTU) is an alternative term of identical meaning. This is the current method of choice. Measurements using older methods based on light extinguishment are expressed in Jackson Turbidity Units (JTU). The two scales are broadly similar but not identical (World Health Organization 1984).

Altogether 27 records were obtained for turbidity, including 16 records from high urban areas other than roads and roofs. The observed range extends from 0.7 units from a rural concrete tile roof in Armidale, Australia, to 1129 units from an urbanising catchment in Lincoln, Nebraska.

Turbidity from all land uses closely follows the log-normal distribution (Figure 30). Basic statistics describing turbidity from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 31. The only land use groups with useful sample sizes are roofs (mostly high urban) and high urban areas excluding roads and roofs (mostly residential).

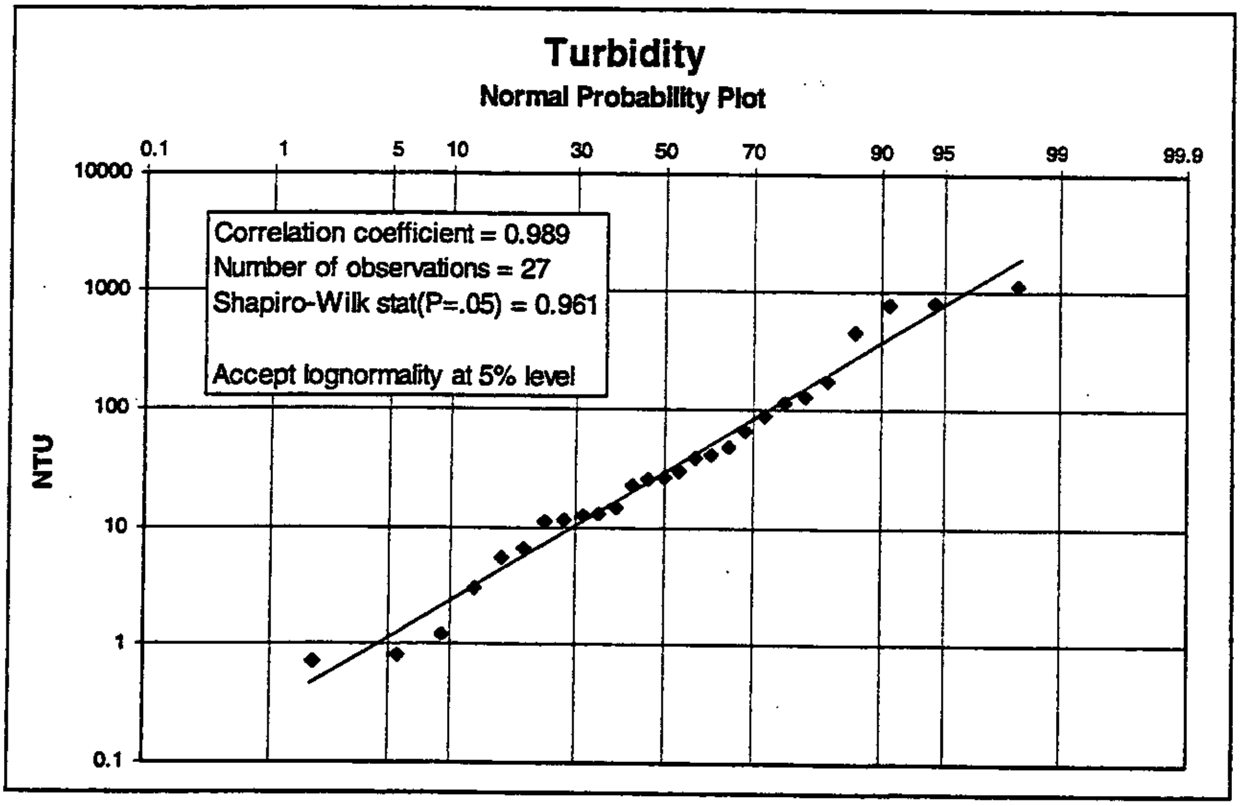

Figure 30. Turbidity Normal Probability Plot

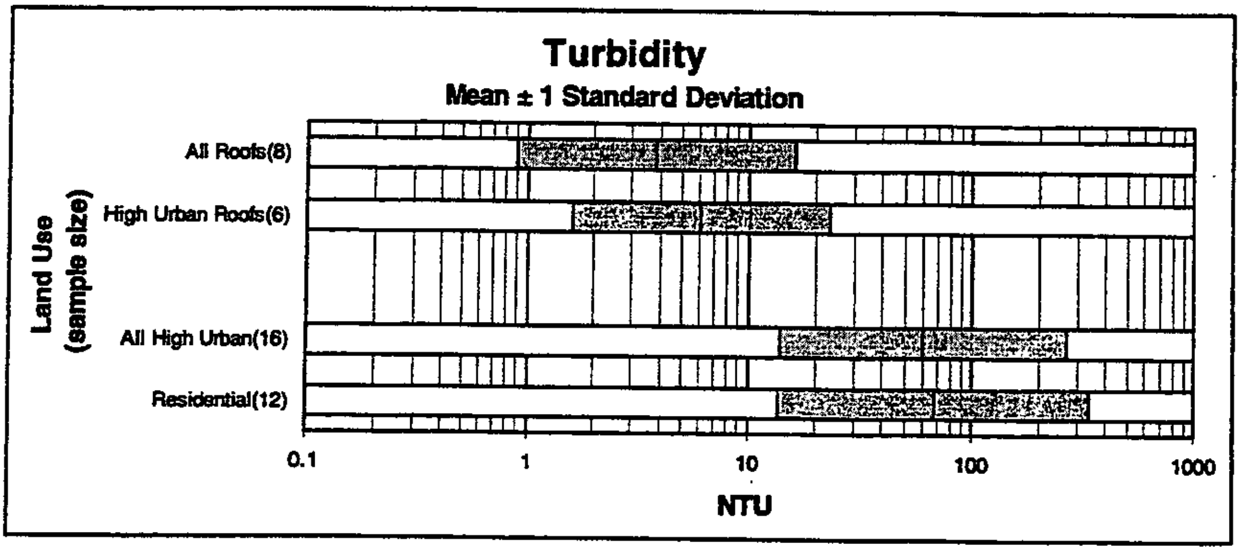

Figure 31. Turbidity vs Land Use

### 3.9.1 Summary

The mean turbidity of roof runoff is less than one tenth that of runoff from other urban land uses, which is a highly significant difference. This suggests that the main sources of turbidity are concentrated at ground level, rather than in the atmosphere. No relationship between turbidity levels and annual rainfall is evident in this sample.

Summary statistics are listed in Table 9 for the distinct land use subgroups identified.

Table 9. Turbidity Summary Statistics

| Subgroup | Sample size | Log Transformed Data |  | Untransformed Data (mg/L) |  |  |
|---|---|---|---|---|---|---|
|  |  | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roofs | 8 | 0.58 | 0.63 | 9.1 | 3.8 | 4.2 |
| High urban | 16 | 1.78 | 0.64 | 172 | 60 | 37 |

## 3.10 Total Lead

Lead is a cumulative general metabolic poison which in animals becomes concentrated mainly in the bones (World Health Organization 1984). Lead bioaccumulates in animals, plants, and bacteria, and has been identified as an important contaminant of concern in stormwater research. Environmental and drinking water guidelines are frequently exceeded in urban stormwater. Lead in stormwater runoff is mostly associated with suspended solids (Makepeace et al. 1995). The most commonly measured components of total lead are dissolved and particulate lead, although speciation schemes that distinguish the bioavailable and potentially toxic forms have also been used to specify the components of total lead (Morrison et al. 1984; Flores-Rodriguez et al. 1993).

The main source of lead in urban runoff is from petrol additives. Other sources include tyres (Makepeace et al. 1995), industrial emissions, lead water pipes and soldered joints (Eaton et al. 1995), plastic pipes and guttering (Good 1993), paints, lead roofs, and flashing.

A total of 275 records were obtained for total lead, including 181 records from high urban areas other than roads and roofs. The observed range extends from 0.0005 mg/L for two rural roofs near Armidale, Australia, to 2.74 mg/L from a residential area in Baltimore, Maryland.

With all data treated as a single group, the fit to the log-normal distribution is not good (Figure 32). When the four major land use groups are taken separately, roads, roofs, and low urban fit satisfactorily, while high urban exhibits several low outliers. Three of these outliers are from the same study (Soderlund & Lehtinen 1972). Comparison of Table 1 and Figure 7 in the source document suggests that the tabulated values may indeed be too low, probably by a factor of 1000 (i.e. misprinted unit). With these three outliers removed, the high urban land use group also fits the log-normal distribution (Figure 33).

Basic statistics describing the concentrations of total lead from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 34.

### 3.10.1 Roads

There are no significant differences in lead concentrations between subgroups in the roads group of land uses. For consistency with the other quality parameters, the Mt. St. Helens group has been excluded from further analysis, although there is no trace of any difference in behaviour. Evidently the eruption neither produced lead, nor affected the availability of lead from other sources. There is also no significant difference between high urban and low urban roads, despite a moderate sample size.

There is no significant correlation between lead concentration from roads and annual rainfall. A tendency for concentration to increase with percent impervious is not significant for roads (Figure 35), although the trendline is almost identical to a significant relationship for high urban land use (Figure 37), suggesting that similar processes are involved.

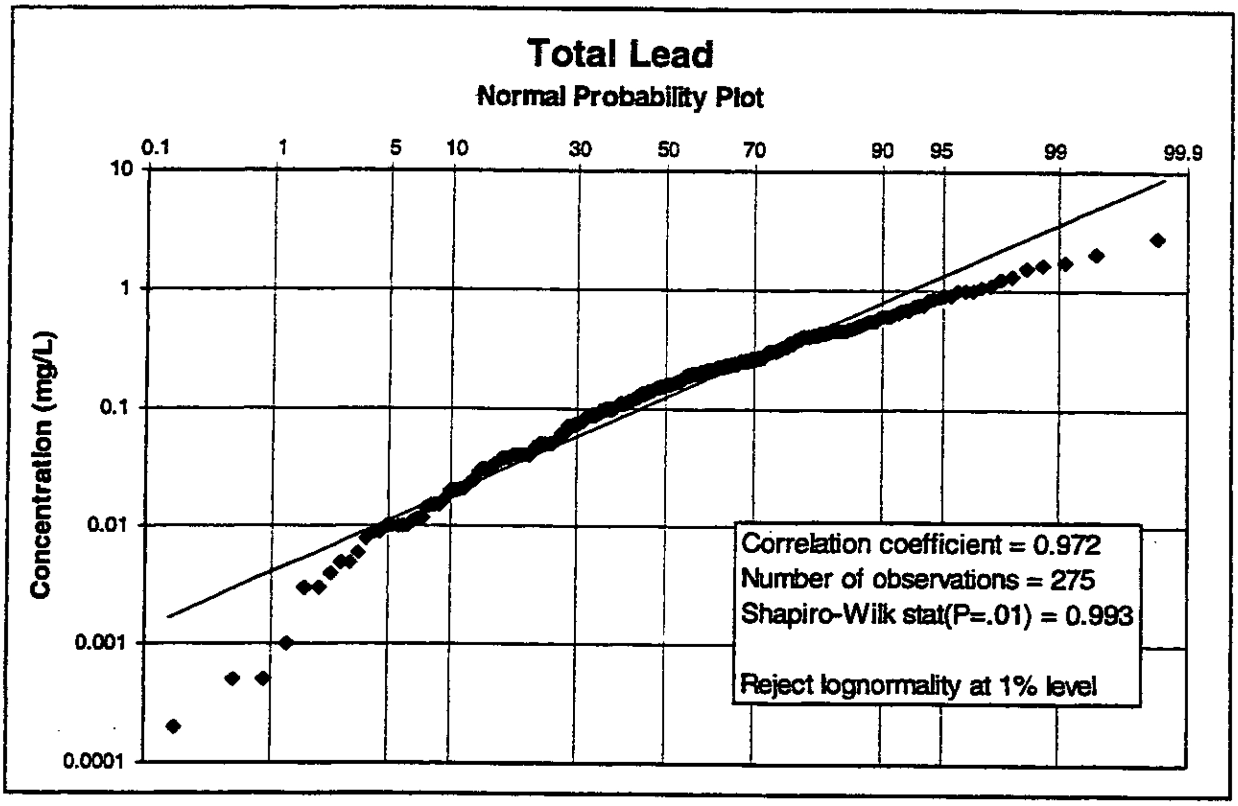

Figure 32. Total Lead Normal Probability Plot (All Data)

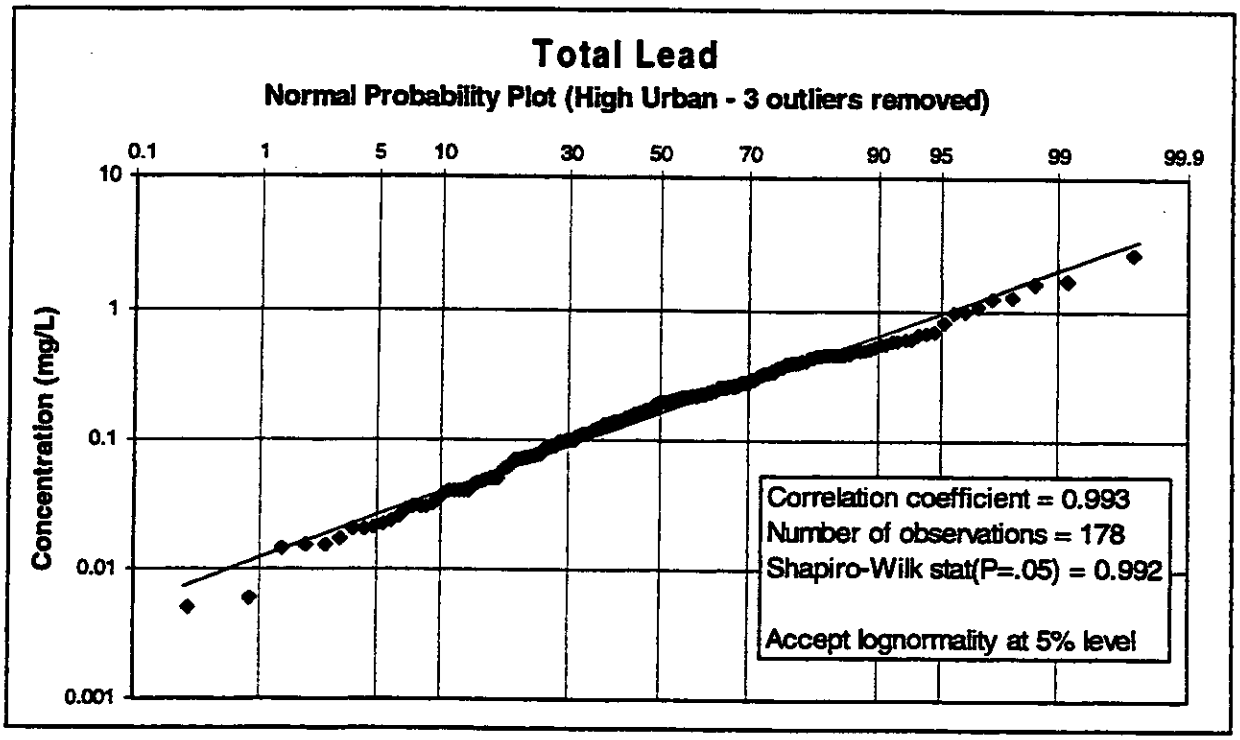

Figure 33. Total Lead Normal Probability Plot (High Urban)

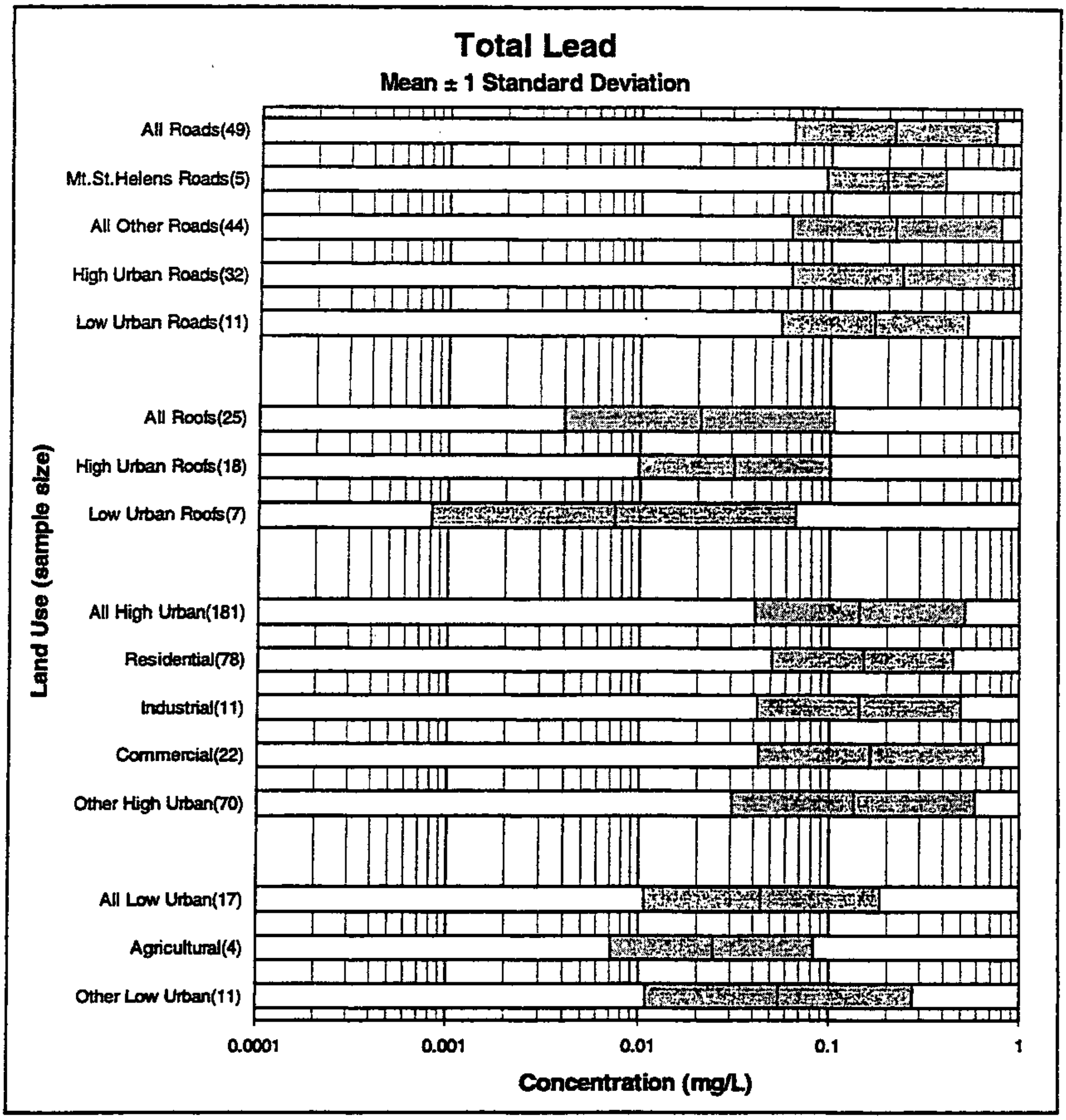

Figure 34. Total Lead Concentration vs Land Use

There is a highly significant relationship between lead concentration and traffic density in vehicles per day (Figure 36). Above about 100,000 vehicles per day all concentrations in this sample lie near 1 mg/L, at the upper end of the observed range. At lower traffic densities concentrations cover a wider range, typically between 0.01 and 1 mg/L. This relationship supports the claim that vehicle emissions are a major source of lead.

### 3.10.2 Roofs

Based on all available data, there is no significant difference in lead concentrations from high urban and low urban roofs. It is worth noting, however, that the wide standard deviation of the low urban roofs data in Figure 34 is caused by a single high reading attributed to plastic guttering (Good 1993). The data point is retained, as this is a valid source of lead in roof water, but otherwise the lead concentration from low urban roofs would have been almost an order of magnitude lower than that from high urban roofs.

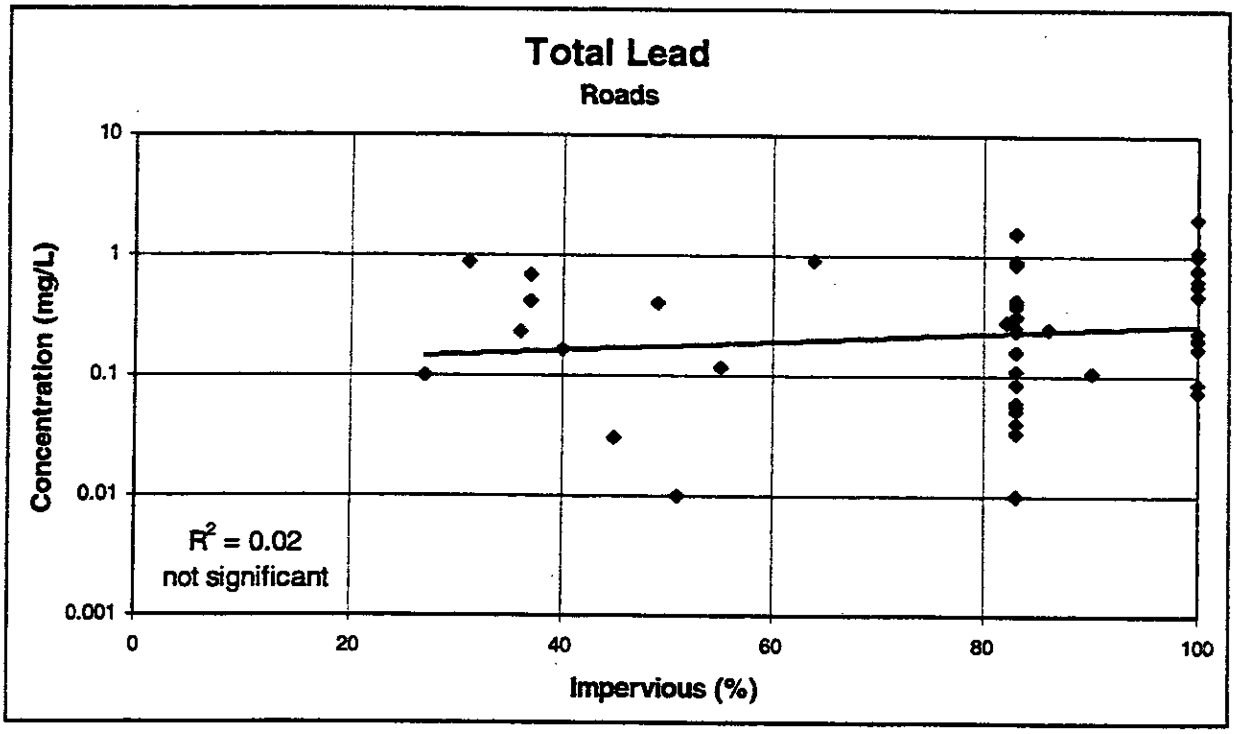

Figure 35. Total Lead Concentration (Roads) vs Percent Impervious

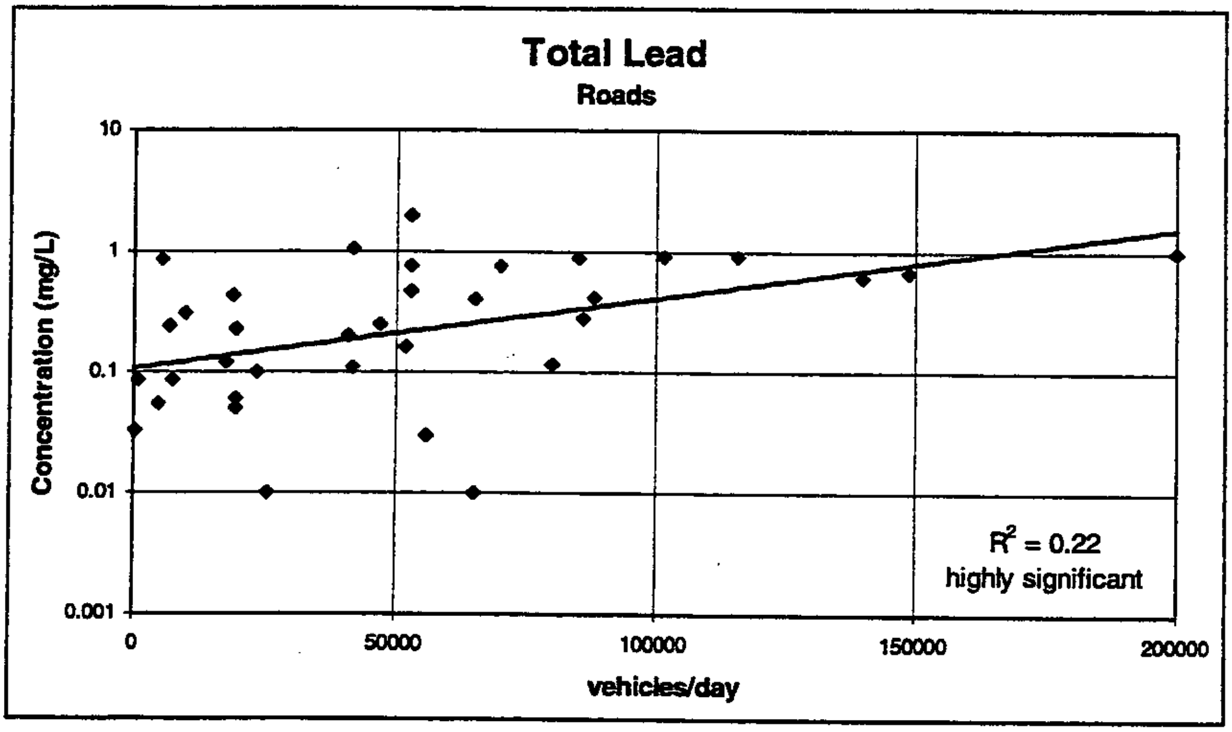

Figure 36. Total Lead Concentration (Roads) vs Traffic Density

The average lead concentration from roofs is about one tenth of that from all roads, and about one eighth of that from high urban areas, but is not significantly different from mean low urban concentrations. The processes that result in low suspended solids concentrations from roofs (Section 3.1.2) can be applied equally to lead, which is generated largely below roof level, and occurs mainly in particulate form. Dissolution of lead roofs and flashing, although possible, does not appear to be a major problem in practice.

### 3.10.3 High Urban

There are no significant differences in total lead concentrations between any subgroups of the high urban group (181 records). But treated as a single group, high urban lead concentrations are significantly higher than low urban concentrations. This agrees well with the NURP study (Athayde et al. 1983), which found that only the urban open and nonurban group was significantly different.

High urban lead concentrations correlate significantly with percent impervious (Figure 37), and the trendline is almost identical to that for roads. A higher percentage of impervious area is associated with higher lead concentrations in runoff. Presumably more impervious area equates to more vehicle-related source area, and relatively less dilution from non-source areas. No significant relationships were found between lead concentration and annual rainfall, catchment area, or population density.

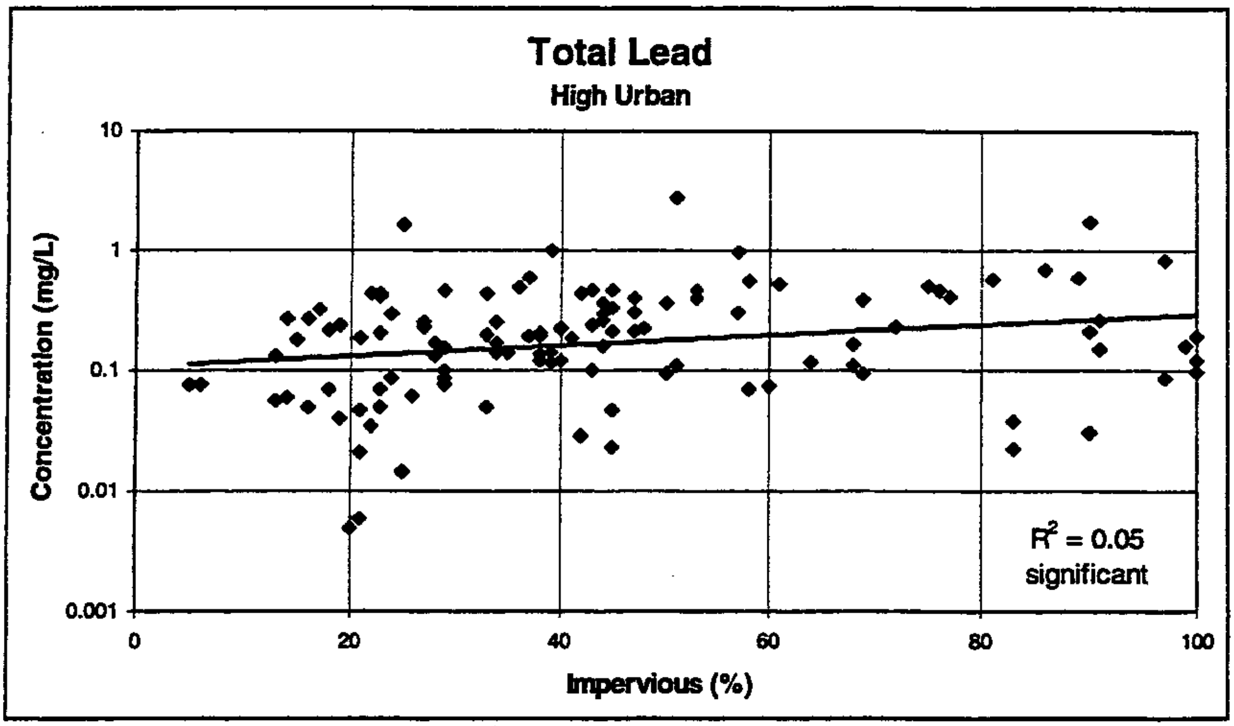

Figure 37. Total Lead Concentration (High Urban) vs Percent Impervious

### 3.10.4 Low Urban

Since the sample size for low urban land use is small (17 records), further division into subgroups is not very informative. The mean lead concentration from all low urban land use is significantly lower than that from all roads and all high urban, but is not significantly different from that for roofs. No significant relationship between concentration and annual rainfall was detected.

### 3.10.5 Summary

All the results described above are consistent with vehicles being the main source of lead in runoff. Roads give the highest concentrations, regardless of the urbanisation of the surrounding area, and higher vehicle densities give higher concentrations. The next highest group is high urban (with high road density), followed by low urban (with low road density), then by roofs (at an elevation which limits dry weather redistribution from road level).

Summary statistics are listed in Table 10 for the distinct land use subgroups identified.

Table 10. Total Lead Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 44 | -0.66 | 0.55 | 0.41 | 0.22 | 0.25 |
| Roofs | 25 | -1.68 | 0.70 | 0.054 | 0.021 | 0.021 |
| High urban | 181 | -0.84 | 0.56 | 0.27 | 0.14 | 0.18 |
| Low urban | 17 | -1.35 | 0.62 | 0.11 | 0.045 | 0.040 |

## 3.11 Total Zinc

Zinc is an essential and beneficial element in human growth (Eaton et al. 1995), and bioaccumulates easily in plants and animals. Zinc in stormwater runoff is mostly associated with dissolved solids, although it will adsorb to suspended sediments and colloidal particles. Environmental guideline levels are frequently exceeded (Makepeace et al. 1995). Water containing higher concentrations of zinc has an undesirable astringent taste, and may have an opalescent appearance (World Health Organization 1984). The most commonly measured components of total zinc are dissolved and particulate zinc, although speciation schemes that distinguish the bioavailable and potentially toxic forms have also been used to specify the components of total zinc (Morrison et al. 1984; Flores-Rodriguez et al. 1993).

Sources of zinc include wear from tyres and brake pads, possible combustion of lubricating oils, and corrosion of galvanised roofs, roadside fittings, pipes, and other metal objects (Makepeace et al. 1995).

A total of 235 records were obtained for total zinc, including 156 records from high urban areas other than roads and roofs. The observed range extends from 0.01 mg/L for two residential areas in Khayelitsha, South Africa, to 43.7 mg/L from a zinc sheet roof in Bayreuth, Germany.

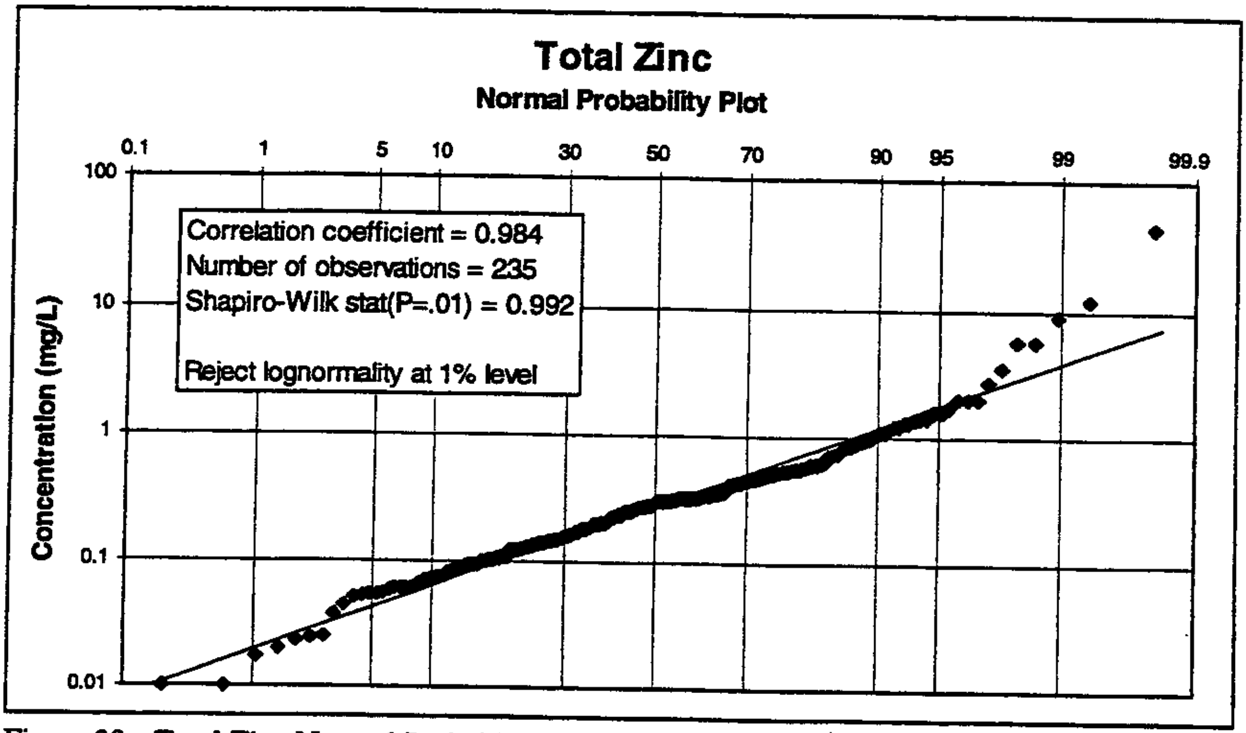

Figure 38. Total Zinc Normal Probability Plot

Total zinc concentrations from all land uses approximately follow the log-normal distribution, apart from a high tail caused by runoff from zinc or galvanised iron roofs (Figure 38). Basic statistics describing the concentrations of total zinc from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 39.

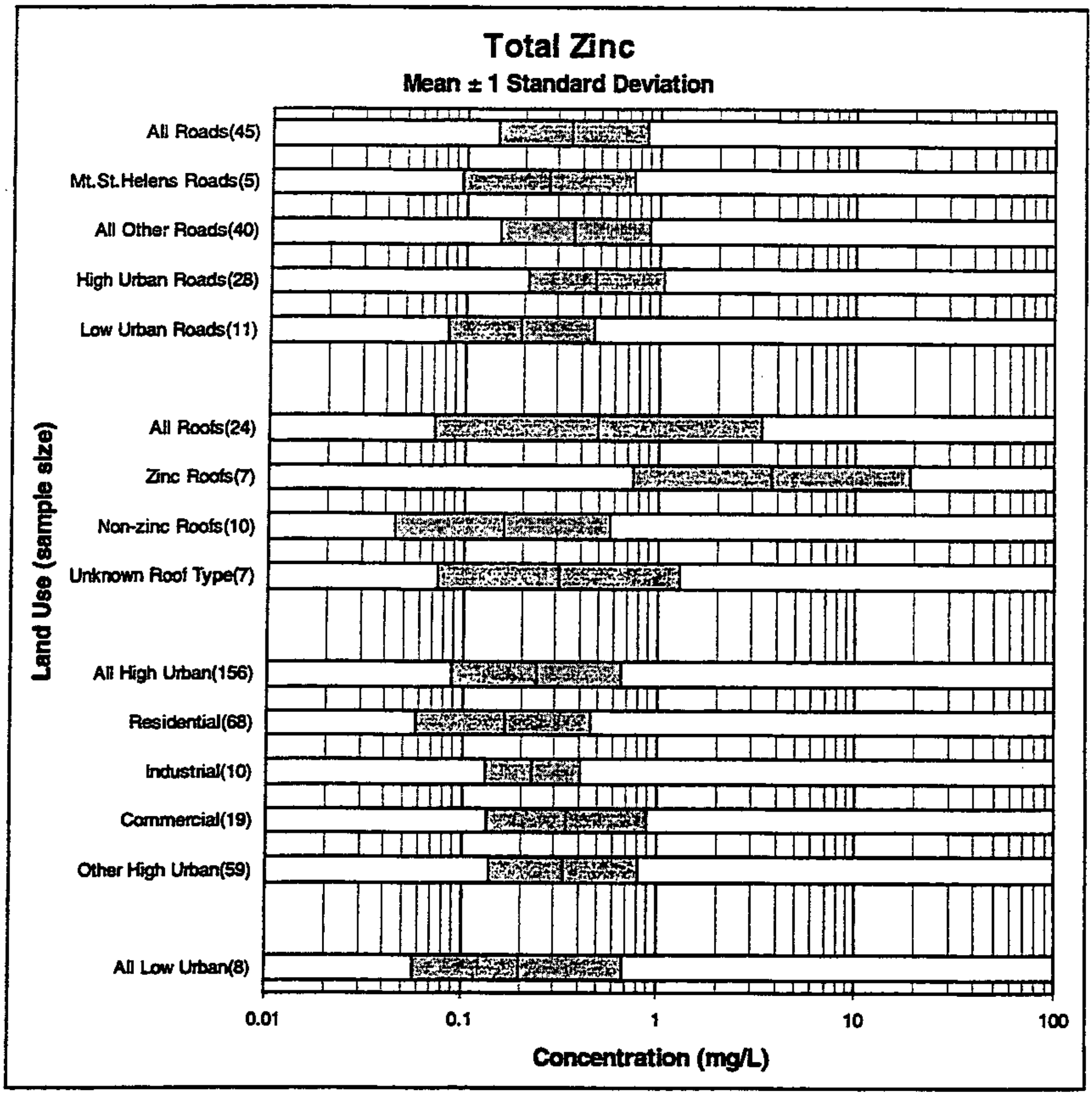

Figure 39. Total Zinc Concentration vs Land Use

### 3.11.1 Roads

The mean zinc concentration of runoff from high urban roads is more than twice that of low urban roads, and the difference is highly significant. This is most probably due to more galvanised roadside hardware in urban areas. The Mt. St. Helens group is not significantly different from unaffected roads, but the group has been excluded from further analysis for consistency with other quality parameters.

Provided the level of urbanisation is accounted for, there are no significant relationships between zinc concentration from roads and annual rainfall, percent impervious, or traffic density.

### 3.11.2 Roofs

By far the most important explanatory variable for zinc concentration from roofs is the roofing material - specifically whether the roof is made of zinc (galvanised iron or zinc sheet) or not. The mean zinc concentration from zinc roofs is by far the highest from any land use group, and is more than 20 times higher than that from non-zinc roofs. Not surprisingly, the difference is statistically highly significant (Figure 39). No other significant relationships were found for the roofs group.

### 3.11.3 High Urban

In the high urban group (156 records), total zinc concentration from residential areas is about half that from all other high urban areas combined, which is a significant difference. No significant differences were found between industrial, commercial, and other high urban uses. The lower concentrations from residential areas is presumably due to a lower density of galvanised roadside hardware, and a lower proportion of galvanised iron roofs, compared with industrial and commercial areas. This is broadly similar to the results of the NURP study (Athayde et al. 1983), which found combined industrial and commercial sites tended to give higher zinc concentrations.

Zinc concentrations from high urban areas decrease significantly as mean annual rainfall increases (Figure 40), and increase significantly as percent impervious increases (Figure 41). The relationship with impervious area is very similar to that for lead, and suggests an impervious source. This accords with the observation that galvanised iron roofs are the major source of zinc. The negative relationship with rainfall suggests that some degree of source limitation is present. In the case of zinc roofs and fittings, the source limitation presumably applies to the *rate* of dissolution, rather than the total *mass* of zinc present, since the total mass is large.

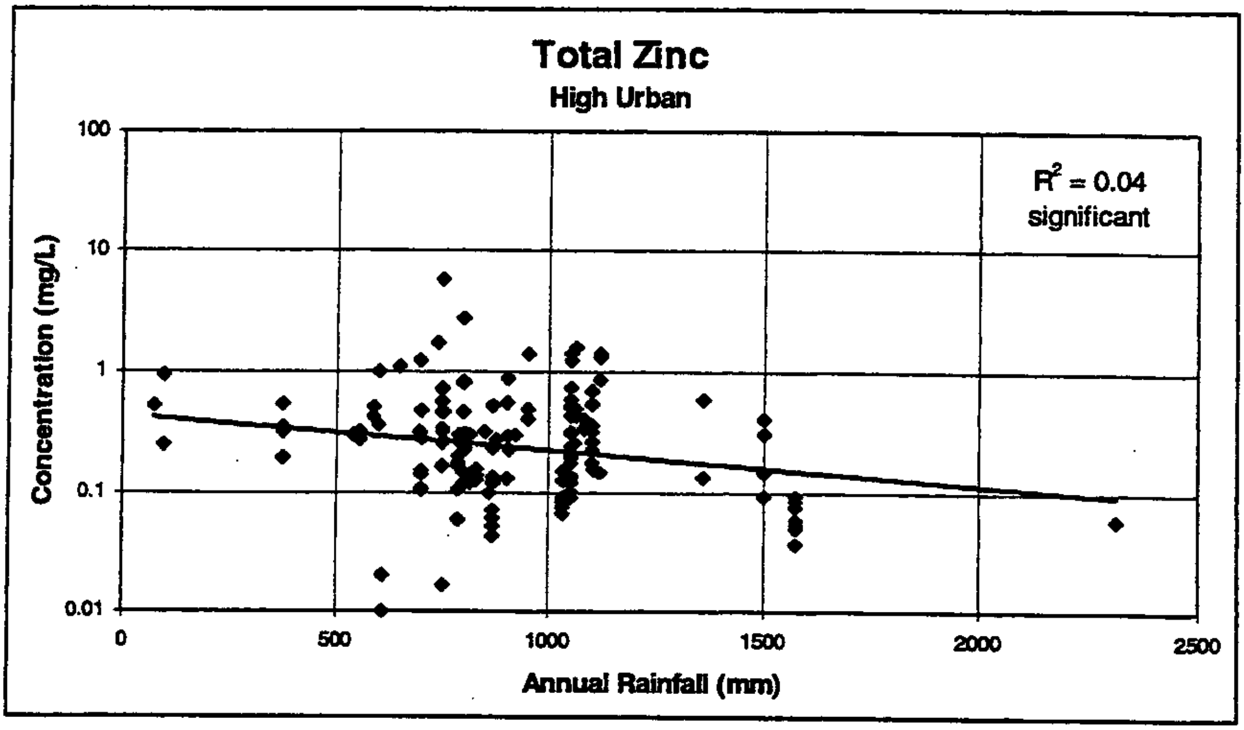

Figure 40. Total Zinc Concentration (High Urban) vs Annual Rainfall

### 3.11.4 Low Urban

Mean zinc concentration for low urban areas (excluding roads and roofs) is not significantly different from that for high urban areas (excluding roads and roofs). This provides an interesting contrast to the roads group, in which high urban roads produce much higher concentrations than low urban roads. Because of the small sample size, the low urban group cannot usefully be subdivided further.

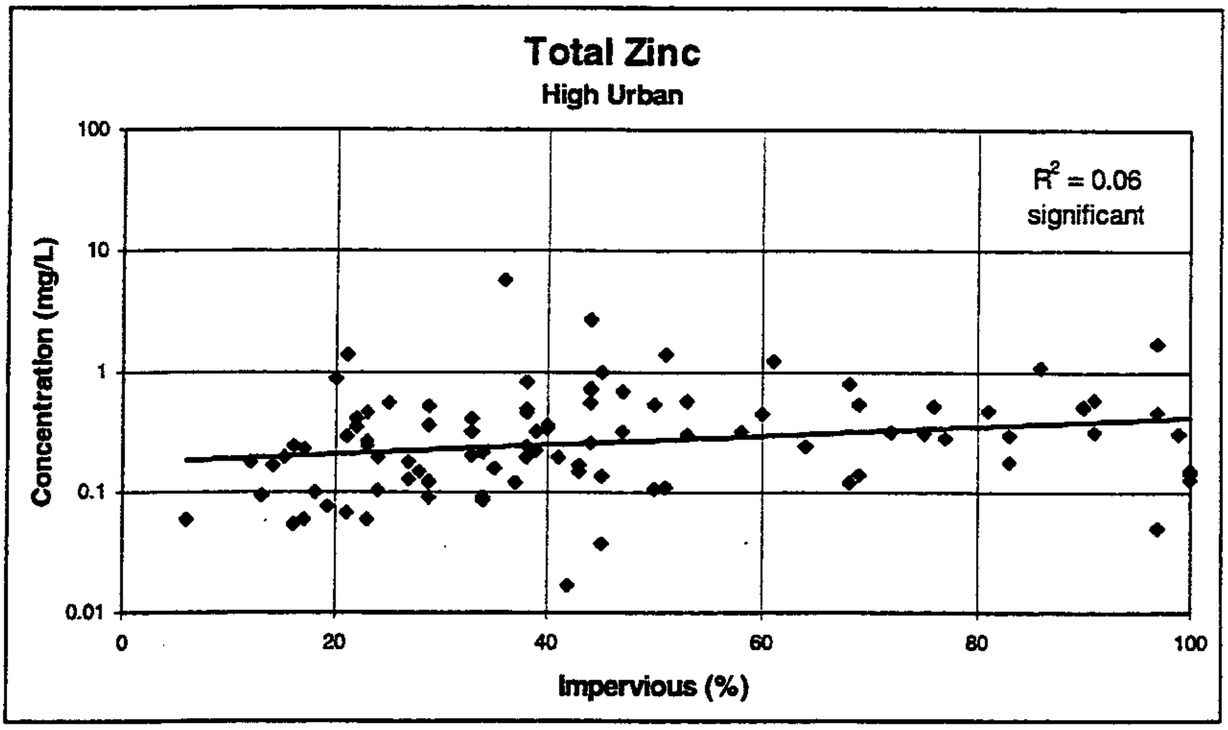

Figure 41. Total Zinc Concentration (High Urban) vs Percent Impervious

### 3.11.5 Summary

All the group results for zinc can be explained in terms of two principal sources - zinc roofs and high urban roads. The source of zinc on high urban roads is presumably galvanised roadside hardware such as railings, signposts, and corrugated metal drains. A tendency towards source limitation must be related to the rate of dissolution, rather than the total mass of zinc present. So a change in the acidity of rainfall would be likely to cause a change in the zinc concentration of urban runoff.

Summary statistics are listed in Table 11 for the distinct land use subgroups identified.

Table 11. Total Zinc Summary Statistics

| Subgroup | Sample | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | size | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| High urban roads | 28 | -0.33 | 0.35 | 0.73 | 0.47 | 0.47 |
| Low urban roads | 11 | -0.71 | 0.38 | 0.26 | 0.20 | 0.27 |
| Zinc roofs | 7 | 0.57 | 0.70 | 10.2 | 3.7 | 3.5 |
| Non-zinc roofs | 10 | -0.80 | 0.55 | 0.34 | 0.16 | 0.10 |
| Residential | 68 | -0.79 | 0.45 | 0.26 | 0.16 | 0.17 |
| Non-resid. high urban | 88 | -0.49 | 0.38 | 0.50 | 0.32 | 0.31 |
| Low urban | 8 | -0.71 | 0.54 | 0.35 | 0.20 | 0.20 |

## 3.12 Total Copper

Copper is an essential element in human metabolism. Very large doses may lead to widespread irritation and damage, but this is rare in practice due to its powerful emetic action. Dissolved copper imparts a colour and an undesirable taste to drinking water (World Health Organization 1984). It is toxic to aquatic organisms, and is quickly accumulated in both plants and animals. Copper in stormwater runoff is mostly associated with dissolved solids and colloidal material, and environmental guidelines are frequently exceeded (Makepeace et al. 1995).

Sources of copper include wear of tyres and brake linings, possible combustion of lubricating oils, corrosion of roofs and water pipes, wear of moving parts in engines, industrial emissions, fungicides and pesticides (Makepeace et al. 1995). Copper salts are used in water supply systems to control biological growths in reservoirs and pipes (Eaton et al. 1995).

A total of 192 records were obtained for total copper, including 140 records from high urban areas other than roads and roofs. The observed range extends from 0.005 mg/L for a gravel and zinc sheet roof in Bayreuth, Germany, to 7.0 mg/L for an urban highway in Spokane, Washington state, affected by the eruption of Mt. St. Helens.

Total copper concentrations from all land uses approximately follow the log-normal distribution (Figure 42). The fit is much improved if the five points affected by Mt. St. Helens are excluded. Basic statistics describing the concentrations of total copper from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 43.

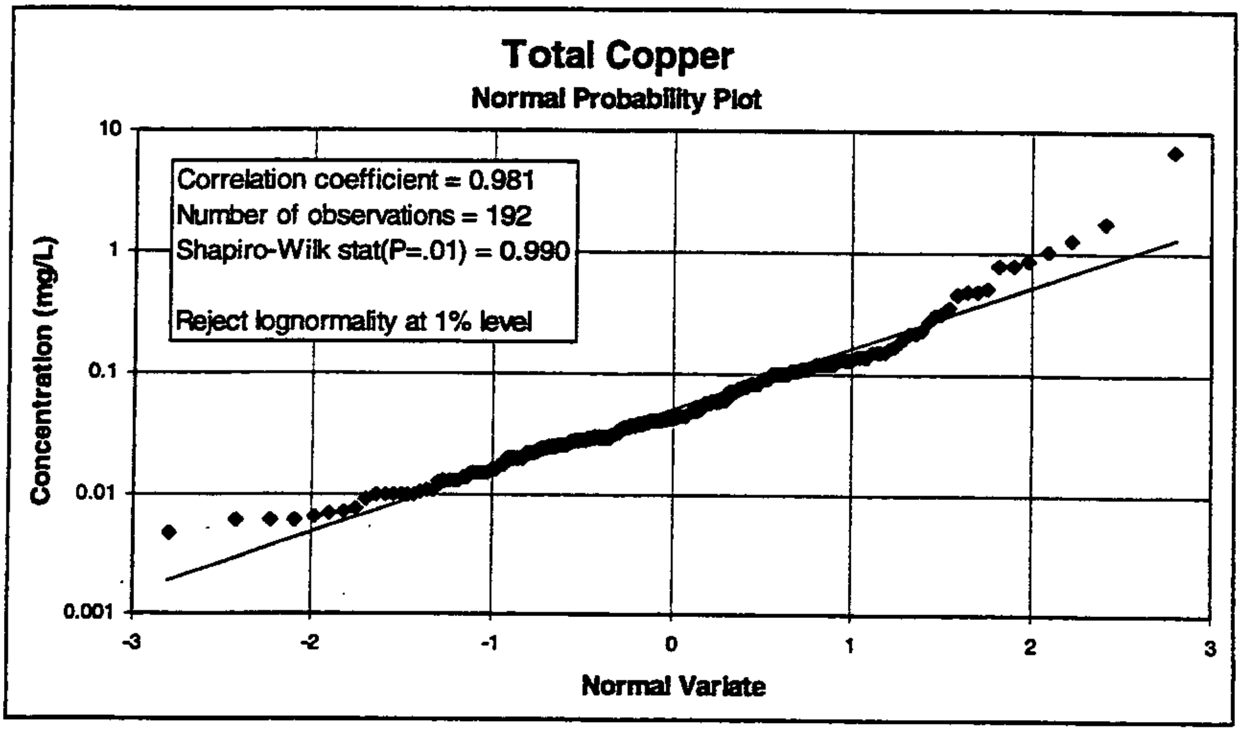

Figure 42. Total Copper Normal Probability Plot

### 3.12.1 Roads

Despite appearances on the bar graphs (Figure 43), there are no statistically significant differences in mean copper concentrations between the three roads subgroups. Even so, the Mt. St. Helens subgroup has been excluded from the analysis, to provide consistency with other water quality parameters.

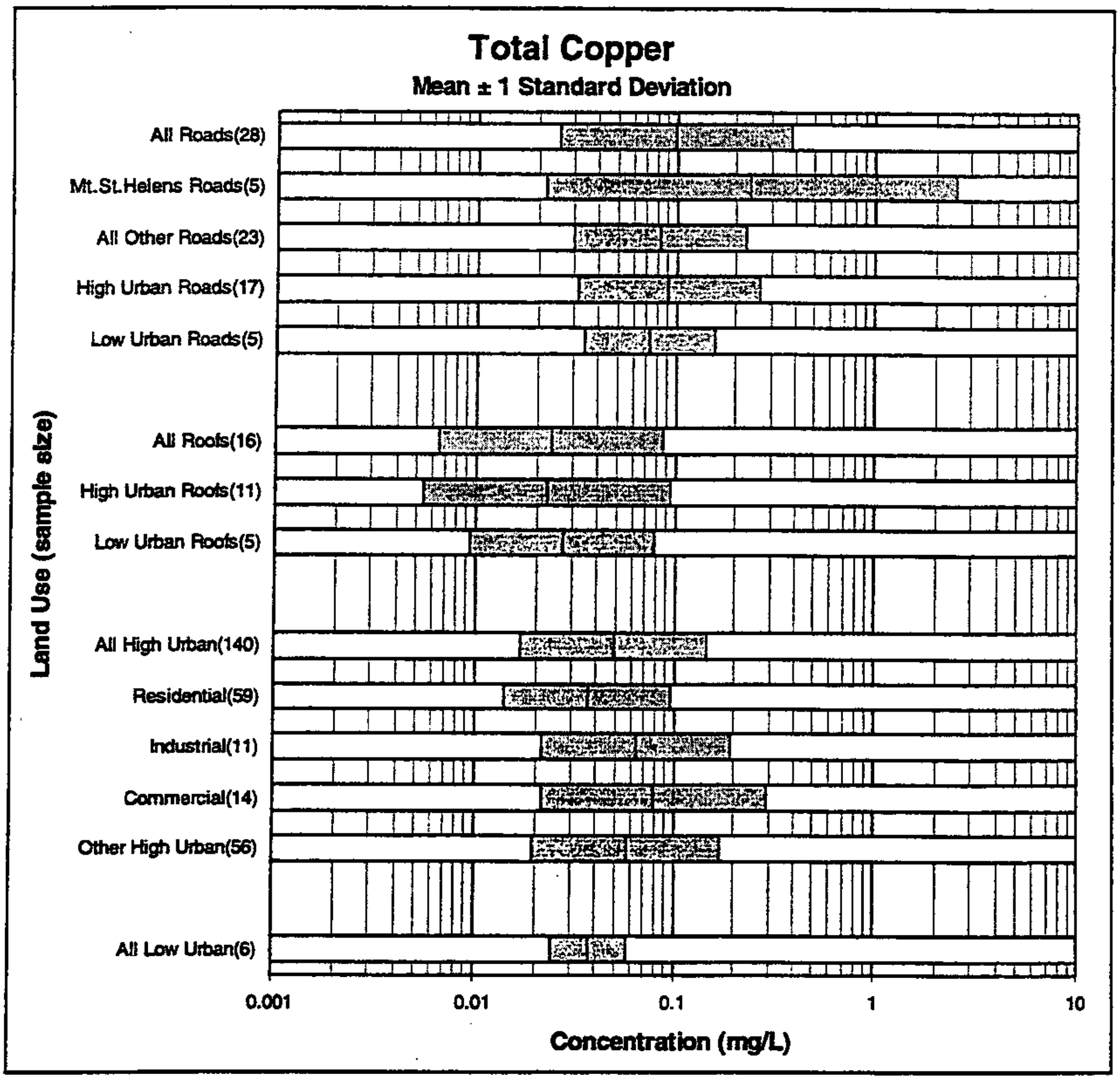

Figure 43. Total Copper Concentration vs Land Use

The relationship between copper concentration from roads and mean annual rainfall (Figure 44) is not significant, nor is it very robust as it depends largely on a single high rainfall reading. It is, however, very similar to the corresponding significant relationship for high urban land use (Figure 45), suggesting that similar processes may be involved. There is no trace of a relationship between copper concentrations from roads and either percent impervious or traffic density.

### 3.12.2 Roofs

There is no significant difference in mean copper concentration between high urban and low urban roofs, nor is there any relationship with mean annual rainfall. Mean copper concentration from all roofs is about one third that from all roads, and about half that from all high urban catchments excluding roads and roofs.

### 3.12.3 High Urban

The mean copper concentration from residential areas is just over half that from all other high urban areas, which is a significant difference. There are no significant differences between the industrial, commercial, and other high urban subgroups. Copper concentrations decrease significantly as mean annual rainfall increases (Figure 45). A similar trend is apparent in the residential and non-residential subgroups taken separately, and also in the roads group.

These figures differ from the results of the NURP study (Athayde et al. 1983), which found no significant differences at all between residential, mixed, and industrial & commercial sites.

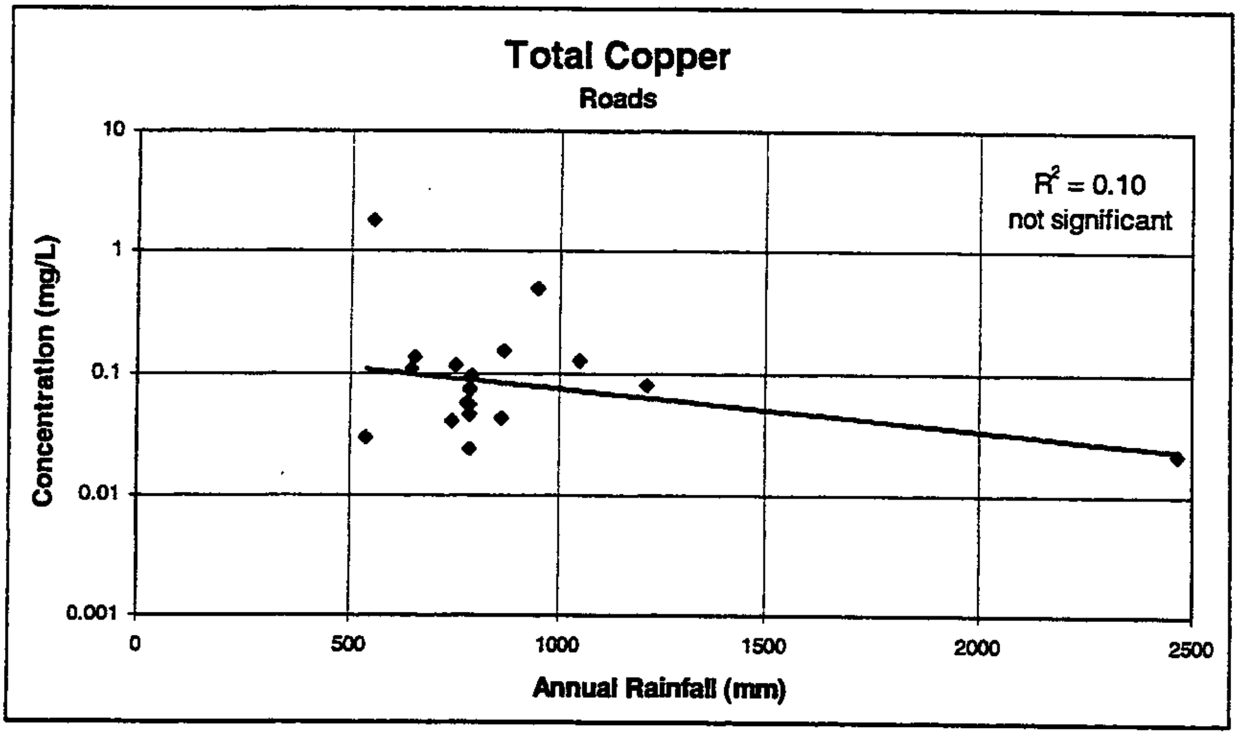

Figure 44. Total Copper Concentration (Roads) vs Annual Rainfall

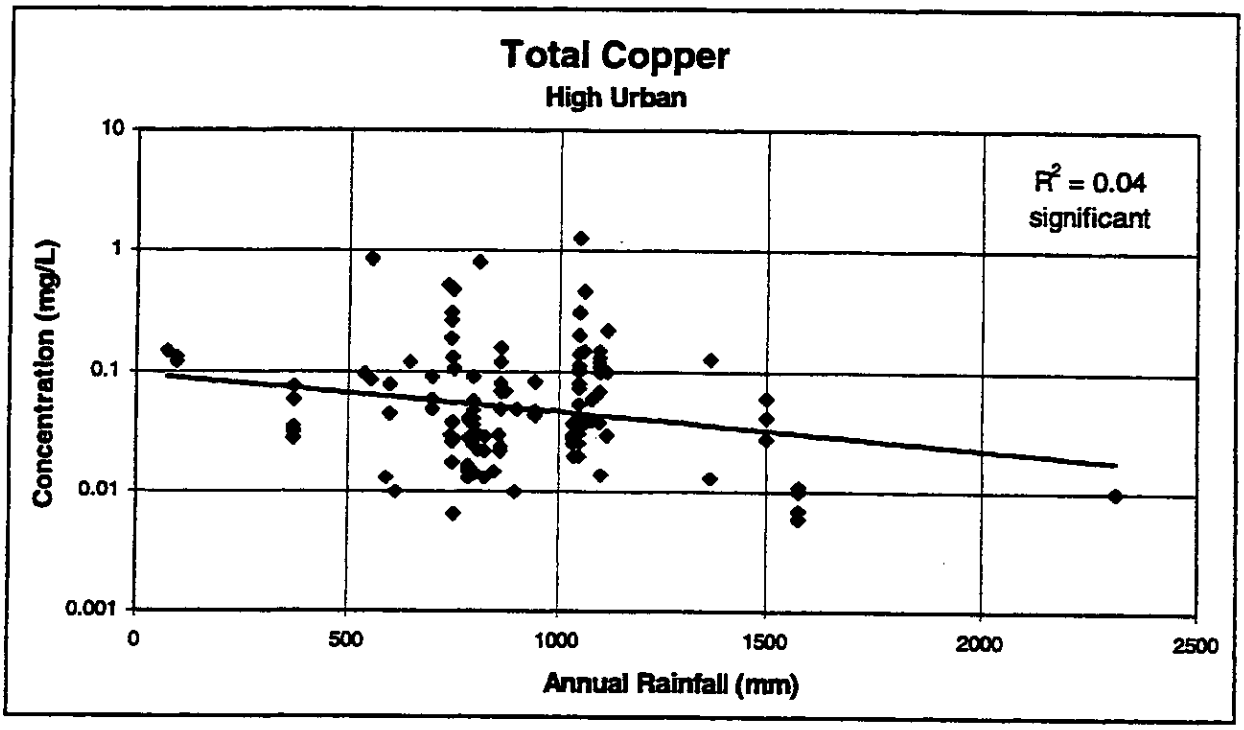

Figure 45. Total Copper Concentration (High Urban) vs Annual Rainfall

### 3.12.4 Summary

Copper concentrations in runoff tend to be highest from roads and non-residential urban areas, and lowest from roofs, low urban, and residential urban areas. This tends to suggest that the main source (or sources) is at a low elevation and associated with main roads and industrial and commercial areas, although the evidence is less compelling than in the case of lead.

Summary statistics are listed in Table 12 for the distinct land use subgroups identified.

Table 12. Total Copper Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 23 | -1.09 | 0.44 | 0.17 | 0.081 | 0.076 |
| Roofs | 16 | -1.62 | 0.56 | 0.061 | 0.024 | 0.018 |
| Residential | 59 | -1.44 | 0.42 | 0.057 | 0.036 | 0.036 |
| Non-resid. high urban | 81 | -1.21 | 0.49 | 0.13 | 0.062 | 0.054 |
| Low urban | 6 | -1.43 | 0.19 | 0.040 | 0.037 | 0.038 |

## 3.13 Total Cadmium

Cadmium is highly toxic and has been implicated in some cases of poisoning through food. Cadmium causes cancer in laboratory animals, and has been linked epidemiologically with some human cancers (Eaton et al. 1995). It accumulates mainly in the liver and kidneys of humans and animals, and tends to be concentrated by shellfish (World Health Organization 1984). Cadmium in stormwater runoff is mostly associated with dissolved solids and colloidal material (Makepeace et al. 1995). The most commonly measured components of total cadmium are dissolved and particulate cadmium, although speciation schemes that distinguish the bioavailable and potentially toxic forms have also been used to specify the components of total cadmium (Morrison et al. 1984; Flores-Rodriguez et al. 1993).

Sources of cadmium include combustion, wear of tyres and brake pads, possible combustion of lubricating oils, industrial emissions, agricultural use of sewage sludge, fertilisers, and pesticides, corrosion of galvanised metals (Makepeace et al. 1995), and landfill leachate (World Health Organization 1984), presumably contaminated by discarded rechargeable batteries.

A total of 86 records were obtained for total cadmium, including 57 records from high urban areas other than roads and roofs. The observed range extends from 0.000067 mg/L for a gravel and zinc sheet roof in Bayreuth, Germany, to 0.063 mg/L for a parking lot in Syracuse, New York state.

Total cadmium concentrations from all land uses closely follow the log-normal distribution (Figure 46). Basic statistics describing the concentrations of total cadmium from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 47.

### 3.13.1 Roads

There is no significant difference in mean cadmium concentration between runoff from high urban roads and low urban roads, although that may be partly due to the small sample size. No significant relationships were found between cadmium concentration in road runoff and annual rainfall, percent impervious, or vehicles per day. Cadmium concentrations from roads are very similar to those from most kinds of urban areas.

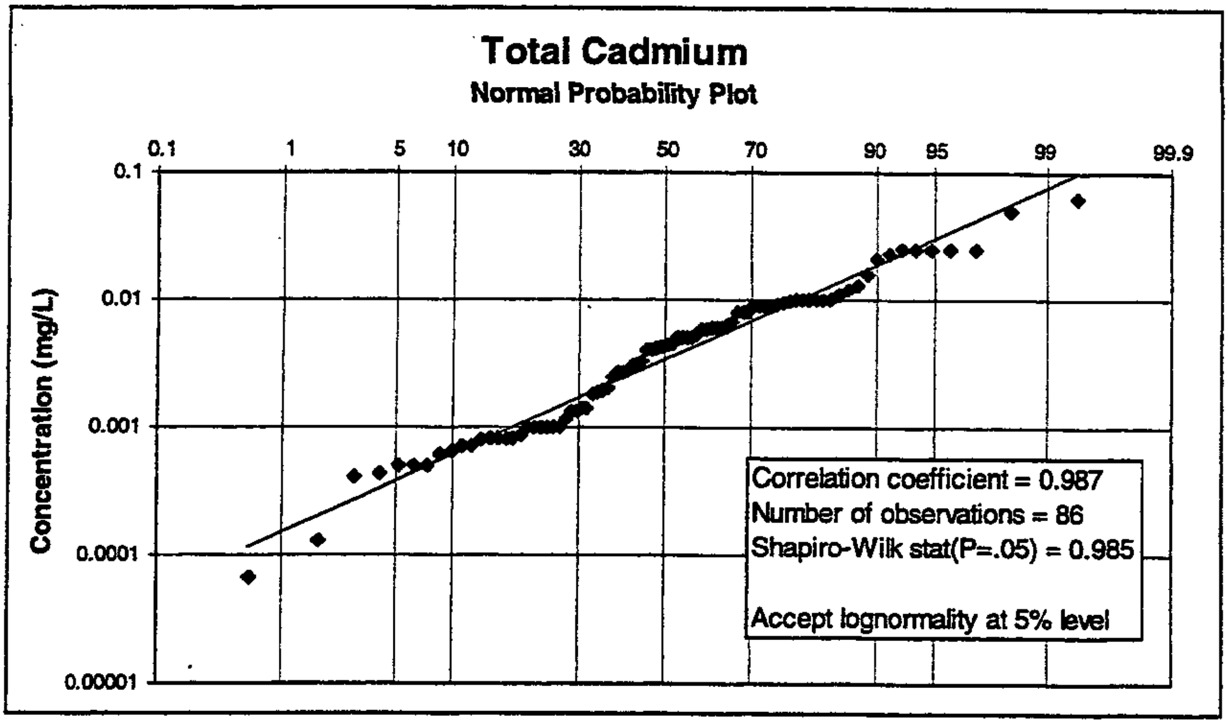

Figure 46. Total Cadmium Normal Probability Plot

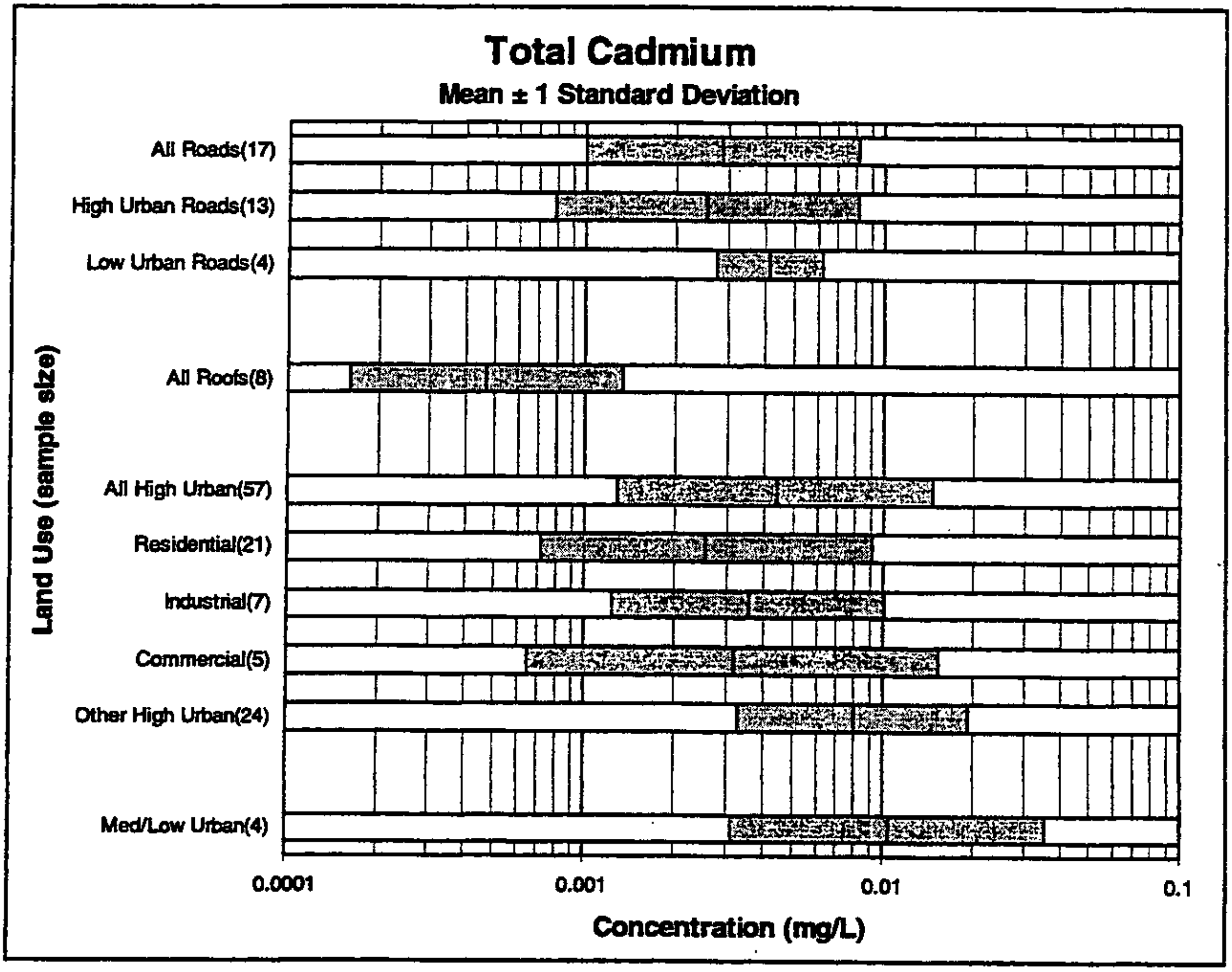

Figure 47. Total Cadmium Concentration vs Land Use

### 3.13.2 Roofs

Cadmium concentration from roofs is significantly lower than from any other major land use group, and is only one tenth of that from all high urban land use. The mean cadmium concentrations from zinc roofs and non-zinc roofs are very similar, although small sample sizes reduce the value of this observation. High urban roofs and low urban roofs cannot be separated using this sample, as all roofs with cadmium data are classified as high urban.

### 3.13.3 High Urban

In the high urban group, mixed use catchments exhibit significantly higher cadmium concentrations than the predominantly single use catchments (residential, industrial, and commercial). It is difficult to see why this should be so. Although in principle the group could contain catchments which were largely institutional or urban open space (i.e. not residential, industrial, or commercial), examination of the data file shows that this is not the case, at least for those records where a detailed breakdown of land use is given. Only two records document urban open space exceeding 20%, and institutional land use exceeding 20% is not recorded at all. So the mixed use catchments in this sample contain just the same land uses as the single use catchments.

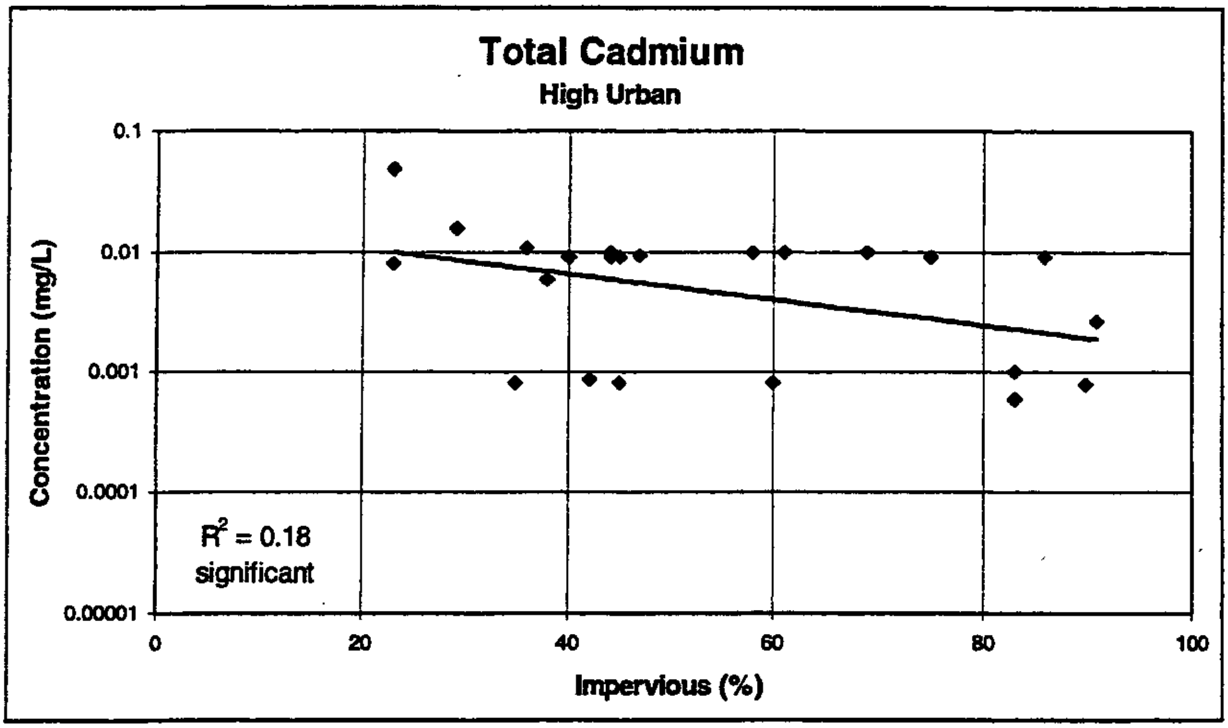

Figure 48. Total Cadmium Concentration (High Urban) vs Percent Impervious

There is a significant relationship in the high urban group between cadmium concentration and percent impervious (Figure 48). A higher percentage of impervious area is associated with lower cadmium concentrations, which tends to suggest a pervious area source. No significant relationships were found between cadmium concentration and mean annual rainfall or population density.

### 3.13.4 Low Urban

The sample size for medium and low urban areas is too small to carry much statistical weight. Even so it is worth noting that this group has superficially (but not always significantly) the highest mean cadmium concentration of any group.

### 3.13.5 Summary

Definitive conclusions are limited in this case by small sample sizes in many of the land use groups. Even so, it appears that roofs contribute very little cadmium to urban runoff. Higher concentrations from medium and low urban areas, higher concentrations from mixed urban catchments, and lower concentrations from impervious areas, all suggest that pervious areas are a major source of cadmium. This is an unexpected result, given the likely sources noted above. Either the urban sources are small compared with the non-urban sources, or the result is just a chance occurrence in a relatively small data set.

Summary statistics are listed in Table 13 for the distinct land use subgroups identified.

Table 13. Total Cadmium Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 17 | -2.54 | 0.46 | 0.0064 | 0.0029 | 0.0028 |
| Roofs | 8 | -3.33 | 0.46 | 0.00066 | 0.00047 | 0.00068 |
| Resid., Ind. & Comm. | 33 | -2.55 | 0.54 | 0.0059 | 0.0028 | 0.0041 |
| Other high urban | 24 | -2.10 | 0.39 | 0.011 | 0.0079 | 0.0091 |
| Medium/low urban | 4 | -1.98 | 0.53 | 0.015 | 0.010 | 0.018 |

## 3.14 Total Chromium

Chromium occurs in both trivalent and hexavalent forms. In chlorinated or aerated water, hexavalent chromium is the predominant form. Trivalent chromium appears to be essential for human metabolism, and is considered to be practically non-toxic. Hexavalent chromium is associated with liver and kidney damage, gastrointestinal irritation, and increased risk of cancer (World Health Organization 1984), and is also more toxic to aquatic organisms. Chromium in stormwater runoff is mostly associated with suspended solids (Makepeace et al. 1995).

Sources of chromium include corrosion of welded metal plating, wear of moving parts in engines, dyes, paints, ceramics, paper, heating and cooling coils, fire sprinkler systems, pesticides, fertilisers (Makepeace et al. 1995), corrosion inhibitors, and sewage sludge applied to land (World Health Organization 1984).

A total of 77 records were obtained for total chromium, including 64 records from high urban areas other than roads and roofs. The observed range extends from 0.0005 mg/L for residential and urban open space sites in Burnaby, Canada, to 0.58 mg/L for an industrial and open space site in Melbourne, Australia.

Total chromium concentrations from all land uses closely follow the log-normal distribution (Figure 49). Basic statistics describing the concentrations of total chromium from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 50.

### 3.14.1 Roads

Roads produce the lowest chromium concentrations of any major group. Concentrations are similar to those from the residential subgroup, but significantly lower than from non-residential high urban areas. Based on this sample, roads do not appear to be a major source of chromium in stormwater runoff.

### 3.14.2 High Urban

Residential catchments produce the lowest concentrations of chromium in the high urban group, significantly lower than both the 'other high urban' mixed land use subgroup and all non-residential high urban subgroups combined. Associated with the lower residential concentrations is a highly significant negative relationship with population density - the more people per hectare the lower the chromium concentration (Figure 51).

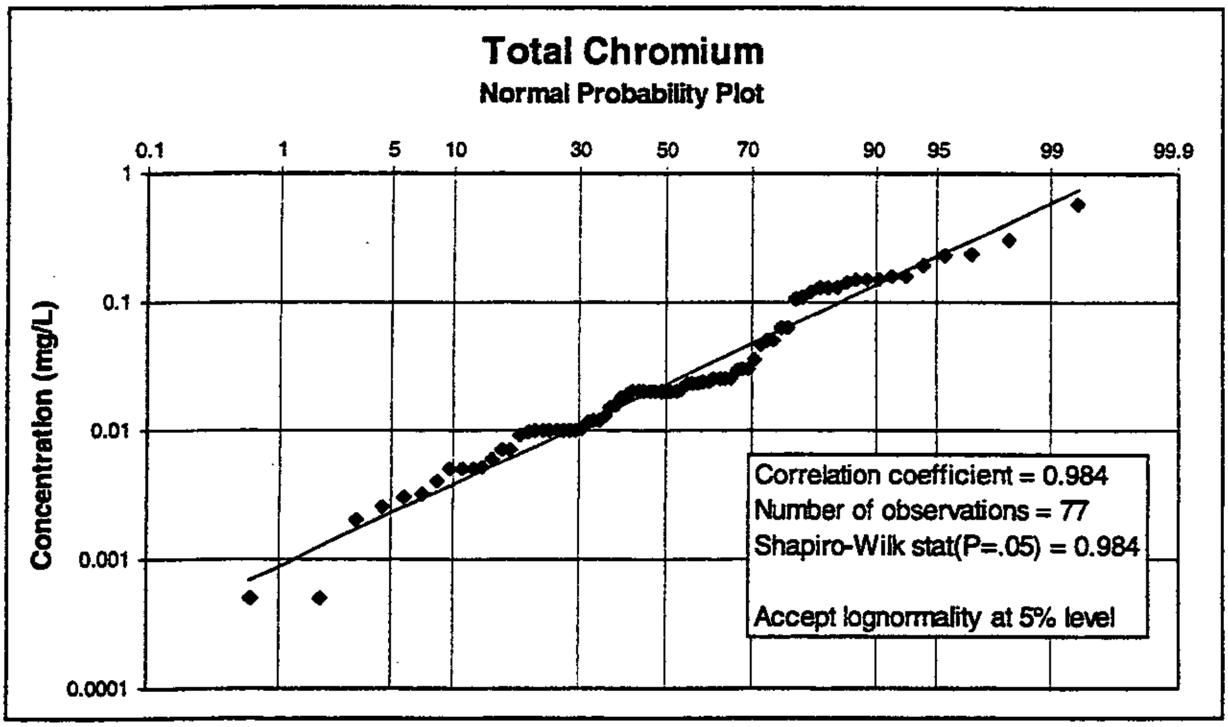

Figure 49. Total Chromium Normal Probability Plot

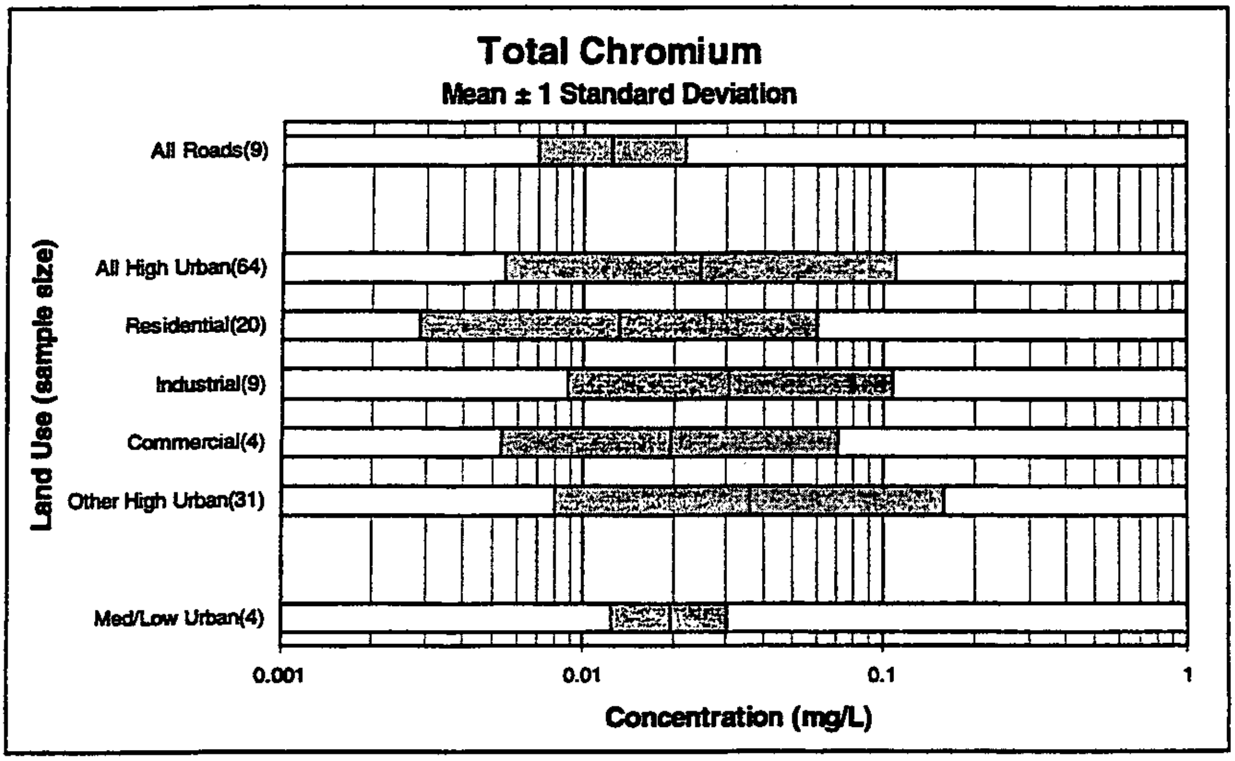

Figure 50. Total Chromium Concentration vs Land Use

There is no significant relationship with either mean annual rainfall or percent impervious. But the relationship with rainfall is interesting, even so, because the slope of the line is very similar to that for many other quality parameters (Figure 52).

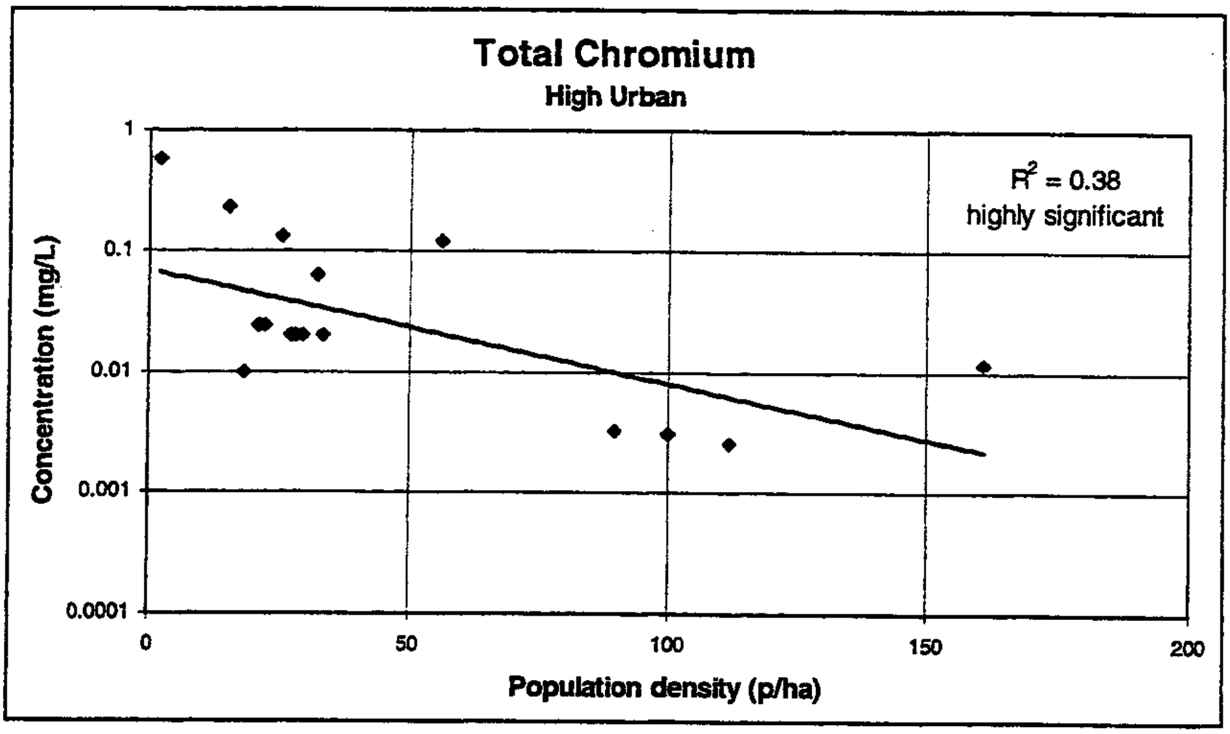

Figure 51. Total Chromium Concentration (High Urban) vs Population Density

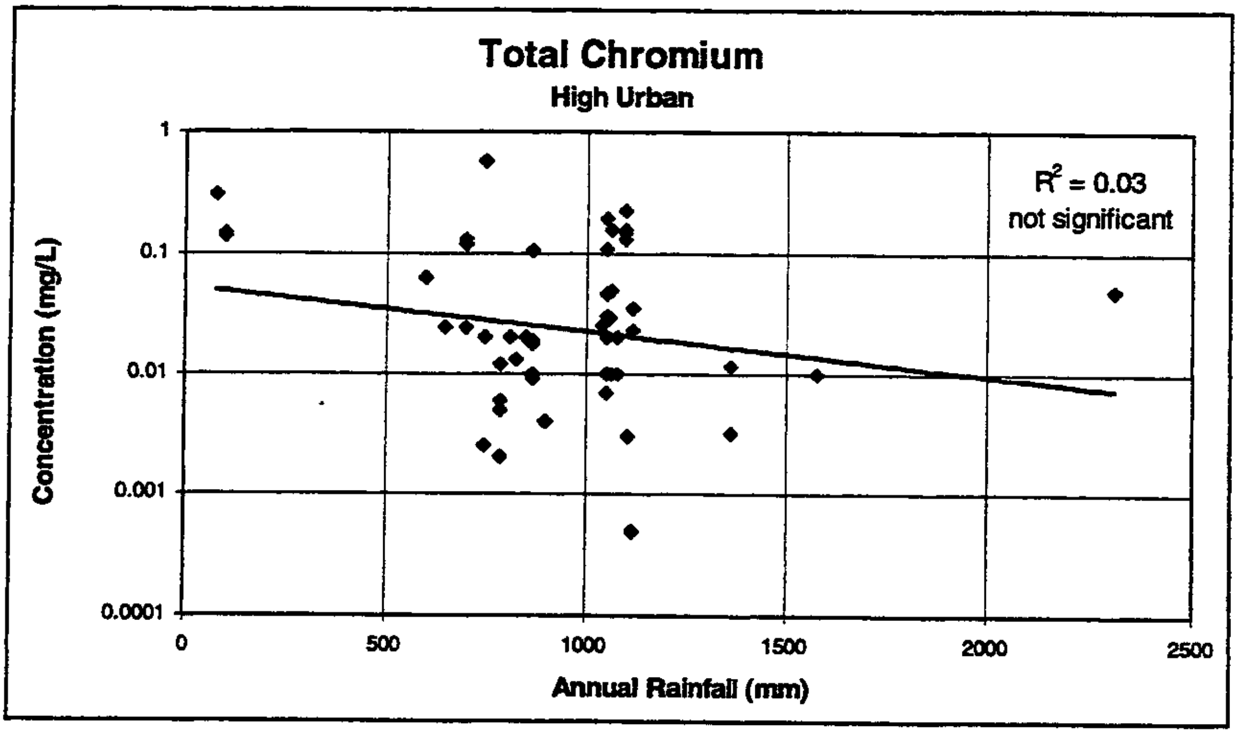

Figure 52. Total Chromium Concentration (High Urban) vs Annual Rainfall

### 3.14.3 Summary

Total chromium is the only quality parameter in this study, other than the microbiological measures, for which concentrations from roads are significantly lower than from all high urban catchments excluding roads and roofs. A mental association between vehicles and metallic chromium evidently does not translate into a similar association for the element in urban runoff. Concentrations from residential areas are significantly lower than from all other high urban areas. Perhaps this can be related to corrosion inhibitors in heating, cooling, and fire protection systems in larger industrial, commercial, and institutional buildings. There are no measurements of chromium in roof runoff in the data set, and the samples for medium and low urban areas are too small to provide useful information.

Summary statistics are listed in Table 14 for the distinct land use subgroups identified.

Table 14. Total Chromium Summary Statistics

| Subgroup | Sample | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | size | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 9 | -1.91 | 0.25 | 0.014 | 0.012 | 0.015 |
| Residential | 20 | -1.88 | 0.66 | 0.034 | 0.013 | 0.010 |
| Non-resid. high urban | 44 | -1.48 | 0.61 | 0.077 | 0.033 | 0.024 |
| Medium/low urban | 4 | -1.71 | 0.19 | 0.021 | 0.020 | 0.024 |

## 3.15 Total Nickel

Nickel is almost certainly essential for animal nutrition. It is relatively non-toxic, and there is little evidence of accumulation in the body. Skin contact through industrial exposure or by handling coins or jewellery may cause dermatitis (World Health Organization 1984). Nickel in stormwater runoff is mostly associated with suspended solids and organic matter. Sources of nickel include corrosion of welded metal plating, wear of moving parts in engines, electroplating and alloy manufacture, and food production equipment (Makepeace et al. 1995).

A total of 53 records were obtained for total nickel, including 48 records from high urban areas other than roads and roofs. The observed range extends from 0.0085 mg/L for a large urban area in Sarnia, Canada, to 0.15 mg/L for urban catchments in Durham, North Carolina, and New York city.

Total nickel concentrations from all land uses closely follow the log-normal distribution (Figure 53). Basic statistics describing the concentrations of total nickel from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown in the form of bar graphs in Figure 54.

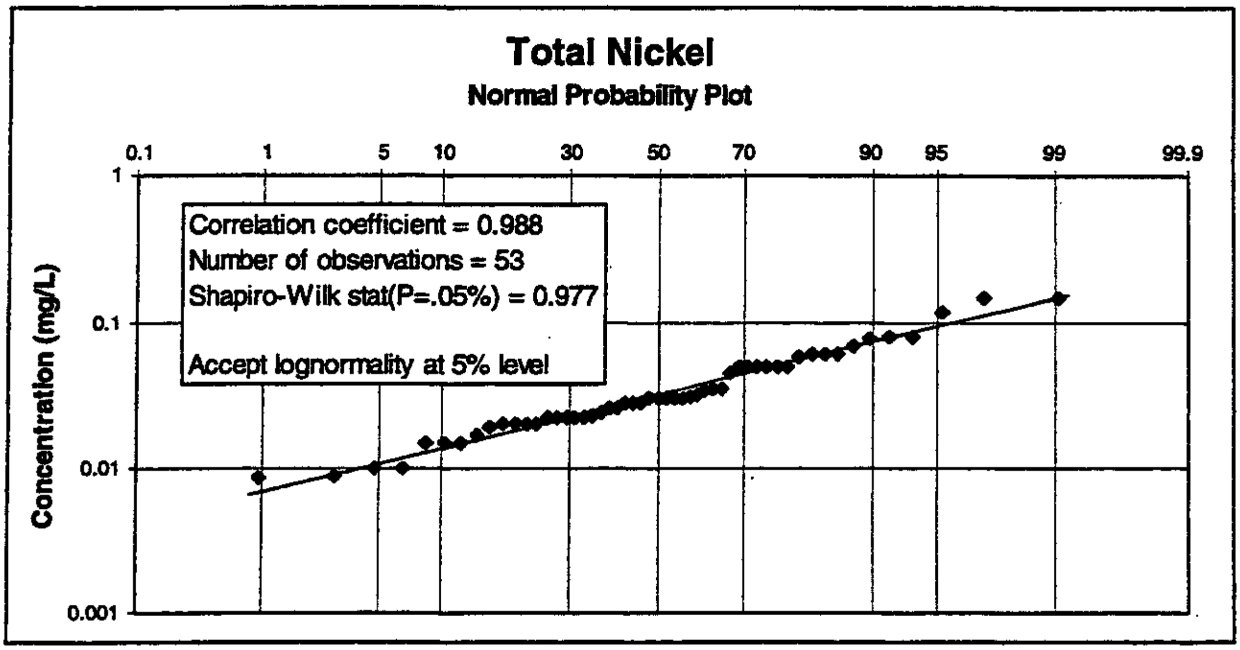

Figure 53. Total Nickel Normal Probability Plot

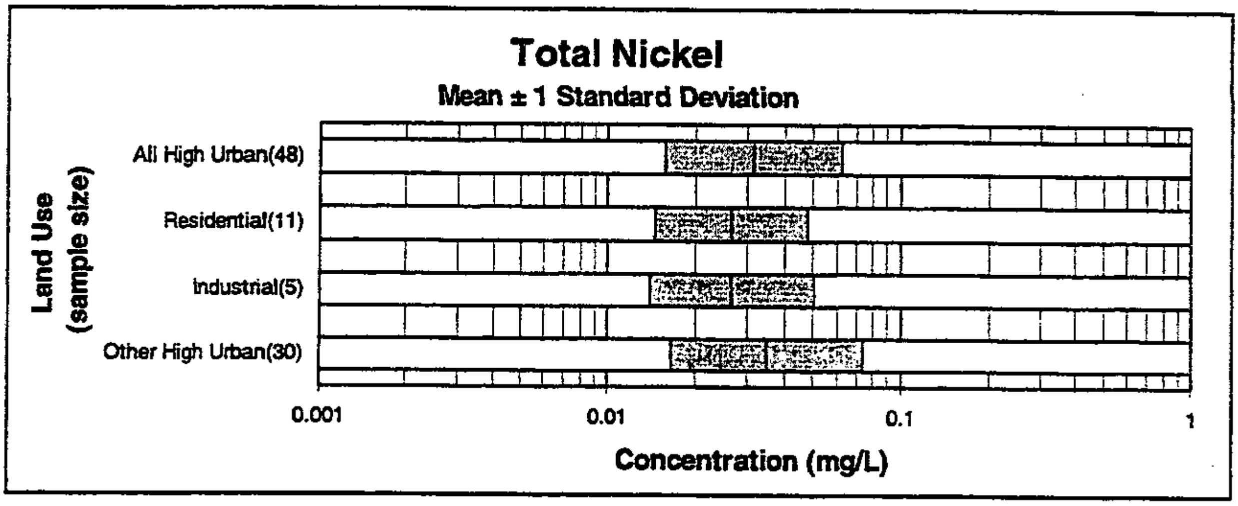

Figure 54. Total Nickel Concentration vs Land Use

### 3.15.1 Summary

Although there is a moderate sample of nickel concentrations from high urban areas, there is very little information from other land use categories. No significant differences were detected between the subgroups of high urban land use, and no significant relationships were found with mean annual rainfall, population density, or percent impervious. Nor do the roads, commercial, and low urban land uses, with too few samples to include on Figure 54, show any interesting deviations from the behaviour of the groups shown (see Appendix B). Summary information on nickel concentrations is therefore limited to statistics of a single sample, for high urban land use, as shown in Table 15.

Table 15. Total Nickel Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| High urban | 48 | -1.50 | 0.30 | 0.040 | 0.032 | 0.030 |

## 3.16 Total Iron

Iron is widely distributed in the environment, and is an essential element in human nutrition. In water it occurs mainly in the divalent (ferrous) and trivalent (ferric) states. The ferrous form occurs under reducing conditions, and is relatively soluble. The ferric form occurs under oxidising conditions, and is generally not significantly soluble unless the pH is very low. Iron in surface waters is normally in the ferric state, and is associated mainly with suspended solids.

Sources of iron in runoff include corrosion of vehicles, roadside hardware, and drains, burning of coke and coal, iron and steel industry emissions, landfill leachate, silt and clay particles, and potable water supplies. Iron in potable water is derived in turn from natural runoff waters, water treatment processes, and corrosion of pipes and fittings. Iron causes staining and has an astringent taste, and may be toxic to fish and invertebrates (World Health Organization 1984; Eaton et al. 1995; Makepeace et al. 1995).

Altogether 68 records were obtained for total iron, including 53 records from high urban areas excluding roads and roofs. The observed concentration range runs from 0.22 mg/L for a tributary of the Stamford Canal in Singapore to 38 mg/L for an agricultural catchment in northern Virginia.

Total iron concentrations from all land uses closely follow the log-normal distribution (Figure 55). Basic statistics describing the concentrations of total iron from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown as bar graphs in Figure 56.

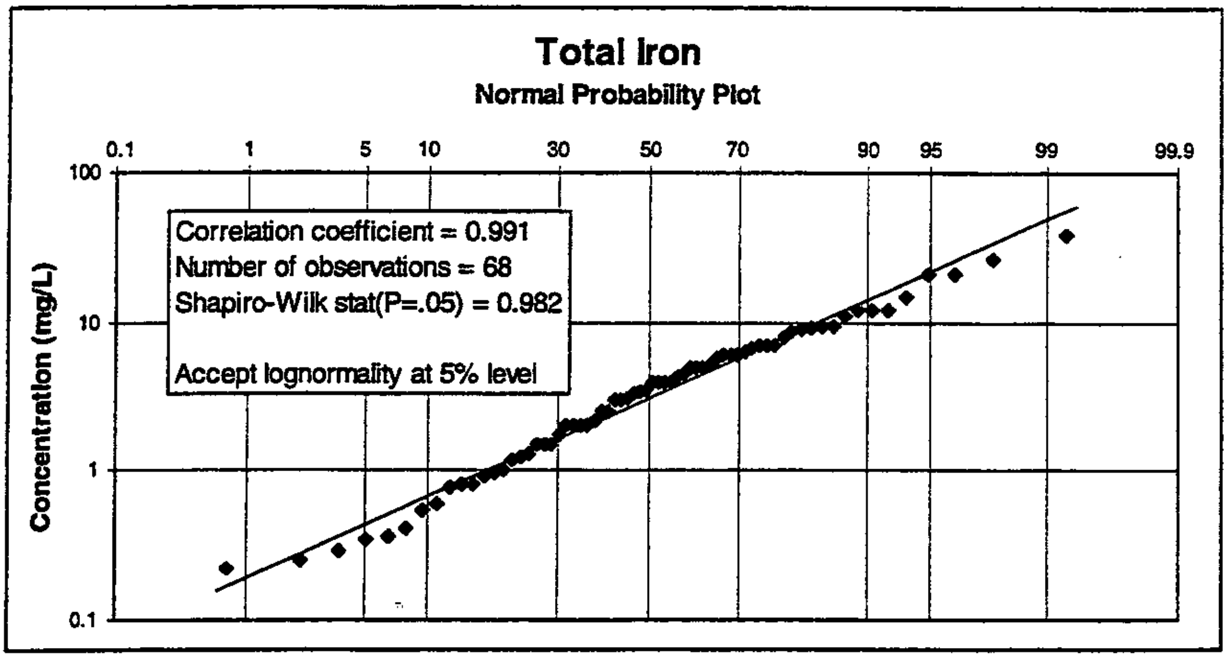

Figure 55. Total Iron Normal Probability Plot

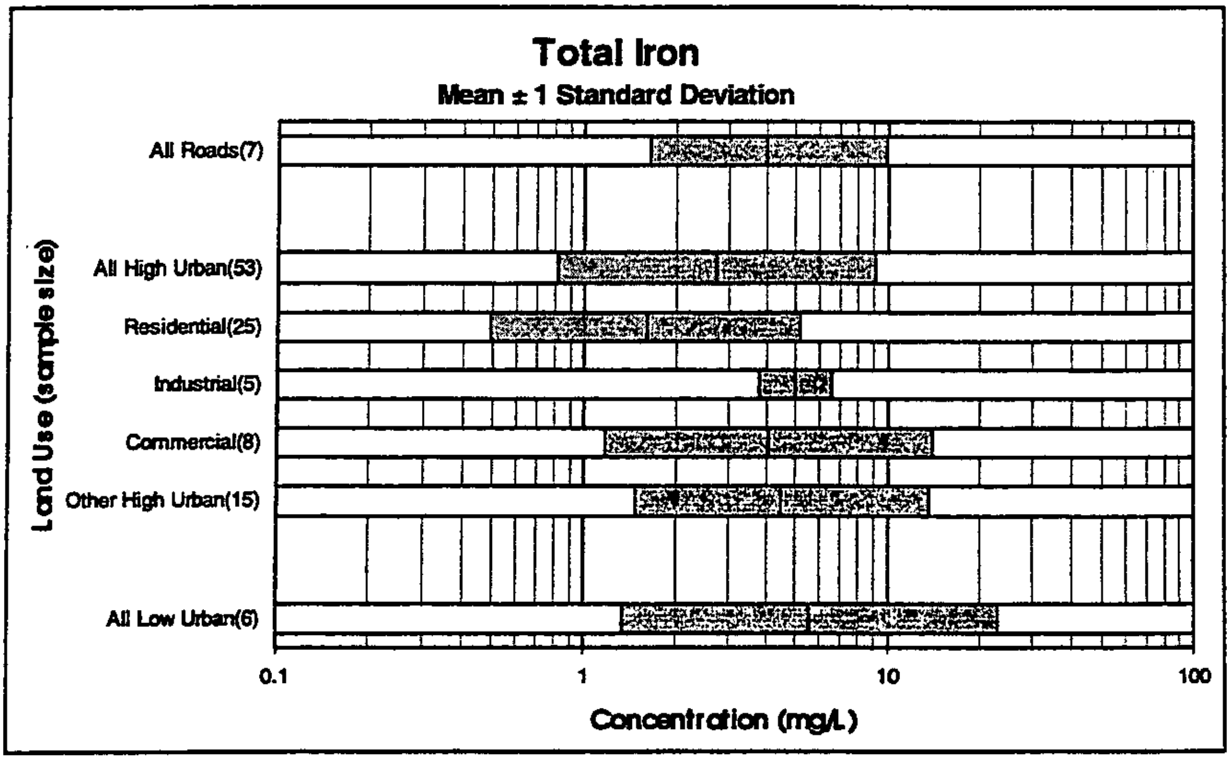

Figure 56. Total Iron Concentration vs Land Use

### 3.16.1 High Urban

Residential catchments produce the lowest concentrations of iron in the high urban group. Typical concentrations are only one third of those from all other high urban land uses, which is a highly significant difference. A tendency for iron concentration to decrease with increasing mean annual rainfall is not significant (Figure 57), yet is very similar in magnitude to the trend observed for many other quality parameters.

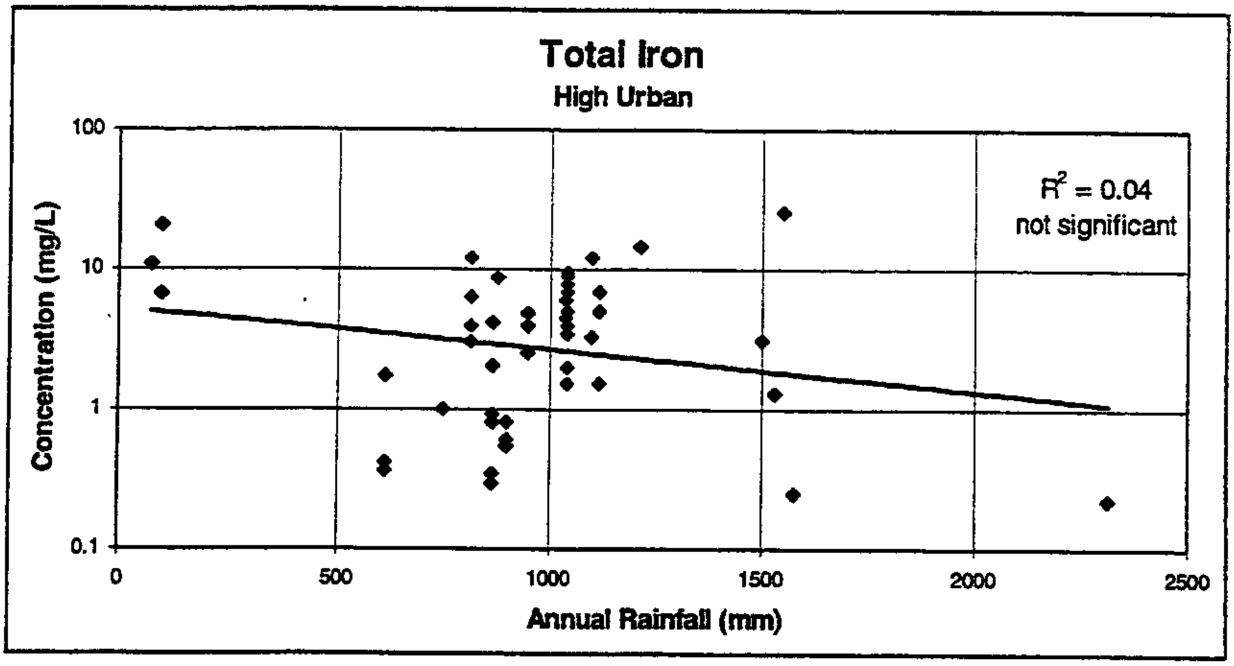

Figure 57. Total Iron Concentration (High Urban) vs Annual Rainfall

### 3.16.2 Summary

Iron concentrations from roads and low urban catchments are very similar to those from high urban catchments other than residential. Hence residential land use is the only subgroup with distinctive behaviour for this parameter. The reasons for lower iron concentrations from residential areas are not immediately obvious, but the similarity of all other subgroups suggests that sources of iron are widely distributed in both urban and rural catchments. Perhaps different sources dominate in different areas.

Summary statistics are listed in Table 16 for the distinct land use subgroups identified.

Table 16. Total Iron Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 7 | 0.60 | 0.39 | 6.0 | 4.0 | 3.4 |
| Residential | 25 | 0.20 | 0.51 | 2.8 | 1.6 | 2.0 |
| Non-resid. high urban | 28 | 0.65 | 0.45 | 6.8 | 4.5 | 5.0 |
| Low urban | 6 | 0.74 | 0.62 | 11.3 | 5.5 | 7.8 |

## 3.17 Total Manganese

Manganese is an essential element in human and animal nutrition, being involved in many important metabolic processes, and is regarded as one of the least toxic elements. Manganese occurs in a range of valence states, and in both dissolved and suspended forms. In potable water supplies it imparts an undesirable taste to beverages, and stains plumbing fixtures and laundry (World Health Organization 1984). Sources of manganese include wear of tyres and brake pads, steel manufacturing, manufacture of paints and dyes, and fertilisers (Makepeace et al. 1995).

A total of 21 records were obtained for manganese, including 16 records from high urban areas other than roads and roofs. The observed range extends from 0.05 mg/L for an urban catchment in Knoxville, Tennessee, to 1.27 mg/L for an urban catchment in Portland, Oregon.

Total manganese concentrations from all land uses closely follow the log-normal distribution (Figure 58). Basic statistics describing the concentrations of total manganese from various land uses (in log coordinates) are listed in Appendix B, while means and standard deviations are shown as bar graphs in Figure 59.

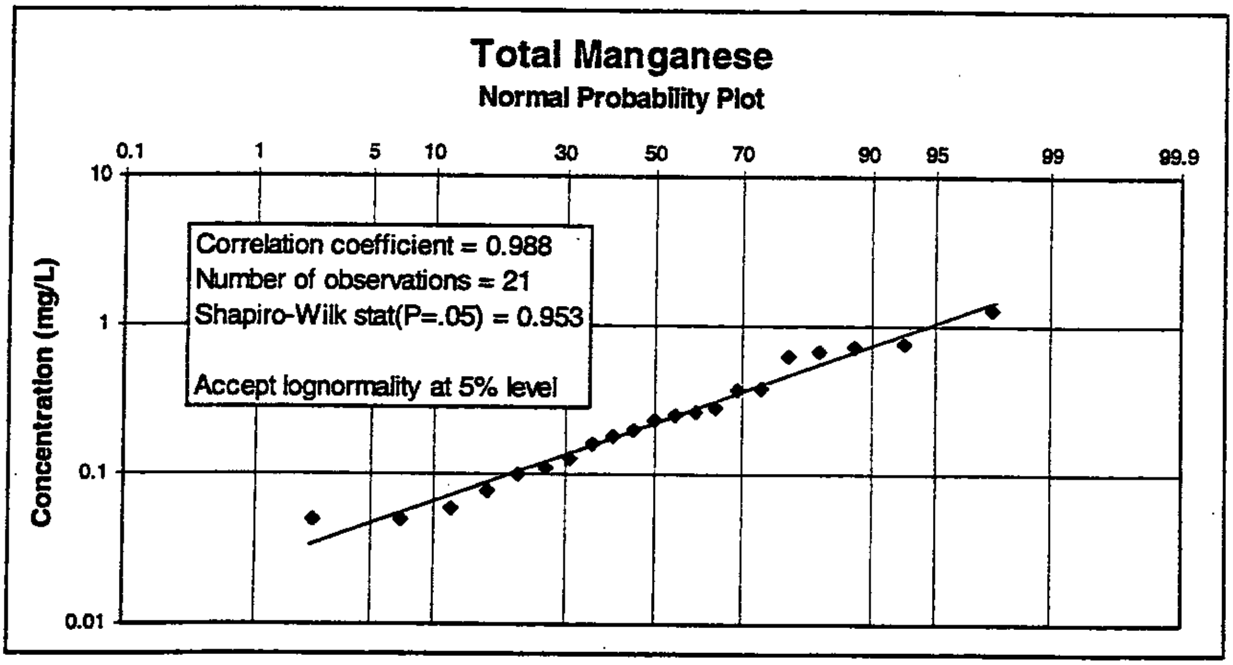

Figure 58. Total Manganese Normal Probability Plot

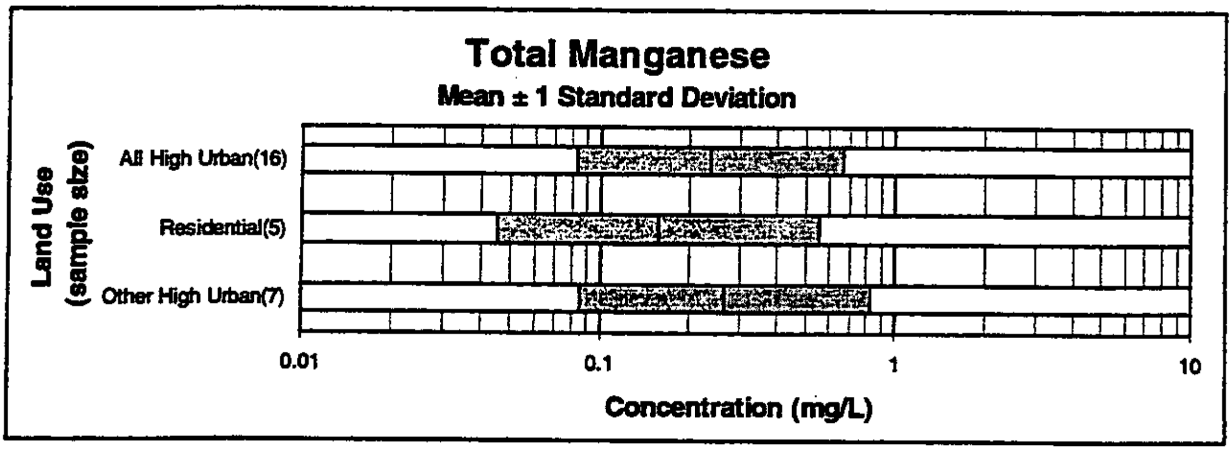

Figure 59. Total Manganese Concentration vs Land Use

### 3.17.1 Summary

Analysis of manganese concentrations is hampered by the limited data available. Only two land use subgroups have sufficient data for comparison, and these are not significantly different. Nor is there any apparent relationship between manganese concentration and mean annual rainfall. Summary information on manganese concentrations is therefore limited to statistics of a single sample, for high urban land use, as shown in Table 17.

Table 17. Total Manganese Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| High urban | 16 | -0.63 | 0.45 | 0.37 | 0.23 | 0.26 |

## 3.18 Total Mercury

Mercury is a highly toxic element which serves no known beneficial physiological function. Mercury can exist in the environment as the metal, as inorganic salts, and as organomercurial compounds such as methyl mercury. Fish and mammals absorb and retain methyl mercury to a greater extent than inorganic mercury, and it is in this form that mercury accumulates along food chains. Mercury causes a wide range of toxic effects in humans, and is also toxic to fish and invertebrates (World Health Organization 1984).

Sources of mercury include emissions from the chlor-alkali industry, coal combustion, paint industry, dental amalgam (Makepeace et al. 1995), and runoff from gold mining sites.

Altogether 17 records were obtained for total mercury, including 13 records from high urban areas excluding roads and roofs. The observed range extends from 0.000028 mg/L for a large urban area in Sault Sainte Marie, Canada, to 0.0027 mg/L for an urban catchment in Knoxville, Tennessee.

Total mercury concentrations from all land uses closely follow the log-normal distribution (Figure 60). Basic statistics describing the concentrations of total mercury from various land uses are listed in Appendix B, while the mean and standard deviation of the high urban group are shown in Figure 61.

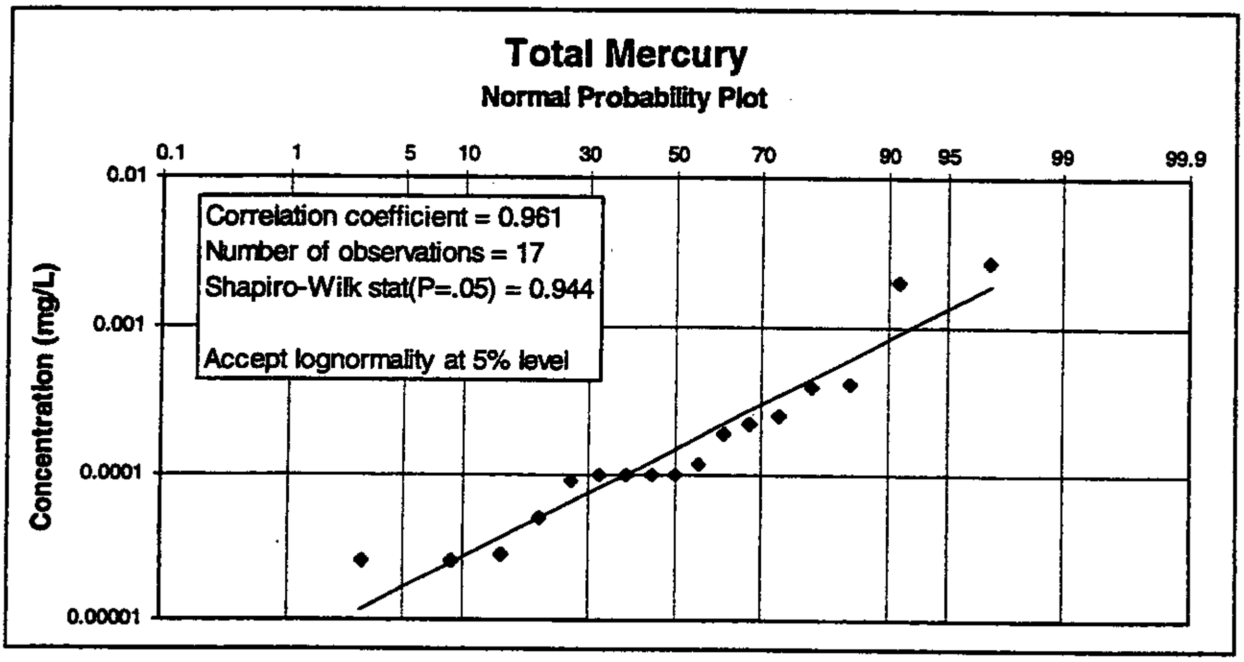

Figure 60. Total Mercury Normal Probability Plot

### 3.18.1 Summary

Most observations in this very small sample fall in the same land use subgroup, so no useful comparisons can be made. There is, however, a significant relationship between mercury concentration and mean annual rainfall, as shown in Figure 62. Mercury concentration appears to increase as annual rainfall increases, which is very unusual. But the three high rainfall points all derive from the same town, and may be influenced together by some local factor other than rainfall. Although the relationship is significant, it is not very robust.

Summary statistics for the high urban land use subgroup are shown in Table 18.

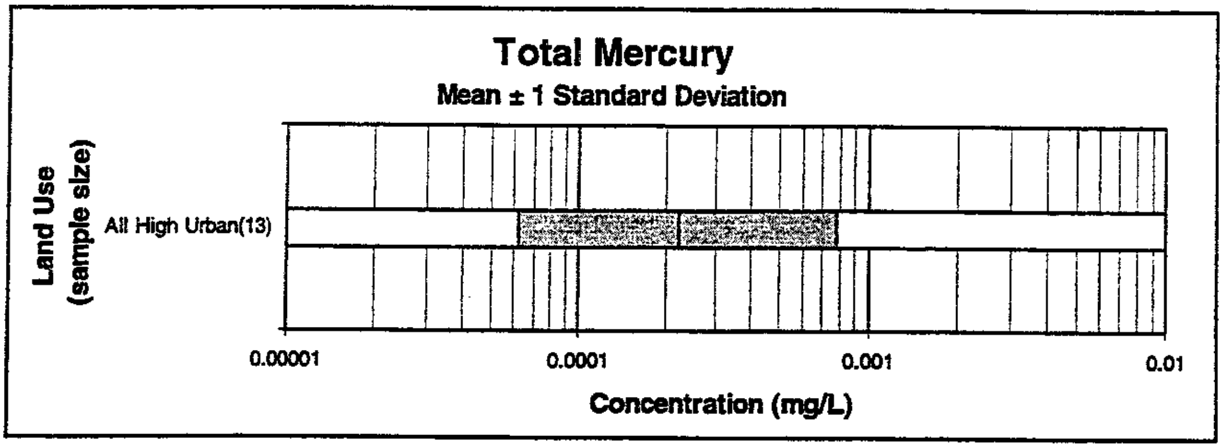

Figure 61. Total Mercury Concentration vs Land Use

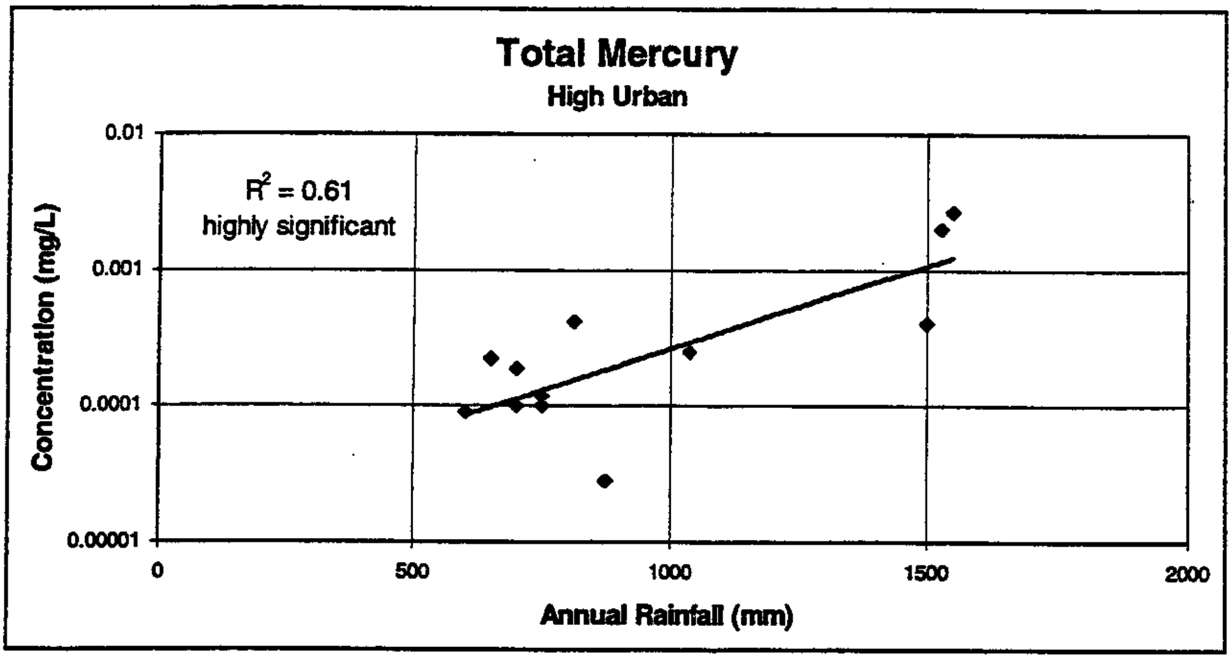

Figure 62. Total Mercury Concentration (High Urban) vs Annual Rainfall

Table 18. Total Mercury Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| High urban | 13 | -3.66 | 0.55 | 0.00052 | 0.00022 | 0.00019 |

## 3.19 Total Coliforms

Total coliforms are used as an indicator of microbiological contamination of water. An indicator organism is not necessarily dangerous in itself, but indicates the likely presence of fecal contamination, and hence the possible presence of pathogens in the sample.

Total coliforms are a sensitive measure of possible fecal contamination, since they are present in large numbers in the feces of warm blooded animals, and can be detected at low concentrations. But they do not confirm the presence of fecal contamination, as they can also be derived from vegetation and soil (World Health Organization 1984; Eaton et al. 1995).

Altogether 57 records were obtained for total coliforms, including 47 records from high urban areas other than roads and roofs. The observed range extends from 47 organisms per 100 mL for a galvanised iron roof in Selangor, Malaysia, to 11,000,000 organisms per 100 mL for a residential catchment in West Lafayette, Indiana.

Total coliform numbers from all land uses closely follow the log-normal distribution (Figure 63). Basic statistics describing total coliform numbers from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown as bar graphs in Figure 64.

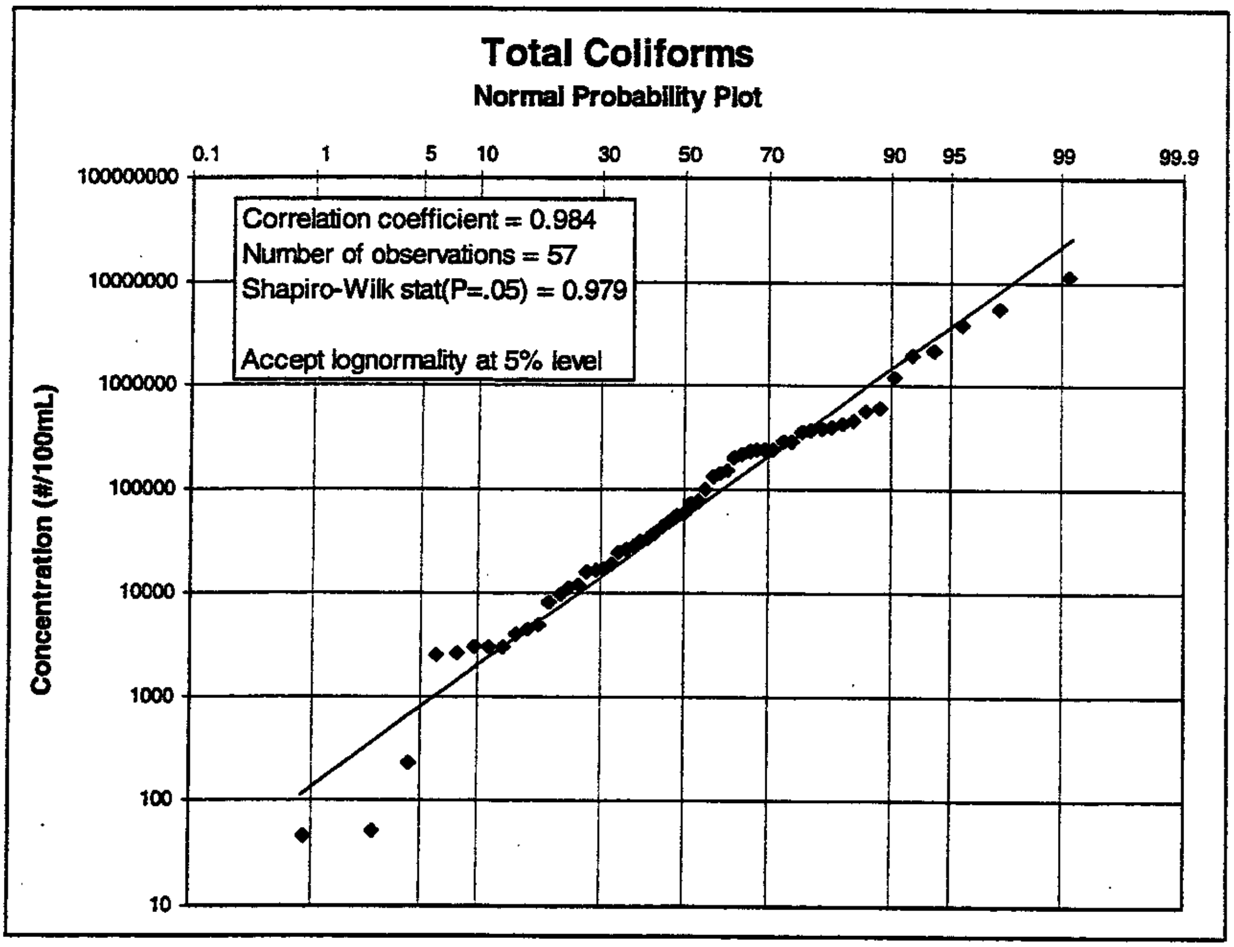

Figure 63. Total Coliforms Normal Probability Plot

### 3.19.1 High Urban

In the high urban group, residential and other high urban land uses are not significantly different. Despite a moderate sample size overall, industrial and commercial land uses are too poorly represented to test. No significant relationships were found between total coliform numbers and population density or mean annual rainfall.

### 3.19.2 Summary

Total coliform numbers are characterised by a very wide observed range, compared with the non-microbiological water quality parameters. As will be seen, this feature is shared by all three microbiological parameters investigated. Typical total coliform numbers from high urban areas are twenty times as high as from low urban areas, but even within the high urban land use group alone the observed range is extraordinarily wide. The highest total coliform counts approach those from raw sewage (Olivieri et al. 1978), and in these cases a degree of cross connection between drainage and sewage systems must be counted among the likely causes.

Summary statistics are listed in Table 19 for the distinct land use subgroups identified.

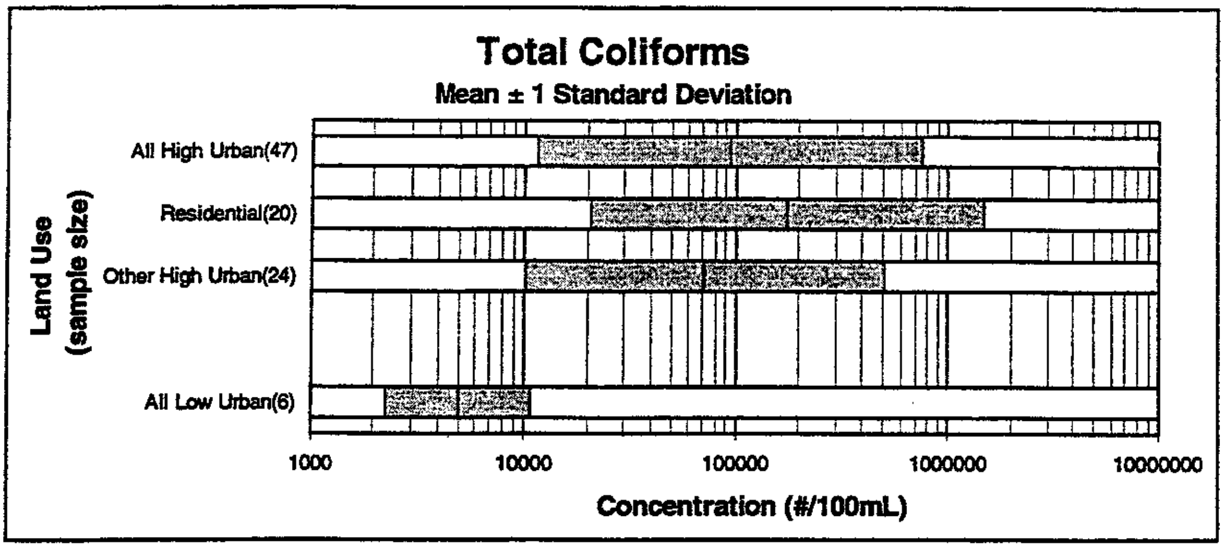

Figure 64. Total Coliforms vs Land Use

Table 19. Total Coliforms Summary Statistics

| Subgroup | Sample size | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| High urban | 47 | 4.97 | 0.91 | 620,000 | 93,000 | 130,000 |
| Low urban | 6 | 3.70 | 0.34 | 6,700 | 5,000 | 3,700 |

## 3.20 Fecal Coliforms

Fecal coliforms are used as an indicator of fecal contamination of water. Fecal (or thermotolerant) coliforms are a subset of total coliforms, and are more closely associated with fecal contamination than the total coliforms. Escherichia coli (E. coli) is a member of this group, and is specifically of fecal origin (World Health Organization 1984).

Altogether 117 records were obtained for fecal coliforms, including 81 records from high urban areas excluding roads and roofs. The observed range extends from less than one organism per 100 mL for a galvanised iron roof in Armidale, Australia, to 3,400,000 organisms per 100 mL for an urban catchment in West Lafayette, Indiana.

Fecal coliform numbers from all land uses closely follow the log-normal distribution (Figure 65). Basic statistics describing fecal coliform numbers from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown as bar graphs in Figure 66.

### 3.20.1 High Urban

Fecal coliform counts from residential areas are typically ten times as large as those from other types of high urban land use, which is a highly significant difference (Figure 66). Associated with this is a highly significant relationship between fecal coliforms and population density, with higher population giving higher fecal coliform counts (Figure 67). Possible causes presumably include sewer overflows, household pets, and native animals acclimatised to urban areas.

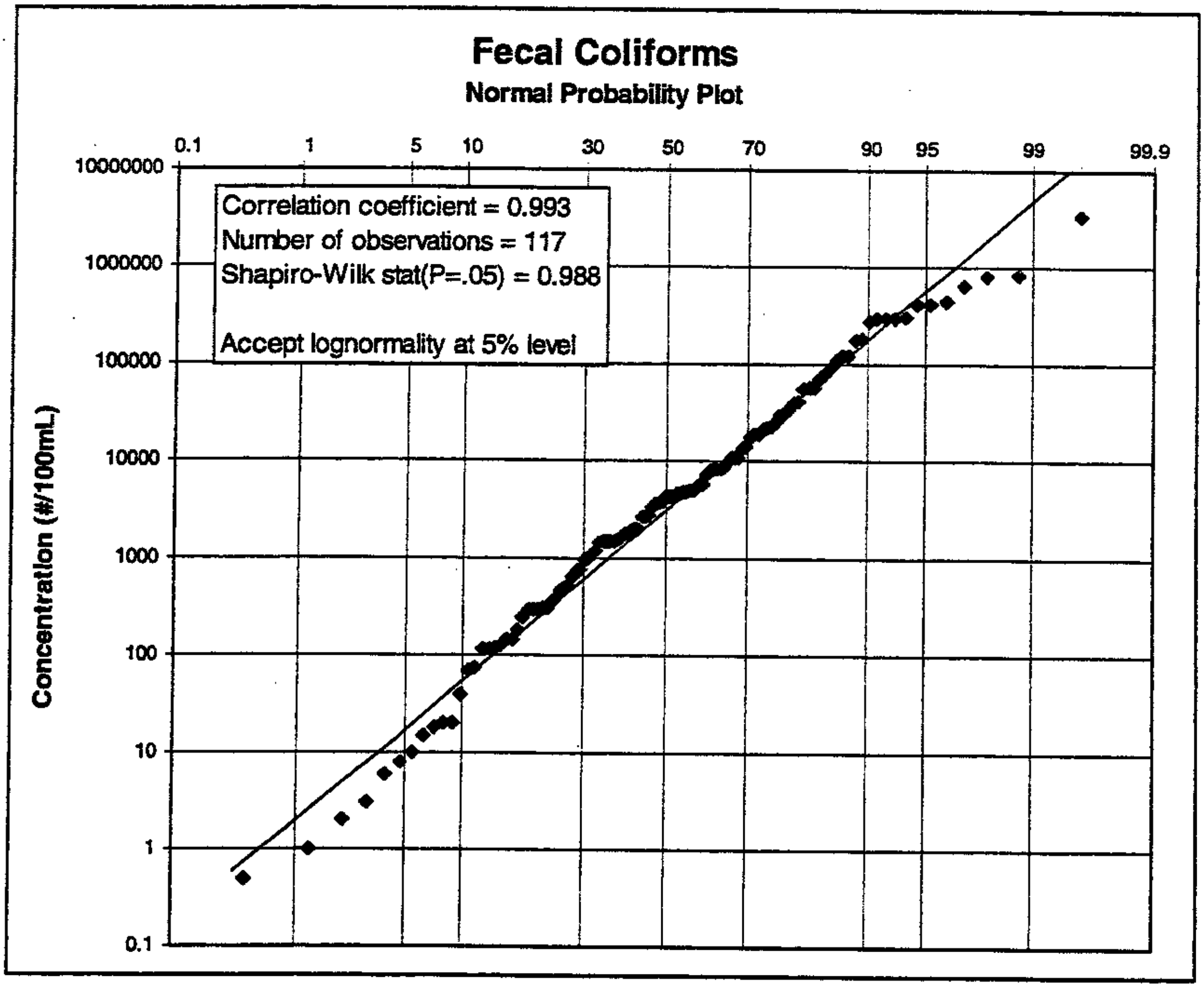

Figure 65. Fecal Coliforms Normal Probability Plot

### 3.20.2 Summary

Taken as a single group, high urban areas produce fecal coliform counts very similar to those from roads, and fully 100 times higher than those from roofs and low urban areas. The observed range across all land uses is exceptionally wide, and so is the difference between land use groups. Summary statistics are listed in Table 20 for the distinct land use subgroups identified.

Table 20. Fecal Coliforms Summary Statistics

| Subgroup | Sample size | Log Transformed Data |  | Untransformed Data (mg/L) |  |  |
|---|---|---|---|---|---|---|
|  |  | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 11 | 3.85 | 0.61 | 18,000 | 7,100 | 4,800 |
| Roofs | 14 | 1.73 | 1.07 | 290 | 54 | 115 |
| Residential | 42 | 4.38 | 0.98 | 200,000 | 24,000 | 17,000 |
| Non-resid. high urban | 39 | 3.38 | 1.08 | 26,000 | 2,400 | 1,900 |
| Low urban | 9 | 1.88 | 1.19 | 880 | 76 | 39 |

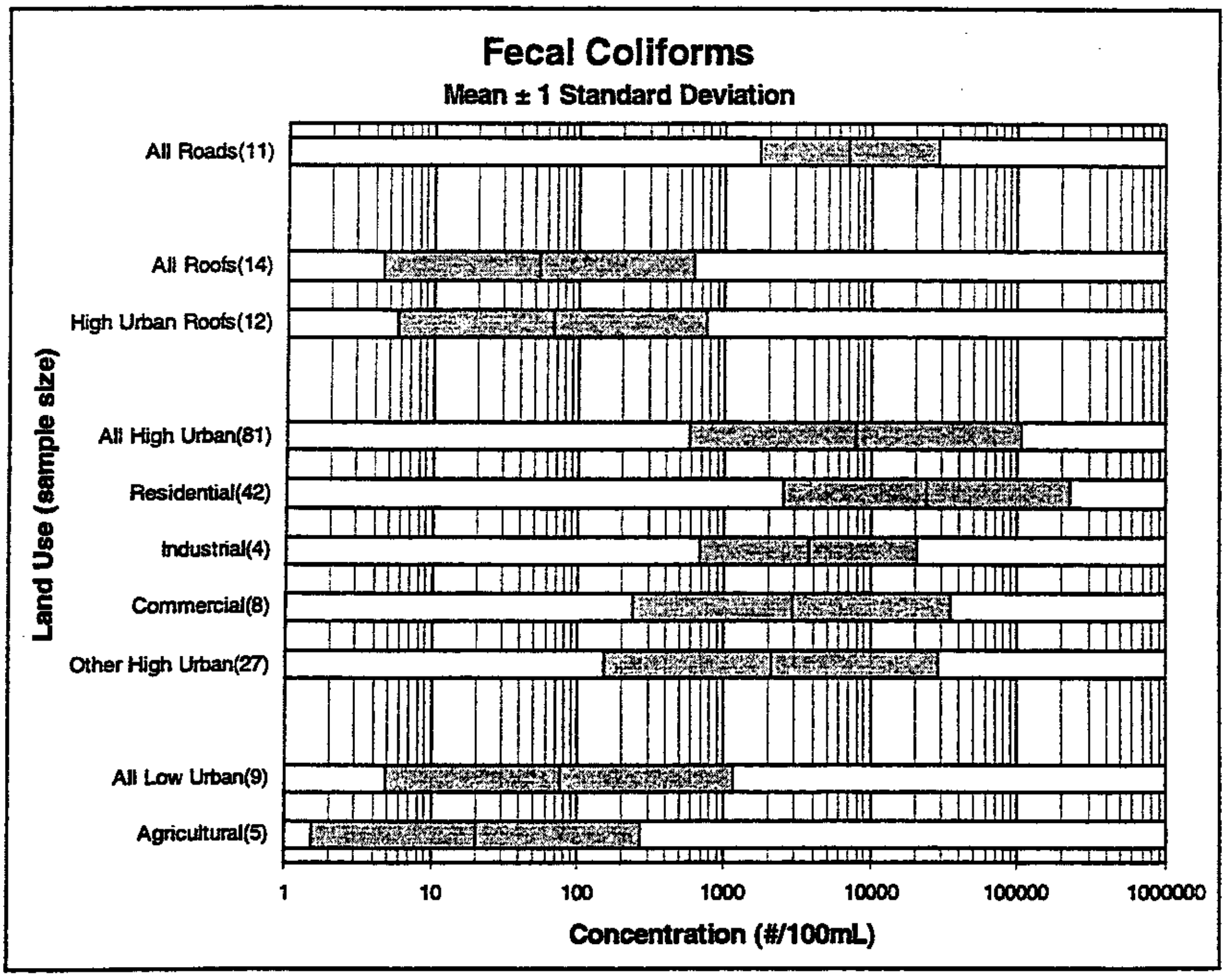

Figure 66. Fecal Coliforms vs Land Use

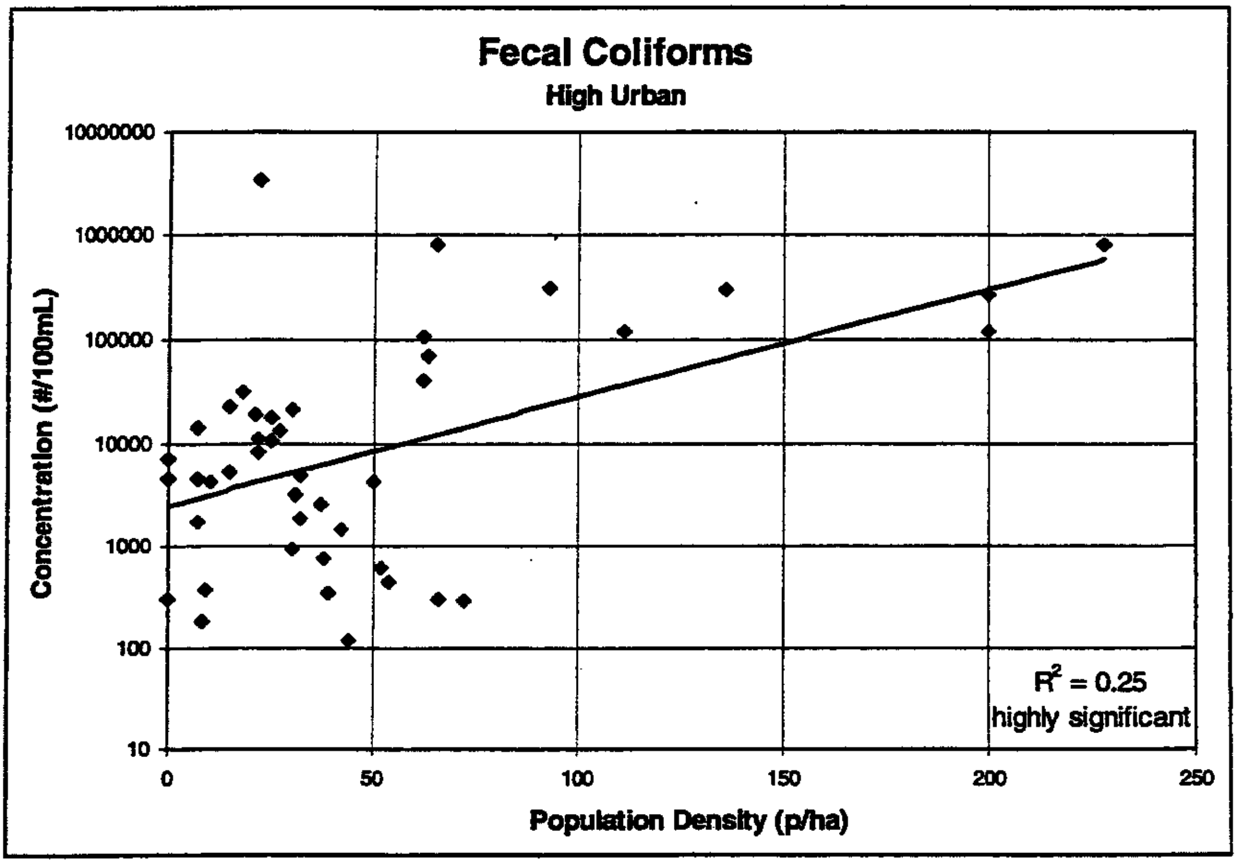

Figure 67. Fecal Coliforms (High Urban) vs Population Density

## 3.21 Fecal Streptococci

The term fecal streptococci refers to those streptococci normally present in the feces of humans and animals. Their presence in water generally indicates fecal pollution, and hence the possible presence of pathogens.

Altogether 34 records were obtained for fecal streptococci, including 19 records from high urban areas excluding roads and roofs. The observed range extends from 29 organisms per 100 mL for an institutional catchment in Ann Arbor, Michigan, to 660,000 organisms per 100 mL for a residential catchment in Baltimore, Maryland.

Fecal streptococci numbers from all land uses closely follow the log-normal distribution (Figure 68). Basic statistics describing fecal streptococci numbers from various land uses (in log coordinates) are tabulated in Appendix B, while means and standard deviations are shown as bar graphs in Figure 69.

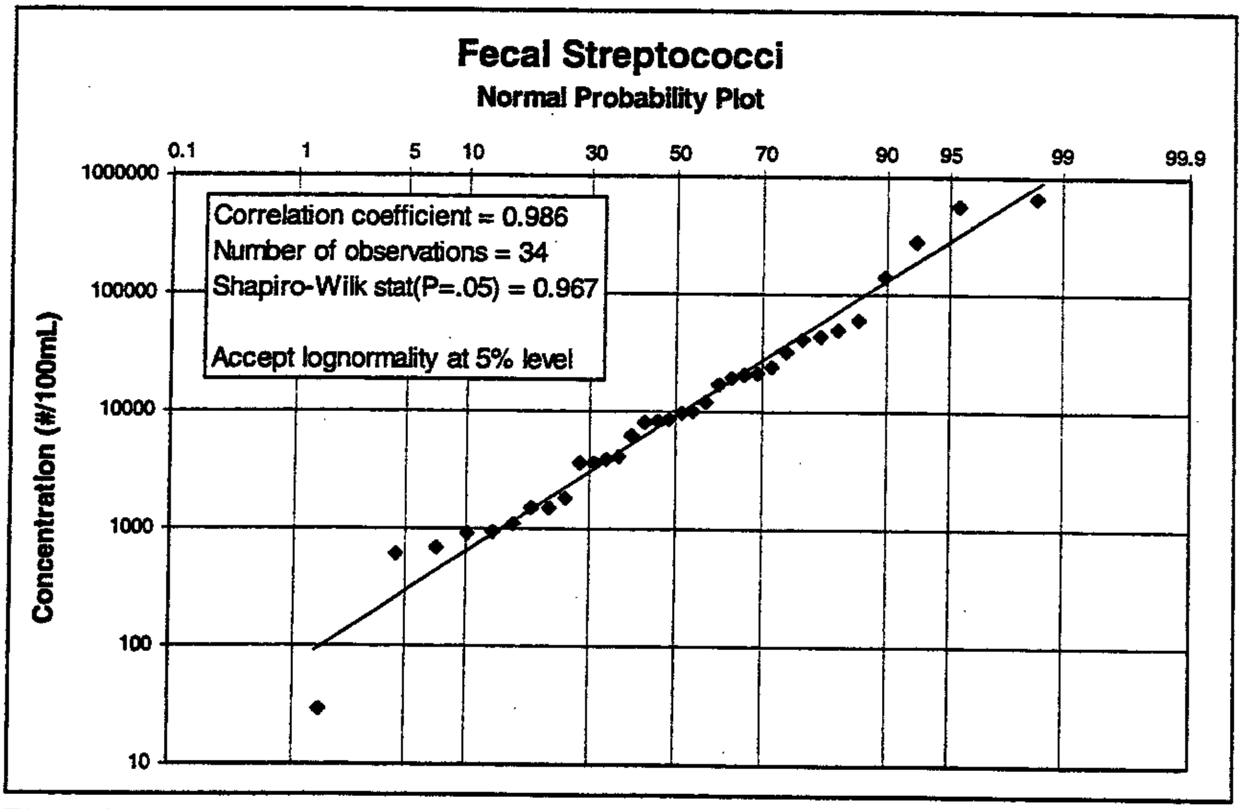

Figure 68. Fecal Streptococci Normal Probability Plot

### 3.21.1 Summary

Roads, high urban catchments excluding residential areas, and low urban catchments all produce very similar fecal streptococci numbers, on average. Typical counts from residential areas are nearly ten times as high, which is a significant difference. As with the other microbiological quality parameters, the observed range overall and the standard deviations of each land use subgroup are both very wide.

Summary statistics are listed in Table 21 for the distinct land use subgroups identified.

Taking the three microbiological parameters together, there is a distinct trend across the various land uses. Residential catchments produce the highest counts, followed by all other urban uses including roads, followed by low urban areas and all roofs with the lowest counts. Associated with the high residential counts is the highly significant (and highly scattered) relationship between fecal coliforms and population density. High bacterial counts are clearly associated with high population counts - of people, and perhaps of their pets.

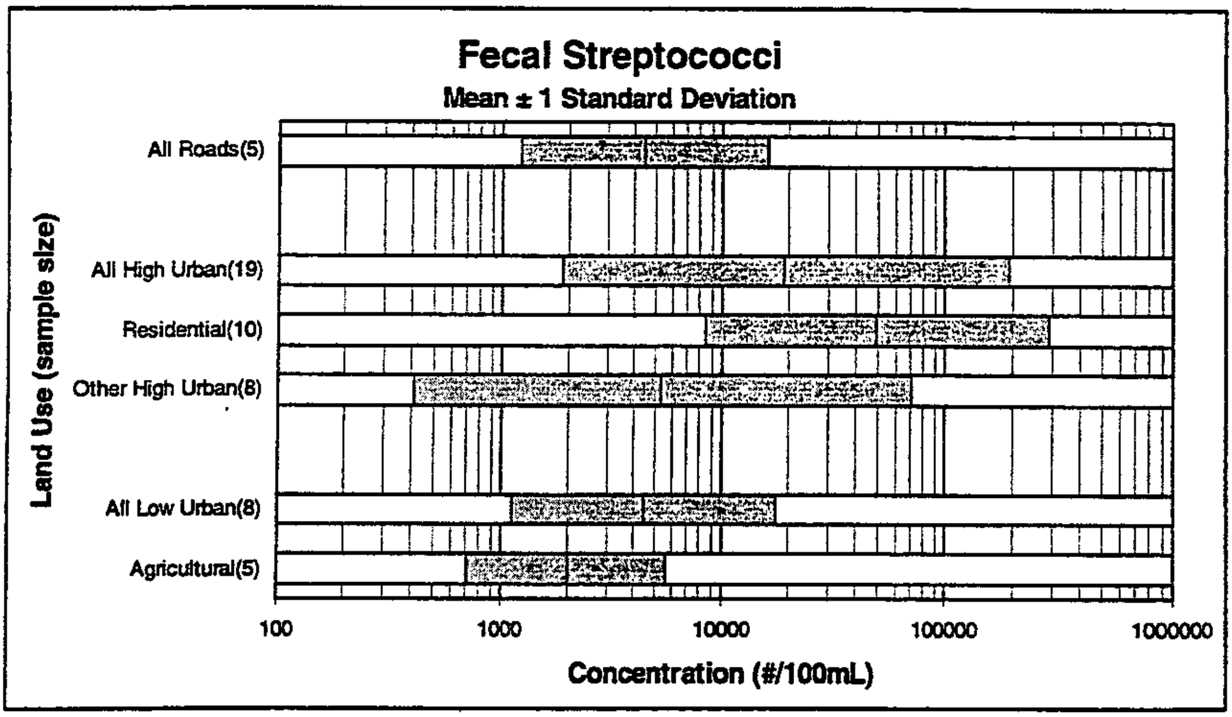

Figure 69. Fecal Streptococci vs Land Use

Table 21. Fecal Streptococci Summary Statistics

| Subgroup | Sample | Log Transformed Data | | Untransformed Data (mg/L) | | |
|---|---|---|---|---|---|---|
| | size | Mean | Std. Dev. | Arith. Mean | Geo. Mean | Median |
| Roads | 5 | 3.65 | 0.56 | 7,700 | 4,500 | 7,900 |
| Residential | 10 | 4.69 | 0.77 | 170,000 | 49,000 | 42,000 |
| Non-resid. high urban | 9 | 3.82 | 1.07 | 29,000 | 6,600 | 6,200 |
| Low urban | 8 | 3.65 | 0.60 | 8,500 | 4,500 | 6,000 |

## 4. CORRELATIONS BETWEEN PARAMETERS

Correlations between the various water quality parameters over repeated measurements at a single site have frequently been noted, particularly between suspended solids and hydrocarbons, phosphorus, and heavy metals (Walesh 1986; Preul & Ruszkowski 1987; Urbonas 1991). This can occur because the sources of pollution on a given catchment tend to remain constant, at least over the time duration of most sampling studies. Using the data set developed here, it is possible to test for associations between parameters over many sites, rather than at a single site as is more usually done.

Coefficients of determination ($R^2$) have been calculated for all pairs of water quality parameters, and are shown in Table 22 for the pairs where the relationship is significant at the 5% level or better. All parameters are expressed as concentrations in log coordinates, except for pH which retains its untransformed index value.

Correlations between pairs of parameters in Table 22 are often statistically significant, but the coefficients of determination in many cases are surprisingly low. Significance depends on sample size as well as goodness of fit, so there can be a significant relationship in a large sample even when the goodness of fit is too low to be useful in practice. At the other extreme, non-significance in Table 22 may simply reflect an inadequate sample size. It does not prove the absence of any underlying relationship.

Table 22. Coefficients of Determination

**Coefficients of Determination ($R^2$) between Parameters**

| | TP | TN | COD | BOD | O&G | TOC | pH | Turb | Pb | Zn | Cu | Cd | Cr | Ni | Fe | Mn | T.coli | F.coli | F.strep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SS | **0.21** | **0.09** | **0.23** | **0.22** | | 0.13 | | **0.79** | **0.14** | **0.06** | **0.17** | 0.10 | 0.11 | **0.48** | **0.49** | **0.71** | | 0.07 | |
| TP | | **0.34** | **0.42** | **0.11** | | | | | **0.24** | **0.06** | **0.08** | | | | | | | **0.47** | |
| TN | | | **0.29** | **0.11** | | 0.17 | | | **0.09** | **0.15** | **0.13** | | | | 0.30 | | | 0.16 | |
| COD | | | | **0.40** | | **0.61** | | 0.30 | **0.37** | **0.22** | **0.27** | | **0.28** | **0.60** | **0.46** | | | **0.16** | |
| BOD | | | | | **0.35** | **0.58** | | | | **0.18** | | | | | | | | **0.14** | |
| O&G | | | | | | | | | | | | | | | 0.22 | | | | |
| TOC | | | | | | | | | **0.38** | **0.32** | **0.39** | | | | | | | | |
| pH | | | | | | | | 0.28 | **0.24** | | | 0.15 | | | | | | | |
| Turb | | | | | | | | | **0.61** | 0.25 | | | | | | | | **0.37** | |
| Pb | | | | | | | | | | 0.04 | **0.21** | 0.28 | 0.06 | | | | | 0.08 | |
| Zn | | | | | | | | | | | **0.15** | | 0.06 | | **0.22** | | | 0.12 | |
| Cu | | | | | | | | | | | | **0.10** | **0.17** | **0.26** | **0.20** | | | | |
| Cd | | | | | | | | | | | | | **0.28** | 0.19 | | | | 0.20 | |
| Cr | | | | | | | | | | | | | | **0.30** | 0.22 | | | | |
| Ni | | | | | | | | | | | | | | | | | | | |
| Fe | | | | | | | | | | | | | | | | **0.77** | | | |
| Mn | | | | | | | | | | | | | | | | | | | |
| T.coli | | | | | | | | | | | | | | | | | | **0.63** | **0.72** |
| F.coli | | | | | | | | | | | | | | | | | | | **0.51** |

blank = $P > 0.05$, normal = $P < 0.05$, **bold = $P < 0.01$**

All parameters except pH in log coordinates

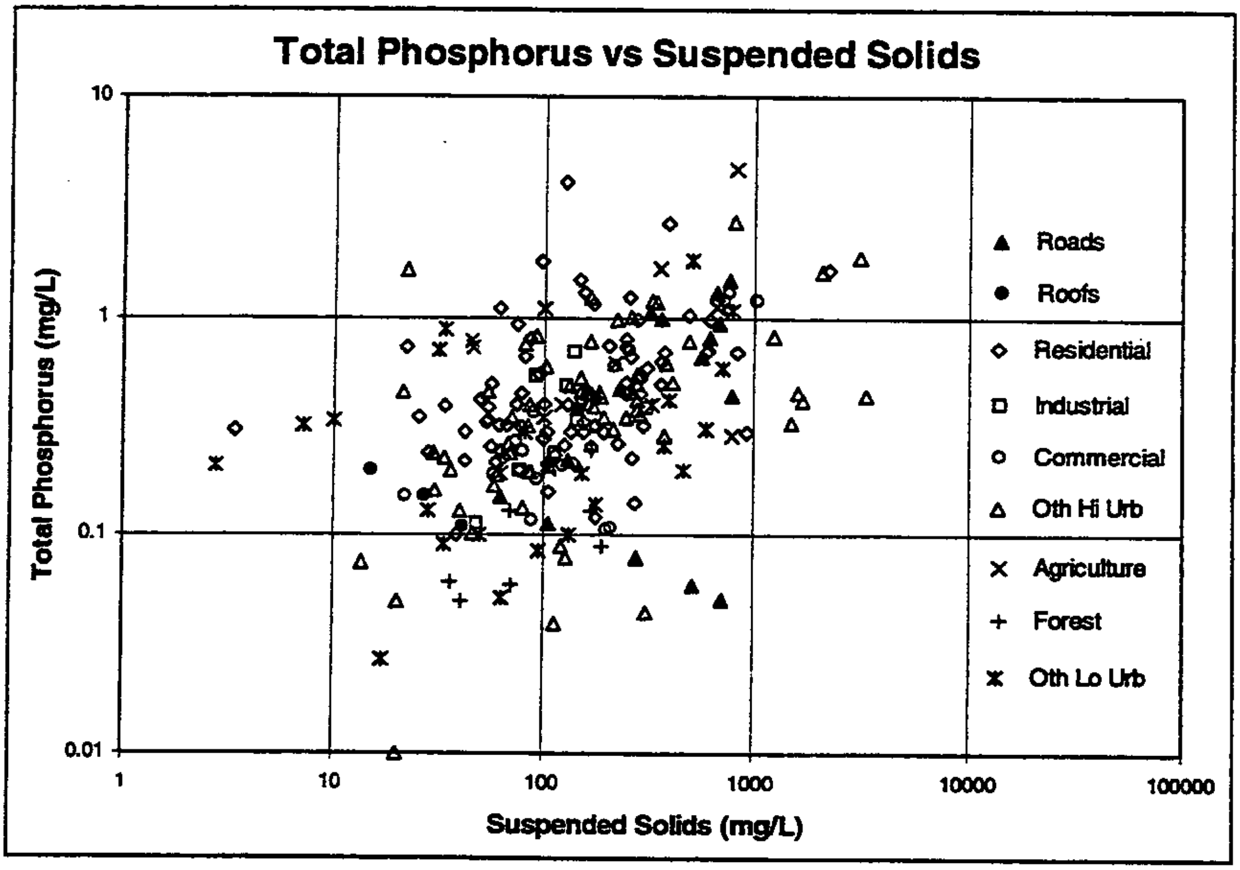

Figure 70. Total Phosphorus vs Suspended Solids

Typically the scatter about the regression line is wide, and the explanatory power of the regression is low. As an example, the relationship between total phosphorus and suspended solids, which has the largest sample size, is shown in Figure 70. With all land uses combined into a single group, the relationship with suspended solids concentration explains only 21% of the variation in total phosphorus concentration, despite being statistically highly significant.

Separate analysis of each land use type does not give an obvious improvement. Consideration of land use in Figure 70 provides little new information, other than an indication of the group means and standard deviations already summarised on the bar graphs in Section 3.

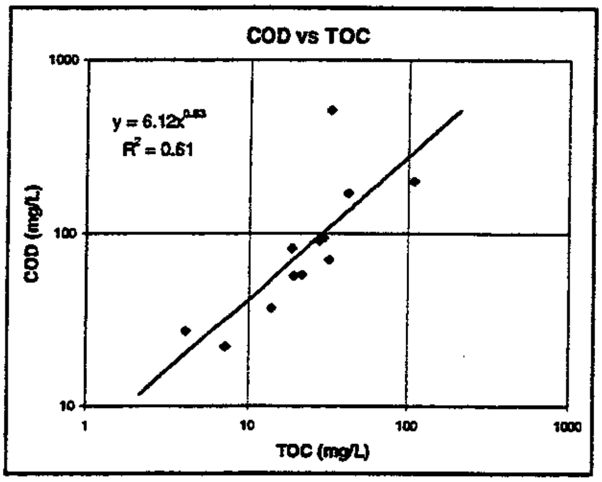

Figure 71. COD vs TOC

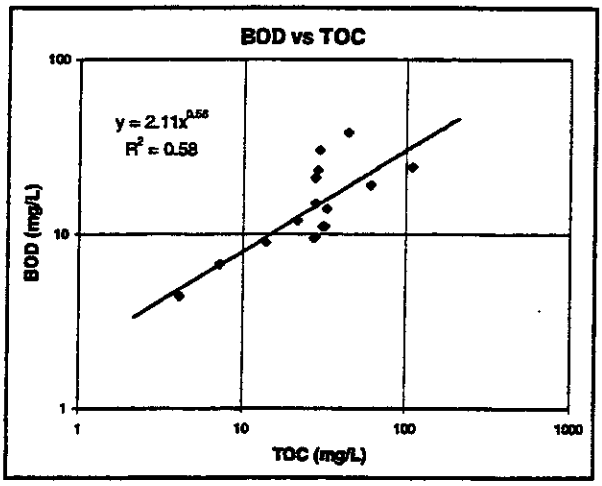

Figure 72. BOD vs TOC

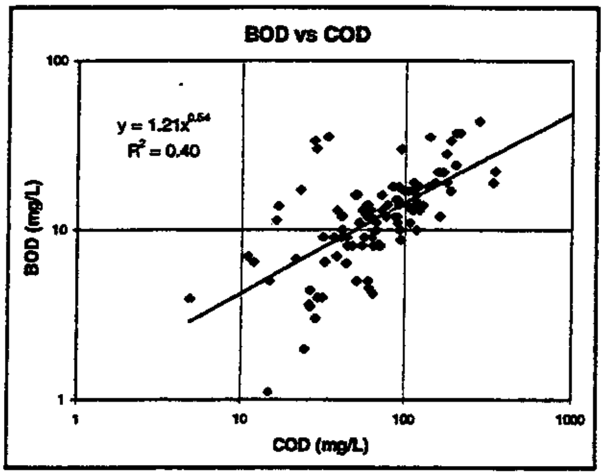

Figure 73. BOD vs COD

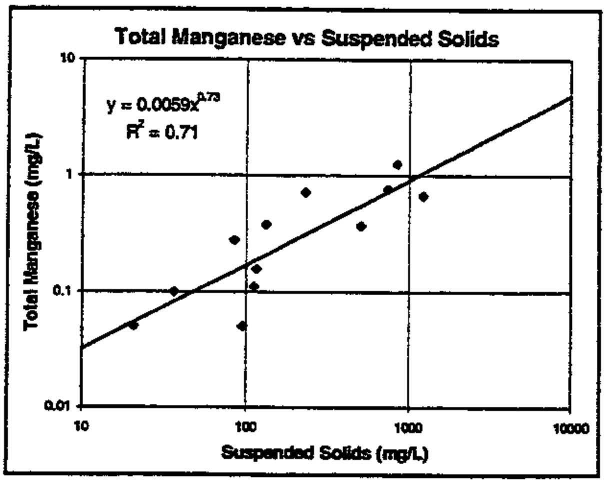

Figure 74. Total Manganese vs Suspended Solids

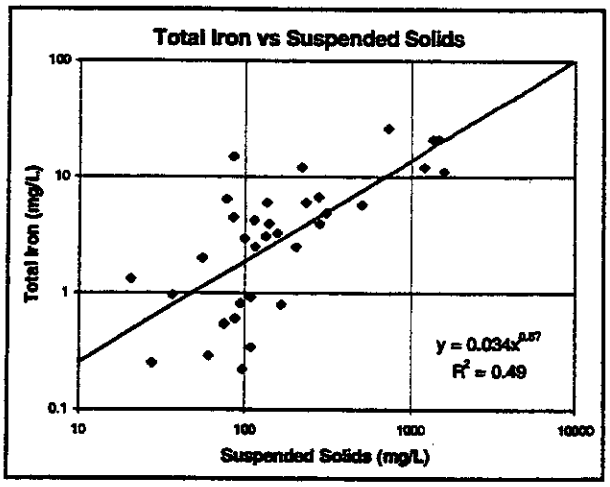

Figure 75. Total Iron vs Suspended Solids

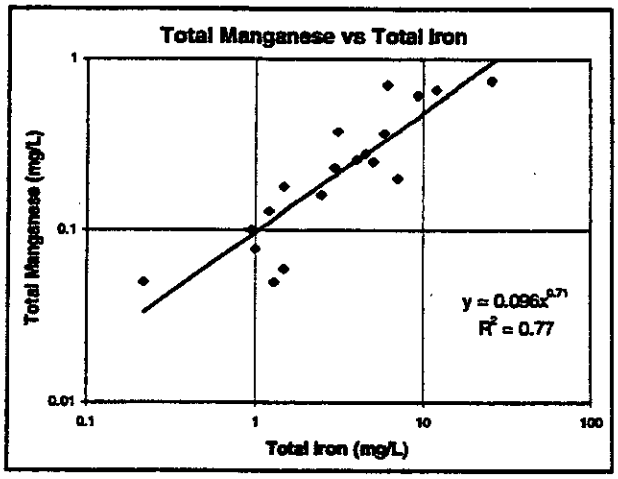

Figure 76. Total Manganese vs Total Iron

Despite the generally low correlations, there are several groups of parameters which exhibit potentially useful relationships. The first group comprises chemical oxygen demand (COD), biochemical oxygen demand (BOD), and total organic carbon (TOC) (Figure 71 to Figure 73). This association has been noted previously, for samples from a specific source (Section 3.4), and still shows a moderately good fit here, across many sources. With only one exception, the recorded CODs in Figure 71 are close to the amount of oxygen required to oxidise the carbon to carbon dioxide (32 mg oxygen per 12 mg carbon), suggesting that in most cases this is the main source of the chemical oxygen demand.

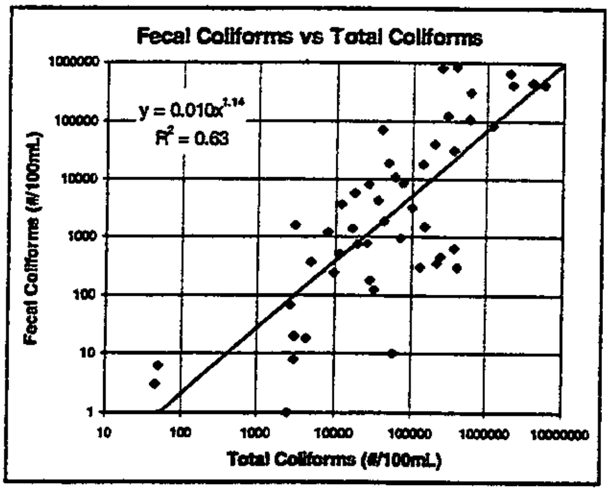

Figure 77. Fecal Coliforms vs Total Coliforms

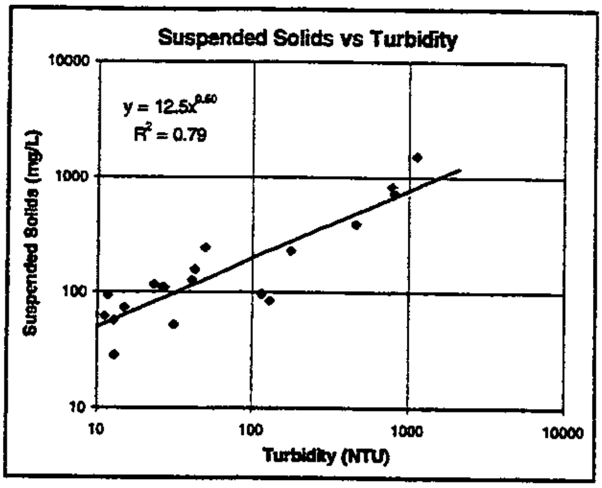

Figure 80. Suspended Solids vs Turbidity

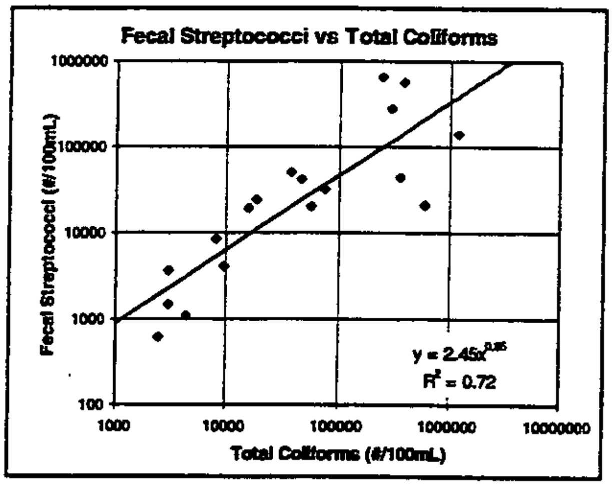

Figure 78. Fecal Streptococci vs Total Coliforms

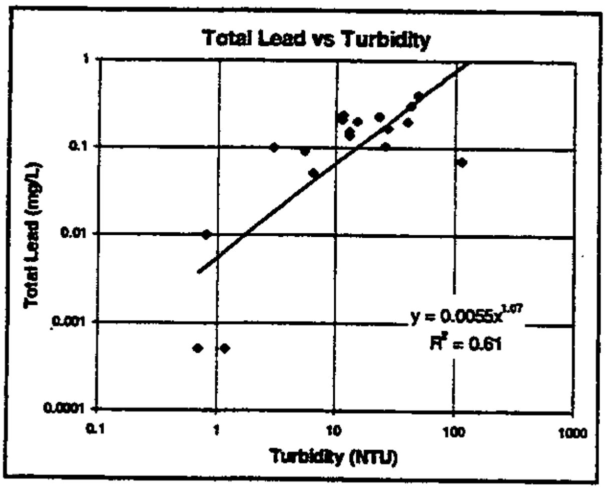

Figure 81. Total Lead vs Turbidity

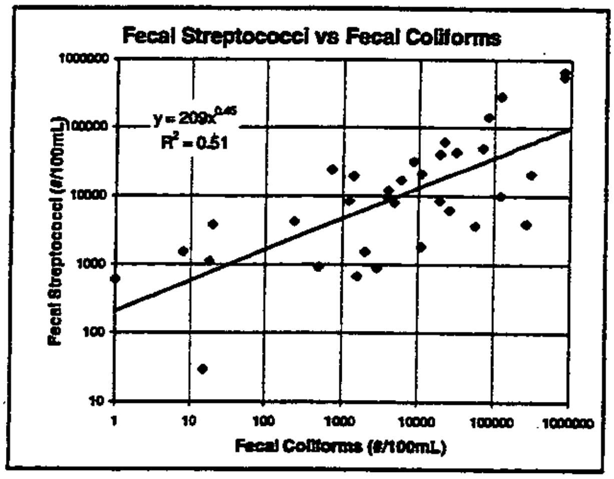

Figure 79. Fecal Streptococci vs Fecal Coliforms

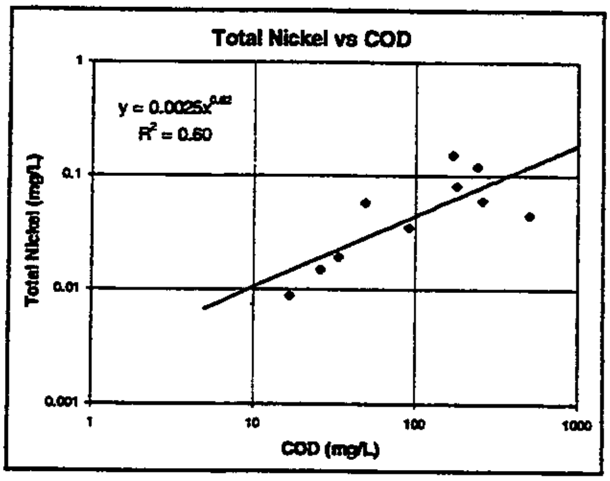

Figure 82. Total Nickel vs COD

A second group includes total iron, total manganese, and suspended solids (Figure 74 to Figure 76). The correlation between iron concentration and manganese concentration, in log coordinates, is particularly high. The chemical similarity between these elements, as indicated by their adjacent positions in the periodic table, evidently does extend to their behaviour in stormwater runoff. The observed concentration of iron is typically ten to twenty times higher than that of manganese.

The three microbiological parameters form a third group (Figure 77 to Figure 79). Their most distinctive common feature is that they are living organisms – they can increase or die off depending on conditions, and hence are not conservative parameters. Other characteristics of this group – a very wide observed range, and a significant association with population density – have been noted previously (Section 3.21.1).

Turbidity and suspended solids are highly correlated (Figure 80), as could be expected, since both parameters are associated with particles suspended in the water sample. The correlation is not even higher because the relationship also depends on the particle size distribution. Finer particles scatter light more effectively giving higher turbidity, but larger particles contribute more to the total suspended mass.

Two more relationships show a coefficient of determination of 0.6 or more – total lead vs turbidity (Figure 81), and total nickel vs COD (Figure 82). They are both plausible relationships, given that climatic or topographic conditions may cause high levels of many parameters simultaneously from a given catchment, but arguably no more so than many other combinations which do not stand out. Perhaps they are just chance associations: in about two hundred tests some false positives are likely to occur, even at the 99% confidence level.

Although the relationships noted above are highly significant, the low coefficients of determination for many other parameter pairs is also an interesting result. The association between water quality parameters which may be expected to apply at a single site is often much reduced when tested over many sites. As a result, there are only a few cases where one quality parameter can provide a good estimate of another parameter. No single quality parameter can provide a good estimate of a range of other parameters.

# 5. DISCUSSION

The relationships between contaminant concentrations and catchment characteristics provide some insight into the likely processes of contamination, and may have implications for management and control. Relationships which apply to single parameters have been noted previously, but there are also some more general effects.

## 5.1 Land Use

Land use zoning and actual surface use are frequently presented in the source documents as descriptive information rather than numeric data, and therefore they have been treated as grouping variables in this study. Their effect has been assessed by comparing the behaviour of the groups they define.

There are fewer significant differences between land use zonings within the high urban group than might be expected. All significant differences are noted under the individual parameters, but broadly speaking residential zonings tend to produce lower concentrations of metals and organic carbon, and higher concentrations of phosphorus and microbiological measures than the other urban zonings. No significant differences were detected between high urban land use zonings for either suspended solids or total nitrogen, despite their very large sample sizes. The scatter of results from the reported studies is wide, but the standard urban land use zonings explain only a small part of it. This, incidentally, helps to explain the good fit of the raw data to a simple statistical distribution. Since the main parameter used to deliberately stratify the measured sites actually has only a small effect, it is almost as if the sites were selected at random from the whole population.

Actual surface use has more effect. Concentrations from roads are generally similar to those from mixed high urban areas or perhaps a little higher, but concentrations from roofs are substantially lower for all parameters tested except zinc. Since roads and roofs together make up a large proportion of the impervious area of an urban catchment, it should not really be surprising that concentrations from mixed high urban catchments tend to lie between those from the two single uses. But it also follows from this that roads are a major source of most contaminants in urban runoff.

The elevation effect noted previously for suspended solids seems to apply to many quality parameters. Any contaminant associated with particles is likely to gravitate to lower levels during dry weather redistribution by wind and eddies. In an urban area, the highest impervious areas are typically roofs, and the lowest are roads. So the high contaminant contributions from roads are a result of their lower elevation, as well as their vehicular traffic.

If urban and rural catchments are compared, a distinction should be made between undisturbed rural and agricultural rural use. Concentrations of suspended solids, total nitrogen, and total phosphorus are on average highest for agricultural catchments, intermediate for urban catchments, and lowest for forested catchments. Where limited sample size does not permit this distinction, concentrations of total lead, BOD, COD, total coliforms, fecal coliforms, and fecal streptococci are higher on average from high urban catchments than from all low urban catchments taken as a single group.

## 5.2 Catchment Characteristics

Mean annual rainfall, percent impervious, population density, and vehicle density are usually described numerically in the source documents, if they are mentioned at all. In this study, they have been used as explanatory variables in regression analysis. Many of the relationships have been noted individually in the previous section. To help provide an overview of quality parameters with similar behaviour, a table of regression coefficients is shown in Appendix C.

A negative relationship between log concentration and mean annual rainfall is very common in the metal and non-metal parameters, but not in the microbiological measures. It appears to apply to the roads, high urban, and low urban groups. It was not detected in the roofs group, but that could be due to the smaller sample tested. The effect is strongest for suspended solids and total organic carbon - increasing the annual rainfall by 500 mm approximately halves the most likely concentration in runoff. For most contaminants the effect is less than this, but even so the mean annual rainfall has less influence on total load than would otherwise be the case. This seems to indicate some measure of source limitation for these water quality parameters.

There is a strong positive relationship between log concentration and population density for total nitrogen, BOD, and fecal coliforms, and a tendency in the same direction for COD and total coliforms, but not for metals. Sewage overflows would contribute to all these parameters, and so must be a possible cause, but pets, garden maintenance, littering, and other human activities may also be involved.

Higher percent impervious area is associated with higher concentrations of lead and zinc, but lower concentrations of cadmium. The effect for lead and zinc presumably derives from an association with impervious roads (lead) and roofs (zinc). Cadmium is an anomaly - much of its behaviour in this sample suggests a pervious source, although it is not clear why this should be so.

Analysis of traffic density is limited by the sample size. There is a strong positive association with lead concentration, presumably due to petrol additives, and a strong negative association with total phosphorus. Apparently vegetation and other sources of phosphorus are less common near high-use roads.

## 5.3 Explanatory Power

The preceding analysis has revealed a number of significant relationships between runoff concentrations and catchment characteristics, and a number of significant differences between land use groups. Some of these are significant at very high confidence levels, but overall the explanatory power remains low.

The lack of explanatory power has two main implications. Firstly, it means that the analysis described here does not in itself provide a useful method for estimating pollutant loads or concentrations, except perhaps at the broadest preliminary screening level. But perhaps, by helping to direct research into other areas, it may be a step on the path to a better method.

Secondly, it means that one or more important explanatory variables is yet to be recognised. Unless we decide that the process is ultimately chaotic, and hence effectively unknowable at a practical level, we must accept that some factor or process can explain more of the observed variability than has been achieved here. Measurement errors and differences in technique and in land use description could scarcely explain scatter of this magnitude. Possibilities include catchment characteristics (such as geology and soil type), storm characteristics (such as rainfall intensity), and the level of detail used in analysis.

Analysis of a subset of this data (sites with retarding basins) as part of another study suggests that geological age of the catchment may have some effect - older sediments give higher concentrations of suspended solids. Yet, as with the other variables, the effect is significant but the explanatory power is low. It is not the lateral step or quantum leap we are looking for.

Rainfall intensity is rather more promising. It is not often documented in the studies analysed here, particularly at short time intervals, but its effect on washoff has nevertheless been noted (Sartor & Boyd 1972; Reinertsen 1981; Desbordes & Servat 1987; Yaziz et al. 1989; Baffaut & Delleur 1990; Bujon et al. 1992; Kuo et al. 1993). Price & Mance (1978) and Coleman (1993) associate washoff specifically with particle detachment by rainfall impact energy, which is a standard technique for erosion of pervious areas (Hudson 1971). Because rainfall energy depends on a high power of rainfall intensity, it is important to incorporate intensity information at short time intervals. Under this hypothesis most contaminant mobilisation in an event may occur during a few minutes of high intensity rainfall. An annual mean or event mean intensity does not provide adequate resolution of these processes. Preliminary investigation of short term rainfall intensity is very promising (Chiew et al. 1997).

Alternatively, better time and space resolution may improve the fit of the factors used here. The relatively greater effect of actual surface use, the documented importance of small areas of soil disturbance (Pisano 1976; Barfield et al. 1978; Konno & Nonomura 1981), and the intuitive significance of local sources and spills, all suggest that this may be the case. If so, it is most unfortunate. Only rainfall is likely to be widely available at short time intervals, and moving to finer spatial scales sharply increases the modelling effort on a given catchment. A level of detail greater than that achieved in documented research is unlikely to be practical in day to day operations.

## 6. CONCLUSIONS

The following conclusions can be drawn from this study.

- Concentration data are approximately log-normally distributed for all water quality parameters investigated except pH, which is approximately normally distributed.
- Concentrations of suspended solids, total nitrogen, and total phosphorus are on average highest for agricultural catchments, intermediate for urban catchments, and lowest for forested catchments.
- Concentrations of total lead, BOD, COD, total coliforms, fecal coliforms, and fecal streptococci are higher on average from high urban catchments than from all low urban catchments taken as a single group.
- Roads are a major source of most contaminants in urban runoff. This is due to their lower elevation as well as their vehicular traffic.
- Concentrations from roofs are substantially lower on average than concentrations from roads and all high urban zonings, for all parameters tested except zinc.
- Within urban areas, residential zonings tend to produce lower concentrations of metals and organic carbon, and higher concentrations of phosphorus and microbiological measures than the other urban zonings, but the explanatory power is low.
- Urban sites with higher mean annual rainfall produce lower stormwater concentrations, on average, for most metal and non-metal parameters, but not for the microbiological measures. For suspended solids, which shows the strongest effect, increasing the mean annual rainfall by 500 mm approximately halves the most likely concentration in runoff.
- Sites with higher population density produce higher stormwater concentrations, on average, for total nitrogen, BOD, and fecal coliforms, and perhaps for COD and total coliforms, but not for metals.
- Correlations between water quality parameters over many measurement sites are often low. As a result, there are only a few cases where one quality parameter can provide a good estimate of another parameter. No single quality parameter can provide a good estimate of a range of other parameters.
- The explanatory power of all normally reported catchment characteristics is low, which implies that one or more important explanatory variables is yet to be recognised. Possible contenders include geological age of catchment rocks and soils, and short term rainfall intensity. A higher level of detail in modelling may also be helpful, but would be difficult to apply in practice.

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# APPENDIX A

## Data

| | |
|---|---|
| **Table A1** | Land use and concentration data |
| **Table A2** | Key to references |

The data set used in this study is listed to permit cross-checking and extension of the analysis. Due to space constraints it is presented in an abbreviated form, and much descriptive information has been omitted. The data set has been collated specifically for this study, and has been structured to fit the three way system of grouping variables described in the body of the report. A complete listing of source references is provided.

**Intending users are strongly urged to refer to the quoted source documents for further information before using this data for any purpose other than that described here.**

# Appendix A

| Location | | | Description | | | Land Use | | | | | | | | | Pop. | Traffic | | Miscellaneous | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country/State | Town/Area | Site | Area | Imp | Urban | Res | Ind | Com | Inst | Open | Other | Agr | For | Other | | Road | Dens | Roof | MtSt | Rain | SS |
| | | | ha | % | % | % | % | % | % | % | urban | % | % | rural | p/ha | % | veh/d | % | Helens | mm | mg/L |
| Arkansas | Little Rock | I-30 | | 90 | 83 | 83 | | | | | | | | | | 83 | 42000 | | | 1237 | 112 |
| Australia | Armidale | Rural galv iron roof | | 100 | 17 | | | | | | | | | | | | | 100 | | 797 | |
| Australia | Armidale | Rural conc tile roof | | 100 | 17 | | | | | | | | | | | | | 100 | | 797 | |
| Australia | Armidale | Urban galv iron roof | | 100 | 83 | | | | | | | | | | | | | 100 | | 797 | |
| Australia | Armidale | Urban conc tile roof | | 100 | 83 | | | | | | | | | | | | | 100 | | 797 | |
| Australia | Armidale | Indust galv iron roof | | 100 | 83 | | 83 | | | | | | | | | | | 100 | | 797 | |
| Australia | Armidale | Indust conc tile roof | | 100 | 83 | | 83 | | | | | | | | | | | 100 | | 797 | |
| Australia | Canberra | Burra Ck at Queanbeyan | 7060 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 60 | 0 | | | | | | 630 | 470 |
| Australia | Canberra | E Valley Way Dr | | | 83 | | | | | | | | | | | | | | | 630 | |
| Australia | Canberra | Ginninderra Ck at Baldwi | 7000 | | 10 | | | | | | | | | | | | | | | 630 | 180 |
| Australia | Canberra | Ginninderra Ck at Barton | 5150 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 85 | 15 | 0 | | | | | | 630 | 60 |
| Australia | Canberra | Giralang test area | 94 | | 85 | | | | | | | | | | | | | | | 630 | 3342 |
| Australia | Canberra | Gungahlin test area | 112 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | | | | | | 630 | 790 |
| Australia | Canberra | Gudgenby R at Tennant | 67100 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | | | | | | 630 | |
| Australia | Canberra | Gudgenby R at Naas | 38800 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 85 | 0 | | | | | | 630 | 150 |
| Australia | Canberra | Licking Hole Ck at Cotter | 2060 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | | | | | | 630 | 40 |
| Australia | Canberra | Yarralumla Ck at Curtin | 2690 | | 60 | | | | | | | 25 | 15 | 0 | | | | | | 630 | 1605 |
| Australia | Katoomba | Wetland | 26 | 40 | 100 | 60 | 0 | 30 | 0 | 10 | 0 | 0 | 0 | 0 | | | | | | | 13.5 |
| Australia | Melbourne | Bulli Road Dr | 78 | 36 | 100 | 3 | 50 | 9 | 0 | 24 | 13 | 0 | 0 | 0 | 2 | 13 | | | | 750 | 331 |
| Australia | Melbourne | St. Kilda Junction Dr | 31 | 86 | 100 | 37 | 0 | 9 | 5 | 2 | 46 | 0 | 0 | 0 | 21 | 46 | | | | 650 | 105 |
| Australia | Melbourne | Vine Street Dr | 78 | 45 | 100 | 55 | 2 | 2 | 1 | 19 | 20 | 0 | 0 | 0 | 32 | 20 | | | | 600 | 168 |
| Australia | Melbourne | Bell Street Main Dr | 283 | 58 | 100 | 43 | 24 | 2 | 2 | 6 | 20 | 0 | 0 | 0 | 25 | 20 | | | | 700 | 22 |
| Australia | Melbourne | Palmer Street Dr | 171 | 75 | 100 | 35 | 8 | 9 | 5 | 10 | 30 | 0 | 0 | 0 | 56 | 30 | | | | 700 | 185 |
| Australia | Melbourne | Hawthorn Main Dr | 800 | 61 | 100 | 60 | 1 | 4 | 7 | 4 | 21 | 0 | 0 | 0 | 22 | 21 | | | | 700 | 146 |
| Australia | Melbourne | Gardenia Ave Dr | 86 | 44 | 100 | 74 | 0 | 1 | 2 | 5 | 17 | 0 | 0 | 0 | 27 | 17 | | | | 750 | 144 |
| Australia | Melbourne | George St Dr at Victoria S | 227 | 44 | 100 | 64 | 0 | 1 | 6 | 16 | 13 | 0 | 0 | 0 | 33 | 13 | | | | 750 | 261 |
| Australia | Melbourne | George St Dr at High Sch | 59 | 44 | 100 | 62 | 0 | 2 | 13 | 3 | 19 | 0 | 0 | 0 | 28 | 19 | | | | 750 | 217 |
| Australia | Melbourne | Ruffeys Cr Dr | 74 | 40 | 100 | 56 | 0 | 1 | 3 | 21 | 19 | 0 | 0 | 0 | 27 | 19 | | | | 750 | 226 |
| Australia | Melbourne | Pickering Rd Dr | 25 | 64 | 100 | 0 | 49 | 3 | 0 | 23 | 25 | 0 | 0 | 0 | 0 | 25 | | | | 850 | 92 |
| Australia | Melbourne | Lum Road Drain | 180 | 47 | 100 | 53 | 0 | 0 | 2 | 20 | 24 | 0 | 0 | 0 | 29 | 24 | | | | 850 | 270 |
| Australia | Melbourne | MMBW Dr at Reynolds Rd | 189 | | 17 | 4 | 0 | 0 | 0 | 0 | 0 | | | | | 13 | | | | 750 | 597 |
| Australia | Perth | Balcatta | 15.9 | | 83 | 83 | | | | | | | | | | 6 | | | | 868 | |
| Australia | Perth | Woodlands | 13.4 | | 83 | 83 | | | | | | | | | | 10 | | | | 868 | |
| Australia | Perth | Bayswater I | 10 | | 83 | 83 | | | | | | | | | | 12 | | | | 868 | |
| Australia | Perth | Bayswater II | 19.9 | | 83 | 83 | | | | | | | | | | 7 | | | | 868 | |
| Australia | Perth | Myaree | 36 | | 83 | 50 | 50 | | | | | | | | | 14 | | | | 868 | |
| Australia | Perth | Beatrice Ave | 191.8 | | 83 | 83 | | | | | | | | | | 7 | | | | 868 | |
| Australia | Perth | South Lake | 66.2 | | 83 | 83 | | | | | | | | | | 10 | | | | 868 | |
| Australia | Perth | Westfield I | 93.4 | | 83 | 83 | | | | | | | | | | 8 | | | | 868 | |
| Australia | Perth | Westfield II | 95.5 | | 83 | 17 | 17 | | | 17 | | | | | | 6 | | | | 868 | |
| Australia | Perth | Kelmscott Hill | 67.6 | | 83 | 50 | | | | 50 | | | | | | 6 | | | | 868 | |
| Australia | Sydney | Bowman Ave | | | 100 | | | | | | | 0 | 0 | 0 | | | | | | 1215 | 170 |
| Australia | Sydney | Bradbury | 98 | | 83 | 83 | | | | | | | | | | | | | | 1215 | 39.6 |
| Australa | Sydney | Bunnerong Channel | 55 | | 100 | 80 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1130 | 275 |
| Australia | Sydney | Cup & Saucer Cr | 506 | 47 | 100 | 81 | 9 | 1 | 0 | 6 | 3 | 0 | 0 | 0 | | | | | | 1100 | 156 |
| Australia | Sydney | Devlins Creek | | | 95 | | | | | | | 0 | 5 | 0 | | | | | | 1215 | 20 |
| Australia | Sydney | Jamison Park | 17.1 | 35 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1215 | 150 |
| Australia | Sydney | Lane Cove River | | | 75 | | | | | | | 10 | 15 | 0 | | | | | | 1215 | 20 |
| Australia | Sydney | Musgrave Ave Dr | 131 | | 83 | 83 | | | | | | | | | | | | | | 1150 | 269 |
| Australia | Sydney | Powells Creek | 231 | | 83 | 83 | | | | | | | | | | | | | | 990 | 236 |
| Australia | Sydney | Qantas Drive | 0.0242 | 83 | 83 | | | | | | | | | | | 100 | | | | 1215 | |
| Australia | Sydney | Ross St Drain | 267 | | 83 | | | | | | | | | | | | | | | 1215 | 84.4 |
| Australia | Sydney | Shrimptons Creek | | | 100 | | | | | | | 0 | 0 | 0 | | | | | | 1215 | 20 |
| Australia | Sydney | Woodbridge | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | | | | | | 1215 | 100 |
| Australia | Wollongong | Byarong Creek | | | 3 | | | | | | | 18 | 79 | 0 | | | | | | 1100 | 170 |
| Australia | Wollongong | Oakey Creek | | | 83 | 83 | | | | | | | | | | | | | | 1100 | |
| Australia | Wollongong | Horsely Creek | | | 83 | | | | | | | | | | | | | | | 1100 | |
| Australia | Wollongong | Macquarie Rivulet | | | 17 | | | | | | | | | | | | | | | 1100 | |
| Australia | Wollongong | Duck Creek | | | 17 | | | | | | | | | | | | | | | 1100 | |
| Australia | Wollongong | Brooks Creek | | | 83 | 83 | | | | | | | | | | | | | | 1100 | |

## Appendix A

| Water Quality | | | | | | | | | | | | | | | | | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TotP | TotN | Pb | Zn | O&G | BOD | COD | Cd | Cr | Cu | Ni | Hg | Fe | Mn | Turb | pH | TOC | TotColi | FecColi | FecStrep | |
| mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | NTU | | mg/L | #/100ml | #/100ml | #/100ml | |
| | | 0.108 | 0.167 | | | | | | | | | | | | | | | | | 127 |
| | | 0.0005 | 1.3 | | | | | | | | | | | 1.2 | | | | 115 | | 132 |
| | | 0.0005 | 0.1 | | | | | | | | | | | 0.7 | | | | 2 | | 132 |
| | | 0.01 | 1.1 | | | | | | | | | | | 0.8 | | | | 0.5 | | 132 |
| | | 0.05 | 0.2 | | | | | | | | | | | 6.5 | | | | 122 | | 132 |
| | | 0.1 | 3.5 | | | | | | | | | | | 3 | | | | 115 | | 132 |
| | | 0.09 | 1.6 | | | | | | | | | | | 5.5 | | | | 72 | | 132 |
| 0.2 | 2.2 | | | | | | | | | | | | | | | | | | | 116 |
| 0.123 | | | | | | | | | | | | | | 90 | | | | | | 53 |
| 0.138 | 1.835 | | | | | | | | | | | | | | | 15.7 | | | | 28 |
| 0.2 | 2.4 | | | | | | | | | | | | | | | | | | | 116 |
| 0.44 | | | | | | | | | | | | | | | | | | | | 115 |
| 0.29 | | | | | | | | | | | | | | | | | | | | 115 |
| 0.03 | | | | | | | | | | | | | | | | | | | | 56, 116 |
| 0.2 | 1.6 | | | | | | | | | | | | | | | | | | | 116 |
| 0.05 | 0.6 | | | | | | | | | | | | | | | | | | | 116 |
| 0.51 | | | | | | | | | | | | | | | | | | | | 115 |
| 0.076 | 1.04 | | | | | | | | | | | | | | | | | 2000 | | 129, 130 |
| 1.2 | 6.76 | 0.49 | 5.8 | | 19 | | 0.011 | 0.58 | 0.48 | 0.02 | 0.0001 | | | | | 61 | | | | 48 |
| 0.21 | 4.6 | 0.69 | 1.1 | | 9.6 | | 0.009 | 0.024 | 0.12 | 0.031 | 0.00022 | | | | | 28 | | | | 48 |
| 0.79 | 1.8 | 0.33 | 1 | | 38 | | 0.009 | 0.063 | 0.045 | 0.069 | 0.00009 | | | | | 44 | | | | 48 |
| 1.65 | 2.9 | 0.07 | 0.32 | | | | 0.01 | 0.13 | 0.05 | 0.01 | | | | | | 21 | | | | 48 |
| 0.46 | 3.86 | 0.51 | 0.31 | | 11 | | 0.009 | 0.12 | 0.059 | 0.03 | 0.00019 | | | | | 32 | | | | 48 |
| 0.39 | 9.16 | 0.53 | 1.23 | | 14 | | 0.01 | 0.024 | 0.091 | 0.022 | 0.0001 | | | | | 33 | | | | 48 |
| 0.39 | 2.84 | 0.36 | 0.71 | | 11 | | 0.0097 | 0.02 | 0.018 | 0.017 | 0.00012 | | | | | 31 | | | | 48 |
| 1.01 | 5.57 | 0.26 | 0.55 | | 23 | | 0.009 | 0.02 | 0.038 | 0.026 | | | | | | 29 | | | | 48 |
| 0.31 | 5.94 | 0.29 | 0.73 | | | | 0.01 | 0.02 | 0.039 | 0.023 | | | | | | 21 | | | | 48 |
| 0.98 | 9.75 | 0.12 | 0.34 | | | | 0.0092 | 0.02 | 0.027 | 0.028 | | | | | | 26 | | | | 48 |
| 0.83 | 2.8 | | | | | | | | | | | | | | | 51 | | | | 48 |
| 0.46 | | 0.21 | 0.32 | | | | 0.0095 | 0.02 | 0.015 | 0.03 | | | | | | 19 | | | | 48 |
| 0.31 | 6.39 | 0.16 | 0.21 | | 21 | | 0.01 | 0.023 | 0.026 | 0.022 | 0.0001 | | | | | 28 | | | | 48 |
| 0.2 | | | | | | | | | | | | | | | | | | | | 131 |
| 0.09 | | | | | | | | | | | | | | | | | | | | 131 |
| 0.13 | | | | | | | | | | | | | | | | | | | | 131 |
| 0.17 | | | | | | | | | | | | | | | | | | | | 131 |
| 0.18 | | | | | | | | | | | | | | | | | | | | 131 |
| 0.44 | | | | | | | | | | | | | | | | | | | | 131 |
| 0.08 | | | | | | | | | | | | | | | | | | | | 131 |
| 0.34 | | | | | | | | | | | | | | | | | | | | 131 |
| 0.22 | | | | | | | | | | | | | | | | | | | | 131 |
| 0.38 | | | | | | | | | | | | | | | | | | | | 131 |
| 0.45 | 2.2 | | | | | | | | | | | | | | | | | | | 116 |
| | | | | | 10 | 41.5 | | | | | | | | | 7.1 | | | 1500 | | 92 |
| | | | | | 28 | | | | | | | | | | 6.47 | | 2000000 | 650000 | | 24 |
| 0.3 | | 0.3 | 0.7 | 3 | 19 | | | | | | | 3.3 | | 42 | 7 | | | | | 119, 120 |
| 0.05 | 1.2 | | | | | | | | | | | | | | | | | | | 116 |
| 0.45 | 3 | | | | | 53 | | | | | | | | | | | | | | 84, 116 |
| 0.05 | 1.4 | | | | | | | | | | | | | | | | | | | 116 |
| | | | | | 30 | | | | | | | | | | 6.78 | | 5600000 | 410000 | | 24 |
| | | | | | 18 | | | | | | | | | | 6.98 | | 2200000 | 410000 | | 24 |
| | | 0.11 | 0.483 | | | | 0.0027 | | 0.081 | | | 1.22 | 0.129 | | | | | | | 5 |
| 0.324 | 1.4 | | | | 9.4 | | | | | | | 14.8 | | 130 | 8.3 | 27.7 | | | | 122, 123 |
| 0.01 | | | | | | | | | | | | | | | | | | | | 116 |
| 1.1 | 3 | | | | | | | | | | | | | | | | | | | 116 |
| 0.25 | 1.4 | | | | | | | | | | | | | | | | | | | 116 |
| 0.835 | | | | | | | | | | | | | | | | | | | | 149 |
| 0.083 | | | | | | | | | | | | | | | | | | | | 149 |
| 0.064 | | | | | | | | | | | | | | | | | | | | 149 |
| 1.202 | | | | | | | | | | | | | | | | | | | | 149 |
| 0.128 | | | | | | | | | | | | | | | | | | | | 149 |

| Location | | | Description | | | Land Use | | | | | | | | | Pop. | Traffic | | Miscellaneous | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country/State | Town/Area | Site | Area | Imp | Urban | Res | Ind | Com | Inst | Open | Other | Agr | For | Other | | Road | Dens | Roof | MtSt | Rain | SS |
| | | | ha | % | % | % | % | % | % | % | urban | % | % | rural | p/ha | % | veh/d | % | Helens | mm | mg/L |
| Australia | Wollongong | Mullet Creek | | | 17 | | | | | | | | | | | | | | | 1100 | |
| Australia | Wollongong | Budjong Creek | | | 83 | 83 | | | | | | | | | | | | | | 1100 | |
| Australia | Wollongong | Minnegang Creek | | | 83 | 83 | | | | | | | | | | | | | | 1100 | |
| Australia | Wollongong | Wegit Creek | | | 83 | 83 | | | | | | | | | | | | | | 1100 | |
| Australia | Wollongong | Warrawong Drain | | | 83 | | | 83 | | | | | | | | | | | | 1100 | |
| California | Coyote Creek | Knox | 625 | | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 30 | | | | | 539 | 283 |
| California | Coyote Creek | Seaview | 256 | | 17 | | | | | 17 | | | | | 0 | | | | | 539 | 718 |
| California | Los Angeles | Urban highway | | 100 | 83 | 50 | | 50 | | | | | | | | 83 | 200000 | | | 320 | 172 |
| California | Los Angeles | Los Angeles River | 210000 | | 83 | | | | | | | | | | | | | | | 320 | 715 |
| California | Oakland | Urban | | | 83 | | | | | | | | | | | | | | | 539 | 203 |
| California | Richmond | Full catchment | 658 | | 100 | 73 | 4 | 12 | 0 | 5 | 6 | 0 | 0 | 0 | | 4 | | | | 498 | |
| California | Richmond | Trucking centre | 10.9 | | 100 | 0 | 77 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | | | | | | 498 | |
| California | Richmond | Parking area | 0.27 | | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 498 | |
| California | Richmond | Petrol stations | 8.1 | | 100 | 70 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 498 | |
| California | Richmond | Residential | 53 | | 100 | 95 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | | | | | | 498 | |
| California | Sacramento | Highway 50 | | 82 | 17 | | | | | | | | | | | 83 | 86000 | | | 414 | 90 |
| California | San Francisco | Vicente North | 6.5 | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 62 | | | | | 539 | 48 |
| California | San Francisco | Vicente South | 8.5 | | 100 | 80 | 0 | 15 | 0 | 0 | 5 | 0 | 0 | 0 | 62 | | | | | 539 | 46 |
| California | San Jose | Urban streets | | 83 | 83 | | | | | | | | | | | 83 | | | | 539 | 240 |
| California | Lake Tahoe | Rural | | | 17 | | | | | | | | | | | | | | | 976 | 50 |
| California | Lake Tahoe | Low dens res | | | 83 | 83 | | | | | | | | | | | | | | 976 | 600 |
| California | Lake Tahoe | High dens res | | | 83 | 83 | | | | | | | | | | | | | | 976 | 250 |
| California | Lake Tahoe | Commercial | | | 83 | | | 83 | | | | | | | | | | | | 976 | 770 |
| California | Walnut Creek | I-680 | | 100 | 83 | 83 | | | | | | | | | | 83 | 70000 | | | 516 | 224 |
| Canada | Toronto | Broadview | | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 813 | 130 |
| Canada | Brucewood | | | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 813 | 101 |
| Canada | Burlington | Aldershot Plaza | 6.9 | 100 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 828 | |
| Canada | Burlington | Blair Road | 10.3 | 69 | 100 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 49 | | 20 | | 828 | |
| Canada | Burlington | Malvern | 23.3 | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 828 | 105 |
| Canada | Burnaby | Commercial1 | | | 83 | | | 83 | | | | | | | | | | | | 1118 | 129 |
| Canada | Burnaby | Residential1 | | | 83 | 83 | | | | | | | | | | | | | | 1118 | 64 |
| Canada | Burnaby | Industrial1 | | | 83 | | 83 | | | | | | | | | | | | | 1118 | 16 |
| Canada | Burnaby | Commercial2 | | | 83 | | | 83 | | | | | | | | | | | | 1118 | 55 |
| Canada | Burnaby | Residential2 | | | 83 | 83 | | | | | | | | | | | | | | 1118 | 15 |
| Canada | Burnaby | Open1 | | | 83 | | | | | 83 | | | | | | | | | | 1118 | 22 |
| Canada | Burnaby | Open2 | | | 83 | | | | | 83 | | | | | | | | | | 1118 | 76 |
| Canada | Burnaby | Residential3 | | | 83 | 83 | | | | | | | | | | | | | | 1118 | 122 |
| Canada | Burnaby | Open3 | | | 83 | | | | | 83 | | | | | | | | | | 1118 | 151 |
| Canada | Burnaby | Industrial2 | | | 83 | | 83 | | | | | | | | | | | | | 1118 | 1868 |
| Canada | Burnaby | Industrial3 | | | 83 | | 83 | | | | | | | | | | | | | 1118 | 444 |
| Canada | Burnaby | Commercial3 | | | 83 | | | 83 | | | | | | | | | | | | 1118 | 33 |
| Canada | Burnaby | Industrial4 | | | 83 | | 83 | | | | | | | | | | | | | 1118 | |
| Canada | Burnaby | Commercial4 | | | 83 | | | 83 | | | | | | | | | | | | 1118 | |
| Canada | Burnaby | Residential4 | | | 83 | 83 | | | | | | | | | | | | | | 1118 | |
| Canada | Burnaby | Open4 | | | 83 | | | | | 83 | | | | | | | | | | 1118 | |
| Canada | Grand River | | 667000 | | 3 | | | | | | | 75 | 19 | 3 | 0.8 | | | | | 850 | 106 |
| Canada | Guelph | Guelph North | | | 100 | 91 | 0 | 6 | 0 | 3 | 0 | 0 | 0 | 0 | | | | | | 850 | 77 |
| Canada | Guelph | Guelph West | | | 100 | 44 | 30 | 3 | 0 | 23 | 0 | 0 | 0 | 0 | | | | | | 850 | 195 |
| Canada | Guelph | Retarding basins | 32.2 | | 100 | 83 | 0 | 0 | 12 | 5 | 0 | 0 | 0 | 0 | | | | | | 850 | 88 |
| Canada | Guelph | Roofs | | 100 | 100 | | | | | | | 0 | 0 | 0 | | | | 100 | | 850 | 36 |
| Canada | Guelph | Street gutters | | 83 | 100 | | | | | | | | | | | 83 | | | | 850 | 95 |
| Canada | Guelph | Commercial | | | 100 | | | 83 | | | | | | | | | | | | 850 | 70 |
| Canada | Ottawa | Storm sewer | | | 83 | | | | | | | | | | | | | | | 900 | |
| Canada | Sarnia | Areawide mean | | | 83 | | 50 | | | | | | | | | | | | | 802 | |
| Canada | Saugeen River | | 398000 | | 1 | | | | | | | 64 | 33 | 2 | 0.1 | | | | | 930 | 96 |
| Canada | Sault Ste Marie | Areawide mean | | | 83 | | 50 | | | | | | | | | | | | | 875 | |
| Canada | Toronto | Emery unpaved driveways | | | 83 | | | | | | | | | | | | | | | 813 | |
| Canada | Toronto | Emery roofs | | 100 | 83 | | | | | | | | | | | | | 100 | | 813 | |
| Canada | Toronto | Emery footpaths | | | 83 | | | | | | | | | | | | | | | 813 | |
| Canada | Toronto | Emery parking | | 83 | 83 | | | | | | | | | | | 83 | | | | 813 | |

# Appendix A

| Water Quality | | | | | | | | | | | | | | | | | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TotP | TotN | Pb | Zn | O&G | BOD | COD | Cd | Cr | Cu | Ni | Hg | Fe | Mn | Turb | pH | TOC | TotColi | FecColi | FecStrep | |
| mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | NTU | | mg/L | #/100ml | #/100ml | #/100ml | |
| 0.064 | | | | | | | | | | | | | | | | | | | | 149 |
| 0.073 | | | | | | | | | | | | | | | | | | | | 149 |
| 0.299 | | | | | | | | | | | | | | | | | | | | 149 |
| 0.076 | | | | | | | | | | | | | | | | | | | | 149 |
| 2.112 | | | | | | | | | | | | | | | | | | | | 149 |
| 0.418 | 3.33 | 0.495 | 0.303 | | | 93 | | | 0.098 | | | | | | | | | | | 3 |
| 0.59 | 5.22 | 0.214 | 0.19 | | | 111 | | | 0.058 | | | | | | | | | | | 3 |
| | | 0.99 | 0.55 | | | 196 | | | | | | | | | | | | | | 117,118,127 |
| | | | | | | | | | | | | | | | | | | | | 33 |
| | | | | | 59 | | | | | | | | | | | | 293000 | | | 83 |
| | | | | 7.87 | | | | | | | | | | | | | | | | 125 |
| | | | | 7.27 | | | | | | | | | | | | | | | | 125 |
| | | | | 16.1 | | | | | | | | | | | | | | | | 125 |
| | | | | 10.9 | | | | | | | | | | | | | | | | 125 |
| | | | | 3.92 | | | | | | | | | | | | | | | | 125 |
| | | 0.28 | 0.27 | | | 51 | | | | | | | | | | | | | | 117,118,127 |
| | | | | 7.5 | 9.8 | 66 | | | | | | | | | 5.5 | | 568000 | 108000 | | 61 |
| | | | | 12.5 | 4.5 | 61 | | | | | | | | | 6.3 | | 200000 | 39900 | | 61 |
| | 7.7 | 0.4 | 0.18 | | 24 | 200 | 0.001 | 0.02 | 0.03 | | 0.00005 | | | 49 | 6.7 | 110 | | | | 104 |
| 0.1 | 0.2 | | | 0.6 | | | | | | | | | | | | | | | | 37 |
| 0.7 | 1.2 | | | 0.8 | | | | | | | | | | | | | | | | 37 |
| 0.8 | 0.7 | | | 20 | | | | | | | | | | | | | | | | 37 |
| 1.3 | 1.7 | | | 33 | | | | | | | | | | | | | | | | 37 |
| | | 0.75 | 0.3 | | | 120 | | | | | | | | | | | | | | 117,118,127 |
| 0.4 | 3.9 | | | | 15.7 | | | | | | | | | | | | | | | 137 |
| 0.28 | 4.1 | | | | 13.7 | | | | | | | | | | | | | | | 137 |
| 0.252 | | 0.098 | 0.127 | | | | | | 0.022 | | | | | | | | | | | 90, 107 |
| 0.122 | 1.33 | 0.095 | 0.14 | | | | 0.01 | 0.013 | 0.029 | 0.026 | | | | | | | | | | 91 |
| 0.159 | | 0.044 | 0.16 | | 11.3 | | | | 0.013 | | | | | | | | | | | 90,107,137 |
| | | | | | | 1031 | | | | | | | | | 5.7 | | | | | 50 |
| | | | | | | 763 | | | | | | | | | 5.8 | | | | | 50 |
| | | | | | | 269 | | | | | | | | | 6 | | | | | 50 |
| | | | | | | 108 | | | | | | | | | 5.8 | | | | | 50 |
| | | | | | | 57 | | | | | | | | | 6.8 | | | | | 50 |
| | | | | | | 70 | | | | | | | | | 6.6 | | | | | 50 |
| | | | | | | 78 | | | | | | | | | 5.8 | | | | | 50 |
| | | | | | | 99 | | | | | | | | | 6.3 | | | | | 50 |
| | | | | | | 46 | | | | | | | | | 7 | | | | | 50 |
| | | | | | | 430 | | | | | | | | | 8.1 | | | | | 50 |
| | | | | | | 406 | | | | | | | | | 7.5 | | | | | 50 |
| | | | | | | 169 | | | | | | | | | 7.3 | | | | | 50 |
| | | 0.65 | 0.85 | | | | 0.008 | 0.035 | 0.22 | 0.02 | | 7 | 0.2 | | | | | | | 50 |
| | | 1.3 | 1.4 | | | | 0.012 | 0.023 | 0.22 | 0.035 | | 5 | 0.25 | | | | | | | 50 |
| | | 0.55 | 1.3 | | | | 0.008 | 0.0005 | 0.1 | 0.022 | | 1.5 | 0.18 | | | | | | | 50 |
| | | 0.1 | 0.15 | | | | 0.006 | 0.0005 | 0.03 | 0.01 | | 1.5 | 0.06 | | | | | | | 50 |
| 0.205 | 3.45 | 0.005 | | | | | | | | | | | | | | | | | | 99 |
| 0.2 | 2.3 | | | | 10.2 | | | | | | | | | | | | | | | 137 |
| 0.35 | 3.7 | | | | 13.9 | | | | | | | | | | | | | | | 137 |
| | | 0.04 | | | 8 | | | | | | | | | | | | | 8000 | | 143 |
| | | 0.04 | | | 4 | | | | | | | | | | | | | 20 | | 143 |
| | | 0.04 | | | 7 | | | | | | | | | | | | | 1500 | | 143 |
| | | | | | 17 | | | | | | | | | | | | | 1500 | | 143 |
| | | 0.13 | | | | | | | | | | | | | | | | | | 71, 96 |
| 0.299 | | 0.233 | 0.307 | | | | 0.0068 | | 0.0571 | 0.0085 | | | | | | | | | | 80 |
| 0.085 | 1.6 | 0.003 | | | | | | | | | | | | | | | | | | 99 |
| 0.309 | | 0.097 | 0.274 | 2.56 | | | 0.006 | | 0.0696 | 0.0313 | 0.000028 | 8.72 | | | | | | | | 79, 80 |
| | | | | | | | | | | | | | | | | | | 26000 | 6200 | 98 |
| | | | | | | | | | | | | | | | | | | 1600 | 690 | 98 |
| | | | | | | | | | | | | | | | | | | 55000 | 3600 | 98 |
| | | | | | | | | | | | | | | | | | | 2800 | 900 | 98 |

| Location | | | Description | | | Land Use | | | | | | | | | Pop. | Traffic | | Miscellaneous | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country/State | Town/Area | Site | Area | Imp | Urban | Res | Ind | Com | Inst | Open | Other | Agr | For | Other | | Road | Dens | Roof | MtSt | Rain | SS |
| | | | ha | % | % | % | % | % | % | % | urban | % | % | rural | p/ha | % | veh/d | % | Helens | mm | mg/L |
| Canada | Toronto | Emery roads | | 83 | 83 | | | | | | | | | | | 83 | | | | 813 | |
| Canada | Toronto | Thistledown roofs | | 100 | 83 | | | | | | | | | | | | | 100 | | 813 | |
| Canada | Toronto | Thistledown paths | | | 83 | | | | | | | | | | | | | | | 813 | |
| Canada | Toronto | Thistledown parking | | 83 | 83 | | | | | | | | | | | 83 | | | | 813 | |
| Canada | Toronto | Thistledown roads | | 83 | 83 | | | | | | | | | | | 83 | | | | 813 | |
| Canada | Toronto | Industrial | | | 83 | | 83 | | | | | | | | | | | | | 813 | 77.7 |
| Canada | Toronto | Industrial | | | 83 | | 83 | | | | | | | | | | | | | 813 | 128 |
| Canada | Toronto | Residential | | | 83 | 83 | | | | | | | | | | | | | | 813 | 100 |
| Canada | Toronto | Commercial | | | 83 | 17 | | 83 | | | | | | | | | | | | 813 | 220 |
| Canada | Toronto | Industrial | | | 83 | 17 | 83 | | | | | | | | | | | | | 813 | 140 |
| Canada | Toronto | Suburban | | | 83 | | | | | | | | | | | | | | | 813 | 304 |
| Canada | Welland | Urban | | | 83 | | | | | | | | | | | | | | | 828 | 58 |
| Canada | Windsor | Windsor A | | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 50 | | | | | 802 | 279 |
| Canada | Windsor | Windsor B | | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | | | | | 802 | 305 |
| Canada | Windsor | Labadie Road | 11.9 | | 83 | 83 | | | | | | | | | 50 | | | | | 802 | 390 |
| Canada | Windsor | Areawide mean | | | 83 | | 50 | | | | | | | | | | | | | 802 | |
| China | Shenzhen | Urban | | | 83 | | | | | | | | | | | | | | | | 313 |
| China | Shenzhen | Urban road | | 83 | 83 | | | | | | | | | | | 83 | | | | | 718 |
| China | Shenzhen | Urban road | | 83 | 83 | | | | | | | | | | | 83 | | | | | 520 |
| China | Zhuhai | Urban | | | 83 | | | | | | | | | | | | | | | | |
| China | Zhuhai | Urban | | | 83 | | | | | | | | | | | | | | | | |
| Colorado | Boulder | South | 74 | 57 | 83 | 50 | | 50 | | | | | | | 62 | | | | | 477 | 805 |
| Colorado | Boulder | North | 51 | 41 | 83 | 83 | | | | | | | | | 30 | | | | | 477 | 179 |
| Colorado | Denver | I-25 | | 37 | 83 | | | | | | | | | | | 83 | 149000 | | | 376 | 410 |
| Colorado | Denver | Big Dry Cr trib | 13 | 41 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 47 | | | | | 376 | 383 |
| Colorado | Denver | Cherry Knolls | 23 | 38 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 59 | | | | | 376 | 180 |
| Colorado | Denver | 116 & Claude | 68 | 24 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | | | | | 376 | 365 |
| Colorado | Denver | Asbury Park | 51 | 22 | 83 | 86 | | | | | | | | | 22 | | | | | 376 | 493 |
| Colorado | Denver | Rooney Gulch | 164 | 1 | 17 | | | | | 17 | | | | | 0 | | | | | 376 | 403 |
| Colorado | Denver | North Ave Drain | 28 | 50 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 22 | | | | | 376 | 492 |
| Colorado | Denver | Villa Italia | 30 | 91 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 376 | 260 |
| Denmark | Viborg | Spring/summer | 22.2 | | 83 | 83 | | | | | | | | | | | | | | 591 | 82 |
| Denmark | Viborg | Autumn | 22.2 | | 83 | 83 | | | | | | | | | | | | | | 591 | 22 |
| Dist of Columbi | Washington | Dufief | 4.9 | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1034 | 56 |
| Dist of Columbi | Washington | Lakeridge Inlet | 28 | 27 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 52 | | | | | 1034 | 175 |
| Dist of Columbi | Washington | Stratton Woods | 3.2 | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1034 | 54 |
| Dist of Columbi | Washington | Westleigh Inlet | 17 | 21 | 83 | 93 | | | | | | | | | 7 | | | | | 1034 | 75 |
| Dist of Columbi | Washington | Fairidge | 7.7 | 34 | 83 | 88 | | | | | | | | | | | | | | 1034 | 25 |
| Dist of Columbi | Washington | Stedwick Inlet | 11 | 34 | 83 | 78 | | | | | | | | | 37 | | | | | 1034 | 54 |
| Dist of Columbi | Washington | Good Hope Run | 107 | | 83 | | | | | | | | | | 93 | | | | | 1034 | 1697 |
| Dist of Columbi | Washington | Urban | | | 83 | | | | | | | | | | | | | | | 1034 | 2100 |
| England | London | Grahame Park | 350 | 35.5 | 100 | 31 | 2 | 6 | 23 | 26 | 12 | 0 | 0 | 0 | 34 | 12 | | | | 756 | 546 |
| England | London | Motorway | 0.0836 | 83 | 83 | | | | | | | | | | | 83 | | | | 756 | 100 |
| England | London | South Oxhey | 243 | 23 | 83 | 83 | | | | | | | | | | | | | | 756 | 194 |
| England | London | S Oxhey subcatchment | 0.05 | 42 | 83 | 83 | | | | | | | | | | 50 | | 50 | | 756 | |
| England | Stevenage New Tow | Shephall | 143 | 23 | 83 | 83 | | | | | | | | | 66 | | | | | 756 | 112 |
| England | Woodplumpton Br | M-55 | | 83 | 17 | | | | | | | 83 | | | | 83 | | | | 800 | |
| England | | Highway | | 83 | 50 | | | | | | | | | | | 83 | | | | | |
| Finland | Four cities | Composite | 22 | 40 | 83 | 50 | | 17 | | | 17 | | | | | 17 | | | | 600 | 250 |
| Florida | Broward County | Highway 834 | | 36 | 17 | | | | | | | | | | | 83 | 20000 | | | 1575 | 9 |
| Florida | Broward County | Pompano Beach | 19.2 | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 11 | | 19 | | 1575 | 28 |
| Florida | EPCOT I'change | Highway | 8.3 | 50 | 17 | | | | | | | | | | | 50 | | | | 1575 | |
| Florida | Maitland I'change ( | Highway | 19.8 | 50 | 17 | | | | | | | | | | | 50 | 54000 | | | 1575 | |
| Florida | Maitland I'change ( | Highway | 19.8 | 50 | 17 | | | | | | | | | | | 50 | 54000 | | | 1575 | |
| Florida | Miami | I-95 | | 100 | 83 | | | | | | | | | | | 83 | 140000 | | | 1519 | 67 |
| Florida | Orlando | | 16.8 | | 73 | 40 | 0 | 0 | 0 | 0 | 33 | 0 | 27 | 0 | | 33 | 22000 | | | 1575 | 30 |
| Florida | St. Petersburg | L Maggiore area 1 | | | 83 | 50 | | | | 50 | | | | | | | | | | 1575 | |
| Florida | St. Petersburg | L Maggiore area 2 | | | 83 | 50 | | | | 50 | | | | | | | | | | 1575 | |
| Florida | Springhill | | 15.2 | 40 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1575 | 3.5 |
| Florida | Tampa | J.L.Young Apartments | 3.6 | 6 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1575 | 53 |

# Appendix A

| Water Quality | | | | | | | | | | | | | | | | | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TotP | TotN | Pb | Zn | O&G | BOD | COD | Cd | Cr | Cu | Ni | Hg | Fe | Mn | Turb | pH | TOC | TotColi | FecColi | FecStrep | |
| mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | NTU | | mg/L | #/100ml | #/100ml | #/100ml | |
| | | | | | | | | | | | | | | | | | | 19000 | 8500 | 98 |
| | | | | | | | | | | | | | | | | | | 500 | 940 | 98 |
| | | | | | | | | | | | | | | | | | | 11000 | 1800 | 98 |
| | | | | | | | | | | | | | | | | | | 2000 | 1500 | 98 |
| | | | | | | | | | | | | | | | | | | 4800 | 7900 | 98 |
| 0.2 | 1.85 | 0.074 | 0.143 | 10.4 | | | 0.00187 | 0.0201 | 0.0232 | 0.0149 | 0.00042 | 6.41 | | | | | | | | 44 |
| 0.49 | 7.31 | | | 7.95 | | | | | | | | | | | | | | | | 44 |
| 0.4 | | 0.04 | 0.12 | | | | | | 0.03 | | | 3 | | | | | | 300000 | | 25 |
| 0.6 | | 0.08 | 0.3 | | | | | | 0.8 | | | 12 | | | | | | 300000 | | 25 |
| 0.7 | | 0.04 | 0.3 | | | | | | 0.8 | | | 4 | | | | | | 30000 | | 25 |
| | | | | | 19 | | | | | | | | | | | | 454000 | | | 15 |
| | | | | | 19 | | | | | | | | | | | | 16800 | | | 83 |
| 0.14 | | | | | 20.5 | | | | | | | | | | | | | | | 137 |
| 0.32 | | | | | 12 | | | | | | | | | | | | | | | 137 |
| | | | | | 17 | | | | | | | | | 459 | 7.5 | | 34500 | 4350 | | 61 |
| 0.231 | | 0.154 | 0.234 | | | | 0.0054 | | 0.0571 | 0.0278 | | | | | | | | | | 80 |
| 0.045 | 2.09 | | | | 11.3 | 16.4 | | | | | | | | | | | | | | 154 |
| 0.051 | 2.35 | | | | 17.1 | 23.3 | | | | | | | | | | | | | | 154 |
| 0.06 | 0.95 | | | | 7 | 10.9 | | | | | | | | | | | | | | 154 |
| 0.042 | 2.51 | | | | 3.9 | 5 | | | | | | | | | | | | | | 154 |
| 0.115 | 4.47 | | | | 6.4 | 11.9 | | | | | | | | | | | | | | 154 |
| 2.74 | 12.95 | 0.98 | | 42 | | 684 | | | | | | | | | | | | | | 11 |
| 0.121 | 3.1 | | | 8.4 | | 123 | | | | | | | | | | | | | | 11 |
| | | 0.68 | 0.62 | | | 289 | | | | | | | | | | | | | | 117,118,127 |
| 0.693 | 2.9 | 0.183 | 0.194 | | | 129 | | | 0.032 | | | | | | | | | | | 3 |
| 0.429 | 3.32 | 0.194 | 0.195 | | | 122 | | | 0.035 | | | | | | | | | | | 3 |
| 0.63 | 3.56 | 0.292 | 0.195 | | | 137 | | | 0.028 | | | | | | | | | | | 3 |
| 1.025 | 4.62 | 0.433 | 0.349 | | | 234 | | | 0.059 | | | | | | | | | | | 3 |
| 0.42 | 3.54 | 0.052 | 0.105 | | | 73 | | | 0.037 | | | | | | | | | | | 3 |
| 0.784 | 5.94 | 0.358 | 0.543 | | | 280 | | | 0.077 | | | | | | | | | | | 3 |
| 0.704 | 4.84 | 0.262 | 0.32 | | | 184 | | | 0.033 | | | | | | | | | | | 3 |
| 0.66 | | 0.073 | 0.425 | | | 40 | 0.0014 | | 0.013 | | | | | | 6 | | | | | 64 |
| 0.74 | | 0.015 | 0.51 | | | 60 | 0.0005 | | | | | | | | | | | | | 64 |
| 0.499 | 2.54 | | 0.156 | | | 64 | | | | | | | | | | | | | | 3 |
| 0.323 | 2.47 | 0.227 | 0.129 | | | 60 | | | 0.038 | | | | | | | | | | | 3 |
| 0.34 | 2.23 | | 0.084 | | | 51 | | | 0.028 | | | | | | | | | | | 3 |
| 0.397 | 2.6 | 0.186 | 0.067 | | | 51 | | | 0.037 | | | | | | | | | 1800 | | 3 |
| 0.351 | 3.14 | | 0.086 | | 5 | 51 | | | 0.026 | | | | | | | | | | | 3 |
| 0.388 | 2.73 | 0.141 | 0.091 | | | 45 | | | 0.03 | | | | | | | | | 2700 | | 3 |
| 0.42 | 2.1 | | | | 19 | 335 | | | | | | | | | 6.5 | | 600000 | 310000 | 21000 | 27 |
| | | | | | 126 | | | | | | | | | | | | | | | 83 |
| | | | | | 22.2 | 343 | | | | | | | | | 7.38 | | 231 | | | 34 |
| | | | | 200 | | | | | | | | | | | 5.5 | | | | | 13 |
| | | 0.41 | 0.467 | | 7 | | 0.008 | | 0.106 | | | | | | | | | | | 35, 83, 111 |
| | | 0.028 | 0.017 | | | | 0.00086 | | 0.0065 | | | | | | | | | | | 52 |
| | | 0.205 | 0.271 | | | | | | 0.028 | | | | 0.11 | | | | | | | 78 |
| | | | | | | | | | | | | | | | 6.8 | | | | | 9 |
| | | 0.254 | 0.322 | | | | | | 0.023 | | | | | | | | | | | 148 |
| 0.35 | 1.9 | 0.22 | 0.36 | | 19 | 150 | | | 0.079 | | | | | | 6.8 | | | | | 87 |
| | | 0.23 | 0.07 | | | 38 | | | | | | | | | | | | | | 117,118,127 |
| 0.24 | 1.46 | 0.155 | 0.077 | | 6.7 | 22 | 0.0013 | 0.01 | 0.0069 | | | 0.249 | | 13 | 7.3 | 7.3 | 355000 | 31200 | 43700 | 61 |
| 0.224 | 1.833 | | | | | | | | | | | | | | 6.7 | | | | | 152, 153 |
| 0.533 | 3.278 | 0.723 | 0.347 | | | | 0.0019 | 0.01 | 0.06 | 0.028 | | 1.176 | | | 6.1 | | | | | 63,152,153 |
| 0.05 | 0.79 | 0.181 | 0.074 | | | | | | 0.0386 | | | | | | 6.9 | | | | | 151,152,153 |
| | | 0.623 | 0.303 | | | | | | | | | | | | | | | | | 127 |
| 0.16 | 1.4 | 0.062 | 0.085 | | | | | | | | | | | | | | | | | 81, 82 |
| 0.25 | 1.6 | | | | | | | | | | | | | | | | | | | 113 |
| 0.48 | 2 | | | | | | | | | | | | | | | | | | | 113 |
| 0.307 | 1.18 | | | | | | | | | | | | | | | | | | | 59 |
| 0.333 | 1.65 | 0.076 | 0.06 | | 16 | 73 | | | 0.006 | | | | | | | | | | | 3 |

| Location | | | Description | | | Land Use | | | | | | | | | Pop. | Traffic | | Miscellaneous | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country/State | Town/Area | Site | Area | Imp | Urban | Res | Ind | Com | Inst | Open | Other | Agr | For | Other | | Road | Dens | Roof | MtSt | Rain | SS |
| | | | ha | % | % | % | % | % | % | % | urban | % | % | rural | p/ha | % | veh/d | % | Helens | mm | mg/L |
| Florida | Tampa | Charter Hrdng | 17 | 16 | 83 | 89 | | | | | | | | | | | | | | 1575 | 33 |
| Florida | Tampa | North Jesuit | 12 | 13 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | | | | | | 1575 | 87 |
| Florida | Tampa | Wilder Ditch | 17 | 97 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | | | | | | 1575 | 33 |
| Florida | Tampa | Norma Park | 19 | 45 | 83 | | | 91 | | | | | | | | | | | | 1575 | 22 |
| France | Paris | Maurepas | 26.7 | 60 | 83 | 77 | | | | | | | | | 100 | | | | | 608 | 191 |
| France | Paris | Les Ulis | 43.1 | 42 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 350 | | | | | 608 | 439 |
| France | Aix-en-Provence | Aix ZUP | 25.6 | 78 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 210 | | | | | 600 | 296 |
| France | Aix-en-Provence | Aix Nord | 92 | 35 | 83 | 90 | | | | | | | | | 40 | | | | | 600 | 473 |
| France | Metz | A-4 | 0.147 | 83 | 17 | | | | | | | | | | | 83 | 5500 | | | 800 | 182 |
| France | Bordeaux | A-61 | 0.63 | 83 | 17 | | | | | | | | | | | 83 | 7000 | | | 942 | 65 |
| France | Pau | Street | | 83 | 83 | | | | | | | | | | | 83 | | | | | |
| France | Pau | Street | | 83 | 83 | | | | | | | | | | | 83 | | | | | |
| Germany | Bayreuth | Tar felt roof | 0.001 | 100 | 83 | | | | | | | | | | | | | 100 | | 642 | 44 |
| Germany | Bayreuth | Clay tile/copper roof | 0.001 | 100 | 83 | | | | | | | | | | | | | 100 | | 642 | 36 |
| Germany | Bayreuth | Asbestos cement roof | 0.001 | 100 | 83 | | | | | | | | | | | | | 100 | | 642 | 48 |
| Germany | Bayreuth | Zinc sheet roof | 0.001 | 100 | 83 | | | | | | | | | | | | | 100 | | 642 | 68 |
| Germany | Bayreuth | Gravel/zinc roof | 0.0032 | 100 | 83 | | | | | | | | | | | | | 100 | | 642 | 4.4 |
| Germany | Hildesheim | Urban | | | 83 | | | | | | | | | | | | | | | 658 | 171 |
| Germany | Hildesheim | P5 | 0.41 | 83 | 83 | | | | | | | | | | | 83 | 10000 | | | 658 | |
| Germany | Karlsruhe/Waldstad | Residential roofs | | 100 | 83 | 83 | | | | | | | | | | | | 100 | | 650 | |
| Germany | Karlsruhe/Waldstad | Residential streets | | 83 | 83 | 83 | | | | | | | | | | 83 | | | | 650 | |
| Germany | Munich | Urban | | | 83 | | | | | | | | | | | | | | | 900 | |
| Germany | Pleidelsheim | A-81 | 1.3 | 100 | 17 | | | | | | | 83 | | | | 83 | 41000 | | | 792 | |
| Germany | Heilbronn-Obereise | A-6 | 2.52 | 86 | 17 | | | | | | | 83 | | | | 83 | 47000 | | | 756 | |
| Germany | Ulm/West | A-8/B-10 | 25 | 40 | 17 | | | | | | | 83 | | | | 83 | 52000 | | | 780 | |
| Hawaii | Kamooalii Stream | | 1134 | | 17 | | | | | | | | | | 18 | | | | | 3000 | |
| Illinois | Carbondale | Campus L - urban | | | 100 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | | | | | | 1100 | 109 |
| Illinois | Carbondale | Campus L - forest | | | 17 | | | | | | | | 83 | | | | | | | 1180 | 120 |
| Illinois | Champaign-Urbana | John North | 22 | 19 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44 | 14 | | | | 946 | 205 |
| Illinois | Champaign-Urbana | John South | 16 | 18 | 83 | 91 | | | | | | | | | 44 | 13 | | | | 946 | 248 |
| Illinois | Champaign-Urbana | Mattis North | 6.8 | 58 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 7 | 26 | | | | 946 | 282 |
| Illinois | Champaign-Urbana | Mattis South | 11.2 | 37 | 83 | 90 | | | | | | | | | 54 | 21 | | | | 946 | 311 |
| Illinois | Chicago | Lake Ellen comb. inlets | 212 | 17 | 100 | 83 | 0 | 5 | 5 | 7 | 0 | 0 | 0 | 0 | 20 | | | | | 904 | 250 |
| Illinois | Northeast | Pioneer | 933 | | 17 | | | | | | | | 83 | | | | | | | 904 | 34 |
| Illinois | Northeast | Perry/Beecher/Olcott/Alde | 1470 | | 17 | | | | | | | 83 | | | | | | | | 904 | 762 |
| Illinois | Northeast | Centex/Elmhurst | 170 | | 83 | | 83 | | | | | | | | | | | | | 904 | 302 |
| Illinois | Northeast | Woodfield/Hawthorn | 90 | | 83 | | | 83 | | | | | | | | | | | | 904 | 386 |
| Illinois | Northeast | Edens | 104 | 83 | 83 | | | | | | 83 | | | | | 83 | | | | 904 | 266 |
| Illinois | Northeast | Mundelein/Glendale/Schau | 466 | | 83 | 83 | | | | | | | | | | | | | | 904 | 513 |
| Illinois | Northeast | Park Forest/Bolingbrook | 51 | | 83 | 83 | | | | | | | | | | | | | | 904 | 797 |
| India | Orrisa | Koraput | | | 83 | | | | | | | | | | | | | | | | |
| India | Uttar Pradesh | Unnao | | | 83 | | 83 | | | | | | | | | | | | | | |
| Indiana | Grissom Air Base | McDowell Ditch | 112 | 20 | 83 | | | | 83 | | | 17 | | | | | | | | 900 | 75.3 |
| Indiana | Grissom Air Base | East Ditch | 31 | 21 | 83 | | | 83 | | | | 17 | | | | | | | | 900 | 166 |
| Indiana | Grissom Air Base | Cline Ditch | 28 | 25 | 83 | 83 | | 17 | | | | | 5 | | | | | | | 900 | 87.8 |
| Indiana | West Lafayette | Ross-Ade upper | 11.7 | 38 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 21 | | 17 | | 900 | 105 |
| Indiana | West Lafayette | Semi-urban (1967) | | | 50 | | | | | | | | | | | | | | | 900 | 955 |
| Indiana | West Lafayette | Rural (1967) | | | 17 | | | | | | | | | | | | | | | 900 | 244 |
| Indiana | West Lafayette | Semi-urban/rural (1974) | 118 | | 50 | 50 | | | 17 | | | 39 | | | 8 | | | | | 900 | 59 |
| Japan | Kobe | Hanakuma | 12.4 | 91 | 83 | 17 | | 83 | | | | | | | 161 | | | | | 1363 | 152 |
| Japan | Kobe | Kitasuma | 26.8 | 45 | 83 | 83 | | | | | | | | | 90 | | | | | 1363 | 67 |
| Japan | Kyoto | Yamashina River | 3220 | | 34 | 18 | | | | | | | | | 44 | | | | | 1571 | 230 |
| Japan | | Parking area | 0.088 | 83 | 83 | | | | | | | | | | | 83 | | | | | |
| Japan | | Urban road | 0.16 | 83 | 83 | | | | | | | | | | | 83 | | | | | |
| Japan | | Industrial road | 0.57 | 83 | 83 | | 83 | | | | | | | | | 83 | | | | | |
| Japan | | Commercial | 0.18 | | 83 | | | 83 | | | | | | | | | | | | | |
| Japan | | Residential | 24.2 | | 83 | 83 | | | | | | | | | | | | | | | |
| Japan | | Farm land | 7 | | 17 | | | | | | | 83 | | | | | | | | | |
| Japan | | Forest | 183 | | 17 | | | | | | | | 83 | | | | | | | | |
| Japan | | Grass bank | 0.0024 | | 17 | | | | | | | | | | | | | | | | |

| Water Quality | | | | | | | | | | | | | | | | | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TotP | TotN | Pb | Zn | O&G | BOD | COD | Cd | Cr | Cu | Ni | Hg | Fe | Mn | Turb | pH | TOC | TotColi | FecColi | FecStrep | |
| mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | NTU | | mg/L | #/100ml | #/100ml | #/100ml | |
| 0.395 | 2.31 | 0.049 | 0.054 | | 13 | 55 | | | 0.01 | | | | | | | | | | | 3 |
| 0.196 | 1.76 | 0.056 | 0.094 | | 16 | 50 | | | 0.007 | | | | | | | | | | | 3 |
| 0.229 | 1.56 | 0.085 | 0.051 | | 16 | 51 | | | 0.006 | | | | | | | | | | | 3 |
| 0.151 | 1.18 | 0.046 | 0.037 | | 12 | 41 | | | 0.011 | | | | | | | | | | | 3 |
| | | | | | 12 | 77 | | | | | | | | | | | | | | 29 |
| | | | | | 34 | 188 | | | | | | | | | | | | | | 29 |
| | | | | | 38 | 202 | | | | | | | | | | | | | | 29 |
| | | | | | 45 | 278 | | | | | | | | | | | | | | 29 |
| | | 0.848 | 0.184 | | | 208 | | | | | | | | | | | | | | 4 |
| | | 0.24 | 0.39 | | | 60 | | | | | | | | | | | | | | 4 |
| | | 0.38 | 2 | | | | | | 0.14 | | | | | | | | | | | 148 |
| | | 0.16 | 0.34 | | | | | | 0.14 | | | | | | | | | | | 148 |
| | | 0.037 | 0.104 | | | | 0.00065 | | 0.0076 | | | | | | 4.2 | | | | | 38, 106 |
| | | 0.039 | 0.054 | | | | 0.00043 | | 0.355 | | | | | | 5 | | | | | 38, 106 |
| | | 0.024 | 0.023 | | | | 0.00013 | | 0.0105 | | | | | | 7.3 | | | | | 38, 106 |
| | | 0.038 | 43.7 | | | | 0.0013 | | 0.027 | | | | | | 6.6 | | | | | 38, 106 |
| | | 0.003 | 9.16 | | | | 0.000067 | | 0.0048 | | | | | | 6.9 | | | | | 38, 106 |
| | | | | | 8.3 | 69.4 | | | | | | | | | | | | | | 72 |
| | | 0.304 | 0.436 | | 14.9 | 91 | 0.0042 | | 0.136 | 0.035 | | | | | 7.5 | 28.3 | | | | 47, 148 |
| | | 0.104 | 0.024 | | | 22 | 0.001 | | 0.235 | | | | | | 6.2 | | | | | 148 |
| | | 0.311 | 0.603 | | | 49 | 0.0064 | | 0.108 | 0.057 | | | | | 6.4 | | | | | 148 |
| 0.7 | | 0.11 | 0.13 | | | | 0.001 | 0.004 | 0.01 | | | | | | | | | | | 42 |
| 0.25 | | 0.202 | 0.36 | 7.02 | | 107 | 0.0059 | 0.0096 | 0.097 | | | 3.42 | | | | | | | | 126 |
| 0.35 | | 0.245 | 0.62 | 5.51 | | 118 | 0.0059 | 0.0204 | 0.117 | | | 5.16 | | | | | | | | 126 |
| 0.31 | | 0.163 | 0.32 | 2.05 | | 85.6 | 0.0028 | 0.0052 | 0.058 | | | 2.18 | | | | | | | | 126 |
| 0.061 | 1.25 | | | | | | | | | | | | | 67 | | | | | | 32 |
| | | | | | 50 | | | | | | | | | | 7.7 | | | 292 | | 86 |
| | | | | | 5.3 | | | | | | | | | | 7.2 | | | 39 | | 86 |
| 0.75 | | 0.237 | | | | 126 | | | 0.083 | | | 2.51 | | | | | | | | 3, 10 |
| 0.732 | | 0.217 | | | | 111 | | | 0.043 | | | | | | | | | | | 3, 10 |
| 0.498 | | 0.554 | | | | 198 | | | 0.048 | | | 3.99 | | | | | | | | 3, 10 |
| 0.587 | | 0.595 | | | | 180 | | | 0.045 | | | 4.91 | | | | | | | | 3, 10 |
| 0.506 | | 0.322 | 0.23 | | | 138 | | | 0.049 | | | | | | | | | | | 3 |
| | 0.7 | | | | 2 | | | | | | | | | | | | | | | 105 |
| | 7.1 | | | | 13 | 122 | | | | | | | | | | | | | | 105 |
| | 2.6 | | | | 14 | 78 | | | | | | | | | | | | | | 105 |
| | 3.6 | | | | 22 | 168 | | | | | | | | | | | | | | 105 |
| | 2.3 | | | | 14 | 128 | | | | | | | | | | | | | | 105 |
| | 3.1 | | | | 17 | 104 | | | | | | | | | | | | | | 105 |
| | 3.2 | | | | 16 | 117 | | | | | | | | | | | | | | 105 |
| | | 0.015 | | | | | 0.023 | 0.063 | 0.033 | | | 9.2 | 0.624 | | | | | | | 19 |
| | | 1.1 | | | | | 0.01 | 0.24 | 0.1 | | | 4 | 0.26 | | | | | | | 19 |
| | | 0.005 | 0.88 | | | 50 | | | | | | 0.54 | | | | | | | | 112 |
| | | 0.006 | 0.29 | | | 30.4 | | | | | | 0.8 | | | | | | | | 112 |
| | | 0.0143 | 0.55 | | | 30.3 | | | | | | 0.6 | | | | | | | | 112 |
| | | | | | 36 | 140 | | | | | | | | | | | 11400000 | 3400000 | | 61, 83 |
| | | | | | 10 | 93 | | | | | | | | | | | | | | 61 |
| | | | | | 4 | 32 | | | | | | | | | | | | | | 61 |
| | | | | | 4.5 | | | | | | | | | | | | 3900000 | 450000 | | 61 |
| 0.41 | | 0.148 | 0.59 | | 35.9 | 34 | 0.0027 | 0.0117 | 0.128 | 0.0192 | | | | | | | | | | 88, 134 |
| 0.32 | | 0.0232 | 0.134 | | 13.8 | 17 | 0.0008 | 0.0032 | 0.0131 | 0.0089 | | | | | | | | | | 88, 134 |
| 1.1 | 11 | | | | | 30 | | | | | | | | | | | | | | 65 |
| 0.068 | 1.2 | | | | | 8.1 | | | | | | | | | | | | | | 114 |
| 0.14 | 1.2 | | | | | 11.9 | | | | | | | | | | | | | | 114 |
| 0.56 | 7.1 | | | | | 17.1 | | | | | | | | | | | | | | 114 |
| 0.14 | 0.9 | | | | | 10.1 | | | | | | | | | | | | | | 114 |
| 0.098 | 0.7 | | | | | 8.5 | | | | | | | | | | | | | | 114 |
| 0.073 | 0.5 | | | | | 5.2 | | | | | | | | | | | | | | 114 |
| 0.023 | 1 | | | | | 5.4 | | | | | | | | | | | | | | 114 |
| 0.48 | 4 | | | | | 57.4 | | | | | | | | | | | | | | 114 |

# Appendix A

| Location | | | Description | | | Land Use | | | | | | | | | Pop. | Traffic | | Miscellaneous | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country/State | Town/Area | Site | Area | Imp | Urban | Res | Ind | Com | Inst | Open | Other | Agr | For | Other | | Road | Dens | Roof | MtSt | Rain | SS |
| | | | ha | % | % | % | % | % | % | % | urban | % | % | rural | p/ha | % | veh/d | % | Helens | mm | mg/L |
| Japan | | Bare ground | 0.0036 | | 17 | | | | | | | | | | | | | | | | |
| Kansas | Kansas City | Rock Ck, Overton | 23 | 38 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | | | | | 800 | 2216 |
| Kansas | Kansas City | Indian Ck, 92nd | 26 | 37 | 83 | 92 | | | | | | | | | | | | | | 800 | 156 |
| Kansas | Kansas City | Rock Ck, Noland | 15 | 68 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 7 | | | | | 800 | 280 |
| Kansas | Kansas City | Indian Ck, Metcalf | 23 | 97 | 83 | | | 96 | | | | | | | | | | | | 800 | 80 |
| Kansas | Kansas City | Indian Ck, Lenaxa | 29 | 44 | 83 | | 56 | | | | | | | | | | | | | 800 | 102 |
| Malaysia | Selangor | Galv iron roof | 0.0015 | 100 | 83 | | | | | | | | | | | | | 100 | | 2396 | 72 |
| Malaysia | Selangor | Conc tile roof | 0.0015 | 100 | 83 | | | | | | | | | | | | | 100 | | 2396 | 124 |
| Maryland | Baltimore | Bolton Hill | 5.7 | 51 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 74 | | | | | 1050 | 74 |
| Maryland | Baltimore | Homeland | 9.3 | 29 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | | | | | 1050 | 50 |
| Maryland | Baltimore | Mt Washington | 6.9 | 29 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | | | | | 1050 | 95 |
| Maryland | Baltimore | Reservoir Hill | 4 | 76 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 136 | | | | | 1050 | 127 |
| Maryland | Baltimore | Hampden | 6.9 | 72 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 99 | | | | | 1050 | 82 |
| Maryland | Baltimore | Stoney Run | 558 | | 100 | 99 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 21 | | | | | 1050 | |
| Maryland | Baltimore | Glen Avenue | 80 | | 100 | 98 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 65 | | | | | 1050 | |
| Maryland | Baltimore | Jones Falls | 253 | | 100 | 97 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 111 | | | | | 1050 | |
| Maryland | Baltimore | Bush Street | 440 | | 100 | 78 | 3 | 3 | 0 | 16 | 0 | 0 | 0 | 0 | 228 | | | | | 1050 | |
| Maryland | Baltimore | Northwood | 20 | | 100 | 60 | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 63 | | | | | 1050 | |
| Maryland | Montgomery | Townhouse/garden apartn | 13.9 | 19.2 | 83 | 83 | | | | | | | | | | | | | | 1034 | 42 |
| Massachusetts | Greenfield | Maple Brook | 410 | 15 | 100 | 69 | 3 | 15 | 0 | 13 | 0 | 0 | 0 | 0 | 36 | | | | | 1050 | 147 |
| Massachusetts | Northampton | Market St Brook Sewer Su | 154 | 24 | 100 | 46 | 7 | 26 | 0 | 21 | 0 | 0 | 0 | 0 | | | | | | 1050 | 149 |
| Massachusetts | L Quinsigamond | Locust Street | 62 | 16 | 83 | 85 | | | | | | | | | 27 | | | | | 1050 | 257 |
| Massachusetts | L Quinsigamond | Jordan Pond | 45 | 34 | 83 | 79 | | | | | | | | | 25 | | | | | 1050 | 78 |
| Massachusetts | L Quinsigamond | Rt 9 | 137 | 23 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 17 | | | | | 1050 | 351 |
| Massachusetts | L Quinsigamond | Convent | 40 | 33 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 2.5 | | | | | 1050 | 54 |
| Massachusetts | L Quinsigamond | Anna Street | 243 | 12 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 22 | | | | | 1050 | 150 |
| Massachusetts | Upper Mystic | Hemlock Road | 20 | 16 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | | | | | 1050 | 78 |
| Massachusetts | Upper Mystic | Addison Wesley | 7.3 | 69 | 100 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 1050 | 48 |
| Michigan | Ann Arbor | Allen Ck (1965) | 1540 | | 100 | 37 | 1 | 16 | 0 | 23 | 23 | 0 | 0 | 0 | | 23 | | | | 800 | 2080 |
| Michigan | Ann Arbor | Allen Ck (1985) | 1540 | | 100 | 73 | 1 | 16 | 0 | 10 | 0 | 0 | 0 | 0 | | 23 | | | | 800 | 52 |
| Michigan | Ann Arbor | Fuller Drain | | | 83 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | | | | | | 800 | |
| Michigan | Ann Arbor | North Campus Dr | 636 | | 38 | 34 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 62 | | | | | | 800 | |
| Michigan | Ann Arbor | Pittsfield N Inlet | 1163 | 26 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 17 | | | | | 800 | 68 |
| Michigan | Ann Arbor | Pittsfield S Inlet | 810 | 21 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 5 | | | | | 800 | 46 |
| Michigan | Ann Arbor | Swift Run Inlet | 489 | 4 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 5 | | | | | 800 | 80 |
| Michigan | Ann Arbor | Traver Ck Inlet | 933 | 6 | 17 | | | | | 17 | | | | | | | | | | 800 | 33 |
| Michigan | Ann Arbor | Traver Drain | 1850 | | 33 | 31 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 67 | | | | | | 800 | |
| Michigan | Detroit | Urban | | | 83 | | | | | | | | | | | | | | | 802 | 158 |
| Michigan | Lansing | Waverly Hills Inlet | 12 | 68 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 27 | | | | | 800 | 85 |
| Michigan | Lansing | Grand River | 183 | 38 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 12 | | | | | 800 | 158 |
| Michigan | Lansing | Grace St N Inlet | 66 | 28 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 12 | | | | | 800 | 172 |
| Michigan | Lansing | Industrial Drain | 25.5 | 64 | 100 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 800 | 92 |
| Michigan | Lansing | Grace St S Inlet | 30 | 39 | 83 | | 52 | | | | | | | | 12 | | | | | 800 | 188 |
| Minnesota | Minneapolis | I-94 | | 55 | 83 | 50 | | 50 | | | | | | | | 83 | 80000 | | | 630 | 51 |
| Minnesota | St. Paul | I-94 | | 49 | 83 | 50 | | 50 | | | | | | | | 83 | 65000 | | | 630 | 85 |
| Minnesota | St. Paul | Vadnais Creek | 103 | 12 | 81 | 39 | 0 | 2 | 0 | 40 | 0 | 18 | 0 | 1 | | | | | | 630 | 165 |
| Minnesota | St. Paul | Lamberts Creek | 1950 | 19 | 76 | 40 | 0 | 10 | 0 | 26 | 0 | 3 | 0 | 21 | | | | | | 630 | 69 |
| Minnesota | St. Paul | Wilkenson Creek | 1250 | 8 | 69 | 25 | 0 | 3 | 0 | 41 | 0 | 1 | 0 | 30 | | | | | | 630 | 36 |
| Minnesota | | Bassett Creek | 7615 | 13 | 58 | 40 | 18 | 0 | 0 | 0 | 0 | 16 | 12 | 14 | 8.4 | | | | | 700 | 64 |
| Minnesota | | Bevens Creek | 21471 | 2 | 5 | 4 | 1 | 0 | 0 | 0 | 0 | 76 | 13 | 6 | 0.8 | | | | | 700 | 45 |
| Minnesota | | Carver Creek | 16887 | 2 | 8 | 7 | 1 | 0 | 0 | 0 | 0 | 58 | 16 | 18 | 1.5 | | | | | 700 | 33 |
| Minnesota | | Credit River | 6009 | 2 | 11 | 9 | 2 | 0 | 0 | 0 | 0 | 41 | 34 | 14 | 1.9 | | | | | 700 | 31 |
| Minnesota | | Elm Creek | 3704 | 13 | 10 | 9 | 1 | 0 | 0 | 0 | 0 | 57 | 13 | 20 | 1.9 | | | | | 700 | 10 |
| Minnesota | | Raven Stream | 8392 | 32 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 79 | 10 | 6 | 0.8 | | | | | 700 | 46 |
| Minnesota | | Shingle Creek | 5931 | 16 | 40 | 20 | 20 | 0 | 0 | 0 | 0 | 36 | 11 | 13 | 4.7 | | | | | 700 | 36 |
| Minnesota | | Vermillion River | 7977 | 31 | 8 | 7 | 1 | 0 | 0 | 0 | 0 | 74 | 13 | 5 | 1.4 | | | | | 700 | 100 |
| Minnesota | | Eagle Point Creek | 665 | 10 | 23 | 20 | 3 | 0 | 0 | 0 | 0 | 33 | 31 | 13 | 3 | | | | | 700 | 28 |
| Minnesota | | Elmo Creek | 170 | 2 | 6 | 6 | 0 | 0 | 0 | 0 | 0 | 37 | 48 | 9 | 1 | | | | | 700 | 330 |
| Minnesota | | Fish Creek | 285 | 7 | 26 | 25 | 1 | 0 | 0 | 0 | 0 | 22 | 32 | 20 | 4.2 | | | | | 700 | 81 |
| Minnesota | | Nine Mile Creek | 382 | 11 | 43 | 41 | 2 | 0 | 0 | 0 | 0 | 4 | 38 | 15 | 3.8 | | | | | 700 | 9.2 |

# Appendix A

| Water Quality | | | | | | | | | | | | | | | | | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TotP | TotN | Pb | Zn | O&G | BOD | COD | Cd | Cr | Cu | Ni | Hg | Fe | Mn | Turb | pH | TOC | TotColi | FecColi | FecStrep | |
| mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | NTU | | mg/L | #/100ml | #/100ml | #/100ml | |
| 0.73 | 3.3 | | | | | 35.9 | | | | | | | | | | | | | | 114 |
| 1.636 | | 0.138 | 0.831 | | 12 | 162 | | | 0.091 | | | | | | | | | | | 3 |
| 1.297 | | | | | 28 | 176 | | | | | | | | | | | | | | 3 |
| 0.555 | | 0.164 | 0.814 | | | 106 | | | 0.048 | | | | | | | | | | | 3 |
| 0.246 | | | 0.465 | | 8 | 55 | | | 0.041 | | | | | | | | | | | 3 |
| 0.599 | | | 2.721 | | 14 | 58 | | | 0.036 | | | | | | | | | | | 3 |
| | | 0.199 | 0.423 | | | | | | | | | | | 15 | 6.5 | | 47 | 3 | | 150 |
| | | 0.197 | 0.094 | | | | | | | | | | | 40 | 6.9 | | 51 | 6 | | 150 |
| 0.932 | 15.6 | 2.745 | 1.388 | | | 218 | | | 0.107 | | | | | | | | | | | 3 |
| 0.421 | 12.85 | 0.076 | 0.12 | | | 172 | | | 0.312 | | | | | | | | | 11000 | | 3 |
| 0.556 | 14.76 | 0.086 | 0.092 | | | 168 | | | 0.026 | | | | | | | | | 21000 | | 3 |
| 4.09 | 17.74 | 0.461 | 0.531 | | | 177 | | | 0.042 | | | | | | | | | 300000 | | 3 |
| 0.754 | 18.52 | 0.227 | 0.318 | | | 111 | | | 0.081 | | | | | | | | | | | 3 |
| | | | | | | | | | | | | | | | | | 48000 | 19000 | 41000 | 97 |
| | | | | | | | | | | | | | | | | | 240000 | 810000 | 660000 | 97 |
| | | | | | | | | | | | | | | | | | 290000 | 120000 | 280000 | 97 |
| | | | | | | | | | | | | | | | | | 380000 | 830000 | 560000 | 97 |
| | | | | | | | | | | | | | | | | | 38000 | 69000 | 50000 | 97 |
| 0.3 | 2.33 | | 0.075 | | | 21 | | | | | | | | | | | | | | 46 |
| 1.5 | | 0.178 | 0.196 | | 12 | 58 | | | | | | | | | 7 | 22 | | | | 61 |
| 0.53 | | 0.087 | 0.102 | | 30 | 94 | | | | | | | | | 6.4 | 30 | | | | 61 |
| 1.228 | 4.4 | 0.271 | 0.247 | | | 104 | | | 0.107 | | | | | | | | | | | 3 |
| 0.448 | 2.64 | 0.168 | 0.218 | | | 79 | | | 0.074 | | | | | | | | | | | 3 |
| 1.176 | 4.23 | 0.439 | 0.244 | | | 107 | | | 0.112 | | | | | | | | | | | 3 |
| 0.459 | 2.04 | 0.196 | 0.202 | | | 72 | | | 0.105 | | | | | | | | | | | 3 |
| 0.534 | 3.15 | | 0.178 | | | 88 | | | 0.054 | | | | | | | | | | | 3 |
| 0.314 | | | | | | | | | | | | | | | | | | | | 3 |
| 0.114 | | | | | | | | | | | | | | | | | | | | 3 |
| 1.63 | 3.5 | | | | 28 | | | | | | | | | | | | 1200000 | 82000 | 140000 | 18 |
| | | | | | | | | | | | | | | 31.1 | 7.7 | | | 3780 | 9800 | 39 |
| | | | | | | | | | | | | | | | | | | 15 | 29 | 39 |
| | | | | | | | | | | | | | | | | | | 3900 | 11900 | 39 |
| 0.268 | 1.52 | 0.061 | | | 6 | | | | | | | | | | | | | | | 3 |
| 0.103 | 1.13 | 0.021 | | | 5 | | | | | | | | | | | | | | | 3 |
| 0.134 | 2.15 | | | | 3 | 29 | | | | | | | | | | | | | | 3, 128 |
| 0.091 | 2 | | | | 2 | 25 | | | | | | | | | | | | | | 3 |
| | | | | | | | | | | | | | | | | | | 5800 | 17100 | 39 |
| | | | | | 146 | | | | | | | | | | | | 431000 | | | 101, 102 |
| 0.198 | 2.26 | 0.111 | 0.121 | | 9 | 64 | | | 0.015 | | | | | | | | | | | 3 |
| 0.458 | 2.51 | 0.122 | 0.245 | | 8 | 71 | | | 0.03 | | | | | | | | | | | 3 |
| 0.394 | 2.87 | 0.17 | 0.149 | | 8 | 72 | | | 0.014 | | | | | | | | | | | 3 |
| 0.546 | 1.96 | 0.116 | 0.244 | | 10 | 67 | | | 0.036 | | | | | | | | | | | 3 |
| 0.435 | 2.46 | 0.115 | 0.223 | | 5 | 60 | | | 0.025 | | | | | | | | | | | 3 |
| | | 0.116 | | | | | | | | | | | | | | | | | | 127 |
| | | 0.407 | | | | | | | | | | | | | | | | | | 127 |
| 0.46 | 1.86 | | | | | | | | | | | | | | | | | | | 17 |
| 0.24 | 1.36 | | | | | | | | | | | | | | | | | | | 17 |
| 0.2 | 0.97 | | | | | | | | | | | | | | | | | | | 17 |
| 0.31 | 2.18 | | | | | | | | | | | | | | | | | | | 16 |
| 0.78 | 6.3 | | | | | | | | | | | | | | | | | | | 16 |
| 0.88 | 3.61 | | | | | | | | | | | | | | | | | | | 16 |
| 0.71 | 3.53 | | | | | | | | | | | | | | | | | | | 16 |
| 0.34 | 2.37 | | | | | | | | | | | | | | | | | | | 16 |
| 0.74 | 7.8 | | | | | | | | | | | | | | | | | | | 16 |
| 0.27 | 2.31 | | | | | | | | | | | | | | | | | | | 16 |
| 0.35 | 5 | | | | | | | | | | | | | | | | | | | 16 |
| 0.13 | 1.9 | | | | | | | | | | | | | | | | | | | 16 |
| 0.4 | 2.9 | | | | | | | | | | | | | | | | | | | 16 |
| 0.3 | 3.1 | | | | | | | | | | | | | | | | | | | 16 |
| 0.08 | 2.55 | | | | | | | | | | | | | | | | | | | 16 |

| Location | | | Description | | | Land Use | | | | | | | | | Pop. | Traffic | | Miscellaneous | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country/State | Town/Area | Site | Area | Imp | Urban | Res | Ind | Com | Inst | Open | Other | Agr | For | Other | | Road | Dens | Roof | MtSt | Rain | SS |
| | | | ha | % | % | % | % | % | % | % | urban | % | % | rural | p/ha | % | veh/d | % | Helens | mm | mg/L |
| Minnesota | | Riley Creek | 1475 | 5 | 11 | 8 | 3 | 0 | 0 | 0 | 0 | 27 | 36 | 26 | 1.2 | | | | | 700 | 2.8 |
| Minnesota | | Spring Creek | 2256 | 1 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 61 | 15 | 20 | 0.1 | | | | | 700 | 7.1 |
| Missouri | Rolla | Frisco Lake | 44.9 | | 100 | 40 | 1 | 8 | 17 | 2 | 32 | 0 | 0 | 0 | 6.3 | | | | | 1055 | 149 |
| Nebraska | Lincoln | 39th & Holdrege | 32 | 30 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | | | | | 695 | 736 |
| Nebraska | Lincoln | 63rd & Holdrege | 39.4 | 38 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | | | | | 695 | 828 |
| Nebraska | Lincoln | 78th & A Street | 145 | 25 | 50 | 50 | | | | | | 50 | | | | | | | | 695 | 1532 |
| Netherlands | Leiystad | Pre-1977 | | | 83 | 50 | | 17 | | | | | | | | | | | | | |
| Netherlands | Leiystad | 1982-1985 | 4.5 | 60 | 83 | 50 | | 17 | | | | | | | | | | | | | 39.5 |
| New Hampshire | Durham | Parking Lot | 2.5 | 90 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 1050 | 74 |
| New Jersey | Hightstown | Twin Rivers 1 | 14.7 | | 100 | 62 | 0 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | | | | | | 1080 | |
| New Jersey | Hightstown | Twin Rivers 2 | 9.6 | | 100 | 47 | 0 | 0 | 0 | 53 | 0 | 0 | 0 | 0 | | | | | | 1080 | |
| New Jersey | Hillsborough | | 258 | | 64 | 64 | 0 | 0 | 0 | 0 | 0 | 17 | 19 | 0 | | | | | | 1050 | |
| New Jersey | Lodi | Stormsewer A | 7.3 | | 100 | 30 | 12 | 58 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1050 | |
| New Jersey | Lodi | Stormsewer B | 9.8 | | 100 | 53 | 5 | 42 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1050 | |
| New Jersey | Lodi | Stormsewer C | 166 | | 100 | 95 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1050 | |
| New Jersey | Lodi | Westerley Brook | 215 | | 100 | 41 | 11 | 15 | 21 | 12 | 0 | 0 | 0 | 0 | | | | | | 1050 | |
| New Jersey | Lodi | Millbank Brook | | | 100 | 61 | 12 | 16 | 3 | 8 | 0 | 0 | 0 | 0 | | | | | | 1050 | |
| New Jersey | Lodi | Lodi Brook | | | 100 | 0 | 94 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | | | | | | 1050 | |
| New Jersey | Lodi | Feld's Brook | | | 100 | 0 | 97 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | | | | | | 1050 | |
| New Jersey | New Brunswick | Mile Run | | | 83 | 38 | 5 | 14 | | | | | | | | | | | | 1050 | |
| New Jersey | Trenton | East State Street | 81.1 | | 100 | 5 | 61 | 6 | 28 | 0 | 0 | 0 | 0 | 0 | | | | | | 1050 | |
| New Jersey | Trenton | Lwr Assunpink Ck | | | 83 | | | | | | | | | | | | | | | 1050 | |
| New Jersey | Trenton | Petti's Run | 81.8 | | 100 | 32 | 19 | 37 | 7 | 5 | 0 | 0 | 0 | 0 | | | | | | 1050 | |
| New York | Irondequoit Bay | Cranston Road | 67 | 22 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | | | | | 950 | 134 |
| New York | Irondequoit Bay | East Rochester | 140 | 38 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 44 | | | | | 950 | 294 |
| New York | Irondequoit Bay | Thornell Road | 11508 | 4 | 17 | | | | | 17 | | | | | 0 | | | | | 950 | 154 |
| New York | Irondequoit Bay | Thomas Creek | 7180 | 11 | 17 | | | | | 17 | | | | | 2.5 | | | | | 950 | 63 |
| New York | Irondequoit Bay | Southgate Road | 72 | 21 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | | | | | 950 | 141 |
| New York | Lake George | English Brook | 2125 | 1 | 17 | | | | | 17 | | | | | 0 | | | | | 950 | 17 |
| New York | Lake George | West Brook | 2162 | 1 | 17 | | | | | 17 | | | | | 0 | | | | | 950 | 64 |
| New York | Lake George | Sheriff's Dock | 224 | 7 | 17 | | | | | 17 | | | | | | | | | | 950 | 378 |
| New York | Lake George | Cedar Lane | 31 | 5 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | | | | | | 950 | 291 |
| New York | Long Island | Carll's R | 30 | 20 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | | | | | 1050 | 42 |
| New York | Long Island | Unqua | | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1050 | 65 |
| New York | New York | Urban | | | 83 | | | | | | | | | | | | | | | 1063 | |
| New York | Syracuse | Parking lot | 16 | 83 | 83 | | | | | | | | | | | 83 | | | | 950 | |
| North Carolina | Asheville | Sweeten Ck 1 | | | 17 | | | | | | | | 83 | | | | | | | 1038 | 37 |
| North Carolina | Asheville | Sweeten Ck 2 | | | 50 | 17 | 17 | | | | | | 50 | | | | | | | 1038 | 116 |
| North Carolina | Asheville | Nasty Branch 1 | | | 83 | 50 | | 50 | | | | | | | | | | | | 1038 | 233 |
| North Carolina | Asheville | Nasty Branch 3 | | | 83 | 50 | 17 | 50 | | | | | | | | | | | | 1038 | 85 |
| North Carolina | Charlotte | Runaway Bay | 28 | | 50 | 50 | | | | | | | 50 | | | | | | | 1129 | 135 |
| North Carolina | Durham | Third Fork | 433 | 29 | 100 | 60 | 19 | 0 | 11 | 10 | 0 | 0 | 0 | 0 | 15 | 23 | | 9 | | 1100 | 1223 |
| North Carolina | Durham | E1 | 22.7 | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1100 | |
| North Carolina | Durham | E2 | 106.4 | | 100 | 50 | 17 | 17 | 0 | 5 | 0 | 0 | 0 | 0 | | | | | | 1100 | |
| North Carolina | Durham | N2 | 77.3 | | 100 | 18 | 17 | 17 | 0 | 25 | 0 | 0 | 0 | 0 | | | | | | 1100 | |
| North Carolina | Durham | W1 | 68.4 | | 100 | 85 | 17 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1100 | |
| North Carolina | Durham | W2 | 83.8 | | 100 | 73 | 17 | 17 | 0 | 14 | 0 | 0 | 0 | 0 | | | | | | 1100 | |
| North Carolina | Efland | I-85 | | 51 | 17 | | | | | | | | | | | 83 | 26000 | | | 1107 | 19 |
| North Carolina | Winston-Salem | Site 1023 | 131 | 27 | 83 | 84 | | | | | | | | | 15 | | | | | 1100 | 291 |
| North Carolina | Winston-Salem | Site 1013 | 9.3 | 69 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 1100 | 163 |
| Norway | Oslo | Site 2 | 10 | 97 | 83 | | | 83 | | | | | | | | | | | | 740 | 1038 |
| Norway | Oslo | Site 3 | 37 | 43 | 83 | 83 | | | | | | | | | 155 | | | | | 790 | 367 |
| Norway | Oslo | Site 4 | 37 | 33 | 83 | 83 | | | | | | | | | 123 | | | | | 750 | 86 |
| Norway | Trondheim | Site 2 | 20 | 18 | 83 | 83 | | | | | | | | | 30 | | | | | 860 | 929 |
| Norway | Lake Padderudvann | | 22 | 83 | 17 | | | | | | | | | | | 83 | 19400 | | | 870 | 1370 |
| Ohio | Cincinnati | | 11 | 37 | 83 | 83 | | 17 | | | | | | | 25 | | | | | 998 | 227 |
| Ohio | Cincinnati | Wooded hillside | | | 83 | | | | | 83 | | | | | | | | | | 998 | |
| Ohio | Cincinnati | Suburban street | | | 83 | 83 | | | | | | | | | | 83 | | | | 998 | |
| Ohio | Cincinnati | Business district | | | 83 | | | 83 | | | | | | | | | | | | 998 | |
| Ohio | Coshocton | Rural | | | 17 | | | | | | | | | 83 | | | | | | 998 | |

## Appendix A

| Water Quality | | | | | | | | | | | | | | | | | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TotP | TotN | Pb | Zn | O&G | BOD | COD | Cd | Cr | Cu | Ni | Hg | Fe | Mn | Turb | pH | TOC | TotColi | FecColi | FecStrep | |
| mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | NTU | | mg/L | #/100ml | #/100ml | #/100ml | |
| 0.21 | 2.68 | | | | | | | | | | | | | | | | | | | 16 |
| 0.32 | 12.2 | | | | | | | | | | | | | | | | | | | 16 |
| 0.46 | 1.64 | | | | | 54 | | | | | | | | | | | | | | 95 |
| | | | | | 38 | 213 | | | | | | | | 800 | | | | | | 61, 89 |
| | | | | | 22 | 156 | | | | | | | | 779 | | | | | | 61, 89 |
| | | | | | 8.7 | 94 | | | | | | | | 1129 | | | | | | 61, 89 |
| 0.4 | 2.8 | | | | 6.4 | 33 | | | | | | 0.76 | | | 7.4 | | | 1000 | | 133 |
| 0.13 | 2.81 | 0.0725 | 0.4503 | | 3.6 | 26.4 | 0.0008 | 0.0102 | 0.0128 | 0.015 | | | | | | | | | | 1 |
| 0.273 | 2.91 | 0.208 | 0.513 | | 17 | 98 | | | 0.104 | | | | | | | | | 300 | | 3 |
| | | 0.26 | 0.41 | | | | | 0.01 | 0.04 | 0.03 | | | | | | | | | | 145 |
| | | 0.11 | 0.34 | | | | | 0.02 | 0.06 | 0.02 | | | | | | | | | | 145 |
| 0.41 | | | | | | 31.4 | | | | | | | | | | | | | | 36 |
| | | 1.25 | 0.6 | | | | | 0.02 | 1.27 | 0.06 | | | | | | | | | | 145 |
| | | 0.67 | 0.43 | | | | | 0.03 | 0.2 | 0.06 | | | | | | | | | | 145 |
| | | 0.61 | 0.31 | | | | | 0.03 | 0.14 | 0.05 | | | | | | | | | | 145 |
| | | 0.21 | 0.141 | | | | | 0.007 | 0.02 | 0.022 | | | | | | | | | | 144 |
| | | 0.22 | 0.123 | | | | | 0.007 | 0.026 | 0.034 | | | | | | | | | | 144 |
| | | 0.354 | 0.132 | | | | | 0.194 | 0.031 | 0.022 | | | | | | | | | | 144 |
| | | 0.33 | 0.138 | | | | | 0.046 | 0.044 | 0.078 | | | | | | | | | | 144 |
| | | | | | 17 | | | | | | | | | | | | | | | 142 |
| | | 0.27 | 1.23 | | | | | 0.11 | 0.1 | 0.08 | | | | | | | | | | 141 |
| | | | | | | | | | | | | | | | | | | | | 141 |
| | | 0.46 | 0.73 | | | | | 0.01 | 0.1 | 0.03 | | | | | | | | | | 141 |
| 0.301 | | 0.034 | 0.415 | | | 33 | | | | | | | | | | | | | | 3 |
| 0.448 | | 0.193 | 0.488 | | | 86 | | | | | | | | | | | | | | 3 |
| 0.193 | | 0.012 | 0.792 | | | 25 | | | | | | | | | | | | | | 3 |
| 0.195 | | 0.035 | 1.063 | | | 26 | | | | | | | | | | | | | | 3 |
| 0.216 | | 0.047 | 1.416 | | | 40 | | | | | | | | | | | | | | 3 |
| 0.027 | 0.58 | 0.009 | | | | | | | | | | | | | | | | | | 3 |
| 0.052 | 1.25 | 0.038 | | | | | | | | | | | | | | | | | | 3 |
| 0.264 | 1.35 | 0.132 | | | | | | | | | | | | | | | | | | 3 |
| 0.363 | 1.48 | 0.075 | | | | | | | | | | | | | | | | | | 3 |
| 0.221 | 2.22 | | | | | | | | | | | | | | | | | 5000 | | 3 |
| 0.229 | 2.94 | 0.088 | | | | | | | | | | | | | | | | 4400 | | 3 |
| | | | 1.6 | | | | 0.025 | 0.16 | 0.46 | 0.15 | | | | | | | | | | 69 |
| | | 1.54 | 1.98 | | | | 0.063 | | 0.49 | | | 3 | 0.23 | | 7.7 | | | | | 100 |
| | | 0.05 | 0.025 | 0.5 | 1.1 | 15 | 0.025 | 0.025 | 0.02 | | 0.000025 | 0.95 | 0.1 | | 6.5 | | | | | 31 |
| | | 0.15 | 0.08 | 2.5 | 3.5 | 27 | 0.025 | 0.025 | 0.07 | | 0.000025 | 2.5 | 0.16 | | 6.9 | | | | | 31 |
| | | 0.05 | 0.085 | 2 | 5 | 15 | 0.025 | 0.025 | 0.02 | | | 6 | 0.72 | | 7.4 | | | | | 31 |
| | | 0.2 | 0.14 | 4.5 | 9 | 32 | 0.025 | 0.025 | 0.02 | | 0.00025 | 4.5 | 0.28 | | 7.3 | | | | | 31 |
| 0.14 | | 0.05 | 0.07 | | | | | | 0.015 | | | 6.1 | | | | | | | | 147 |
| 0.82 | | 0.46 | 0.36 | | | 170 | | 0.23 | 0.15 | 0.15 | | 12 | 0.67 | | 7 | 42 | | 23000 | | 23 |
| | | 0.26 | 0.22 | | | | | 0.13 | 0.11 | 0.05 | | | | | | | | | | 145 |
| | | 0.13 | 0.32 | | | | | 0.15 | 0.13 | 0.05 | | | | | | | | | | 145 |
| | | 0.32 | 0.27 | | | | | 0.16 | 0.12 | 0.05 | | | | | | | | | | 145 |
| | | 0.27 | 0.32 | | | | | 0.13 | 0.1 | 0.05 | | | | | | | | | | 145 |
| | | 0.25 | 0.23 | | | | | 0.15 | 0.12 | 0.05 | | | | | | | | | | 145 |
| | | 0.01 | 0.06 | | | 49 | | | | | | | | | | | | | | 117,118,127 |
| 0.529 | 2.2 | 0.254 | 0.178 | | 11 | 90 | | | 0.039 | | | | | | | | | 5400 | | 3 |
| 0.395 | 2.73 | 0.382 | 0.533 | | 18 | 120 | | | 0.07 | | | | | | | | | 4800 | | 3 |
| 1.2 | 4.2 | 0.82 | 1.73 | | | 244 | | | 0.52 | | | | | | | | | | | 73 |
| 0.5 | 4.9 | 0.1 | 0.17 | | | 73 | | | 0.04 | | | | | | | | | | | 73 |
| 0.8 | 5.9 | 0.05 | 0.32 | | | 63 | | | 0.13 | | | | | | | | | | | 73 |
| 0.3 | 2.3 | 0.07 | 0.1 | | | 74 | | | 0.03 | | | | | | | | | | | 73 |
| | | 0.425 | 0.45 | | | 510 | 0.003 | | 0.153 | 0.045 | | 21 | | | | 33 | | | | 41 |
| | 3.1 | | | | 17 | 111 | | | | | | | | 176 | 7.5 | | 58000 | 10900 | 20500 | 139 |
| | | | | | | | | | | | | | | | | | 9700 | 240 | 4200 | 40 |
| | | | | | | | | | | | | | | | | | 16000 | 1400 | 19500 | 40 |
| | | | | | | | | | | | | | | | | | 76000 | 8600 | 32000 | 40 |
| | | | | | | | | | | | | | | | | | 19000 | 730 | 24000 | 40 |

| Location | | | Description | | | Land Use | | | | | | | | | Pop. | Traffic | | Miscellaneous | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country/State | Town/Area | Site | Area | Imp | Urban | Res | Ind | Com | Inst | Open | Other | Agr | For | Other | | Road | Dens | Roof | MtSt | Rain | SS |
| | | | ha | % | % | % | % | % | % | % | urban | % | % | rural | p/ha | % | veh/d | % | Helens | mm | mg/L |
| Ohio | Coshocton | Watershed 113 | | | 17 | | | | | | | 83 | | | | | | | | | |
| Ohio | Coshocton | Watershed 118 | | | 17 | | | | | | | 83 | | | | | | | | | |
| Ohio | Coshocton | Watershed 185 | | | 17 | | | | | | | 83 | | | | | | | | | |
| Ohio | Coshocton | Watershed 192 | | | 17 | | | | | | | 83 | | | | | | | | | |
| Ohio | Coshocton | Watershed 196 | | | 17 | | | | | | | 83 | | | | | | | | | |
| Oklahoma | Tulsa | Test area 1 | | | 100 | 4 | 47 | 9 | 0 | 25 | 15 | 0 | 0 | 0 | 30 | 15 | | | | 839 | 2052 |
| Oklahoma | Tulsa | Test area 2 | | | 100 | 30 | 1 | 24 | 0 | 25 | 20 | 0 | 0 | 0 | 32 | 20 | | | | 839 | 169 |
| Oklahoma | Tulsa | Test area 3 | | | 100 | 57 | 0 | 5 | 0 | 19 | 19 | 0 | 0 | 0 | 31 | 19 | | | | 839 | 280 |
| Oklahoma | Tulsa | Test area 4 | | | 100 | 25 | 18 | 28 | 0 | 6 | 23 | 0 | 0 | 0 | 38 | 23 | | | | 839 | 340 |
| Oklahoma | Tulsa | Test area 5 | | | 100 | 53 | 0 | 11 | 0 | 16 | 20 | 0 | 0 | 0 | 42 | 20 | | | | 839 | 136 |
| Oklahoma | Tulsa | Test area 6 | | | 100 | 33 | 35 | 6 | 0 | 3 | 23 | 0 | 0 | 0 | 25 | 23 | | | | 839 | 195 |
| Oklahoma | Tulsa | Test area 7 | | | 100 | 65 | 0 | 10 | 0 | 1 | 24 | 0 | 0 | 0 | 44 | 24 | | | | 839 | 84 |
| Oklahoma | Tulsa | Test area 8 | | | 100 | 52 | 5 | 11 | 0 | 4 | 28 | 0 | 0 | 0 | 54 | 28 | | | | 839 | 240 |
| Oklahoma | Tulsa | Test area 9 | | | 100 | 47 | 0 | 11 | 0 | 5 | 37 | 0 | 0 | 0 | 72 | 37 | | | | 839 | 260 |
| Oklahoma | Tulsa | Test area 10 | | | 100 | 16 | 0 | 18 | 0 | 16 | 50 | 0 | 0 | 0 | 66 | 50 | | | | 839 | 300 |
| Oklahoma | Tulsa | Test area 11 | | | 100 | 45 | 5 | 4 | 0 | 4 | 42 | 0 | 0 | 0 | 52 | 42 | | | | 839 | 401 |
| Oklahoma | Tulsa | Test area 12 | | | 100 | 0 | 2 | 48 | 0 | 50 | 0 | 0 | 0 | 0 | | 0 | | | | 839 | 89 |
| Oklahoma | Tulsa | Test area 13 | | | 100 | 75 | 0 | 3 | 0 | 2 | 20 | 0 | 0 | 0 | 8 | 20 | | | | 839 | 332 |
| Oklahoma | Tulsa | Test area 14 | | | 100 | 27 | 0 | 0 | 0 | 65 | 8 | 0 | 0 | 0 | 9 | 8 | | | | 839 | 445 |
| Oklahoma | Tulsa | Test area 15 | | | 100 | 70 | 0 | 1 | 0 | 7 | 22 | 0 | 0 | 0 | 39 | 22 | | | | 839 | 183 |
| Oregon | Portland | Fanno Creek | | | 83 | 83 | | | | | | | | | | | | | | 1059 | 832 |
| Pennsylvania | Butler | Locust Street | 30 | 53 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 920 | 396 |
| Pennsylvania | Harrisburg | I-81 (urban) | | 45 | 83 | | | | | | | | | | | 83 | 56000 | | | 958 | 184 |
| Pennsylvania | Harrisburg | I-81 (rural) | | 27 | 17 | | | | | | | | | | | 83 | 24000 | | | 958 | 31 |
| Pennsylvania | North Philadelphia | 13 foot drain | 616 | | 100 | 75 | 1 | 9 | 3 | 12 | 0 | 0 | 0 | 0 | | | | | | 1063 | 87 |
| Pennsylvania | North Philadelphia | 27 inch drain | 6.5 | | 100 | 93 | 0 | 1 | 0 | 6 | 0 | 0 | 0 | 0 | | | | | | 1063 | |
| Pennsylvania | Central | Residential roof | | 100 | 83 | 83 | | | | | | | | | | | | 100 | | 950 | |
| Pennsylvania | Central | Residential street | | 83 | 83 | 83 | | | | | | | | | | 83 | | | | 950 | |
| Pennsylvania | Central | Shopping centre | | | 83 | | | 83 | | | | | | | | | | | | 950 | |
| Pennsylvania | Central | Highway | | 83 | 83 | | | | | | | | | | | 83 | | | | 950 | |
| Pennsylvania | Central | Business district | | | 83 | | | 83 | | | | | | | | | | | | 950 | |
| Rhode Island | Cranston | I-95 | 44.8 | 83 | 83 | | | | | | | | | | | 83 | 101500 | | | 1050 | 505 |
| Rhode Island | Warwick | Shopping centre | 12.5 | | 83 | | | 83 | | | | | | | | | | | | 1050 | 38 |
| Russia | Leningrad | Urban streets | | 83 | 83 | | | | | | | | | | | 83 | | | | 554 | 14541 |
| Saudi Arabia | Dhahran | As-Salamah | 182 | 29 | 83 | 50 | | 50 | | | | | | | | | | | | 76 | 1600 |
| Saudi Arabia | Riyadh | SW1 | | | 83 | | | | | | | | | | | | | | | 98 | 1500 |
| Saudi Arabia | Riyadh | SW5 | | | 83 | | | | | | | | | | | | | | | 98 | 280 |
| Singapore | | Stamford Canal trib. | 65 | 23 | 83 | 83 | | | | | | | | | | | | | | 2314 | 96.1 |
| South Africa | Durban | | 6.8 | 20 | 83 | 83 | | | | | | | | | | | | | | 1013 | 104 |
| South Africa | Khayelitsha | Unserviced informal | | | 83 | 83 | | | | | | | | | 200 | | | | | 613 | |
| South Africa | Khayelitsha | Serviced informal | | | 83 | 83 | | | | | | | | | 200 | | | | | 613 | |
| South Africa | Khayelitsha | Permanent housing | | | 83 | 83 | | | | | | | | | | | | | | 613 | |
| South Africa | Pretoria | Residential | | | 83 | 83 | | | | 17 | | | | | | | | | | 704 | |
| South Africa | Pretoria | Commercial | | | 83 | 50 | | 50 | | | | | | | | | | | | 704 | |
| South Dakota | Rapid City | Meade St Drain | 822 | | 83 | 17 | 17 | 17 | 17 | 17 | | | | | | | | | | 405 | 3093 |
| South Dakota | Rapid City | Hawthorne Drain | | | 83 | | | | | | | | | | | | | | | 405 | 2760 |
| Spain | Madrid | Composite | | 83 | 83 | | | | | | | | | | | 83 | | | | 474 | |
| Sweden | Goteborg | Vegagatan | 5.8 | 53 | 83 | | | 83 | | | | | | | 250 | | | | | 749 | 91 |
| Sweden | Goteborg | Mellbyleden | 15.6 | 39 | 83 | | | | | | | | | | 115 | | | | | 749 | 60 |
| Sweden | Goteborg | Bergsjosvangen | 4.8 | 44 | 83 | | | | | | | | | | 85 | | | | | 749 | 86 |
| Sweden | Goteborg | Floda - suburban | 18 | 14 | 83 | | | | | | | | | | 22 | | | | | 749 | 58 |
| Sweden | Goteborg | Vara - roofs | 0.004 | 100 | 83 | | 83 | | | | | | | | | | | 100 | | 749 | |
| Sweden | Goteborg | Lidkoping - roofs | 0.004 | 100 | 83 | 83 | | | | | | | | | | | | 100 | | 749 | |
| Sweden | Goteborg | Floda - highway | | 83 | 83 | | | | | | | | | | | 83 | | | | 749 | |
| Sweden | Goteborg | Bergsjon | 16 | 38 | 83 | 83 | | 83 | | | | | | | 112 | | 3100 | | | 749 | |
| Sweden | Goteborg | Torslanda | 325 | | 49 | | | | | | | | | | | | | | | 749 | 150 |
| Sweden | Stockholm | Urban | | | 83 | | | | | | | | | | | | | | | 555 | 210 |
| Sweden | Stockholm | Lake Trekanten | 16 | | 83 | | | | | | | | | | | | | | | 555 | 210 |
| Sweden | Stockholm | Kungsholmen | 2 | | 83 | | | | | | | | | | | 85 | 18000 | 15 | | 555 | |
| Sweden | Stockholm | Terrace houses | 25 | | 83 | 64 | | | | 36 | | | | | 28 | | | | | 555 | 113 |

| Water Quality | | | | | | | | | | | | | | | | | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TotP | TotN | Pb | Zn | O&G | BOD | COD | Cd | Cr | Cu | Ni | Hg | Fe | Mn | Turb | pH | TOC | TotColi | FecColi | FecStrep | |
| mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | NTU | | mg/L | #/100ml | #/100ml | #/100ml | |
| | | | | | | | | | | | | | | | | | 3000 | 8 | 1500 | 140 |
| | | | | | | | | | | | | | | | | | 2500 | 1 | 610 | 140 |
| | | | | | | | | | | | | | | | | | 3000 | 20 | 3700 | 140 |
| | | | | | | | | | | | | | | | | | 4400 | 18 | 1100 | 140 |
| | | | | | | | | | | | | | | | | | 8100 | 1200 | 8400 | 140 |
| | | | | | 13 | 110 | | | | | | | | | | | 71000 | 940 | | 22, 83 |
| | | | | | 8 | 45 | | | | | | | | | | | 43000 | 1900 | | 22, 83 |
| | | | | | 8 | 65 | | | | | | | | | | | 100000 | 3300 | | 22, 83 |
| | | | | | 14 | 103 | | | | | | | | | | | 25000 | 770 | | 22, 83 |
| | | | | | 18 | 138 | | | | | | | | | | | 150000 | 1500 | | 22, 83 |
| | | | | | 12 | 90 | | | | | | | | | | | 140000 | 18000 | | 22, 83 |
| | | | | | 8 | 48 | | | | | | | | | | | 32000 | 120 | | 22, 83 |
| | | | | | 15 | 115 | | | | | | | | | | | 240000 | 450 | | 22, 83 |
| | | | | | 10 | 117 | | | | | | | | | | | 400000 | 290 | | 22, 83 |
| | | | | | 11 | 107 | | | | | | | | | | | 130000 | 300 | | 22, 83 |
| | | | | | 14 | 116 | | | | | | | | | | | 370000 | 620 | | 22, 83 |
| | | | | | 8 | 45 | | | | | | | | | | | 56000 | 10 | | 22, 83 |
| | | | | | 15 | 88 | | | | | | | | | | | 28000 | 180 | | 22, 83 |
| | | | | | 11 | 53 | | | | | | | | | | | 5000 | 370 | | 22, 83 |
| | | | | | 12 | 42 | | | | | | | | | | | 220000 | 350 | | 22, 83 |
| 0.7 | 1.93 | 0.145 | 0.257 | | | | 0.0005 | 0.029 | 0.036 | 0.015 | | | 1.27 | | | | | | | 110 |
| | | 0.47 | 0.3 | 9.2 | 30 | | | | | | | | | | | | | 186000 | | 49 |
| | | 0.03 | 0.17 | | | 34 | | | | | | | | | | | | | | 117,118,127 |
| | | 0.1 | 0.06 | | | 31 | | | | | | | | | | | | | | 117,118,127 |
| | | 0.45 | 0.5 | | | | | 0.05 | 0.15 | 0.02 | | | | | | | | | | 62, 75, 145 |
| | | 0.5 | 0.43 | | | | | 0.01 | 0.04 | 0.03 | | | | | | | | | | 145 |
| 0.04 | | | | | | | | | | | | | | | 4.6 | | | | | 51 |
| 0.15 | | | | | | | | | | | | | | | 7.2 | | | | | 51 |
| 0.16 | | | | | | | | | | | | | | | 7.4 | | | | | 51 |
| 0.28 | | | | | | | | | | | | | | | 7.6 | | | | | 51 |
| 0.68 | | | | | | | | | | | | | | | 7.6 | | | | | 51 |
| | | 0.9 | 5.8 | | | | 0.0031 | | 0.128 | | | 5.75 | 0.37 | | | | | | | 58 |
| | | | | | | | | | | | | | | | | | | | | 57 |
| | | | | | 36 | | | | | | | | | | | | | | | 138 |
| 0.46 | 6.2 | 0.1 | 0.53 | 3.5 | | 240 | 0.016 | 0.31 | 0.15 | 0.12 | | 11 | | | | | | | | 66, 67 |
| 0.33 | 6.7 | 0.04 | 0.95 | 1.5 | | 260 | 0.013 | 0.15 | 0.12 | 0.06 | | 21 | | | | | | | | 68 |
| 0.38 | 6.6 | 0.03 | 0.25 | 1.7 | | 180 | 0.004 | 0.14 | 0.13 | 0.08 | | 6.7 | | | | | | | | 68 |
| 1.8 | | 0.07 | 0.06 | 21.6 | 4.4 | 27.1 | 0.05 | 0.05 | 0.01 | | | 0.22 | 0.05 | 115 | 7.3 | 4.2 | | | | 20 |
| 0.303 | 2.059 | | | | | | | | | | | | | | | | | | | 121 |
| | | 0.02 | 0.02 | | | | 0.005 | | 0.01 | | | 0.36 | | | 6.7 | | | 120000 | 9900 | 146 |
| | | 0.02 | 0.01 | | | | 0.005 | | 0.01 | | | 0.41 | | | 7 | | | 270000 | 3900 | 146 |
| | | 0.03 | 0.01 | | | | 0.005 | | 0.01 | | | 1.74 | | | 6.9 | | | 22000 | 61000 | 146 |
| | | | | | 30 | 29 | | | | | | | | | | | 240000 | | | 83, 138 |
| | | | | | 34 | 28 | | | | | | | | | | | 230000 | | | 83, 138 |
| 1.885 | 4.86 | 0.383 | | | 19 | 179 | | | | | | | | | | | | 57000 | | 3 |
| | | 0.253 | | | | 195 | | | | | | | | | | | | | | 30 |
| | | | | | | | | | | | | | | | | | | | | 14 |
| 0.37 | | 0.4 | 0.57 | | | 117 | | | 0.31 | | | | | | | | | | | 77 |
| 0.19 | | 0.14 | 0.32 | | | 70 | | | 0.19 | | | | | | | | | | | 77 |
| 0.4 | | 0.16 | 0.26 | | | 89 | | | 0.03 | | | | | | | | | | | 77 |
| 0.17 | | 0.06 | 0.17 | | | 63 | | | 0.03 | | | | | | | | | | | 77 |
| 0.29 | 7.1 | 0.016 | 0.31 | | | | 0.0007 | | 0.037 | | | | | | | | | | | 76 |
| 0.12 | 4.5 | 0.012 | 0.34 | | | | 0.001 | | 0.029 | | | | | | | | | | | 76 |
| 0.18 | 1.7 | 0.16 | 0.15 | | | | 0.0007 | | 0.041 | | | | | | | | | | | 76 |
| | | 0.2 | 0.465 | | | | 0.006 | 0.0025 | 0.27 | 0.024 | 0.0001 | 1 | 0.078 | | | | | | | 60 |
| 0.1 | | 0.15 | | | 15 | | | | | | | | | | | | | | | 77 |
| | | | | | 17 | 188 | | | | | | | | | | | 4000 | | | 83, 138 |
| | | 0.315 | 0.325 | | | | 0.002 | | 0.865 | | | | | | | | | | | 103 |
| | | 0.12 | 0.56 | | | | 0.00115 | | 1.8 | | | | | | | | | | | 103 |
| 0.04 | 1.4 | 0.0002 | | 30 | 10 | | | | | | | | | | | | | | | 124 |

| Location | | | Description | | | Land Use | | | | | | | | | Pop. | Traffic | | Miscellaneous | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country/State | Town/Area | Site | Area | Imp | Urban | Res | Ind | Com | Inst | Open | Other | Agr | For | Other | | Road | Dens | Roof | MtSt | Rain | SS |
| | | | ha | % | % | % | % | % | % | % | urban | % | % | rural | p/ha | % | veh/d | % | Helens | mm | mg/L |
| Sweden | Stockholm | Commercial | 25 | | 83 | 50 | | 50 | | 32 | | | | | 104 | | | | | 555 | 122 |
| Sweden | Stockholm | Highway | 3.3 | 83 | 83 | | | | | | | | | | | 83 | 65000 | | | 555 | 282 |
| Sweden | Stockholm | Residential | 530 | | 83 | 59 | 7 | | | 34 | | | | | 57 | | | | | 555 | 129 |
| Switzerland | Zurich | Schwamendingen | 9 | 35 | 83 | 83 | | | | | | | | | 100 | | | | | 1105 | 59 |
| Tennessee | Brush Creek | Site 1 | 194 | | 31 | 24 | 2 | 1 | 1 | 0 | 3 | 56 | 13 | 0 | | 3 | | | | 1500 | |
| Tennessee | Brush Creek | Site 2 | 1705 | | 45 | 24 | 2 | 2 | 12 | 0 | 5 | 42 | 13 | 0 | | 5 | | | | 1500 | |
| Tennessee | Brush Creek | Site 3 | 2191 | | 53 | 29 | 2 | 3 | 11 | 0 | 8 | 37 | 10 | 0 | | 8 | | | | 1500 | |
| Tennessee | Brush Creek | Site 4 | 2863 | | 58 | 31 | 3 | 4 | 10 | 0 | 10 | 32 | 10 | 0 | | 10 | | | | 1500 | |
| Tennessee | Brush Creek | Site 5 | 3540 | | 52 | 28 | 3 | 3 | 9 | 0 | 9 | 36 | 12 | 0 | | 9 | | | | 1500 | |
| Tennessee | Brush Creek | Site 6 | 3669 | | 50 | 27 | 3 | 3 | 9 | 0 | 8 | 37 | 13 | 0 | | 8 | | | | 1500 | |
| Tennessee | Knoxville | R2 | 36 | 13 | 83 | 96 | | | | | | | | | 10 | | | | | 1500 | 63 |
| Tennessee | Knoxville | R1 | 28 | 33 | 83 | 91 | | | | | | | | | 27 | | | | | 1500 | 611 |
| Tennessee | Knoxville | SC | 76 | 43 | 83 | 17 | 17 | 17 | 17 | 17 | | | | | 7 | | | | | 1500 | 71 |
| Tennessee | Knoxville | CBD | 11 | 99 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 1500 | 123 |
| Tennessee | Knoxville | Fourth Creek | 221 | 45 | 83 | | | 83 | | | | | | | 6.2 | | | | | 1550 | 730 |
| Tennessee | Knoxville | Third Creek | 414 | 28 | 83 | 50 | 50 | | | | | | | | 18.8 | | | | | 1500 | 133 |
| Tennessee | Knoxville | Plantation Hills | 62 | 23 | 83 | | | | | | | | | | 8.6 | | | | | 1530 | 21 |
| Tennessee | Nashville | I-40 | | 37 | 83 | | | | | | | | | | | 83 | 88000 | | | 1143 | 190 |
| Texas | Austin | Hart Lane | 153 | 40 | 83 | 99 | | | | | | | | | 22 | | | | | 1100 | 156 |
| Texas | Austin | Rollingwood | 24 | 21 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | | | | | 1100 | 227 |
| Texas | Austin | Turkey Creek | 525 | 1 | 17 | | | | | | | | | | | | | | | 1100 | 132 |
| Texas | Houston | Bintliff Ditch | 1140 | 44 | 70 | 50 | | 50 | | | | | | | | | | | | 1100 | 388 |
| Texas | Houston | Brays Bayou at S Main St | 22400 | 25 | 37 | 17 | | 17 | | | | | | | | | | | | 1100 | 592 |
| Texas | Houston | Brays Bayou at Gessner S | 13800 | 16 | 21 | 17 | | | | 17 | | | | | | | | | | 1100 | 787 |
| Texas | Houston | Hunting Bayou | 803 | 21 | 94 | 48 | 14 | 32 | 0 | 0 | 0 | 0 | 0 | 6 | | | | | | 1100 | 167 |
| Texas | Houston | Keegans Bayou | 3210 | 12 | 20 | 17 | | | | 17 | | | | | | | | | | 1100 | 515 |
| Texas | Houston | Westbury Square | 85 | 35 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 1100 | 61 |
| Texas | Houston | Woodlands P-10 | 6500 | | 1 | | | | | | | | 83 | | | | | | | 1170 | 36 |
| Texas | Houston | Woodlands P-30 | 8750 | | 10 | | | | | | | | 83 | | | | | | | 1170 | 192 |
| Texas | Lubbock | Urban | | | 83 | | | | | | | | | | | | | | | 500 | 530 |
| Virginia | Chesapeake Bay | Pequea 3 | | | 17 | | | | | | | 83 | | | | | | | | 1041 | 829 |
| Virginia | Chesapeake Bay | Ware 7 | | | 17 | | | | | | | 83 | | | | | | | | 1041 | 222 |
| Virginia | Chesapeake Bay | Occoquan 2 | | | 17 | | | | | | | 83 | | | | | | | | 1041 | 361 |
| Virginia | Chesapeake Bay | Occoquan 10 | | | 17 | | | | | | | 83 | | | | | | | | 1041 | 121 |
| Virginia | Chesapeake Bay | Occoquan 9 | | | 17 | | | | | | | | 83 | | | | | | | 1041 | 70 |
| Virginia | Chesapeake Bay | Pequea 2 | | | 17 | | | | | | | | 83 | | | | | | | 1041 | 169 |
| Virginia | Chesapeake Bay | Ware 8 | | | 17 | | | | | | | | 83 | | | | | | | 1041 | 71 |
| Virginia | Chesapeake Bay | Occoquan 1 | | | 17 | | | | | | | 83 | | | | | | | | 1041 | 670 |
| Virginia | Chesapeake Bay | Occoquan 5 | | | 17 | | | | | | | 83 | | | | | | | | 1041 | 145 |
| Virginia | Chesapeake Bay | Pequea 4 | | | 83 | 83 | | | | | | | | | | | | | | 1041 | 194 |
| Virginia | Chesapeake Bay | Ware 5 | | | 83 | 83 | | | | | | | | | | | | | | 1041 | 38 |
| Virginia | Northern | Stonewall Road | 19.5 | 14 | 83 | 83 | | | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Colchester Hunt | 3.6 | 19 | 83 | 83 | | | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Parkfairfax | 19.5 | 25 | 83 | 83 | | | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Chalet Woods | 18.1 | 34 | 83 | 83 | | | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Allencrest/Meadows | | 39 | 83 | 83 | | | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Valleywood | 3.6 | 42 | 83 | 83 | | | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Irongate | 6.9 | 43 | 83 | 83 | | | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Madison Apartments | 18.2 | 47 | 83 | 83 | | | | | | | | | | | | | | 1041 | |
| Virginia | Northern | London Towne/Cavalier Club | | 48 | 83 | 83 | | | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Manassas Mall | 8.3 | 89 | 83 | | | 83 | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Parkington | 10.4 | 90 | 83 | | | 83 | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Seven Corners | | | 83 | | | 83 | | | | | | | | | | | | 1041 | |
| Virginia | Northern | Duncan Farm | | | 17 | | | | | | | 83 | | | | | | | | 1041 | |
| Virginia | Northern | Kline Farm | | | 17 | | | | | | | 83 | | | | | | | | 1041 | |
| Virginia | Northern | Farino Farm | | | 17 | | | | | | | 83 | | | | | | | | 1041 | |
| Virginia | Northern | Norman Forest | | | 17 | | | | | | | | 83 | | | | | | | 1041 | |
| Virginia | Occoquan Basin | Lower Bull Run | 1680 | | 100 | 69 | 1 | 9 | 5 | 16 | 0 | 0 | 0 | 0 | 18 | | | | | 840 | 617 |
| Virginia | Occoquan Basin | Denver Street | 80 | | 100 | 95 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 35 | | | | | 840 | 750 |
| Washington | Bellevue | Surrey Downs | 38 | 29 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | | | | | 866 | 113 |

# Appendix A

| Water Quality | | | | | | | | | | | | | | | | | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TotP | TotN | Pb | Zn | O&G | BOD | COD | Cd | Cr | Cu | Ni | Hg | Fe | Mn | Turb | pH | TOC | TotColi | FecColi | FecStrep | |
| mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | NTU | | mg/L | #/100ml | #/100ml | #/100ml | |
| 0.09 | 1.5 | 0.001 | | 47 | 13 | | | | | | | | | | | | | | | 124 |
| 0.08 | 2.1 | 0.01 | | 58 | 36 | | | | | | | | | | | | | | | 124 |
| 0.08 | 1.2 | 0.004 | 0.278 | 41 | 9 | | | | 0.086 | | | | | | | | | | | 124 |
| 0.22 | 2.9 | 0.14 | 0.16 | | 9 | 37 | 0.0008 | 0.003 | 0.014 | | | | | | | 14 | | | | 111 |
| | | | | | 1.6 | | | | | | | | | | | | | | | 85 |
| | | | | | 11 | 67 | | | | | | | | | | | | | | 85 |
| | | | | | 11 | | | | | | | | | | | | | | | 85 |
| | | | | | 13 | 39 | | | | | | | | | | | | | | 85 |
| | | | | | 3.8 | | | | | | | | | | | | | | | 85 |
| | | | | | 4 | 30 | | | | | | | | | | | | | | 85 |
| 0.246 | 0.873 | 0.133 | 0.093 | | 9 | 45 | | | 0.028 | | | | | | | | | 4400 | | 3 |
| 0.705 | 1.71 | 0.44 | 0.412 | | 14 | 120 | | | 0.061 | | | | | | | | | 13500 | | 3 |
| 0.352 | 1.21 | 0.237 | 0.149 | | 14 | 60 | | | 0.042 | | | | | | | | | 4700 | | 3 |
| 0.212 | 1.31 | 0.158 | 0.315 | | 13 | 73 | | | 0.042 | | | | | | | | | 7300 | | 3 |
| 1.2 | 3.1 | 0.21 | | | | 109 | | | | | 0.0027 | 26 | 0.76 | | | | | | | 12 |
| 0.49 | 1.77 | 0.13 | | | | 68 | | | | | 0.0004 | 3.1 | 0.38 | | | | | | | 12 |
| 0.46 | 1.62 | 0.05 | | | | 33 | | | | | 0.002 | 1.3 | 0.05 | | | | | | | 12 |
| | | 0.41 | 0.26 | | | 113 | | | | | | | | | | | | | | 117,118,127 |
| 0.333 | 4.64 | | | | | 82 | | | | | | | | | | 18.9 | | 8400 | | 3 |
| 0.268 | 5.88 | | | | | 70 | | | | | | | | | | 32.5 | | 14400 | | 3 |
| 0.1 | 2.27 | | | | | 57 | | | | | | | | | | 19.6 | | 142 | | 3 |
| 0.62 | | | | | | | | | | | | | | | | | | | | 8 |
| 1.41 | | | | | | | | | | | | | | | | | | | | 8 |
| 1.08 | | | | | | | | | | | | | | | | | | | | 8 |
| 1.24 | 4.8 | | | | | 84 | | | | | | | | | | | | | | 7 |
| 1.81 | | | | | | | | | | | | | | | | | | | | 8 |
| 1.1 | 2.2 | | | | | 42 | | | | | | | | | | | | | | 7 |
| 0.062 | 1.35 | | | | | 60 | | | | | | | | | | | | | | 7 |
| 0.09 | 1.39 | | | | | 54 | | | | | | | | | | | | | | 7 |
| | | | | | 25 | | | | | | | | | | | | | | | 83 |
| 4.7 | 19.2 | | | | | | | | | | | | | | | | | | | 54 |
| 0.62 | 1.3 | | | | | | | | | | | | | | | | | | | 54 |
| 1.67 | 6.6 | | | | | | | | | | | | | | | | | | | 54 |
| 0.4 | 3.8 | | | | | | | | | | | | | | | | | | | 54 |
| 0.13 | 0.9 | | | | | | | | | | | | | | | | | | | 54 |
| 0.13 | 3.6 | | | | | | | | | | | | | | | | | | | 54 |
| 0.06 | 0.4 | | | | | | | | | | | | | | | | | | | 54 |
| 1.12 | 6.2 | | | | | | | | | | | | | | | | | | | 54 |
| 0.38 | 2.2 | | | | | | | | | | | | | | | | | | | 54 |
| 0.3 | 2.4 | | | | | | | | | | | | | | | | | | | 54 |
| 0.1 | 0.7 | | | | | | | | | | | | | | | | | | | 54 |
| | | 0.27 | | | | | | | | | | 7 | | | | | | | | 45, 55 |
| | | 0.04 | | | | | | | | | | 9.5 | | | | | | | | 45, 55 |
| | | 1.63 | | | | | | | | | | 8 | | | | | | | | 45, 55 |
| | | 0.25 | | | | | | | | | | 1.5 | | | | | | | | 45, 55 |
| | | 1 | | | | | | | | | | 9 | | | | | | | | 45, 55 |
| | | 0.43 | | | | | | | | | | 2 | | | | | | | | 45, 55 |
| | | 0.46 | | | | | | | | | | 3.5 | | | | | | | | 45, 55 |
| | | 0.4 | | | | | | | | | | 4 | | | | | | | | 45, 55 |
| | | 0.22 | | | | | | | | | | 2 | | | | | | | | 45, 55 |
| | | 0.6 | | | | | | | | | | 5 | | | | | | | | 45, 55 |
| | | 1.75 | | | | | | | | | | 7 | | | | | | | | 45, 55 |
| | | 0.4 | | | | | | | | | | 2 | | | | | | | | 45, 55 |
| | | 0.04 | | | | | | | | | | 12 | | | | | | | | 45, 55 |
| | | 0.09 | | | | | | | | | | 38 | | | | | | | | 45, 55 |
| | | 0.02 | | | | | | | | | | 6 | | | | | | | | 45, 55 |
| | | 0.04 | | | | | | | | | | 9.5 | | | | | | | | 45, 55 |
| 0.98 | 4.67 | | | | | | | | | | | | | | | 13.8 | | | | 108, 109 |
| 1.1 | 3.84 | | | | | | | | | | | | | | | 28 | | | | 108, 109 |
| 0.239 | | 0.152 | 0.124 | | | 48 | | | | | | | | | | | | | | 3 |

| Location | | | Description | | | Land Use | | | | | | | | | Pop. | Traffic | | Miscellaneous | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Country/State | Town/Area | Site | Area | Imp | Urban | Res | Ind | Com | Inst | Open | Other | Agr | For | Other | | Road | Dens | Roof | MtSt | Rain | SS |
| | | | ha | % | % | % | % | % | % | % | urban | % | % | rural | p/ha | % | veh/d | % | Helens | mm | mg/L |
| Washington | Bellevue | Lake Hills (NURP) | 41 | 37 | 83 | 91 | | | | | | | | | 30 | | | | | 866 | 127 |
| Washington | Seattle | View Ridge 1 | 255 | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 866 | 56 |
| Washington | Seattle | View Ridge 2 | 42 | | 100 | 90 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 866 | 108 |
| Washington | Seattle | South Seattle | 11.1 | | 100 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 866 | 114 |
| Washington | Seattle | South Center | 9.8 | | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 866 | 94 |
| Washington | Seattle | Lake Hills (Huber) | 61 | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 866 | 61 |
| Washington | Seattle | Highlands | 34 | | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 866 | 109 |
| Washington | Seattle | Whispering Heights | 31 | | 83 | 83 | | | | | | | | | | | | | | 866 | 9.6 |
| Washington | Seattle | Bus depot | 6 | 90 | 83 | | | 83 | | | | | | | | | | | | 866 | 88 |
| Washington | | Rusty galv. iron roof | | 100 | 17 | | | | | | | | | | | | | 83 | | 1000 | |
| Washington | | Weathered metal roof | | 100 | 17 | | | | | | | | | | | | | 83 | | 1000 | |
| Washington | | Tar paper roof | | 100 | 17 | | | | | | | | | | | | | 83 | | 1000 | |
| Washington | | Tarred roof | | 100 | 17 | | | | | | | | | | | | | 83 | | 1000 | |
| Washington | | Anodised aluminium roof | | 100 | 17 | | | | | | | | | | | | | 83 | | 1000 | |
| Washington | Seattle | I-5 | 0.49 | 100 | 83 | 83 | | | | | | | | | | 83 | 53000 | | | 866 | 106 |
| Washington | Seattle | I-5* | | 100 | 83 | 83 | | | | | | | | | | 83 | 53000 | | | 866 | 131 |
| Washington | Seattle | SR-520 | 0.04 | 100 | 83 | | | | | | | | | | | 83 | 42000 | | | 889 | 244 |
| Washington | Vancouver | I-205 | 0.11 | 100 | 83 | | | | | | | | | | | 83 | 8600 | | 1 | 991 | 106 |
| Washington | Snoqualmie Pass | I-90 | 0.072 | 100 | 17 | | | | | | | | 83 | | | 83 | 7700 | | | 2464 | 63 |
| Washington | Montesano | SR-12 | 0.11 | 100 | 17 | | | | | | | 83 | | | | 83 | 7300 | | 1 | 2134 | 798 |
| Washington | Pasco | SR-12 | 0.51 | 100 | 17 | | | | | | | 83 | | | | 83 | 2000 | | 1 | 191 | 570 |
| Washington | Spokane | I-90 | 0.089 | 100 | 83 | | | | | | | | | | | 83 | 17300 | | 1 | 437 | 370 |
| Washington | Pullman | SR-270E | 0.099 | 100 | 17 | | | | | | | 83 | | | | 83 | 2500 | | 1 | 457 | 622 |
| Washington | Yakima River | | | | 17 | | | | | | | | 83 | | | | | | | 2000 | |
| Washington | Tieton River | | | | 17 | | | | | | | | 83 | | | | | | | 2000 | |
| Washington | Cedar River | | | | 17 | | | | | | | | 83 | | | | | | | 2000 | |
| Wisconsin | Madison | Monroe | 94.4 | | 100 | 97 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | | 15 | | 13 | | 788 | 262 |
| Wisconsin | Madison | Syene | 115.6 | | 100 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 7 | | 21 | | 788 | 146 |
| Wisconsin | Madison | Resid feeder streets | | 83 | 83 | 83 | | | | | | | | | | 83 | 250 | | | 788 | 662 |
| Wisconsin | Madison | Resid collector streets | | 83 | 83 | 83 | | | | | | | | | | 83 | 5000 | | | 788 | 326 |
| Wisconsin | Madison | Resid lawns | | 17 | 83 | 83 | | | | | | | | | | | | | | 788 | 397 |
| Wisconsin | Madison | Resid driveways | | | 83 | 83 | | | | | | | | | | | | | | 788 | 173 |
| Wisconsin | Madison | Resid roofs | | 100 | 83 | 83 | | | | | | | | | | | | 100 | | 788 | 27 |
| Wisconsin | Madison | Comm arterial streets | | 83 | 83 | | | 83 | | | | | | | | 83 | 20000 | | | 788 | 232 |
| Wisconsin | Madison | Comm roofs | | 100 | 83 | | | 83 | | | | | | | | | | 100 | | 788 | 15 |
| Wisconsin | Madison | Comm parking lots | | 83 | 83 | | | 83 | | | | | | | | | | | | 788 | 58 |
| Wisconsin | Madison | Indust collector streets | | 83 | 83 | | 83 | | | | | | | | | 83 | 1000 | | | 788 | 763 |
| Wisconsin | Madison | Indust arterial streets | | 83 | 83 | | 83 | | | | | | | | | 83 | 19800 | | | 788 | 690 |
| Wisconsin | Madison | Indust roofs | | 100 | 83 | | 83 | | | | | | | | | | | 100 | | 788 | 41 |
| Wisconsin | Madison | Indust parking lots | | 83 | 83 | | 83 | | | | | | | | | | | | | 788 | 312 |
| Wisconsin | Madison | Manitou Way | 50 | 27 | 83 | 83 | | | | | | | | | | | | | | 788 | 280 |
| Wisconsin | Milwaukee | Kinnickinnic River | 6436 | | 88 | 51 | 9 | 8 | 0 | 6 | 14 | | | | | | | | | 701 | |
| Wisconsin | Milwaukee | Hwy 795 | | 100 | 83 | | | | | | | | | | | 83 | 53000 | | | 701 | 183 |
| Wisconsin | Milwaukee | Hwy 45 | | 31 | 83 | | | | | | | | | | | 83 | 85000 | | | 701 | 343 |
| Wisconsin | Milwaukee | Hwy 94 | | 64 | 83 | | | | | | | | | | | 83 | 116000 | | | 701 | 161 |
| Wisconsin | Milwaukee | Stadium I'change | 65 | 45 | 100 | 17 | 0 | 14 | 0 | 28 | 41 | 0 | 0 | 0 | | 41 | | | | 701 | 29.6 |
| Wisconsin | Milwaukee | Burbank | 26 | 50 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37 | | | | | 701 | 266 |
| Wisconsin | Milwaukee | Hastings | 13.4 | 51 | 100 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42 | | | | | 701 | 170 |
| Wisconsin | Milwaukee | Lincoln | 14.6 | 57 | 83 | 97 | | | | | | | | | 44 | | | | | 701 | 251 |
| Wisconsin | Milwaukee | Wood Center | 18 | 81 | 100 | 35 | 52 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | | | | | 701 | 383 |
| Wisconsin | Milwaukee | Post Office | 4.9 | 100 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 701 | 212 |
| Wisconsin | Milwaukee | Rustler | 4.9 | 100 | 100 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 701 | 202 |
| Wisconsin | Milwaukee | State Fair | 11.7 | 77 | 100 | 37 | 0 | 63 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | | | | | 701 | 412 |

# Appendix A

| Water Quality | | | | | | | | | | | | | | | | | | | | References |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TotP | TotN | Pb | Zn | O&G | BOD | COD | Cd | Cr | Cu | Ni | Hg | Fe | Mn | Turb | pH | TOC | TotColi | FecColi | FecStrep | |
| mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | NTU | | mg/L | #/100ml | #/100ml | #/100ml | |
| 0.264 | | 0.192 | 0.12 | | | 44 | | | 0.022 | | | | | | | | | | | 3 |
| 0.26 | 2.69 | 0.137 | 0.072 | 12.5 | 18 | 84 | 0.004 | 0.019 | 0.024 | | | 2.015 | | 12.9 | 6.8 | | 26100 | 8280 | | 61 |
| | 1.7 | 0.169 | 0.052 | 20 | 13 | 62 | 0.0041 | 0.0092 | 0.049 | | | 0.912 | | 27 | 7.3 | | 17000 | 5910 | | 61 |
| 0.24 | 2.47 | 0.225 | 0.234 | 12 | 12 | 87 | 0.005 | 0.018 | 0.12 | | | 4.237 | | 23 | 6.8 | | 11400 | 485 | | 61 |
| 0.18 | 1.53 | 0.233 | 0.136 | 11 | 12 | 62 | 0.021 | 0.105 | 0.07 | | | 0.806 | | 11.6 | 6.5 | | 2650 | 67 | | 61 |
| 0.32 | 1.24 | 0.21 | 0.062 | 9.5 | 6.3 | 44 | 0.0044 | 0.0099 | 0.081 | | | 0.289 | | 11.2 | 7.4 | | 11900 | 3630 | | 61 |
| | 2.38 | 0.103 | 0.044 | 9.5 | 4.2 | 65 | 0.0045 | 0.01 | 0.159 | | | 0.345 | | 26 | 7.2 | | 3050 | 1560 | | 61 |
| | | | | | | | | | | | | | | | | | | | | 26 |
| 0.118 | | 0.03 | 0.53 | 9.9 | | | 0.00079 | | | | | | | | | | | | | 26 |
| | | 0.302 | 12.2 | | | | | | 0.02 | | | | | | 5.9 | | | | | 43 |
| | | 0.01 | 1.98 | | | | | | 0.011 | | | | | | 4.8 | | | | | 43 |
| | | 0.011 | 0.877 | | | | | | 0.166 | | | | | | 4.3 | | | | | 43 |
| | | 0.01 | 0.297 | | | | | | 0.025 | | | | | | 4.1 | | | | | 43 |
| | | 0.015 | 0.101 | | | | | | 0.016 | | | | | | 5.9 | | | | | 43 |
| 0.226 | 2.46 | 0.466 | 0.638 | | | 150 | | | 0.043 | | | | | | | | | | | 2, 21, 127 |
| 0.224 | 2.69 | 0.76 | 0.968 | | | 135 | | | 0.043 | | | | | | | | | | | 2, 21, 127 |
| | | 1.065 | 0.28 | | | | | | | | | | | | | | | | | 2, 21, 127 |
| 0.113 | 56.6 | 0.073 | 0.056 | | | 45 | | | 0.025 | | | | | | | | | | | 2, 21, 127 |
| 0.15 | 1.03 | 0.086 | 0.101 | | | 44 | | | 0.022 | | | | | | | | | | | 2, 21, 127 |
| 0.441 | 2.65 | 0.556 | 0.38 | | | 109 | | | 0.089 | | | | | | | | | | | 2, 21, 127 |
| 0.666 | 9.42 | 0.196 | 0.352 | | | 265 | | | 1.039 | | | | | | | | | | | 2, 21, 127 |
| 0.998 | 8.36 | 0.167 | 0.929 | | | 219 | | | 7.033 | | | | | | | | | | | 2, 21, 127 |
| 0.81 | 1.94 | 0.227 | 0.199 | | | 110 | | | 0.044 | | | | | | | | | | | 2, 21, 127 |
| 0.07 | 0.28 | | | | | | | | | | | | | | | | | | | 74 |
| 0.115 | 0.194 | | | | | | | | | | | | | | | | | | | 74 |
| 0.022 | | | | | | | | | | | | | | | | | | | | 74 |
| 0.66 | | 0.032 | 0.203 | | | | 0.0004 | 0.005 | 0.016 | | | | | | | | | 175000 | | 6 |
| 0.34 | | 0.025 | 0.265 | | | | 0.001 | 0.006 | 0.028 | | | | | | | | | 5100 | | 6 |
| 1.31 | | 0.033 | 0.22 | | | | 0.0008 | 0.005 | 0.024 | | | | | | | | | 92000 | | 6 |
| 1.07 | | 0.055 | 0.339 | | | | 0.0014 | 0.012 | 0.056 | | | | | | | | | 57000 | | 6 |
| 2.67 | | | 0.059 | | | | | | 0.013 | | | | | | | | | 42000 | | 6 |
| 1.16 | | 0.017 | 0.107 | | | | 0.0005 | 0.002 | 0.017 | | | | | | | | | 34000 | | 6 |
| 0.15 | | 0.021 | 0.149 | | | | | | 0.015 | | | | | | | | | 294 | | 6 |
| 0.47 | | 0.05 | 0.508 | | | | 0.0018 | 0.016 | 0.046 | | | | | | | | | 9600 | | 6 |
| 0.2 | | 0.009 | 0.33 | | | | | | 0.009 | | | | | | | | | 1100 | | 6 |
| 0.19 | | 0.022 | 0.178 | | | | 0.0006 | 0.005 | 0.015 | | | | | | | | | 1800 | | 6 |
| 1.5 | | 0.086 | 0.479 | | | | 0.0033 | 0.015 | 0.076 | | | | | | | | | 8300 | | 6 |
| 0.94 | | 0.06 | 0.575 | | | | 0.0025 | 0.023 | 0.074 | | | | | | | | | 4600 | | 6 |
| 0.11 | | 0.008 | 1.155 | | | | | | 0.006 | | | | | | | | | 144 | | 6 |
| 0.39 | | 0.038 | 0.304 | | | | 0.001 | 0.012 | 0.041 | | | | | | | | | 2700 | | 6 |
| 0.98 | 4.55 | | | | | | | | | | | | | | | | | | | 70 |
| 0.3 | 1.5 | | | | 15 | | | | | | | | | | | | | | | 136 |
| | | 2.03 | 0.46 | | | 130 | | | | | | | | | | | | | | 117,118,127 |
| | | 0.88 | 0.44 | | | 134 | | | | | | | | | | | | | | 117,118,127 |
| | | 0.9 | 0.52 | | | 122 | | | | | | | | | | | | | | 117,118,127 |
| 0.24 | | 0.46 | | | | | | | | | | | | | 7.36 | | | | | 93 |
| 0.229 | 2.04 | 0.095 | 0.106 | | 7 | 39 | | | | | | | | | | | | | | 3, 94 |
| 0.258 | 1.73 | 0.108 | 0.108 | | 9 | 41 | | | | | | | | | | | | | | 3, 94 |
| 0.453 | | 0.303 | | | 18 | 91 | | | | | | | | | | | | | | 3, 94 |
| 0.289 | 2.2 | 0.582 | 0.476 | | 14 | 92 | | | | | | | | | | | | | | 3, 94 |
| 0.108 | 1.73 | 0.193 | 0.145 | | 9 | 57 | | | | | | | | | | | | | | 3, 94 |
| 0.105 | 1.85 | 0.121 | 0.156 | | 13 | 59 | | | | | | | | | | | | | | 3, 94 |
| 0.511 | 2.44 | 0.409 | 0.28 | | 19 | 113 | | | | | | | | | | | | | | 3, 94 |

# Appendix A

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# APPENDIX B

## Descriptive Statistics

Descriptive statistics are tabulated for all quality parameters considered and all observed land uses. Units are as shown in the page heading, and with only one exception (pH) are in log coordinates. The land use classification system is described in Chapter 2. Intending users should particularly note the sample size for the subgroups of interest, as some samples are very small.

# Suspended Solids

log(mg/L)

**Roads:**

| *SS* | *All roads* | *MtStHelens* | *All others* | *High urban* | *Low urban* |
|---|---|---|---|---|---|
| Mean | 2.324 | 2.609 | 2.286 | 2.410 | 1.836 |
| Std Error | 0.084 | 0.156 | 0.092 | 0.086 | 0.235 |
| Median | 2.315 | 2.756 | 2.265 | 2.365 | 1.806 |
| Mode | 2.025 | | | | |
| Std Dev | 0.544 | 0.348 | 0.557 | 0.464 | 0.665 |
| Variance | 0.296 | 0.121 | 0.310 | 0.215 | 0.442 |
| Kurtosis | 2.602 | 2.684 | 2.968 | 6.361 | 1.434 |
| Skewness | 0.427 | -1.627 | 0.613 | 1.863 | 0.894 |
| Range | 3.208 | 0.877 | 3.208 | 2.455 | 2.182 |
| Minimum | 0.954 | 2.025 | 0.954 | 1.708 | 0.954 |
| Maximum | 4.163 | 2.902 | 4.163 | 4.163 | 3.137 |
| Sum | 97.614 | 13.045 | 84.569 | 69.881 | 14.688 |
| Count | 42 | 5 | 37 | 29 | 8 |
| 95% | 0.164 | 0.305 | 0.180 | 0.169 | 0.461 |

**Roofs:**

| *All roofs* |
|---|
| 1.553 |
| 0.116 |
| 1.613 |
| 1.556 |
| 0.384 |
| 0.148 |
| 2.619 |
| -1.289 |
| 1.450 |
| 0.643 |
| 2.093 |
| 17.084 |
| 11 |
| 0.227 |

**High urban excluding roads & roofs:**

| *SS* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* |
|---|---|---|---|---|---|
| Mean | 2.186 | 2.150 | 2.176 | 2.126 | 2.241 |
| Std Error | 0.030 | 0.043 | 0.150 | 0.084 | 0.052 |
| Median | 2.182 | 2.167 | 2.127 | 2.111 | 2.228 |
| Mode | 2.447 | 2.193 | | | 2.447 |
| Std Dev | 0.478 | 0.448 | 0.518 | 0.418 | 0.518 |
| Variance | 0.228 | 0.200 | 0.268 | 0.175 | 0.269 |
| Kurtosis | 0.630 | 0.960 | 1.371 | 0.047 | 0.255 |
| Skewness | 0.141 | -0.359 | 0.321 | 0.409 | 0.356 |
| Range | 2.980 | 2.802 | 2.067 | 1.674 | 2.394 |
| Minimum | 0.544 | 0.544 | 1.204 | 1.342 | 1.130 |
| Maximum | 3.524 | 3.346 | 3.271 | 3.016 | 3.524 |
| Sum | 540.001 | 234.377 | 26.107 | 53.144 | 226.373 |
| Count | 247 | 109 | 12 | 25 | 101 |
| 95% | 0.060 | 0.084 | 0.293 | 0.164 | 0.101 |

**Medium & low urban excluding roads & roofs:**

| *SS* | *All medium* | *All low* | *Agricultural* | *Forest* | *Other low* |
|---|---|---|---|---|---|
| Mean | 2.248 | 2.040 | 2.271 | 1.905 | 1.971 |
| Std Error | 0.199 | 0.080 | 0.125 | 0.092 | 0.134 |
| Median | 2.153 | 2.052 | 2.122 | 1.851 | 1.982 |
| Mode | | 2.000 | 2.000 | | 1.519 |
| Std Dev | 0.689 | 0.565 | 0.467 | 0.305 | 0.672 |
| Variance | 0.475 | 0.320 | 0.218 | 0.093 | 0.452 |
| Kurtosis | -0.527 | 0.120 | -1.443 | -1.953 | -0.500 |
| Skewness | -0.136 | -0.408 | 0.264 | -0.054 | -0.479 |
| Range | 2.242 | 2.471 | 1.265 | 0.752 | 2.449 |
| Minimum | 0.964 | 0.447 | 1.653 | 1.531 | 0.447 |
| Maximum | 3.205 | 2.919 | 2.919 | 2.283 | 2.896 |
| Sum | 26.973 | 102.007 | 31.792 | 20.951 | 49.264 |
| Count | 12 | 50 | 14 | 11 | 25 |
| 95% | 0.390 | 0.157 | 0.244 | 0.180 | 0.263 |

## Total Phosphorus

log(mg/L)

**Roads:**

| *Total P* | *All roads* | *MtStHelens* | *All others* | *High urban* | *Low urban* |
|---|---|---|---|---|---|
| Mean | -0.532 | -0.314 | -0.586 | -0.583 | -0.598 |
| Std Error | 0.087 | 0.169 | 0.099 | 0.123 | 0.081 |
| Median | -0.553 | -0.177 | -0.624 | -0.648 | -0.555 |
| Mode | -0.824 |  | -0.824 |  |  |
| Std Dev | 0.436 | 0.377 | 0.441 | 0.491 | 0.163 |
| Variance | 0.190 | 0.142 | 0.194 | 0.241 | 0.026 |
| Kurtosis | -1.009 | 2.675 | -0.766 | -1.229 | 1.259 |
| Skewness | -0.068 | -1.623 | 0.183 | 0.160 | -1.248 |
| Range | 1.469 | 0.946 | 1.469 | 1.469 | 0.368 |
| Minimum | -1.292 | -0.947 | -1.292 | -1.292 | -0.824 |
| Maximum | 0.176 | -0.001 | 0.176 | 0.176 | -0.456 |
| Sum | -13.295 | -1.571 | -11.724 | -9.334 | -2.391 |
| Count | 25 | 5 | 20 | 16 | 4 |
| 95% | 0.171 | 0.331 | 0.193 | 0.240 | 0.159 |

**Roofs:**

| *Roofs* |
|---|
| -0.890 |
| 0.120 |
| -0.872 |
|  |
| 0.293 |
| 0.086 |
| 1.699 |
| -0.966 |
| 0.860 |
| -1.398 |
| -0.538 |
| -5.338 |
| 6 |
| 0.234 |

**High urban excluding roads & roofs:**

| *Total P* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* | *Non-resid* |
|---|---|---|---|---|---|---|
| Mean | -0.454 | -0.396 | -0.531 | -0.482 | -0.499 | -0.498 |
| Std Error | 0.026 | 0.036 | 0.094 | 0.079 | 0.045 | 0.037 |
| Median | -0.436 | -0.410 | -0.469 | -0.599 | -0.420 | -0.447 |
| Mode | -0.337 | -0.523 |  | 0.079 | -0.337 | -0.337 |
| Std Dev | 0.377 | 0.342 | 0.281 | 0.381 | 0.416 | 0.398 |
| Variance | 0.142 | 0.117 | 0.079 | 0.145 | 0.173 | 0.159 |
| Kurtosis | 1.145 | 0.332 | -1.200 | -0.671 | 1.464 | 1.205 |
| Skewness | -0.341 | 0.174 | -0.330 | 0.613 | -0.747 | -0.516 |
| Range | 2.612 | 1.748 | 0.788 | 1.304 | 2.438 | 2.438 |
| Minimum | -2.000 | -1.137 | -0.943 | -0.979 | -2.000 | -2.000 |
| Maximum | 0.612 | 0.612 | -0.155 | 0.325 | 0.438 | 0.438 |
| Sum | -93.436 | -35.658 | -4.780 | -11.088 | -41.909 | -57.778 |
| Count | 206 | 90 | 9 | 23 | 84 | 116 |
| 95% | 0.052 | 0.071 | 0.184 | 0.156 | 0.089 | 0.072 |

**Medium & low urban excluding roads & roofs:**

| *Total P* | *All medium* | *All low* | *Agricultural* | *Forest* | *Other low* |
|---|---|---|---|---|---|
| Mean | -0.502 | -0.663 | -0.271 | -1.136 | -0.643 |
| Std Error | 0.145 | 0.067 | 0.120 | 0.093 | 0.079 |
| Median | -0.509 | -0.683 | -0.303 | -1.155 | -0.650 |
| Mode |  | -0.699 |  | -0.886 | -1.000 |
| Std Dev | 0.434 | 0.516 | 0.450 | 0.337 | 0.455 |
| Variance | 0.188 | 0.266 | 0.203 | 0.113 | 0.207 |
| Kurtosis | -1.013 | -0.399 | 0.643 | -0.843 | -0.720 |
| Skewness | 0.136 | 0.143 | 0.198 | -0.151 | -0.020 |
| Range | 1.246 | 2.330 | 1.809 | 1.056 | 1.826 |
| Minimum | -1.097 | -1.658 | -1.137 | -1.658 | -1.569 |
| Maximum | 0.149 | 0.672 | 0.672 | -0.602 | 0.258 |
| Sum | -4.517 | -39.762 | -3.796 | -14.762 | -21.204 |
| Count | 9 | 60 | 14 | 13 | 33 |
| 95% | 0.284 | 0.130 | 0.236 | 0.183 | 0.155 |

## Total Nitrogen

log(mg/L)

**Roads:**

| *Total N* | *All roads* | *MtStHelens* | *All others* |
|---|---|---|---|
| Mean | 0.491 | 0.872 | 0.333 |
| Std Error | 0.110 | 0.258 | 0.085 |
| Median | 0.371 | 0.922 | 0.342 |
| Mode | 0.079 | | 0.079 |
| Std Dev | 0.455 | 0.577 | 0.295 |
| Variance | 0.207 | 0.333 | 0.087 |
| Kurtosis | 2.385 | 0.563 | 0.144 |
| Skewness | 1.416 | 0.856 | 0.846 |
| Range | 1.775 | 1.465 | 0.909 |
| Minimum | -0.022 | 0.288 | -0.022 |
| Maximum | 1.753 | 1.753 | 0.886 |
| Sum | 8.353 | 4.360 | 3.993 |
| Count | 17 | 5 | 12 |
| 95% | 0.216 | 0.506 | 0.167 |

**Roofs:**

| *All roofs* |
|---|
| 0.752 |
| 0.099 |
| 0.752 |
| |
| 0.140 |
| 0.020 |
| |
| |
| 0.198 |
| 0.653 |
| 0.851 |
| 1.504 |
| 2 |
| 0.194 |

**High urban excluding roads & roofs:**

| *Total N* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* |
|---|---|---|---|---|---|
| Mean | 0.422 | 0.443 | 0.392 | 0.332 | 0.423 |
| Std Error | 0.024 | 0.039 | 0.103 | 0.063 | 0.036 |
| Median | 0.393 | 0.426 | 0.342 | 0.267 | 0.348 |
| Mode | 0.342 | 0.491 | | | 0.146 |
| Std Dev | 0.282 | 0.294 | 0.253 | 0.226 | 0.287 |
| Variance | 0.080 | 0.086 | 0.064 | 0.051 | 0.082 |
| Kurtosis | 0.796 | 1.469 | 3.102 | -1.089 | 0.213 |
| Skewness | 0.703 | 0.562 | 1.523 | 0.001 | 0.827 |
| Range | 1.423 | 1.404 | 0.740 | 0.731 | 1.281 |
| Minimum | -0.155 | -0.155 | 0.124 | -0.046 | -0.013 |
| Maximum | 1.268 | 1.249 | 0.864 | 0.685 | 1.268 |
| Sum | 58.615 | 25.717 | 2.355 | 4.320 | 26.223 |
| Count | 139 | 58 | 6 | 13 | 62 |
| 95% | 0.047 | 0.076 | 0.203 | 0.123 | 0.071 |

**Medium & low urban excluding roads & roofs:**

| *Total N* | *All medium* | *All low* | *Agricultural* | *Forest* | *Other low* |
|---|---|---|---|---|---|
| Mean | 0.538 | 0.314 | 0.591 | -0.075 | 0.344 |
| Std Error | 0.169 | 0.059 | 0.103 | 0.103 | 0.068 |
| Median | 0.385 | 0.349 | 0.639 | -0.023 | 0.365 |
| Mode | | 0.342 | | | 0.097 |
| Std Dev | 0.337 | 0.426 | 0.385 | 0.355 | 0.348 |
| Variance | 0.114 | 0.182 | 0.149 | 0.126 | 0.121 |
| Kurtosis | 3.858 | 0.263 | 1.367 | -0.080 | 2.575 |
| Skewness | 1.959 | -0.403 | -0.682 | -0.242 | -0.868 |
| Range | 0.703 | 1.995 | 1.584 | 1.269 | 1.785 |
| Minimum | 0.338 | -0.712 | -0.301 | -0.712 | -0.699 |
| Maximum | 1.041 | 1.283 | 1.283 | 0.556 | 1.086 |
| Sum | 2.150 | 16.314 | 8.267 | -0.906 | 8.952 |
| Count | 4 | 52 | 14 | 12 | 26 |
| 95% | 0.330 | 0.116 | 0.202 | 0.201 | 0.134 |

## Chemical Oxygen Demand

log(mg/L)

**Roads:**

| *COD* | *All roads* | *MtStHelens* | *All others* | *High urban* | *Low urban* |
|---|---|---|---|---|---|
| Mean | 1.891 | 2.099 | 1.856 | 1.828 | 1.905 |
| Std Error | 0.072 | 0.136 | 0.080 | 0.111 | 0.109 |
| Median | 2.037 | 2.041 | 1.994 | 2.079 | 1.778 |
| Mode | 1.690 | | 1.690 | | |
| Std Dev | 0.426 | 0.304 | 0.438 | 0.484 | 0.361 |
| Variance | 0.182 | 0.092 | 0.192 | 0.234 | 0.131 |
| Kurtosis | -0.084 | -0.081 | -0.224 | -0.854 | 1.159 |
| Skewness | -0.580 | -0.609 | -0.483 | -0.761 | 1.174 |
| Range | 1.799 | 0.770 | 1.799 | 1.552 | 1.216 |
| Minimum | 0.908 | 1.653 | 0.908 | 0.908 | 1.491 |
| Maximum | 2.708 | 2.423 | 2.708 | 2.461 | 2.708 |
| Sum | 66.176 | 10.496 | 55.680 | 34.730 | 20.950 |
| Count | 35 | 5 | 30 | 19 | 11 |
| 95% | 0.141 | 0.266 | 0.157 | 0.217 | 0.214 |

**Roofs:**

| *All roofs* |
|---|
| 1.342 |
| 0.000 |
| 1.342 |
| |
| |
| |
| |
| |
| 0.000 |
| 1.342 |
| 1.342 |
| 1.342 |
| 1 |
| |

**High urban excluding roads & roofs:**

| *COD* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* | *Non-indust* |
|---|---|---|---|---|---|---|
| Mean | 1.903 | 1.883 | 2.222 | 1.924 | 1.890 | 1.891 |
| Std Error | 0.027 | 0.036 | 0.154 | 0.093 | 0.045 | 0.027 |
| Median | 1.886 | 1.863 | 2.185 | 1.927 | 1.875 | 1.863 |
| Mode | 1.778 | 1.708 | | | 1.653 | 1.778 |
| Std Dev | 0.352 | 0.315 | 0.376 | 0.415 | 0.363 | 0.347 |
| Variance | 0.124 | 0.099 | 0.141 | 0.172 | 0.132 | 0.120 |
| Kurtosis | 1.246 | 1.007 | -2.903 | 2.013 | 1.482 | 1.401 |
| Skewness | -0.051 | 0.014 | 0.095 | 0.400 | -0.413 | -0.087 |
| Range | 2.314 | 1.953 | 0.807 | 2.009 | 2.136 | 2.314 |
| Minimum | 0.699 | 0.929 | 1.826 | 1.004 | 0.699 | 0.699 |
| Maximum | 3.013 | 2.883 | 2.633 | 3.013 | 2.835 | 3.013 |
| Sum | 313.986 | 141.199 | 13.329 | 38.484 | 120.973 | 300.656 |
| Count | 165 | 75 | 6 | 20 | 64 | 159 |
| 95% | 0.054 | 0.071 | 0.301 | 0.182 | 0.089 | 0.054 |

**Medium & low urban excluding roads & roofs:**

| *COD* | *All medium* | *All low* | *Agricultural* | *Forest* | *Other low* |
|---|---|---|---|---|---|
| Mean | 1.655 | 1.528 | 1.401 | 1.355 | 1.633 |
| Std Error | 0.081 | 0.106 | 0.685 | 0.249 | 0.078 |
| Median | 1.544 | 1.555 | 1.401 | 1.454 | 1.555 |
| Mode | 1.477 | 1.398 | | | 1.398 |
| Std Dev | 0.230 | 0.411 | 0.969 | 0.497 | 0.233 |
| Variance | 0.053 | 0.169 | 0.939 | 0.247 | 0.054 |
| Kurtosis | -1.744 | 0.247 | | -2.384 | -0.855 |
| Skewness | 0.643 | -0.816 | | -0.635 | 0.605 |
| Range | 0.542 | 1.370 | 1.370 | 1.046 | 0.647 |
| Minimum | 1.431 | 0.716 | 0.716 | 0.732 | 1.398 |
| Maximum | 1.973 | 2.086 | 2.086 | 1.778 | 2.045 |
| Sum | 13.241 | 22.916 | 2.802 | 5.419 | 14.695 |
| Count | 8 | 15 | 2 | 4 | 9 |
| 95% | 0.160 | 0.208 | 1.343 | 0.487 | 0.152 |

## Biochemical Oxygen Demand

log(mg/L)

| | **Roads:** | **Roofs:** |
|---|---|---|
| *BOD* | *High Urban* | *High Urban* |
| Mean | 1.217 | 0.602 |
| Std Error | 0.098 | 0.000 |
| Median | 1.203 | 0.602 |
| Mode | 1.556 | |
| Std Dev | 0.278 | |
| Variance | 0.077 | |
| Kurtosis | -1.136 | |
| Skewness | -0.184 | |
| Range | 0.711 | 0.000 |
| Minimum | 0.845 | 0.602 |
| Maximum | 1.556 | 0.602 |
| Sum | 9.735 | 0.602 |
| Count | 8 | 1 |
| 95% | 0.193 | |

**High urban excluding roads & roofs:**

| *BOD* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* |
|---|---|---|---|---|---|
| Mean | 1.137 | 1.143 | 1.075 | 1.169 | 1.130 |
| Std Error | 0.025 | 0.036 | 0.042 | 0.055 | 0.041 |
| Median | 1.137 | 1.137 | 1.079 | 1.114 | 1.145 |
| Mode | 1.079 | 1.079 | | 1.230 | 1.279 |
| Std Dev | 0.280 | 0.256 | 0.073 | 0.183 | 0.319 |
| Variance | 0.078 | 0.065 | 0.005 | 0.033 | 0.102 |
| Kurtosis | 1.653 | -0.394 | | 0.872 | 1.996 |
| Skewness | 0.605 | -0.026 | -0.250 | 0.674 | 0.875 |
| Range | 1.687 | 1.030 | 0.146 | 0.652 | 1.687 |
| Minimum | 0.477 | 0.623 | 1.000 | 0.903 | 0.477 |
| Maximum | 2.164 | 1.653 | 1.146 | 1.555 | 2.164 |
| Sum | 144.437 | 58.279 | 3.225 | 12.857 | 70.076 |
| Count | 127 | 51 | 3 | 11 | 62 |
| 95% | 0.049 | 0.070 | 0.083 | 0.108 | 0.079 |

**Medium & low urban excluding roads & roofs:**

| *BOD* | *All medium* | *All low* |
|---|---|---|
| Mean | 0.869 | 0.576 |
| Std Error | 0.078 | 0.161 |
| Median | 0.970 | 0.452 |
| Mode | 1.041 | 0.301 |
| Std Dev | 0.246 | 0.454 |
| Variance | 0.060 | 0.206 |
| Kurtosis | -1.941 | -0.823 |
| Skewness | -0.293 | 0.666 |
| Range | 0.632 | 1.281 |
| Minimum | 0.544 | 0.041 |
| Maximum | 1.176 | 1.322 |
| Sum | 8.691 | 4.610 |
| Count | 10 | 8 |
| 95% | 0.152 | 0.315 |

## Oil and Grease

log(mg/L)

**Roads:**

| *Oil & Grease* | *All Roads* | *High Urban* | *Low Urban* |
|---|---|---|---|
| Mean | 1.193 | 2.032 | 0.633 |
| Std Error | 0.364 | 0.269 | 0.164 |
| Median | 0.846 | 2.032 | 0.741 |
| Mode | | | |
| Std Dev | 0.815 | 0.380 | 0.283 |
| Variance | 0.664 | 0.145 | 0.080 |
| Kurtosis | -1.546 | | |
| Skewness | 0.563 | | -1.467 |
| Range | 1.989 | 0.538 | 0.535 |
| Minimum | 0.312 | 1.763 | 0.312 |
| Maximum | 2.301 | 2.301 | 0.846 |
| Sum | 5.964 | 4.064 | 1.899 |
| Count | 5 | 2 | 3 |
| 95% | 0.714 | 0.527 | 0.320 |

**High urban excluding roads & roofs**

| *Oil & Grease* | *All High* | *Residential* | *Industrial* | *Commercial* | *Other High* |
|---|---|---|---|---|---|
| Mean | 0.942 | 0.917 | 0.965 | 1.191 | 0.870 |
| Std Error | 0.076 | 0.095 | 0.051 | 0.118 | 0.203 |
| Median | 0.978 | 0.978 | 0.959 | 1.124 | 0.599 |
| Mode | 1.097 | 1.097 | | | |
| Std Dev | 0.437 | 0.367 | 0.101 | 0.237 | 0.642 |
| Variance | 0.191 | 0.135 | 0.010 | 0.056 | 0.412 |
| Kurtosis | -0.131 | 3.382 | -3.589 | 0.842 | -2.107 |
| Skewness | -0.413 | -1.602 | 0.191 | 1.234 | 0.344 |
| Range | 1.769 | 1.431 | 0.218 | 0.523 | 1.496 |
| Minimum | -0.097 | -0.097 | 0.862 | 0.996 | 0.176 |
| Maximum | 1.672 | 1.334 | 1.079 | 1.519 | 1.672 |
| Sum | 31.075 | 13.756 | 3.858 | 4.762 | 8.698 |
| Count | 33 | 15 | 4 | 4 | 10 |
| 95% | 0.149 | 0.186 | 0.099 | 0.232 | 0.398 |

**Medium & low urban excluding roads and roofs**

| *Oil & Grease* | *Med/Low* |
|---|---|
| Mean | -0.042 |
| Std Error | 0.221 |
| Median | -0.222 |
| Mode | |
| Std Dev | 0.383 |
| Variance | 0.146 |
| Kurtosis | |
| Skewness | 1.649 |
| Range | 0.699 |
| Minimum | -0.301 |
| Maximum | 0.398 |
| Sum | -0.125 |
| Count | 3 |
| 95% | 0.433 |

## Total Organic Carbon

log(mg/L)

**Roads:**

| *TOC* | *All roads* |
|---|---|
| Mean | 1.671 |
| Std Error | 0.186 |
| Median | 1.519 |
| Mode | |
| Std Dev | 0.323 |
| Variance | 0.104 |
| Kurtosis | |
| Skewness | 1.649 |
| Range | 0.590 |
| Minimum | 1.452 |
| Maximum | 2.041 |
| Sum | 5.012 |
| Count | 3 |
| 95% | 0.365 |

**High urban excluding roads & roofs:**

| *TOC* | *All high* | *Residential* | *Other high* |
|---|---|---|---|
| Mean | 1.382 | 1.205 | 1.496 |
| Std Error | 0.054 | 0.100 | 0.040 |
| Median | 1.447 | 1.276 | 1.470 |
| Mode | 1.447 | | 1.322 |
| Std Dev | 0.259 | 0.300 | 0.149 |
| Variance | 0.067 | 0.090 | 0.022 |
| Kurtosis | 2.621 | 0.279 | -0.391 |
| Skewness | -1.334 | -0.990 | 0.462 |
| Range | 1.162 | 0.889 | 0.507 |
| Minimum | 0.623 | 0.623 | 1.279 |
| Maximum | 1.785 | 1.512 | 1.785 |
| Sum | 31.792 | 10.842 | 20.951 |
| Count | 23 | 9 | 14 |
| 95% | 0.106 | 0.196 | 0.078 |

**Low urban excluding roads & roofs:**

| *TOC* | *All low* |
|---|---|
| Mean | 1.312 |
| Std Error | 0.073 |
| Median | 1.292 |
| Mode | |
| Std Dev | 0.127 |
| Variance | 0.016 |
| Kurtosis | |
| Skewness | 0.676 |
| Range | 0.251 |
| Minimum | 1.196 |
| Maximum | 1.447 |
| Sum | 3.935 |
| Count | 3 |
| 95% | 0.143 |

## pH

pH units

**Roads:**

| *pH* | *Roads* |
|---|---|
| Mean | 6.925 |
| Std Error | 0.262 |
| Median | 7.000 |
| Mode | |
| Std Dev | 0.740 |
| Variance | 0.548 |
| Kurtosis | 0.681 |
| Skewness | -0.971 |
| Range | 2.200 |
| Minimum | 5.500 |
| Maximum | 7.700 |
| Sum | 55.400 |
| Count | 8 |
| 95% | 0.513 |

**Roofs:**

| *All roofs* | *High urban* | *Low urban* |
|---|---|---|
| 5.657 | 6.022 | 5.000 |
| 0.301 | 0.376 | 0.385 |
| 5.900 | 6.500 | 4.800 |
| 6.900 | 6.900 | 5.900 |
| 1.126 | 1.127 | 0.860 |
| 1.267 | 1.269 | 0.740 |
| -1.616 | -1.209 | -2.955 |
| -0.098 | -0.702 | 0.247 |
| 3.200 | 3.100 | 1.800 |
| 4.100 | 4.200 | 4.100 |
| 7.300 | 7.300 | 5.900 |
| 79.200 | 54.200 | 25.000 |
| 14 | 9 | 5 |
| 0.590 | 0.736 | 0.754 |

**High urban excluding roads & roofs:**

| *pH* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* |
|---|---|---|---|---|---|
| Mean | 6.922 | 6.860 | 7.100 | 6.717 | 7.067 |
| Std Error | 0.092 | 0.114 | 0.453 | 0.342 | 0.167 |
| Median | 7.000 | 6.990 | 7.150 | 6.900 | 7.150 |
| Mode | 7.300 | 7.300 | | | 7.400 |
| Std Dev | 0.635 | 0.559 | 0.906 | 0.838 | 0.623 |
| Variance | 0.403 | 0.312 | 0.820 | 0.702 | 0.389 |
| Kurtosis | -0.198 | 0.332 | -1.117 | -2.384 | 0.575 |
| Skewness | -0.385 | -0.859 | -0.264 | -0.319 | -0.136 |
| Range | 2.800 | 2.200 | 2.100 | 1.900 | 2.500 |
| Minimum | 5.500 | 5.500 | 6.000 | 5.700 | 5.800 |
| Maximum | 8.300 | 7.700 | 8.100 | 7.600 | 8.300 |
| Sum | 332.270 | 164.630 | 28.400 | 40.300 | 98.940 |
| Count | 48 | 24 | 4 | 6 | 14 |
| 95% | 0.180 | 0.223 | 0.887 | 0.670 | 0.327 |

**Medium & low urban excluding roads & roofs:**

| *pH* | *All medium* | *All low* |
|---|---|---|
| Mean | 6.900 | 6.680 |
| Std Error | 0.000 | 0.185 |
| Median | 6.900 | 6.700 |
| Mode | | |
| Std Dev | | 0.415 |
| Variance | | 0.172 |
| Kurtosis | | 0.014 |
| Skewness | | -0.290 |
| Range | 0.000 | 1.100 |
| Minimum | 6.900 | 6.100 |
| Maximum | 6.900 | 7.200 |
| Sum | 6.900 | 33.400 |
| Count | 1 | 5 |
| 95% | | 0.364 |

## Turbidity

log turbidity units

**Roads:**

| *Turbidity* | *All roads* |
|---|---|
| Mean | 1.690 |
| Std Error | 0.000 |
| Median | 1.690 |
| Mode | |
| Std Dev | |
| Variance | |
| Kurtosis | |
| Skewness | |
| Range | 0.000 |
| Minimum | 1.690 |
| Maximum | 1.690 |
| Sum | 1.690 |
| Count | 1 |
| 95% | |

**Roofs:**

| | *All roofs* | *High urban* | *Low urban* |
|---|---|---|---|
| Mean | 0.579 | 0.785 | -0.038 |
| Std Error | 0.221 | 0.238 | 0.117 |
| Median | 0.609 | 0.777 | -0.038 |
| Mode | | | |
| Std Dev | 0.626 | 0.582 | 0.166 |
| Variance | 0.391 | 0.339 | 0.027 |
| Kurtosis | -0.901 | 0.341 | |
| Skewness | 0.363 | -0.169 | |
| Range | 1.757 | 1.699 | 0.234 |
| Minimum | -0.155 | -0.097 | -0.155 |
| Maximum | 1.602 | 1.602 | 0.079 |
| Sum | 4.636 | 4.712 | -0.076 |
| Count | 8 | 6 | 2 |
| 95% | 0.434 | 0.466 | 0.229 |

**High urban excluding roads & roofs:**

| *Turbidity* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* |
|---|---|---|---|---|---|
| Mean | 1.781 | 1.833 | 1.362 | 1.064 | 2.034 |
| Std Error | 0.161 | 0.201 | 0.000 | 0.000 | 0.080 |
| Median | 1.558 | 1.558 | 1.362 | 1.064 | 2.034 |
| Mode | | | | | |
| Std Dev | 0.642 | 0.696 | | | 0.113 |
| Variance | 0.412 | 0.484 | | | 0.013 |
| Kurtosis | -0.899 | -1.303 | | | |
| Skewness | 0.599 | 0.532 | | | |
| Range | 1.854 | 1.854 | 0.000 | 0.000 | 0.160 |
| Minimum | 1.049 | 1.049 | 1.362 | 1.064 | 1.954 |
| Maximum | 2.903 | 2.903 | 1.362 | 1.064 | 2.114 |
| Sum | 28.493 | 21.999 | 1.362 | 1.064 | 4.068 |
| Count | 16 | 12 | 1 | 1 | 2 |
| 95% | 0.315 | 0.394 | | | 0.157 |

**Medium & low urban excluding roads & roofs:**

| *Turbidity* | *All medium* | *All low* |
|---|---|---|
| Mean | 3.053 | 1.826 |
| Std Error | 0.000 | 0.000 |
| Median | 3.053 | 1.826 |
| Mode | | |
| Std Dev | | |
| Variance | | |
| Kurtosis | | |
| Skewness | | |
| Range | 0.000 | 0.000 |
| Minimum | 3.053 | 1.826 |
| Maximum | 3.053 | 1.826 |
| Sum | 3.053 | 1.826 |
| Count | 1 | 1 |
| 95% | | |

# Total Lead

log(mg/L)

**Roads:**

| *Lead* | *All roads* | *MtStHelens* | *All others* | *High urban* | *Med. urban* | *Low urban* |
|---|---|---|---|---|---|---|
| Mean | -0.660 | -0.704 | -0.655 | -0.619 | -0.595 | -0.765 |
| Std Error | 0.076 | 0.141 | 0.083 | 0.103 | 0.000 | 0.148 |
| Median | -0.620 | -0.708 | -0.603 | -0.464 | -0.595 | -0.638 |
| Mode | -0.046 |  | -0.046 | -0.046 |  |  |
| Std Dev | 0.529 | 0.315 | 0.551 | 0.581 |  | 0.492 |
| Variance | 0.280 | 0.099 | 0.303 | 0.337 |  | 0.242 |
| Kurtosis | 0.099 | 1.572 | -0.035 | -0.616 |  | 3.979 |
| Skewness | -0.542 | 0.127 | -0.562 | -0.467 |  | -1.555 |
| Range | 2.307 | 0.882 | 2.307 | 2.307 | 0.000 | 1.928 |
| Minimum | -2.000 | -1.137 | -2.000 | -2.000 | -0.595 | -2.000 |
| Maximum | 0.307 | -0.255 | 0.307 | 0.307 | -0.595 | -0.072 |
| Sum | -32.350 | -3.521 | -28.830 | -19.822 | -0.595 | -8.413 |
| Count | 49 | 5 | 44 | 32 | 1 | 11 |
| 95% | 0.148 | 0.276 | 0.163 | 0.201 |  | 0.291 |

**Roofs:**

| *Lead* | *All roofs* | *High urban* | *Low urban* |
|---|---|---|---|
| Mean | -1.679 | -1.504 | -2.129 |
| Std Error | 0.140 | 0.119 | 0.362 |
| Median | -1.678 | -1.426 | -2.000 |
| Mode | -2.000 |  | -3.301 |
| Std Dev | 0.701 | 0.504 | 0.957 |
| Variance | 0.491 | 0.254 | 0.915 |
| Kurtosis | 0.738 | -0.511 | 0.442 |
| Skewness | -0.651 | -0.127 | 0.263 |
| Range | 2.781 | 1.822 | 2.781 |
| Minimum | -3.301 | -2.523 | -3.301 |
| Maximum | -0.520 | -0.701 | -0.520 |
| Sum | -41.980 | -27.075 | -14.905 |
| Count | 25 | 18 | 7 |
| 95% | 0.275 | 0.233 | 0.709 |

**High urban excluding roads & roofs:**

| *Lead* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* |
|---|---|---|---|---|---|
| Mean | -0.837 | -0.820 | -0.840 | -0.781 | -0.873 |
| Std Error | 0.041 | 0.054 | 0.162 | 0.126 | 0.076 |
| Median | -0.738 | -0.734 | -0.936 | -0.698 | -0.777 |
| Mode | -1.398 | -1.398 |  | -0.398 | -0.337 |
| Std Dev | 0.557 | 0.474 | 0.536 | 0.591 | 0.640 |
| Variance | 0.310 | 0.224 | 0.288 | 0.349 | 0.409 |
| Kurtosis | 4.328 | -0.023 | -1.104 | 0.438 | 6.203 |
| Skewness | -1.318 | -0.221 | 0.181 | -0.504 | -2.060 |
| Range | 4.138 | 2.283 | 1.643 | 2.465 | 3.796 |
| Minimum | -3.699 | -1.845 | -1.602 | -2.222 | -3.699 |
| Maximum | 0.439 | 0.439 | 0.041 | 0.243 | 0.097 |
| Sum | -151.443 | -63.957 | -9.235 | -17.175 | -61.076 |
| Count | 181 | 78 | 11 | 22 | 70 |
| 95% | 0.081 | 0.105 | 0.317 | 0.247 | 0.150 |

**Medium & low urban excluding roads & roofs:**

| *Lead* | *All medium* | *All low* | *Agricultural* | *Forest* | *Other low* |
|---|---|---|---|---|---|
| Mean | -0.983 | -1.354 | -1.611 | -1.349 | -1.262 |
| Std Error | 0.159 | 0.150 | 0.266 | 0.048 | 0.212 |
| Median | -0.824 | -1.398 | -1.548 | -1.349 | -1.284 |
| Mode | -0.824 | -1.398 |  |  |  |
| Std Dev | 0.275 | 0.620 | 0.532 | 0.069 | 0.703 |
| Variance | 0.076 | 0.385 | 0.283 | 0.005 | 0.494 |
| Kurtosis |  | -0.149 | 0.282 |  | -0.459 |
| Skewness | -1.732 | -0.105 | -0.616 |  | -0.308 |
| Range | 0.477 | 2.382 | 1.255 | 0.097 | 2.382 |
| Minimum | -1.301 | -2.523 | -2.301 | -1.398 | -2.523 |
| Maximum | -0.824 | -0.141 | -1.046 | -1.301 | -0.141 |
| Sum | -2.949 | -23.020 | -6.444 | -2.699 | -13.878 |
| Count | 3 | 17 | 4 | 2 | 11 |
| 95% | 0.312 | 0.295 | 0.521 | 0.095 | 0.415 |

# Total Zinc

log(mg/L)

**Roads:**

| *Zinc* | *All roads* | *MtStHelens* | *All others* | *High urban* | *Med. urban* | *Low urban* |
|---|---|---|---|---|---|---|
| Mean | -0.452 | -0.572 | -0.437 | -0.328 | -0.492 | -0.709 |
| Std Error | 0.058 | 0.201 | 0.061 | 0.066 | 0.000 | 0.113 |
| Median | -0.444 | -0.453 | -0.426 | -0.328 | -0.492 | -0.569 |
| Mode | -0.208 | | -0.208 | | | -1.222 |
| Std Dev | 0.392 | 0.449 | 0.388 | 0.350 | | 0.376 |
| Variance | 0.153 | 0.202 | 0.150 | 0.122 | | 0.142 |
| Kurtosis | 1.663 | 1.195 | 1.915 | 2.619 | | -1.603 |
| Skewness | 0.305 | -0.709 | 0.445 | 1.285 | | -0.343 |
| Range | 2.015 | 1.220 | 1.985 | 1.587 | 0.000 | 1.014 |
| Minimum | -1.252 | -1.252 | -1.222 | -0.824 | -0.492 | -1.222 |
| Maximum | 0.763 | -0.032 | 0.763 | 0.763 | -0.492 | -0.208 |
| Sum | -20.337 | -2.859 | -17.478 | -9.186 | -0.492 | -7.800 |
| Count | 45 | 5 | 40 | 28 | 1 | 11 |
| 95% | 0.114 | 0.394 | 0.120 | 0.129 | | 0.222 |

**High urban excluding roads & roofs:**

| *Zinc* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* | *Non-resid* |
|---|---|---|---|---|---|---|
| Mean | -0.619 | -0.786 | -0.637 | -0.461 | -0.476 | -0.491 |
| Std Error | 0.035 | 0.054 | 0.078 | 0.095 | 0.050 | 0.040 |
| Median | -0.596 | -0.760 | -0.622 | -0.495 | -0.498 | -0.515 |
| Mode | -0.495 | -0.921 | | | -0.495 | -0.495 |
| Std Dev | 0.433 | 0.446 | 0.247 | 0.415 | 0.383 | 0.377 |
| Variance | 0.188 | 0.199 | 0.061 | 0.172 | 0.146 | 0.142 |
| Kurtosis | 1.136 | 0.547 | 2.251 | 0.389 | 1.108 | 0.855 |
| Skewness | -0.195 | -0.471 | 1.287 | -0.302 | 0.676 | 0.505 |
| Range | 2.763 | 2.142 | 0.809 | 1.670 | 2.056 | 2.195 |
| Minimum | -2.000 | -2.000 | -0.879 | -1.432 | -1.292 | -1.432 |
| Maximum | 0.763 | 0.142 | -0.071 | 0.238 | 0.763 | 0.763 |
| Sum | -96.640 | -53.430 | -6.369 | -8.756 | -28.086 | -43.210 |
| Count | 156 | 68 | 10 | 19 | 59 | 88 |
| 95% | 0.068 | 0.106 | 0.153 | 0.187 | 0.098 | 0.079 |

**Medium & low urban excluding roads & roofs:**

| *Zinc* | *All medium* | *All low* |
|---|---|---|
| Mean | -1.126 | -0.706 |
| Std Error | 0.029 | 0.190 |
| Median | -1.126 | -0.700 |
| Mode | | |
| Std Dev | 0.041 | 0.537 |
| Variance | 0.002 | 0.289 |
| Kurtosis | | -0.344 |
| Skewness | | -0.232 |
| Range | 0.058 | 1.629 |
| Minimum | -1.155 | -1.602 |
| Maximum | -1.097 | 0.027 |
| Sum | -2.252 | -5.645 |
| Count | 2 | 8 |
| 95% | 0.057 | 0.372 |

**Roofs:**

| *All roofs* | *Zinc* | *Non-zinc* | *Don't know* |
|---|---|---|---|
| -0.313 | 0.573 | -0.799 | -0.507 |
| 0.171 | 0.265 | 0.174 | 0.235 |
| -0.475 | 0.544 | -0.989 | -0.481 |
| | | | |
| 0.837 | 0.701 | 0.551 | 0.621 |
| 0.701 | 0.491 | 0.303 | 0.386 |
| -0.018 | -0.910 | 0.104 | 1.092 |
| 0.527 | 0.211 | 0.592 | -0.692 |
| 3.279 | 2.014 | 1.842 | 1.916 |
| -1.638 | -0.374 | -1.638 | -1.620 |
| 1.640 | 1.640 | 0.204 | 0.297 |
| -7.522 | 4.014 | -7.990 | -3.546 |
| 24 | 7 | 10 | 7 |
| 0.335 | 0.519 | 0.341 | 0.460 |

## Total Copper

log(mg/L)

**Roads:**

| *Copper* | *All roads* | *MtStHelens* | *All others* | *High urban* | *Med. urban* | *Low urban* |
|---|---|---|---|---|---|---|
| Mean | -1.004 | -0.629 | -1.086 | -1.040 | -1.638 | -1.131 |
| Std Error | 0.111 | 0.461 | 0.091 | 0.112 | 0.000 | 0.149 |
| Median | -1.105 | -1.051 | -1.119 | -1.119 | -1.638 | -1.013 |
| Mode | -0.854 |  | -0.854 | -0.854 |  |  |
| Std Dev | 0.587 | 1.031 | 0.436 | 0.460 |  | 0.332 |
| Variance | 0.344 | 1.062 | 0.190 | 0.212 |  | 0.110 |
| Kurtosis | 3.032 | -1.211 | 3.080 | 3.071 |  | 1.101 |
| Skewness | 1.656 | 0.801 | 1.357 | 1.546 |  | -1.208 |
| Range | 2.505 | 2.449 | 1.913 | 1.875 | 0.000 | 0.842 |
| Minimum | -1.658 | -1.602 | -1.658 | -1.620 | -1.638 | -1.658 |
| Maximum | 0.847 | 0.847 | 0.255 | 0.255 | -1.638 | -0.815 |
| Sum | -28.120 | -3.145 | -24.974 | -17.682 | -1.638 | -5.655 |
| Count | 28 | 5 | 23 | 17 | 1 | 5 |
| 95% | 0.217 | 0.903 | 0.178 | 0.219 |  | 0.291 |

**High urban excluding roads & roofs:**

| *Copper* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* | *Non-resid* |
|---|---|---|---|---|---|---|
| Mean | -1.305 | -1.435 | -1.191 | -1.101 | -1.240 | -1.210 |
| Std Error | 0.040 | 0.054 | 0.144 | 0.151 | 0.063 | 0.054 |
| Median | -1.377 | -1.444 | -1.387 | -1.155 | -1.255 | -1.268 |
| Mode | -1.523 | -2.000 |  | -1.155 | -1.523 | -0.921 |
| Std Dev | 0.469 | 0.416 | 0.476 | 0.565 | 0.471 | 0.485 |
| Variance | 0.220 | 0.173 | 0.227 | 0.320 | 0.221 | 0.235 |
| Kurtosis | 0.320 | -0.634 | 1.547 | -0.765 | 0.800 | 0.329 |
| Skewness | 0.476 | 0.107 | 1.412 | 0.291 | 0.491 | 0.552 |
| Range | 2.326 | 1.716 | 1.538 | 1.862 | 2.326 | 2.326 |
| Minimum | -2.222 | -2.222 | -1.635 | -1.959 | -2.222 | -2.222 |
| Maximum | 0.104 | -0.506 | -0.097 | -0.097 | 0.104 | 0.104 |
| Sum | -182.661 | -84.684 | -13.096 | -15.418 | -69.462 | -97.977 |
| Count | 140 | 59 | 11 | 14 | 56 | 81 |
| 95% | 0.078 | 0.106 | 0.282 | 0.296 | 0.123 | 0.106 |

**Medium & low urban excluding roads & roofs:**

| *Copper* | *All medium* | *All low* |
|---|---|---|
| Mean | -1.489 | -1.431 |
| Std Error | 0.335 | 0.077 |
| Median | -1.489 | -1.423 |
| Mode |  |  |
| Std Dev | 0.473 | 0.188 |
| Variance | 0.224 | 0.035 |
| Kurtosis |  | -1.214 |
| Skewness |  | -0.280 |
| Range | 0.669 | 0.477 |
| Minimum | -1.824 | -1.699 |
| Maximum | -1.155 | -1.222 |
| Sum | -2.979 | -8.588 |
| Count | 2 | 6 |
| 95% | 0.656 | 0.151 |

**Roofs:**

| *All roofs* | *High urban* | *Low urban* |
|---|---|---|
| -1.623 | -1.648 | -1.567 |
| 0.140 | 0.187 | 0.205 |
| -1.747 | -1.824 | -1.699 |
|  |  |  |
| 0.560 | 0.620 | 0.459 |
| 0.314 | 0.384 | 0.211 |
| 0.199 | 0.234 | 3.528 |
| 1.020 | 1.073 | 1.778 |
| 1.869 | 1.869 | 1.179 |
| -2.319 | -2.319 | -1.959 |
| -0.450 | -0.450 | -0.780 |
| -25.960 | -18.125 | -7.835 |
| 16 | 11 | 5 |
| 0.274 | 0.366 | 0.403 |

## Total Cadmium

log(mg/L)

**Roads:**

| *Cadmium* | *All roads* | *High urban* | *Low urban* |
|---|---|---|---|
| Mean | -2.544 | -2.594 | -2.384 |
| Std Error | 0.111 | 0.141 | 0.089 |
| Median | -2.553 | -2.602 | -2.376 |
| Mode | -2.229 | | -2.229 |
| Std Dev | 0.457 | 0.509 | 0.179 |
| Variance | 0.209 | 0.259 | 0.032 |
| Kurtosis | 3.869 | 4.290 | -5.860 |
| Skewness | 1.445 | 1.752 | -0.024 |
| Range | 1.954 | 1.954 | 0.324 |
| Minimum | -3.155 | -3.155 | -2.553 |
| Maximum | -1.201 | -1.201 | -2.229 |
| Sum | -43.256 | -33.722 | -9.534 |
| Count | 17 | 13 | 4 |
| 95% | 0.217 | 0.277 | 0.175 |

**Roofs:**

| *All roofs* |
|---|
| -3.332 |
| 0.163 |
| -3.171 |
| -3.000 |
| 0.461 |
| 0.213 |
| 0.121 |
| -1.160 |
| 1.288 |
| -4.174 |
| -2.886 |
| -26.655 |
| 8 |
| 0.320 |

**High urban excluding roads & roofs:**

| *Cadmium* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* | *Res/Ind/Com* |
|---|---|---|---|---|---|---|
| Mean | -2.359 | -2.592 | -2.447 | -2.498 | -2.100 | -2.547 |
| Std Error | 0.070 | 0.121 | 0.171 | 0.308 | 0.079 | 0.094 |
| Median | -2.222 | -2.387 | -2.301 | -2.569 | -2.041 | -2.387 |
| Mode | -2.000 | -2.301 | -3.000 | | -2.046 | -2.301 |
| Std Dev | 0.528 | 0.553 | 0.454 | 0.689 | 0.389 | 0.542 |
| Variance | 0.279 | 0.306 | 0.206 | 0.475 | 0.151 | 0.293 |
| Kurtosis | -0.791 | -0.317 | -2.214 | -2.617 | 1.553 | -0.801 |
| Skewness | -0.410 | 0.244 | -0.344 | 0.185 | -1.173 | 0.122 |
| Range | 2.097 | 2.097 | 1.000 | 1.544 | 1.495 | 2.097 |
| Minimum | -3.398 | -3.398 | -3.000 | -3.222 | -3.097 | -3.398 |
| Maximum | -1.301 | -1.301 | -2.000 | -1.678 | -1.602 | -1.301 |
| Sum | -134.438 | -54.422 | -17.126 | -12.491 | -50.399 | -84.039 |
| Count | 57 | 21 | 7 | 5 | 24 | 33 |
| 95% | 0.137 | 0.237 | 0.336 | 0.604 | 0.156 | 0.185 |

**Medium & low urban excluding roads & roofs:**

| *Cadmium* | *All Med/Low* |
|---|---|
| Mean | -1.981 |
| Std Error | 0.264 |
| Median | -1.801 |
| Mode | -1.602 |
| Std Dev | 0.528 |
| Variance | 0.279 |
| Kurtosis | 1.159 |
| Skewness | -1.342 |
| Range | 1.119 |
| Minimum | -2.721 |
| Maximum | -1.602 |
| Sum | -7.925 |
| Count | 4 |
| 95% | 0.517 |

# Total Chromium

log(mg/L)

**Roads:**

| *Chromium* | *All roads* |
|---|---|
| Mean | -1.908 |
| Std Error | 0.083 |
| Median | -1.824 |
| Mode | |
| Std Dev | 0.248 |
| Variance | 0.061 |
| Kurtosis | -0.762 |
| Skewness | -0.784 |
| Range | 0.663 |
| Minimum | -2.301 |
| Maximum | -1.638 |
| Sum | -17.171 |
| Count | 9 |
| 95% | 0.162 |

**High urban excluding roads & roofs:**

| *Chromium* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* | *Non-resid* |
|---|---|---|---|---|---|---|
| Mean | -1.608 | -1.882 | -1.511 | -1.712 | -1.445 | -1.483 |
| Std Error | 0.081 | 0.148 | 0.181 | 0.280 | 0.117 | 0.093 |
| Median | -1.698 | -2.000 | -1.697 | -1.785 | -1.602 | -1.620 |
| Mode | -1.699 | -2.000 | | | -1.699 | -1.699 |
| Std Dev | 0.652 | 0.662 | 0.544 | 0.559 | 0.650 | 0.615 |
| Variance | 0.425 | 0.438 | 0.296 | 0.313 | 0.422 | 0.378 |
| Kurtosis | 0.026 | -0.308 | -0.461 | 0.542 | 0.745 | 0.378 |
| Skewness | -0.245 | -0.142 | 0.718 | 0.690 | -0.490 | -0.245 |
| Range | 3.064 | 2.477 | 1.602 | 1.322 | 3.064 | 3.064 |
| Minimum | -3.301 | -3.301 | -2.222 | -2.301 | -3.301 | -3.301 |
| Maximum | -0.237 | -0.824 | -0.620 | -0.979 | -0.237 | -0.237 |
| Sum | -102.890 | -37.640 | -13.595 | -6.850 | -44.804 | -65.250 |
| Count | 64 | 20 | 9 | 4 | 31 | 44 |
| 95% | 0.160 | 0.290 | 0.355 | 0.548 | 0.229 | 0.182 |

**Medium & low urban excluding roads & roofs:**

| *Chromium* | *All med/low* |
|---|---|
| Mean | -1.711 |
| Std Error | 0.097 |
| Median | -1.620 |
| Mode | -1.602 |
| Std Dev | 0.194 |
| Variance | 0.038 |
| Kurtosis | 3.836 |
| Skewness | -1.954 |
| Range | 0.398 |
| Minimum | -2.000 |
| Maximum | -1.602 |
| Sum | -6.842 |
| Count | 4 |
| 95% | 0.190 |

## Total Nickel

log(mg/L)

**Roads:**

| *Nickel* | *All Roads* |
|---|---|
| Mean | -1.349 |
| Std Error | 0.061 |
| Median | -1.347 |
| Mode | |
| Std Dev | 0.106 |
| Variance | 0.011 |
| Kurtosis | |
| Skewness | -0.092 |
| Range | 0.212 |
| Minimum | -1.456 |
| Maximum | -1.244 |
| Sum | -4.047 |
| Count | 3 |
| 95% | 0.120 |

**High urban excluding roads & roofs:**

| *Nickel* | *All High* | *Residential* | *Industrial* | *Commercial* | *Other High* |
|---|---|---|---|---|---|
| Mean | -1.502 | -1.577 | -1.575 | -1.586 | -1.457 |
| Std Error | 0.043 | 0.077 | 0.123 | 0.130 | 0.059 |
| Median | -1.523 | -1.620 | -1.658 | -1.586 | -1.523 |
| Mode | -1.301 | -1.301 | | | -1.523 |
| Std Dev | 0.299 | 0.256 | 0.276 | 0.184 | 0.324 |
| Variance | 0.089 | 0.065 | 0.076 | 0.034 | 0.105 |
| Kurtosis | -0.094 | -0.777 | 3.261 | | -0.245 |
| Skewness | 0.327 | -0.341 | 1.666 | | 0.184 |
| Range | 1.247 | 0.750 | 0.719 | 0.261 | 1.247 |
| Minimum | -2.071 | -2.051 | -1.827 | -1.717 | -2.071 |
| Maximum | -0.824 | -1.301 | -1.108 | -1.456 | -0.824 |
| Sum | -72.100 | -17.347 | -7.876 | -3.173 | -43.704 |
| Count | 48 | 11 | 5 | 2 | 30 |
| 95% | 0.085 | 0.151 | 0.242 | 0.256 | 0.116 |

**Low urban excluding roads & roofs:**

| *Nickel* | *All Low* |
|---|---|
| Mean | -1.605 |
| Std Error | 0.052 |
| Median | -1.605 |
| Mode | |
| Std Dev | 0.074 |
| Variance | 0.005 |
| Kurtosis | |
| Skewness | |
| Range | 0.105 |
| Minimum | -1.658 |
| Maximum | -1.553 |
| Sum | -3.210 |
| Count | 2 |
| 95% | 0.103 |

## Total Iron

log(mg/L)

**Roads:**

| *Iron* | *All roads* | *High urban* | *Low urban* |
|---|---|---|---|
| Mean | 0.604 | 0.441 | 0.727 |
| Std Error | 0.147 | 0.195 | 0.213 |
| Median | 0.534 | 0.477 | 0.623 |
| Mode | | | |
| Std Dev | 0.390 | 0.338 | 0.425 |
| Variance | 0.152 | 0.114 | 0.181 |
| Kurtosis | 1.550 | | 1.758 |
| Skewness | 0.846 | -0.475 | 1.259 |
| Range | 1.236 | 0.673 | 0.984 |
| Minimum | 0.086 | 0.086 | 0.338 |
| Maximum | 1.322 | 0.760 | 1.322 |
| Sum | 4.231 | 1.323 | 2.907 |
| Count | 7 | 3 | 4 |
| 95% | 0.289 | 0.383 | 0.417 |

**High urban excluding roads & roofs:**

| *Iron* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* | *Non-resid* |
|---|---|---|---|---|---|---|
| Mean | 0.437 | 0.202 | 0.697 | 0.606 | 0.651 | 0.646 |
| Std Error | 0.072 | 0.102 | 0.053 | 0.190 | 0.125 | 0.084 |
| Median | 0.544 | 0.301 | 0.627 | 0.699 | 0.778 | 0.699 |
| Mode | 0.176 | 0.176 | 0.602 | 0.699 | | 0.602 |
| Std Dev | 0.523 | 0.511 | 0.119 | 0.538 | 0.483 | 0.446 |
| Variance | 0.274 | 0.261 | 0.014 | 0.290 | 0.233 | 0.199 |
| Kurtosis | -0.638 | -1.050 | -2.957 | -0.926 | -0.634 | -0.399 |
| Skewness | -0.398 | -0.220 | 0.634 | -0.082 | -0.629 | -0.500 |
| Range | 2.073 | 1.635 | 0.243 | 1.512 | 1.590 | 1.683 |
| Minimum | -0.658 | -0.658 | 0.602 | -0.097 | -0.268 | -0.268 |
| Maximum | 1.415 | 0.978 | 0.845 | 1.415 | 1.322 | 1.415 |
| Sum | 23.157 | 5.056 | 3.483 | 4.848 | 9.770 | 18.101 |
| Count | 53 | 25 | 5 | 8 | 15 | 28 |
| 95% | 0.141 | 0.200 | 0.105 | 0.373 | 0.244 | 0.165 |

**Medium & low urban excluding roads & roofs:**

| *Iron* | *All medium* | *All Low* |
|---|---|---|
| Mean | 0.592 | 0.744 |
| Std Error | 0.194 | 0.252 |
| Median | 0.592 | 0.878 |
| Mode | | |
| Std Dev | 0.274 | 0.618 |
| Variance | 0.075 | 0.382 |
| Kurtosis | | -1.181 |
| Skewness | | -0.153 |
| Range | 0.387 | 1.602 |
| Minimum | 0.398 | -0.022 |
| Maximum | 0.785 | 1.580 |
| Sum | 1.183 | 4.463 |
| Count | 2 | 6 |
| 95% | 0.380 | 0.494 |

## Total Manganese

log(mg/L)

**Roads:**

| *Manganese* | *All roads* |
|---|---|
| Mean | -0.653 |
| Std Error | 0.132 |
| Median | -0.638 |
| Mode | |
| Std Dev | 0.229 |
| Variance | 0.053 |
| Kurtosis | |
| Skewness | -0.291 |
| Range | 0.458 |
| Minimum | -0.889 |
| Maximum | -0.432 |
| Sum | -1.959 |
| Count | 3 |
| 95% | 0.259 |

**High urban excluding roads & roofs:**

| *Manganese* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* |
|---|---|---|---|---|---|
| Mean | -0.627 | -0.802 | -0.642 | -0.361 | -0.574 |
| Std Error | 0.113 | 0.244 | 0.057 | 0.241 | 0.186 |
| Median | -0.594 | -0.959 | -0.642 | -0.361 | -0.420 |
| Mode | -1.301 | | | | |
| Std Dev | 0.453 | 0.546 | 0.081 | 0.341 | 0.492 |
| Variance | 0.206 | 0.298 | 0.006 | 0.117 | 0.242 |
| Kurtosis | -1.147 | 2.490 | | | -1.152 |
| Skewness | -0.131 | 1.502 | | | -0.896 |
| Range | 1.405 | 1.405 | 0.114 | 0.483 | 1.158 |
| Minimum | -1.301 | -1.301 | -0.699 | -0.602 | -1.301 |
| Maximum | 0.104 | 0.104 | -0.585 | -0.119 | -0.143 |
| Sum | -10.031 | -4.008 | -1.284 | -0.721 | -4.017 |
| Count | 16 | 5 | 2 | 2 | 7 |
| 95% | 0.222 | 0.478 | 0.112 | 0.473 | 0.365 |

**Medium & low urban excluding roads & roofs:**

| *Manganese* | *All medium* | *All low* |
|---|---|---|
| Mean | -0.796 | -1.000 |
| Std Error | 0.000 | 0.000 |
| Median | -0.796 | -1.000 |
| Mode | | |
| Std Dev | | |
| Variance | | |
| Kurtosis | | |
| Skewness | | |
| Range | 0.000 | 0.000 |
| Minimum | -0.796 | -1.000 |
| Maximum | -0.796 | -1.000 |
| Sum | -0.796 | -1.000 |
| Count | 1 | 1 |
| 95% | | |

# Total Mercury

log(mg/L)

**Roads:**

| *Mercury* | *All roads* |
|---|---|
| Mean | -4.301 |
| Std Error | 0.000 |
| Median | -4.301 |
| Mode | |
| Std Dev | |
| Variance | |
| Kurtosis | |
| Skewness | |
| Range | 0.000 |
| Minimum | -4.301 |
| Maximum | -4.301 |
| Sum | -4.301 |
| Count | 1 |
| 95% | |

**High urban excluding roads & roofs:**

| *Mercury* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* |
|---|---|---|---|---|---|
| Mean | -3.657 | -3.960 | -3.377 | -2.569 | -3.742 |
| Std Error | 0.153 | 0.040 | 0.000 | 0.000 | 0.171 |
| Median | -3.721 | -3.960 | -3.377 | -2.569 | -3.721 |
| Mode | -4.000 | | | | -4.000 |
| Std Dev | 0.550 | 0.056 | | | 0.514 |
| Variance | 0.303 | 0.003 | | | 0.265 |
| Kurtosis | 0.545 | | | | 1.734 |
| Skewness | 0.764 | | | | 0.688 |
| Range | 1.984 | 0.079 | 0.000 | 0.000 | 1.854 |
| Minimum | -4.553 | -4.000 | -3.377 | -2.569 | -4.553 |
| Maximum | -2.569 | -3.921 | -3.377 | -2.569 | -2.699 |
| Sum | -47.543 | -7.921 | -3.377 | -2.569 | -33.676 |
| Count | 13 | 2 | 1 | 1 | 9 |
| 95% | 0.299 | 0.078 | | | 0.336 |

**Medium & low urban excluding roads & roofs:**

| *Mercury* | *All medium* | *All low* |
|---|---|---|
| Mean | -4.602 | -4.301 |
| Std Error | 0.000 | 0.301 |
| Median | -4.602 | -4.301 |
| Mode | | |
| Std Dev | | 0.426 |
| Variance | | 0.181 |
| Kurtosis | | |
| Skewness | | |
| Range | 0.000 | 0.602 |
| Minimum | -4.602 | -4.602 |
| Maximum | -4.602 | -4.000 |
| Sum | -4.602 | -8.602 |
| Count | 1 | 2 |
| 95% | | 0.590 |

# Total Coliforms

log(#/100mL)

**Roads:**

| *Total Coli* | *All roads* |
|---|---|
| Mean | 4.204 |
| Std Error | 0.000 |
| Median | 4.204 |
| Mode | |
| Std Dev | |
| Variance | |
| Kurtosis | |
| Skewness | |
| Range | 0.000 |
| Minimum | 4.204 |
| Maximum | 4.204 |
| Sum | 4.204 |
| Count | 1 |
| 95% | |

**Roofs:**

| *All roofs* |
|---|
| 1.690 |
| 0.018 |
| 1.690 |
| |
| 0.025 |
| 0.001 |
| |
| |
| 0.035 |
| 1.672 |
| 1.708 |
| 3.380 |
| 2 |
| 0.035 |

**High urban excluding roads & roofs:**

| *Total Coli* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* |
|---|---|---|---|---|---|
| Mean | 4.973 | 5.242 | 4.057 | 4.152 | 4.857 |
| Std Error | 0.132 | 0.207 | 0.000 | 0.729 | 0.173 |
| Median | 5.114 | 5.361 | 4.057 | 4.152 | 5.057 |
| Mode | 5.380 | 5.380 | | | |
| Std Dev | 0.908 | 0.926 | | 1.031 | 0.849 |
| Variance | 0.824 | 0.858 | | 1.062 | 0.721 |
| Kurtosis | 0.643 | -0.344 | | | 1.811 |
| Skewness | -0.292 | 0.176 | | | -1.174 |
| Range | 4.693 | 3.573 | 0.000 | 1.458 | 3.716 |
| Minimum | 2.364 | 3.484 | 4.057 | 3.423 | 2.364 |
| Maximum | 7.057 | 7.057 | 4.057 | 4.881 | 6.079 |
| Sum | 233.753 | 104.836 | 4.057 | 8.304 | 116.557 |
| Count | 47 | 20 | 1 | 2 | 24 |
| 95% | 0.259 | 0.406 | | 1.428 | 0.340 |

**Medium & low urban excluding roads & roofs:**

| *Total Coli* | *All medium* | *All low* |
|---|---|---|
| Mean | 6.591 | 3.697 |
| Std Error | 0.000 | 0.138 |
| Median | 6.591 | 3.560 |
| Mode | | 3.477 |
| Std Dev | | 0.338 |
| Variance | | 0.114 |
| Kurtosis | | 0.653 |
| Skewness | | 1.224 |
| Range | 0.000 | 0.881 |
| Minimum | 6.591 | 3.398 |
| Maximum | 6.591 | 4.279 |
| Sum | 6.591 | 22.183 |
| Count | 1 | 6 |
| 95% | | 0.271 |

## Fecal Coliforms

log(#/100mL)

**Roads:**

| *Fecal Coli* | *All Roads* |
|---|---|
| Mean | 3.847 |
| Std Error | 0.184 |
| Median | 3.681 |
| Mode | |
| Std Dev | 0.612 |
| Variance | 0.374 |
| Kurtosis | -0.459 |
| Skewness | 0.718 |
| Range | 1.818 |
| Minimum | 3.146 |
| Maximum | 4.964 |
| Sum | 42.314 |
| Count | 11 |
| 95% | 0.362 |

**Roofs:**

| | *All roofs* | *High urban* | *Low urban* |
|---|---|---|---|
| Mean | 1.728 | 1.819 | 1.181 |
| Std Error | 0.285 | 0.308 | 0.880 |
| Median | 2.061 | 2.074 | 1.181 |
| Mode | 2.061 | | |
| Std Dev | 1.065 | 1.066 | 1.244 |
| Variance | 1.135 | 1.137 | 1.548 |
| Kurtosis | -0.667 | -0.202 | |
| Skewness | -0.531 | -0.694 | |
| Range | 3.505 | 3.505 | 1.760 |
| Minimum | -0.301 | -0.301 | 0.301 |
| Maximum | 3.204 | 3.204 | 2.061 |
| Sum | 24.193 | 21.831 | 2.362 |
| Count | 14 | 12 | 2 |
| 95% | 0.558 | 0.603 | 1.724 |

**High urban excluding roads & roofs**

| *Fecal Coli* | *All high* | *Residential* | *Industrial* | *Commercial* | *Other high* | *Non-resid* |
|---|---|---|---|---|---|---|
| Mean | 3.896 | 4.379 | 3.575 | 3.461 | 3.321 | 3.376 |
| Std Error | 0.126 | 0.151 | 0.370 | 0.384 | 0.219 | 0.172 |
| Median | 3.863 | 4.219 | 3.569 | 3.468 | 3.176 | 3.279 |
| Mode | 5.477 | 5.477 | | | | 2.477 |
| Std Dev | 1.137 | 0.977 | 0.740 | 1.087 | 1.140 | 1.076 |
| Variance | 1.293 | 0.955 | 0.548 | 1.181 | 1.299 | 1.158 |
| Kurtosis | -0.219 | -0.506 | 0.821 | 1.173 | -0.467 | -0.261 |
| Skewness | -0.067 | 0.142 | 0.046 | 0.448 | -0.022 | -0.004 |
| Range | 5.531 | 4.276 | 1.791 | 3.651 | 4.491 | 4.491 |
| Minimum | 1.000 | 2.255 | 2.686 | 1.826 | 1.000 | 1.000 |
| Maximum | 6.531 | 6.531 | 4.477 | 5.477 | 5.491 | 5.491 |
| Sum | 315.581 | 183.915 | 14.302 | 27.691 | 89.674 | 131.666 |
| Count | 81 | 42 | 4 | 8 | 27 | 39 |
| 95% | 0.248 | 0.296 | 0.725 | 0.753 | 0.430 | 0.338 |

**Medium & low urban excluding roads & roofs:**

| *Fecal Coli* | *All medium* | *All low* | *Agricultural* | *Forest* | *Other low* |
|---|---|---|---|---|---|
| Mean | 4.622 | 1.879 | 1.308 | 1.591 | 2.926 |
| Std Error | 1.031 | 0.397 | 0.501 | 0.000 | 0.466 |
| Median | 4.622 | 1.591 | 1.255 | 1.591 | 2.863 |
| Mode | | | | | |
| Std Dev | 1.458 | 1.190 | 1.120 | | 0.807 |
| Variance | 2.126 | 1.416 | 1.254 | | 0.652 |
| Kurtosis | | -0.658 | 2.179 | | |
| Skewness | | 0.132 | 0.967 | | 0.349 |
| Range | 2.062 | 3.763 | 3.079 | 0.000 | 1.611 |
| Minimum | 3.591 | 0.000 | 0.000 | 1.591 | 2.152 |
| Maximum | 5.653 | 3.763 | 3.079 | 1.591 | 3.763 |
| Sum | 9.244 | 16.909 | 6.539 | 1.591 | 8.779 |
| Count | 2 | 9 | 5 | 1 | 3 |
| 95% | 2.021 | 0.777 | 0.981 | | 0.914 |

## Fecal Streptococci

log(#/100mL)

**Roads:**

| *Fecal Strep* | *All roads* |
|---|---|
| Mean | 3.649 |
| Std Error | 0.251 |
| Median | 3.898 |
| Mode | |
| Std Dev | 0.561 |
| Variance | 0.314 |
| Kurtosis | -2.157 |
| Skewness | -0.336 |
| Range | 1.336 |
| Minimum | 2.954 |
| Maximum | 4.290 |
| Sum | 18.247 |
| Count | 5 |
| 95% | 0.491 |

**Roofs:**

| | *All roofs* |
|---|---|
| Mean | 2.906 |
| Std Error | 0.067 |
| Median | 2.906 |
| Mode | |
| Std Dev | 0.095 |
| Variance | 0.009 |
| Kurtosis | |
| Skewness | |
| Range | 0.134 |
| Minimum | 2.839 |
| Maximum | 2.973 |
| Sum | 5.812 |
| Count | 2 |
| 95% | 0.132 |

**High urban excluding roads & roofs:**

| *Fecal Strep* | *All high* | *Residential* | *Commercial* | *Other high* | *Non-resid* |
|---|---|---|---|---|---|
| Mean | 4.279 | 4.694 | 4.505 | 3.732 | 3.818 |
| Std Error | 0.231 | 0.243 | 0.000 | 0.394 | 0.358 |
| Median | 4.322 | 4.627 | 4.505 | 3.708 | 3.792 |
| Mode | | | | | |
| Std Dev | 1.005 | 0.768 | | 1.115 | 1.075 |
| Variance | 1.010 | 0.590 | | 1.244 | 1.155 |
| Kurtosis | 2.332 | -1.111 | | 2.098 | 2.437 |
| Skewness | -0.930 | 0.287 | | -1.081 | -1.268 |
| Range | 4.357 | 2.228 | 0.000 | 3.684 | 3.684 |
| Minimum | 1.462 | 3.591 | 4.505 | 1.462 | 1.462 |
| Maximum | 5.820 | 5.820 | 4.505 | 5.146 | 5.146 |
| Sum | 81.305 | 46.943 | 4.505 | 29.857 | 34.362 |
| Count | 19 | 10 | 1 | 8 | 9 |
| 95% | 0.452 | 0.476 | | 0.773 | 0.702 |

**Low urban excluding roads & roofs:**

| *Fecal Strep* | *All low* | *Agricultural* | *Other low* |
|---|---|---|---|
| Mean | 3.648 | 3.299 | 4.230 |
| Std Error | 0.210 | 0.201 | 0.088 |
| Median | 3.746 | 3.176 | 4.233 |
| Mode | | | |
| Std Dev | 0.595 | 0.450 | 0.152 |
| Variance | 0.354 | 0.202 | 0.023 |
| Kurtosis | -1.666 | -0.896 | |
| Skewness | -0.252 | 0.501 | -0.101 |
| Range | 1.595 | 1.139 | 0.305 |
| Minimum | 2.785 | 2.785 | 4.076 |
| Maximum | 4.380 | 3.924 | 4.380 |
| Sum | 29.184 | 16.495 | 12.689 |
| Count | 8 | 5 | 3 |
| 95% | 0.412 | 0.394 | 0.172 |

# APPENDIX C

## Coefficients of Concentration vs Catchment Characteristics

Regression coefficients (in the log domain) are tabulated for a range of water quality parameters, land uses, and catchment characteristics. Empty cells indicate a sample size too small for analysis. Quality parameters with no numeric entries have been omitted. Three levels of statistical significance are indicated by the density of type.

## Appendix C

| Quality Parameter | Land Use | Coefficients of log concentration versus: | | | |
|---|---|---|---|---|---|
| | | Vehicles/day | Rainfall (mm) | Impervious (%) | People/ha |
| Suspended Solids | Roads | n.s. | -0.00057 | 0.00675 | |
| | Roofs | | 0.00030 | | |
| | High urban | | **-0.00064** | n.s. | n.s. |
| | Low urban | | n.s. | | |
| Total Phosphorus | Roads | **-0.000013** | n.s. | | |
| | Roofs | | | | |
| | High urban | | n.s. | -0.00185 | n.s. |
| | Low urban | | -0.00030 | | |
| Total Nitrogen | Roads | | -0.00027 | | |
| | Roofs | | | | |
| | High urban | | **-0.00028** | 0.00170 | **0.00326** |
| | Low urban | | **-0.00038** | | |
| BOD | Roads | | | | |
| | Roofs | | | | |
| | High urban | | n.s. | n.s. | **0.00162** |
| | Low urban | | | | |
| COD | Roads | 0.000002 | -0.00032 | n.s. | |
| | Roofs | | | | |
| | High urban | | **-0.00032** | 0.00181 | 0.00076 |
| | Low urban | | n.s. | | |
| Total Organic Carbon | Roads | | | | |
| | Roofs | | | | |
| | High urban | | **-0.00054** | | |
| | Low urban | | | | |
| Total Lead | Roads | **0.000006** | n.s. | n.s. | |
| | Roofs | | 0.00061 | | |
| | High urban | | n.s. | 0.00429 | -0.00118 |
| | Low urban | | n.s. | n.s. | |
| Total Zinc | Roads | 0.000003 | -0.00033 | 0.00576 | |
| | Roofs | | n.s. | | |
| | High urban | | -0.00029 | 0.00385 | -0.00168 |
| | Low urban | | | | |
| Total Cadmium | Roads | 0.000004 | n.s. | n.s. | |
| | Roofs | | | | |
| | High urban | | n.s. | -0.01065 | -0.00234 |
| | Low urban | | | | |
| Total Chromium | Roads | | | | |
| | Roofs | | | | |
| | High urban | | -0.00037 | n.s. | **-0.00936** |
| | Low urban | | | | |
| Total Copper | Roads | n.s. | -0.00034 | n.s. | |
| | Roofs | | n.s. | | |
| | High urban | | -0.00031 | n.s. | n.s. |
| | Low urban | | | | |
| Total Nickel | Roads | | | | |
| | Roofs | | | | |
| | High urban | | -0.00022 | -0.00624 | n.s. |
| | Low urban | | | | |
| Total Iron | Roads | | | | |
| | Roofs | | | | |
| | High urban | | -0.00030 | 0.00690 | |
| | Low urban | | | | |
| Total Mercury | Roads | | | | |
| | Roofs | | | | |
| | High urban | | **0.00122** | n.s. | n.s. |
| | Low urban | | | | |
| Total Coliforms | Roads | | | | |
| | Roofs | | | | |
| | High urban | | 0.00113 | | 0.00554 |
| | Low urban | | | | |
| Fecal Coliforms | Roads | | | | |
| | Roofs | | | | |
| | High urban | | n.s. | n.s. | **0.01031** |
| | Low urban | | | | |
| Fecal Streptococci | Roads | | | | |
| | Roofs | | | | |
| | High urban | | 0.00166 | | n.s. |
| | Low urban | | | | |

blank = not tested, n.s. = not significant, small type = $P < 0.2$, normal = $P < 0.05$, **bold = $P < 0.01$**

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Goulburn-Murray Water

Melbourne Water

Monash University

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