CHARACTERISTICS OF URBAN DEVELOPMENT

AND ASSOCIATED STORMWATER

QUALITY

by

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A DISSERTATION

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ABSTRACT

Urban land uses and their associated impervious cover increase the quantity and worsen the quality of stormwater runoff, which can seriously impair receiving waters. It is known that there is considerable variability in runoff quantity and quality between rain-to-rain events due to rainfall spatial variability. In addition, runoff presents significant variability between neighborhoods, even if they are affected by the same rain event. It is hypothesized that the variability in stormwater quality between sites is associated with the difference in land uses and surface covers.

This research examined the variability in stormwater quality characteristics as contained in the National Stormwater Quality Database (NSQD) for different land use categories and nine selected stormwater constituents (TSS, total zinc, total copper, total lead, total phosphorous, dissolved phosphorous, total nitrogen, TKN, and fecal coliform) at different geographical scales - national, regional (EPA Rain Zone 2), and local levels (Jefferson County, AL). The results of the local data analyses were compared to the results obtained from the national and regional analyses.

This research also examined the detailed land development characteristics based on actual local field measurements and explained how this variability affects the variability in stormwater characteristics. The land development characteristics information was collected from Little Shades Creek watershed and five highly urbanized drainage areas situated in Jefferson County, AL (in and near the city of Birmingham). About 170 neighborhoods were surveyed in detailed to determine the actual development characteristics and their variability.

This research found that each major land use had unique patterns and mixtures of surfaces. These, in addition to the activities taking place within the land uses, affect the runoff quality and its variability from these areas. It was found that there is less variability in stormwater quality characteristics within each land use category compared to the variability between the land use categories. This finding is also true for land cover areas in that there are lower levels of variations in these area types within each land use compared to between the different land uses.

The results from this dissertation analyses can be used as guidance for local stormwater quality monitoring efforts, but the specific results are not all expected to be applicable everywhere. The main focus of this research was in investigating stormwater variability, specifically its sources and how it can be reduced. The general concern with the high variability that is associated with stormwater quality is the uncertainty of being able to meet discharge requirements, even with extensive use of stormwater control practices. This uncertainty can be eliminated, or at least reduced, by a better understanding of sources of this variability. Specifically, appropriate discharge regulations that recognize this variability will assist the stormwater managers to better use their financial resources and to maximize receiving water quality improvements.

DEDICATION

To My Mothers
Ileana Bochis and Mariana Caslaru

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1.1 Introduction

Wastewater treatment plants reduce pollution discharges from point sources to the waters of the United States, while most nonpoint sources are untreated and have long been considered to be the major contributor of most pollutants to receiving waters (Sartor et al. 1974). Urban stormwater runoff is classified as nonpoint source of pollution and has become a large pollution source as worldwide urbanization continues. The increase in land development results in increases in impervious surface area, leading to increases of runoff volume and peak flow rates. Sartor's et al. (1974) major conclusion was that stormwater runoff is highly contaminated and in some cases is as bad as or worse than municipal sewage. Also, they found that concentrations of suspended solids, nutrients and heavy metals in urban runoff were much higher than that of vacant land and rural runoff. Concentrations of stormwater contaminants from urbanized watersheds can be highly variable due to multiple land uses, storm event size, duration, and constituent sources (Stenstrom et al. 1984).

Local development characteristics (such as land use, land cover, the amounts of impervious areas, and the drainage system type) are the most important elements that affect stormwater quality and quantity (Maestre and Pitt 2005b).Water quality problems are exacerbated with increasing imperviousness and certain activities associated with the land use (Pitt et al. 2005a and 2005b). The nonpoint source water pollution discharge quantities from impervious areas are directly related to land use activities. Impervious surfaces have also become a key issue in growth management and watershed planning, and an indicator in measuring the impact of land development on drainage systems and aquatic life (Schueler 1994; Arnold and Gibbons 1996).

Previous studies (Stenstrom et al. 1984; Fam et al. 1987; Lau and Stenstrom 2003; Ha and Stenstrom 2003) identified relationships between water quality and land use. This relationship is supported by stormwater databases developed during the Nationwide Urban Runoff Program (NURP) study (USEPA 1983), by CDM (Smullen and Cave 2002), USGS (Driver et al. 1985), and the National Stormwater Quality Database (NSQD) (Maestre and Pitt 2005a). Estimation of stormwater characteristics based on land use is a common approach and generally accepted by researchers because land use is related to the activity in the watershed and, in addition, many site features are consistent within each land use category, including the amounts of impervious cover. However, Lee et al. 2007 found no relationship between various types of industrial activities or land use and water quality data in Los Angeles County. They concluded that the results of their study were probably affected by monitoring errors such as grab samples and non-standard timing for sample collection. Lee et al. 2007 also concluded that the variability in the stormwater data is several times greater the mean value, so there is a need to develop better monitoring programs that will reduce the variability due to sampling errors. The variability in stormwater quality is usually assumed to be influenced by many factors, including seasons, traffic density, antecedent conditions (number of days since the last rainfall), land use, and rainfall intensity. Consequently, it is necessary to clearly identify the relationships existent between land use and nonpoint sources of pollution to better support land use control strategies and to effectively control stormwater pollution.

Good watershed area descriptions, accurate drainage area delineations, and descriptions of source areas of pollution are needed for all monitored sites if the intention is to determine the variations in runoff quantity and quality associated with variations in site characteristics. In order to determine how land development variability affects the quantity and quality of runoff, different land surfaces (roofs, streets, landscaped areas, parking lots, etc.) for different land uses (residential, commercial, industrial, institutional, etc.) have to be measured. This information can be used with stormwater models to calculate the runoff quantity and quality for each neighborhood investigated.

1.2 Research Objectives

The main study areas for this research are the Little Shades Creek watershed (Jefferson County, near Birmingham, AL) and five highly urbanized drainage areas situated in Jefferson County, AL (in and near the city of Birmingham). The field data for about 125 neighborhoods located in the Little Shades Creek Corridor was collected during an earlier study of this watershed as part of a cooperative study conducted by the University of Alabama at Birmingham, the Jefferson County office of the U.S. Natural Resources Conservation Service (NRCS), the U.S. Army Corps of Engineers, and other city and county governments. The field data collection effort for the 45 neighborhoods located in the highly urbanized drainage basins was performed during the author's master thesis research (Bochis 2007). The sites were surveyed to determine their actual development characteristics and their variability.

The current research used the stormwater MS4 (municipal separate storm sewer system) permit data for the five drainage areas (included in the National Stormwater Quality Database, Maestre and Pitt 2005a) to evaluate the stormwater constituents' variability for Jefferson County, Alabama. Similar analyses were performed on national data and were compared with local data in order to establish a pattern of stormwater constituents' variability and clustering. The field measurements for Little Shades Creek and the five Jefferson County drainage basins were used to examine the local variability in land use development characteristics and to explain how this variability (especially impervious cover) affects the variability in stormwater characteristics. This research quantifies the calculated uncertainty based on actual field measurements of land development characteristics for each neighborhood, and determines how much detail is needed to be known about each land use in order to explain the stormwater variability. Evaluations include statistical analyses conducted at several levels to establish the quantitative and qualitative runoff sensitivity associated with variations of these site characteristics, stressing the impervious surfaces.

This research aims to explain the role land use/land cover has in impairing stormwater quality and help communities and local governments make their investment in stormwater management and monitoring useful. Stormwater managers have been long concerned with the high variability in stormwater quality and the associated uncertainty of being able to meet discharge requirements, even with extensive use of stormwater control practices. A better understanding of this variability, along with more appropriate discharge regulations that recognize this variability, will assist these decision makers to better use their scarce financial resources and to maximize receiving water quality improvements.

1.3 Dissertation Organization

This dissertation is organized in six chapters and six appendices. Chapter 2 is a review of relevant literature on impervious surfaces and nonpoint sources of pollutants in stormwater. Next, the experimental design and a description of methodology utilized to collect, to process the

field data, and to build the WinSLAMM files, along with a detailed description of the Birmingham watersheds, are presented in Chapter 3. Chapter 4 presents the study of the stormwater variability at the national level and at the local level (Jefferson County, Alabama). Chapter 5 analyzes the local land use development characteristics variability. The results, discussions, and conclusions are presented in Chapter 6.

The appendices contain the detailed analyses of stormwater constituents at both national and local levels, the detailed analyses of land development characteristics, and the WinSLAMM model re-calibration processes using the local data.

The preliminary results for this dissertation research were published as book chapters, and as articles in several conference proceedings, including:

<u>Book Chapters (peer-reviewed)</u>:

Bochis, Celina, and Robert Pitt. Impervious Cover Variability in Urban Watersheds. In: *Dynamic Modeling of Urban Water Systems*, *Monograph 18.* ISBN 978-0-9808853-3-0. (Edited by W. James, K. N. Irvine, J. Li, E.A. McBean, R.E. Pitt and S.J. Wright). CHI, Guelph, ON Canada. 2010. pp. 131-146.

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Bochis, Celina and Robert Pitt. Characteristics of Land Development in Central Alabama. *Proceedings of the Water Environment Federation, WEFTEC 2008.* Chicago, IL, Session 73. October 18-22, 2008.

Bochis, Celina, Robert Pitt, and Pauline Johnson. Modeled Flow Duration Characteristics for Different Stormwater Controls. *World Environmental and Water Resources Congress 2007. ASCE- EWRI. Conference Proceedings.* Tampa, FL, May 15-19, 2007 (poster).

Bochis, Celina, Robert Pitt, and Pauline Johnson. Modeled Flow Duration Characteristics for Different Stormwater Controls. *30th Annual Alabama's Water Environment Association Technical Conference. Conference Proceedings.* Orange Beach, AL, April 15-18, 2007 (poster) – Winner of the Best Poster Award

Pitt, Robert, Celina Bochis, and Shen-En Chen. Development and Soil Characteristics Effects on Runoff. *2nd National Low Impact Development Conference. Conference Proceedings.* Wilmington, NC, March 12-14, 2007.

Chapter 2
Literature Review

2.1 Stormwater and Impervious Surfaces

Stormwater is the flow of water that results from precipitation and occurs during and immediately following rainfall or is a result of snowmelt. Stormwater discharges are generated by precipitation and runoff from land, pavements, building rooftops and other surfaces. Precipitation in the form of rain contains some impurities that accumulate as it falls through the Earth's atmosphere, but usually does not contain any bacteria (Davis and Cornwell 1998). Once the precipitation reaches the Earth's surface, the possibility of it becoming contaminated (with organic and inorganic substances) is imminent (Davis and Cornwell 1998). In natural watersheds, a part of the rainfall is infiltrated into the soil, stored as groundwater and after that moved back into streams through seeps and springs, is taken up by plants, or is evaporated into the atmosphere. Thus, much of the rainfall does not directly enter streams during the rain event, which moderates stream flows during the rains while recharging groundwater and supplies water for later dry season stream flows. Under natural conditions, about 90% of the rainfall infiltrates into the soil surface, while only about 10% directly enters the streams (Reilly et al. 2004). Stormwater runoff is the portion of the precipitation that runs off land surfaces directly into the receiving waters.

Impervious surfaces exist in nature in the form of exposed bedrock, but their exposure on the surface is limited. More commonly, imperviousness is associated with human growth. In urban areas, impervious surfaces include roads, road shoulders, parking lots, driveways, sidewalks, rooftops, and patios. They restrict the infiltration of water during rains leading to multiple impacts on stream systems. In addition, severely compacted soils resulting from development activities and continuous use also severely restrict infiltration (Wigmosta et al. 1994; Pitt et al. 1999) and act as near-impervious surfaces having lower storage volumes (Alberti et al. 2007). Compacted, uncovered, or paved-over soils may allow some precipitation to infiltrate, but the soil reaches surface saturation rapidly and more frequently (Booth 1991; Arnold and Gibbons 1996).

Imperviousness has long been used as an indicator in measuring the impacts of land development on drainage systems. It is one of the variables that can be quantified, managed, and controlled at each stage of land development (Schueler 1994). Water quality problems increase with increased imperviousness and intensity of land use. The change in hydrology, water quality and quantity, and biodiversity of aquatic systems is directly related with the imperviousness of the drainage area. The percentage of impervious surface within a particular watershed has been recognized as a key indicator of the effects of nonpoint runoff and of future water and ecosystem quality (Schueler 1994; USEPA 1994; Arnold and Gibbons 1996).

Research conducted in many geographic areas, using many different variables and employing different methods, has addressed the relationship between watershed urbanization and overall stream quality. They all concluded that stream degradation starts to occur in watersheds having relatively low levels of imperviousness (usually between 5 and 10%), and watershed health becomes severely impaired and considered degraded if the imperviousness exceeds 25 or 30% of the total watershed area (Schueler 1994; Arnold and Gibbons 1996; Booth and Jackson 1997).

Due to credible scientific evidence, more local communities are using the impervious cover of a watershed as a tool in their local planning, zoning and watershed analysis efforts. Therefore, the accuracy of describing impervious cover measurements is essential when using it as a management tool, especially when the variability of imperviousness increases with increasing watershed development (Ackerman and Stein 2008). Impervious cover is also a critical input variable in many water quality and quantity simulation models, such as the Storm Water Management Model (SWMM) (Huber and Dickenson 1988), the Hydrologic Simulation Program Fortran (HSPF) model (Al-Abed and Whiteley 2002), and the Source Loading and Management Model (SLAMM) (Pitt and Voorhees 1995; 2002), as well as engineering models such as the Simple Method (Schueler 1987), TR-20 and TR-55 (USDA SCS 1982 and USDA NRCS 1986), and the Corp of Engineers' HEC-HMS model.

2.2 Components of Imperviousness, Its Measurements, and Estimation

Impervious cover is a major topic of this dissertation and refers to any land surface that has been covered with material that significantly decreases or prevents the infiltration of runoff (but not considering compacted urban soils). The term **imperviousness** refers to the percentage of impervious cover within a specified area of land.

Urban impervious cover is composed of two principal components: building rooftops and the transportation system (roads, driveways, and parking lots). It is most visible in industrialized and commercial areas, but is also abundant in residential areas, even if not as abundant. Compacted soils, unpaved parking, and graveled driveway areas also have "impervious" characteristics because they severely restrict the infiltration of water, even though they are not composed of pavement or roofing material.

Impervious surfaces can be separated into two components: *people habitat* where we live and work, and *car habitat* where we drive and park our vehicles (Schueler 1994). In terms of total impervious area, the transportation component often exceeds the rooftop component (City of Olympia 1994; Schueler 1994; Cappiella and Brown 2001). In the City of Olympia, WA (1994), 11 residential, multifamily, and commercial areas were analyzed in detail, concluding that the areas associated with transportation-related applications involve 63-70 % of the total impervious cover (City of Olympia 1994). Cappiella and Brown (2001), analyzed four suburban Chesapeake Bay communities having 12 different land uses, and reached a similar conclusion: the transportation environment ranges from 55% to 75% of the total impervious surface area.

A significant portion of these impervious areas, mainly parking lots, driveways, and road shoulders, experience only minimal traffic activity (Wells 1995). Most retail parking lots are sized to accommodate peak parking usage, which occurs only occasionally during the peak holiday shopping season, leaving most of the area unused for a majority of the time, while many business and school parking areas are used to their full capacity nearly every work day and during the school year. Other differences at parking areas relate to the turn-over of parking during the day. Parked vehicles in business and school parking lots are mostly stationary throughout the work and school hours. The lighter traffic in these areas results in less vehicle-associated pollutant deposition and less surface wear in comparison to the greater parking turn-over and larger traffic volumes in retail areas (Brattebo and Booth 2003).

The construction of impervious surfaces leads to multiple impacts on stream systems. Many therefore have concluded that future development plans and water resource protection programs should take into consideration reducing impervious cover in the potential expansion of communities. Research (Schueler 1994; City of Olympia 1994; Wells 1995; Booth 2000; Kwon

2000; Stone 2004; Gregory et al. 2005) shows that reducing the size and dimensions of residential parcels, promoting cluster developments (clustered medium density residential areas in conjunction with open space, instead of large tracts of low density areas), building taller buildings, reducing the residential street width (local access streets), narrowing the width and/or building one-side sidewalks, reducing the size of paved parking areas to reflect the average parking needs instead of peak parking needs, and using permeable pavement for intermittent/overflow parking, can reduce the traditional impervious cover in communities by 10-50% . Many of these benefits can also be met by paying better attention to how the pavement and roof areas are connected to the drainage system. Impervious surfaces that are "disconnected" by allowing their drainage water to flow long distances over adjacent landscaped areas can result in reduced runoff quantities.

There are two main categories in which impervious cover should be classified: directly connected impervious areas (or effective impervious area) (DCIA or EIA) and non-directly connected (disconnected) impervious area (Sutherland 2000; Gregory et al. 2005). An impervious area is considered directly connected if runoff from it flows directly into a sealed drainage system. It is also considered directly connected if runoff from it occurs as a concentrated flow that runs over a short length of a pervious surface (usually a flow length less than 5 to 20 feet, depending on soil compaction and slope characteristics and the amount of runoff), and then into a drainage system.

Approximately 80% of directly connected impervious areas are associated with vehicle use areas (streets, driveways, and parking) (Heaney 2000). Usually, for a given basin, effective imperviousness (EIA) is less than the total impervious area (TIA). However, in highly urbanized basins, EIA values can approach and equal TIA (Sutherland 2000).

It is incorrect to assume that all the precipitation reaching the impervious areas becomes direct runoff. In reality, the precipitation falling on disconnected impervious areas will not always result in direct runoff. Therefore, for accurate estimates of runoff quantity and especially runoff quality, only the effective impervious area should be used. The use of total imperviousness would result in overestimated pollutant loads.

Urban imperviousness is site specific and can be complicated to measure. There are several methods used to measure actual and future impervious covers, some of which are more accurate than others. The most accepted techniques include direct measurement, estimation of impervious cover based on land use, estimation from road density (length of road per unit area), and estimation of impervious cover from population data, aerial photograph interpretation, and satellite remote sensing. Most common methods of determining EIA are field measurements and empirical equations.

Several studies have investigated imperviousness cover estimation methods:

- Stankowski (1972), Graham et al. (1974), Heaney et al. (1977), Hicks and Woods (2000), Sheng and Wilson (2009) approximated imperviousness as being a function of developed population density.
- Dinicola (1989) showed that dwellings per unit area can be used to predict impervious cover, but estimating the impervious cover from population numbers is a better approach since the US Census Bureau has reported that the number of residents per household has declined from 3.1 in 1970 to 2.6 in 2002 and the average size of single-family homes increased from 1,500 square feet to over 2,200 square feet between 1970 and 2000.
- Graham et al. (1974) and Novotny and Olem (1994) found a strong relation between the residential total impervious area and the curb length per unit area.

- The US Environmental Protection Agency estimated that approximately 21 feet of stormwater sewer is needed per resident in the service area (USEPA 2008).
- The City of Olympia (1994) study estimated imperviousness from engineering plans and Hydrological Simulation Program-Fortran (HSPF) models.
- Cappiella and Brown (2001) used direct measurement for their calculations of imperviousness in the suburban Chesapeake Bay area.
- Debo and Reese (2003) demonstrated a method to adjust the Soil Conservation Service curve number based on the proportion of directly connected impervious area.
- Schueler (1994, 1995) summarized the importance of imperviousness for urban water environment and presented a relationship between urban land use and imperviousness.
- Booth and Jackson (1997) suggested using EIA to characterize urban development and explained the limitations of using TIA in urban hydrology.
- Empirical equations for determining EIA have been developed as part of several different studies (Alley and Veenhuis 1983; Laenen 1983; Sutherland 2000). The results can be generalized either as a correlation between the TIA and EIA parameters or as a "typical" value for a given land use.

Livingston and Veenhuis (1981) (as reported by Alley and Veenhuis 1983) developed a commonly used empirical relationship between TIA and EIA from 14 highly urbanized basins in Denver, CO ($R^2 = 0.98$):

$$EIA = 0.15(TIA)^{1.41} \tag{2.1}$$

Where: EIA = effective impervious area (directly connected impervious area)

TIA = the total impervious area

Laenen (1983) (as cited by Sutherland 2000) developed another relationship based on USGS work completed in the Portland and Salem, OR areas on more than 40 watersheds. Their equation was:

$$EIA = 03.6 + 0.43(TIA) \qquad (2.2)$$

This equation works well for TIA values in the range of 10% to 50%, but gives unrealistic EIA estimates for TIA values situated outside of this range. Therefore, the equation is not feasible for management of small sub-basins which normally have values greater than 50% TIA.

Using typical land use values, Dinicola (1989) compiled the results of earlier research and recommended a single set of impervious area values based on five land use categories for use in western Washington watersheds (Table 1).

Table 1. Presumed Relationship between Imperviousness and Land Use

Land Use	**TIA (%)**	**EIA (%)**
Low density residential (1 unit/2-5 acres)	10	4
Medium density residential (1 unit/ acre)	20	10
Suburban density (4 units/acre)	35	24
High density (multi family or 8+ units/acre)	60	48
Commercial and Industrial	90	86

Source: Dinicola, R. S., 1989. *Characterization and Simulation of Rainfall-Runoff Relations for Headwater Basins in Western King and Snohomish Counties, Washington State*. U. S. Geological Survey. Water Resources Investigation Report 89-4052: 52 pages.

The same USGS data used by Laenen was re-analyzed by Sutherland (2000) to develop a series of equations to describe the relationship between effective impervious area and total impervious area for use in hydrologic models. Its general form is:

$$EIA = A(TIA)^B \qquad (2.3)$$

Where: EIA = effective impervious area

TIA = total impervious area

A and B = unique combination of numbers that satisfy the following criteria:

TIA = 1 then EIA = 0%

TIA = 100 then EIA = 100%

This equation has several alternatives, known as the "Sutherland EIA Equations," developed to apply to various conditions of sub-basins that might exist in a watershed. They are summarized as follows:

1. Extremely disconnected basins, with either extensive infiltration measures or the basin is served predominantly with ditches/swales:

$$EIA = 0.01(TIA)^{2.0}, TIA \geq 1 \tag{2.4}$$

2. Somewhat disconnected basins with at least 50% of urban areas served by ditches or swales, and roofs disconnected, or an average basin with some infiltration measures:

$$EIA = 0.04(TIA)^{1.7}, TIA \geq 1 \tag{2.5}$$

3. Average basins where the predominant drainage collector is a storm sewer with curb and gutters, no infiltration measures, and the roofs in the residential areas are disconnected:

$$EIA = 0.1(TIA)^{1.5}, TIA \geq 1 \tag{2.6}$$

4. Highly connected basins, drainage collectors are storm sewers with curb and gutters, roofs are connected, no infiltration devices:

$$EIA = 0.4(TIA)^{1.2}, TIA \geq 1 \tag{2.7}$$

5. Totally connected basins, the complete urban area is serviced by storm sewers, and all impervious areas are connected:

$$EIA = TIA \tag{2.8}$$

There is a similarity between the Alley and Veenhuis equation and the Sutherland "average basins" equation. These equations provide very close estimates of EIA with the Alley and Veenhuis equation, and are slightly more conservative for TIAs less than 50%.

There are numerous methods available for making stormwater runoff quantity and pollutant load computations, most relying on impervious cover as one of the most important input variables. Watershed managers use these methods to design storm drainage systems and to predict the health of the receiving waters. Some models use predefined impervious cover values (e.g. runoff coefficients or curve numbers developed using typical impervious values for different land uses), while more complex computer models use the measured or estimated impervious cover values directly. Therefore, the measurement accuracy of imperviousness is very important.

The "Rational Method" is an empirical method that uses a coefficient that is a function of the land cover and drainage basin slope to determine peak discharge from a drainage area. It is one of the oldest methods still in use, being introduced by the Irish engineer Mulvaney in1850 (Butler and Davies 2004). It was later used by Emil Kuichling (1889) in the United States who applied it to drainage system designs in Rochester, NY (1877-1888) (Walesh 1989; Butler and Davies 2004) and by D.E. Lloyd-Davies (1906) who also used it for sewer design in United Kingdom (Butler and Davies 2004). Mulvaney proposed that:

$$Q_p = CiA \tag{2.9}$$

Where: Q = drainage area runoff rate (ft^3/sec)

C = runoff coefficient (0.0 to 1.0)

i= rainfall intensity for the time of concentration (in/hr)

A = drainage area (below 200 acres) (acres)

The runoff coefficient considers a combination of rainfall abstractions (infiltration, interception, retention, and depression storage) and diffusion (evaporation), all of which affect the time distribution and peak rate of runoff. As an empirical parameter, the runoff coefficient is selected based on land use, soil type and drainage basin slope (Chow 1964; ASCE 1992). The runoff coefficient of the Rational Method is presumed to be directly proportional to the total imperviousness. Literature presents typical values of the coefficient for different surface characteristics. The method persists because of its ease of use, not because of its confirmation.

Technical Release 55 (TR-55) developed by the USDA Soil Conservation Service (SCS), now the Natural Resources Conservation Service (NRCS), in 1975, provides a number of tools useful for modeling small and urbanized watersheds, all based on the “curve number” method. TR-55 utilizes the SCS rainfall-runoff equation that includes the runoff factor, to predict the peak rate of runoff as well as the total volume. The runoff calculations rely on the runoff curve numbers (CN) which is sensitive to some of the characteristics of the watershed, including the soil hydrologic group, the land use (and assumed imperviousness), and the antecedent soil moisture. The method was originally based on observed runoff from agricultural watersheds. The SCS has classified over 8,500 soil series into four hydrologic groups according to their infiltration characteristics. Infiltration rate decreases and surface runoff potential increases as soil types are classified A (sandy) through D (clayey) (USDA NRCS 1986).

One feature of the TR-55 method that is of particular concern is the curve numbers for urbanized watersheds because they were developed based on assumed percentages of impervious areas for different development categories (land uses). The SCS cites the following method for the development of curve numbers as listed in their tables (Debo and Reese 2003):

1. The method is based on a typical degree of imperviousness assigned to each urban land use. The SCS uses 12, 20, 25, 30, and 38 percent impervious surfaces for residential lots of average size 2 acre, 1 acre, 1/2 acre, 1/3 acre, 1/4 acres, respectively, and 65, 72, and 85 percent imperviousness for row houses, industrial, and commercial land uses, respectively (Table 2).
2. The impervious area is assigned a curve number of 98 regardless of underlying soil type while the remaining pervious area is assigned the same curve number as open space (lawn) in good hydrologic condition .
3. The aggregate curve number for any of these land uses is then just the weighted average of the curve numbers for these two land cover classifications resulting from the assumed degree of imperviousness.

This method was empirically developed and assumptions were made in all areas, while data collection for the SCS Runoff Curve Number Method is not clearly defined in Technical Release 55 (USDA NRCS 1986).

Schueler (1987) proposed the Simple Method to calculate urban stormwater loads as the product of mean pollutant concentrations and runoff depths over a period of time. This method also calculates annual runoff as a product of runoff volume and volumetric runoff coefficient, which is calculated based on impervious cover in the sub-watershed. The equations are:

$$\begin{aligned} R &= P * P_j * R_v \\ R_v &= 0.05 + 0.9 * I_a \end{aligned} \tag{2.10}$$

Where: R = Annual runoff (in)

P = Annual rainfall (in)

P_j = Fraction of annual rainfall events that produce runoff

R_v = Volumetric runoff coefficient

I_a = Impervious fraction

Representative impervious cover data, along with model default values, are presented in Table 2. It must be noted that Northern Virginia (NVPDC 1980) data includes effective impervious cover, but this study does not account for rooftops in the residential data. Also, the Prisloe et al. (2000) data does not include area from state and local roads. The Simple Method model default values for impervious cover are approximately equal to the median of Olympia, Puget Sound, NRCS, and Rouge River data, with adjustments made where studies estimate impervious cover for a broad range of housing densities. The study conducted in Chesapeake Bay by the Center for Watershed Protection under a USEPA grant (Cappiella and Brown 2001) was intended to update the previous studies' impervious cover values.

Continuous simulation models, such as the Storm Water Management Model (SWMM), Hydrologic Simulation Program-Fortran (HSPF) model, or the Source Loading and Management Model (WinSLAMM) also use sub-watershed impervious values as input variables to simulate runoff quantity and quality from primarily urban areas.

Values of imperviousness can vary significantly according to the method used to determine the impervious cover (Lee and Heaney 2003; Ackerman and Stein 2008). Ackerman and Stein (2008) found that imperviousness in southern California study areas could vary by 20 to 40 % within a land use category. In a detailed analysis of urban imperviousness in Boulder, CO, Lee and Heaney (2003) found that hydrologic modeling of the study area (I of 35.9% and the EIA of 13.0%) resulted in large variations (265% difference) in the calculations of peak discharge when impervious surface areas were determined using different methods. They concluded that the main focus should be on EIA when examining the effects of urbanization on stormwater quantity and quality, because it is known that impervious surfaces interrupt the hydrologic cycle. Reducing the EIA will not restore hydrologic function to pre-development

Table 2. Percent Impervious Covers for Various Land Uses

Land Use	**Density (units/ac)**	**Source**									
		Northern Virginia (NVPDC, 1980)[1]	**TR-55 NRCS (USDA, 1986)**[1]	**Puget Sound, WA (Aqua Terra, 1994)** [1]	**Rouge River, MI (Kluitenberg, 1994)** [1]	**Olympia, WA (COPWD, 1995)** [1]	**Holliston, MA (CRWA, 1999)** [1]	**Connecticut (Prisloe, 2000)** [1]	**Chesapeake Bay (CWP, 2000)** [1]	**Birmingham, AL (Bochis, 2007)** [2]	**Simple Method (Schueler 1987)** [3]
Forest	-	1	-	-	2	-	1	-	-		-
Agriculture	-	1	-	-	2	-	1	-	2		-
Urban Open Land	-	-	-	-	11	-	7-23	-	9	13	-
Water/ Wetlands	-	-	0	-	-	-	-	-	-	-	-
Low Density Residential	<0.5	2-6	-	10	19	-	12	7-10	-	-	10
	0.5	9	12						11	-	
	1	12	20						14	18	
Medium Density Residential	2	18	25	-	19	-	14	14-21	21	22	30
	3	20	30	40		40			-		
	4	25	38						28		
High Density Residential	5-7	35	65	40	38	40	19	28	33	30	40
Multifamily all >7 units/acre	Townhouse	40	65	60	51	48	47	39	41	35	60
	Apartments	50							44	42	-
	High Rise	60-75	-	-	-	-	-	-	-	-	-
Commercial	-	90-95	85	90	56	86	45	54	72	73	85
Institutional	-	-	-	-	-	-	-	-	34	46	-
Industrial	-	60-80	72	90	76	86	60	53	53	59	75
Roadway	-	-	-	-	-	-	-	-	-	58	80

Source: [1] Cappiella, Karen, and Ken Brown. 2001. Land Use and Impervious Cover in the Chesapeake Bay Region. *Watershed Protection Techniques*, 3(4): 835-840.

[2] Bochis, Celina. 2007. Magnitude of Impervious Surfaces in Urban Areas. Master Thesis. Department of Civil, Construction, and Environmental Engineering. The University of Alabama. Tuscaloosa, AL.

[3] Schueler, Thomas. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices. Publ. No. 87703. *Metropolitan Washington Council of Governments*. Washington, D.C.: 272 pp.

levels, but will improve the base flows, lessen the frequency of bank erosion, and improve stream functions. Reducing effective impervious areas can be accomplished by disconnecting impervious surfaces (sidewalks, rooftops, parking areas, and streets) from the drainage system, encouraging increased runoff infiltration, decreasing the amount of direct runoff into the receiving waters.

Runoff from disconnected impervious areas is allowed to spread over pervious surfaces as sheet flows and partially or completely infiltrates before reaching the drainage system. Therefore, there can be a substantial reduction in the runoff volume and a delay in the remaining runoff in entering the storm drainage collection system, depending on the soil infiltration rate, the depth of the flow, and the available flow length. Examples of disconnected impervious surfaces are rooftops that discharge into lawns, streets with swales, parking lots with runoff directed to adjacent open space or swales, etc. From a hydrological point of view, road-related imperviousness usually exerts larger impacts than the rooftop-related imperviousness, because roadways are usually directly connected while roofs can be hydrologically disconnected (Schueler 1994). For small rain depths, almost all the runoff and pollutants originate from directly connected impervious areas, as disconnected areas have most of their flows infiltrated (Pitt 1987). For larger storms, both directly connected and disconnected impervious areas contribute runoff to the stormwater drainage system. In many cases, pervious areas are not hydrologically active (produce runoff) until the rain depths are relatively large and are not significant runoff contributors until the rainfall exceeds about 25 millimeters for many land uses and soil conditions, depending on soil compaction, etc.

EIA reductions can occur as part of new development (compared to traditional mostly connected developments), redevelopment, or as retrofit construction. The level of benefit is determined by how well the practices minimize runoff in small to mid size storm events. Cappiella and Brown (2001) proposed that the estimation of impervious cover be based on land use according to their research conducted by the Center for Watershed Protection in the Chesapeake Bay area.

2.3 Assumptions about Impervious Areas and the Need for Local Surveys

There are many assumptions concerning impervious areas, most concerning how impervious cover varies for each type of land use. There is a general recognition that directly connected impervious areas are the most important feature of impervious surfaces. A number of approaches have been used for measuring and estimating impervious cover. While ground surveys and determinations of impervious cover from satellite images can be extremely accurate, they can be very expensive and labor intensive. Although this is called direct measurement, there is a need for some assumptions to give precise answers. For example, modelers make assumptions to estimate the additional area of sidewalks and driveways because of GIS limitations or lack of data. Sidewalks appear in most GIS layouts as a line, so they have to be multiplied by a standard width (usually 4 feet) to obtain an area (Cappiella and Brown 2001). Most of the time, driveways do not appear in GIS analyses, so each single-family detached lot is assumed to have a standard average driveway area of 450 sq. ft (MNCPPC 1995). It is common to make assumptions regarding the imperviousness of non-paved areas, such as forest land is 1% impervious and non-paved, but non-forest land is 3% impervious (MNCPPC 1995), although this particular set of assumptions may not be appropriate everywhere. Similar assumptions are needed to account for smaller impervious areas such as sheds, pools, and decks that do not show up with GIS analyses or aerial photography (Cappiella and Brown 2001). There are very little data available and published to support the assumptions of impervious cover for different types of land uses. For example, TR- 55 (USDA NRCS 1986) assumes all impervious areas to be directly connected to the drainage system (their documentation presents a crude method to adjust for partially connected impervious cover, but it is seldom used). TR-55 also presents specific percentages of impervious area (Table 2) for typical land uses, based on locations where the urban curve numbers were developed. Again, it is possible for a user to select another category that better corresponds with locally measured imperviousness, but that local data is seldom available, especially for effective imperviousness.

In 1998, the Center for Watershed Protection published the *The Rapid Watershed Planning Handbook,* which presents an efficient, eight-point program for developing effective watershed plans, and details various methodologies used in watershed planning, such as impervious cover measurement and estimation. The Impervious Cover Model (Center for Watershed Protection 1998) which classifies urban streams based on the percentage of impervious cover existing in the watershed assumes that all watershed impervious cover (total impervious cover) contributes runoff to the streams. The model also assumes that in urban watersheds, pervious areas have little importance and therefore little direct influence on stream quality. Consequently, the model neglects the effect of soil compaction that can cause severely compacted soils to produce the same runoff response as impervious areas (Pitt et al.1999). Also not considered in this simplified approach is the pervious areas' capacity to capture and store runoff generated from impervious areas, thus sharply reducing the effective impervious area in the landscape (Sutherland 2000).

Because available impervious cover data do not have sufficient detailed observations, many modelers estimate the amount of imperviousness based on published assumptions from the

USDA NRCS (1986), the Center for Watershed Protection (1998), or National Education for Municipal Officials (NEMO 2000) about the average imperviousness of different land uses. Other modelers use the population-density data (Stankowski 1972; Graham et al. 1974; Hicks and Woods 2000; Sheng and Wilson 2009), housing density (Yoder et al. 1999), or road density (Myers et al. 1998) to estimate the percentage imperviousness. City planners often utilize land use zoning for rapid estimates of total impervious area (Exum et al. 2005). Both population density and land use zoning based estimation methods provide a means for projecting increases in impervious cover in a watershed, using either population growth or build-out scenarios as the forcing function (Arnold and Gibbons 1996). Population density is available nationally from the U.S. Census Bureau, but comprehensive land-use zoning data is not available regionally. None of these methods estimates the effective impervious cover, the most important factor in calculating runoff.

Many modelers prefer to use a combination of direct measurement and estimation methods. Large areas of impervious cover, such as roofs and parking lots, can be directly measured from available GIS data. When street centerline lengths are available, many modelers assign a fixed width to streets, depending on the street description, and calculate street areas. For the remaining impervious areas that could not be readily determined from GIS (small parking areas, sidewalks, and driveways), they establish alternative methods such as subtracting the previously determined impervious areas from the total impervious area of each catchment, as determined based on the literature published assumptions about the impervious area of the land use. This remaining area which is assumed to be parking, sidewalks, or driveway can be expressed as a ratio of the total measured roof area. This approach is seldom accurate because the published data are highly variable, and subtracting a large number from another large number will result in uncertain values that can even result in negative areas. In many areas, more detailed aerial coverage with the GIS data sets are becoming available showing and quantifying these finer elements of an area. Figure 1 is an example from the National Demonstration Project of Green Infrastructure for the Control of Combined Sewer Overflows, a new USEPA project being conducted in Kansas City, MO. This high-resolution GIS data shows all of the elements, but field surveys are still being conducted to verify the drainage pattern for each impervious element in the test and control watersheds.

2.4 Direct Role of Impervious Cover on Receiving Water Conditions

This section summarizes the findings of currently available research on the relationship between watershed characteristics and the health of the receiving water, specifically the assumed relationships between the watershed impervious area and the biological conditions in a stream. Numerous studies have found a negative relationship between the imperviousness of the urban catchment and stormwater quality and quantity.

When urbanization occurs, natural vegetation is replaced by impermeable surfaces. The rapid increase of impervious cover is responsible for many negative implications related to environmental quality (Arnold and Gibbons 1996). Schueler (1994) predicted that the replacement of a one-acre meadow with impervious material would increase the runoff from a one-inch rainstorm by about 16 times. Since there is less vegetation to slow the flow of stormwater, more runoff and erosion results (Sherman 1949; Andrews 1954; and Ogrosky 1956 – as reported in Reilly et al. 2004), and more sediment is washed into streams (Trimble 1997).

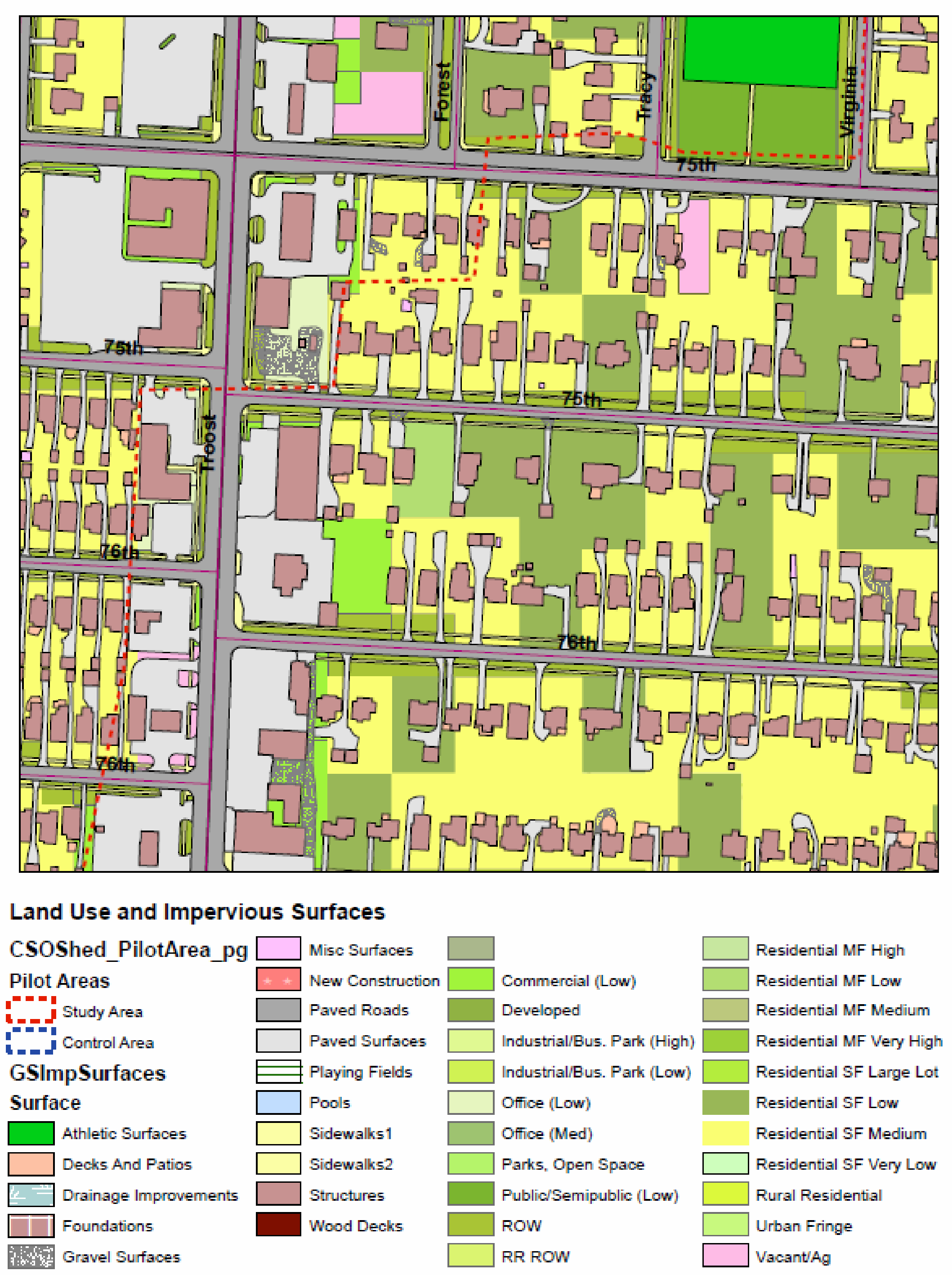


Fig. 1. Example of Detailed Aerial Coverage
(Kansas City Green Infrastructure Study Area)

Generally speaking, the effects of increased impervious cover are lower groundwater levels (Evett et al. 1994; Finkenbine et al. 2000); lower dry weather stream flows (Simmons and Reynolds 1982; Pitt and Bissonnette 1984 in Bellevue, WA; Pitt and Shawley 1982 in Castro Valley, CA; Pitt and Bozeman 1982 in Coyote Creek, CA); increases in the frequency and magnitude of flood events (Leopold 1968; Espey and Winslow 1974; Harley 1978; Sauer et al. 1983); modifications of the stream and channel morphology such as channel incision, bank erosion, scouring of channels, increased sediment transport (Hammer 1972; Booth 1991; Booth and Reinelt 1993; Shaver et al. 1994; MacRae 1996; Poff et al. 1997; Trimble 1997; Nelson and Booth 2002; Brattebo and Booth 2003); decreases in the stream water quality because of increased pollutant loads (Pitt 1987; Bannerman et al. 1993; Schueler 1994; Winter and Duthie 1998; Pitt et al. 2005a; 2005b; 2005c); increases of the stream water temperature (Galli 1991; Van Buren et al. 2000; Gregory et al. 2005; Frazer 2005); and decreases of the stream biodiversity (Pitt and Bozeman 1982; Steedman 1988; Schueler 1994; Booth and Jackson 1997; Center of Watershed Protection 1998; Ayers et al. 2000). Sediment from eroded stream banks clogs the gills of fish, blocks light needed for plants, fills in stream channels, and degrades the habitat for plants and animals that depend on clean water (Booth 1991; May et al. 1997; Gesford and Anderson 2006).

Urbanization may ultimately result in decreased local surface erosion rates when large areas are covered with impervious surfaces (Nelson and Booth 2002). Also, the impervious surfaces influence regional climate through the urban heat island effect by acting as thermal energy collectors (Van Buren et al. 2000), causing the summer air temperature of large cities to increase by about 3- 5^{o}C compared to surrounding areas (Stone 2004). This thermal energy is later transferred to stormwater runoff as the runoff passes over heated surfaces (Van Buren et al.

2000). Urbanization and land clearing result in riparian corridor minimization, which worsen the effects of warmer water entering streams from paved surfaces (Galli 1991). The increased temperature of receiving water above ambient levels can have direct biological impacts (increase level of bacteria, disturbance of aquatic life) or can change the water quality (reduce dissolve oxygen, increase metal and hydrocarbon solubility) leading to biological impacts (not enough oxygen for fish/insect survival, increase toxicity to aquatic life) (Van Buren et al. 2000).

The volumetric runoff coefficient (Rv) is the fraction of the rainfall that is converted to direct runoff and varies for different land uses and land covers. Schueler 1994, Booth 2000, Gregory et al. 2005 found that an increase in effective impervious area will give a linearly proportional increase in runoff volume and concurrent decreases in infiltration. Figure 2 is based on 44 small urban catchments monitored during the national NURP study and illustrates the increase in the site Rv as a result of its DCIA (Schueler 1994).

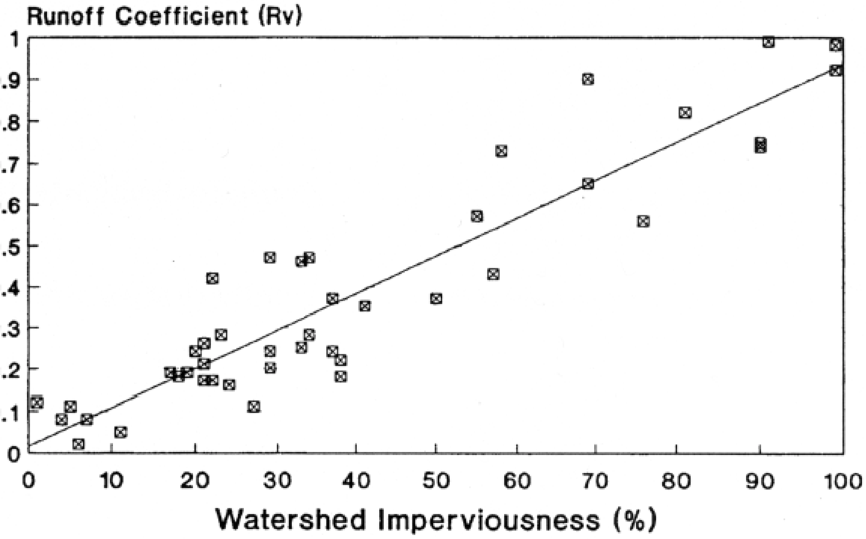


Fig. 2. Relationship between Watershed Imperviousness and the Storm Runoff Coefficient (Rv) (Schueler 1994)

The increase in watershed urbanization leads to frequent and severe floods, followed by changes in channel morphology (increases in the cross-sectional area through increases in channel width), and changes in water quality. The widening and destabilization of urban stream channels has resulted in habitat degradation. Research models developed in the U.S. Pacific Northwest Region suggest that a threshold for urban stream stability exists at approximately 10% imperviousness of a watershed (beyond this, the stream morphology changes significantly resulting in unstable and eroding channels) (Figure 3) (Booth and Reinelt 1993). In addition, development pressure has a negative impact on native riparian forests and wetlands, which are intimately involved in stream ecosystem functions. More studies in the Pacific Northwest Region (Puget Sound Lowland region) by Richey (1982), Scott et al. (1986), Booth and Reinelt (1993), Horner et al. (1997), May et al. (1997) show evidence of these effects.

The May et al. (1997) study found that wide, continuous and mature-forested riparian corridors are effective in mitigating some of the cumulative effects of adjoining development. Figure 4 illustrates how the combination of riparian buffer condition and basin imperviousness explains much of the variation in stream quality, as measured by the benthic index of biotic integrity (B-IBI). Even though the B-IBI decreases with increasing impervious area (Figure 4), this fact is less useful in understanding the large variation observed in biological condition among sites with similar low percentages of imperviousness (3% to 8%). This can be explained by natural variability or by the differences in human activities in the watershed.

May’s observations suggest possible stream quality zones similar to those proposed by Steedman (1988). Excellent (or natural) stream quality requires a low level of watershed development and a substantial amount of intact, high-quality riparian corridor.

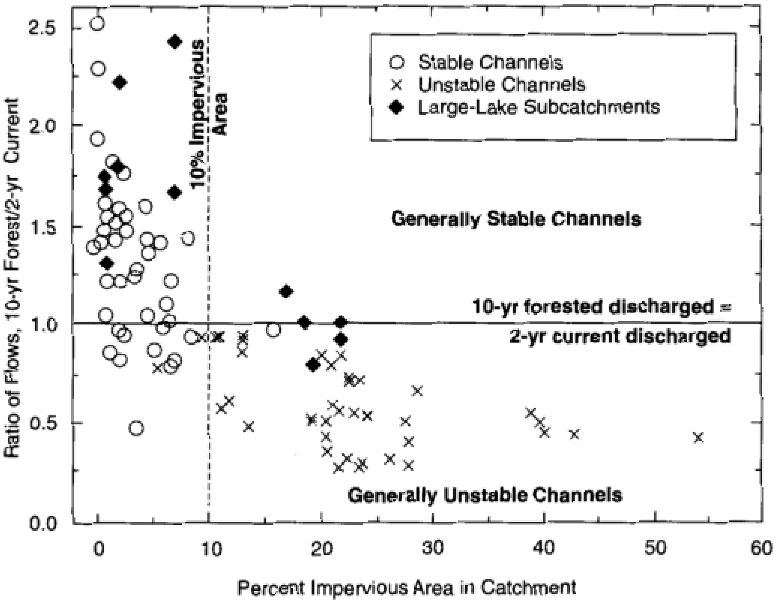


Fig. 3. Channel Stability as a Function of Imperviousness (Booth and Reinelt 1993)

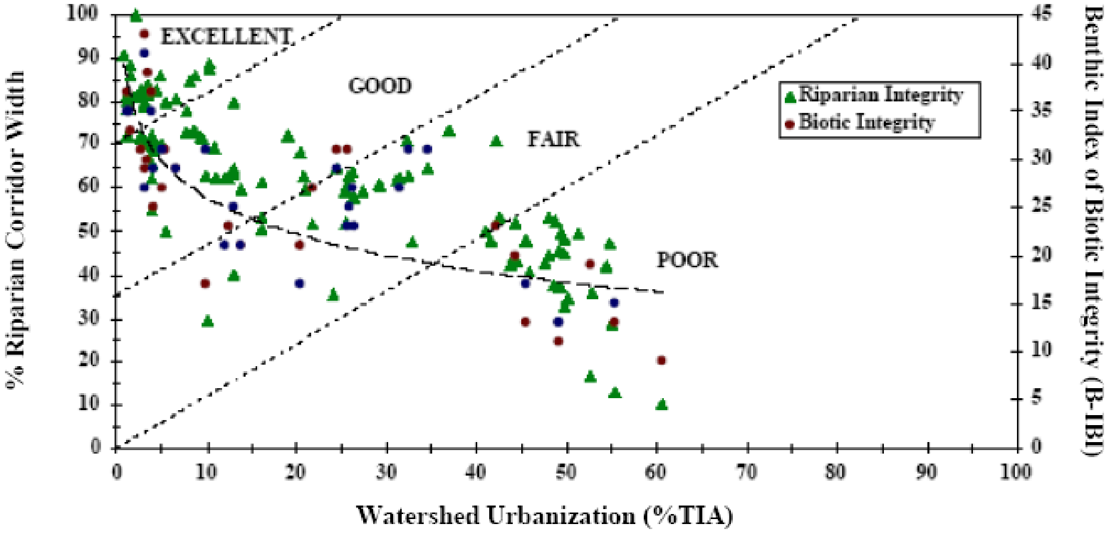


Fig. 4. The Relationship between Biological Stream Quality and Watershed Development Showing the Potential Benefits of Riparian Buffers in Urbanizing Watersheds (May et al. 1997)

A “good” or “fair” stream quality may be achieved, even if a large amount of development is present, but an increased amount of protected riparian buffer is required. Poor stream quality is almost guaranteed in highly urbanized watersheds or where riparian corridors are not present.

Increased imperviousness leads to poorer water quality and increased pollution discharges to urban receiving waters. Research has consistently demonstrated that a threshold in habitat quality exists at about 5-10% imperviousness, beyond which urban stream habitat quality is classified as poor. Based on the relationship between steam quality and watershed imperviousness, the Center for Watershed Protection (1998) created an urban stream classification scheme, the “Impervious Cover Model” (ICM) based on more than 200 reports and papers. This scheme provides a simple, but powerful method to predict the future quality of streams based on measurable land use change. Each watershed can be classified into one of three functional categories according to the current percent of impervious cover: sensitive streams up to 10% impervious cover (at this level of imperviousness steam degradation starts to occur and sensitive steam elements vanish from the system); impacted streams between 11-25% impervious cover (considerable degradation is observed, the steams are in poor conditions and the aquatic habitat is severely damaged); and non-supporting stream at more than 26% imperviousness. When impervious cover exceeds 60%, stream channels are often paved or engineered to be stabilized (urban drainage). Concrete channels were often used to speed runoff further along, but there is no habitat value to these engineered channels.

Schueler and Fraley-McNeal (2008) reformulated the “Impervious Cover Model” based on recent research (67 peer review studies) that confirmed or reinforced the model.
The reformulated ICM includes three important changes to the original model (Figure 5).

1. The impervious cover versus stream quality relationship is expressed as a cone (original model has it as a straight line) that is widest at lower levels of impervious cover and progressively narrows at higher impervious cover The cone represents the observed sub-watershed variability in the response of stream indicators to urban disturbance. Also, it outlines the general range in expected improvement that could be attributed to watershed treatment. In reality, sharply defined impervious cover thresholds are rare and most of the regions show a generally continuous but variable gradient of stream degradation as impervious cover increases, therefore the use of a cone rather than a line is justified.
2. The cone width is greatest for impervious cover values less than 10%. This reflects the wide variability in stream indicator scores observed for this range of streams and prevents the misperception that streams with low sub-watershed impervious cover will automatically possess good or excellent water quality. Below 10% imperviousness, the expected steam quality is heavily influenced by other watershed metrics such as forest cover, road density, riparian continuity, and cropping practices.
3. The transition between stream quality classifications is expressed as a band rather than a fixed line (e.g. 5 to 10% impervious cover for the transition from sensitive to impacted, 20 to 25% impervious cover for the transition from impacted to non-supporting, and 60 to 70% impervious cover for the transition from non-supporting to urban drainage). The band reflects the variability in the relationship between stream hydrologic, physical, chemical, and biological responses and the qualitative endpoints that determine stream quality classifications.

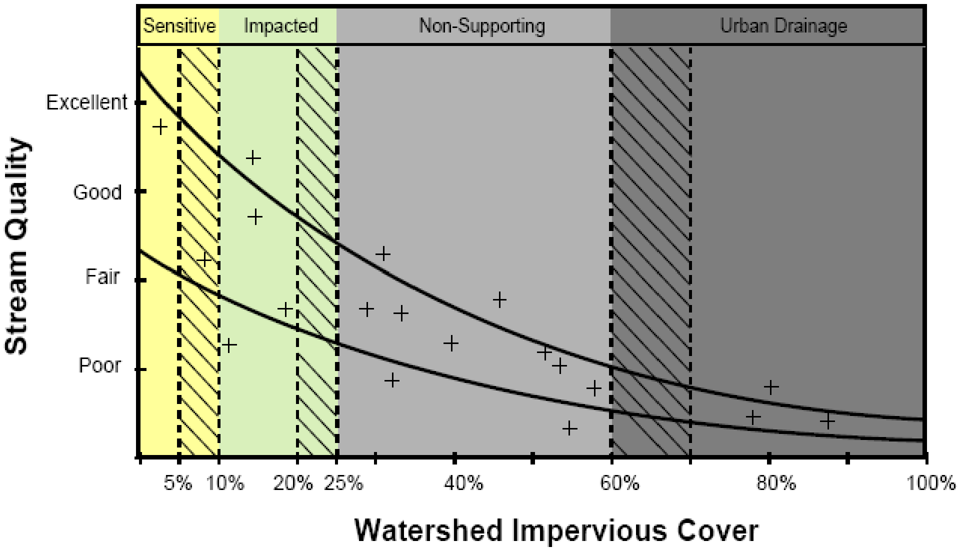


Fig. 5. The Reformulated Impervious Cover Model (Schueler and Fraley-McNeal 2008)

2.5 Impervious Cover as Source of Urban Runoff

In many urban areas where the impervious cover is larger than 50%, stormwater management practices has focused on flood control through built conveyance systems (curb and gutter, underground culverts, pipe, and concrete channel) (Anderson et al. 2008; CSN 2008). These "hard-engineered" systems are effective in preventing local floods, but do nothing to protect the integrity and health of the receiving waters. Later on, people came to realize that in order to protect these areas, the overall volume of runoff, the peak discharge, and the quantity of pollutants discharged needs to be reduced. To implement effective stormwater control practices, it is important to know where the pollutants and flows of concern originate.

Urban runoff is a collection of many separate source area flow components that are combined within the drainage area before entering the receiving waters (Pitt 1987 and 2000; Pitt et al. 2005a; 2005b; 2005c). A popular way to identify sources of urban runoff is to divide the urban watershed into major land uses categories according to their main land use (residential, institutional, industrial, commercial, open space, freeway). For local planning and modeling purposes, those major land uses can be further sub-categorized according to the population density (high density, medium density, low density, apartments, multi-family, trailer parks, suburban for residential land use) or with the dominant activity that takes place in the land use (strip commercial, shopping center, office park, downtown business district for commercial land use; manufacturing, non-manufacturing, high/medium industrial for industrial land use; education, hospital for institutional land use; cemeteries, parks, undeveloped for open space land use) (Pitt and Voorhees 1995).

The sources of pollutants in stormwater are predominately associated with impervious areas, since that is where most of the flows originate. Thus, a functional way of partitioning urban areas is by the nature of the impervious cover and by its connection to the drainage system. Therefore, an area can be divided into the following components: roofs, streets, sidewalk, driveways, parking lots, storage area, playgrounds, front landscape, back landscape, undeveloped area, and other pervious areas (Pitt and Voorhees 1995). This partitioning helps to better predict the discharge characteristics and/or the effect of source area controls. Bochis (2007) showed the runoff characteristics of a commercial/mall area in Hoover, AL (Figure 6). This figure shows the percentage of runoff volume originating from different sources, as a function of rain depth. In this example, for precipitation depths for the smallest rainfalls that are likely to produce runoff, about 80% of the runoff originates from the parking areas. This contribution decreases to about 55% at rain depths of 0.5 inches. This decrease in the importance of parking areas as a source of runoff is associated with an increase in runoff contributions from streets and directly connected roofs.

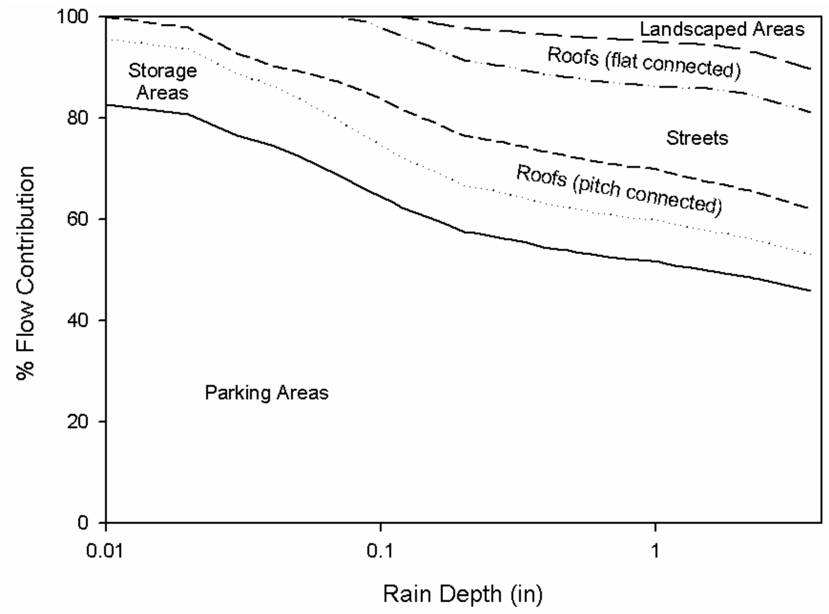


Fig. 6. Flow Sources for Example Commercial/Mall Area (Bochis 2007)

The relative contributions of source areas for different pollutants and flows are both site specific and rain pattern dependent for different geographical regions. However, the initial runoff is always generated by the directly connected impervious areas, with pervious areas contributing runoff only during the later portions of larger rains, or during periods of high rainfall intensities. As mentioned above, the relative contribution of flows and pollutants are site specific and rain pattern dependent. However, the initial runoff is always generated by the directly connected impervious areas, with pervious areas contributing runoff only during the larger rains.

Many studies have indicated that there are significant differences in stormwater constituents for different land use categories (Pitt et al. 2004). This is supported by data presented in the NSQD (Maestre and Pitt 2005a). Estimation of stormwater characteristics based on land use is a normal approach and generally accepted by researchers, because it is related to the activity in the watershed and, in addition, many site features are consistent within each land use, including imperviousness. Pitt et al. (2004) analyzed several constituents (TKN, copper, lead, zinc, phosphorus, nitrates, fecal coliforms, COD, etc.) for different major land use categories contained in the NSQD and found significant differences in concentrations for the different land use categories for the pollutants examined, although the variation in each category was also large. However, this method can result in large variations in predicted values. In order to reduce the variability of predicted values, accurate values of the actual surfaces in each land use and how they are connected to the drainage system are needed (Bochis et al. 2008).

2.6 Chapter Summary

Urbanization radically transforms natural watershed conditions and introduces impervious surfaces into the previously natural landscape. Total impervious areas are mostly composed of rooftop and transport components that can be either directly connected or disconnected to the drainage system. The impervious areas that are directly connected to the storm drainage system are the greatest contributor of runoff and contamination under most conditions.

Reported hydrologic and geomorphic impacts, associated with increases in impervious surfaces, are summarized in Table 3. These impacts are often cumulative and affect fish and wildlife, causing ecological and monetary losses to local agencies and governments within a watershed. Research conducted in many geographical areas has similarly concluded that stream degradation starts to occur when the watershed is composed of approximately 10-15% total impervious areas. Channel stability and fish habitat quality rapidly decline after this amount of development.

Table 3. Impacts on Streams due to Increased Impervious Surface Areas

	Resulting Impacts				
Increased Imperviousness Leads to:	**Flooding**	**Habitat Loss**	**Erosion**	**Channel Widening**	**Streambed Alteration**
Increased runoff volume	✓	✓	✓	✓	✓
Increased peak flow rates	✓	✓	✓	✓	✓
Increased peak flow durations	✓	✓	✓	✓	✓
Changes in sediment loadings	✓	✓	✓	✓	✓
Increased stream temperature	n/a	✓	n/a	n/a	n/a
Decreased base flows	n/a	✓	n/a	n/a	n/a

Source: Environmental Protection Agency. Urbanization and Streams: Studies of Hydrologic Impacts (http://www.epa.gov/owow/nps/urbanize/report.html)

The general conclusion of many studies is that in urban areas, the amount of stormwater generated has increased since the early years of the 20th century because of the tendency toward greater automobile use, which is associated with paved facilities necessary to accommodate them (larger streets, parking lots, and garages). Also, the tendency toward bigger houses and adjacent parking has increased imperviousness in urban watersheds. The amount of impervious cover has become recognized as a tool for evaluating the health of a watershed and serves as an indicator of urban stream quality. It also can be used as a management tool in reducing the impacts of development within a watershed. Although there is some variability in the data, watershed imperviousness does appear to be a reasonable predictor of runoff coefficient (Schueler 1994; Booth 2000; Gregory et al. 2005).

Stormwater runoff from urbanized areas carries with it a wide variety of pollutants from diverse sources. Based on data collected throughout the country over many decades, it is apparent that there is a great variability in urban runoff pollutant composition and concentrations. This large variability of stormwater characteristics is often encountered within a storm event and from storm event to storm event, affecting the performance of stormwater controls. Stormwater pollutant concentrations tend to be highly variable as a result of variations in rainfall characteristics (seasonal factors), geographic regions, different watershed features (land use) that affect runoff quantity and quality, and variability in urban activities. Because of this variability, it is difficult to establish generalized pollutant values for each land use. Goonetilleke et al. 2005 found that stormwater runoff from the urban catchments display the highest standard deviation for all study water quality parameters (pH, DO, SS, TN, TP), indicating high variability of stormwater quality from those watersheds. Also, very little similarity was found among urban sub-catchments. This fact was attributed to the variability in the land use/land cover characteristics and the spatial distribution of impervious areas that are appreciably different.

Need for Research

The literature summarized above has shown that impervious surfaces are acknowledged to be the greatest contributor of runoff and contamination to urban streams. Studies have illustrated that increases in urbanization are associated with increases of impervious surfaces and degradation of urban stream habitat. A common objective of most urban water quality studies has been the attempt to relate land use to pollutant loadings. However, the outcomes may not be very conclusive, making it difficult to identify cause – effect relationships and to establish generalized pollutant values for land uses.

It is known that land cover characteristics and the spatial distribution of impervious areas are different from land use to land use, but there is very little literature information available and many assumptions concerning the variability of land use development characteristics and how this can affect the variability of stormwater characteristics. Even if the total impervious areas of different land uses are the same, the land cover, its distribution, its connectivity, and the activities conducted in the land use play an important role in determining stormwater quality.

Therefore, it is important to understand the role of land use/land cover when dealing with urban stormwater management in order to make the investment in stormwater monitoring functional.

The results from this research can be used to obtain large-scale understandings of stormwater characteristics (geographical areas and land use interactions of water quality) and as guidance for local stormwater quality monitoring efforts. However, its specific results are not expected to be applied everywhere.

Proposed research

The proposed dissertation research work will:

1. Examine the variability in land use development characteristics to explain how this affects the variability in stormwater characteristics.
2. Quantify the predicted uncertainty based on actual field measurement of land development characteristics for each neighborhood in different land uses.
3. Describe the measured stormwater variability for the test locations, and for regionally available data.
4. Determine the level of detail needed about land uses in order to explain as much of the stormwater variability as possible.
5. Conduct an uncertainty analysis to understand stormwater quality variability.

Chapter 3
Hypothesis and Experimental Design

3.1 Introduction

The literature review revealed a common approach of estimating stormwater pollutant characteristics. This approach, based on land use categories, is generally accepted by researchers because it is related to the activity in the watershed. In addition, many site features (such as percent imperviousness) are generally consistent within each land use. However, data collected throughout the country show that urban runoff is highly variable within a storm event and from storm event to storm event even when collected in the same land use category. Stormwater pollutant concentrations tend to be highly variable as a result of variations in rainfall characteristics (seasonal factors), geographic regions, and different watershed features (watershed size, land use, conveyance type, and existing stormwater controls). Sample collection methods (manual or automatic) and analyses methods are also known to affect the stormwater characteristics, adding to its variability. All those factors affect urban runoff quantity and quality, making it difficult to establish generalized pollutant values for each land use.

Maestre (2005) evaluated the factors affecting stormwater concentrations using the National Stormwater Quality Database version 1.1 (monitoring efforts of 65 communities from throughout the U.S. using 10 years of data from1992 to 2002). He concluded that the effect of the factors influencing stormwater characteristics cannot be extrapolated from one area to the rest of the country. Maestre (2005) also found that a certain amount of redundancy (self-correlation) is present between land use and the percentage of impervious areas, as each land use category generally has a relatively narrow range of paved areas and roofs. Therefore, it was not possible to test if different levels of imperviousness (surface coverage) are more important than differences in land use (activities within the area). However, he concluded that there are significant differences in stormwater constituents for different land use categories. This finding was also supported by NURP (USEPA 1983) database, but was not supported by CDM (Smullen and Cave 2002) database. However, seasonal variations of stormwater quality are not as obvious as the land use or geographical variations (Maestre 2005).

3.2 Hypothesis

The goal of this dissertation research is to improve the understanding of the variability of stormwater characteristics by measuring and quantifying the variability of land use development characteristics related to observed stormwater quality.

The primary objectives of this research are to examine the variability in land use development characteristics and to explain how this affects the variability in stormwater characteristics; to quantify the predicted uncertainty based on actual field measurements of land development characteristics for many homogeneous neighborhoods in different land uses; and to determine how much detail is needed for each land use description in order to adequately explain stormwater variability.

The literature review revealed that watershed imperviousness is a commonly used indicator to predict the impact of land development on urban receiving waters. It is difficult to confidently set watershed management objectives based on uncertain watershed development characteristics. The design and performance of stormwater controls is highly dependent on the flow rates and runoff volumes, and treatability of the stormwater. Therefore, more accurate knowledge of the specific stormwater characteristics in an area will help in the design of more effective stormwater controls and will enable more accurate predictions of the environmental health of urban receiving waters.

The following hypothesis statement for this dissertation is based on the literature review and preliminary analyses, and indicates how this research addresses a significant issue pertaining to stormwater management. This dissertation tests the hypothesis using locally collected stormwater quality data, a calibrated stormwater model, and much information concerning local land development characteristics. Information from throughout the nation is also be used to verify these findings for other conditions.

Hypothesis:

The variability of development characteristics for different land uses explains an important portion of the variability of the observed stormwater characteristics. Activities conducted in the land uses also significantly affect observed stormwater quality.

a) Variability in stormwater quality characteristics is less within each land use category than between the land use categories.

b) Variability in land use development characteristics is less within each land use category than between the land use categories.

c) The variability in land development and stormwater characteristics are correlated and this correlation can be used to more effectively predict receiving water responses to stormwater controls for an area.

Prediction:

Stormwater runoff from urbanized watersheds can be highly variable in quantity and constituent loadings due to the multiple land uses in an area, the varying activities conducted in each land use, different contaminant sources, and the wide range of storm event sizes and durations that may occur. The variability of stormwater characteristics often encountered within a storm event and from storm event to storm event, makes stormwater problems difficult to evaluate. Observed variabilities in stormwater characteristics from watershed to watershed should be explained by considering the variability in the land use/land cover and by quantifying the uncertainty based on actual field measurements of land cover for each representative neighborhood in a land use.

Watershed development characteristics are very different from one area to another, as the land use mixes for each watershed usually varies greatly. However, separate land use characteristics do not vary much for different US regions. Therefore, it is important to know how land use varies for different watersheds. Both land use and geographical location (including rain conditions) are important factors to consider when predicting stormwater pollutant loads. In addition, impervious cover variability between land use types is greater than the variability within a single land use type, so it is critical that the land surface covers within each land use also be examined.

Research Activities:

a. Quantify the variability in land use development characteristics based on actual field measurements for each neighborhood surveyed in the Little Shades Creek watershed and in the Jefferson County test drainage areas.

b. Describe how the variability in land cover affects the variability in observed and predicted stormwater characteristics.
c. Describe the measured stormwater variability for the test locations, for regionally available data, and conduct uncertainty analysis to understand stormwater quality variability using the National Stormwater Quality Database version 3.
d. Determine how much detail is needed for each land use in order to explain the measured stormwater variability as much as possible.

Critical Tests:

a. Examine the strength and significance of the relationships between watershed physical characteristics and stormwater characteristics using several independent methods, including box and whisker plots, Pearson's correlations, along with cluster and principal component analyses. This enables all the analyzed data to be categorized into groups based on stormwater pollutant concentration and land cover characteristic variabilities. Principal component analyses consider the characteristics of the land cover as variables and pollutants concentrations as the responses. These tools identify simple and complex relationships between the sets of watershed and stormwater characteristics.
b. Perform correlation and multiple linear regression analyses to quantify relationships between identified significant watershed physical characteristics and stormwater pollutant concentrations.
c. Perform analyses of variance and post-hoc tests for each land cover (e.g. roof and street areas) and each pollutant to determine the differences within and between land uses and to verify the correlations.

3.3 Methodology

3.3.1 Geographical Location

As part of this research, Little Shades Creek watershed (Jefferson County, near Birmingham, Alabama) and five highly urbanized drainage areas situated in Jefferson County, AL (in and near city of Birmingham) were surveyed in detail to determine the actual development characteristics and their variability (Figure 7).

Jefferson County is the largest county by population and fifth by size (NACo 2010) in the state of Alabama having as county seat the city of Birmingham, historically a heavily industrialized (manufacturer of coal, iron, and steel, textiles, chemicals, automotive parts) and urbanized area, but service businesses and education are now very important to the local economy.

According to the EPA Rain Zone map (USEPA 2004), Alabama belongs in EPA Rain Zone 3 (Southeast Rain Zone) and has about 110 rains a year larger than 0.01 inches, with an average of 55 inches of precipitation. The USDA Soil Conservation Service (1986) designated Birmingham, AL to be in the Type III rainfall distribution for TR-55 and TR-20 hydrology analyses.

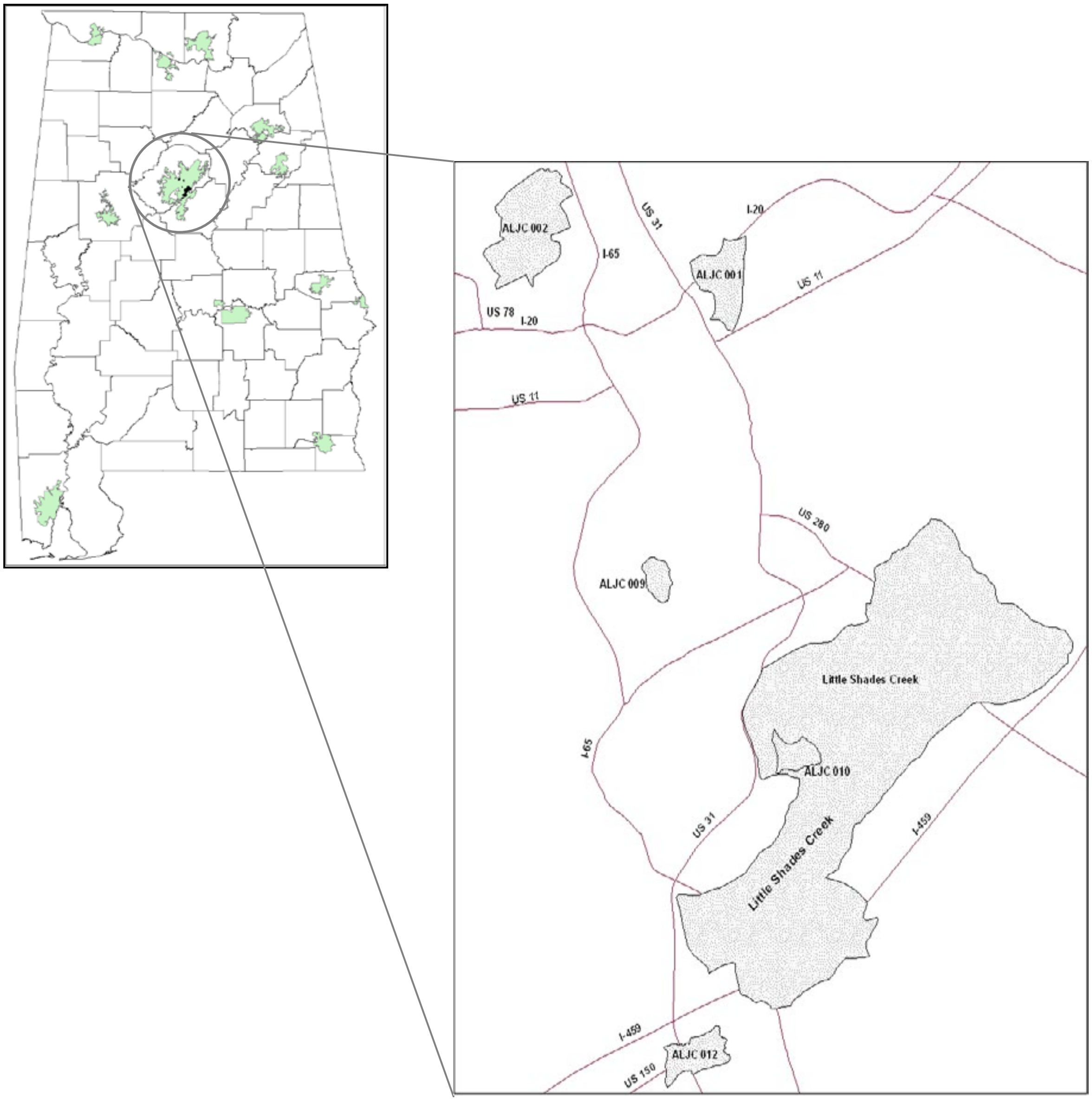


Fig. 7. Location of Jefferson County and Study Watersheds in Birmingham, AL Area

Table 4 summarizes the rainfall-runoff distribution characteristics for different locations in the U.S. including Birmingham, AL. Lower and upper runoff distribution breakpoints were identified on all of the individual distributions. Ranges given for the values correspond to commercial and residential land use categories.

Table 4. Rainfall and Runoff Distribution Characteristics for Different Locations in the U.S.

	Median Rain Depth, by Count (in)	**Percentage of Runoff Occurring during Rains Less than the Median Rain Depth**	**Rain Depth Associated with Median Runoff Depth (in)**	**Lower Breakpoint Rain Depth (in)**	**Percentage of Rain Events Less than Lower Breakpoint**	**Percentage of Runoff Volume Less than Lower Breakpoint**	**Upper Breakpoint Rain Depth (in)**	**Percentage of Rain Events Less than Upper Breakpoint**	**Percentage of Runoff Volume Less than Upper Breakpoint**	**Percentage of Runoff Volume between Breakpoints**	**Percentage of Rain Events between Breakpoints**
Boise, ID	0.07	3 - 5	0.30 - 0.35	0.10	52	9 - 11	0.91	99	89 - 93	80 - 82	47
Seattle, WA	0.12	4 - 6	0.62 - 0.80	0.18	60	8 - 11	3.4	99	92 - 96	84 - 85	39
Los Angeles, CA	0.18	3 - 5	1.2 - 1.5	0.29	64	7 - 10	3.5	99	92 - 98	85 - 88	35
Reno, NV	0.07	3 - 5	0.35 - 0.41	0.10	61	8 - 10	1.7	99	93 - 95	85	38
Phoenix, AZ	0.10	4 - 6	0.55 - 0.68	0.19	64	9 - 12	2.3	99	94 - 98	85 - 87	35
Billings, MT	0.06	2 - 4	0.55 - 0.60	0.12	64	8 - 10	1.6	99	89 - 93	81 - 83	35
Denver, CO	0.08	2 - 4	0.50 - 0.60	0.19	71	13 - 17	1.8	99	91 - 95	78	28
Rapid City, SD	0.06	2 - 4	0.50 - 0.55	0.15	69	10 - 13	1.9	99	92 - 96	82 - 83	30
Wichita, KS	0.13	2 - 5	1.1 - 1.4	0.31	65	10 - 13	3.0	99	88 - 93	78 - 80	34
Austin, TX	0.14	2 - 3	1.4 - 1.8	0.50	72	8 - 12	6.0	99	88 - 94	80 - 82	27
Minneapolis, MN	0.11	3 - 5	0.73 - 1.0	0.22	65	9 - 13	2.8	99	94 - 96	83 - 85	34
Madison, WI	0.12	3 - 5	0.78 - 0.98	0.23	65	9 - 13	3.5	99	97 - 99	86 - 88	34
Milwaukee, WI	0.12	2 - 4	0.9 - 1.1	0.25	65	9 - 12	2.5	99	89 - 95	80 - 83	34
St. Louis, MO	0.14	4 - 6	1.0 - 1.2	0.31	65	10 - 13	2.8	99	90 - 95	80 - 82	34
Detroit, MI	0.20	7 - 11	0.72 - 0.81	0.20	50	7 - 11	2.4	99	92 - 95	85 - 84	49
Buffalo, NY	0.11	2 - 4	0.61 - 0.72	0.12	64	8 - 12	2.1	99	88 - 93	80 - 81	35
Columbus, OH	0.12	3 - 5	0.80 - 1.0	0.22	63	8 - 12	2.2	99	85 - 91	77 - 79	36
Portland, ME	0.15	2 - 4	1.1 - 1.5	0.30	64	8 - 12	4.5	99	90 - 96	82 - 84	35
Newark, NJ	0.28	6 - 12	1.2 - 1.5	0.33	54	8 - 12	3.3	99	89 - 94	81 - 82	45
New Orleans, LA	0.25	3 - 5	1.7 - 2.2	0.45	62	7 - 11	4.0	99	88 - 93	81 - 82	37
Atlanta, GA	0.22	3 - 5	1.2 - 1.7	0.32	58	5 - 9	4.0	99	91 - 95	86	41
Birmingham, AL	***0.20***	***3 - 5***	***1.2 - 1.5***	***0.40***	***64***	***8 - 13***	***5.0***	***99***	***90 - 96***	***82 - 83***	***35***
Raleigh, NC	0.18	4 - 6	1.0 - 1.2	0.26	60	7 - 11	2.5	99	87 - 93	80 - 82	39
Miami, FL	0.13	3 - 5	1.2 - 1.6	0.30	67	9 - 13	4.0	99	87 - 93	78 - 80	32

Source: Pitt, Robert, and John Voorhees. 1995. Source Loading and Management Model (SLAMM). *Seminar Publication: National Conference on Urban Runoff Management: Enhancing Urban Watershed Management at the Local, County, and State Levels*. March 30 – April 2, 1993. EPA-625-R-95-003. U.S. Environmental Protection Agency. Center for Environmental Research Information. Cincinnati, OH: 225-243.

3.3.2 Description of Study Areas

- The ***Little Shades Creek Watershed*** has an area of about 2,072 ha (5,120 ac) and was about 70% developed at the time of the initial surveys (mid 1990s). It lies under the jurisdiction of several municipal governments as well as the county government, which made land development highly variable and uncoordinated. Many types of land development are represented, even though the residential areas, mostly as single family residential units, are predominant. Several land use sub-categories belonging to ten major land uses (such as residential, commercial, institutional, industrial, and open space) were surveyed by investigating about 10 neighborhoods for each land use. The predominant land use in the watershed is residential land (52%), subdivided according to the density type, and age (Table 5). The soil of Little Shades Creek watershed is sandy loam and silt loam, in about equal amounts, but is highly disturbed due to the extensive land development. The land is mostly flat or with medium slopes.

Table 5. Imperviousness Percentage based on
Land Cover in Birmingham, AL Land Uses

Land Use	**Total Impervious Area (%)**	**Directly Connected Impervious Area (%)**	**Pervious Area (%)**
High Density Residential	30	19	70
Medium Density Residential	22	13	78
Low Density Residential	18	9	83
High Rise Res/Apartments	42	17	58
Multi Family	35	27	65
Commercial	73	72	27
Institutional	46	41	54
Industrial	59	50	41
Open Space	13	9	87
Freeways	58	0	42

Source: Bochis, Celina. 2007. Magnitude of Impervious Surfaces in Urban Areas. Master Thesis. The University of Alabama, Tuscaloosa.

- ***Light Industrial (ALJC001)*** drainage area is 138 ha (341 ac). This area drains approximately 62% industrial property (scrap yards, manufacturing, railroad tracks), 12% commercial land use (shopping centers), a small percentage of residential land (8.5%) and open space (6.4%) areas. About 11% of this watershed is represented by freeways.

- ***Heavy Industrial (ALJC002)*** drainage area is 292 ha (721 ac). Approximately 75% of the drainage area is industrial land use (railroad yard, steel, and cast iron pipe companies), while 14.5% is high and medium density residential, and a small percentage (2.5%) is represented by commercial land use (farmers market and shops) and open space (6.7%).

- ***High-Density Residential (ALJC009)*** drainage area is 42 ha (102 ac). Most of the drainage area is comprised of residential lots 0.25 of an acre or less in size. A small portion of the land use within the basin is institutional (6.7%) and commercial (4.1%), which includes an elementary school, a small church, and a small strip commercial area consisting of small shops, restaurants, and a grocery store. This was found to be typical for many dense residential neighborhoods where small isolated institutional and commercial land uses are not large enough to be assigned separate land use categories.

- ***Low-Density Residential (ALJC010)*** drainage area is 54 ha (133 ac). The drainage area is almost entirely residential lots greater than a third of an acre (82.5%), except for a small portion of undeveloped woodland (17.5%) on a steep slope that is wooded with heavy cover.

- ***Commercial Mall (ALJC012)*** drainage area is 92 ha (228 ac). Most of the drainage basin is composed of strip shopping centers and a portion of the Riverchase Galleria shopping mall, except for some apartments that make up 25% of the drainage area along with some undeveloped woodland, which is 5% of the drainage area.

All surveyed residential areas (high density, medium density, low density, apartments, and multi-family complexes) had pitched roofs that drained mainly to pervious surfaces with the only exception being multi-family areas. Some landscaping was present near the roads and was mostly lawns and evergreen shrubs. Streets and driveways had asphalt as the most common pavement material and had intermediate textures. The predominant drainage system was composed of concrete rolled curbs and gutters in good or fair condition with a small percentage of grass swales in high and medium density residential areas.

Commercial land use was represented in the watersheds by office parks and shopping centers with flat roofs draining mostly to impervious areas. Lawns and evergreen shrubs in excellent condition were found near the roads. The paved parking lots represented the largest connected impervious source areas. The runoff from the roofs drains directly to parking areas and then to the drainage systems that were mostly curbs and gutters in good condition. The streets, driveways, and parking areas were paved with asphalt having intermediate or smooth textures.

Schools and churches represented the institutional land use category of the drainage areas. The school roofs were flat and drained slightly more toward impervious surfaces than to pervious areas. However, school playgrounds were mostly unpaved. Churches had pitched roofs that drained to impervious areas. Landscape areas had an even distribution of deciduous and evergreen shrubs. Lawns were near the streets. Streets and parking lots were paved with asphalt and had intermediate textures. The drainage systems had both grass swales and curbs and gutters, all in fair condition.

The industrial land uses included a lumber manufacturing facility, several equipment storage and office complexes, a public mini-storage facility, a construction supply center, a door manufacturer, an automobile scrapyard, and a steel factory. The facilities were similar with all buildings being directly connected to the stormwater collection system. All facilities were closely bounded by other developments, roads, and steep banks. The industrial sites were medium to small size, covering no more than a few acres and they were all dominated by parking, storage, and roof areas.

The open space land use included parks, cemeteries, golf course, vacant land, and areas under construction. The few roofs that were found in the vacant land use and golf course areas drained to pervious areas. The parking lots were paved and directly connected to the drainage system. The stormwater drainage system was a combination of curbs and gutters and grass swales.

The drainage system in the freeway land use was comprised of grass swales in the medians and at the shoulders. The pavement was asphalt, with smooth textures.

3.3.3 Field Data Collection and Data Processing

About 170 neighborhoods in the six Jefferson County, AL drainage areas were extensively investigated to determine the surface covers for each land use type and to check the impervious cover connectivity. During each neighborhood survey, a field data description sheet was completed and the corresponding aerial photographs from TerraServer USA and satellite images provided by Storm Water Management Authority Inc. in Birmingham were examined. The individual land cover elements (roofs, parking areas, street areas, sidewalks, landscaping, etc.) were manually measured from those aerial photographs and satellite imagines using planimeter and respective GIS Tools, as automated mapping software resulted in many errors and could not distinguish the necessary surface components.

The gathering of the field data and the aerial photograph measurements for Little Shades Creek Watershed were performed as part of a cooperative study conducted by the University of Alabama at Birmingham, the Jefferson County office of the U.S. Natural Resources Conservation Service (NRCS), the U.S. Army Corps of Engineers, and other city and county governments. This information was originally recorded on paper sheets and later was manually tabulated and summarized into electronic format (Excel spreadsheets) (Bochis 2007). Normalizing of the actual area measurements so they summed 100% was used to account for minor rounding errors.

The initial field data collection effort for the five additional Jefferson County drainage basins was performed during the author's master thesis research (Bochis 2007). Every impervious surface was checked to determine its properties and connectivity. Streets were classified according to their drainage system: with curb and gutter (directly connected to the storm drainage system) or with swales (disconnected). Also, the pavement material of every street and parking lot was examined and classified. Two 1-meter panchromatic IKONOS satellite images of Jefferson County (one flown on December 2000 when minimum leaf cover existed and one flown summer 2001) were overlapped and the electronic delineation of the five watersheds was performed. Using map digitizing techniques and GIS tools, the corresponding satellite image for the five drainage areas was cut and the individual land covers were measured (Bochis 2007). The individual land cover elements were measured in square feet units and recorded directly in an electronic format converted into Excel spreadsheets for easier handling of the information. Data normalizing was also performed to account for minor rounding errors.

For residential land uses, the most visible neighborhoods (having minimal tree cover) were selected and their individual elements were measured from the aerial photographs.

However, for industrial, commercial, and institutional areas, it was necessary to take account of all the visible elements incorporated into the land use due to greater variabilities of the different surface cover areas.

3.4 Monitoring Data for the Jefferson County Sites

Several Jefferson County drainage basins have been monitored for the counties MS4 (municipal separate storm sewer system) NPDES (National Pollutant Discharge Elimination System) stormwater permit. Available data were also incorporated in the National Stormwater Quality Database (NSQD) database (Pitt et al. 2004; Maestre and Pitt 2005a). According to the published sampling guidance in the *Federal Register* (40 CFR 122.21), each community was required to sample at least a residential, a commercial and an industrial watershed for the permit application. At least three samples were to be collected every year at each location. Each storm should be at least one month apart and have at least a three days antecedent dry period. Rain events greater than 0.1 inches and close to the annual mean conditions were typically required by the state programs. Composite samples made up of subsamples collected during the first three hours of the event were usually specified. An additional grab sample during the first 30 minutes of the event, to evaluate the “first flush” effect, was sometimes also required. “First flush” refers to the hypothesis that the concentrations of the stormwater constituents are higher at the beginning of the event than during the complete event.

The stormwater quality data used during this research were from samples collected between 2001 and 2008 by the Storm Water Management Authority, Inc. (SWMA), a public corporation in charge of the regional stormwater program. The agency used aerial photographs, topographic maps, and field inspections to select the monitoring sites for each particular land use. The sampling sites were selected so that the pollutant loadings would be typical of the specific land use. Monitoring locations were also selected that had suitable hydraulic characteristics as well as provided safety and accessibility for the sampling crew. The five Jefferson County drainage areas have no structural stormwater controls located above the discharge points and the samples were obtained at end-of-pipe locations in separate storm drainage systems. The agency evaluated a typical list of stormwater constituents (Table 6), but they did not monitor the runoff volume, although all events have local rainfall information, including the peak 15 minute rainfall intensity. About three events per calendar year were sampled at each location from 2001 to 2008. All samples were manually collected with "first flush" and composite samples taken at each site during each sampled event.

Table 6. Jefferson County Watersheds Sampled Constituents

Conventional Stormwater Pollutants	**Metals**	**Nutrients**
Total Dissolved Solids	Total Zinc	Total Kjeldahl Nitrogen
Total Suspended Solids	Total Copper	Total Nitrogen
Oil and grease	Total Lead	Nitrate
Biological Oxygen Demand		Nitrite
Chemical Oxygen Demand		Total Phosphorus
Fecal Coliform		Dissolved Phosphorus
Temperature		
pH		

Source: Storm Water Management Inc. support documents

There are different approved methods to measure the concentration of a specific constituent in a water sample. *Methods for Chemical Analysis of Water and Wastes* (USEPA 1979, revised 1983) and *Standard Methods for the Examination of Water and Waste Water* (Greenberg 1992 and more recent) list several approved methods for the detection of many of these constituents. The choice of methods is important as they have varying features and costs.

The objective is usually to select a method with a detection limit that results in useable data for most samples.

Maestre (2005) determined that the percentage of samples below the detection limit should be no greater than 15% for important constituents to enable accurate statistical analyses. Table 7 shows the analytical methods used for the local SWMA stormwater samples for all constituents except temperature.

Table 7. Analytical Methods Used for Stormwater Parameter Analyses in Jefferson County, AL

Parameter	**Analytical Method**
Total Dissolved Solids	EPA Methods for Chemical Analysis (1983), Method 160.1
Total Suspended Solids	EPA Methods for Chemical Analysis (1983), Method 160.2
Oil and grease	EPA Methods for Chemical Analysis (1983), Method 413.1
Biological Oxygen Demand	EPA Methods for Chemical Analysis (1983), Method 405.1
Chemical Oxygen Demand	EPA Methods for Chemical Analysis (1983), Method 410.4
Fecal Coliform	Standard Methods (1992) SM-9222 D
pH	EPA Methods for Chemical Analysis (1983), Method 150.1
Total Zinc	EPA Methods for Chemical Analysis (1983), Method 200.7
Total Copper	EPA Methods for Chemical Analysis (1983), Method 200.7
Total Lead	EPA Methods for Chemical Analysis (1983), Method 200.9
Total Kjeldahl Nitrogen	EPA Methods for Chemical Analysis (1983), Method 351.2
Total Nitrogen	Standard Methods (1992) 4500-N
Nitrate	EPA Methods for Chemical Analysis (1983), Method 300.0
Nitrite	EPA Methods for Chemical Analysis (1983), Method 300.0
Total Phosphorus	EPA Methods for Chemical Analysis (1983), Method 365.2
Dissolved Phosphorus	EPA Methods for Chemical Analysis (1983), Method 365.2

Source: Storm Water Management Inc. support documents

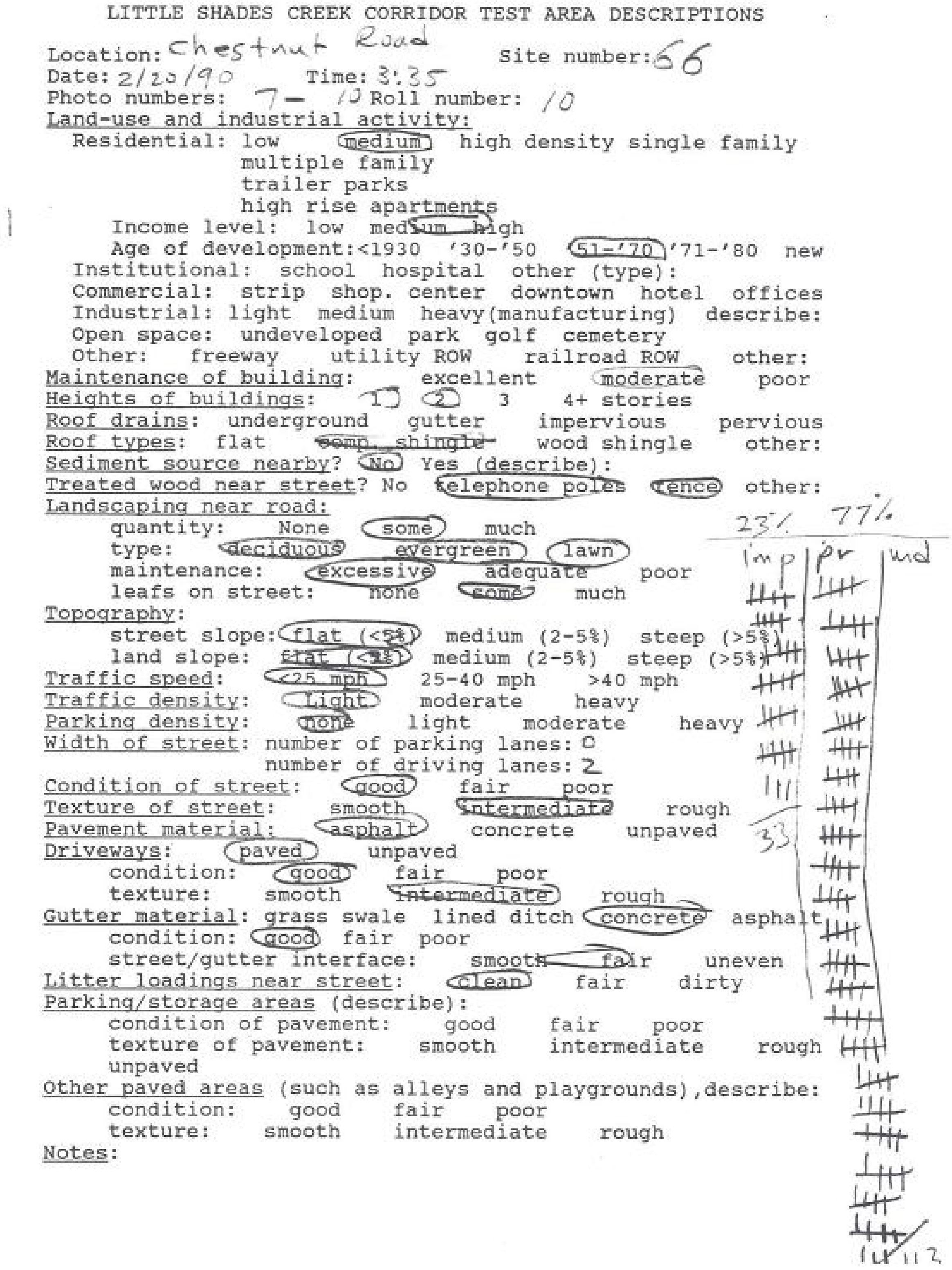
Runoff volume was not measured during the local stormwater monitoring program. To supplement this missing information, detailed watershed development characteristics and local rain events were used as input for the Source Loading and Management Model (WinSLAMM) (Pitt and Voorhees 1995; 2002) to calculate runoff volumes for each event. In order to obtain accurate runoff volumes, an individual rain file was created for each of the SWMA monitoring watersheds. The file contained rainfall depth information gathered during the sampling events along with rainfall data recorded at nearby stations and at the Birmingham International Airport.

The stormwater quality data collected by the Storm Water Management Authority, Inc., along with calibrated hydrology components from earlier monitoring efforts, were also used to recalibrate and validated the WinSLAMM model for local stormwater constituents. The model could not be locally calibrated for runoff volume due to lack of data. The calibration process using the local data is described in Appendix A.

3.5 Quality Control and Quality Assurance Procedures

Quality control and quality assurance techniques were used during all parts of the research, from field data collection, manipulation, and statistical analyses. The tasks relied on basic activities such as identification of unusual measurements.

For the Little Shades Creek measurements, where the area of individual land cover elements were initially recorded on paper (Figure 9), the information had to be manually transferred to a spreadsheet. Once the database was completed, the main table was reviewed by rows (corresponding to individual neighborhoods) and then by columns (corresponding to measured surface cover). Each row and column in the database was reviewed at least twice and compared to information contained in the original paper reports. The “Area Description” field sheet (Figure 8) used to record the important characteristics of the individual sites during field surveys was checked to identify possible errors associated with the transcription of the information, or as typographical errors in the original reports.



LITTLE SHADES CREEK CORRIDOR TEST AREA DESCRIPTIONS

Location: Chestnut Road Site number: 66
Date: 2/20/90 Time: 3:35
Photo numbers: 7 – 10 Roll number: 10

Land-use and industrial activity:
Residential: low [✓ medium] high density single family
multiple family
trailer parks
high rise apartments
Income level: low medium high
Age of development: <1930 '30-'50 [✓ '51-'70] '71-'80 new
Institutional: school hospital other (type):
Commercial: strip shop. center downtown hotel offices
Industrial: light medium heavy(manufacturing) describe:
Open space: undeveloped park golf cemetery
Other: freeway utility ROW railroad ROW other:

Maintenance of building: excellent [✓ moderate] poor
Heights of buildings: [✓ 1] [✓ 2] 3 4+ stories
Roof drains: underground gutter impervious pervious
Roof types: flat [✓ comp. shingle] wood shingle other:
Sediment source nearby? [✓ No] Yes (describe):
Treated wood near street? No [✓ telephone poles] [✓ fence] other:

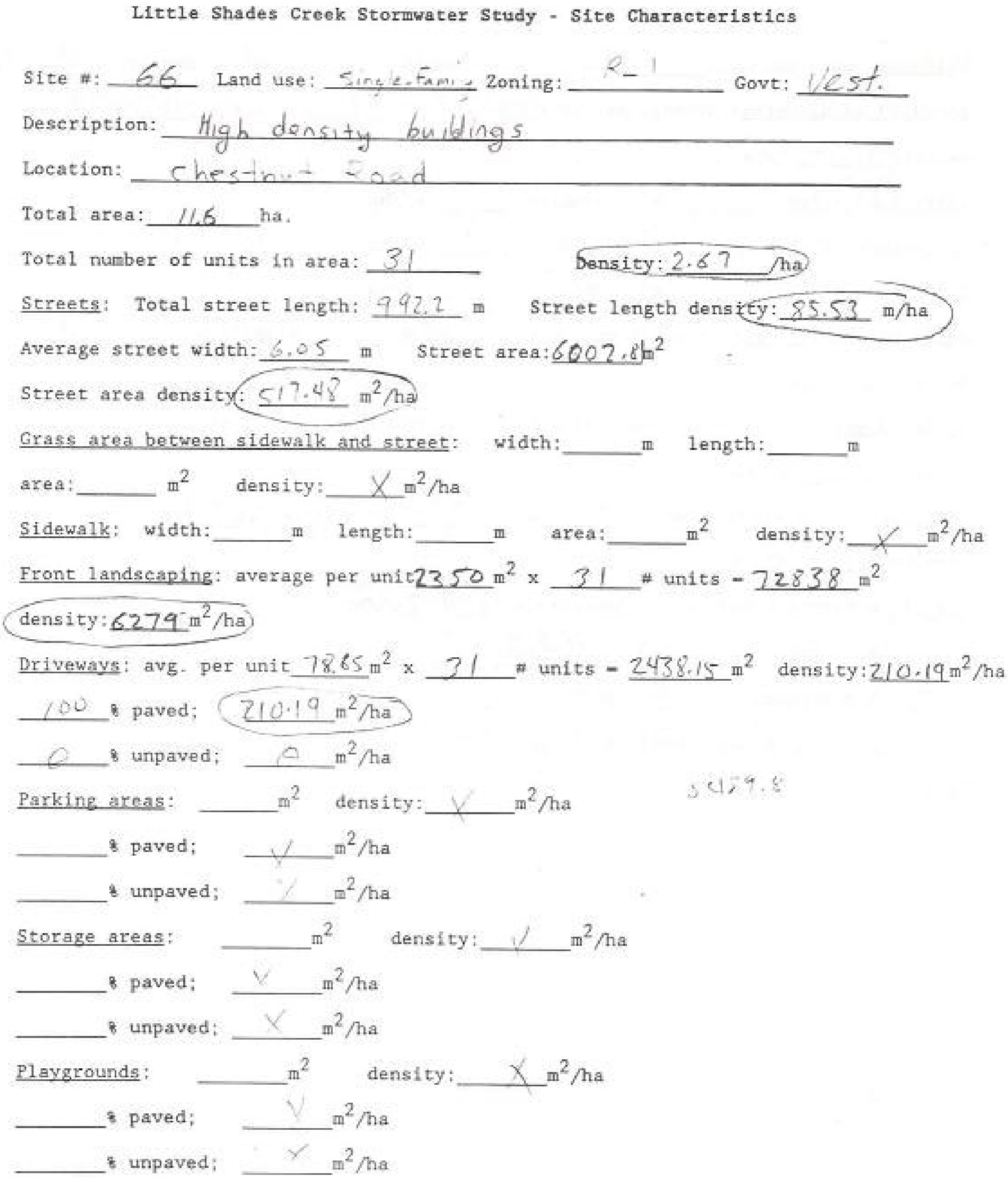
Landscaping near road:
quantity: None [✓ some] much
type: [✓ deciduous] [✓ evergreen] [✓ lawn]
maintenance: [✓ excessive] [✓ adequate] poor
leafs on street: none [✓ some] much

Topography:
street slope: [✓ flat (<5%)] medium (2-5%) steep (>5%)
land slope: [✓ flat (<5%)] medium (2-5%) steep (>5%)

Traffic speed: [✓ <25 mph] 25-40 mph >40 mph
Traffic density: [✓ Light] moderate heavy
Parking density: [✓ none] light moderate heavy
Width of street: number of parking lanes: 0
number of driving lanes: 2
Condition of street: [✓ good] fair poor
Texture of street: smooth [✓ intermediate] rough
Pavement material: [✓ asphalt] concrete unpaved
Driveways: [✓ paved] unpaved
condition: [✓ good] fair poor
texture: smooth [✓ intermediate] rough
Gutter material: grass swale lined ditch [✓ concrete] asphalt
condition: [✓ good] fair poor
street/gutter interface: smooth [✓ fair] uneven
Litter loadings near street: [✓ clean] fair dirty
Parking/storage areas (describe):
condition of pavement: good fair poor
texture of pavement: smooth intermediate rough
unpaved
Other paved areas (such as alleys and playgrounds), describe:
condition: good fair poor
texture: smooth intermediate rough
Notes:

23% 77%
imp pr ud
33
112

Fig 8. Example Test Area Description Field Sheet



Little Shades Creek Stormwater Study - Site Characteristics

Site #: 66 Land use: Single-Family Zoning: R-1 Govt: West.

Description: High density buildings

Location: Chestnut Road

Total area: 11.6 ha.

Total number of units in area: 31 Density: 2.67 /ha

Streets: Total street length: 992.2 m Street length density: 85.53 m/ha

Average street width: 6.05 m Street area: 6007.8 m²

Street area density: 517.48 m²/ha

Grass area between sidewalk and street: width:____ m length:____ m

area:____ m² density: X m²/ha

Sidewalk: width:____ m length:____ m area:____ m² density: X m²/ha

Front landscaping: average per unit 2350 m² x 31 # units = 72838 m²

density: 6279 m²/ha

Driveways: avg. per unit 78.65 m² x 31 # units = 2438.15 m² density: 210.19 m²/ha

100 % paved; 210.19 m²/ha

0 % unpaved; 0 m²/ha

Parking areas: ____ m² density: X m²/ha

5459.8

____ % paved; ✓ m²/ha

____ % unpaved; ✓ m²/ha

Storage areas: ____ m² density: ✓ m²/ha

____ % paved; ✓ m²/ha

____ % unpaved; X m²/ha

Playgrounds: ____ m² density: X m²/ha

____ % paved; ✓ m²/ha

____ % unpaved; ✓ m²/ha

Fig. 9. Example Development Characteristics Calculation Sheet

Important elements such as location, land use, roof type and connection, presence of sediment sources, street/parking lots/storage area pavement material, texture, and material condition, driveways characteristics, etc. were noted on this field sheet. If categories of characteristics varied in the study subarea (e.g. paved or unpaved driveways/streets; connected or disconnected roofs) then they were totaled for each category and the approximate percentage distribution was noted on the sheet.

The field data collected for the five Jefferson County drainage basins were used to supplement the aerial photographic information. Watershed maps and additional information about the outfall location and safety issues affecting the field work were provided by SWMA. Land cover measurements from aerial photographs were stored in electronic form, after which they were manipulated and stored in the main Excel spreadsheet.

Each individual site had at least two photographs taken: one as a general scene and the other as a close-up showing about 25 by 40 centimeters of pavement. Additional photographs were usually taken to record unusual conditions. These photographs were very important to confirm the descriptions recorded on the sheets and to verify the consistency of information for the many areas. The photographs were also very important when additional site information was needed, but not recorded on the data sheets. These photographs were also checked during the spreadsheet review to account for an accurate recording of the impervious area connectivity.

In all cases, suspect values were carefully reviewed and most were found to be associated with simple transcription errors which could be corrected. None of the data were deleted because there was no sufficient evidence of likely errors.

Quality control and quality assurance was also performed on the data extracted from the National Stormwater Quality Database (NSQD) and supplemental local stormwater quality data.

The main QC/QA process was performed by the compilers of the databases (The University of Alabama graduate students for NSQD and Storm Water Management Authority, Inc. employees for the local data). However, before the data were used for statistical analyses, additional QC/QA reviews were performed by the author. It was found that not all of the NSQD data could be used in this research since about 300 rain events were obtained from monitoring locations classified as "unknown" or "mixed unknown" land use. Therefore these events were not included in the statistical analyses. Also, when reviewing the local stormwater database, five concentration values were extremely high which could not be substantiated. They were therefore considered as faulty values and eliminated.

3.6 Statistical Analyses of the Data

This section outlines the experimental objectives and describes the statistical tests and their data requirements that were used for data evaluation during this dissertation research.

3.6.1 Exploratory Data Analyses using Basic Data Plots

Probability and scatter plots are the most basic exploratory data analysis methods and were used for a preliminary examination of the surface cover data for each land use. The probability plots indicate the possible range of the values expected, their likely probability distribution type, and the data variations. Scatter plots, made by plotting the primary variable (such as a water quality constituent) against a factor that may influence its value (such as time, season, flow, another constituent like suspended solids, etc.), were largely used throughout this research for WinSLAMM model calibration, water quality modeling, residual analyses, and other various checks of the data. Examples of their use are presented in the next section (Figures 15, 16, and 17).

Grouped box-and-whisker plots are also exploratory data analysis tools used primarily when differences between sample groups are of interest. For this research the grouped box and whisker plots were mainly used to examine the variability of a certain pollutant or land cover (such as TSS or impervious surface, etc) within and between land uses or drainage areas and to identify significant groupings of data. These plots indicate the range and major percentile locations of the data, as shown in Figure 10. Generally, if the 75 or 25 percentile lines of one box are higher or lower than the medians of another box, then the data groupings may be significantly different at the chosen confidence level for relatively few data in each category (Chambers et al. 1983).

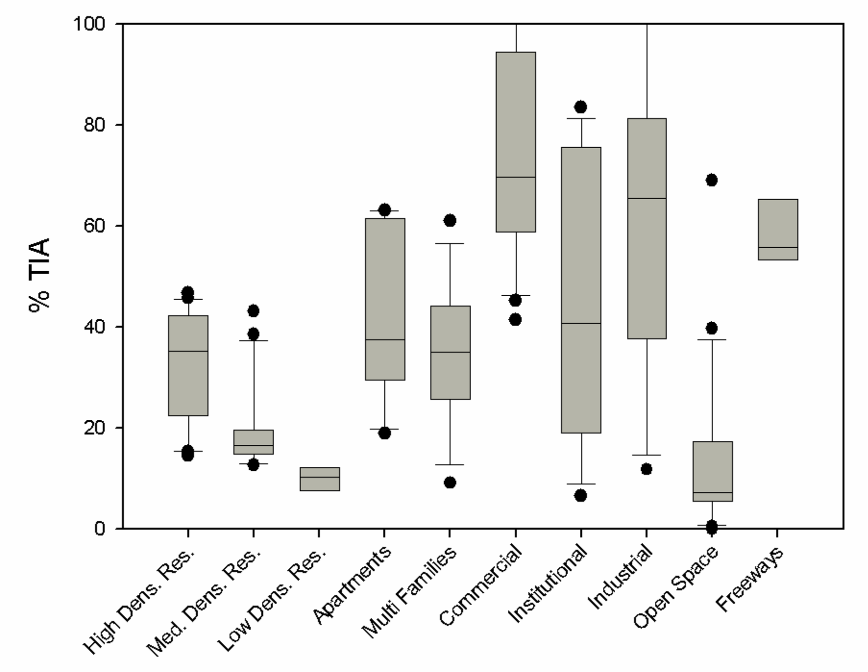


Fig. 10. Example - Box and Whisker Plot of Total Impervious Areas for Different Land Use Categories

In Figure 10, land use groupings of total impervious area measurements from Jefferson County drainage areas were plotted to indicate obvious differences in the values. The relative overlapping or separation of the boxes was used to identify possible groupings of the separate sets. In this case, the low density residential land use category has a lower percentage of total impervious area than the institutional land use category for example. The open space and low density residential areas are likely not significantly different, while the high density residential and medium density residential areas are likely significantly different, to point out two examples,

3.6.2 Statistical Significance Measures

The regionally available data from the National Stormwater Quality Database version 3 were used to conduct an uncertainty analysis in order to quantify and understand stormwater quality variability for the test locations. Using sensitivity and uncertainty analysis, this research showed how much land use detail one must know to correctly predict stormwater quality with a certain objective.

This research made use of ***p-value*** and ***alpha level*** as statistical significance measures to quantify the confidence that what was observed in the sample did not occur by chance and it was also true for the population. Alpha level, the probability of making a Type I error or rejecting the null hypothesis when the null hypothesis is in fact true, is not calculated, but chosen by the researcher. Therefore, the alpha level this dissertation accepted to prove the hypothesis was set to be the traditional 0.05 level, meaning that the obtained results would theoretically occur by chance variation no more than 5 out of 100 times. Literature (Markman 1999; Trochim 2006; Simon 2008) suggested that an alpha level of 0.05 is a good compromise between the likelihoods of making Type I and Type II errors since a smaller alpha level decreases the probability of making a Type I error, but increases the likelihood of making a Type II error.

P-value is the probability that measures how much evidence there is against the null hypothesis. Traditionally, the null hypothesis is rejected if p-value is less than or equal to the alpha value. Below the threshold set for the p-value, the results were reported as being statistically significant. This research did not report the results as being "very/extremely significant" when the p-values were very small.

Although much emphasis is placed on finding significance at a chosen alpha level, this research also found that it is important to be concerned with finding no significance, when theoretically we expect to find one (beta level). The research therefore uses the <u>***power analysis***</u> to make sure that we have looked hard enough to find the significance in the null hypothesis.

Power of the test is the ability to detect an effect size if there is one. The effect size is the degree of deviation from the null hypothesis and it will always be there. Thus, the bigger the effect size, the easier it will be to detect it. The effect size is closely related to the sample size since a larger sample size leads to more accurate parameter estimates, which leads to a greater ability to find what we were looking for. Therefore, the smaller an effect size, the more observations the research needs to establish its existence. This research did not specify a minimum effect size considered important enough to deserve attention (if effect is smaller than the specified effect size the test results are considered not significant), but rather focuses on finding/not finding significance.

A prospective power analysis is usually done in order to determine an appropriate sample size that will achieve acceptable power and give the research confidence that the null hypothesis was correctly rejected (or accepted). A power curve graph is a useful and easy way of making the best decision regarding the trade-off between power and sample size. The graphs are built to give information about power, alpha level, sample size, and effect size. Figures 11, 12, 13, and 14 are example of power curves with fixed effect size (difference between means). The curves are built based on Cohen's *d* type of effect size "f" (0.05 - very small; 0.10 – small; 0.25 – medium; and 0.40 - large) that are defined as the difference between means divided by the pooled standard deviation of the data (Cohen 1969, 1977, 1988, and 1992). The graphs give the power of an ANOVA test with four groups (the power curves will change with the number of groups) for specific combinations of alpha level and sample sizes. G*Power 3.1 software (Faul et al. 2009) was used to create these power curves.

Retrospective power analysis is completed after a study has been carried out to help explain the results of a study which did not find any significant effects. Most often studies with small sample sizes will not gain sufficient power to detect the existing effect size. In order to increase power, a study must increase sample size, increase alpha level, or use homogeneous groups.

This research uses the data from NSQD database version 3. Therefore, a prospective power analysis was not justified. Instead, a retrospective power analysis was conducted. Given the already available samples, the sensitivity of the data could not be increased by increasing the sample size. The existing sample sizes and effect sizes were used to determine what the power was in the study which helped accept/reject the null hypothesis. It was assumed that the effect size in the sample was equal to the effect size in the population.

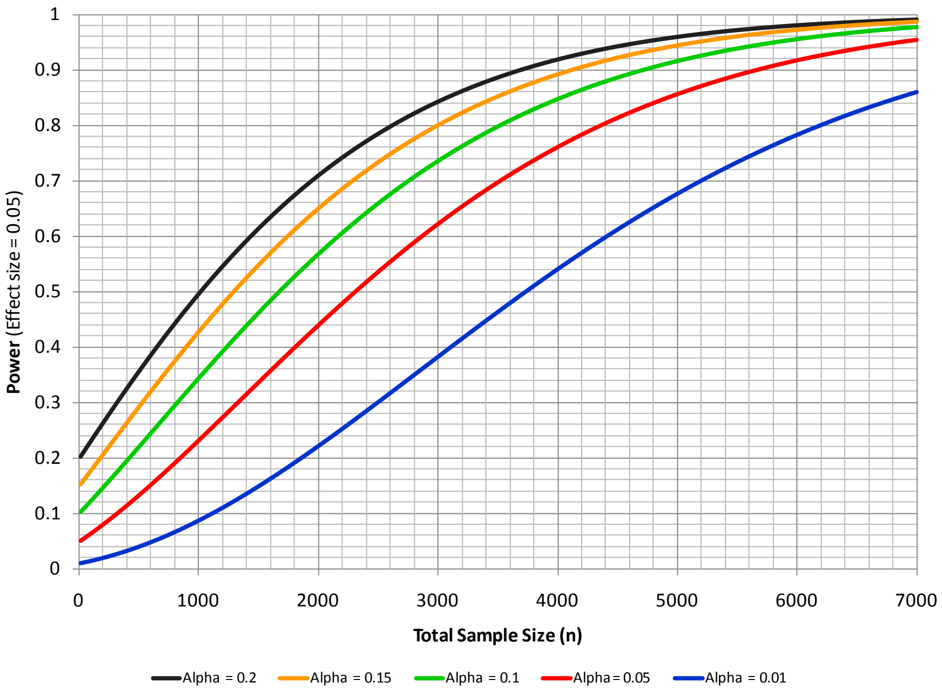


Fig. 11. Power Curves for "Very Small" Effect Size (f = 0.05)
for an ANOVA Test with 4 Groups

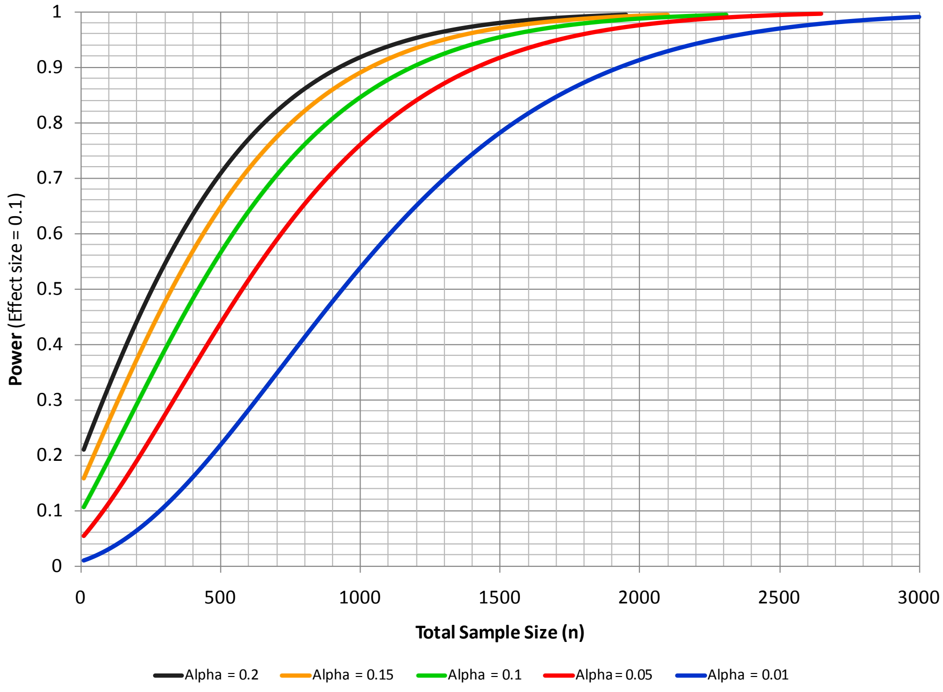


Fig. 12. Power Curves for "Small" Effect Size (f = 0.1)
for an ANOVA Test with 4 Groups

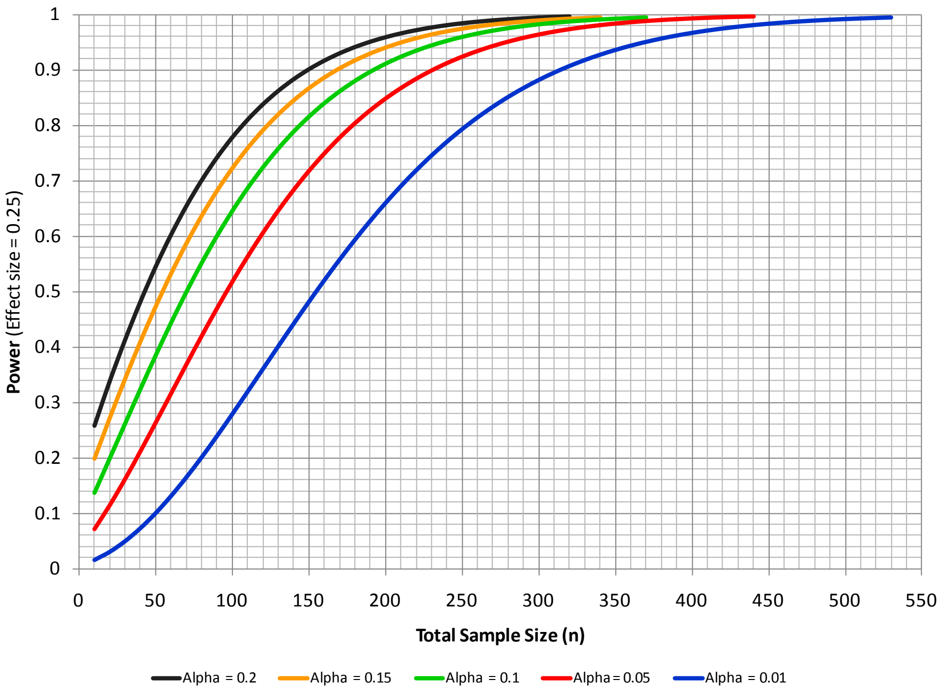


Fig. 13. Power Curves for “Medium” Effect Size (f = 0.25)
for an ANOVA Test with 4 Groups

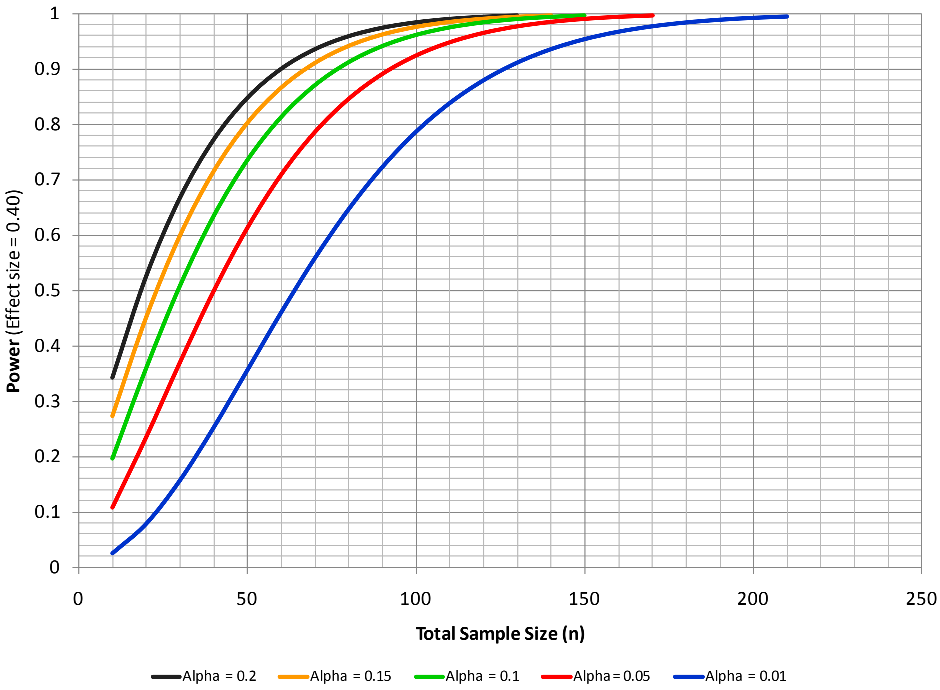


Fig. 14. Power Curves for “Large” Effect Size (f = 0.40)
for an ANOVA Testwith 4 Groups

3.6.3 Normality Test

This research assessed the normality in a data set by using normal probability plots and the Anderson-Darling test for normality. The assumption of normality is required for many statistical analyses performed during this research.

The normal probability plot (Chambers et al. 1983) is a graphical technique for assessing whether or not a data set follows a normal distribution (Figure 16). If the distribution is close to normal, the plotted points will lie close to a line. However, systematic deviations from a line indicate a non-normal distribution.

The Anderson-Darling (AD) test for normality (Stephens 1974) is one of three general normality tests designed to detect all departures from normality. The hypothesis of normality is rejected if the p-values given by Anderson-Darling test is less than or equal to the alpha level. Failing the normality test allows to state with *100(1 –alpha)* confidence that the data does not fit the normal distribution. Passing the normality test only allows to state that no significant departure from normality was found in the data set.

3.6.4 Regression Analyses

Regression analyses are very popular statistical analysis tools. Their main use is to explore the relationship between a dependent variable and one or more independent variables, preferably fitting data to a theoretically derived equation that has some physical meaning. The goal of the regression is to determine the values of the parameters that minimize the sum of the squared residual values for the given set of observations.

This research used simple linear regression ($y = b_0 + b_1x$) and nonlinear regression

($y = b^x$) equations when predicting the relationships between directly connected impervious areas and total impervious areas, for example. The evaluation of the regression results was done by examining the coefficient of determination (R^2, the proportion of the total variability in the dependent variables that the regression equation explains) and the results of the analyses of variance of the model (ANOVA). High R^2 values do not guarantee that the model has any predictive value; similarly a seemingly low R^2 does not mean that the regression model is useless. ANOVA and residual analyses were also used to supplement the interpretation of the basic equation fitting results. The significance of the regression coefficients was verified by performing residual analyses for the fitted equations. Therefore, analyses of the residuals (they must be independent, zero mean, constant variance, and normally distributed) and evaluation of the results were performed through graphical analyses. Because the residuals are the unexplained variation of a model and are calculated as the differences between what is actually observed and what is predicted by the model (equation), their examination should confirm if the fitted model conforms to the regression assumptions (Chatterjee et al. 2000).

Figure 15 is an example of linear regression for high density residential land use from the study area. The regression equation shows that the observed directly connected imperviousness is 66% of the total impervious area over the observed range of conditions. The normal probability plot of the residuals (Figure 16) shows that the residuals are normally distributed (Anderson Darling test for normality has a p-value greater than 0.05 in this example, indicating that the fitted data is not statistically different from a normal distribution). Also, the scatter plot of the residuals versus the predicted values shows independently distributed residuals with some constant variance (Figure 17). Therefore, the fitted model for this land use can be correctly evaluated using the regression equation.

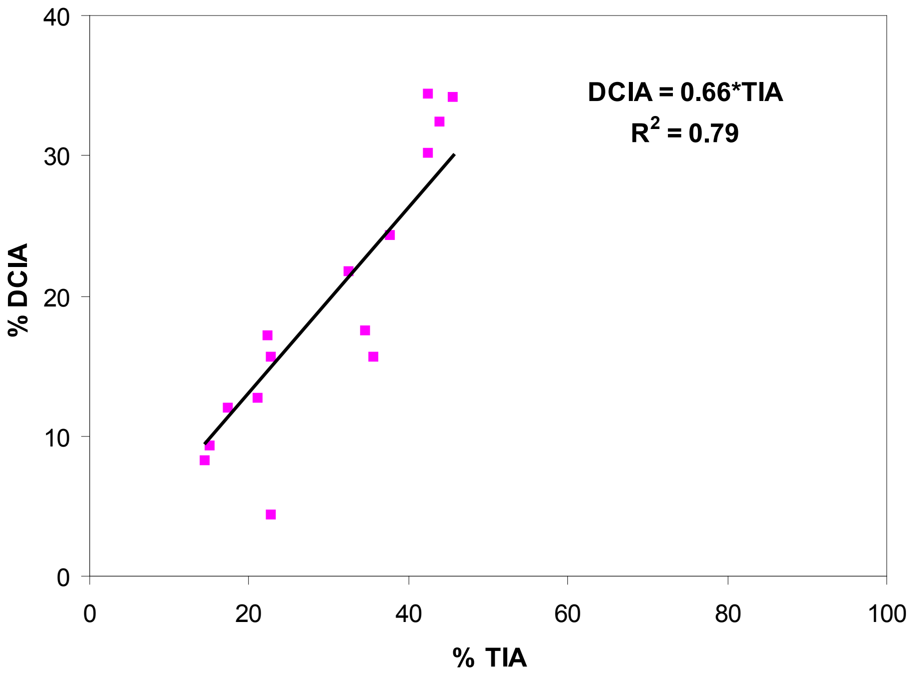


Fig. 15. Example - Linear Regression for High Density Residential Land Use, Jefferson County, AL

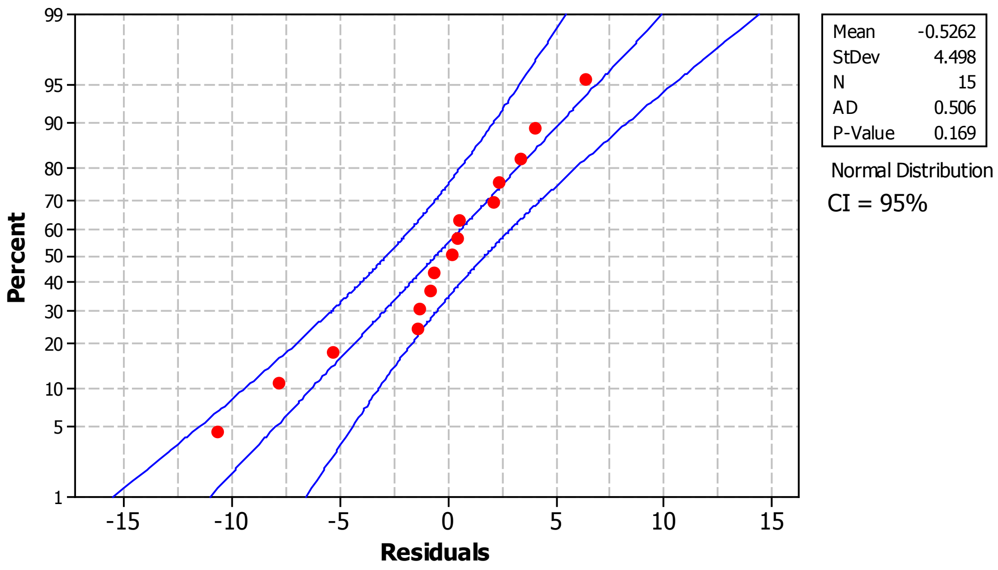


Fig. 16. Example - Probability Plot of the Residuals for Linear Regression of High Density Residential Land Use, Jefferson County, AL

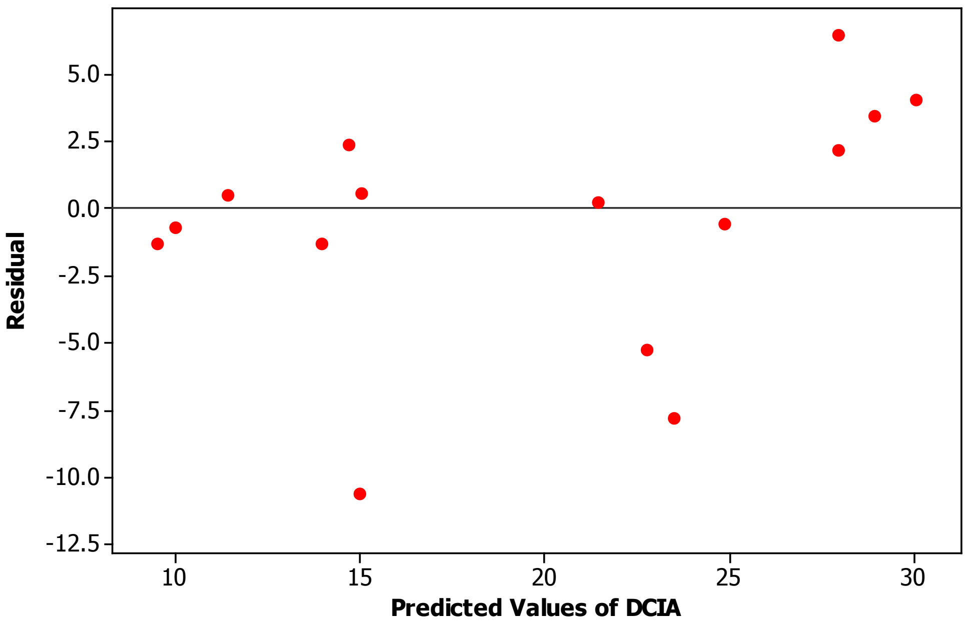


Fig.17. Example - Residuals versus Fitted Values (Response is DCIA Measurements) for Linear Regression of High Density Residential Land Use, Jefferson County, AL

3.6.5 Analyses of Variance

In this research, analyses of variance (ANOVA) were used to test the hypothesis that the means among two or more groups are equal, under the assumption that the samples are either normally distributed or have sizes larger than 30 data points. Generally, even if a sample was not entirely normally distributed, more than 90% of the data in a group were normal. The central limit theorem guarantees that parametric tests are robust to deviations from normality as long as the sample size is larger than 30 (Motulsky 1995). However, if the distributions of the variables under consideration were not normal distributed and the sample size was small then the Kruskal-Wallis test on ranks was used. To better meet the assumptions of homogeneity of variance and normality, transformation of binomial data was needed for the stormwater pollutant values (the log transformation was utilized for these data).

Those tests were able to detect differences among the groups, but were not able to identify which subsets of the data were different from the others. The tests only indicated that there was at least one subset that was statistically different from at least one other subset. Further, a multiple comparison procedure (such as Scheffé for parametric data and Mann-Whitney U Test for nonparametric data) was used to identify significant differences in sample groupings if the analysis of variance tests found that a significant difference really existed.

When multiple groupings needed to be compared according to only one factor (independent variable such as TIA, DCIA, etc.) taken at several levels (observations) from each location, a one-way ANOVA or Kruskal-Wallis analysis were used. The total variation in the data (response measurements) was partitioned into components that correspond to different sources of variation: portion due to random error and portion due to changes in the values of the independent variable. When evaluating data, *p-value* was the sensitivity test for rejecting the hypothesis.

The ANOVA test was also used to test the significance of the regression coefficients (highly dependent on the number of data observations available). When only few data observations were available, strong and important relationships may not be shown to be significant, or high R^2 values could occur with insignificant equation coefficients. Because it was not possible to determine how accurate predictions were based on the value of R^2 alone, this research evaluated the models by using the standard error of the estimate (ANOVA evaluation). The ANOVA table partitioned the variability of the responses and thus distinguished what can be explained by regression and what remained unexplained (i.e., error). A large F value resulting from an ANOVA test suggested that there was a significant linear relationship between the response (endpoint) and the predictor variable. However, a significant F value was not an indication that the used regression equation is the “best fit” model. Calculation of the Pearson’s correlation (r) and the coefficient of determination (R^2) better indicated the fitness or strength of the regression.

To supplement the visual presentation with the grouped box and whisker plots, one-way ANOVA or nonparametric Kruskal-Wallis tests were used to determine if there were any statistically significant differences between the different boxes on the box and whisker plots. Multiple comparison procedures were used if significant differences were found.

3.6.6 Post-hoc Tests

After obtaining a significant result from an ANOVA F-test or Kruskal-Wallis H-test, it was very useful to use multiple comparison procedures to determine which categories significantly differ from each other. The post hoc procedures require a larger difference between means to define where significance lies in the data and were used to make all possible comparisons among groups of data. The post hoc techniques used during this research were Scheffé’s method for parametric data and Mann-Whitney *U* test for nonparametric data.

The Scheffé's method is a single-step multiple comparison procedure which tests all possible contrasts at the same time and it is preferred when many contrasts are of interest. The method is used with normally distributed data of equal or unequal sample sizes and requires equal variances (NIST/SEMATECH 2003). The Scheffé test is a procedure that allows the testing of comparisons among means without inflating the Type I error rate, but it has lower power.

The Mann-Whitney *U* Test was used to compare two independent and non-parametric groups of data. The test has a lower Type II error, but potentially high Type I error. This test was performed as pairwise comparisons at a chosen significance level alpha.

After performing the pairwise comparisons, each individual sample was assigned to a homogeneous group that included only samples that are not statistically significant. A sample could belong to more than one group in which case it was assigned to the group in which the mean (or median) association was the least significant (larger p-values) and confirmed graphically.

3.6.7 Pearson Correlation Matrix Analyses

Pearson correlation matrices are an association technique used to identify simple relationships and the degree of association between parameters. This analysis was used to substantiate possible data groupings identified when using the box-and-whisker plots. During this research, Pearson correlation matrices were constructed using the microcomputer program SYSTAT 10 (SPSS Inc., Chicago, IL) to measure the degree of association between development characteristics and runoff. Table 8 is an example of a standard correlation matrix that shows the relationships between field measurements for those six highly urbanized drainage areas in Jefferson County, Alabama. This example shows several high correlations between pairs of parameters (>0.5). As an example, high correlations are seen between runoff volume and impervious surfaces, suggesting that runoff volume can be accurately predicted by using streets, parking lot areas, and connected roofs OR just by using DCIA. This fact is also supported by the strong negative correlation among those components and pervious surface areas.

Table 8. Example - Pearson Correlation Matrix for Land Development Characteristics

	DCIA	**DSIA**	**STREET**	**PARKING**	**DRWAY**	**CONROOF**	**DISROOF**	**LANDSCAPE**	**PERVIOUS**
DCIA	1.000								
DSIA	-0.365	1.000							
STREET	0.382	0.378	1.000						
PARKING	**0.828**	-0.107	0.378	1.000					
DRWAY	-0.096	0.073	-0.137	-0.231	1.000				
CONROOF	**0.711**	-0.226	0.143	0.495	0.058	1.000			
DISROOF	-0.147	0.300	-0.124	-0.191	0.148	-0.237	1.000		
LANDSCAPE	**-0.566**	0.125	-0.351	**-0.541**	0.290	-0.359	0.209	1.000	
PERVIOUS	-0.248	-0.205	-0.173	-0.218	-0.262	-0.232	-0.241	**-0.569**	1.000
RUNVOL	**0.900**	-0.135	**0.516**	**0.823**	-0.105	**0.671**	-0.212	**-0.604**	-0.204

3.6.8 Cluster and Principal Component Analyses

Cluster and principal component analyses were used to identify more complex patterns and associations in the data as part of exploratory data analyses. Identifying data associations was a critical approach for identifying possible cause and effect relationships. Combinations of hierarchical cluster analyses and principal component analyses (PCA) helped examine complex interrelationships between parameters, as a supplement of the simple correlations found previously. Cluster and principal component analyses were used to identify complex groupings of parameters by factors, so variables within each factor were more highly correlated with variables in that factor than with variables in other factors. PCA were also used to identify similar sites. This research used cluster analyses to examine correlations between field measurement and water quality parameters, and correlations between individual neighborhoods. Data were first standardized to reduce scaling influences. Figure 18 is a dendrogram produced by SYSTAT 10 (SPSS Inc., Chicago, IL) using the same field data as presented in the correlation matrix. A dendrogram can illustrate simple and complex correlations between parameters. Parameters with short branches linking them are more closely correlated than parameters linked by longer branches. The advantage of a cluster analyses is the ability to identify complex correlations that cannot be observed using a simple correlation matrix. In this example, the runoff volume and directly connected impervious areas that had a high correlation as found using the correlation matrix are also seen to have a simple and strong relationship in the cluster analyses.

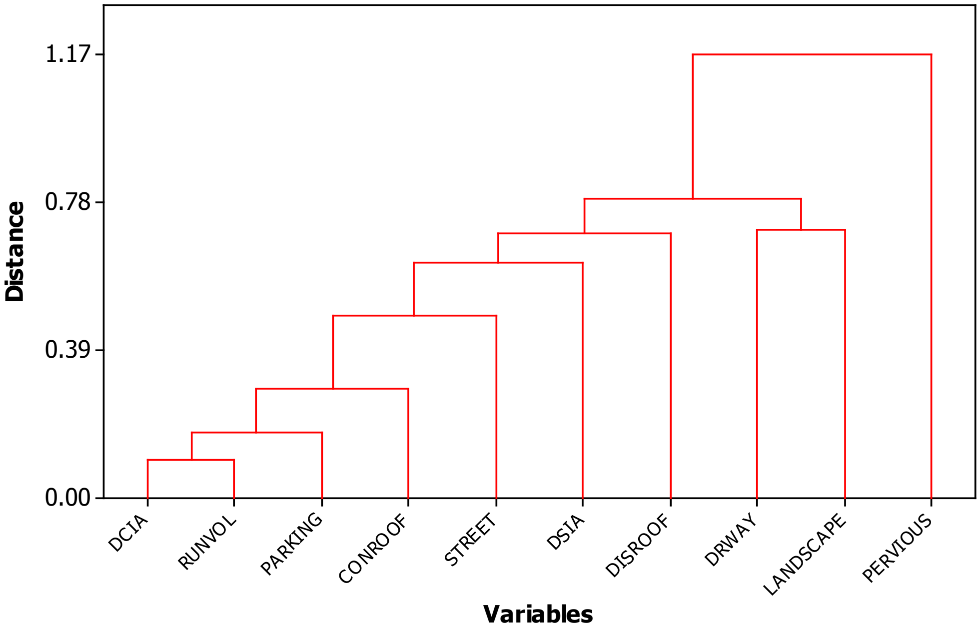


Fig. 18. Example - Tree Diagram (Dendrogram) from Cluster Analyses for Development Characteristics and Runoff Volume for Jefferson County, AL (Distance metric is 1-Pearson correlation coefficient (normalized) and the linkage method is nearest neighbor)

Principal component analyses are variable reduction procedures used to identify relationships and natural groupings of field measurements. Principal component analyses are appropriate when there are large numbers of measured variables that might be redundant. In this case, redundancy means that some of the variables are correlated with each other, possibly because they are measuring the same construct. If the redundancy is justified, then the observed variables are reduced into a smaller number of principal components (artificial variables) that will account for most of the variance in the observed conditions. A principal component analysis was used to identify characteristics of individual sites in the study areas. Table 9 is an example showing the first four components' loadings for the 158 surveyed neighborhoods (collectively comprising most of the information). Figure 19 is an example scree plot showing how much of the total variance is explained by each of the first ten principal components calculated.

Table 9. Example - Percent of Total Variance Explained by the Principal Components

	% Variance	**Cumulative Variance**
PC1	40.3	40.3
PC2	18.6	58.9
PC3	14.5	73.4
PC4	8.58	82.0

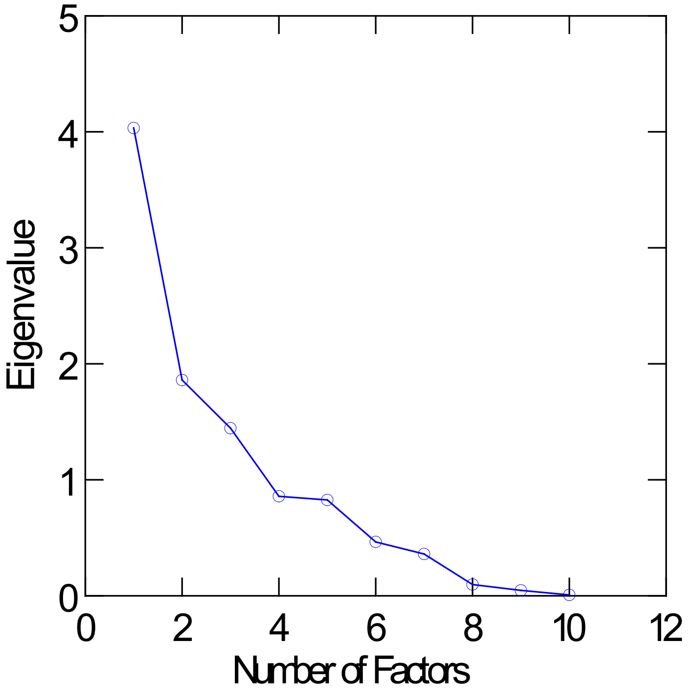


Fig. 19. Example - Scree Plot Showing the Total Variance Explained by the Principal Components

The additional contributions are relatively small after the fourth component, which agrees with the literature conclusion that four principal components should provide a reasonable summary of the data (SAS Institute Inc. 2003).

Figure 20 displays the relationship among the first three principal components that explained about 73% of the cumulative variance. Each vector corresponds to one of the analyzed variables and is proportional to its component loading.

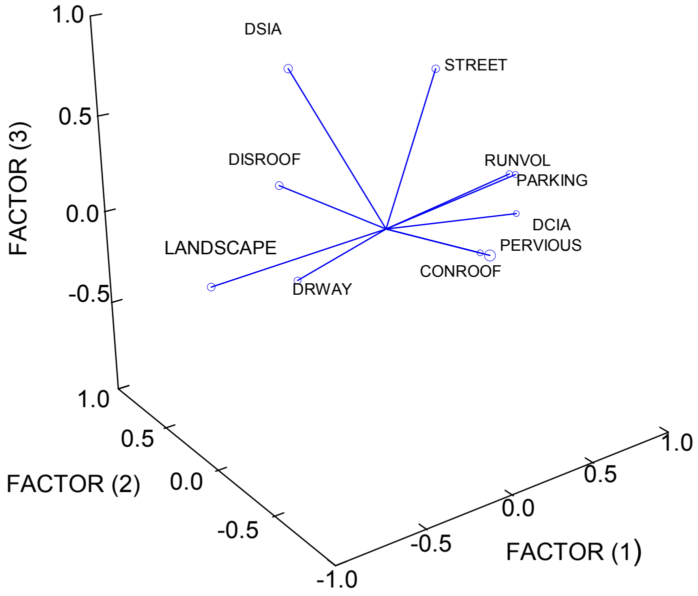
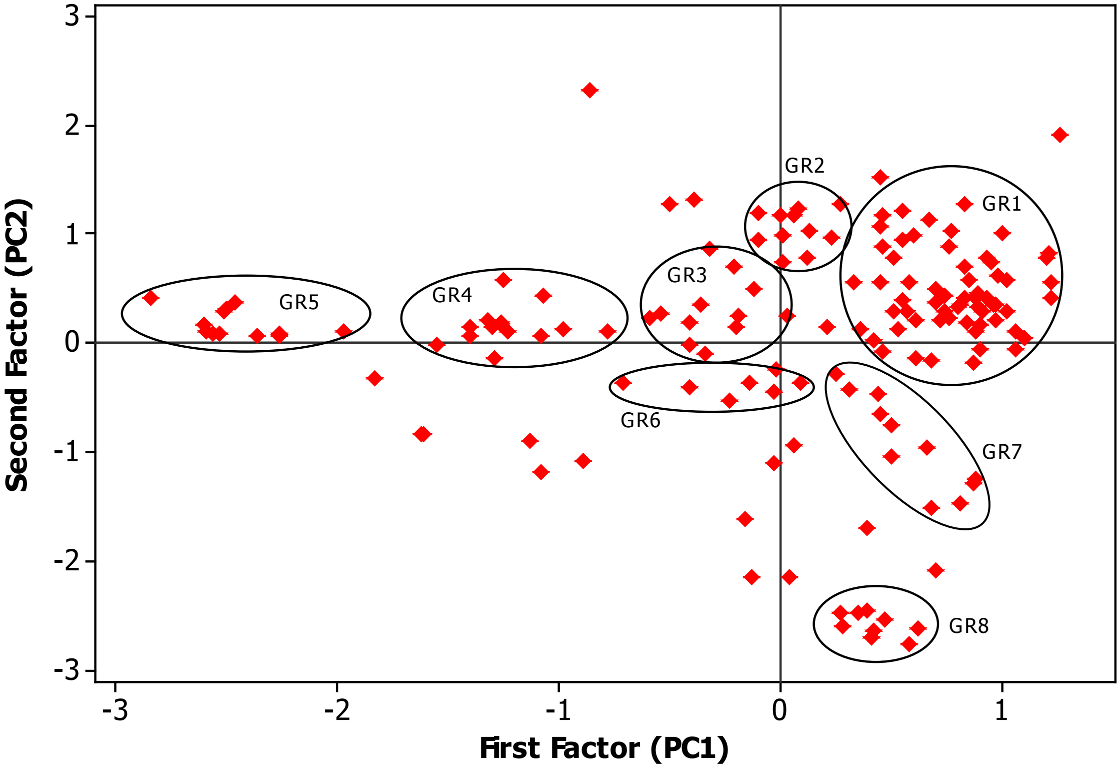


Fig. 20. Example - Loading of Principal Components for Development Characteristics and Runoff Volume for Jefferson County, AL

Figure 21 is a scatter plot of the eigenvalues of the first two principal components for all sites, showing several groupings of samples, corresponding to neighborhoods having similar land uses and similar PCA loadings. As an example, group 1 is mostly residential sites, group 5 is mostly commercial sites, and group 8 is made up exclusively of open space sites. Therefore, the land development characteristics in each of these major groups are consistent in explaining large portions of the variance.



Group 1 (%)		Group 2 (%)		Group 3 (%)		Group 4 (%)		Group 5 (%)		Group 6 (%)		Group 7 (%)		Group 8 (%)	
RES	89	RES	55	AP+MF	42	COM	50	COM	83	RES	43	INST	64	OPEN	100
OPEN	6	FW	36	COM	42	INST	36	IND	17	IND	57	RES	18		
IND	3	COM	9	IND	8	MF	7					OPEN	18		
FW	2			OPEN	8	IND	7								

Fig. 21. Example - Score Plot of Principal Components for Development Characteristics and Runoff Volume for Jefferson County, AL

3.7 Chapter Summary

This chapter describes the research hypothesis and the steps used for its examination and proof. This research aims to explain a portion of the variability of stormwater characteristics by explaining the variability of the development characteristics. The research study area includes five highly urbanized drainage areas in Jefferson County, Alabama. Those watersheds are part of the city of Birmingham's stormwater monitoring program and have been monitored since 2001.

A large portion of this chapter deals with describing the study area, the stormwater monitoring process, the quality control procedures, and the analytical methods used during sample analyses. All the statistical tests used a critical alpha level of 0.05 and $\log_{10}$ transformed data. Analyses of variance, post-hoc tests, and power of the test were the most used tools to test and prove the hypothesis.

The following two chapters (Chapter 4 and 5) present the study of the stormwater variability at national and local levels, along with the analysis of the local land use development characteristic variability. The data from the NSQD was compared with local information from Jefferson County, Alabama, to establish a pattern of stormwater variability. Uncertainty, especially for the measurements that are the most variable, can be reduced by increasing the sampling effort to obtain a better estimate of the mean value. The statistical tools and concepts presented in this chapter were used to test the research hypothesis, explain the uncertainty found in the data, and give recommendations about sample size.

Chapter 4
Stormwater Variability Analyses using the National Stormwater Quality Database (NSQD)

4.1 Introduction

This chapter describes the methods used to analyze stormwater characterization data from the National Stormwater Quality Database (NSQD) version 3 in order to determine stormwater variability and to cluster the constituents with statistically comparable concentrations. Similar analyses were performed on local data (Jefferson County, Alabama) in the later parts of this chapter in order to compare the local pattern of stormwater constituents' variability and clustering with the national data. Statistical tests were performed on $\log_{10}$ transformed values in order to produce data sets that were close to symmetrical, had minimal errors, and created uniform distributions of the residuals after model building. Both main factors and interactions were considered in order to identify significant groupings of data. The factors examined included land use (residential, commercial, industrial, institutional, open space, and freeways), season (fall, spring, summer, and winter), and EPA Rain Zone (the nine EPA rain zones, as shown on Figure 22).

The National Stormwater Quality Database version 3 is a database of stormwater monitoring data compiled by The University of Alabama (Maestre 2005; Hyche 2007), mostly from sampling conducted as part of local stormwater permit programs from throughout the country. The data was reviewed during prior University of Alabama research to describe the characteristics of national stormwater quality, to provide guidance for future sampling needs, and to enhance local stormwater management activities in areas having limited data (Maestre 2005; Pitt and Maestre 2005a). The most recent version of this database (http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml) is a compilation of selected data collected from various stormwater sampling efforts including the Nationwide Urban Runoff Program (NURP) (USEPA 1983), US Geological Survey Urban Stormwater Database (USGS 1987), the International Best Management Practices Database (BMP database), the National Stormwater Quality Database version 1.1 (Maestre 2005), and additional data collected from the NPDES (National Pollutant Discharge Elimination System) MS4 (municipal separate storm sewer system) permit holders. Table 10 shows the contribution of each individual database to the NSQD version 3.

Table 10. Database Contributions

Source	Total Events	Percentage
NURP	1,858	21.6
USGS	62	0.72
International BMP Database	1,696	19.7
NSQD ver 1.1 NPDES MS4	3,765	43.8
NSQD ver 3, Additional NPDES MS4	1,221	14.2
Total	**8,602**	**100**

Source: National Stormwater Quality Database (NSQD) version 3

The National Stormwater Quality Database (NSQD) version 3 contains separate stormwater system outfall quality data for 8,602 separate events from 104 agencies and municipalities from 29 states, representing all of the EPA Rain Zones, filling in the gaps that exist in the individual data sources. This database is useful in characterizing stormwater on a national level and is meant to provide assistance to many municipalities affected by the NPDES stormwater permit program and for researchers.

There are many factors that can be considered when examining the quality of stormwater. Those factors include, but there are not limited to, land use, geographical region (EPA rain zone), and season. The sites were assigned land use categories according to their predominant land use in the watershed. When more than one land use was present, it was considered a mixed site with the major land use noted. About 30% of the storm events stored in the database were collected in residential land use areas, followed by mixed residential and commercial areas with 16% and 15% of the total events respectively. Tables 11 and 12 show the number of storm events included in the latest version of the NSQD database separated by land use, geographical area, and season.

Table 11. Land Use Existent in the NSQD version 3 Database

Land Use	Total Events	Percentage
Residential	2,290	26.6
Mixed Residential	2,108	24.5
Commercial	983	11.4
Mixed Commercial	636	7.4
Institutional	55	0.64
Mixed Institutional	15	0.17
Industrial	639	7.4
Mixed Industrial	457	5.3
Open Space	52	0.60
Mixed Open Space	307	3.6
Freeways	734	8.5
Mixed Freeways	26	0.30
Unknown	300	3.5
Total	**8,602**	**100**

Source: National Stormwater Quality Database (NSQD) version 3

More than 4,750 events represent single land use areas, as shown in Table 12. More than 100 events represent each EPA Rain Zone, except for rain zone 8, where there were no single land use sites.

Table 12. Storm Events Distribution by Geographical Regions, Land Use, and Season

	Zone 1 Great Lakes				**Zone 2 Mid Atlantic**				**Zone 3 Southeast**				**Zone 4 Lower Mississippi Valley**				**Zone 5 Texas**			
SEASON	**FL**	**WI**	**SP**	**SU**	**FL**	**WI**	**SP**	**SU**	**FL**	**WI**	**SP**	**SU**	**FL**	**WI**	**SP**	**SU**	**FL**	**WI**	**SP**	**SU**
Residential	88	20	47	69	290	302	306	233	91	51	55	76	20	23	24	27	10	3	16	21
Commercial	105	30	36	63	129	116	117	103	59	24	12	36	9	8	10	7	6	7	6	3
Institutional	3	0	0	6	11	14	11	10	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	35	17	16	29	67	67	66	51	19	20	23	20	9	11	10	7	1	0	3	3
Open Space	4	0	2	0	7	6	8	7	0	0	0	0	4	5	4	5	0	0	0	0
Freeways	0	0	0	0	72	40	39	90	2	4	3	5	0	0	0	0	69	66	94	33
TOTAL	**235**	**67**	**101**	**167**	**576**	**545**	**547**	**494**	**171**	**99**	**93**	**137**	**42**	**47**	**48**	**46**	**86**	**76**	**119**	**60**
	570				**2162**				**500**				**183**				**341**			
Mixed Residential	149	19	88	119	293	207	276	324	44	37	34	41	15	6	7	20	28	52	66	19
Mixed Commercial	32	0	22	40	78	75	82	66	5	3	0	9	9	6	2	19	12	26	39	20
Mixed Institutional	0	0	0	0	0	0	0	0	5	3	3	4	0	0	0	0	0	0	0	0
Mixed Industrial	0	0	1	2	33	43	49	30	6	9	10	6	10	7	5	12	23	29	35	18
Mixed Open Space	59	8	28	42	22	22	27	14	0	0	0	0	0	0	0	0	9	25	34	8
Mixed Freeways	0	0	1	2	2	2	0	4	0	0	0	0	0	0	0	0	3	3	8	1
TOTAL	**240**	**27**	**140**	**205**	**428**	**349**	**434**	**438**	**60**	**52**	**47**	**60**	**34**	**19**	**14**	**51**	**75**	**135**	**182**	**66**
	612				**1649**				**219**				**118**				**458**			

Source: National Stormwater Quality Database (NSQD) version 3

Table 12 – *Continued*

	Zone 6 Southwest				**Zone 7 Northwest**				**Zone 8 Rocky Mountains**				**Zone 9 Midwest**				**TOTAL**			
SEASON	**FL**	**WI**	**SP**	**SU**	**FL**	**WI**	**SP**	**SU**	**FL**	**WI**	**SP**	**SU**	**FL**	**WI**	**SP**	**SU**	**FL**	**WI**	**SP**	**SU**
Residential	9	9	6	8	50	136	198	21	0	0	0	0	24	2	13	42	582	546	665	497
Commercial	4	2	1	4	10	21	19	14	0	0	0	0	4	2	8	8	326	210	209	238
Institutional	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	14	11	16
Industrial	0	0	0	0	92	30	21	3	0	0	0	0	4	2	7	6	227	147	146	119
Open Space	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	11	14	12
Freeways	8	77	104	0	10	12	4	2	0	0	0	0	0	0	0	0	161	199	244	130
TOTAL	**21**	**88**	**111**	**12**	**162**	**199**	**242**	**40**	**0**	**0**	**0**	**0**	**32**	**6**	**28**	**56**	**1325**	**1127**	**1289**	**1012**
	232				**643**				**0**				**122**				**4753**			
Mixed Residential	5	18	22	5	33	59	35	33	6	2	7	1	6	3	7	22	579	403	542	584
Mixed Commercial	7	9	10	5	8	17	13	5	3	1	3	0	1	1	0	8	155	138	171	172
Mixed Institutional	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3	3	4
Mixed Industrial	19	30	40	13	0	1	5	0	0	0	1	0	3	2	0	15	94	121	146	96
Mixed Open Space	0	1	1	0	0	0	0	0	0	0	0	0	3	1	0	3	93	57	90	67
Mixed Freeways	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	9	7
TOTAL	**31**	**58**	**73**	**23**	**41**	**77**	**53**	**38**	**9**	**3**	**11**	**1**	**13**	**7**	**7**	**48**	**931**	**727**	**961**	**930**
	185				**209**				**24**				**75**				**3549**			

Most of the single land use sites represent residential, commercial, and industrial areas in EPA Rain Zones 1, 2, 3, 4, 5, 6, 7 and 9, with 32 to 1,470 events per rain zone per land use. Many freeway data are also available, but they only represent EPA Rain Zones 2, 5, and 6.

Figure 22 is a map showing the EPA Rain Zones in the U.S., along with the locations of the communities represented in the database.

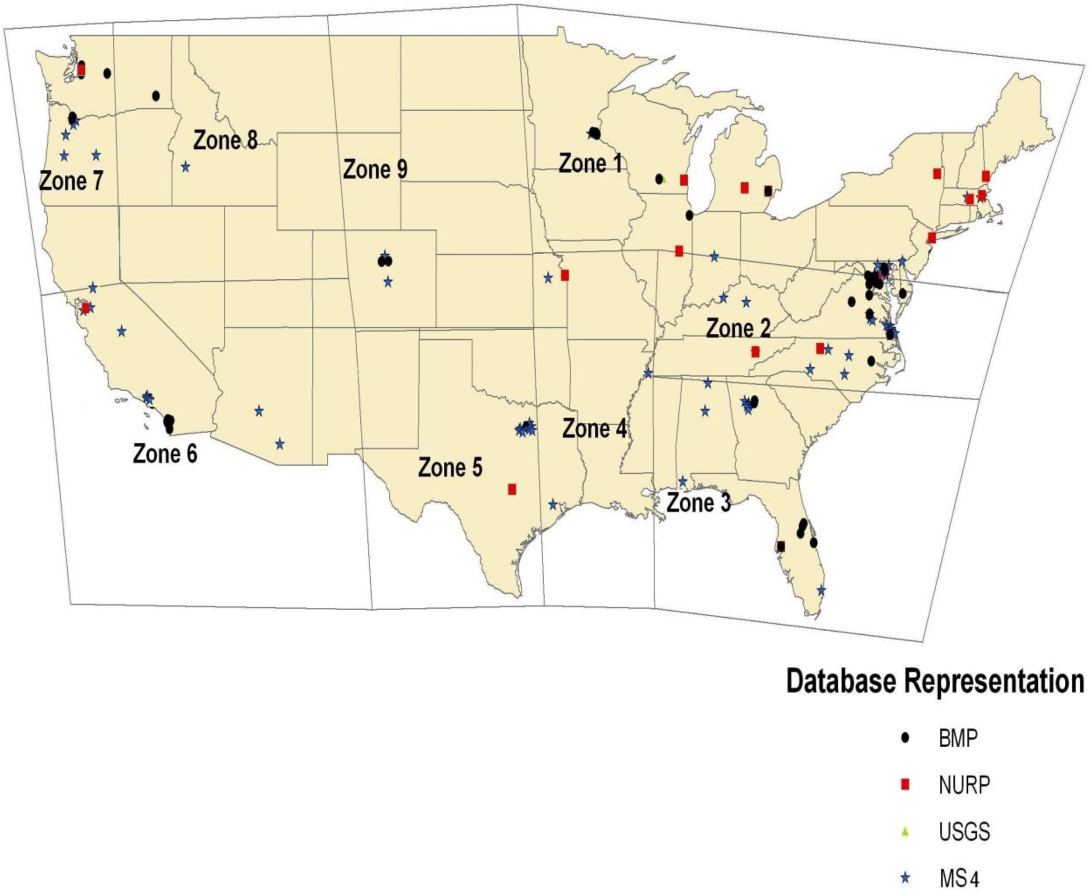


Fig. 22. Sampling Locations for Data Contained in the National Stormwater Quality Database, version 3

There are many data observations in the NSQD with left censored values, which are observations that are below the detection limit. These can greatly affect the outcome of many basic statistical tests. Maestre (2005) concluded that the non-detected values in NSQD can be best estimated using Cohen's method (method that randomly generates the missing data based on the known probability distributions of the data) or they can be adequately adjusted by substituting half of the detection limit when the percentage of left censored observations represents less than about 15% of the total data set. Replacing all of the non-detected values by the same number can have an unwanted effect on the calculated variance. However, if at least 85% of the total observations are above the detection limit, replacing non-detected values by half the detection limit has little effect on the mean and variance of the data sets. However, any substitution method creates problems when conducting paired analyses or model building. For all statistical analyses described in this chapter, the non-detected values were therefore removed. Also, values reported as N/A, ND, N/C, or "0" were also removed. All the concentrations were also $\log_{10}$ transformed to better represent normal distributions to enable parametric statistical evaluations.

4.2 Effects of Geographical Region, Land Use, and Season on NSQD Stormwater Quality

This section examines the effect of geographical region, land use, and season on stormwater constituent concentrations and variability. Hyche (2007) evaluated the NSQD version 3 database and showed that there are significant differences in certain land uses and rain zone combinations. Hyche (2007) found that significantly higher concentrations of total suspended solids and total phosphorous were observed in EPA Rain Zones 4, 6, and 9 compared to the other EPA Rain Zones (Figure 22). Also, concentrations of total zinc and total copper are higher in EPA Rain Zones 4 and 6. As expected, metals concentrations were higher for industrial and commercial land uses.

The ***hypothesis to be tested*** for this research is that the geographical region, the land use, and the seasons, singly or in combination, influence the stormwater constituents' concentrations. As a result, stormwater concentrations collected from different seasons, land uses, and/or geographical regions are significantly different and cannot be pooled into a single category.

The examination of the hypothesis was performed by statistically evaluating the stormwater concentrations observed at single land use areas (residential, commercial, industrial) that have no controls at outfall or in the watershed, for all seasons, and for all EPA Rain Zones (except Rain Zone 8 which has no data) for selected constituents contained in the NSQD. In addition, EPA Rain Zone 2 data were chosen for further detailed analyses due to the availability of larger fractions of the complete NSQD dataset in this area. EPA Rain Zone 2 contains the Chesapeake Bay region in Maryland, one of the original targeted areas for the database, and the states of Virginia, North Carolina, Kentucky, and Tennessee. Local stormwater data from five urban watersheds located in Jefferson County, AL were also analyzed in detail. The results of the local data analysis were compared to the results obtained from the national and EPA Rain Zone 2 analyses.

All EPA Rain Zones were represented in the database, but not for every constituent, land use, or season (Table 12). The database also contains 300 rain events classified as "unknown" or "mixed unknown" land use. These data are from Worchester, Massachusetts and further information about the land use was not available; therefore these events were not included in the statistical analyses. Table 13 is a summary of the selected stormwater constituents included in NSQD version 3 and analyzed as part of this dissertation. The table includes information for some conventional constituents [total suspended solids (mg/L)], metals [total zinc (µg/L), total copper (µg/L), total lead (µg/L)], nutrients [total and dissolved phosphorous (mg/L), total nitrogen (mg/L), Total Kjeldahl Nitrogen (mg/L)], and bacteria [fecal coliform (colonies/100mL)]. These constituents are only a small fraction of all that are available in the NSQD and were selected as representative of stormwater quality constituents commonly monitored by regional authorities. These also have large amounts of available data from throughout the US with few detection limit problems, and cover a range of concentration variabilities. Table 13 describes the total number of observations, the percentage of observations above the detection limits, and the basic statistics including minimum, maximum, average, median, standard deviation, and coefficient of variation for these selected constituents, separated by land use categories. Table 14 is a synopsis for only the coefficients of variation (standard deviation/mean) for all EPA Rain Zones combined, while Table 15 is a summary of the coefficients of variation separated by land uses and rain zones. The coefficient of variation was used to simplify the comparison between pollutants measured in different units and with widely different means, and is therefore a good normalized measure of the concentration variability for different tested conditions.

In order to examines the effect of geographical region, land use, and season on stormwater constituent concentrations, single land uses representing residential, commercial, and industrial were analyzed for all EPA Rain Zones. Total suspended solids are one of the most important constituents in stormwater and are commonly used to measure the effectiveness of controls. Therefore, this constituent is presented in the text as an example of the detailed analyses conducted, while the detailed data for the other constituents are presented in Appendix B.

Table 13. Summary Statistics of Selected Stormwater Constituents Available in NSQD version 3

	% Impervious	**Rainfall Depth (in)**	**Runoff Depth (in)**	**TSS (mg/L)**	**Total Zinc (µg/L)**	**Total Copper (µg/L)**	**Total Lead (µg/L)**	**Total Phosphorous (mg/L)**	**Dissolved Phosphorous (mg/L)**	**Total Nitrogen (mg/L)**	**Total Kjeldahl Nitrogen (mg/L)**	**Fecal Coliform (Colonies/100mL)**
Overall Summary (Single and Mixed Land Uses)												
Number of Observations	1926	4528	2691	6226	5791	4918	4311	6749	2785	567	5787	1931
No. of Samples with Values above DL	1926	4450	2691	6151	5643	4325	3430	6565	2256	532	5621	1767
% of Samples above DL	100	98	100	99	97	88	80	97	81	94	97	92
Average	55	0.71	0.27	140	186	31	38	0.42	0.21	2.5	1.9	51376
Standard Deviation	24	0.77	0.54	304	609	64	75	1.2	0.33	4.4	2.3	250159
Coefficient of Variation	0.44	1.1	2.0	2.2	3.3	2.0	2.0	2.8	1.6	1.8	1.2	4.9
Maximum	100	14	10	10700	22500	1360	1200	80	7.0	90	66	5230000
Median	55	0.51	0.11	64	93	16	15	0.25	0.13	1.7	1.3	4600
Minimum	1.0	0	0	0.11	0.37	0.17	0.05	0.003	0.003	0.20	0.01	1.0
Residential												
Number of Observations	411	1,292	844	1,683	1,558	1,409	1,228	1,814	699	103	1,590	464
No. of Samples with Values above DL	411	1,246	844	1,664	1,509	1,192	935	1,773	557	102	1,551	400
% of Samples above DL	100	96	100	99	97	85	76	98	80	99	98	86
Average	39	0.77	0.17	111	95	24	17	0.36	0.23	2.3	1.7	36606
Standard Deviation	14	0.74	0.32	242	147	51	39	0.66	0.25	1.7	1.8	200873
Coefficient of Variation	0.37	0.97	1.9	2.2	1.6	2.2	2.3	1.8	1.1	0.73	1.1	5.5
Maximum	74	6.5	4.4	4,168	2,000	590	585	20	3.1	9.1	22	3380000
Median	37	0.55	0.06	50	57	10	5.0	0.2	0.16	1.9	1.2	3000
Minimum	10	0.02	0.0002	0.11	0.37	0.33	0.10	0.01	0.01	0.20	0.05	1.0
Mixed Residential												
Number of Observations	331	991	704	1,641	1,377	1,155	821	1,763	573	104	1,560	473
No. of Samples with Values above DL	331	979	704	1,632	1,323	1,047	648	1,734	501	97	1,527	448
% of Samples above DL	100	99	100	99	96	91	79	98	87	93	98	95
Average	45	0.79	0.25	167	161	32	40	0.47	0.18	3.3	2.1	103693
Standard Deviation	14	1.1	0.45	415	487	45	92	0.63	0.17	9.2	2.8	379387
Coefficient of Variation	0.32	1.4	1.8	2.5	3.0	1.4	2.3	1.4	0.92	2.8	1.3	3.7
Maximum	89	14	3.7	10,700	14,700	753	1,200	10	1.4	90	66	5230000
Median	45	0.55	0.11	78	95	20	17	0.32	0.14	2.0	1.4	14668
Minimum	7.0	0.01	0.0003	0.50	1.0	0.50	0.25	0.01	0.01	0.21	0.01	8.0

Table 13. – *Continued*

	% Impervious	Rainfall Depth (in)	Runoff Depth (in)	TSS (mg/L)	Total Zinc (µg/L)	Total Copper (µg/L)	Total Lead (µg/L)	Total Phosphorous (mg/L)	Dissolved Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Fecal Coliform (Colonies/100mL)
Commercial												
Number of Observations	193	478	194	778	789	705	562	857	374	69	659	244
No. of Samples with Values above DL	193	478	194	769	782	593	428	812	253	67	642	212
% of Samples above DL	100	100	100	99	99	84	76	95	68	97	97	87
Average	80	0.63	0.41	120	194	32	34	0.30	0.18	2.55	1.8	26327
Standard Deviation	10	0.61	0.46	210	272	46	56	0.35	0.22	2.96	1.7	81166
Coefficient of Variation	0.13	0.98	1.1	1.8	1.4	1.4	1.7	1.2	1.2	1.2	0.91	3.1
Maximum	98	4.4	2.9	2,385	3,050	569	689	3.4	1.6	18	15	610000
Median	80	0.45	0.25	55	100	18	15	0.19	0.11	1.7	1.4	3000
Minimum	65	0.01	0.003	1.0	0.38	0.17	0.05	0.005	0.01	0.22	0.05	4.0
Mixed Commercial												
Number of Observations	278	371	171	565	414	366	355	543	316	89	473	164
No. of Samples with Values above DL	278	371	171	548	410	346	317	533	287	80	459	153
% of Samples above DL	100	100	100	97	99	95	89	98	91	90	97	93
Average	66	0.60	0.37	151	202	45	35	0.51	0.26	2.5	2.0	33913
Standard Deviation	20	0.47	0.33	248	288	124	52	1.1	0.47	2.8	1.8	105591
Coefficient of Variation	0.31	0.79	0.89	1.6	1.4	2.7	1.5	2.1	1.9	1.1	0.93	3.1
Maximum	94	3.0	2.1	2,996	4,600	1,300	440	16	5.5	20	13	810000
Median	70	0.46	0.30	73	140	18	16	0.28	0.12	1.6	1.4	6000
Minimum	25	0.02	0.01	2.0	2.0	1.1	0.25	0.02	0.01	0.20	0.10	32
Industrial												
Number of Observations	139	278	180	429	421	362	375	443	292	55	386	214
No. of Samples with Values above DL	139	275	180	426	416	287	255	424	211	54	368	194
% of Samples above DL	100	99	100	99	99	79	68	96	72	98	95	91
Average	66	0.73	0.14	129	195	36	42	0.33	0.17	1.9	1.7	41669
Standard Deviation	13	0.72	0.31	194	447	101	107	0.46	0.31	1.4	1.8	301132
Coefficient of Variation	0.20	1.0	2.1	1.5	2.3	2.8	2.6	1.4	1.8	0.78	1.1	7.2
Maximum	90	6.0	2.0	1,550	8,100	1,360	1,200	6.0	3.2	6.4	25	3600000
Median	75	0.50	0.01	64	129	16	17	0.23	0.10	1.5	1.3	1377
Minimum	39	0.03	0.001	1.0	0.37	0.39	0.46	0.02	0.00	0.20	0.05	2.0

Table 13. - *Continued*

	% Impervious	Rainfall Depth (in)	Runoff Depth (in)	TSS (mg/L)	Total Zinc (µg/L)	Total Copper (µg/L)	Total Lead (µg/L)	Total Phosphorous (mg/L)	Dissolved Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Fecal Coliform (Colonies/100mL)
Mixed Industrial												
Number of Observations	222	332	192	351	345	336	342	316	263	55	329	178
No. of Samples with Values above DL	222	332	192	343	340	316	296	296	222	51	314	173
% of Samples above DL	100	100	100	98	99	94	87	94	84	93	95	97
Average	64	0.61	0.31	211	711	41	75	0.56	0.20	2.7	2.4	39720
Standard Deviation	22	0.46	0.33	321	2,053	47	101	0.81	0.35	2.8	3.0	205043
Coefficient of Variation	0.34	0.77	1.1	1.5	2.9	1.1	1.4	1.4	1.7	1.0	1.2	5.2
Maximum	97	3.0	1.8	2,490	22,500	340	620	7.9	4.4	15	22	2500000
Median	75	0.48	0.20	105	230	25	32	0.28	0.11	1.8	1.4	5000
Minimum	15	0.06	0.005	4.0	10	1.5	2.0	0.04	0.02	0.20	0.05	5.0
Institutional												
Number of Observations	18	52	14	54	53	52	52	53	22	7.0	53	3
No. of Samples with Values above DL	18	52	14	53	53	42	48	52	19	7.0	51	3
% of Samples above DL	100	100	100	98	100	81	92	98	86	100	96	100
Average	45	0.67	0.02	87	243	26	30	0.24	0.11	1.6	1.5	3100
Standard Deviation	0	0.60	0.03	80	219	18	44	0.18	0.06	0.60	1.3	1375
Coefficient of Variation	0	0.90	2.1	0.92	0.90	0.67	1.5	0.76	0.60	0.39	0.84	0.44
Maximum	45	2.4	0.13	340	1,300	91	269	1.0	0.24	2.4	7.3	4300
Median	45	0.52	0.002	67	170	22	18	0.19	0.10	1.4	1.2	3400
Minimum	45	0.04	0.0002	5.0	47	2.5	1.9	0.04	0.02	0.83	0.05	1600
Open Space												
Number of Observations	29	38	6.0	38	37	36	32	38	32	13	32	17
No. of Samples with Values above DL	29	38	6.0	35	20	23	17	31	23	12	20	15
% of Samples above DL	100	100	100	92	54	64	53	82	72	92	63	88
Average	3.0	0.68	0.11	72	29	12	22	0.23	0.15	1.3	0.53	15808
Standard Deviation	2.2	0.87	0.09	131	29	14	39	0.17	0.16	0.87	0.21	19383
Coefficient of Variation	0.75	1.3	0.86	1.8	1.0	1.2	1.8	0.73	1.1	0.68	0.39	1.2
Maximum	10	5.1	0.28	565	120	60	140	0.60	0.50	3.2	0.90	63000
Median	2.0	0.49	0.07	24	20	5.0	6.0	0.16	0.06	1.1	0.50	4800
Minimum	1.0	0.06	0.04	3.0	5.0	2.0	0.20	0.02	0.01	0.28	0.20	1500

Table 13. - *Continued*

	% Impervious	Rainfall Depth (in)	Runoff Depth (in)	TSS (mg/L)	Total Zinc (µg/L)	Total Copper (µg/L)	Total Lead (µg/L)	Total Phosphorous (mg/L)	Dissolved Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Fecal Coliform (Colonies/100mL)
Mixed Open Space												
Number of Observations	133	172	95	280	163	110	157	291	149	58	229	87
No. of Samples with Values above DL	133	172	95	275	160	99	117	285	128	48	217	85
% of Samples above DL	100	100	100	98	98	90	75	98	86	83	95	98
Average	26	0.62	0.17	185	118	15	32	0.29	0.16	2.0	1.2	33540
Standard Deviation	11	0.50	0.21	356	128	23	72	0.37	0.18	1.6	1.2	77607
Coefficient of Variation	0.41	0.80	1.2	1.9	1.1	1.6	2.3	1.3	1.1	0.78	1.0	2.3
Maximum	40	3.6	1.2	3,375	840	210	450	2.5	1.1	9.4	8.8	390000
Median	33	0.52	0.09	68	80	9.0	10	0.18	0.10	1.7	0.82	2600
Minimum	1.0	0.01	0.003	0.50	5.0	2.0	1.0	0.003	0.01	0.30	0.15	4.0
Freeways												
Number of Observations	154	498	279	369	596	349	364	594	54	14	439	67
No. of Samples with Values above DL	154	481	279	368	592	342	356	588	44	14	435	67
% of Samples above DL	100	97	100	100	99	98	98	99	81	100	99	100
Average	86	0.71	0.62	113	161	33	73	0.65	0.42	1.8	2.5	8553
Standard Deviation	11	0.71	1.2	290	225	72	80	3.4	1.2	1.1	3.0	22719
Coefficient of Variation	0.13	0.99	1.9	2.6	1.4	2.2	1.1	5.3	2.8	0.64	1.2	2.7
Maximum	100	6.1	10	4,800	2,100	800	660	80	7.0	3.9	36	160000
Median	80	0.50	0.29	52	98	17	47	0.25	0.12	1.4	1.7	2000
Minimum	70	0	0.01	0.42	0.37	0.39	0.42	0.01	0.02	0.70	0.03	20
Mixed Freeways												
Number of Observations	18	26	12	23	23	23	23	22	11	0	22	20
No. of Samples with Values above DL	18	26	12	23	23	23	13	22	11	0	22	17
% of Samples above DL	100	100	100	100	100	100	57	100	100	ND	100	85
Average	29	0.65	0.28	117	205	30	19	0.33	0.04	ND	4.0	17001
Standard Deviation	4.2	0.53	0.24	124	191	29	24	0.22	0.04	ND	5.0	39924
Coefficient of Variation	0.15	0.81	0.85	1.1	0.93	1.0	1.3	0.7	0.92	ND	1.3	2.3
Maximum	38	1.9	0.77	614	657	112	92	0.85	0.14	0	21	160000
Median	27	0.47	0.19	88	130	14	10	0.34	0.03	ND	2.3	2600
Minimum	27	0.03	0.06	16	30	5.0	5.0	0.04	0.01	0	0.10	33

Table 14. Summary of the Coefficients of Variation* (All Rain Zones Combined) for Selected Stormwater Constituents from NSQD version 3

Coefficient of Variation	**% Imp. Cover**	**Rainfall Depth (in)**	**Runoff Depth (in)**	**TSS (mg/L)**	**Total Zinc (µg/L)**	**Total Copper (µg/L)**	**Total Lead (µg/L)**	**Total Phosphorous (mg/L)**	**Dissolved Phosphorous (mg/L)**	**Total Nitrogen (mg/L)**	**Total Kjeldahl Nitrogen (mg/L)**	**Fecal Coliform (Colonies/ 100mL)**
Overall	0.44	1.1	1.9	2.2	3.3	2.1	2.0	2.8	1.6	1.7	1.2	5.0
Residential	0.37	0.97	1.9	2.2	1.6	2.2	2.3	1.8	1.1	0.73	1.1	5.5
Commercial	0.13	0.98	1.1	1.8	1.4	1.4	1.7	1.2	1.2	1.2	0.91	3.1
Industrial	0.20	1.0	2.1	1.5	2.3	2.8	2.6	1.4	1.8	0.78	1.1	7.2
Institutional	0	0.90	2.1	0.92	0.90	0.67	1.5	0.76	0.60	0.39	0.84	0.44
Open Space	0.75	1.3	0.86	1.8	1.0	1.2	1.8	0.73	1.1	0.68	0.39	1.2
Freeways	0.13	0.99	1.9	2.6	1.4	2.2	1.1	5.3	2.8	0.64	1.2	2.7
Mixed Residential	0.32	1.4	1.8	2.5	3.0	1.4	2.3	1.4	0.92	2.8	1.3	3.7
Mixed Commercial	0.31	0.79	0.89	1.6	1.4	2.7	1.5	2.1	1.9	1.1	0.93	3.1
Mixed Industrial	0.34	0.77	1.1	1.5	2.9	1.1	1.4	1.4	1.7	1.0	1.2	5.2
Mixed Open Space	0.41	0.80	1.2	1.9	1.1	1.6	2.3	1.3	1.1	0.78	1.0	2.3
Mixed Freeways	0.15	0.81	0.85	1.1	0.93	1.0	1.3	0.7	0.92	ND	1.3	2.3

*Land uses have no controls

Table 15. Summary of the Coefficients of Variation for Selected Stormwater Constituents by EPA Rain Zone and Land Use

TSS (mg/L)	**Rain Zone 1**	**Rain Zone 2**	**Rain Zone 3**	**Rain Zone 4**	**Rain Zone 5**	**Rain Zone 6**	**Rain Zone 7**	**Rain Zone 8**	**Rain Zone 9**
Overall (single land uses)	1.3	1.6	1.8	1.7	1.0	2.6	1.0	0	1.4
Residential	1.2	1.6	2.0	1.7	0.87	0.76	0.89	ND	1.5
Commercial	1.2	1.8	1.9	1.4	1.0	1.0	1.1	ND	1.5
Industrial	1.4	1.1	1.4	1.4	0.46	ND	1.2	ND	1.1
Institutional	0.69	1.0	ND	ND	ND	ND	ND	ND	ND
Open Space	0.56	1.2	ND	1.0	ND	ND	ND	ND	ND
Freeways	ND	1.6	1.4	ND	ND	2.8	0.86	ND	ND
Overall (mixed land uses)	1.7	1.6	1.4	1.2	1.5	1.2	2.0	0.91	1.8
Mixed Residential	1.1	1.6	1.4	1.1	0.96	0.86	2.0	0.90	1.6
Mixed Commercial	1.2	1.5	0.73	1.1	1.5	0.66	0.80	0.77	0.50
Mixed Industrial	0.58	1.8	1.0	1.0	1.8	1.2	0.55	ND	0.72
Mixed Institutional	ND	ND	1.4	ND	ND	ND	ND	ND	ND
Mixed Open Space	2.3	1.3	ND	ND	1.6	ND	ND	ND	0.44
Mixed Freeways	0.29	0.57	ND	ND	1.1	ND	ND	ND	ND

Total Zinc (µg/L)	**Rain Zone 1**	**Rain Zone 2**	**Rain Zone 3**	**Rain Zone 4**	**Rain Zone 5**	**Rain Zone 6**	**Rain Zone 7**	**Rain Zone 8**	**Rain Zone 9**
Overall (single land uses)	1.8	1.5	1.4	1.3	1.2	1.1	2.7	0	1.4
Residential	1.9	1.6	1.1	1.6	1.0	1.2	0.67	ND	0.95
Commercial	1.7	1.2	1.5	1.0	0.76	0.44	1.2	ND	0.62
Industrial	1.1	1.0	1.2	1.1	0.33	ND	2.9	ND	1.3
Institutional	0.24	0.92	ND	ND	ND	ND	ND	ND	ND
Open Space	ND	1.0	ND	0.74	ND	ND	ND	ND	ND
Freeways	ND	1.3	1.0	ND	1.3	1.1	0.78	ND	ND
Overall (mixed land uses)	0.92	3.1	2.0	2.8	1.1	2.4	0.82	1.1	0.82
Mixed Residential	0.87	3.9	1.3	2.2	0.80	1.2	0.83	0.56	1.0
Mixed Commercial	0.82	0.89	0.70	0.79	0.80	2.2	0.82	1.1	0.66
Mixed Industrial	0.42	0.78	1.8	2.9	1.1	2.0	0.48	ND	0.66
Mixed Institutional	ND	ND	0.49	ND	ND	ND	ND	ND	ND
Mixed Open Space	0.66	0.66	ND	ND	1.3	1.0	ND	ND	0.43
Mixed Freeways	0.14	0.64	ND	ND	0.47	ND	ND	ND	ND

Total Copper (µg/L)	**Rain Zone 1**	**Rain Zone 2**	**Rain Zone 3**	**Rain Zone 4**	**Rain Zone 5**	**Rain Zone 6**	**Rain Zone 7**	**Rain Zone 8**	**Rain Zone 9**
Overall (single land uses)	1.4	1.8	4.3	1.9	1.5	1.6	0.95	0	1.0
Residential	2.3	2.0	3.3	1.8	0.28	1.5	1.0	ND	0.83
Commercial	0.86	1.4	1.6	1.1	0.81	0.40	0.80	ND	0.70
Industrial	1.7	1.8	1.1	1.9	0.37	ND	0.74	ND	1.1
Institutional	0.39	0.74	ND	ND	ND	ND	ND	ND	ND
Open Space	0.14	1.3	ND	0.69	ND	ND	ND	ND	ND
Freeways	ND	2.0	3.7	ND	1.8	1.4	0.81	ND	ND
Overall (mixed land uses)	1.5	1.1	1.5	0.67	4.0	1.0	1.2	1.0	1.4
Mixed Residential	1.6	1.1	1.6	0.76	1.8	1.2	0.54	0.44	1.2
Mixed Commercial	0.68	0.90	0.45	0.55	3.2	1.0	1.4	1.2	1.7
Mixed Industrial	0.05	0.80	1.0	0.46	0.73	0.85	0.26	ND	0.74
Mixed Institutional	ND	ND	0.61	ND	ND	ND	ND	ND	ND
Mixed Open Space	ND	0.60	ND	ND	1.0	1.1	ND	ND	0.70
Mixed Freeways	0.10	0.57	ND	ND	0.36	ND	ND	ND	ND

Table 15. - *Continued*

Total Lead (µg/L)	**Rain Zone 1**	**Rain Zone 2**	**Rain Zone 3**	**Rain Zone 4**	**Rain Zone 5**	**Rain Zone 6**	**Rain Zone 7**	**Rain Zone 8**	**Rain Zone 9**
Overall (single land uses)	0.94	1.9	3.6	2.1	0.94	1.5	1.3	ND	2.9
Residential	1.0	2.4	4.7	1.7	1.7	1.2	1.6	ND	0.99
Commercial	1.1	1.7	1.6	0.86	0.83	0.74	1.6	ND	0.57
Industrial	0.78	2.3	1.2	1.8	0.38	ND	0.73	ND	1.2
Institutional	0.78	1.5	ND	ND	ND	ND	ND	ND	ND
Open Space	ND	1.7	ND	ND	ND	ND	ND	ND	ND
Freeways	ND	0.78	ND	ND	0.76	1.5	1.3	ND	ND
Overall (mixed land uses)	2.2	1.5	1.1	0.68	1.5	1.1	1.1	1.3	0.72
Mixed Residential	2.2	1.5	1.2	0.51	1.5	0.78	0.89	0.79	0.49
Mixed Commercial	0.68	1.6	0.52	0.70	1.3	2.7	1.1	1.2	0.62
Mixed Industrial	ND	1.0	0.80	0.86	1.3	0.90	0.57	ND	0.73
Mixed Institutional	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mixed Open Space	ND	0.70	ND	ND	2.4	1.2	ND	ND	0.47
Mixed Freeways	ND	ND	ND	ND	0.73	ND	ND	ND	ND

Total Phosphorous (mg/L)	**Rain Zone 1**	**Rain Zone 2**	**Rain Zone 3**	**Rain Zone 4**	**Rain Zone 5**	**Rain Zone 6**	**Rain Zone 7**	**Rain Zone 8**	**Rain Zone 9**
Overall (single land uses)	0.95	1.8	1.3	1.2	9.0	1.5	1.2	0	0.69
Residential	0.92	2.0	1.4	0.93	0.65	0.50	1.2	ND	0.68
Commercial	0.92	1.0	1.1	0.85	0.74	0.94	1.5	ND	0.67
Industrial	0.76	1.7	1.1	0.54	0.47	ND	0.88	ND	0.50
Institutional	0.42	0.80	ND	ND	ND	ND	ND	ND	ND
Open Space	0.32	0.81	ND	0.60	ND	ND	ND	ND	ND
Freeways	ND	1.3	0.74	ND	9.3	1.6	0.57	ND	ND
Overall (mixed land uses)	1.4	1.4	1.3	1.4	2.2	1.1	1.1	0.83	1.2
Mixed Residential	1.0	1.5	1.4	1.4	0.92	1.4	1.2	0.84	0.98
Mixed Commercial	2.1	1.3	0.41	1.5	2.8	0.65	0.61	0.62	0.65
Mixed Industrial	1.0	1.5	0.90	1.2	1.3	0.92	0.40	ND	0.76
Mixed Institutional	ND	ND	0.48	ND	ND	ND	ND	ND	ND
Mixed Open Space	1.7	1.1	ND	ND	1.0	0.25	ND	ND	0.52
Mixed Freeways	0.22	0.46	ND	ND	0.96	ND	ND	ND	ND

Dissolved Phosphorous (mg/L)	**Rain Zone 1**	**Rain Zone 2**	**Rain Zone 3**	**Rain Zone 4**	**Rain Zone 5**	**Rain Zone 6**	**Rain Zone 7**	**Rain Zone 8**	**Rain Zone 9**
Overall (single land uses)	1.1	1.2	1.6	0.81	0.86	2.3	1.7	ND	0.89
Residential	1.1	1.1	1.5	0.68	0.29	0.56	1.7	ND	0.94
Commercial	0.44	1.0	1.7	0.96	0.66	ND	1.9	ND	0.63
Industrial	0.94	1.9	1.3	0.69	0.60	ND	0.83	ND	0.99
Institutional	0.64	0.49	ND	ND	ND	ND	ND	ND	ND
Open Space	ND	1.1	ND	0.65	ND	ND	ND	ND	ND
Freeways	ND	0.78	1.3	ND	ND	2.1	ND	ND	ND
Overall (mixed land uses)	1.3	1.8	0.80	0.94	1.0	0.89	0.56	0	0.72
Mixed Residential	1.3	0.98	0.64	0.55	0.69	0.47	0.62	ND	0.37
Mixed Commercial	0.69	1.9	0.42	1.1	0.99	0.79	0.79	ND	0.60
Mixed Industrial	ND	2.0	1.1	0.78	1.1	0.88	0.22	ND	0.86
Mixed Institutional	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mixed Open Space	ND	1.1	ND	ND	1.2	ND	ND	ND	0.46
Mixed Freeways	ND	ND	ND	ND	0.92	ND	ND	ND	ND

Table 15. - *Continued*

Total Nitrogen (mg/L)	**Rain Zone 1**	**Rain Zone 2**	**Rain Zone 3**	**Rain Zone 4**	**Rain Zone 5**	**Rain Zone 6**	**Rain Zone 7**	**Rain Zone 8**	**Rain Zone 9**
Overall (single land uses)	0.54	1.0	0.94	0.55	ND	ND	ND	ND	0.56
Residential	0.43	0.39	1.0	0.48	ND	ND	ND	ND	0.59
Commercial	0.52	1.0	1.0	0.54	ND	ND	ND	ND	0.60
Industrial	0.44	0.55	0.79	0.56	ND	ND	ND	ND	0.55
Institutional	0.39	ND	ND	ND	ND	ND	ND	ND	ND
Open Space	0.47	0.20	ND	0.41	ND	ND	ND	ND	ND
Freeways	ND	ND	0.64	ND	ND	ND	ND	ND	ND
Overall (mixed land uses)	0.58	2.5	0.67	0.81	0	0.43	ND	ND	0.44
Mixed Residential	0.55	3.0	0.28	0.28	ND	0.46	ND	ND	ND
Mixed Commercial	0.66	1.2	0.88	0.82	ND	0.35	ND	ND	0.36
Mixed Industrial	ND	1.1	0.81	1.1	ND	0.46	ND	ND	0.50
Mixed Institutional	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mixed Open Space	ND	0.78	ND	ND	ND	ND	ND	ND	ND
Mixed Freeways	ND	ND	ND	ND	ND	ND	ND	ND	ND

Total Kjeldahl Nitrogen (mg/L)	**Rain Zone 1**	**Rain Zone 2**	**Rain Zone 3**	**Rain Zone 4**	**Rain Zone 5**	**Rain Zone 6**	**Rain Zone 7**	**Rain Zone 8**	**Rain Zone 9**
Overall (single land uses)	0.64	1.1	0.95	0.67	0.88	1.2	0.93	ND	0.79
Residential	0.68	1.0	1.0	0.60	0.87	0.66	1.0	ND	0.79
Commercial	0.61	1.0	0.57	0.63	0.65	0.71	0.93	ND	0.63
Industrial	0.60	1.4	0.80	0.58	0.39	ND	0.58	ND	0.56
Institutional	0.74	0.82	ND	ND	ND	ND	ND	ND	ND
Open Space	ND	0.29	ND	0.57	ND	ND	ND	ND	ND
Freeways	ND	1.1	ND	ND	0.86	1.4	0.58	ND	ND
Overall (mixed land uses)	1.0	1.2	0.74	0.78	2.1	0.85	0.87	0.81	0.58
Mixed Residential	0.94	1.2	0.72	0.60	2.3	1.0	0.84	0.78	0.47
Mixed Commercial	0.92	0.80	0.73	0.96	0.62	0.65	0.98	0.66	0.60
Mixed Industrial	0.52	1.5	0.91	0.55	0.89	0.83	0.51	ND	0.59
Mixed Institutional	ND	ND	0.51	ND	ND	ND	ND	ND	ND
Mixed Open Space	0.90	0.81	ND	ND	0.92	0.16	ND	ND	0.65
Mixed Freeways	0.31	0.95	ND	ND	1.0	ND	ND	ND	ND

Fecal Colifom (Colonies/100mL)	**Rain Zone 1**	**Rain Zone 2**	**Rain Zone 3**	**Rain Zone 4**	**Rain Zone 5**	**Rain Zone 6**	**Rain Zone 7**	**Rain Zone 8**	**Rain Zone 9**
Overall (single land uses)	5.8	2.6	5.7	3.9	2.3	1.9	3.9	ND	1.1
Residential	4.5	2.9	4.2	1.0	1.1	1.5	2.6	ND	0.80
Commercial	2.2	2.1	1.0	2.1	2.4	ND	3.9	ND	1.5
Industrial	5.7	2.3	1.9	4.6	0.92	ND	2.6	ND	1.3
Institutional	0.44	ND	ND	ND	ND	ND	ND	ND	ND
Open Space	1.7	1.0	ND	0.75	ND	ND	ND	ND	ND
Freeways	3.3	ND	ND	ND	ND	2.1	1.8	ND	ND
Overall (mixed land uses)	3.0	2.3	2.3	2.4	2.9	1.4	2.9	2.3	1.6
Mixed Residential	2.9	1.9	2.3	1.0	1.8	0.71	2.3	2.1	0.07
Mixed Commercial	ND	1.3	ND	1.4	3.0	1.5	3.5	1.3	0.88
Mixed Industrial	ND	1.5	1.6	2.9	4.7	1.0	2.2	ND	1.8
Mixed Institutional	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mixed Open Space	ND	3.6	ND	ND	2.1	ND	ND	ND	0.59
Mixed Freeways	ND	1.8	ND	ND	2.0	ND	ND	ND	ND

Figure 23 is a box-and-whisker plot of total suspended solids concentrations for the EPA Rain Zones. Figure 24 shows their coefficients of variation and Figure 25 is a probability plot with test statistics used to check for the normality of the data. The hypothesis of normality is rejected if the p-values given by Anderson-Darling (AD) test is less than or equal to the alpha level of 0.05.

The box-and-whisker plot shows that there are likely significant variations among the rain zones. Also, the coefficients of variation for the non-transformed data show differences among rain zones and land uses. The next step was therefore to examine the rain zone and land use category interactions and separate effects.

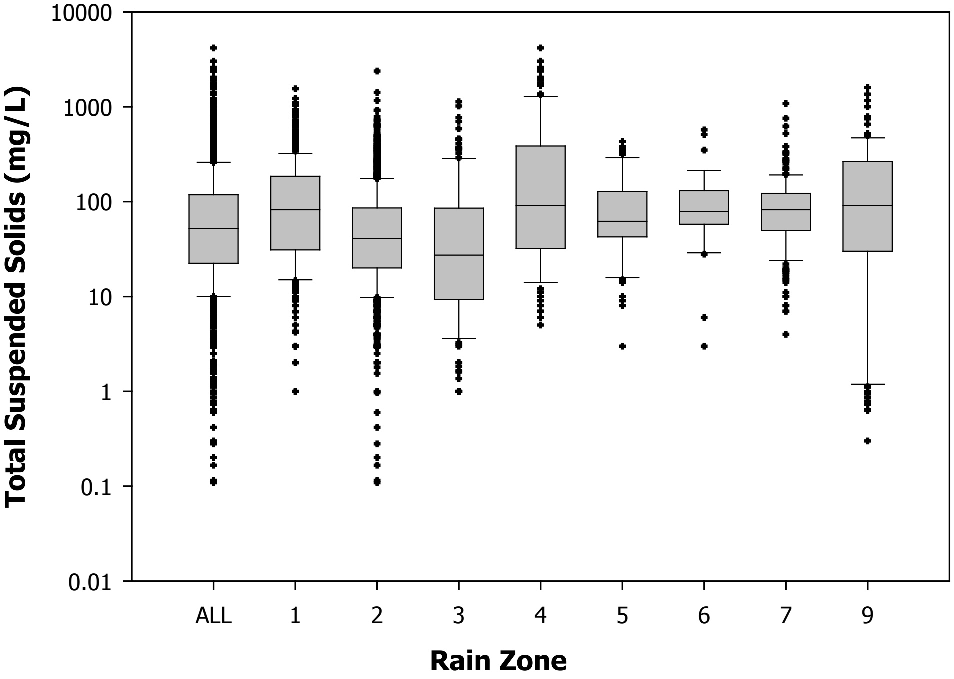
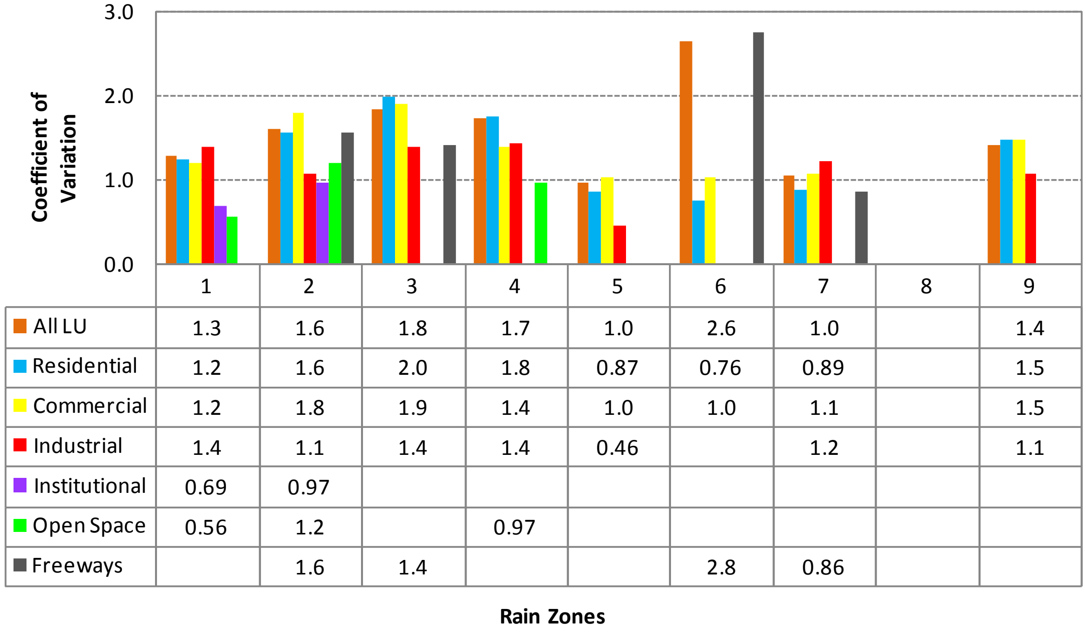
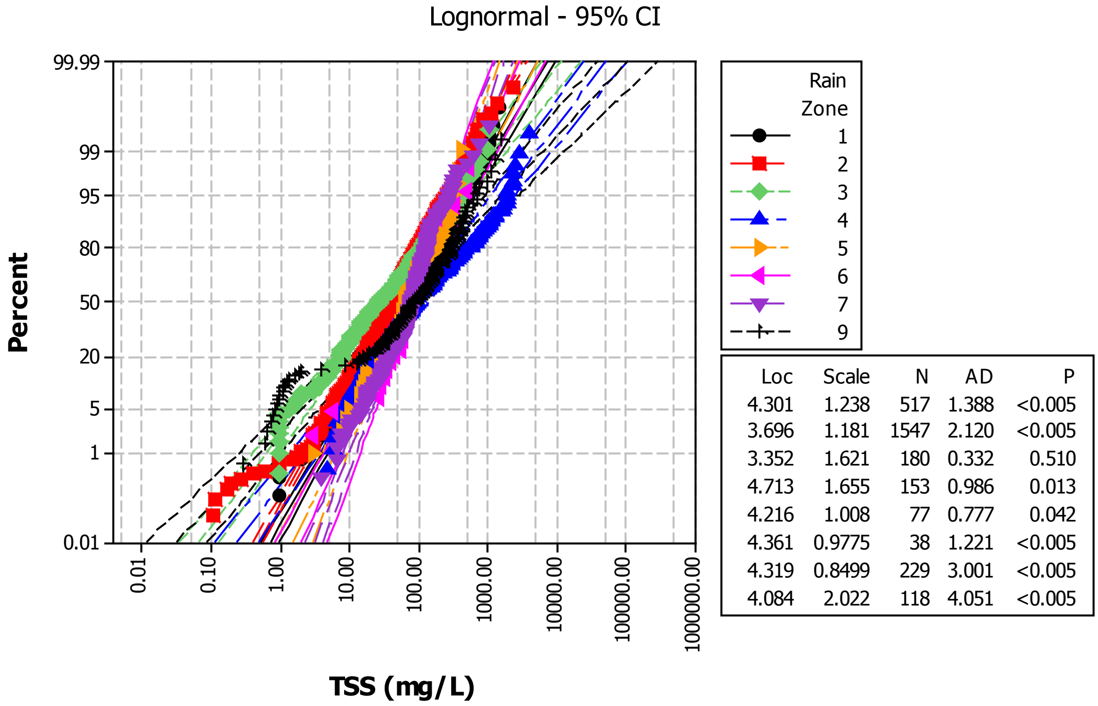


Fig. 23. Total Suspended Solids – Residential, Commercial and Industrial Land Uses in the Contiguous United States



	1	2	3	4	5	6	7	8	9
🟧 All LU	1.3	1.6	1.8	1.7	1.0	2.6	1.0		1.4
🟦 Residential	1.2	1.6	2.0	1.8	0.87	0.76	0.89		1.5
🟨 Commercial	1.2	1.8	1.9	1.4	1.0	1.0	1.1		1.5
🟥 Industrial	1.4	1.1	1.4	1.4	0.46		1.2		1.1
🟪 Institutional	0.69	0.97							
🟩 Open Space	0.56	1.2		0.97					
⬛ Freeways		1.6	1.4			2.8	0.86		

Fig. 24. Total Suspended Solids - Regional Coefficients of Variation for Single Land Uses in the Contiguous United States



Loc	Scale	N	AD	P
4.301	1.238	517	1.388	<0.005
3.696	1.181	1547	2.120	<0.005
3.352	1.621	180	0.332	0.510
4.713	1.655	153	0.986	0.013
4.216	1.008	77	0.777	0.042
4.361	0.9775	38	1.221	<0.005
4.319	0.8499	229	3.001	<0.005
4.084	2.022	118	4.051	<0.005

Fig. 25. Total Suspended Solids – Residential, Commercial and Industrial Land Uses in the Contiguous United State (Checks for Normality)

Figure 26 shows the three land uses by their respective rain zone. Again, the box-and-whisker plot shows variations among land uses and rain zones. Next, each land use was separated in four seasons (fall, winter, spring, and summer) and checked for variations.

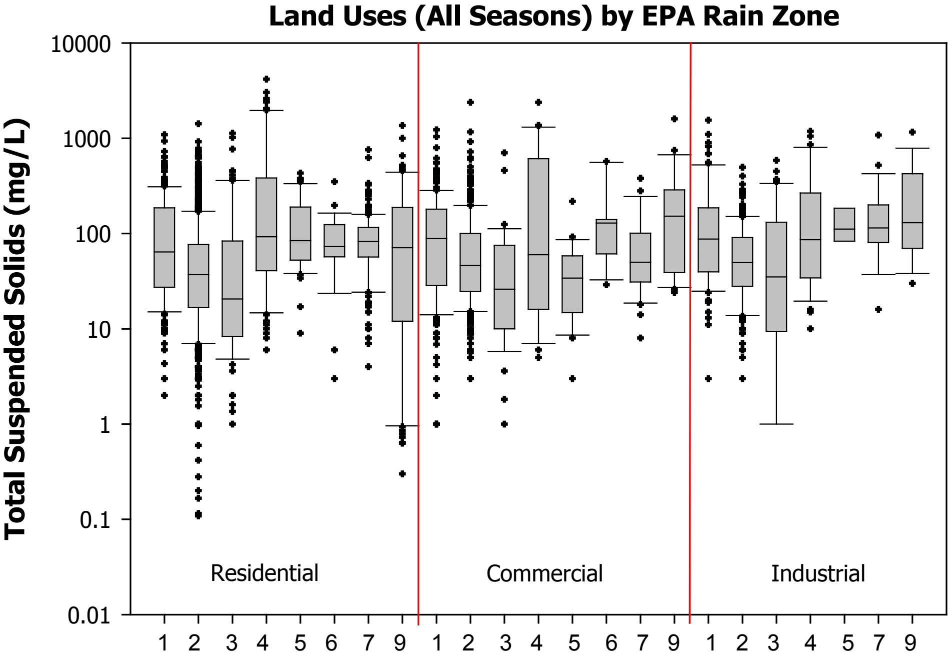


Fig. 26. Total Suspended Solids – Land Uses by EPA Rain Zone

It was desired to reduce the potentially large number of possible land use-rain zone-season categories (96) to account for similar conditions. The statistical software packages, Minitab 15 (Minitab, Inc.) and SPSS 16 (SPSS, Inc.), were used to evaluate the interactions of these three factors using analysis of variance methods. As noted, the pollutant concentrations were $\log_{10}$ transformed and separated by rain zone, land use, and season (8 rain zones, 3 land uses, and 4 seasons) to be checked for normality (Anderson-Darling test at 0.05 significance level). Not all of the transformed groups of data were normally distributed (Figure 27, 28, and 29), but more than 95% of the data in a group were normal.

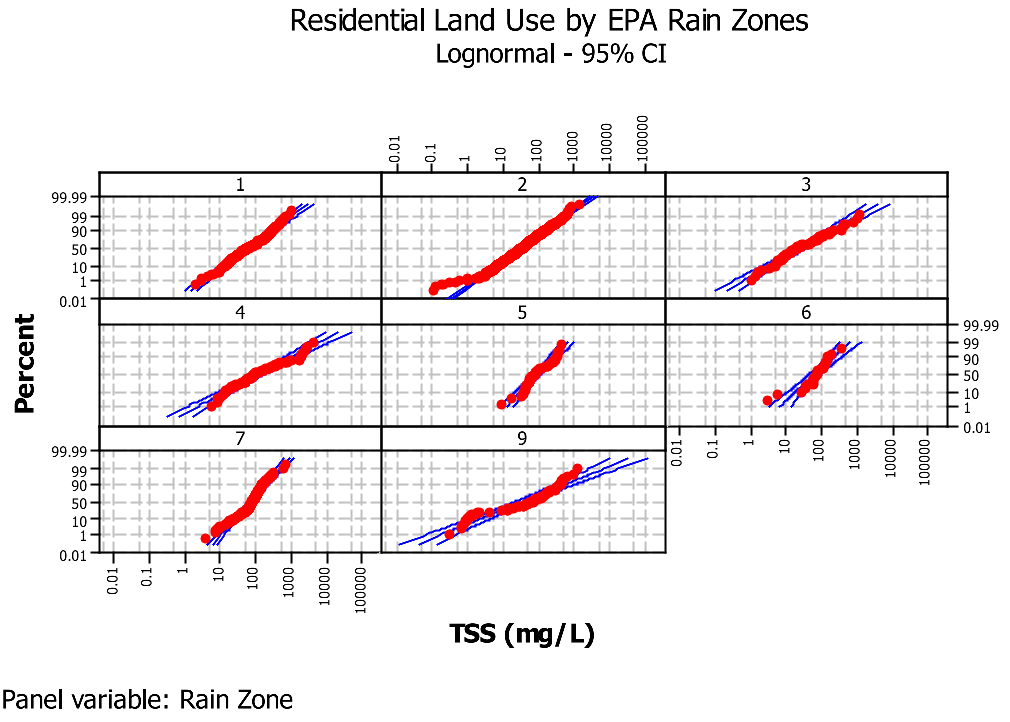


Fig. 27. Total Suspended Solids – Residential Land Use by EPA Rain Zone (Checks for Normality)

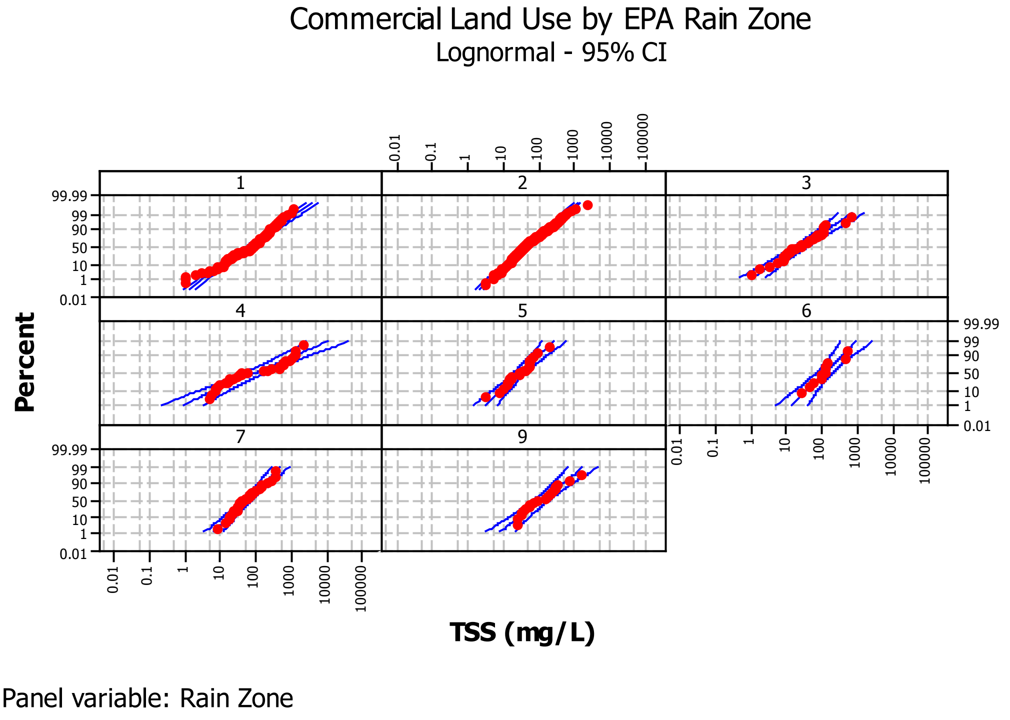


Fig. 28. Total Suspended Solids – Commercial Land Use by EPA Rain Zone (Checks for Normality)

Because the pollutant data were measured on a scale interval (continuous data, not rank or score data), they were suitable for parametric tests of means (Motulsky 1995). The central limit theorem ensures that parametric tests are robust to deviations from normality as long as the sample size has more than 25 subjects in each group (Motulsky 1995).

Table 16 is a summary of Anderson-Darling's p-values for the study rains zones and land uses.

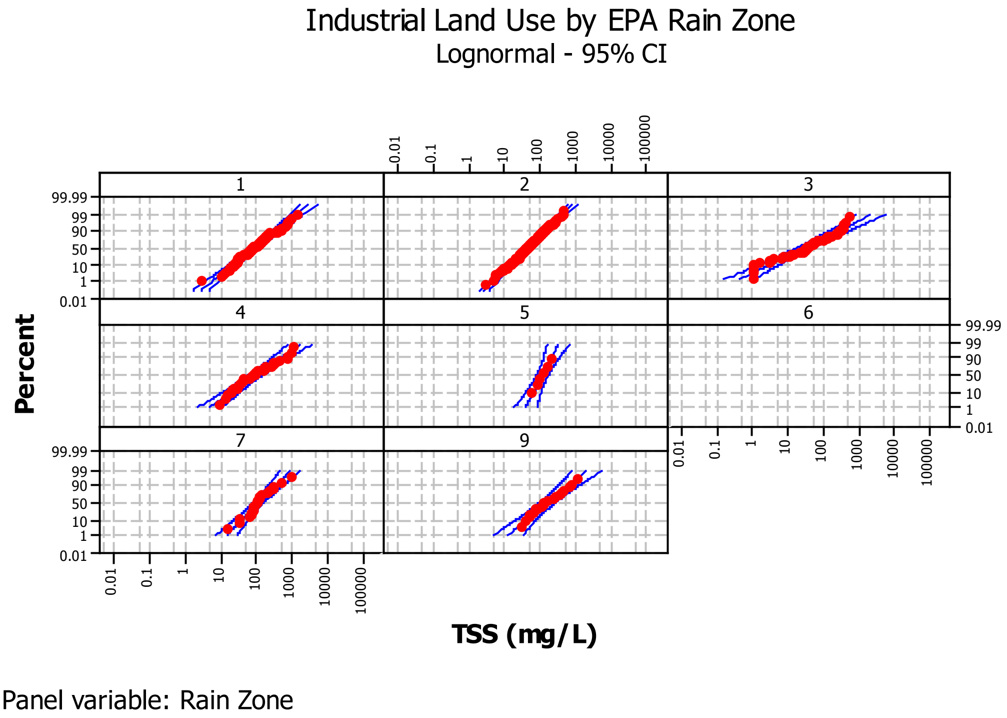


Fig. 29. Total Suspended Solids – Industrial Land Use by EPA Rain Zone (Checks for Normality)

Table 16. Summary of Anderson-Darling p-values by EPA Rain Zone and Land Use for Total Suspended Solids

Land Use/EPA Rain Zone	**Rain Zone 1**	**Rain Zone 2**	**Rain Zone 3**	**Rain Zone 4**	**Rain Zone 5**	**Rain Zone 6**	**Rain Zone 7**	**Rain Zone 8**	**Rain Zone 9**
Residential	0.049	<0.005	0.113	0.026	0.022	<0.005	<0.005	ND	<0.005
Commercial	<0.005	<0.005	0.537	<0.005	0.349	0.211	0.607	ND	0.394
Industrial	0.409	0.799	0.036	0.425	0.909	ND	0.113	ND	0.690

Since the majority of the data distributions were normal, it was decided to use the 3-way parametric analysis of variance (ANOVA) test to examine the interactions among rain zones, land uses, and seasons (Table 17), since there are no 3-way nonparametric tests available. When significant differences were found in the mean of the data ($p\text{-values} < 0.05$), multiple comparisons (using the Scheffe post-hoc test) were performed to collect the data in homogeneous groups. Power analyses for several significance levels were also performed on the $\log_{10}$ transformed data. This research uses the retrospective power analysis to decide how accurate the statistical test was in detecting the effect size present in the available sample data, or to give an estimate of how large the sample size needs to be to enable accurate and reliable statistical judgments.

Table 17 shows the three-way ANOVA interaction of rain zone, land use, and season for the total suspended solids concentrations for the single land use sites in the NSQD. The interaction addressed the question of whatever the total suspended solids concentrations taken by land use in each season were the same for all EPA Rain Zones. The analysis' p-value shows that the three independent variables do not interact because the difference in means of one variable does not differ depending on the level of another variable. Therefore, the three-way interaction term is not significant in explaining the variability between these data set categories.

The next step was to interpret the significant two-way interaction of land use and rain zone, and the significant two-way interaction of season and rain zone (the two-way interaction of land use and season is not shown to be significant). The main effects of rain zone, land use, and season alone could not be interpreted at this point because they were involved in the higher order (two-way) interactions. To understand the interaction between land use and rain zone, the simple effect of land use within each rain zone was examined using the multivariate analysis of variance (MANOVA) model in SPSS 16 software.

Table 17. Total Suspended Solids – Univariate 3-way ANOVA Tests of Between-Subjects Effects

Dependent Variable: Log TSS

	Source	**Type III Sum of Squares**	**DF**	**Mean Square**	**F**	**P-value**
	Corrected Model*	123*	90	1.4	4.7	0.000
	Intercept	1780	1	1780	6080	0.000
Main Effects	Rain Zone (8 levels)	51	7	7.3	25	0.000*
	Land Use (3 levels)	2.5	2	1.3	4.3	0.013*
	Season (4 levels)	2.4	3	0.78	2.7	0.045*
Two-way Interactions	Rain Zone * Land Use	12	13	0.89	3.1	0.000*
	Rain Zone * Season	10	21	0.48	1.6	0.034*
	Land Use * Season	2.7	6	0.45	1.5	0.162
Three-way Interaction	Rain Zone * Land Use * Season	11	38	0.29	0.99	0.479
	Error	810	2768	0.29		
	Total	9249	2859			
	Corrected Total	934	2858			

* Significant P-value

The MANOVA is an extension of ANOVA model in which main effects and interactions are assessed on a combination of dependant variables. MANOVA model forms linear combinations of the individual dependent variables that maximize the differences between the groups. The advantage of this analysis over separate one-way ANOVA (t-tests) is that ANOVA only uses half of the subjects to compute the error term and is only based on half of the degrees of freedom. Simple effects tests use the within-cell variation for all the cases in the data set and result in a smaller and more reliable error term, thus leading to higher power (Page et al. 2003).

The MANOVA statistical test found significant differences among land uses for EPA Rain Zones 2, 4, 5, 7, and 9 (Figure 30 and Table 18), but did not explicitly show which land uses were different. Therefore, the rain zones with significant differences in land uses were tested separately using the one-way ANOVA model and the Scheffe post-hoc test (Table 19) to identify where the difference in the land uses occurs.

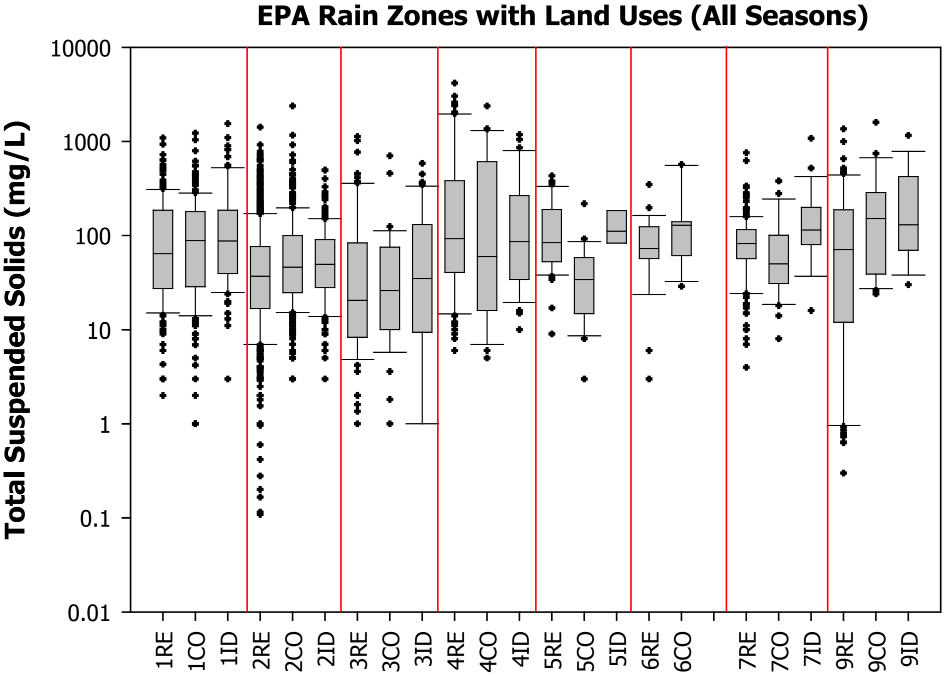


Fig. 30. Total Suspended Solids – EPA Rain Zones with Land Uses

Table 18. Total Suspended Solids - MANOVA Test for Significance of Land Use within Rain Zone using Unique Sum of Squares

Source of Variation	Sum of Squares	DF	Mean Square	F	p-value
WITHIN CELLS	810	2768	0.29		
Land Use WITHIN Rain Zone (1)	0.10	2	0.05	0.16	0.850
Land Use WITHIN Rain Zone (2)	22	2	11	38	0.000*
Land Use WITHIN Rain Zone (3)	1.4	2	0.69	2.4	0.094
Land Use WITHIN Rain Zone (4)	5.0	2	2.5	8.5	0.000*
Land Use WITHIN Rain Zone (5)	4.4	2	2.2	7.4	0.001*
Land Use WITHIN Rain Zone (6)	1.4	2	0.70	2.4	0.091
Land Use WITHIN Rain Zone (7)	2.6	2	1.3	4.4	0.013*
Land Use WITHIN Rain Zone (9)	4.9	2	2.5	8.5	0.000*

* Significant P-value

The multiple comparison tests detected significant differences among the land uses from EPA Rain Zones 2, 5, 7, and 9. Therefore, the land uses were grouped based on their significance, such that the land uses that form a homogeneous group are considered to have non-significant TSS mean concentrations. The retrospective power analyses confirmed that the post-hoc tests were effective at identifying differences in land uses (power > 80% at the study alpha level of 0.05 for all rain zones) (Table 19). However, for EPA Rain Zone 4, it was concluded that the available sample size (153) was too small to detect the very small effect size (0.08, representing 35% difference in mean concentrations ranging from 93 to 126 mg/L) present among the TSS mean concentrations for the three land uses. Even if the MANOVA model showed significant differences among this rain zone's land uses, the post-hoc test did not detect the difference. Also, the power analysis confirmed that the test was not very powerful due to the limited sample size. For the mean effect size of 0.08 to be detected, the study needs a minimum of 1,470 samples (calculation performed with G*Power 3.1.2 software). The actual sample size (153) can detect differences among the land uses' TSS mean concentrations only if the difference is at least 100%. Therefore, the differences between the three land uses were not considered significant and land uses were therefore combined for Rain Zone 4 (Table 19).

The MANOVA test did not detect significant differences among the land uses' TSS mean concentrations from EPA Rain Zones 1, 3, and 6. Power analyses confirmed that the maximum differences between any two land uses (for each EPA Rain zone taken separately) were quite small. Therefore, the test needed more samples to detect the differences at 5% significance level and 80% power (920 samples needed vs. 517 available for Rain Zone 1; 22800 samples needed vs. 180 available for Rain Zone 3; and 100 samples needed vs. 38 available for Rain Zone 6). In addition, more samples were required to facilitate accurate statistical judgments about the significance of TSS mean concentrations coming from EPA Rain Zones 1, 3, and 6. The differences among the land uses were not considered significant and land uses were therefore combined for each rain zone.

Table 19. Total Suspended Solids **-** Test of Significance: Land Use within Rain Zone

Rain Zone	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log TSS				**Power Analysis**	
		(I) LU	**(J) LU**	**p-value**	**LU**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
2	0.000*	RE	CO	0.000*	RE	959	1.55		0.20	100
			ID	0.004*	CO	398		1.70	0.15	100
		CO	ID	0.904	ID	190		1.68	0.10	100
					Pooled St. Dev = 0.508				***0.05***	***99.9***
					Obtained Effect Size = 0.14				0.01	99.6
4	0.603	-	-	-	RE	86	2.10		0.20	35.1
					CO	31	1.99		0.15	28.8
					ID	36	1.97		0.10	21.6
					Pooled St. Dev = 0.721				***0.05***	***13.1***
					Obtained Effect Size = 0.08				0.01	3.9
5	0.000*	RE	CO	0.000*	RE	49	1.96		0.20	100
			ID	0.811	ID	6	2.07		0.15	100
		CO	ID	0.004*	CO	22		1.47	0.10	99.9
					Pooled St. Dev = 0.377				***0.05***	***99.8***
					Obtained Effect Size = 0.61				0.01	98.9
7	0.003*	RE	CO	0.222	RE	170	1.87		0.20	96.6
			ID	0.029*	CO	35	1.76		0.15	95.2
		CO	ID	0.003*	ID	24		2.08	0.10	92.7
					Pooled St. Dev = 0.361				***0.05***	***87.2***
					Obtained Effect Size = 0.23				0.01	69.7
9	0.003*	RE	CO	0.054	RE	78	1.58		0.20	97.4
			ID	0.012*	CO	21		2.09	0.15	96.2
		CO	ID	0.865	ID	19		2.23	0.10	94.0
					Pooled St. Dev = 0.841				***0.05***	***89.1***
					Obtained Effect Size = 0.33				0.01	72.7

* Significant P-value

A second MANOVA test was also performed to understand the interaction between season and rain zone for the other areas. Based on the Table 20 test results, only EPA Rain Zone 2 and 5 were affected by seasonal variations of the total suspended solids concentrations.

Next, the land uses from EPA Rain Zone 2 and 5 were re-grouped based on land uses difference finding (Table 19) and checked for seasonal variations (Table 21).

Table 20. Total Suspended Solids - MANOVA Test for Significance of Season within Rain Zone using Unique Sum of Squares

Source of Variation	Sum of Squares	DF	Mean Square	F	p-value
WITHIN CELLS	812	2768	0.29		
Season WITHIN Rain Zone (1)	0.9	3	0.3	1.03	0.379
Season WITHIN Rain Zone (2)	2.4	3	0.81	2.77	0.040*
Season WITHIN Rain Zone (3)	0.8	3	0.27	0.92	0.433
Season WITHIN Rain Zone (4)	2.3	3	0.77	2.61	0.050
Season WITHIN Rain Zone (5)	2.8	3	0.94	3.22	0.022*
Season WITHIN Rain Zone (6)	1.3	3	0.43	1.48	0.218
Season WITHIN Rain Zone (7)	1.7	3	0.58	1.99	0.114
Season WITHIN Rain Zone (9)	1.3	3	0.43	1.46	0.224

* Significant P-value

The post-hoc test did not detect differences among seasons for commercial and industrial land uses in EPA Rain Zone 2 and the entire EPA Rain Zone 5 area (Table 21). The power of the tests were small, leading to conclude that the analyses failed to prove seasonal effect on TSS concentrations most likely because the available sample sizes were not large enough to detect the mean effect size present among seasonal samples (Table 21). Even if the commercial-industrial group from EPA Rain Zone 2 had a total of 588 samples, the small effect size based on TSS seasonal mean concentrations (0.11, representing 26% difference in the seasonal mean concentrations ranging from 44 and 55 mg/L) requires a minimum of 1000 samples to be detected at an alpha level of 0.05 and 80% power (approximation made with G*Power 3.1.2 software). The number of samples available (588) could detect seasonal differences if the mean effect size would be at least 0.14 (about 33% differences in median concentrations of the four seasons).

Table 21. Total Suspended Solids – Test of Significance: Land Use and Season within Rain Zone

Rain Zone	Land Use	1-Way ANOVA p-value	Multiple Comparison (Scheffe Post-Hoc Test)			Homogeneous Groups Dependent Variable: Log TSS				Power Analysis	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
2	RE	0.017*	FA	SP	0.169	FA	246	1.50		0.20	97.8
				SU	0.275	WI	228	1.48		0.15	96.8
				WI	0.953	SP	280		1.60	0.10	95.0
			SP	SU	1.000	SU	205		1.61	***0.05***	***90.9***
				WI	0.027*					0.01	76.8
			SU	WI	0.089	Obtained Effect Size = 0.11 , Pooled St. Dev = 0.546					
	CO ID	0.085	-	-	-	FA	159	1.64		0.20	80.4
						SP	151	1.74		0.15	75.4
						SU	124	1.67		0.10	68.2
						WI	154	1.74		***0.05***	***56.1***
										0.01	32.3
						Obtained Effect Size = 0.11, Pooled St. Dev = 0.434					
5	RE ID	0.068	-	-	-	FA	11	1.75		0.20	83.2
						SP	18	2.04		0.15	78.5
						SU	23	2.06		0.10	71.4
						WI	3	1.80		***0.05***	***59.0***
										0.01	33.6
						Obtained Effect Size = 0.37 , Pooled St. Dev = 0.343					
	CO	0.750	-	-	-	FA	6	1.59		0.20	33.7
						SP	6	1.52		0.15	27.1
						SU	3	1.28		0.10	19.9
						WI	7	1.41		***0.05***	***11.5***
										0.01	3.0
						Obtained Effect Size = 0.24, Pooled St. Dev = 0.437					

* Significant P-value

The effect size for EPA Rain Zone 5's residential and industrial group was large (0.37, about 100% difference in TSS seasonal mean concentrations ranging from 56 and 115 mg/L), but the sample size was only 55. At the study's alpha level, a minimum of 85 samples are needed to detect this effect size. The number of samples available (55) could detect seasonal differences if the mean effect size would be at least 0.47 (about 130% differences in median concentrations of the four seasons). Commercial land use had a similar situation: large effect size of 0.24 (100%

differences in TSS seasonal mean concentrations ranging from 19 to 39 mg/L), but small sample size (22) and a minimum of 200 samples needed to detect it. The number of samples available (22) could detect seasonal differences if the mean effect size would be at least 0.79 (about 300% differences in mean concentrations of the four seasons).

Figure 31 shows the significant land use and seasonal subcategories for the rain zone groups for total suspended solids concentrations, based on mean statistical significance. The one-way ANOVA test performed on the rain zone groups showed statistical significance (p-value = 0). Again, multiple comparison tests were employed to detect significance among the rain zone - land use - season subcategories (Table 22).Table 23 and Figure 32 show the final groups of TSS mean concentrations based on the outcome of the multiple comparison analyses. The large number of possible combinations of rain zone - land use - season categories was reduced to three homogeneous groups that account for similar conditions (Figure 32). Statistical analyses on the TSS mean concentrations showed a few significant land use differences (when only residential, commercial, and industrial land uses were used), and no seasonal effect for total suspended solids concentrations for these rain zones. Table 24 shows the total suspended solids geographical region homogeneous clusters, along with their basic statistics.

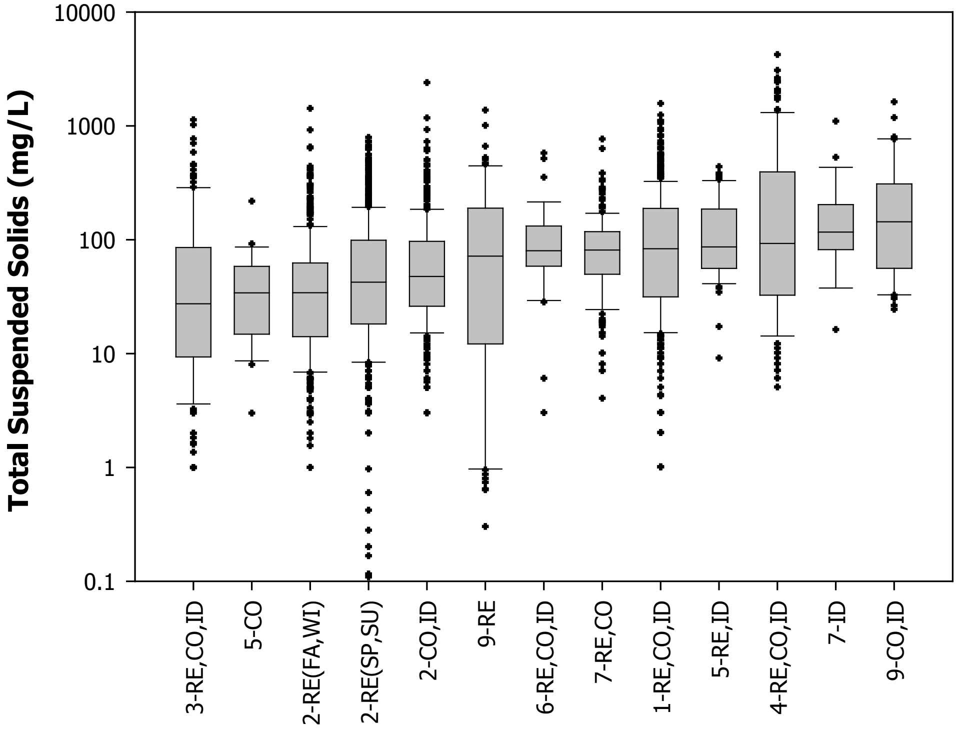


Fig. 31. Total Suspended Solids – Rain Zone Groups

Table 22. Total Suspended Solids – Rain Zone Groups Multiple Comparisons

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
1-RE,CO,ID	3-RE,CO,ID	0.000*	3-RE,CO,ID	4-RE,CO,ID	0.000*	4-RE,CO,ID	6-RE,CO	0.998
	4-RE,CO,ID	0.385		6-RE,CO	0.060		2-RE (FA,WI)	0.000*
	6-RE,CO	1.000		2-RE (FA,WI)	1.000		2-RE (SP,SU)	0.000*
	2-RE (FA,WI)	0.000*		2-RE(SP,SU)	0.630		2-CO,ID	0.000*
	2-RE (SP,SU)	0.000*		2-CO,ID	0.008*		5-RE,ID	1.000
	2-CO,ID	0.007*		5-RE,ID	0.000*		5-CO	0.042*
	5-RE,ID	0.999		5-CO	1.000		7-RE,CO	0.503
	5-CO	0.503		7-RE,CO	0.000*		7-ID	1.000
	7-RE,CO	1.000		7-ID	0.005*		9-RE	0.000*
	7-ID	0.990		9-RE	0.997		9-CO,ID	1.000
	9-RE	0.087		9-CO,ID	0.000*			
	9-CO,ID	0.595						

* Significant P-value

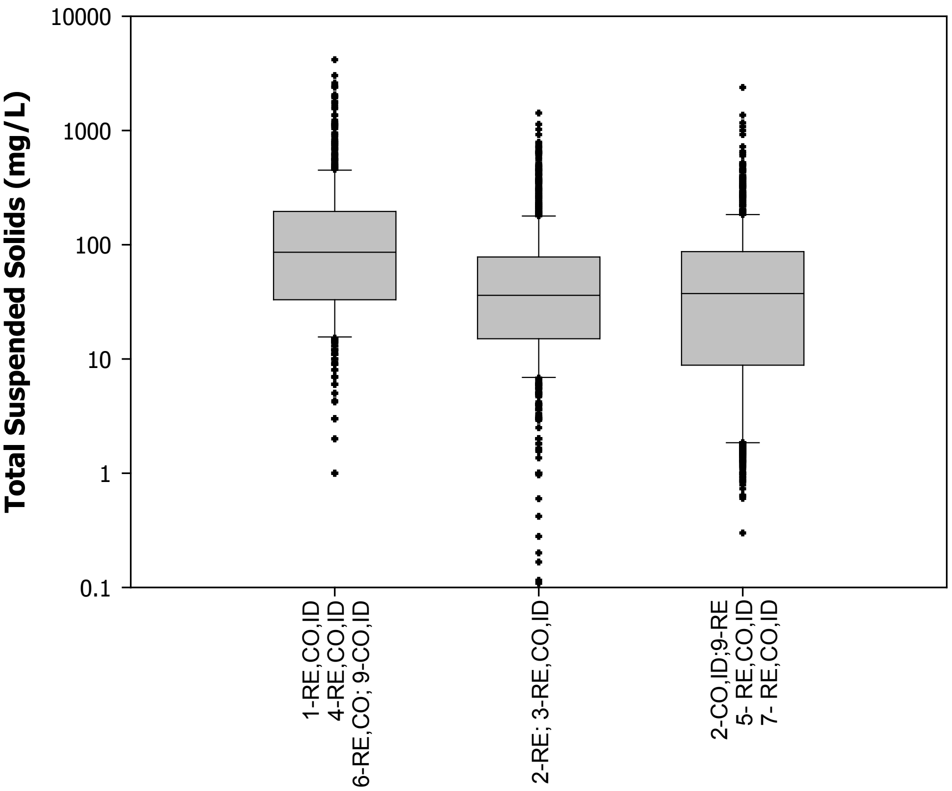
Table 22. - *Continued*

(I) Group	(J) Group	p-value
6-RE,CO	2-RE(FA,WI)	0.086
	2-RE(SP,SU)	0.616
	2-CO,ID	0.967
	5-RE,ID	1.000
	5-CO	0.746
	7-RE,CO	1.000
	7-ID	1.000
	9-RE	0.740
	9-CO,ID	0.974
5-RE,ID	5-CO	0.329
	7-RE,CO	0.999
	7-ID	1.000
	9-RE	0.146
	9-CO,ID	0.998
5-CO	7-RE,CO	0.634
	7-ID	0.266
	9-RE	1.000
	9-CO,ID	0.033*
2-RE (SP,SU)	2-CO,ID	0.812
	5-RE,ID	0.028*
	5-CO	1.000
	7-RE,CO	0.003*
	7-ID	0.126
	9-RE	1.000
	9-CO,ID	0.000*
2-RE (FA,WI)	2-RE(SP,SU)	0.610
	2-CO,ID	0.000*
	5-RE,ID	0.000*
	5-CO	1.000
	7-RE,CO	0.000*
	7-ID	0.008*
	9-RE	1.000
	9-CO,ID	0.000*
2-CO,ID	5-RE,ID	0.354
	5-CO	0.988
	7-RE,CO	0.419
	7-ID	0.476
	9-RE	0.994
	9-CO,ID	0.010*
7-RE,CO	7-ID	0.985
	9-RE	0.291
	9-CO,ID	0.588
7-ID	9-RE	0.205
	9-CO,ID	1.000
9-RE	9-CO,ID	0.003*

* Significant P-value

Table 23. Total Suspended Solids – Homogeneous Groups

Groups	N	Homogeneous Groups Dependent Variable: Log TSS		
		A	**B**	**C**
1-RE,CO,ID	517	1.868		
4-RE,CO,ID	153	2.047		
6-RE,CO	38	1.894		
9-CO,ID	40	2.153		
2-RE(FA,WI)	474		1.493	
2-RE(SP,SU)	485		1.604	
3-RE,CO,ID	180		1.456	
2-CO,ID	588			1.696
5-CO	22			1.47
5-RE,ID	55			1.975
7-ID	24			2.082
7-RE,CO	205			1.851
9-RE	78			1.579



Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	126(1.4)	73(1.9)	73(2.1)	243(1.9)	74(0.84)	76(0.55)	134(1.1)	135(1.1)
	WI	127(0.97)	50(1.2)	93(1.4)	270(1.9)	65(0.34)	53(0.84)	79(0.63)	47(0.61)
	SP	150(1.4)	74(1.3)	109(2.3)	478(1.6)	148(0.91)	92(0.42)	85(0.58)	221(1.7)
	SU	124(1.0)	100(1.5)	134(1.9)	799(1.4)	153(0.75)	135(0.74)	119(0.63)	151(1.4)
Commercial	FA	93(0.98)	79(2.8)	59(2.0)	489(1.6)	63(1.2)	193(1.1)	142(0.90)	546(1.3)
	WI	188(1.2)	91(1.5)	41(1.1)	125(1.9)	37(0.69)	118(0.27)	78(1.2)	32(0.25)
	SP	240(0.98)	93(1.4)	107(1.8)	606(1.0)	43(0.72)	ND	59(0.57)	198(1.3)
	SU	118(1.2)	86(1.4)	45(0.86)	294(1.0)	25(0.88)	202(1.2)	76(1.3)	170(0.46)
Industrial	FA	118(1.4)	60(0.92)	130(1.2)	306(1.0)	ND	ND	359(1.0)	245(0.61)
	WI	314(0.90)	76(1.0)	95(1.6)	116(1.2)	ND	ND	96(0.27)	72(0.04)
	SP	275(1.4)	88(1.0)	94(1.0)	189(1.7)	173(0.28)	ND	182(0.68)	297(1.1)
	SU	131(1.5)	71(1.2)	81(1.2)	256(1.6)	94(0.06)	ND	61(0.65)	387(1.1)

Fig. 32. Total Suspended Solids – Rain Zone Homogeneous Groups: Mean (CV)

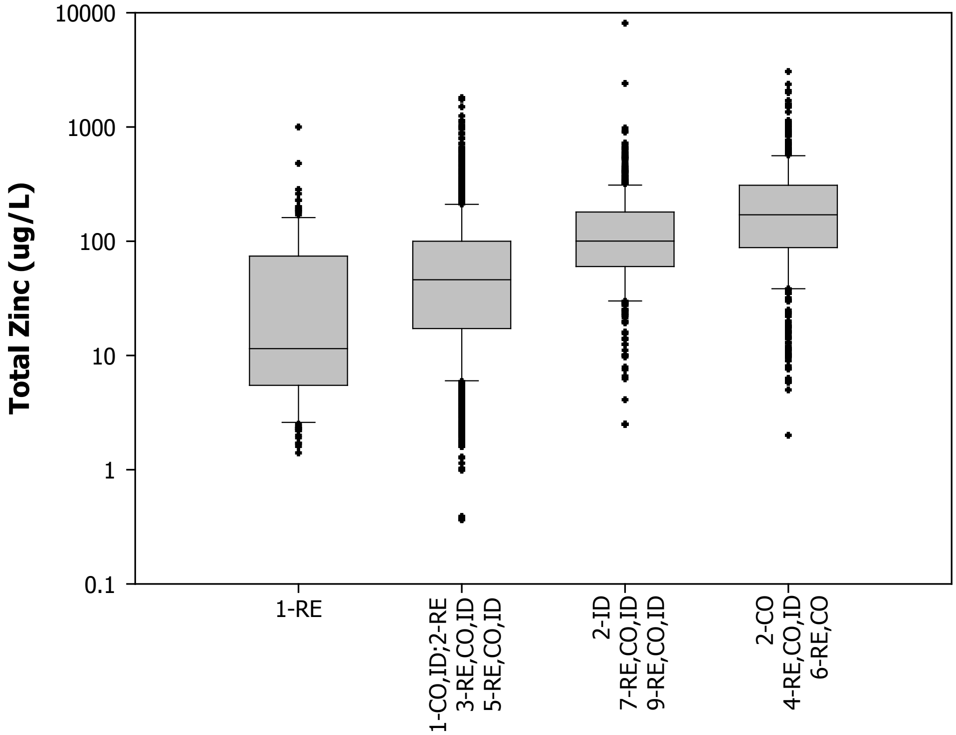
Table 24. Basic Statistics for Total Suspended Solids –
Rain Zone Homogeneous Groups (Real Space Data) (mg/L)

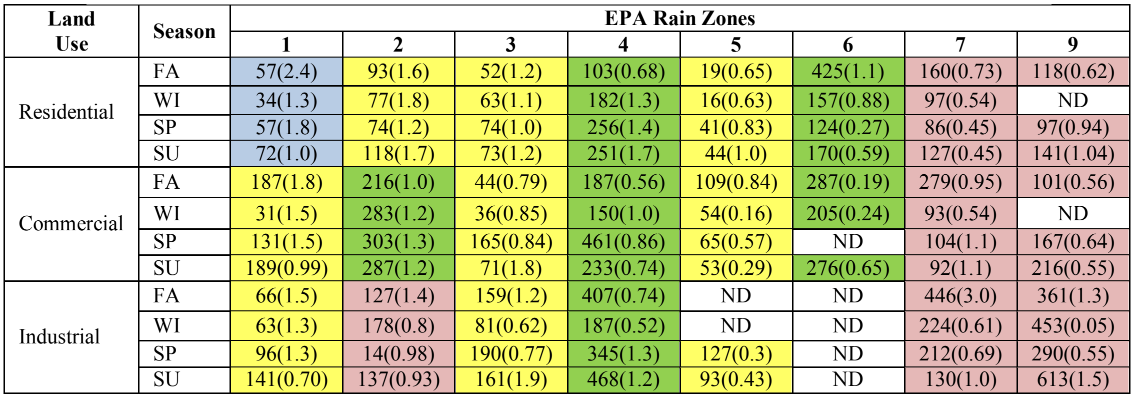
		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	1-RE,CO,ID 4-RE,CO,ID 6-RE,CO; 9-CO,ID	748	199	369	1.9	1.0	86	4168
B	2-RE; 3-RE,CO,ID	1139	76	125	1.6	0.11	36	1420
C	2-CO,ID ; 9-RE 5- RE,CO,ID 7- RE,CO,ID	972	78	145	1.9	0.30	37	2381

Similar analyses were performed for total zinc, total copper, total lead, total and dissolved phosphorous, total nitrogen, Total Kjeldahl Nitrogen, and fecal coliforms (Appendix B). The analyses showed statistical differences/similarities among geographical regions for all stormwater pollutants, but very little seasonal influence, except for the bacteria. Therefore, for each constituent, the nine geographical regions were clustered according to their similarities in mean concentrations. Figures 33 to 40 and Tables 25 to 32 show the geographical regions homogeneous groups for each pollutant along with their basic statistics. Table 33 shows the summary of homogeneous groups.

The residential land use in EPA Rain Zone 6 (Pacific Southwest) was the only land use that has monitoring data for all stormwater constituents' analyzed. The commercial and industrial land uses in this rain zone lack the stormwater quality data for several pollutants. Therefore, the statistical tests were not able to find significant differences among the three land uses for EPA Rain Zone 6 due to lack of data. In EPA Rain Zone 4 (Lower Mississippi Valley), the only land use difference identified was for fecal coliforms, where residential land use groups with commercial land use. In EPA Rain Zone 9 (Midwest), the only land use difference identified was for total suspended solids, where commercial land use groups with industrial land use. EPA Rain Zone 3 (Southeast) and EPA Rain Zone 5 (Texas) showed significant differences among land uses for total lead (where commercial land use groups with industrial land use for both rain zones) and total phosphorous (where residential land use groups with industrial land use for both rain zones). Also, in EPA Rain Zone 5 there were significant differences for dissolved phosphorous (the same land use groups). In addition, EPA Rain Zone 3 showed significant differences among the three land uses for TKN (commercial land use groups with industrial land use). In contrast, EPA Rain Zone 1 (Great Lakes) and EPA Rain Zone 2 (Mid Atlantic) showed significant differences among land uses for most of the analyzed constituents.

It was found that the analyzed stormwater constituents did not have enough seasonal samples to conclude (at 5% significance level and 80% minimum power) that seasonal differences were present in the majority of the geographical regions. Even if the statistical tests confirmed significant differences among seasons for most of the constituents from all EPA Rain Zones, the power analysis established that the tests were not very powerful due to the limited sample sizes. Therefore, the pollutant concentrations were not separated by seasons. In addition, there were few seasonal influences detected using analyses of means and they were for (1) the residential and commercial land uses in EPA Rain Zone 7 **-** Pacific Northwest (total lead, dissolved phosphorous, and TKN); (2) the residential, commercial, and industrial land uses in EPA Rain Zone 3 – Southeast (total nitrogen), and (3) the residential, commercial, and industrial land uses in EPA Rain Zone 1, 2, 3, and 9 for fecal coliforms.



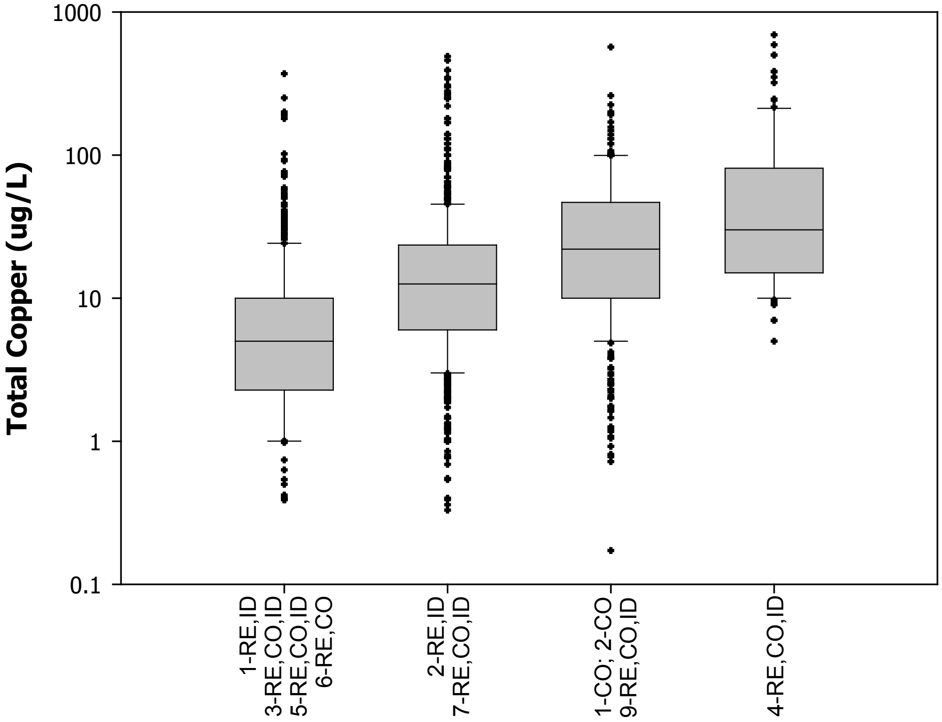


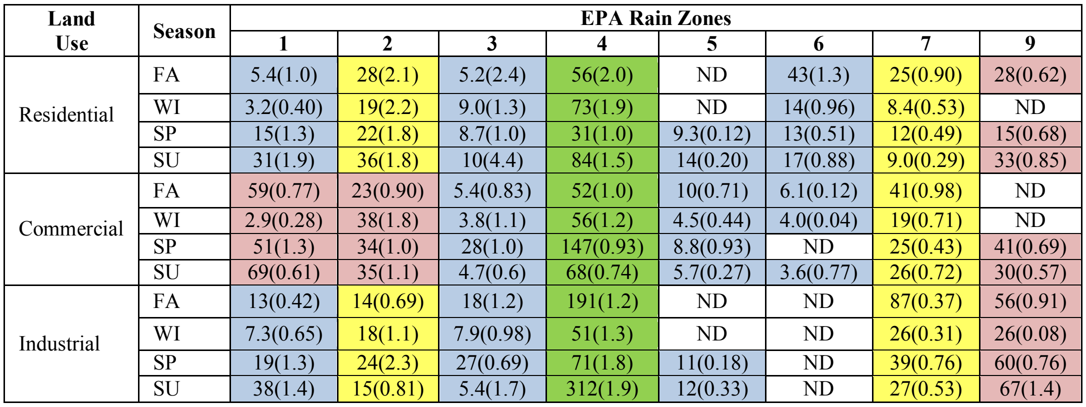
Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	57(2.4)	93(1.6)	52(1.2)	103(0.68)	19(0.65)	425(1.1)	160(0.73)	118(0.62)
	WI	34(1.3)	77(1.8)	63(1.1)	182(1.3)	16(0.63)	157(0.88)	97(0.54)	ND
	SP	57(1.8)	74(1.2)	74(1.0)	256(1.4)	41(0.83)	124(0.27)	86(0.45)	97(0.94)
	SU	72(1.0)	118(1.7)	73(1.2)	251(1.7)	44(1.0)	170(0.59)	127(0.45)	141(1.04)
Commercial	FA	187(1.8)	216(1.0)	44(0.79)	187(0.56)	109(0.84)	287(0.19)	279(0.95)	101(0.56)
	WI	31(1.5)	283(1.2)	36(0.85)	150(1.0)	54(0.16)	205(0.24)	93(0.54)	ND
	SP	131(1.5)	303(1.3)	165(0.84)	461(0.86)	65(0.57)	ND	104(1.1)	167(0.64)
	SU	189(0.99)	287(1.2)	71(1.8)	233(0.74)	53(0.29)	276(0.65)	92(1.1)	216(0.55)
Industrial	FA	66(1.5)	127(1.4)	159(1.2)	407(0.74)	ND	ND	446(3.0)	361(1.3)
	WI	63(1.3)	178(0.8)	81(0.62)	187(0.52)	ND	ND	224(0.61)	453(0.05)
	SP	96(1.3)	14(0.98)	190(0.77)	345(1.3)	127(0.3)	ND	212(0.69)	290(0.55)
	SU	141(0.70)	137(0.93)	161(1.9)	468(1.2)	93(0.43)	ND	130(1.0)	613(1.5)

Fig. 33. Total Zinc – Rain Zone Homogeneous Groups: Mean (CV)

Table 25. Basic Statistics for Total Zinc –
Rain Zone Homogeneous Groups (Real Space Data) (μg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	1-RE	138	59	109	1.9	1.4	11	1000
B	1-CO,ID; 2-RE 3-RE,CO,ID 5-RE,CO,ID	1457	92	151	1.6	0.36	46	1807
C	2-ID 7-RE,CO,ID 9-RE,CO,ID	574	163	371	2.3	2.5	100	8100
D	2-CO; 4-RE,CO,ID 6-RE,CO	538	261	317	1.2	2.0	170	3051



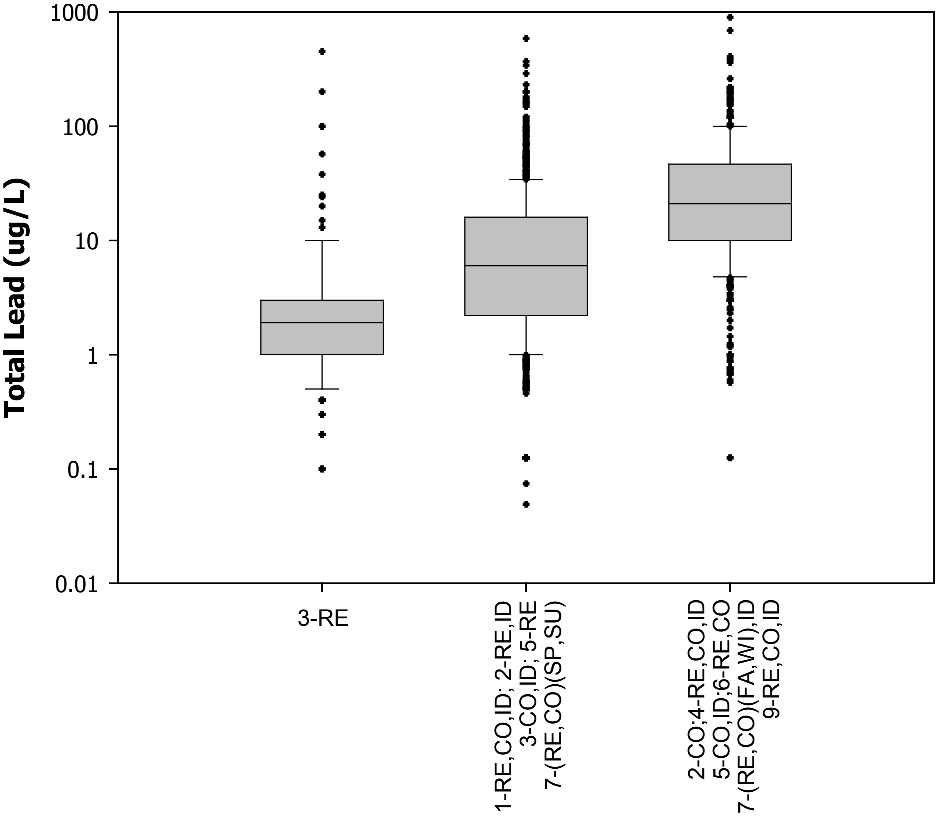


Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	5.4(1.0)	28(2.1)	5.2(2.4)	56(2.0)	ND	43(1.3)	25(0.90)	28(0.62)
	WI	3.2(0.40)	19(2.2)	9.0(1.3)	73(1.9)	ND	14(0.96)	8.4(0.53)	ND
	SP	15(1.3)	22(1.8)	8.7(1.0)	31(1.0)	9.3(0.12)	13(0.51)	12(0.49)	15(0.68)
	SU	31(1.9)	36(1.8)	10(4.4)	84(1.5)	14(0.20)	17(0.88)	9.0(0.29)	33(0.85)
Commercial	FA	59(0.77)	23(0.90)	5.4(0.83)	52(1.0)	10(0.71)	6.1(0.12)	41(0.98)	ND
	WI	2.9(0.28)	38(1.8)	3.8(1.1)	56(1.2)	4.5(0.44)	4.0(0.04)	19(0.71)	ND
	SP	51(1.3)	34(1.0)	28(1.0)	147(0.93)	8.8(0.93)	ND	25(0.43)	41(0.69)
	SU	69(0.61)	35(1.1)	4.7(0.6)	68(0.74)	5.7(0.27)	3.6(0.77)	26(0.72)	30(0.57)
Industrial	FA	13(0.42)	14(0.69)	18(1.2)	191(1.2)	ND	ND	87(0.37)	56(0.91)
	WI	7.3(0.65)	18(1.1)	7.9(0.98)	51(1.3)	ND	ND	26(0.31)	26(0.08)
	SP	19(1.3)	24(2.3)	27(0.69)	71(1.8)	11(0.18)	ND	39(0.76)	60(0.76)
	SU	38(1.4)	15(0.81)	5.4(1.7)	312(1.9)	12(0.33)	ND	27(0.53)	67(1.4)

Fig. 34. Total Copper – Rain Zone Homogeneous Groups: Mean (CV)

Table 26. Basic Statistics for Total Copper –
Rain Zone Homogeneous Groups (Real Space Data) (μg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	1-RE,ID; 3-RE,CO,ID 5-RE,CO,ID; 6-RE,CO	530	11	26	2.3	0.39	5.0	370
B	2-RE,ID; 7-RE,CO,ID	934	25	47	1.9	0.33	13	490
C	1-CO; 2-CO 9-RE,CO,ID	482	36	43	1.2	0.17	22	569
D	4-RE,CO,ID	126	86	164	1.9	5.0	30	1360

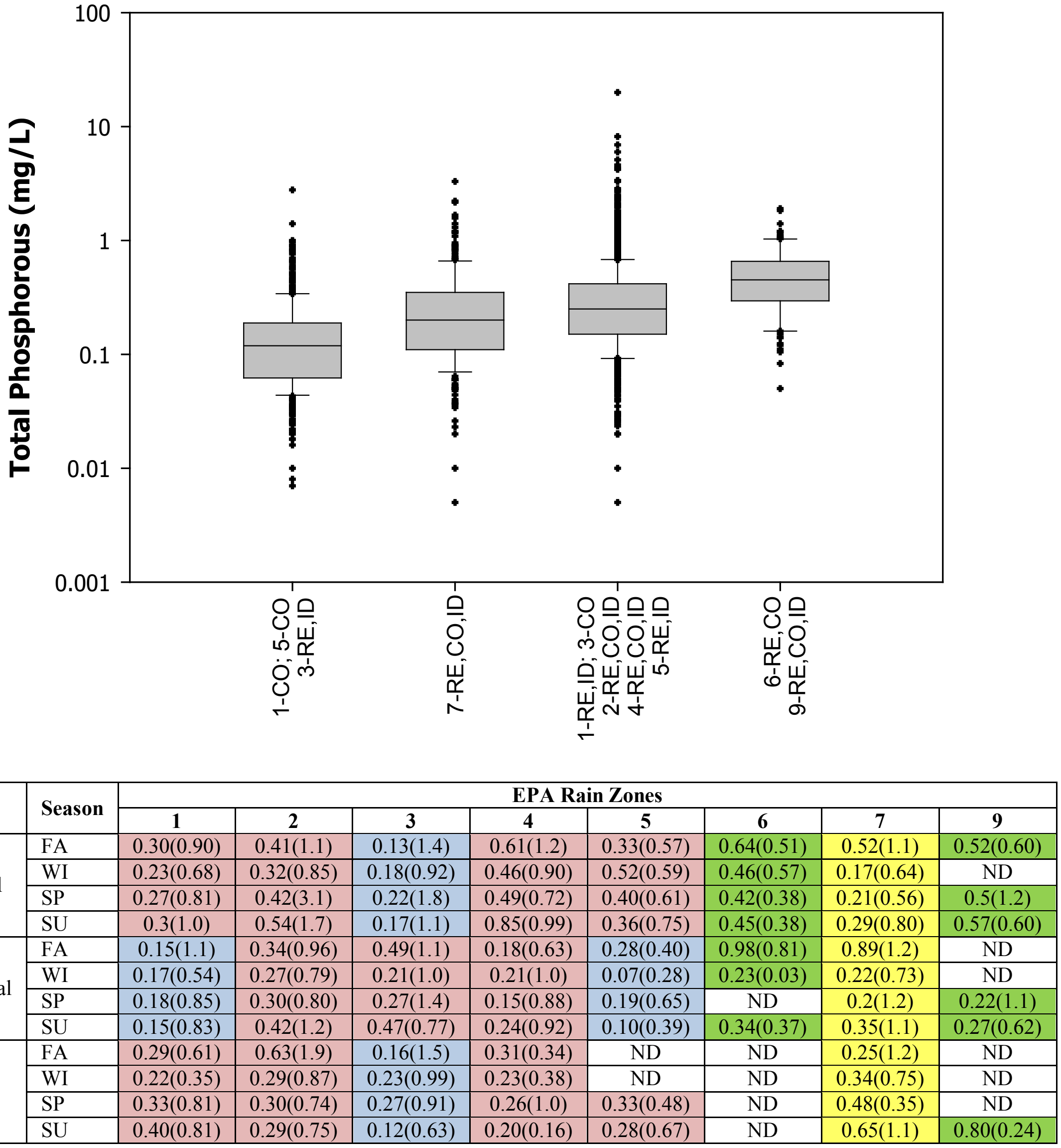


Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	14(0.77)	18(2.1)	3.9(3.6)	16(1.1)	6.0(1.4)	51(1.2)	39(1.5)	15(0.55)
	WI	ND	13(1.8)	24(3.7)	13(1.0)	3.0(0.58)	20(0.61)	18(1.2)	ND
	SP	22(1.0)	18(2.3)	12(3.0)	27(1.9)	15(1.3)	18(0.38)	11(0.52)	11(0.65)
	SU	21(0.97)	23(2.7)	2.7(0.85)	48(1.3)	20(1.7)	37(0.49)	15(1.4)	25(0.99)
Commercial	FA	16(1.2)	48(1.9)	6.7(1.5)	43(0.79)	46(0.87)	40(0.86)	53(0.64)	ND
	WI	7.2(0.78)	41(1.2)	4.7(0.71)	53(1.1)	28(0.29)	ND	29(1.3)	ND
	SP	8.5(0.77)	33(1.8)	29(0.92)	126(0.68)	28(0.71)	ND	30(2.4)	46(0.92)
	SU	10(0.87)	32(1.3)	5.4(0.69)	68(0.64)	12(0.22)	62(0.56)	35(1.8)	53(0.53)
Industrial	FA	12(0.23)	7.0(0.96)	ND	154(1.2)	ND	ND	54(0.61)	ND
	WI	10(0.41)	16(1.6)	7.7(1.4)	58(1.7)	ND	ND	40(0.77)	ND
	SP	27(0.73)	25(2.5)	40(1.1)	71(1.8)	39(0.14)	ND	47(0.86)	ND
	SU	13(0.67)	12(0.94)	ND	312(1.6)	20(0.25)	ND	14(0.64)	515(1.1)

Fig. 35. Total Lead – Rain Zone Homogeneous Groups: Mean (CV)

Table 27. Basic Statistics for Total Lead –
Rain Zone Homogeneous Groups (Real Space Data) (µg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	3-RE	170	8.4	39	4.7	0.10	1.9	450
B	1-RE, CO,ID; 5-RE 2-RE,ID; 3-CO,ID 7-(RE,CO)(SP,SU)	886	17	38	2.3	0.05	6.0	585
C	2-CO;4-RE,CO,ID 5-CO,ID; 6-RE,CO 7-(RE,CO)(FA,WI),ID 9-RE,CO,ID	562	44	85	1.9	0.13	21	1200

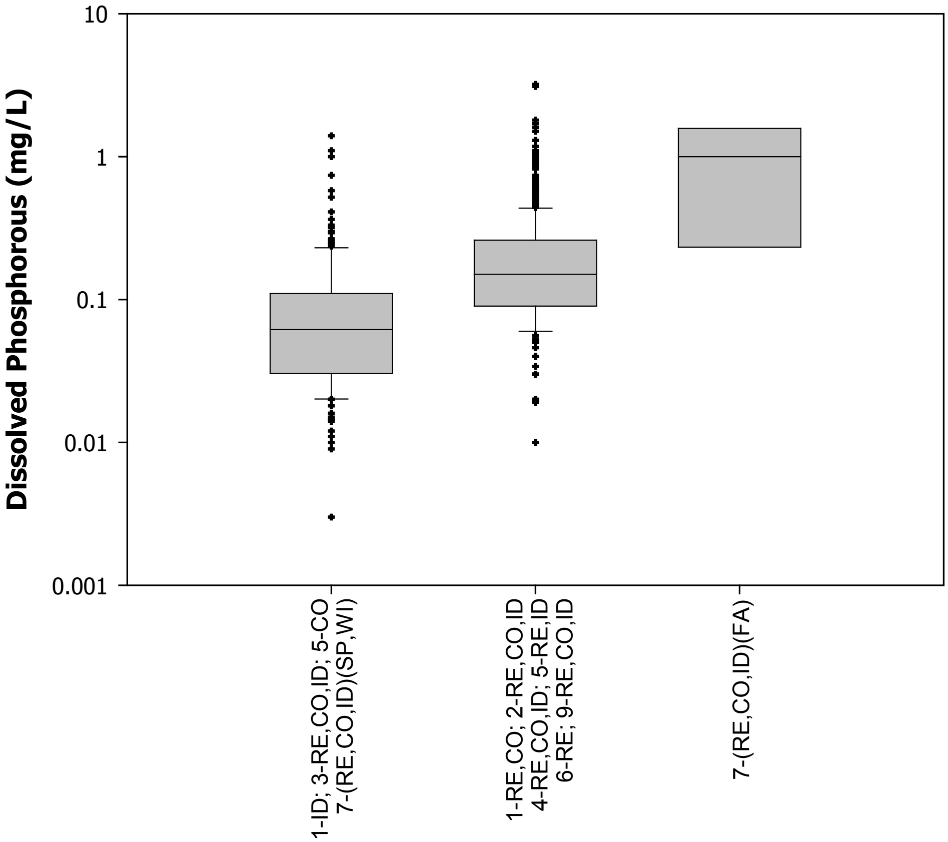


Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	0.30(0.90)	0.41(1.1)	0.13(1.4)	0.61(1.2)	0.33(0.57)	0.64(0.51)	0.52(1.1)	0.52(0.60)
	WI	0.23(0.68)	0.32(0.85)	0.18(0.92)	0.46(0.90)	0.52(0.59)	0.46(0.57)	0.17(0.64)	ND
	SP	0.27(0.81)	0.42(3.1)	0.22(1.8)	0.49(0.72)	0.40(0.61)	0.42(0.38)	0.21(0.56)	0.5(1.2)
	SU	0.3(1.0)	0.54(1.7)	0.17(1.1)	0.85(0.99)	0.36(0.75)	0.45(0.38)	0.29(0.80)	0.57(0.60)
Commercial	FA	0.15(1.1)	0.34(0.96)	0.49(1.1)	0.18(0.63)	0.28(0.40)	0.98(0.81)	0.89(1.2)	ND
	WI	0.17(0.54)	0.27(0.79)	0.21(1.0)	0.21(1.0)	0.07(0.28)	0.23(0.03)	0.22(0.73)	ND
	SP	0.18(0.85)	0.30(0.80)	0.27(1.4)	0.15(0.88)	0.19(0.65)	ND	0.2(1.2)	0.22(1.1)
	SU	0.15(0.83)	0.42(1.2)	0.47(0.77)	0.24(0.92)	0.10(0.39)	0.34(0.37)	0.35(1.1)	0.27(0.62)
Industrial	FA	0.29(0.61)	0.63(1.9)	0.16(1.5)	0.31(0.34)	ND	ND	0.25(1.2)	ND
	WI	0.22(0.35)	0.29(0.87)	0.23(0.99)	0.23(0.38)	ND	ND	0.34(0.75)	ND
	SP	0.33(0.81)	0.30(0.74)	0.27(0.91)	0.26(1.0)	0.33(0.48)	ND	0.48(0.35)	ND
	SU	0.40(0.81)	0.29(0.75)	0.12(0.63)	0.20(0.16)	0.28(0.67)	ND	0.65(1.1)	0.80(0.24)

Fig. 36. Total Phosphorous – Rain Zone Homogeneous Groups: Mean (CV)

Table 28. Basic Statistics for Total Phosphorous –
Rain Zone Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	1-CO; 3-RE,ID; 5-CO	526	0.17	0.20	1.2	0.01	0.12	2.8
B	7-RE,CO,ID	305	0.30	0.37	1.2	0.01	0.20	3.3
C	1-RE,ID; 2-RE,CO,ID 3-CO; 4-RE,CO,ID 5-RE,ID	2077	0.38	0.64	1.7	0.01	0.25	20
D	6-RE,CO; 9-RE,CO,ID	101	0.52	0.35	0.67	0.05	0.45	1.9

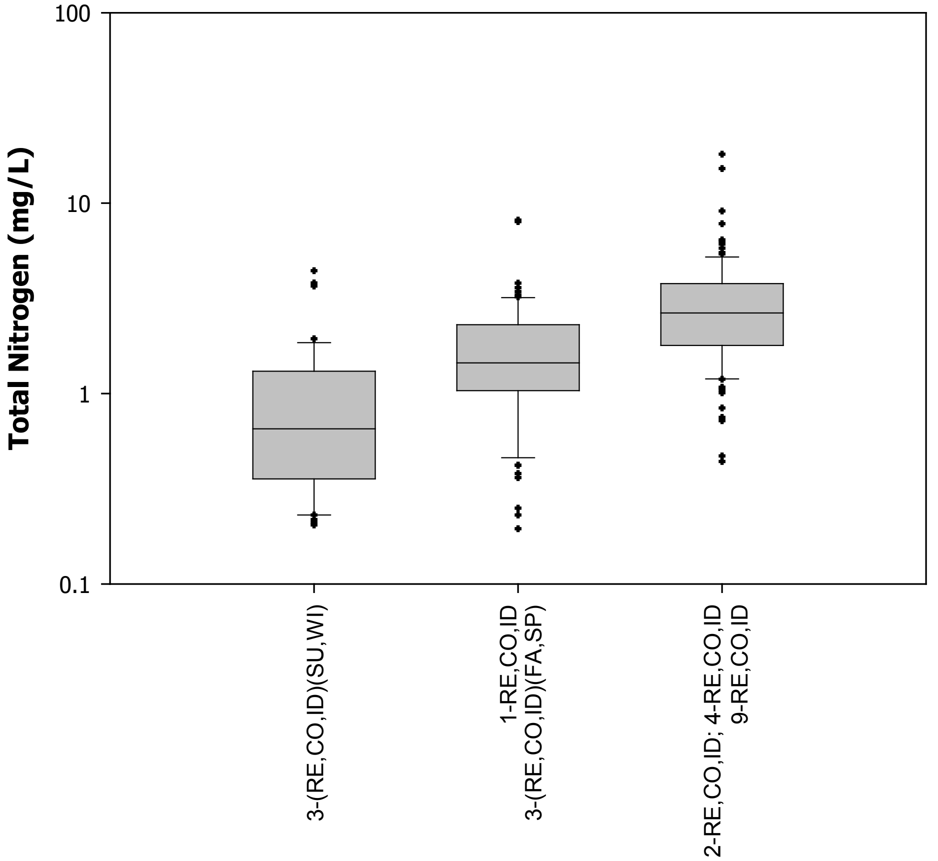


Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	0.29(1.0)	0.28(1.2)	0.17(2.0)	0.19(0.66)	ND	0.35(0.39)	0.96(0.68)	0.22(0.32)
	WI	0.14(0.33)	0.23(0.86)	0.11(0.94)	0.20(0.78)	ND	0.28(0.79)	0.04(0.61)	ND
	SP	0.12(0.50)	0.18(0.98)	0.11(0.80)	0.31(0.56)	0.32(0.35)	0.19(0.17)	0.04(0.73)	ND
	SU	0.13(0.54)	0.23(0.79)	0.19(1.1)	0.32(0.78)	0.3(0.28)	0.21(0.17)	ND	0.34(0.94)
Commercial	FA	0.14(0.54)	0.22(0.85)	0.25(1.6)	0.10(0.40)	0.08(0.24)	ND	0.89(1.11)	ND
	WI	0.15(0.17)	0.21(1.1)	0.08(0.80)	0.22(0.98)	0.03(0.42)	ND	0.06(0.70)	ND
	SP	0.13(0.58)	0.17(0.85)	0.08(0.86)	0.10(0.84)	0.08(0.71)	ND	0.04(0.14)	0.14(1.2)
	SU	0.12(0.12)	0.25(1.1)	0.07(0.54)	0.24(0.79)	0.06(0.38)	ND	ND	0.17(0.48)
Industrial	FA	0.08(0.91)	0.44(1.7)	0.10(1.1)	0.20(0.67)	ND	ND	ND	ND
	WI	0.18(0.45)	0.14(1.1)	0.18(1.24)	0.15(0.73)	ND	ND	ND	ND
	SP	0.07(0.95)	0.11(0.38)	0.07(0.81)	0.16(1.1)	0.22(0.76)	ND	ND	ND
	SU	0.03(0.98)	0.15(0.98)	0.06(0.71)	0.18(0.14)	0.21(0.70)	ND	ND	0.37(0.96)

Fig. 37. Dissolved Phosphorous – Rain Zone Homogeneous Groups: Mean (CV)

Table 29. Basic Statistics for Dissolved Phosphorous – Rain Zone Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	1-ID; 5-CO 3-RE,CO,ID 7-(RE,CO,ID)(SP,WI)	190	0.11	0.17	1.5	0.003	0.06	1.4
B	1-RE,CO; 2-RE,CO,ID 4-RE,CO,ID; 5-RE,ID 6-RE; 9-RE,CO,ID	823	0.22	0.25	1.1	0.01	0.15	3.2
C	7-(RE,CO,ID)(FA)	8	0.94	0.67	0.71	0.19	1.0	1.7

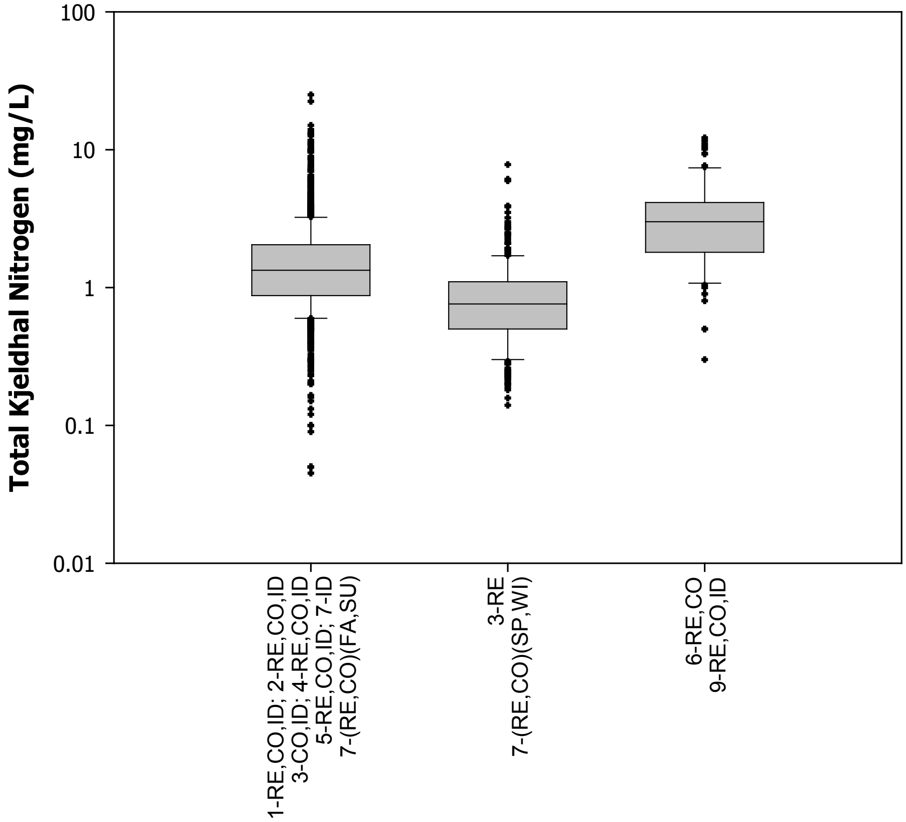


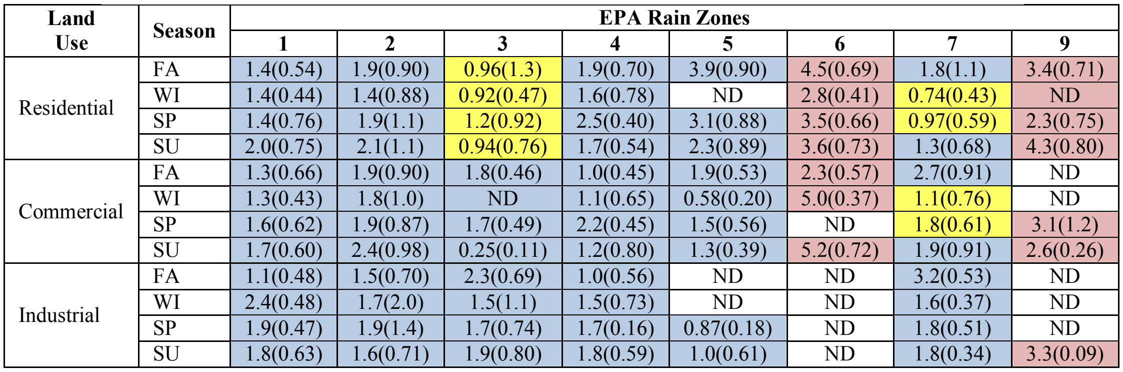
Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	2.2(0.27)	3.4(0.15)	1.7(1.3)	2.7(0.48)	ND	ND	ND	2.7(0.21)
	WI	ND	ND	0.81(0.69)	2.4(0.65)	ND	ND	ND	ND
	SP	2.4(0.57)	ND	1.6(0.47)	3.3(0.32)	ND	ND	ND	ND
	SU	2.1(0.49)	3.3(0.17)	1.2(0.91)	3.2(0.55)	ND	ND	ND	5.7(0.42)
Commercial	FA	1.9(0.69)	3.2(0.13)	1.3(0.49)	2.5(0.26)	ND	ND	ND	ND
	WI	ND	ND	1.1(0.55)	1.7(0.66)	ND	ND	ND	ND
	SP	ND	ND	2.4(1.0)	3.3(0.47)	ND	ND	ND	4.3(1.1)
	SU	1.6(0.23)	11(0.75)	1.6(1.3)	1.9(0.67)	ND	ND	ND	3.6(0.23)
Industrial	FA	1.8(0.07)	3.3(0.64)	1.6(0.83)	1.7(0.34)	ND	ND	ND	ND
	WI	ND	3.6(0.74)	0.73(0.55)	2.2(0.62)	ND	ND	ND	ND
	SP	ND	ND	1.3(0.34)	2.4(0.06)	ND	ND	ND	ND
	SU	0.92(0.62)	ND	0.59(0.71)	3.9(0.66)	ND	ND	ND	4.5(0.05)

Fig. 38. Total Nitrogen – Rain Zone Homogeneous Groups: Mean (CV)

Table 30. Basic Statistics for Total Nitrogen –
Rain Zone Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	3-(RE,CO,ID)(SU,WI)	43	0.98	0.96	0.98	0.20	0.65	4.4
B	1-RE,CO,ID 3-(RE,CO,ID)(FA,SP)	77	1.7	1.4	0.79	0.20	1.5	8.1
C	2-RE,CO,ID 4-RE,CO,ID 9-RE,CO,ID	103	3.2	2.5	0.78	0.44	2.7	18



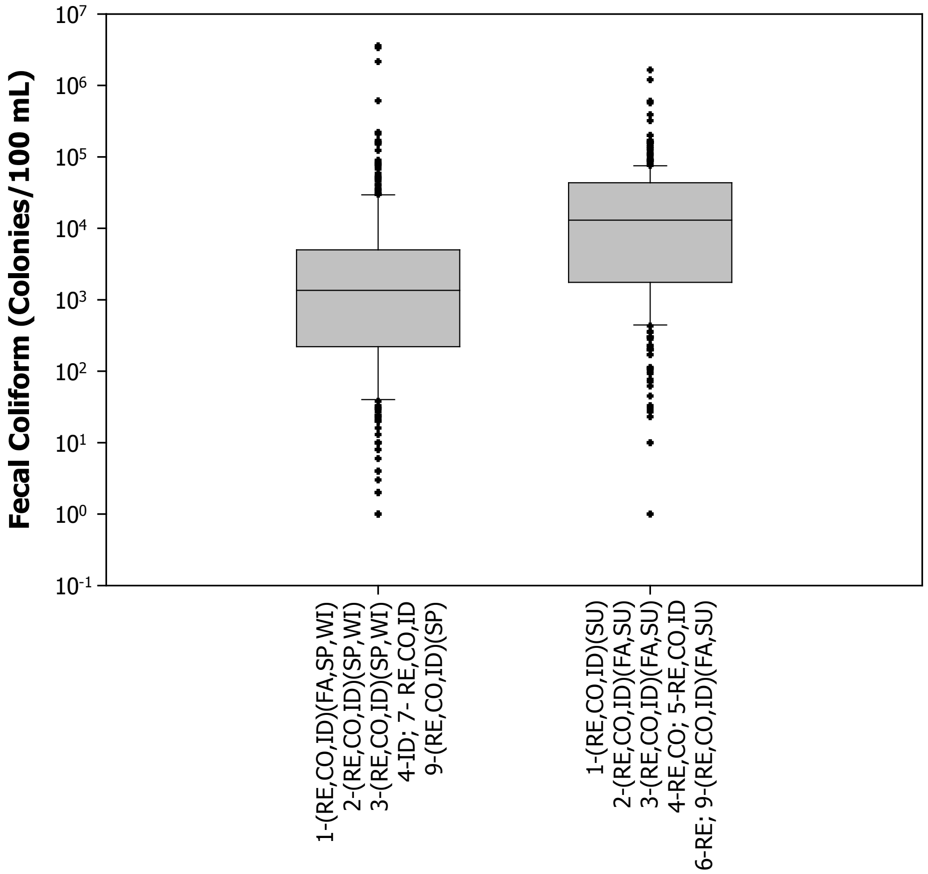


Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	1.4(0.54)	1.9(0.90)	0.96(1.3)	1.9(0.70)	3.9(0.90)	4.5(0.69)	1.8(1.1)	3.4(0.71)
	WI	1.4(0.44)	1.4(0.88)	0.92(0.47)	1.6(0.78)	ND	2.8(0.41)	0.74(0.43)	ND
	SP	1.4(0.76)	1.9(1.1)	1.2(0.92)	2.5(0.40)	3.1(0.88)	3.5(0.66)	0.97(0.59)	2.3(0.75)
	SU	2.0(0.75)	2.1(1.1)	0.94(0.76)	1.7(0.54)	2.3(0.89)	3.6(0.73)	1.3(0.68)	4.3(0.80)
Commercial	FA	1.3(0.66)	1.9(0.90)	1.8(0.46)	1.0(0.45)	1.9(0.53)	2.3(0.57)	2.7(0.91)	ND
	WI	1.3(0.43)	1.8(1.0)	ND	1.1(0.65)	0.58(0.20)	5.0(0.37)	1.1(0.76)	ND
	SP	1.6(0.62)	1.9(0.87)	1.7(0.49)	2.2(0.45)	1.5(0.56)	ND	1.8(0.61)	3.1(1.2)
	SU	1.7(0.60)	2.4(0.98)	0.25(0.11)	1.2(0.80)	1.3(0.39)	5.2(0.72)	1.9(0.91)	2.6(0.26)
Industrial	FA	1.1(0.48)	1.5(0.70)	2.3(0.69)	1.0(0.56)	ND	ND	3.2(0.53)	ND
	WI	2.4(0.48)	1.7(2.0)	1.5(1.1)	1.5(0.73)	ND	ND	1.6(0.37)	ND
	SP	1.9(0.47)	1.9(1.4)	1.7(0.74)	1.7(0.16)	0.87(0.18)	ND	1.8(0.51)	ND
	SU	1.8(0.63)	1.6(0.71)	1.9(0.80)	1.8(0.59)	1.0(0.61)	ND	1.8(0.34)	3.3(0.09)

Fig. 39. Total Kjeldhal Nitrogen – Rain Zone Homogeneous Groups: Mean (CV)

Table 31. Basic Statistics for Total Kjeldhal Nitrogen –
Rain Zone Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	1-RE,CO,ID; 2-RE,CO,ID 3-CO,ID; 4-RE,CO,ID 5-RE,CO,ID 7-(RE,CO)(FA,SU),ID	2127	1.8	1.8	0.99	0.05	1.3	25
B	3-RE 7-(RE,CO)(SP,WI)	339	0.97	0.87	0.90	0.14	0.76	7.8
C	6-RE,CO; 9-RE,CO,ID	95	3.6	2.6	0.73	0.30	3.0	12



Land Use	**Season**	**EPA Rain Zones**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**9**
Residential	FA	145241(4.6)	16556(1.9)	17279(1.1)	63765(0.74)	ND	ND	36881(1.7)	ND
	WI	201(1.2)	7264(1.8)	12051(1.5)	52219(1.3)	ND	ND	6965(2.6)	ND
	SP	3735(2.3)	11987(2.7)	2918(1.5)	27402(1.1)	26825(0.97)	1800(0.39)	16651(3.2)	ND
	SU	148277(2.9)	51533(2.1)	603750(1.4)	45212(0.61)	155000(0.14)	ND	3200(0.59)	36300(0.70)
Commercial	FA	3190(1.7)	23139(1.5)	6450(0.19)	109289(1.7)	214600(1.2)	ND	4683(0.94)	ND
	WI	661(1.3)	13876(3.1)	ND	65000(1.2)	6786(1.1)	ND	12367(3.3)	ND
	SP	3403(1.2)	22960(2.1)	825(1.0)	5168(0.89)	4012(2.1)	ND	94797(2.4)	342(1.4)
	SU	20960(1.1)	23149(1.1)	ND	34214(1.1)	53667(0.60)	ND	4233(0.61)	11193(1.2)
Industrial	FA	281493(3.5)	37625(1.6)	7030(1.1)	21224(2.5)	ND	ND	5350(2.5)	ND
	WI	265(1.8)	18158(2.7)	6170(2.3)	276558(2.8)	ND	ND	7225(2.8)	ND
	SP	3099(2.1)	9056(2.1)	1841(2.5)	13793(2.0)	7633(0.50)	ND	4209(1.3)	ND
	SU	20255(1.3)	16530(1.4)	5000(0.67)	22154(2.6)	21500(0.83)	ND	2950(1.0)	25050(0.96)

Fig. 40. Fecal Coliform Bacteria – Rain Zone Homogeneous Groups: Mean (CV)

Table 32. Basic Statistics for Fecal Coliform Bacteria –
Rain Zone Homogeneous Groups (Real Space Data) (Colonies/100mL)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	1-(RE,CO,ID)(FA,SP,WI) 2-(RE,CO,ID)(SP,WI) 3-(RE,CO,ID)(SP,WI) 4-ID 7-RE,CO,ID 9-(RE,CO,ID)(SP)	515	29120	239500	8.2	1.0	1350	3600000
B	1-(RE,CO,ID)(SU) 2-(RE,CO,ID)(FA,SU) 3-(RE,CO,ID)(FA,SU) 4-RE,CO; 5-RE,CO,ID; 6-RE 9-(RE,CO,ID)(FA,SU)	401	40286	119279	3.0	1.0	13000	1650000

Table 33. Summary of Geographical Regions Groups

TSS	ZN	Cu	LB	TP	DP	N	TKN	FC
1-RE,CO,ID 4-RE,CO,ID 6-RE,CO 9-CO,ID	1-RE	1-RE,ID 3-RE,CO,ID 5-RE,CO,ID 6-RE,CO	1-RE, CO,ID 2-RE,ID 3-CO,ID 5-RE 7-(RE,CO)(SP,SU)	1-CO 3-RE,ID 5-CO	1-ID 3-RE,CO,ID 5-CO 7-(RE,CO,ID)(SP,WI)	1-RE,CO,ID 3-(RE,CO,ID)(FA,SP)	1-RE,CO,ID 2-RE,CO,ID 3-CO,ID 4-RE,CO,ID 5-RE,CO,ID 7-(RE,CO)(FA,SU), ID	1-(RE,CO,ID)(FA,SP,WI) 2-(RE,CO,ID)(SP,WI) 3-(RE,CO,ID)(SP,WI) 4-ID 7-RE,CO,ID 9-(RE,CO,ID)(SP)
2-RE 3-RE,CO,ID	1-CO,ID 2-RE 3-RE,CO,ID 5-RE,CO,ID	2-RE,ID 7-RE,CO,ID	3-RE	7-RE,CO,ID	1-RE,CO 2-RE,CO,ID 4-RE,CO,ID 5-RE,ID 6-RE 9-RE,CO,ID	3-(RE,CO,ID)(SU,WI)	3-RE 7-(RE,CO)(SP,WI)	1-(RE,CO,ID)(SU) 2-(RE,CO,ID)(FA,SU) 3-(RE,CO,ID)(FA,SU) 4-RE,CO 5-RE,CO,ID 6-RE 9-(RE,CO,ID)(FA,SU)
2-CO,ID 5-RE,CO,ID 7-RE,CO,ID 9-RE	2-ID 7-RE,CO,ID 9-RE,CO,ID	1-CO 2-CO 9-RE,CO,ID	2-CO 4-RE,CO,ID 5-CO,ID 6-RE,CO 7-(RE,CO)(FA,WI),ID 9-RE,CO,ID	1-RE,ID 2-RE,CO,ID 3-CO 4-RE,CO,ID 5-RE,ID	7-(RE,CO,ID)(FA)	2-RE,CO,ID 4-RE,CO,ID 9-RE,CO,ID	6-RE,CO 9-RE,CO,ID	
	2-CO 4-RE,CO,ID 6-RE,CO	4-RE,CO,ID		6-RE,CO 9-RE,CO,ID				

4.3 Detailed Analyses in EPA Rain Zone 2

In order to better examine the effect of land use and season on stormwater constituent concentrations, EPA Rain Zone 2 was chosen for detailed analyses due to the availability of a complete data set. All the pollutants concentrations were $\log_{10}$ transformed and checked for normality at a 0.05 significance level. The concentrations were not consistently normally distributed and the sample sizes were not always larger than 30. Therefore, the Kruskal-Wallis one-way analysis of variance by ranks was selected for these analyses. If significant differences were found in the median of the data (p-values < 0.05), the next step was to performed multiple comparisons (Mann-Whitney *U* test) and to combine the seasons in homogeneous groups. Power analyses for several significance levels were also performed on the $\log_{10}$ transformed data. The Kruskal-Wallis test was found to be competitive with the ANOVA F-test in terms of alpha (confidence), but it is less powerful due to loss of information involved in substituting ranks for the original values (Feir and Toothaker 1974).

Figure 41 and Table 34 show the single land uses available in EPA Rain Zone 2 and their seasonal coefficient of variation for total suspended solids concentrations.

The box-and-whisker plot and the Kruskal-Wallis test (p-value = 0.0) showed that there were significant differences between land uses within this rain zone. Also, the coefficients of variation for the non-transformed data showed difference among seasons for all land uses. Thus, the next step was to separate each land use into seasons. The “All LU” (all land uses) category was used as a benchmark for comparing the single land uses and their seasonal variability for the entire EPA Rain Zone 2.

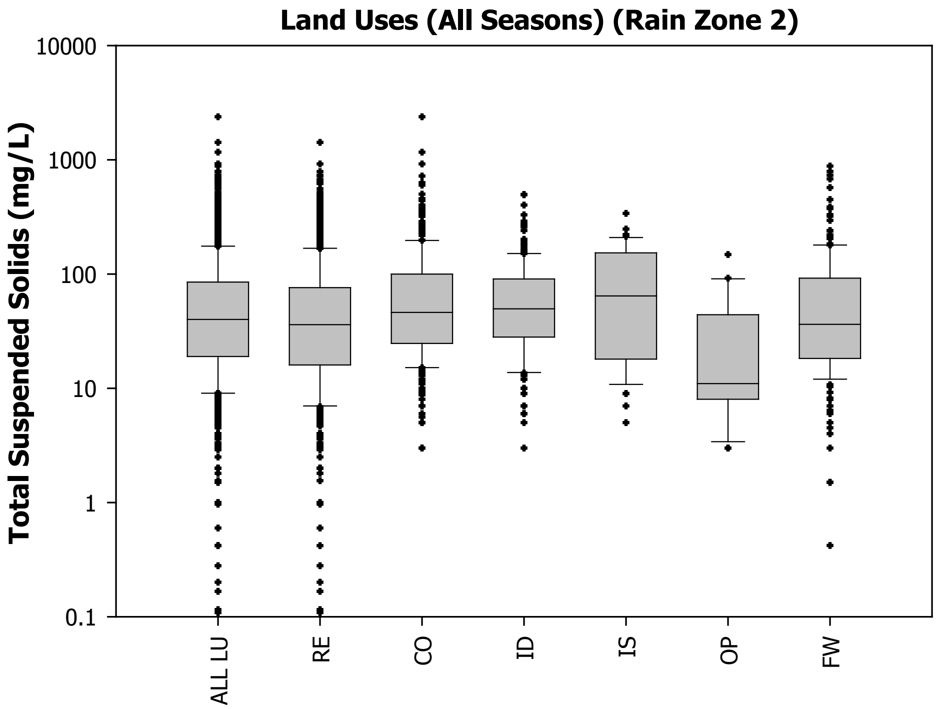


Fig. 41. Total Suspended Solids - Single Land Uses in EPA Rain Zone 2

Table. 34. Seasonal Coefficients of Variation for Single Land Uses in EPA Rain Zone 2 for Total Suspended Solids

Land Uses	**All Seasons**		**Fall**		**Winter**		**Spring**		**Summer**	
	N	**COV**	**N**	**COV**	**N**	**COV**	**N**	**COV**	**N**	**COV**
All LU	1881	1.6	499	2.0	448	1.5	498	1.3	436	1.5
Residential	1000	1.6	261	1.9	236	1.2	290	1.3	213	1.5
Commercial	398	1.8	112	2.8	101	1.5	102	1.7	83	1.3
Industrial	190	1.1	47	0.90	53	0.97	49	1.1	41	1.3
Institutional	45	0.97	10	0.52	14	1.2	11	0.82	10	1.6
Open Space	23	1.2	6	0.67	4	1.7	8	0.79	5	1.1
Freeways	225	1.6	63	1.1	40	1.6	38	1.1	84	1.8

The study began by first separating the existing total suspended solids concentration data from the EPA Rain Zone 2 (“All LU” category) into four seasons (fall, winter, spring, and summer) to check for seasonal variability and normality (Figure 42 and 43). A Kruskal-Wallis test was performed with a resultant p-value of 0.092, showing that the results were not significant at the chosen alpha level of 0.05 (Table 35).

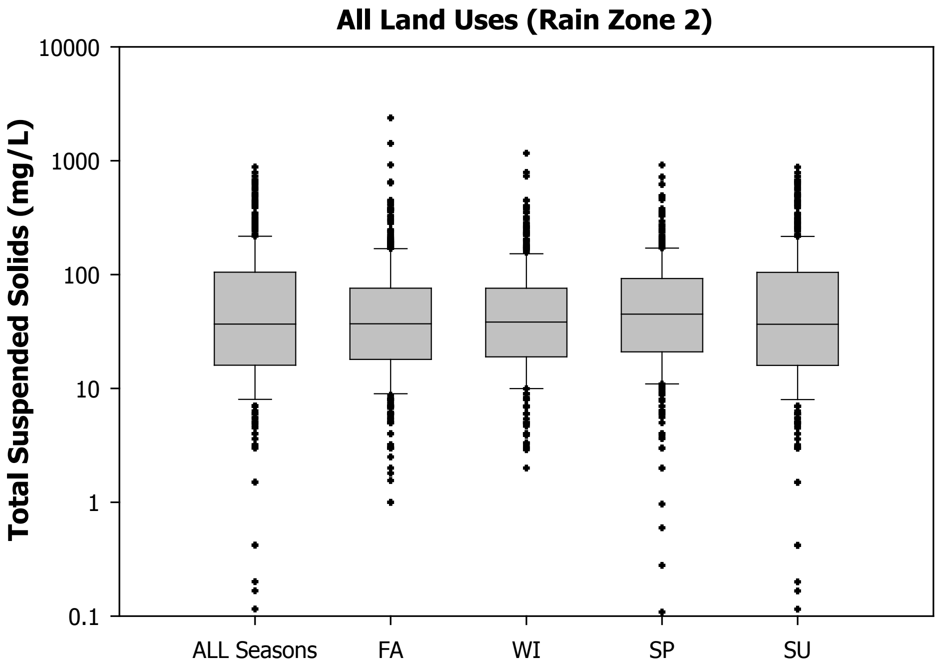
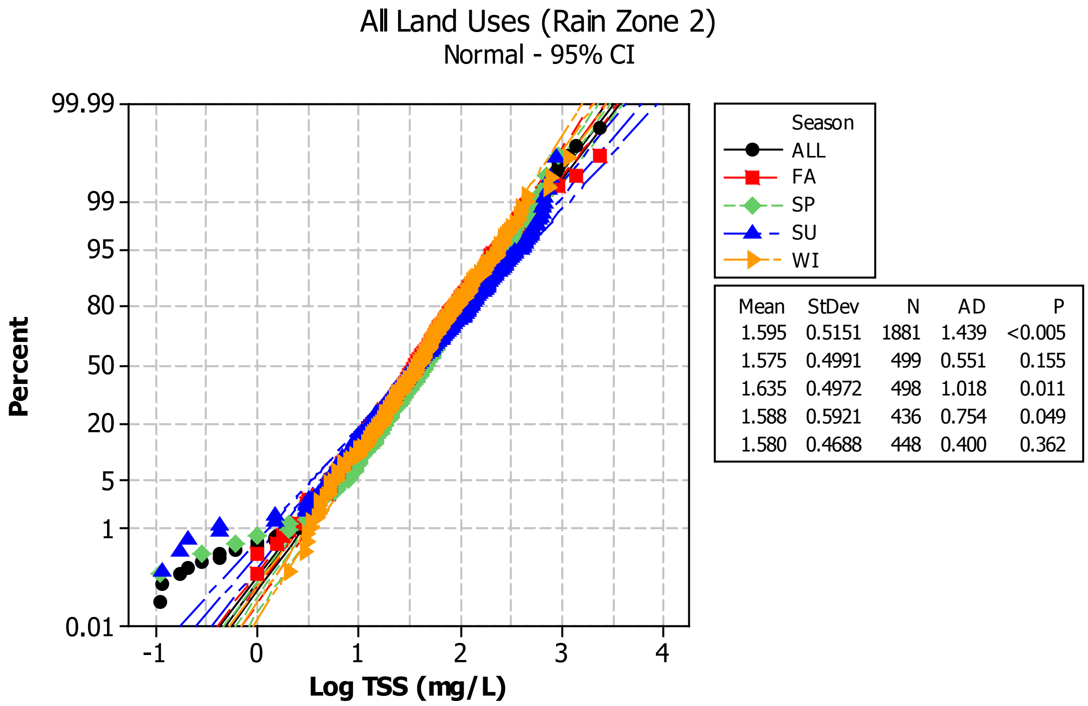


Fig. 42. Total Suspended Solids - All Single Land Uses



Mean	StDev	N	AD	P
1.595	0.5151	1881	1.439	<0.005
1.575	0.4991	499	0.551	0.155
1.635	0.4972	498	1.018	0.011
1.588	0.5921	436	0.754	0.049
1.580	0.4688	448	0.400	0.362

Fig. 43. Total Suspended Solids - All Single Land Uses (Checks for Normality)

Table 35. Nonparametric Analyses of Variance and Power Analyses for Total Suspended Solids - All Single Land Uses

Kruskal-Wallis Test (All Land Uses: Log TSS)

H = 6.45 DF = 3 P = 0.092
H = 6.45 DF = 3 P = 0.092 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	499	1.568	916	-1.2
SP	498	1.653	993	2.5
SU	436	1.565	93	-0.39
WI	448	1.584	919	-0.96
Overall	1881		941	

Power of the Test (All Land Uses: Log TSS)

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	499	1.58	0.499
SP	498	1.64	0.497
SU	436	1.59	0.592
WI	448	1.58	0.469

Pooled Standard Deviation	0.514
Obtained Effect Size	0.05

α level	**Power (%)**
0.20	68.0
0.15	61.7
0.10	53.3
0.05	***40.5***
0.01	19.6

The retrospective power analysis showed that this analysis lacked power most likely because the effect size needed to be detected was very small (0.05, from Table 35), corresponding to 15% differences in mean concentrations of the four seasons (real space values). In addition, the corresponding available sample size was not large enough to prove that seasons had an effect on total suspended solids concentrations, even though there were more than 400 samples in each category. From Figure 11 (Chapter 3) it can be estimated that a minimum of 4,470 samples would be needed to detect (at a significance level of 5% and a power of 80%) that the seasons would have a statistically significant effect on total suspended solids concentrations when all single land uses are analyzed. The number of samples available (1881) could detect seasonal differences if the mean effect size would be at least 0.08 (about 24% differences in mean concentrations of the four seasons, real space values).

Figure 44 shows the total suspended solids seasonal variability observed when only the residential land use data were analyzed within EPA Rain Zone 2. Figure 45 is a probability plot used to check the normality of the data.

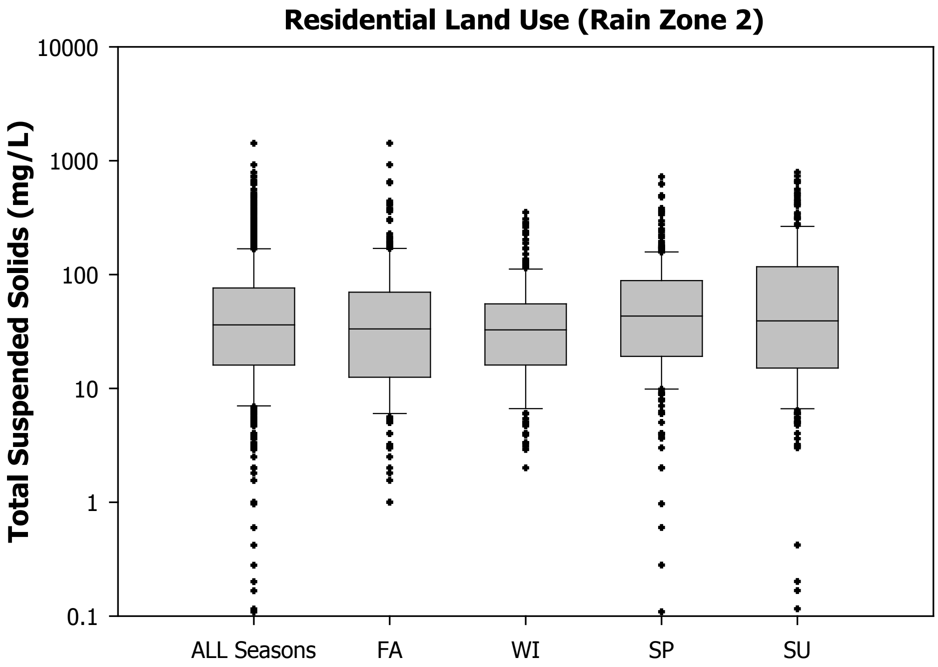
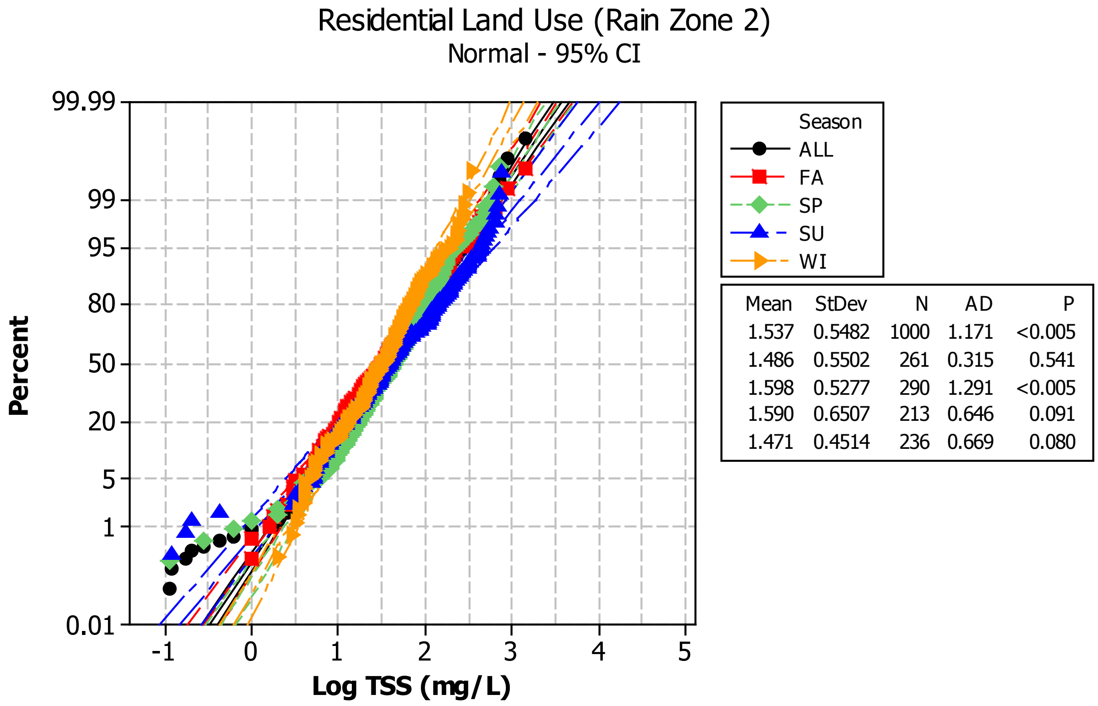


Fig. 44. Total Suspended Solids – Residential Land Use



Mean	StDev	N	AD	P
1.537	0.5482	1000	1.171	<0.005
1.486	0.5502	261	0.315	0.541
1.598	0.5277	290	1.291	<0.005
1.590	0.6507	213	0.646	0.091
1.471	0.4514	236	0.669	0.080

Fig. 45. Total Suspended Solids – Residential Land Use (Checks for Normality)

A Kruskal-Wallis analysis showed significant differences among seasons, therefore the Mann–Whitney *U* test was used to assess whether each two independent seasonal sets came from the same population (Table 36). The analysis showed that the median differences between at least one of the total possible two distinct season groupings were significant at the 0.05 level, so the seasons were separated according to their homogeneity and significance (Table 36 and Figure 46). Figure 46 represents a Venn diagram for all possible group combinations giving a visual image of the homogeneous groups. The retrospective power analysis (Table 37) revealed that this analysis was performed on a good sample size and it was well powered (82%) to detect the small effect size (0.11) that existed among the residential total suspended solids seasonal concentrations seasonal groupings. Therefore, the results of the statistical test were accepted with confidence, resulting in two likely seasonal groups: fall plus winter vs. summer plus spring.

Table 36. Nonparametric Analyses of Variance, Multiple Comparisons and Data Groups for Total Suspended Solids - Residential Land Use

Kruskal-Wallis Test
(Residential: Log TSS)

H = 15.46 DF = 3 P = 0.001
H = 15.46 DF = 3 P = 0.00 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	261	1.521	467	-2.1
SP	290	1.634	541	2.9
SU	213	1.591	528	1.58
WI	236	1.512	460	-2.4
Overall	1000		501	

*Significant P-value

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.003*
	SU	0.036*
	WI	0.827
SP	SU	0.783
	WI	0.001*
SU	WI	0.018*

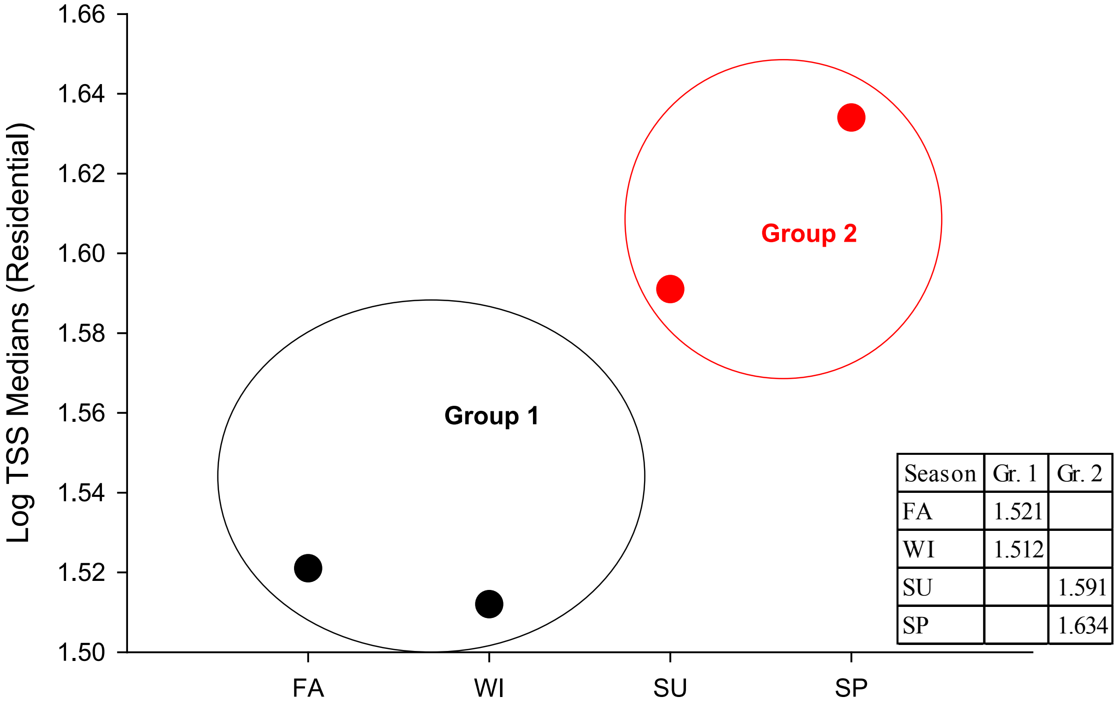
Residential Log TSS
Groups (medians)

Season	Gr. 1	Gr. 2
FA	1.521	
WI	1.512	
SU		1.591
SP		1.634

Table 37. Power of the Test for Total Suspended Solids - Residential Land Use

Season	$\boldsymbol{\mu_{\bar{x}}}$	**n**	$\boldsymbol{\sigma_{\bar{x}}}$
FA	1.49	261	0.550
SP	1.60	290	0.528
SU	1.59	213	0.651
WI	1.47	236	0.451
Pooled Standard Deviation			0.545
Obtained Effect Size			0.11

α level	**Power (%)**
0.20	94.5
0.15	92.4
0.10	88.9
0.05	***81.7***
0.01	61.7



Season	Gr. 1	Gr. 2
FA	1.521	
WI	1.512	
SU		1.591
SP		1.634

Fig. 46. All Possible Seasonal Combinations for Total Suspended Solids – Residential Land Use

The next step was to verify that the two residential seasonal groupings were statistically significant. Figure 47 shows the box-and-whisker plots of the two residential seasonal groups, while Table 38 shows the statistical analyses confirming that the groups were indeed statistically different. The box-and-whisker plot shows little separation in the boxes, but the large number of samples in each group (about 500) was sufficient to detect a significant difference in the resulting concentrations, even though the differences were small (about a 20% differences in the median concentrations of 33 and 41 mg/L for the two groupings of data) (Figure 47).

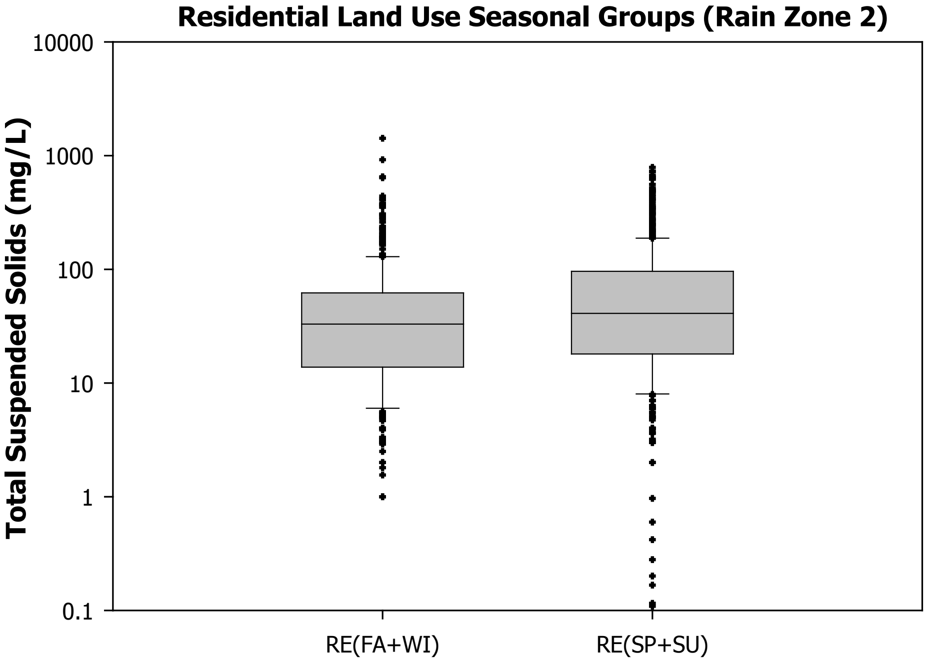


Fig. 47. Total Suspended Solids – Residential Land Use Seasonal Groups

Table 38. Nonparametric Analyses of Variance and Power Analyses for Total Suspended Solids – Residential Land Use Seasonal Groups

Kruskal-Wallis Test
(Residential: Log TSS Groups)

H = 15.10 DF = 1 P = 0.000
H = 15.10 DF = 1 P = 0.000 (adjusted for ties)

Groups	**N**	**Median**	**Ave Rank**	**Z**
RE(FA,WI)	497	1.519	465	-3.9
RE(SP,SU)	503	1.613	536	3.89
Overall	1000		501	

Power of the Test (Residential: Log TSS Groups)

Groups	$\mu_{\bar{x}}$	**n**	$\sigma_{\bar{x}}$
RE(FA,WI)	1.48	497	0.505
RE(SP,SU)	1.59	503	0.582

Pooled Standard Deviation	0.544
Obtained Effect Size	0.10

α level	**Power (%)**
0.20	97.2
0.15	96.0
0.10	93.9
0.05	***89.1***
0.01	73.1

Figures 48 and 49 show the total suspended solids seasonal variability observed and the data normality check when only the commercial land use was analyzed.

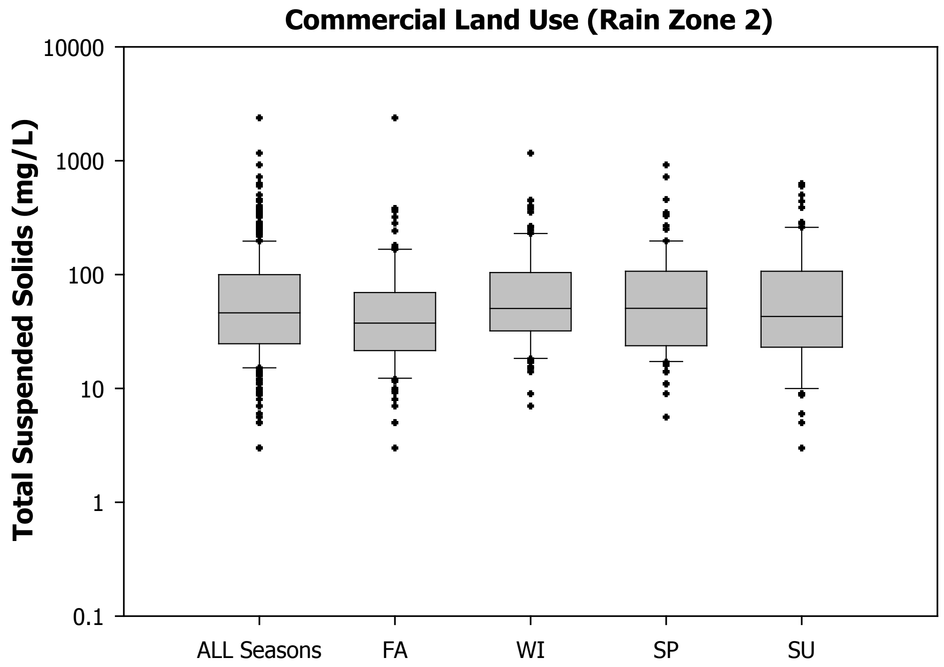


Fig. 48. Total Suspended Solids – Commercial Land Use

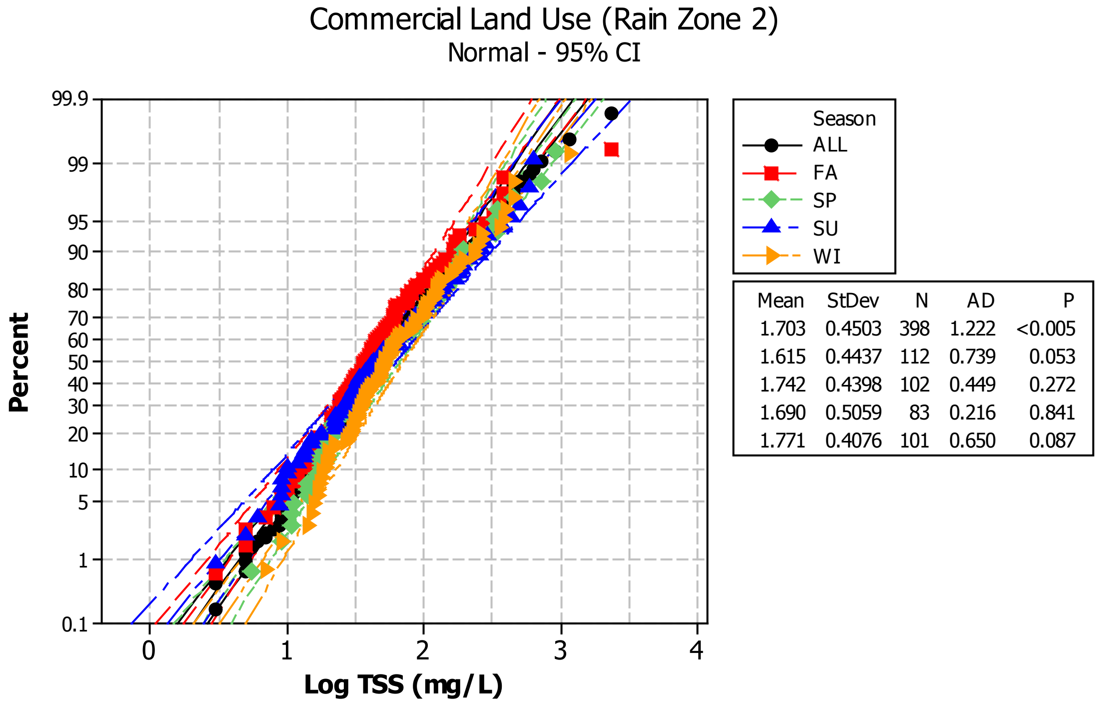


Fig. 49. Total Suspended Solids – Commercial Land Use (Checks for Normality)

The Kruskal-Wallis analysis showed significant differences among seasons, therefore the Mann–Whitney *U* test was used to assess whether each of any two independent seasonal groupings came from the same population (Table 39). The multiple comparison analysis showed that the median differences between two distinct seasonal groupings were significant at the 0.05 level, so the seasons were separated according to their homogeneity and significance (Table 39 and Figure 50).

Table 39. Nonparametric Analyses of Variance, Multiple Comparisons and Data Groups for Total Suspended Solids - Commercial Land Use

Kruskal-Wallis Test
(Commercial: Log TSS)

H = 8.01 DF = 3 P = 0.046
H = 8.01 DF = 3 P = 0.046 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	112	1.574	176	-2.6
SP	102	1.703	209	0.97
SU	83	1.633	197	-0.2
WI	101	1.702	218	1.86
Overall	398		199.5	

*Significant P-value

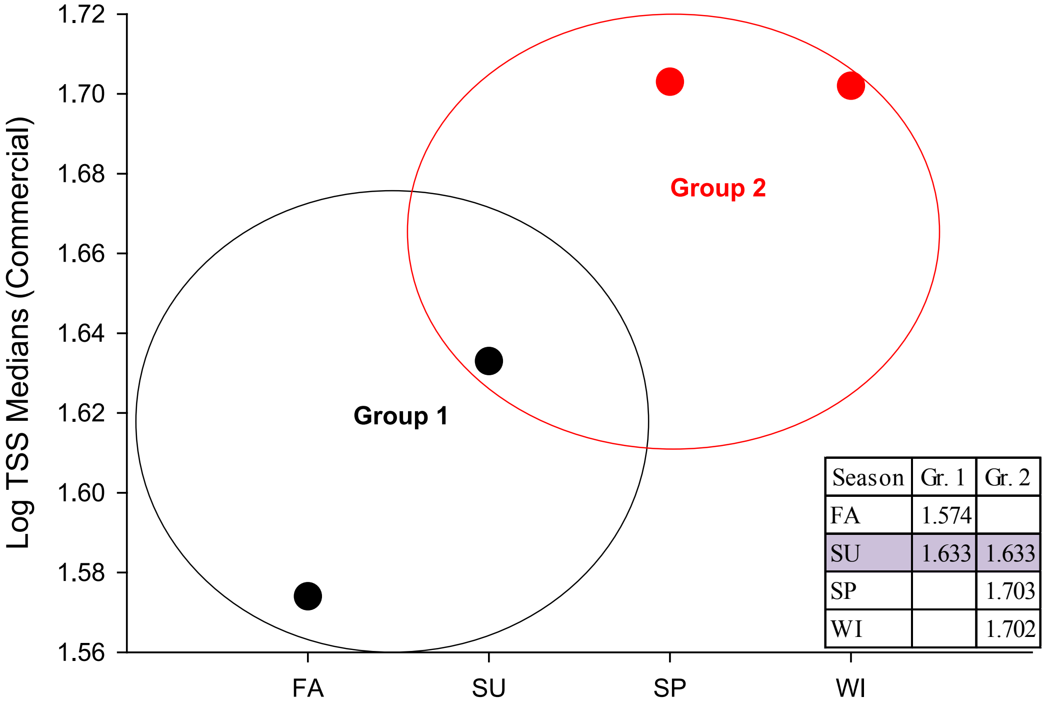
Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.036*
	SU	0.250
	WI	0.006*
SP	SU	0.514
	WI	0.615
SU	WI	0.247

Commercial Log TSS
Groups (medians)

Season	Gr. 1	Gr. 2
FA	1.574	
SU	1.633	
SP		1.703
WI		1.702

However, the retrospective power analysis (Table 40) revealed that total suspended solids sample counts for commercial land use were not large enough to detect the existing effect size (power 58%). Therefore, we cannot be confident that the results were significant. In any case, the commercial land use data were separated in two seasonal groups (Figure 51) and they were checked for significance (Table 41). Even if the Kruskal-Wallis test showed significance (p-value = 0.013), the test power was not sufficiently large (69%) to accept that there were differences among commercial total suspended solids seasonal concentrations for EPA Rain Zone 2.



Season	Gr. 1	Gr. 2
FA	1.574	
SU	1.633	1.633
SP		1.703
WI		1.702

Fig. 50. All Possible Seasonal Combinations for Total Suspended Solids – Commercial Land Use

Table 40. Power of the Test for Total Suspended Solids - Commercial Land Use

Season	$\mu_{\bar{x}}$	**n**	$\sigma_{\bar{x}}$
FA	1.62	112	0.444
SP	1.74	102	0.440
SU	1.69	83	0.506
WI	1.77	101	0.408
Pooled Standard Deviation			0.446
Obtained Effect Size			0.13

α level	**Power (%)**
0.20	81.7
0.15	76.9
0.10	70.0
0.05	***58.0***
0.01	34.0

Even with about 200 samples in each category (the median concentrations of the two groups varied by about 20%; 40 vs. 50 mg/L), each group had relatively large variations as indicated on the box and whisker plots in Figure 51. Consequently, the commercial land use total solids concentration data were not separated by seasons.

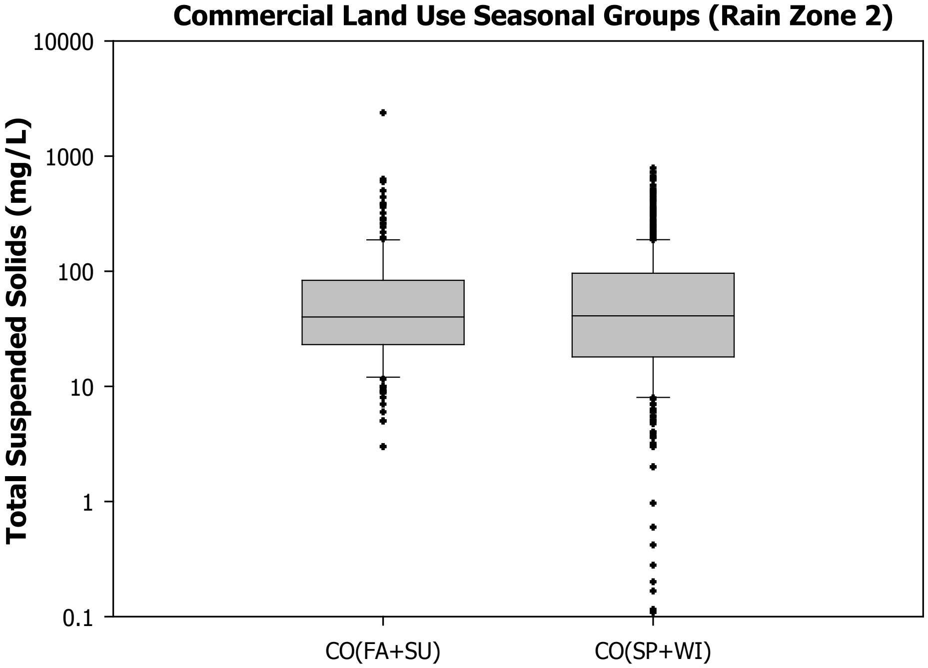


Fig. 51. Total Suspended Solids – Commercial Land Use Seasonal Groups

Table 41. Nonparametric Analyses of Variance and Power Analyses for Total Suspended Solids – Commercial Land Use Seasonal Groups

Kruskal-Wallis Test
(Commercial: Log TSS Groups)

H = 6.12 DF = 1 P = 0.013
H = 6.12 DF = 1 P = 0.013 (adjusted for ties)

Groups	**N**	**Median**	**Ave Rank**	**Z**
CO(FA,SU)	195	1.602	185	-2.5
CO(SP,WI)	203	1.702	214	2.5
Overall	398		200	

Power of the Test (Commercial: Log TSS Groups)

Groups	$\mu_{\bar{x}}$	**n**	$\sigma_{\bar{x}}$
CO(FA,SU)	1.65	195	0.471
CO(SP,WI)	1.76	203	0.423

Pooled Standard Deviation 0.446
Obtained Effect Size 0.12

α level	**Power (%)**
0.20	88.0
0.15	84.5
0.10	79.1
0.05	***68.9***
0.01	45.0

Figure 52 shows the total suspended solids seasonal variability observed when only industrial land use data were analyzed. Figure 53 represents the probability plot used to check the normality of the data. Kruskal-Wallis analyses showed no significant differences among seasons

(Table 42), and the retrospective power analysis showed that the analysis also lacked power at the chosen confidence level.

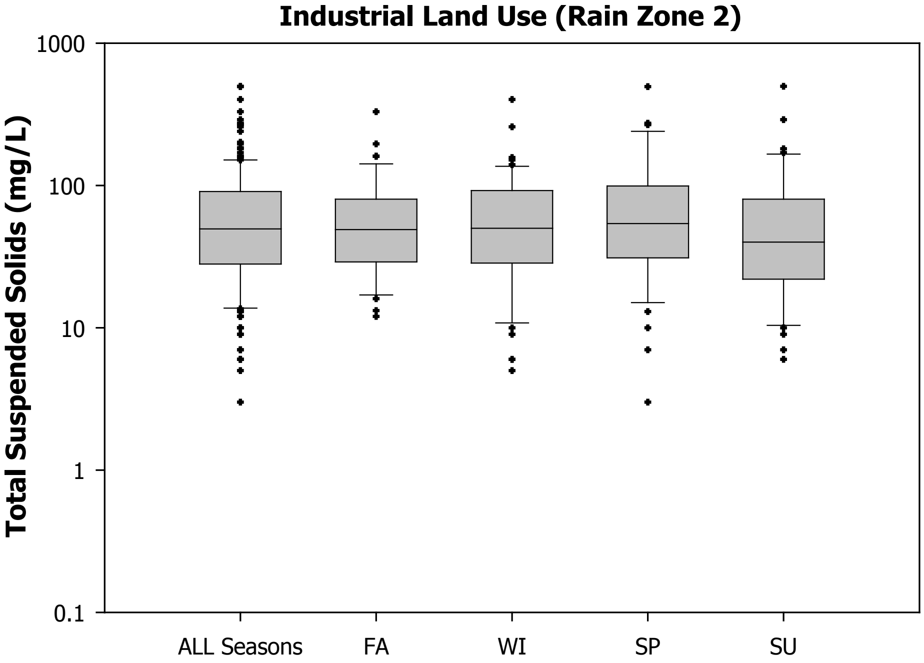


Fig. 52. Total Suspended Solids - Industrial Land Use

The available sample size did not detect seasonal differences in the industrial land use TSS concentrations, because the differences were small (about a 30% differences in the mean concentrations of the four seasons, real space values) and the sample size was not large enough. From Figure 12 (Chapter 3) it can be estimated that for a mean effect size of 0.10 (from Table 42) to be detected, this analysis needs about 1000 samples to show that, at 5% significance level and 80% power, the seasons would show a significant effect on industrial total suspended solids concentrations. The number of samples available (190) would only be able to detect seasonal differences if the mean effect size would be a minimum of 0.2424 (about 75% differences in mean concentrations of the four seasons, real space values).

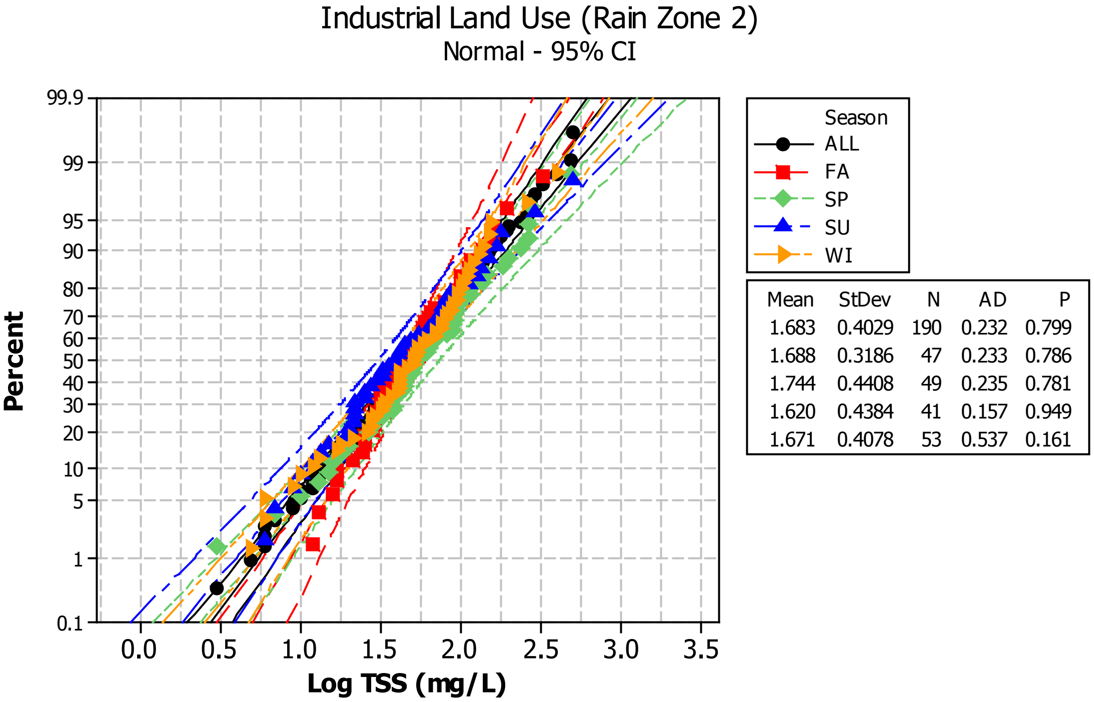


Fig. 53. Total Suspended Solids - Industrial Land Use (Checks for Normality)

Table 42. Nonparametric Analyses of Variance and Power Analyses for Total Suspended Solids - Industrial Land Use

Kruskal-Wallis Test (Industrial: Log TSS)

H = 2.80 DF = 3 P = 0.423
H = 2.80 DF = 3 P = 0.423 (adjusted for ties)

Season	**N**	**Median**	**Ave Rank**	**Z**
FA	47	1.690	94	-0.2
SP	49	1.732	105	1.4
SU	41	1.602	85	-1.4
WI	53	1.699	96	0.08
Overall	190		95.5	

Power of the Test (Industrial: Log TSS)

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	47	1.69	0.319
SP	49	1.74	0.441
SU	41	1.62	0.438
WI	53	1.67	0.408
Pooled Standard Deviation			0.402
Obtained Effect Size			0.10

α level	**Power (%)**
0.20	44.8
0.15	37.9
0.10	29.8
0.05	***19.4***
0.01	6.7

Therefore, it was concluded that the available sample size could not demonstrate that there were significant differences among seasons in the industrial land use sample group for EPA Rain Zone 2.

Figure 54 shows the total suspended solids seasonal variability observed when only institutional land use data were analyzed. Figure 55 represents the probability plot used to check the normality of the data. Kruskal-Wallis analysis showed significant differences among seasons, therefore the Mann–Whitney *U* test was used to assess whether any two independent seasons came from the same population (Table 43). The multiple comparisons showed that the median differences between at least two distinct seasons were significant. The seasons were therefore separated according to their homogeneity and significance (Table 43 and Figure 56). Because the analysis only needed to detect a large effect size between the medians, the available sample size was adequate to detect this difference (test power 84%) (Table 44).

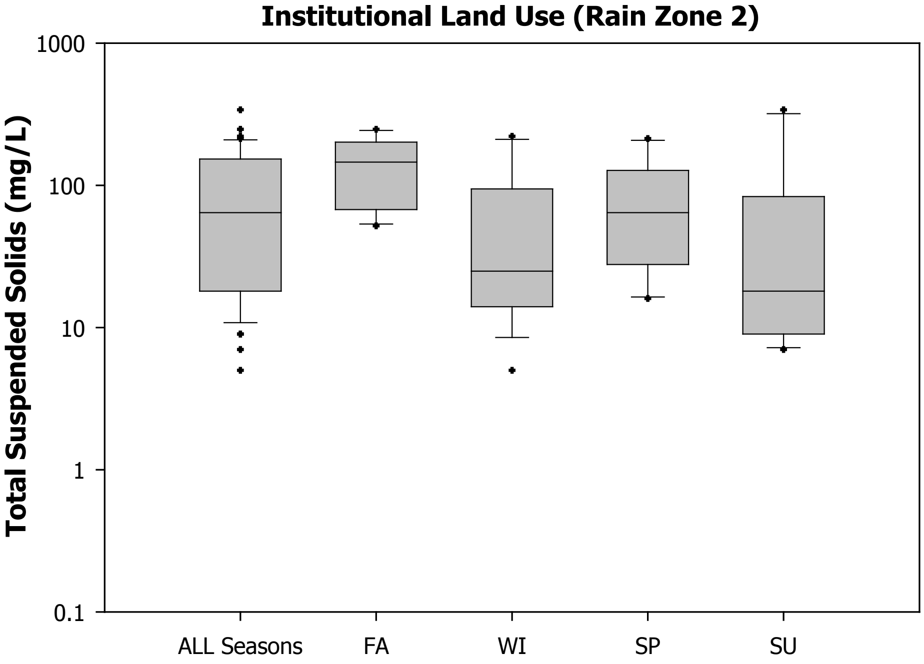


Fig. 54. Total Suspended Solids - Institutional Land Use

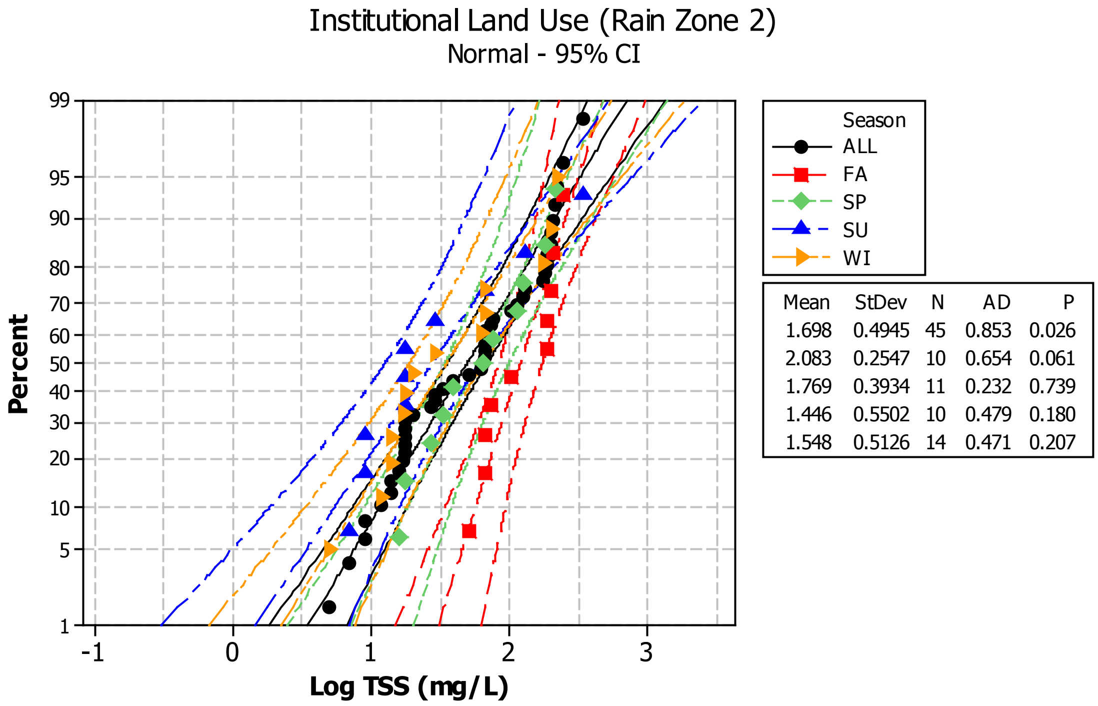


Fig. 55. Total Suspended Solids - Institutional Land Use (Checks for Normality)

Table 43. Nonparametric Analyses of Variance, Multiple Comparisons and Data Groups for Total Suspended Solids - Institutional Land Use

Kruskal-Wallis Test
(Institutional: Log TSS)

H = 10.14 DF = 3 P = 0.017
H = 10.15 DF = 3 P = 0.017(adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	10	2.146	33.4	2.8
SP	11	1.808	24.6	0.48
SU	10	1.255	16.9	-1.7
WI	14	1.389	18.6	-1.5
Overall	45		23	

*Significant P-value

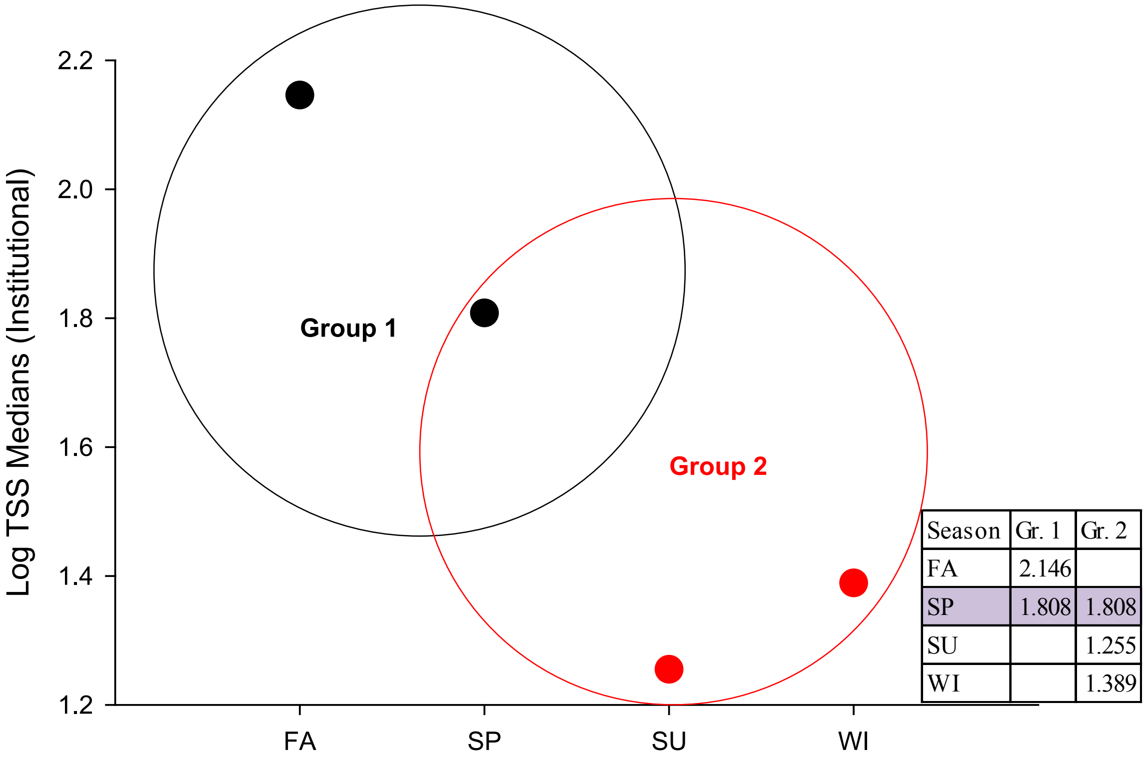
Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.073
	SU	0.017*
	WI	0.008*
SP	SU	0.139
	WI	0.228
SU	WI	0.682

Institutional Log TSS Groups (medians)

Season	Gr. 1	Gr. 2
FA	2.146	
SP	1.808	
SU		1.255
WI		1.389

It was concluded that the available data gave sufficient confidence to believe that there were differences among institutional total suspended solids seasonal concentrations for EPA Rain Zone 2.



Season	Gr. 1	Gr. 2
FA	2.146	
SP	1.808	1.808
SU		1.255
WI		1.389

Fig. 56. All Possible Seasonal Combinations for Total Suspended Solids – Institutional Land Use

Table 44. Power of the Test for Total Suspended Solids - Institutional Land Use

Season	$\mu_{\bar{x}}$	**n**	$\sigma_{\bar{x}}$
FA	2.08	10	0.255
SP	1.77	11	0.393
SU	1.45	10	0.550
WI	1.55	14	0.513
Pooled Standard Deviation			0.428
Obtained Effect Size			0.54

α level	**Power (%)**
0.20	96.1
0.15	94.3
0.10	91.2
0.05	***84.3***
0.01	91.2

The next step was to verify if the differences in the total suspended solids concentrations in the institutional seasonal groups were statistically significant. Figure 57 shows the box-and-whisker plots of the two institutional seasonal groups for these data, and Table 45 shows the statistical analyses. The figure and the table confirmed that the groups were significant (p-value = 0.006, power 86%): fall plus spring vs. summer plus winter, at median concentrations of 76 and 19 mg/L respectively.

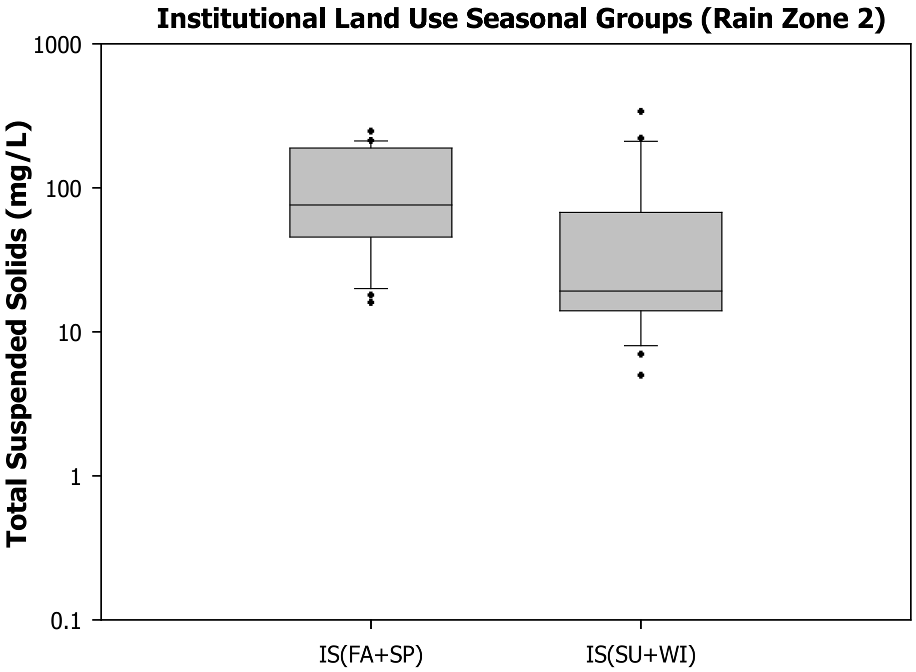


Fig. 57. Total Suspended Solids – Institutional Land Use Seasonal Groups

Table 45. Nonparametric Analyses of Variance and Power Analyses for Total Suspended Solids – Institutional Land Use Seasonal Groups

Kruskal-Wallis Test
(Institutional: Log TSS Groups)

H = 7.70 DF = 1 P = 0.006
H = 7.72 DF = 1 P = 0.005 (adjusted for ties)

Groups	**N**	**Median**	**Ave Rank**	**Z**
IS(FA,SP)	21	1.881	29	2.78
IS(SU,WI)	24	1.283	18	-2.8
Overall	45		23	

Power of the Test (Institutional: Log TSS Groups)

Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
IS(FA,SP)	21	1.92	0.364
IS(SU,WI)	24	1.51	0.519

Pooled Standard Deviation 0.442
Obtained Effect Size 0.46

α level	**Power (%)**
0.20	96.4
0.15	94.8
0.1	92.1
0.05	***85.9***
0.01	65.9

Figure 58 shows the total suspended solids seasonal variability observed when only the open space land use data were analyzed. Figure 59 represents the probability plot used to check the normality of the data. Kruskal-Wallis analysis showed that no significant differences among seasons were likely (Table 46).

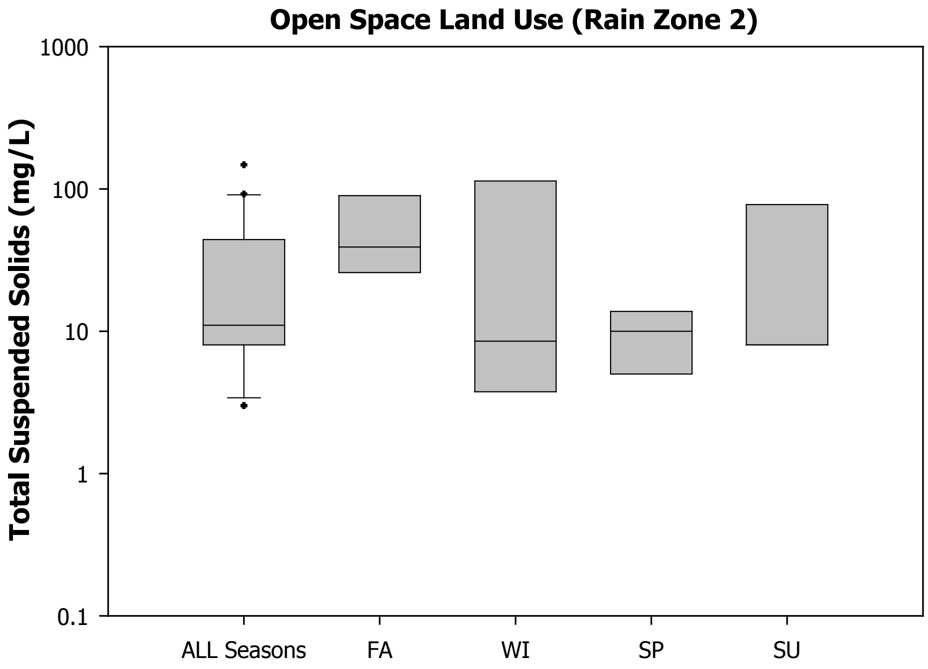
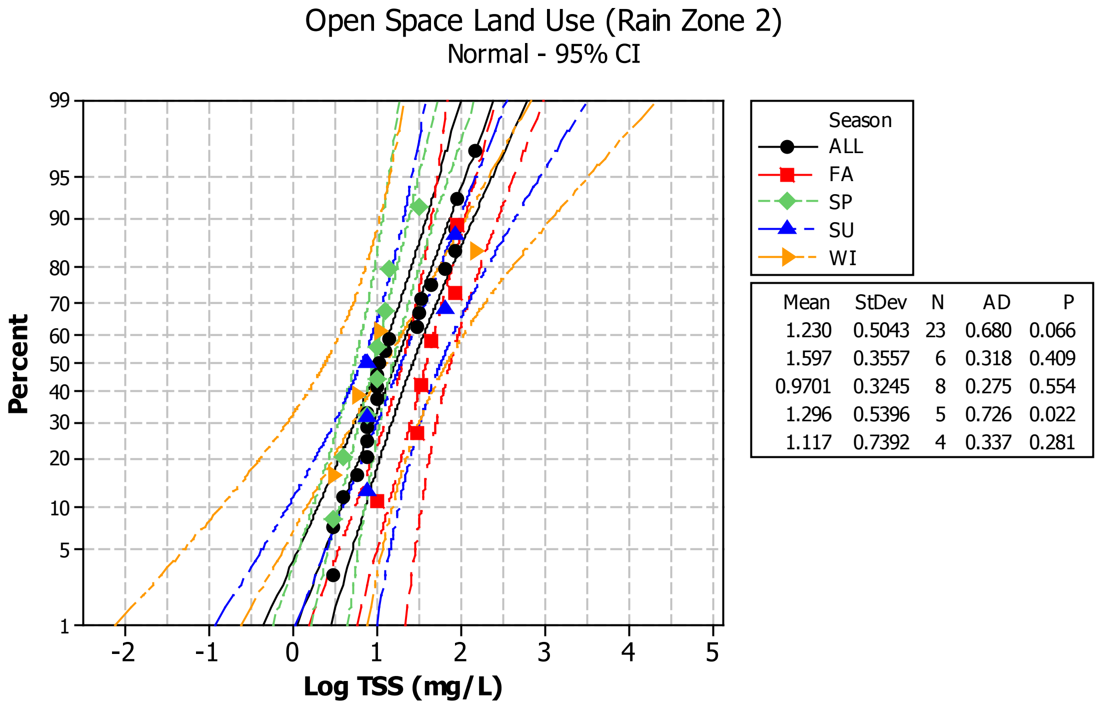


Fig. 58. Total Suspended Solids – Open Space Land Use

The available sample size did not allow detection of seasonal differences in the open space land use TSS concentrations, even though the differences were large (about 300% differences in the mean concentrations for the four seasons, real space values). The retrospective power analysis also showed that even if the mean effect size that needed to be detected was large (0.51, from Table 46), the available sample size was too small (23) to detect any significance; therefore the analysis lacked sufficient power (Table 46).



Mean	StDev	N	AD	P
1.230	0.5043	23	0.680	0.066
1.597	0.3557	6	0.318	0.409
0.9701	0.3245	8	0.275	0.554
1.296	0.5396	5	0.726	0.022
1.117	0.7392	4	0.337	0.281

Fig. 59. Total Suspended Solids – Open Space Land Use (Checks for Normality)

Table 46. Nonparametric Analyses of Variance and Power Analyses for Total Suspended Solids – Open Space Land Use

Kruskal-Wallis Test (Open Space: Log TSS)

H = 5.11 DF = 3 P = 0.164
H = 5.15 DF = 3 P = 0.161 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	6	1.588	17	2.2
SP	8	1.000	9.3	-1.4
SU	5	0.903	12	-0.1
WI	4	0.910	10	-0.6
Overall	23		12	

Power of the Test (Open Space: Log TSS)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	6	1.60	0.356
SP	8	0.97	0.325
SU	5	1.30	0.540
WI	4	1.12	0.739

Pooled Standard Deviation 0.49
Obtained Effect Size 0.51

α level	Power (%)
0.20	73.0
0.15	66.5
0.10	57.5
0.05	***43.1***
0.01	19.1

From Figure 14, it can be estimated that for an effect size of 0.51 to be detected, about 50 samples would be needed to show that, at 5% significance level and 80% power, the seasons would have a significant effect on open space total suspended solids concentrations. The number of samples available (23 for all seasons combined) would only be able to detect seasonal differences if they have at least a minimum mean effect size of 0.80 (about 500% difference in mean concentrations of the four seasons, real space values). It was concluded that the given sample size cannot demonstrate that there were significant differences among seasons in the open space land use for EPA Rain Zone 2.

Figure 60 shows the total suspended solids seasonal variability observed when only freeways land use data were analyzed. Figure 61 shows the probability plots used to check the normality of the data. Kruskal-Wallis analysis showed no significant differences among seasonal groupings (Table 47). The available sample size did not detect seasonal differences in the TSS concentrations, even though the differences were large (about a 60% differences in the mean concentrations of the four seasons, real space values).

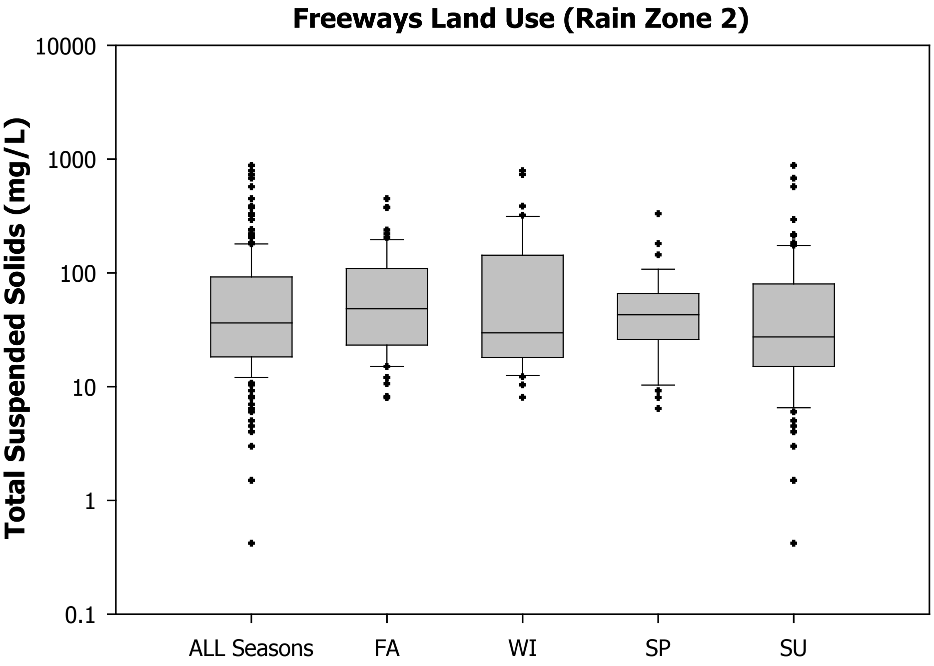


Fig. 60. Total Suspended Solids – Freeways Land Use

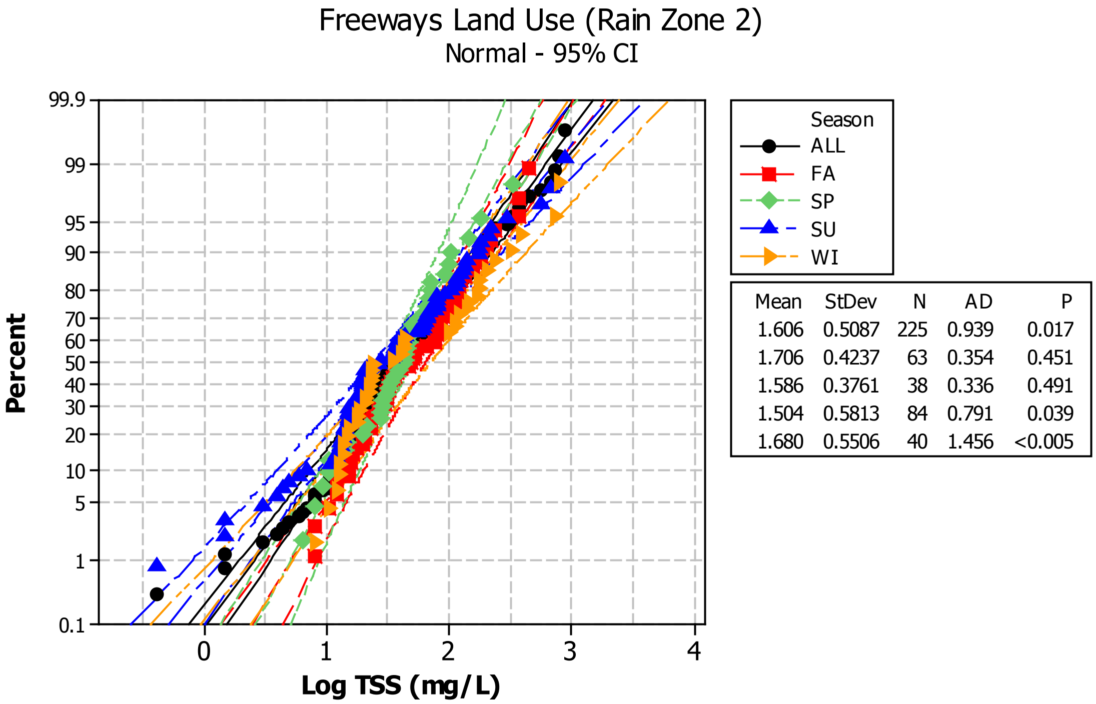


Fig. 61. Total Suspended Solids – Freeways Land Use (Checks for Normality)

Table 47. Nonparametric Analyses of Variance and Power Analyses for
Total Suspended Solids – Freeways Land Use

Kruskal-Wallis Test (Freeways: Log TSS)

H = 5.98 DF = 3 P = 0.113
H = 5.98 DF = 3 P = 0.113 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	63	1.683	127	2.03
SP	38	1.631	112	-0.1
SU	84	1.436	101	-2.2
WI	40	1.464	117	0.4
Overall	225		113	

Power of the Test (Freeways: Log TSS)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	63	1.71	0.424
SP	38	1.59	0.376
SU	84	1.50	0.581
WI	40	1.68	0.551
Pooled Standard Deviation			0.483
Obtained Effect Size			0.19

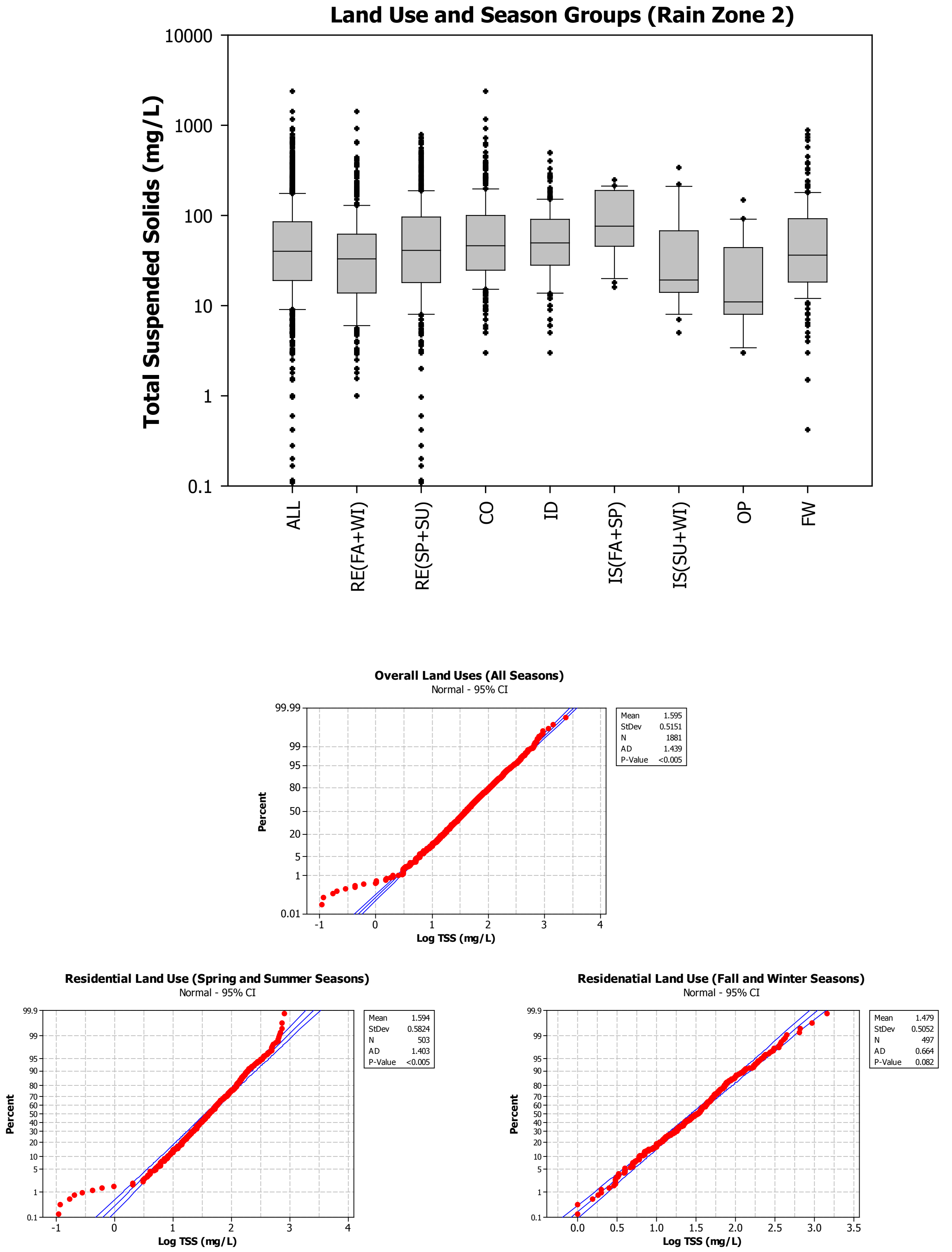
α level	Power (%)
0.20	84.9
0.15	80.6
0.10	74.2
0.05	***62.8***
0.01	38.6

The retrospective power analysis also showed that the test did not have enough power to detect the medium effect size that existed among the freeways seasons (total number of observations was 225 for all seasons combined). From Figure 12 and 13 it can be estimated that for an effect size of 0.19 to be detected (from Table 47), this analysis needs about 300 samples to show that, at 5% significance level and 80% power, the seasons would have an effect on the freeways total suspended solids concentration values. The number of samples available (225) would only be able to detect seasonal differences if the mean effect size would be minimum 0.25 (80% difference in mean concentrations of the four seasons). It was concluded that the available sample size could not demonstrate that there were significant differences among the seasonal total suspended solids concentrations in the freeways land use group for EPA Rain Zone 2.

The next step was to re-group the land uses to reflect the seasonal effect (Figure 62). It can be seen that for total suspended solids concentrations in EPA Rain Zone 2, there were sufficient samples to calculate significant seasonal effects only for residential and institutional land uses with sufficient confidence and power. Statistical analyses showed significant differences among total suspended solids medians (Table 48, 49, 50, and 51) pointing out that land uses can be clustered in five homogeneous groups (Figure 63 and 64). Further checking of the main homogeneous groups confirmed that this grouping was statistically correct (Table 52 and 53).

Tables 54 and Figure 63 show the basic statistics for these homogeneous groups and a color-coded clustering map to help visualize the data groups.

Similar analyses were performed using the total zinc, total copper, total lead, total and dissolved phosphorous, total nitrogen, Total Kjeldahl Nitrogen, and fecal coliform data (Appendix C). The analyses on medians for EPA Rain Zone 2 showed some differences among land uses and detected seasonal influences for all stormwater pollutants investigated.



Land Use and Season Groups (Rain Zone 2)

Overall Land Uses (All Seasons)

Normal - 95% CI

Residential Land Use (Spring and Summer Seasons)

Normal - 95% CI

Residenatial Land Use (Fall and Winter Seasons)

Normal - 95% CI

Fig. 62. Total Suspended Solids – Land Use and Season Groups (Checks for Normality)

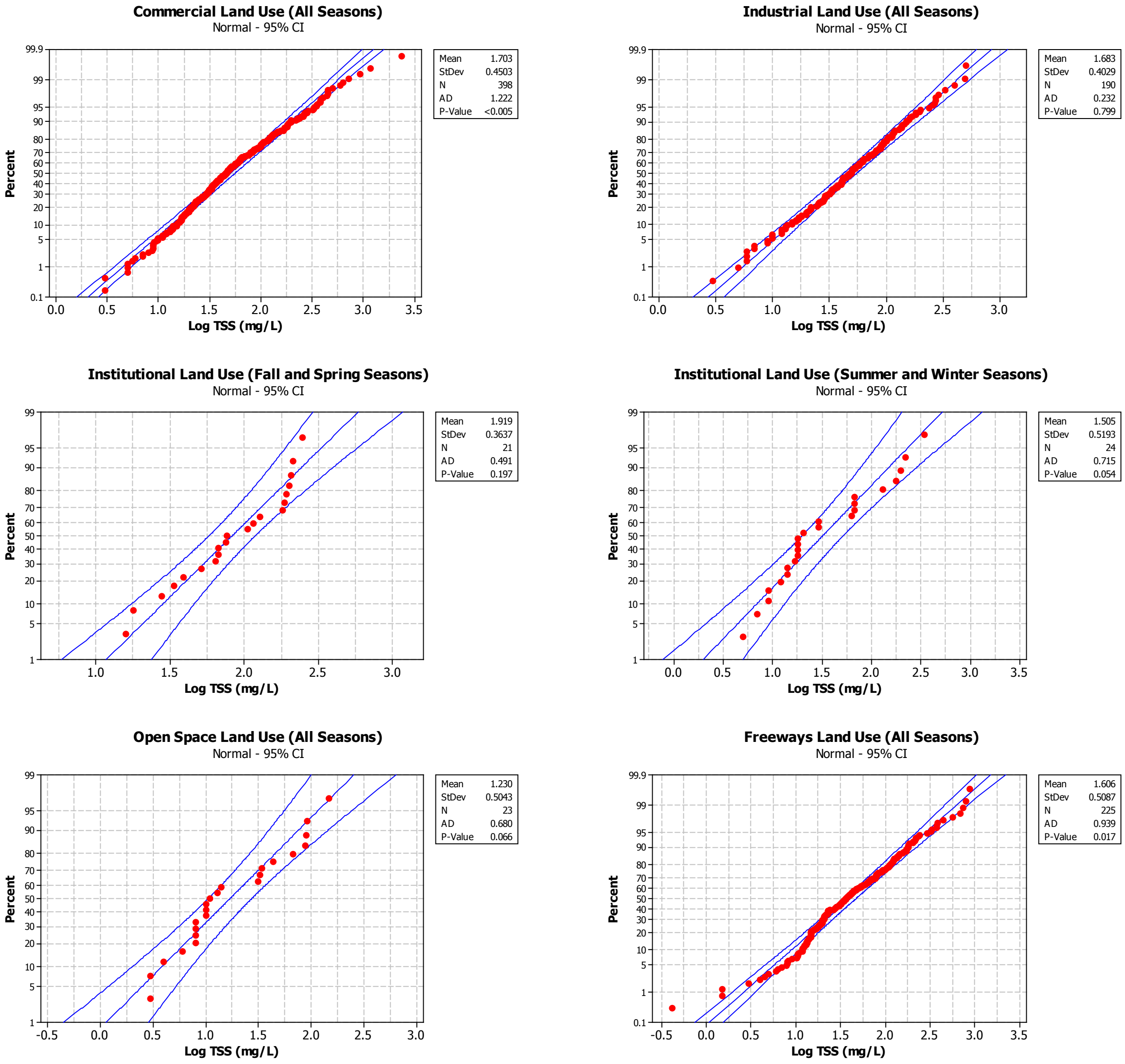


Fig. 62. – *Continued*

The seasonal influences were detected mostly for residential land use (likely due to this land use having the largest data set available), and occasionally for commercial, industrial, and freeways land uses. Figures 65 to 72 and Tables 56, 58, 60, 62, 64, 66, 68, and 70 show the clustered homogeneous groups along with their basic statistics for these other constituents.

Table 48. Nonparametric Analyses of Variance and Data Groups for Total Suspended Solids – Land Use and Season Groups

Kruskal-Wallis Test
(Land Use and Season Groups: Log TSS)

H = 70.26 DF = 7 P = 0.000
H = 70.26 DF = 7 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE(FA,WI)	497	1.519	815	-6
RE(SP,SU)	503	1.613	954	0.6
CO	398	1.663	1043	4.2
ID	190	1.695	1044	2.8
IS(FA,SP)	21	1.881	1321	3.2
IS(SU,WI)	24	1.283	808	-1
OP	23	1.041	565	-3
FW	225	1.560	938	0
Overall	1881		941	

Land Use and Season
Groups (medians)

Groups	Gr.A	Gr.B	Gr.C	Gr.D	Gr.E
RE(FA,WI)	1.519				
IS(SU,WI)	1.283				
RE(SP,SU)		1.613			
FW		1.560			
ID			1.695		
CO			1.663		
IS(FA,SP)				1.881	
OP					1.041

Table 49. Land Use and Season Multiple Comparisons for Total Suspended Solids

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
RE(FA,WI)	RE(SP,SU)	0.000*	RE(SP,SU)	CO	0.022*	CO	ID	0.954
	CO	0.000*		ID	0.078		IS(FA,SP)	0.013*
	ID	0.000*		IS(FA,SP)	0.004*		IS(SU,WI)	0.033*
	IS(FA,SP)	0.000*		IS(SU,WI)	0.248		OP	0.000*
	IS(SU,WI)	0.907		OP	0.001*		FW	0.015*
	OP	0.023*		FW	0.752			
	FW	0.005*				ID	IS(FA,SP)	0.009*
			IS(SU,WI)	OP	0.072		IS(SU,WI)	0.049*
IS(FA,SP)	IS(SU,WI)	0.006*		FW	0.218		OP	0.000*
	OP	0.000*					FW	0.041*
	FW	0.002*	OP	FW	0.001*			

*Significant P-value

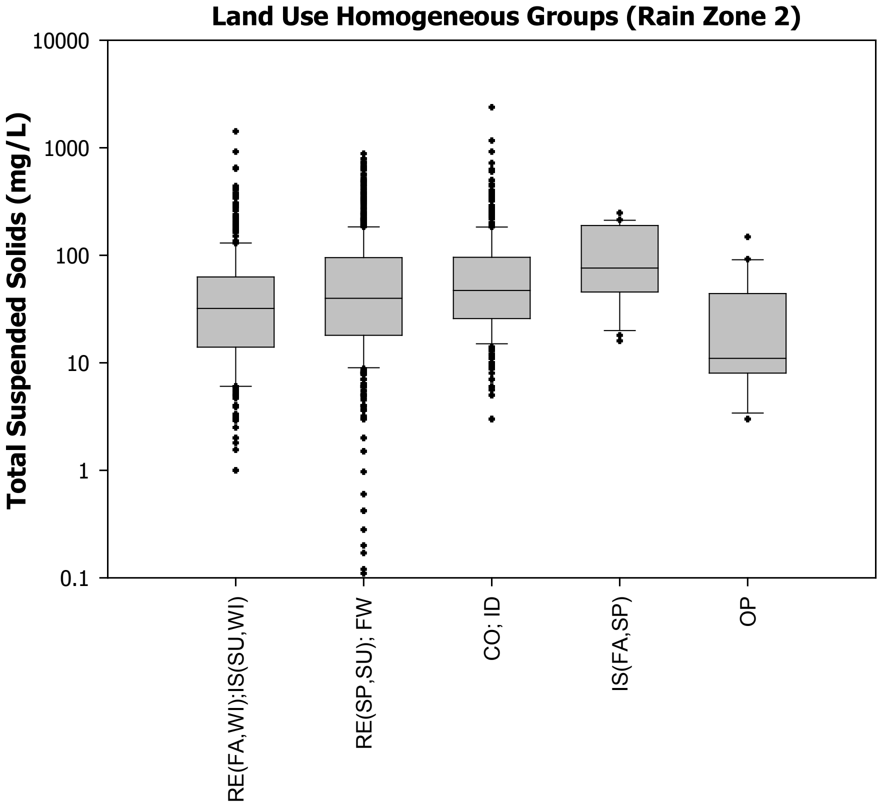
Table 50. All Possible Land Use and Season Combinations for Total Suspended Solids

Groups	Gr. A	Gr. B	Gr. C	Gr. D	Gr. E
RE(FA,WI)	1.519				
IS(SU,WI)	1.283	1.283			1.283
RE(SP,SU)		1.613			
FW		1.560			
ID			1.695		
CO			1.663		
IS(FA,SP)				1.881	
OP					1.041

Table 51. Power of the Test for Total Suspended Solids – Land Use and Season Groups

Seasonal Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,WI)	497	1.48	0.505
RE(SP,SU)	503	1.59	0.582
CO	398	1.70	0.450
ID	190	1.68	0.403
IS(FA,SP)	21	1.92	0.364
IS(SU,WI)	24	1.51	0.519
OP	23	1.23	0.504
FW	225	1.61	0.509
Pooled Standard Deviation			0.480
Obtained Effect Size			0.20

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	99.9



Land Use	FALL	WINTER	SPRING	SUMMER
Residential	70(1.9)	49(1.2)	73(1.3)	97(1.5)
Commercial	84(2.7)	98(1.5)	96(1.4)	95(1.3)
Industrial	65(0.90)	69(0.97)	87(1.1)	70(1.3)
Institutional	140(0.52)	66(1.1)	83(0.82)	65(1.6)
Open Space	50(0.67)	42(1.7)	12(0.79)	36(1.1)
Freeways	82(1.1)	112(1.6)	56(1.1)	76(1.8)

Fig. 63. Total Suspended Solids – Land Use Homogeneous Groups: Mean (CV)

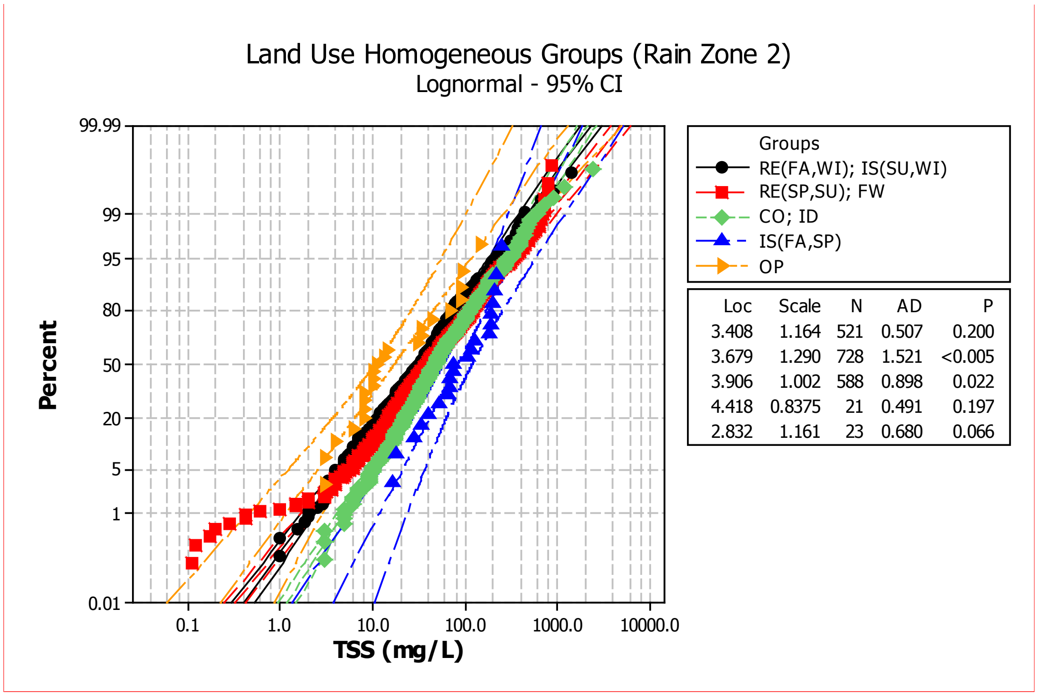


Fig. 64. Total Suspended Solids – Probability Plots of Land Use Homogeneous Groups

Table 52. Nonparametric Analyses of Variance, Multiple Comparisons and Data Groups for Total Suspended Solids – Land Use Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: Log TSS)

H = 70.09 DF = 4 P = 0.000
H = 70.09 DF = 4 P = 0.000 (adjusted for ties)

	Groups	N	Median	Ave Rank	Z
1	RE(FA,WI) IS(SU,WI)	521	1.505	816	-6.2
2	RE(SP,SU); FW	728	1.599	949	0.5
3	CO; ID	588	1.672	1043	5.5
4	IS(FA,SP)	21	1.881	1322	3.2
5	OP	23	1.041	565	-3.3
	Overall	1881		941	

Log Total Suspended Solids
Homogeneous Groups (medians)

Group	Gr.A	Gr.B	Gr.C	Gr.D	Gr.E
1	1.505				
2		1.599			
3			1.672		
4				1.881	
5					1.041

Multiple Comparisons
(Mann-Whitney U Test)

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
1	2	0.000*	3	4	0.010*
	3	0.000*		5	0.000*
	4	0.000*	4	5	0.000*
	5	0.023*			
2	3	0.002*			
	4	0.003*			
	5	0.001*			

*Significant P-value

Table 53. Power of the Test for Total Suspended Solids – Land Use Homogeneous Groups

Homogeneous Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,WI);IS(SU,WI)	521	1.48	0.505
RE(SP,SU); FW	728	1.60	0.560
CO; ID	588	1.70	0.435
IS(FA,SP)	21	1.92	0.364
OP	23	1.23	0.504

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	99.9

Pooled Standard Deviation	0.506
Obtained Effect Size	0.19

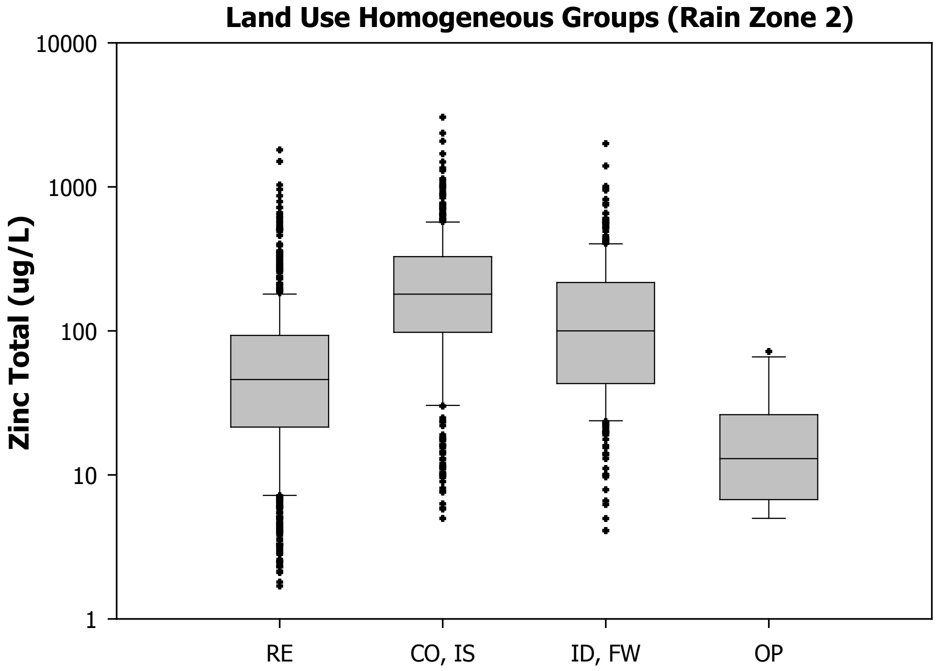
Table 54. Basic Statistics for Total Suspended Solids
Homogeneous Groups (Real Space Data) (mg/L)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	RE(FA,WI);IS(SU,WI)	521	60	105	1.7	1.0	32	1420
B	RE(SP,SU); FW	728	82	121	1.5	0.11	40	880
C	CO; ID	588	86	145	1.7	3.0	47	2381
D	IS(FA,SP)	21	110	75	0.68	16	76	247
E	OP	23	32	39	1.2	3.0	11	148

Statistical analyses showed that the available sample sizes (Table 55) for total zinc in EPA Rain Zone 2 were not large enough to detect seasonal influences among land uses at the study's significance level. In addition, Table 55 shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the four seasons at 5% significance level and 80% minimum power (calculations performed for real space data). For some land uses, using the available sample size but increasing the alpha level, the power of the test was increased and seasonal differences were detected. However, the data did not provide sufficient evidence to conclude that for total zinc there were significant differences among seasons for any land use in the EPA Rain Zone 2 area. Significant differences were detected only among land uses, with the six individual land uses clustered into four homogeneous groups (Figure 65 and Table 56).

Table 55. Total Zinc – Required Number of Samples to Detect Seasonal Mean Differences

Land Use	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
Residential	783	26	52	2600
Commercial	350	51	66	550
Industrial	152	100	130	240
Institutional	46	95	130	88
Open Space	14	250	290	18
Freeways	200	82	94	245



Land Use	FALL	WINTER	SPRING	SUMMER
Residential	90(1.6)	77(1.8)	74(1.2)	114(1.8)
Commercial	216(1.0)	283(1.2)	303(1.3)	287(1.2)
Industrial	127(1.5)	178(0.80)	145(0.98)	137(0.93)
Institutional	230(0.55)	200(0.80)	190(0.68)	431(0.91)
Open Space	29(0.86)	17(0.80)	6.8(0.25)	ND
Freeways	235(1.5)	182(1.0)	101(0.82)	186(0.98)

Fig. 65. Total Zinc – Land Use Homogeneous Groups: Mean (CV)

Table 56. Basic Statistics for Total Zinc Homogeneous Groups (Real Space Data) (µg/L)

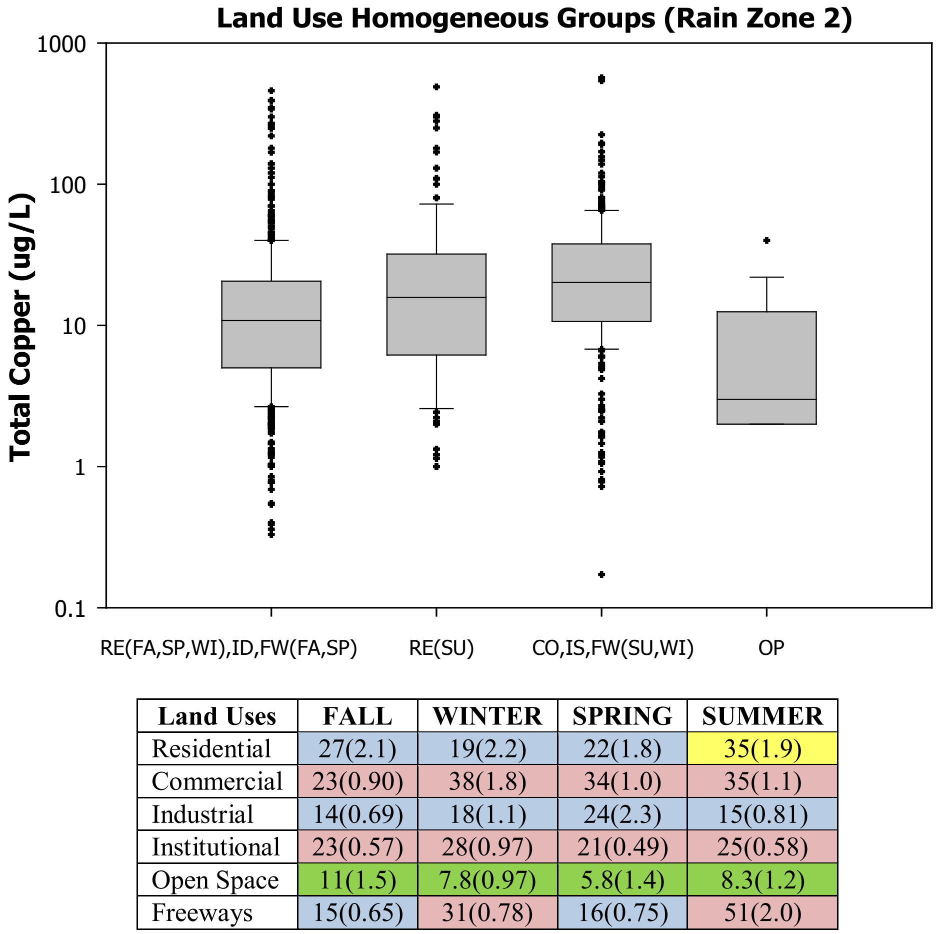
Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
1	RE	783	87	143	1.6	1.7	46	1807
2	CO, IS	396	268	315	1.2	5.0	180	3050
3	ID, FW	352	169	207	1.2	4.1	100	2000
4	OP	14	21	21	0.98	5.0	13	72

The statistical analyses showed that total copper in EPA Rain Zone 2 exhibits seasonal influences for residential and freeways land uses. The remaining land uses did not have enough data observations to detect significant differences among seasons at the study's alpha level (Table 57). In addition, Table 57 shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the four seasons at 5% significance level and 80% minimum power (calculations performed for real space data). However, significant differences were found among the land uses. Therefore, the total copper concentrations were clustered into four homogeneous groups (Figure 66 and Table 58).

Table 57. Total Copper – Required Number of Samples to Detect Seasonal Mean Differences

Land Use	**Available Sample Size**	**Maximum Difference in Seasonal Means (%)**	**Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)**	**Sample Size Required to Detect the Maximum Difference in Seasonal Means**
Commercial	315	58	62	344
Industrial	120	44	91	490
Institutional	35	15	125	2500
Open Space	18	74	230	280

Statistical analyses showed that the available sample size for total lead in EPA Rain Zone 2 was not large enough to detect seasonal influences among land uses at the study's significance level (Table 59). In addition, Table 59 shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the four seasons at 5% significance level and 80% minimum power (calculations performed for real space data). Increasing alpha level did not adequately increase the power of the test to be able to conclude otherwise. Significant differences were detected only among land, with the six individual land uses clustered into three homogeneous groups (Figure 67 and Table 60).



Land Uses	FALL	WINTER	SPRING	SUMMER
Residential	27(2.1)	19(2.2)	22(1.8)	35(1.9)
Commercial	23(0.90)	38(1.8)	34(1.0)	35(1.1)
Industrial	14(0.69)	18(1.1)	24(2.3)	15(0.81)
Institutional	23(0.57)	28(0.97)	21(0.49)	25(0.58)
Open Space	11(1.5)	7.8(0.97)	5.8(1.4)	8.3(1.2)
Freeways	15(0.65)	31(0.78)	16(0.75)	51(2.0)

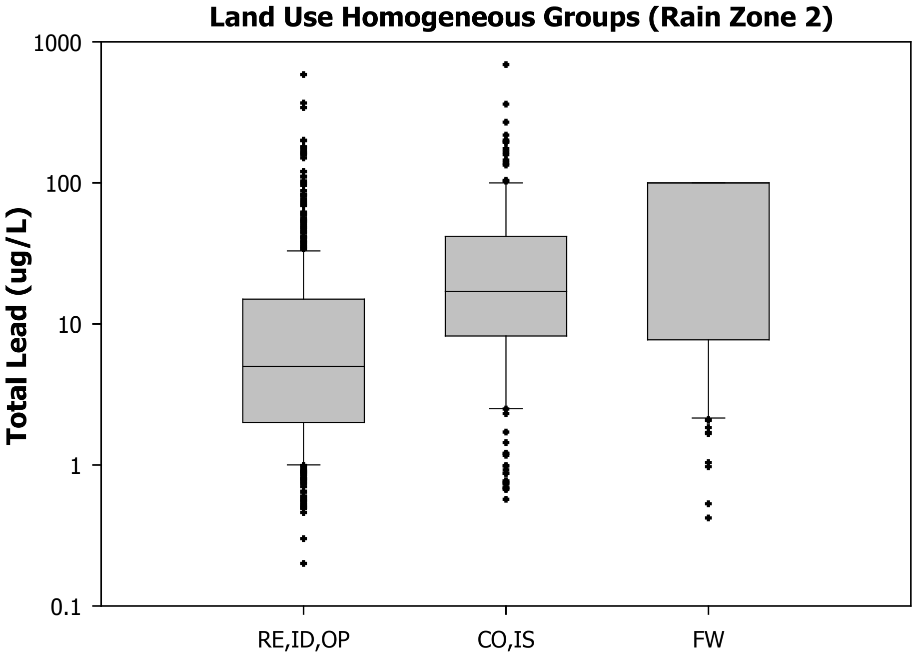
Fig. 66. Total Copper – Land Use Homogeneous Groups: Mean (CV)

Table 58. Basic Statistics for Total Copper Homogeneous Groups (Real Space Data) (µg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	RE(FA,SP,WI), FW(FA,SP), ID	740	22	43	2.0	0.33	11	460
B	RE(SU)	144	35	65	1.9	1.0	16	490
C	CO, IS, FW(SU,WI)	396	33	48	1.5	0.17	20	569
D	OP	18	8.2	10	1.3	2.0	3.0	40

Table 59. Total Lead – Required Number of Samples to Detect Seasonal Mean Differences

Land Use	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
Residential	557	32	68	2200
Commercial	222	55	105	830
Industrial	105	100	155	245
Institutional	42	200	270	76
Open Space	16	210	850	195
Freeways	92	125	185	195



Land Uses	FALL	WINTER	SPRING	SUMMER
Residential	17(2.1)	12(1.9)	17(2.3)	22(2.8)
Commercial	48(1.9)	41(1.2)	33(1.7)	32(1.3)
Industrial	7.0(0.96)	16(1.6)	25(2.5)	12(0.94)
Institutional	54(1.4)	15(1.2)	34(1.3)	25(0.65)
Open Space	8.4(0.40)	6.1(1.2)	19(1.8)	41(1.4)
Freeways	45(0.97)	70(0.63)	53(0.89)	65(0.66)

Fig. 67. Total Lead – Land Use Homogeneous Groups: Mean (CV)

Table 60. Basic Statistics for Total Lead Homogeneous Groups (Real Space Data) (µg/L)

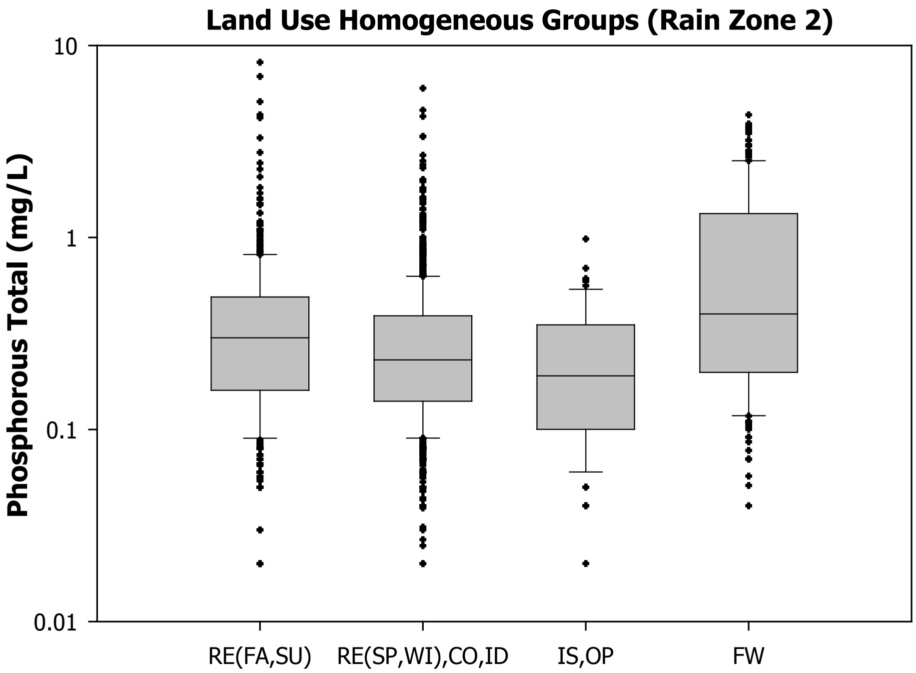
Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	RE, ID, OP	678	16	39	2.4	0.20	5.0	585
B	CO, IS	264	38	62	1.6	0.57	17	689
C	FW	92	57	45	0.78	0.42	100	100

The statistical analyses showed that total phosphorous in EPA Rain Zone 2 is affected by seasonal influences only for the residential land use area. The remaining land uses did not have enough data observations to detect significant differences among seasons at the study's alpha level (Table 61). In addition, Table 61 shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the four seasons at 5% significance level and 80% minimum power (calculations performed for real space data). Increasing the alpha level did not adequately increase the power of the test to be able to conclude otherwise. Significant differences were found among the other land uses. Therefore, the seven seasonal groups were clustered into three homogeneous groups (Figure 68 and Table 62).

Table 61. Total Phosphorous – Required Number of Samples to Detect Seasonal Mean Differences

Land Use	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
Commercial	375	32	44	660
Industrial	186	35	58	525
Institutional	44	58	130	200
Open Space	19	95	295	150
Freeways	181	62	97	450

The statistical analyses showed that dissolved phosphorous in EPA Rain Zone 2 is affected by seasonal influences for residential and industrial land use data. The remaining land uses did not have enough data to detect significant differences among seasons at the study's alpha level (Table 63). In addition, Table 63 shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the four seasons at 5% significance level



Land Uses	FALL	WINTER	SPRING	SUMMER
Residential	0.39(1.1)	0.32(0.86)	0.40(3.1)	0.51(1.8)
Commercial	0.34(0.96)	0.27(0.79)	0.30(0.80)	0.42(1.2)
Industrial	0.63(1.9)	0.29(0.87)	0.30(0.74)	0.29(0.75)
Institutional	0.24(0.61)	0.20(0.89)	0.24(0.67)	0.32(0.90)
Open Space	0.24(0.69)	0.27(0.82)	0.22(1.2)	0.29(0.70)
Freeways	0.96(1.2)	0.96(0.97)	0.71(1.4)	1.0(1.5)

Fig. 68. Total Phosphorous – Land Use Homogeneous Groups: Mean (CV)

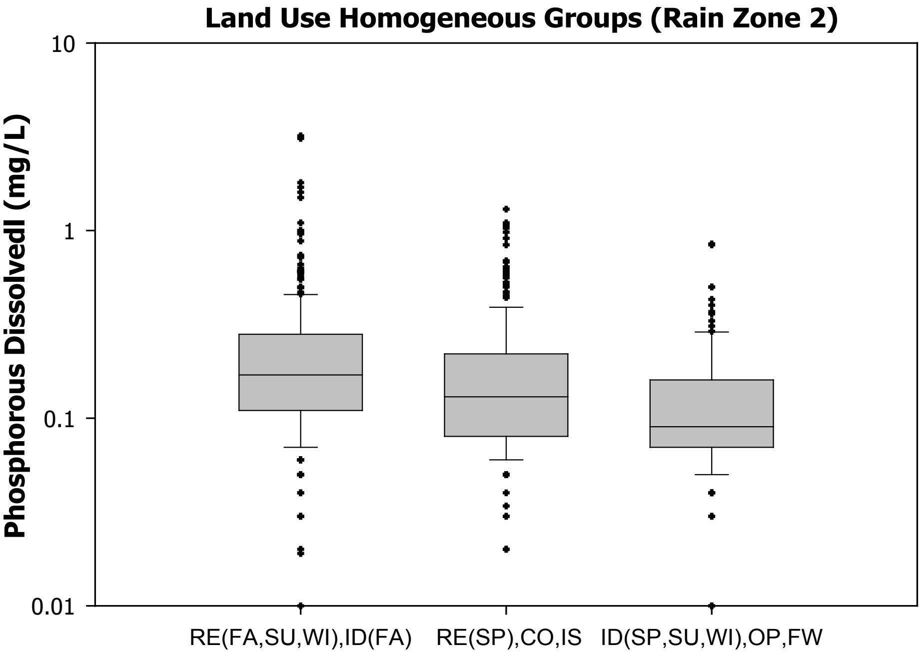
Table 62. Basic Statistics for Total Phosphorous
Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	RE(FA,SU)	461	0.45	0.69	1.5	0.02	0.30	8.2
B	RE(SP,WI), CO,ID	1103	0.35	0.72	2.0	0.02	0.23	20
C	IS,OP	63	0.24	0.19	0.79	0.02	0.19	0.98
D	FW	181	0.95	1.3	1.3	0.04	0.40	12

and 80% minimum power (calculations performed for real space data). Increasing the alpha level did not adequately increase the power of the test to be able to conclude otherwise. In addition, significant differences were found among the other land uses. Therefore, the eight seasonal groups were clustered into three homogeneous groups (Figure 69 and Table 64).

Table 63. Dissolved Phosphorous – Required Number of Samples to Detect Seasonal Mean Differences

Land Use	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
Commercial	148	32	59	460
Institutional	14	62	210	115
Open Space	17	270	750	72
Freeways	9	78	120	18



Land Uses	FALL	WINTER	SPRING	SUMMER
Residential	0.27(1.3)	0.22(0.88)	0.17(0.99)	0.22(0.80)
Commercial	0.22(0.85)	0.21(1.1)	0.17(0.85)	0.25(1.1)
Industrial	0.44(1.7)	0.14(1.1)	0.11(0.38)	0.15(0.98)
Institutional	ND	0.09(0.39)	0.15(0.65)	0.15(0.46)
Open Space	0.17(1.0)	0.24(0.93)	0.12(1.7)	0.13(1.3)
Freeways	0.18(0.78)	0.10(0.0)	0.08(0.06)	ND

Fig. 69. Dissolved Phosphorous – Land Use Homogeneous Groups: Mean (CV)

Table 64. Basic Statistics for Dissolved Phosphorous Homogeneous Groups (Real Space Data) (mg/L)

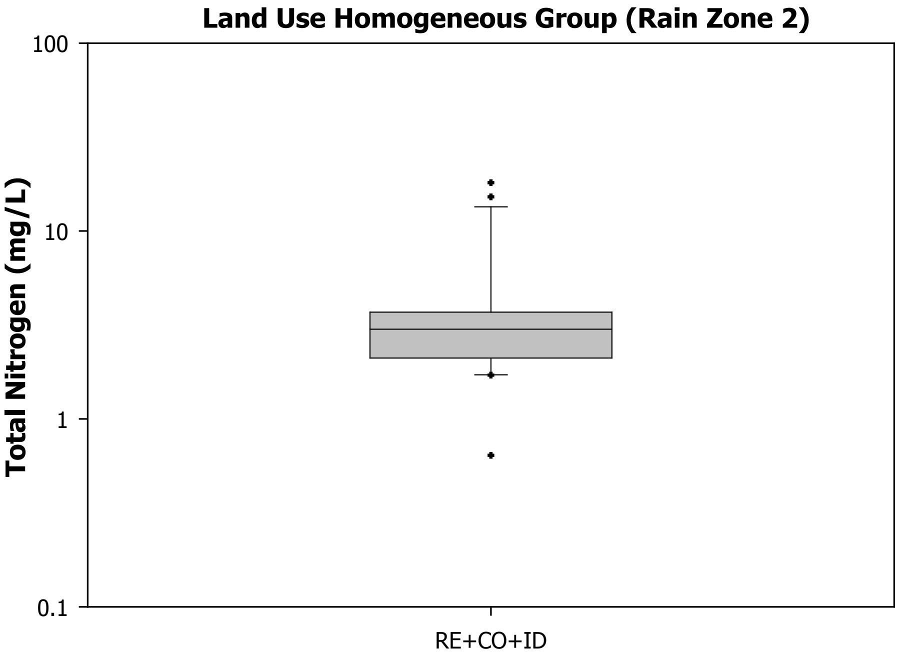
Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	RE(FA,SU,WI),ID(FA)	323	0.26	0.33	1.3	0.01	0.17	3.2
B	RE(SP),CO,IS	259	0.19	0.20	1.0	0.02	0.13	1.3
C	ID(SP,SU,WI),OP,FW	111	0.14	0.14	0.97	0.01	0.09	0.9

Total nitrogen had data available only for residential, commercial, and industrial land uses in EPA Rain Zone 2. The sample size in each land use was small (Table 65) and failed to detect seasonal influences at any reasonable significance level. In addition, Table 65 shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the four seasons at 5% significance level and 80% minimum power (calculations performed for real space data). Also, the statistical analyses showed no significant differences among land uses for total nitrogen. Therefore, all three land uses were combined into a single homogeneous group (Figure 70 and Table 66).

Total Kjeldahl Nitrogen concentrations in EPA Rain Zone 2 are affected by seasonal influences in residential and commercial land use areas. The remaining land uses did not have enough data to detect significant differences among seasons at the study’s alpha level (Table 67). In addition, Table 67 shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the four seasons at 5% significance level and 80% minimum power (calculations performed for real space data). Increasing the alpha level did not adequately increase the power of the test to be able to conclude otherwise. In addition, significant differences were found among the other land uses. Therefore, the eight seasonal groups were clustered into four homogeneous groups (Figure 71 and Table 68).

Table 65. Total Nitrogen – Required Number of Samples to Detect Seasonal Mean Differences

Land Use	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
Residential	7	10	73	170
Commercial	7	145	330	24
Industrial	7	5	250	7900



Land Uses	FALL	WINTER	SPRING	SUMMER
Residential	3.1(0.21)	ND	ND	3.3(0.17)
Commercial	3.2(0.13)	ND	ND	12(0.75)
Industrial	3.3(0.64)	3.56(0.74)	ND	ND

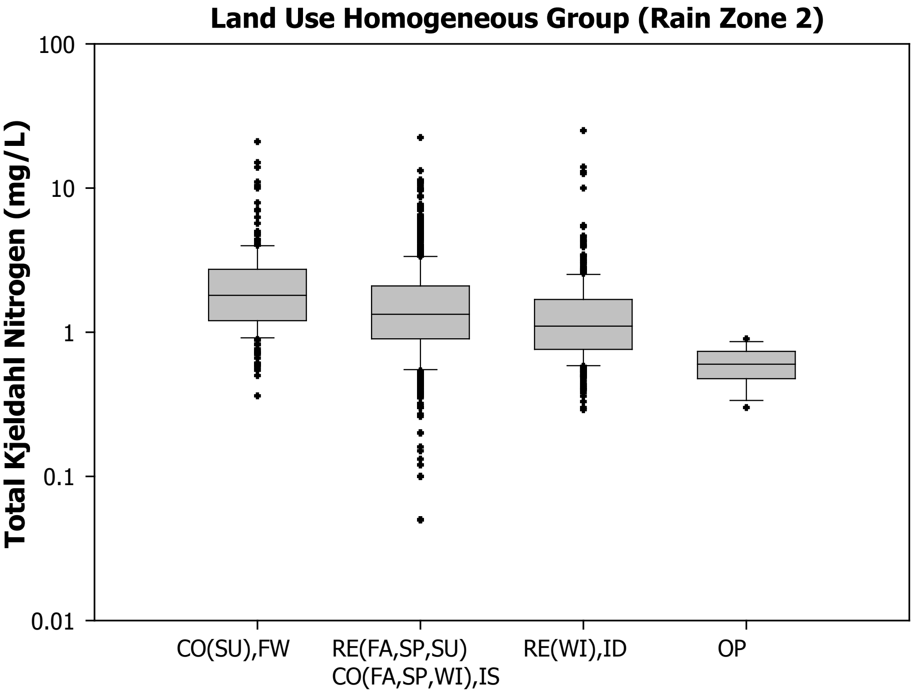
Fig. 70. Total Nitrogen – Land Use Homogeneous Groups: Mean (CV)

Table 66. Basic Statistics for Total Nitrogen Homogeneous Groups (Real Space Data) (mg/L)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE, CO, ID	21	4.3	4.3	0.99	0.64	3.0	18

Table 67. Total Kjeldahl Nitrogen – Required Number of Samples to Detect Seasonal Mean Differences

Land Use	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
Industrial	179	20	45	940
Institutional	46	125	580	96
Open Space	13	23	100	150
Freeways	100	32	64	360



Land Uses	FALL	WINTER	SPRING	SUMMER
Residential	1.8(0.93)	1.4(0.88)	1.9(1.1)	2.1(1.1)
Commercial	1.9(0.90)	1.8(1.0)	1.9(0.87)	2.4(0.98)
Industrial	1.5(0.70)	1.7(2.0)	1.9(1.3)	1.6(0.71)
Institutional	1.7(1.0)	1.4(0.42)	2.1(0.87)	1.1(0.55)
Open Space	0.63(0.40)	0.54(0.32)	0.54(0.35)	0.65(0.26)
Freeways	1.9(0.48)	2.7(0.60)	2.4(1.5)	2.8(1.0)

Fig. 71. Total Kjeldahl Nitrogen – Land Use Homogeneous Groups: Mean (CV)

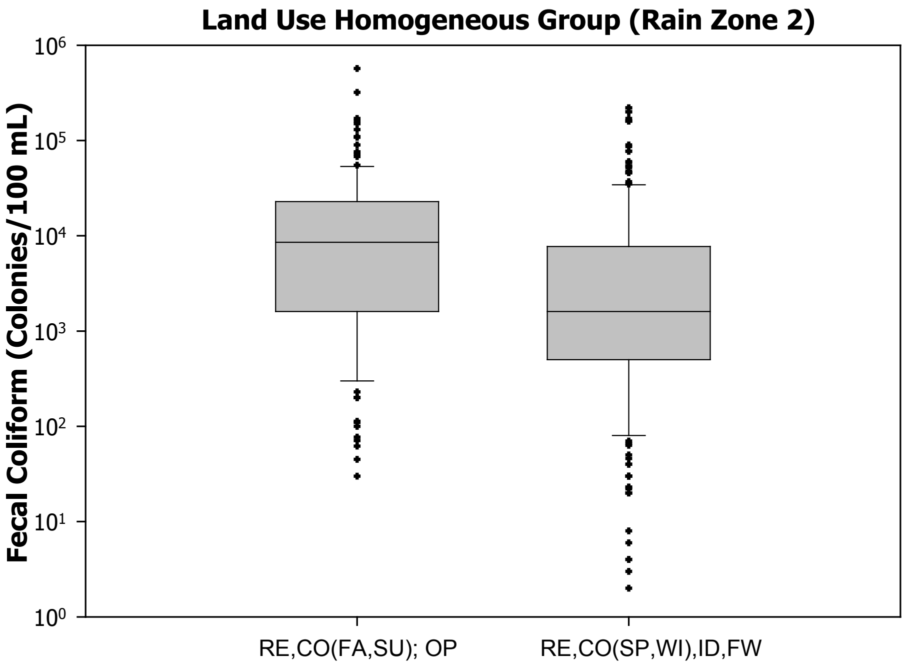
Table 68. Basic Statistics for Total Kjeldahl Nitrogen
Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	CO(SU), FW	183	2.4	2.5	1.0	0.36	1.8	21
B	RE(FA,SP,SU), CO(FA,SP,WI), IS	1072	1.9	1.9	1.0	0.05	1.4	22
C	RE(WI), ID	405	1.5	1.8	1.2	0.29	1.1	25
D	OP	13	0.59	0.17	0.29	0.30	0.60	0.90

Fecal coliform bacteria levels in EPA Rain Zone 2 are affected by seasonal influences in residential and commercial land use areas. Those land uses have greater bacteria populations in warm seasons (fall and summer) compared to the cold seasons (spring and winter). Institutional land use data was missing for this constituent, and the open space, industrial and freeways land uses did not have enough data to detect significant differences among seasons at the study’s alpha level (Table 69). In addition, Table 69 shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the four seasons at 5% significance level and 80% minimum power (calculations performed for real space data). Increasing the alpha level did not adequately increase the power of the test to be able to conclude otherwise. Therefore, a larger sample size is needed to detect seasonal differences for those land uses (Table 69).The seven seasonal groups were collected into two homogeneous groups that reflect seasonal influences (Figure 72 and Table 70).

Table 69. Fecal Coliform Bacteria – Required Number of Samples to
Detect Seasonal Mean Differences

Land Use	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
Industrial	67	530	770	136
Open Space	5	690	1250	9
Freeways	18	1485	2900	56



Land Uses	FALL	WINTER	SPRING	SUMMER
Residential	17130 (1.9)	7971 (1.7)	11987 (2.7)	53659 (2.2)
Commercial	17131 (2.0)	14267 (3.1)	15113 (2.5)	23132 (1.0)
Industrial	36132 (1.8)	19023 (2.6)	8622 (2.3)	14492 (1.4)
Institutional	ND	ND	ND	ND
Open Space	2300 (0.49)	ND	ND	17125 (0.40)
Freeways	3359 (1.1)	1179 (0.88)	ND	33544 (2.1)

Fig. 72. Fecal Coliform Bacteria – Land Use Homogeneous Groups: Mean (CV)

Table 70. Basic Statistics for Fecal Coliform Bacteria Homogeneous Groups (Real Space Data) (Colonies/100mL)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	RE,CO(FA,SU), OP	137	25344	61865	2.4	30	8550	570000
B	RE,CO(SP,WI), ID,FW	246	13635	35457	2.6	2	1600	220000

The analyses of stormwater constituents showed that even for EPA Rain Zone 2, the geographical region with the largest number of available data, there were not enough samples in each individual land use category to indicate seasonal influences of the stormwater median concentrations. The only notable exception was for residential land use areas (30% of the storm events stored in the database were collected in this land use) in which the seasonal influences were systematically found. This was especially indicated when comparing the results for Total Nitrogen (n = 21) and Total Kjeldahl Nitrogen (n = 1,673), two closely related constituents. The COVs were about the same overall for each of these constituents (about 1), but the ability to detect differences between land uses and even seasons was much greater for TKN with its greater number of data.

Statistical tests also indicated differences/similarities in stormwater median concentrations for the individual land uses (Table 71). In EPA Rain Zone 2, commercial and institutional land use samples had statistically similar median concentrations for total zinc, total copper, total lead, dissolved phosphorous, and Total Kjeldahl Nitrogen. Although for total suspended solids, total phosphorous, and total nitrogen, the commercial land use samples had statistically similar median concentrations with industrial land use samples. It was interesting to note that residential and industrial land use data paired for most of the studied constituents, except for total suspended solids and total zinc. As expected for total zinc and total copper, industrial land use data paired with freeway data, while open space land use data were usually different from the rest of the land use data.

Table 71. Summary of EPA Rain Zone 2 Stormwater Constituents Groups

TSS	Zn	Cu	Pb	TP	DP	N	TKN	FC
RE(FA,WI) IS(SU,WI)	RE	RE(FA,SP,WI) FW(FA,SP) ID	RE ID OP	RE(FA,SU)	RE(FA,SU,WI) ID(FA)	RE CO ID	RE(FA,SP,SU) CO(FA,SP,WI) IS	RE(FA,SU) CO(FA,SU) OP
RE(SP,SU) FW	CO IS	RE(SU)	CO IS	RE(SP,WI) CO ID	RE(SP) CO IS		RE(WI) ID	RE(SP,WI) CO(SP,WI) ID FW
CO ID	ID FW	CO IS FW(SU,WI)	FW	IS OP	ID(SP,SU,WI) OP FW		CO(SU) FW	
IS(FA,SP)	OP	OP		FW			OP	
OP								

4.4 Effect of Land Use and Season on Alabama Jefferson County Watersheds Stormwater Quality

Five additional urban watersheds that are located near the City of Birmingham, AL (Jefferson County) were investigated during this research. These sites were studied as a comparison to the national sites also investigated. Greater details are available for these drainage areas located in a smaller geographical rain zone. These scaling issues are important when demonstrating the utility of the national results when applied to local areas, such as during Phase II of the stormwater NPDES program.

This monitoring was conducted as part of the local area's NPDES Phase 1 Stormwater Permit as required by the Alabama Department of Environmental Management (ADEM), as delegated by the US EPA. The stormwater quality data used by this research was collected from 2001-2008 by the Storm Water Management Authority, Inc. (SWMA), a public corporation. Table 72 is a summary of the existing watersheds and their land uses. Jefferson County's monitored watersheds have only mixed land uses, although each watershed is dominated by a single land use category comprising 62 to 88% of the area.

Table 72. Percentage of Land Use for Alabama Jefferson County Watersheds

	ALJC001 Industrial	**ALJC002** Industrial	**ALJC009** High Density Residential	**ALJC010** Low Density Residential	**ALJC012** Commercial
Area(ac/ha)	341 (138)	721 (292)	102 (41)	133 (54)	228 (92)
High Density Residential	0	5.1	**86***	0	0
Medium Density Residential	0.7	9.3	0	0	0
Low Density Residential	7.7	0	0	**88***	0
Apartments	0	0	0	0	25
Commercial	12	2.5	6.3	0	**75***
Industrial	**62***	**76***	0	0	0
Institutional	0	0.8	7.6	0	0
Open Space	6.4	6.7	0	12	0
Freeways	11	0	0	0	0

*The dominant land uses in each watershed

SWMA monitored common stormwater constituents (TSS, COD, turbidity, some bacteria and nutrients, and several heavy metals), but did not record the runoff volume, although all events have rainfall depth information from regional rain gages. The runoff volumes used for this study were calculated using the Source Loading and Management Model (WinSLAMM) (Pitt and Voorhees 1995), and the measured development characteristics for each land use present in the watershed. The collected stormwater data were verified by SWMA employees for accuracy during their QA/QC process and again when the data was entered in the NSQD. There were two values for total zinc (watersheds ALJC001 and ALJC002), one value for total copper (watershed ALJC001), and one value for total and dissolved phosphorus, (watershed ALJC009) that were extremely high and were considered faulty and therefore eliminated from the database.

There were many observations in the local data (e.g. metals) with left censored values that were below the analytical detection limits. If less than 40% of the data were non-detected, these data were substituted with half of the detection limit (Maestre 2005). Otherwise, that particular constituent was not used for these analyses. Table 73 shows the percentage of samples having values above the detection limits.

Table 73. Percentage of Samples with Values above Detection Limit

	TSS (mg/L)	**Total Zinc (µg/L)**	**Total Copper (µg/L)**	**Total Lead (µg/L)**	**Total Phosphorous (mg/L)**	**Dissolved Phosphorous (mg/L)**	**Total Nitrogen (mg/L)**	**Total Kjeldahl Nitrogen (mg/L)**
ALJC001	100	100	65	100	100	100	100	100
ALJC002	100	100	94	100	100	100	100	100
ALJC009	100	***55****	***20****	70	100	100	100	100
ALJC010	100	***23****	***23****	***46****	100	100	100	85
ALJC012	100	90	***0****	70	100	100	80	80
Detection Limit	**n/a**	**30**	**20**	**3.0**	**n/a**	**n/a**	**0.7**	**0.05**

*Constituent was not used for analyses due to a large number of undetected values; ALJC009 is mostly a high-density residential area, while ALJC010 is mostly a low-density residential area

The state of Alabama is in the EPA Rain Zone 3 (Southeast subtropical region). The Birmingham, AL area receives an average of 55 inches of rain/year. In Alabama, there is not much distinction among the four calendar based seasons. It is more common to speak about warm-wet (March - July) versus cold-dry seasons (August - February), although the rainfall variations by season is not as large as in much of the country. The locally available data were therefore separated into these two broad seasonal groups (Table 74) and to prevent the already small sample size from being further reduced.

Table 74. Storm Event Data Distribution for Local Watersheds

Watershed	**Land Use**	**Season**					
		WI	**SP**	**SU**	**FL**	**Warm-Wet**	**Cold-Dry**
ALJC001	Mixed Industrial	4	7	5	4	10	10
ALJC002	Mixed Industrial	3	4	5	4	8	8
ALJC009	Mixed Residential	4	4	6	6	7	13
ALJC010	Mixed Residential	3	4	2	4	6	7
ALJC012	Mixed Commercial	2	2	4	2	6	4
	TOTAL	**16**	**21**	**22**	**20**	**37**	**42**

All the pollutant concentrations were $\log_{10}$ transformed and checked for normality at the 0.05 significance level. Figures 73 and 74 show the Alabama watershed TSS data with their seasonal coefficient of variation (real space data). Each watershed had its data separated into these two seasons (Figure 75). They were checked for normality and seasonal differences (Figure 76 to Figure 80).

The total suspended solids concentrations were log-normally distributed (the Anderson-Darling, AD, p-value statistic was >0.05, indicating that they were not statistically different from normal distributions, based on the number of data observations available). Therefore, one-way ANOVA and power of the tests were used to verify if there were significant differences between wet and dry seasons' concentration means for each watershed (Figure 75, Tables 75 and 76).

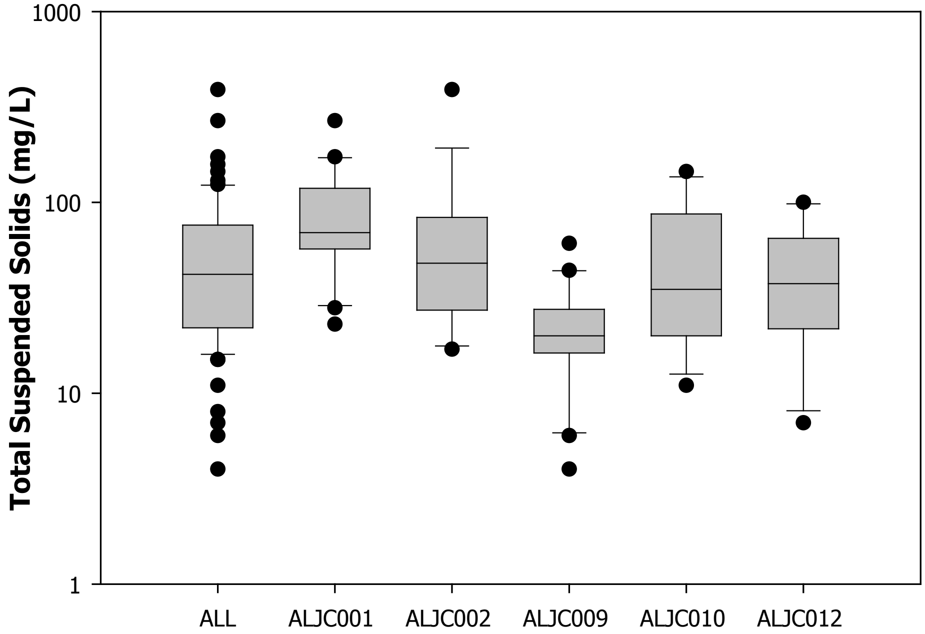
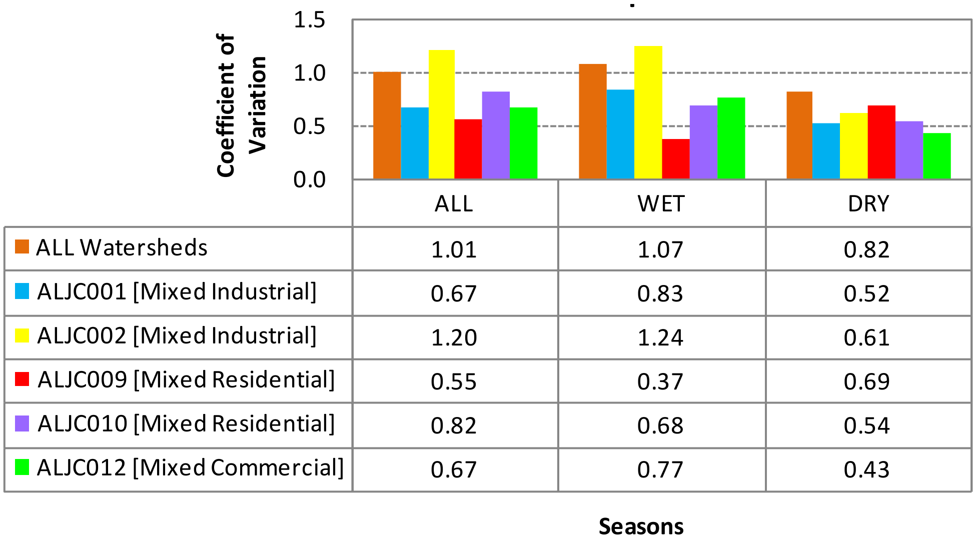


Fig. 73. Total Suspended Solids – Alabama Jefferson Co. Watersheds



	ALL	WET	DRY
🟧 ALL Watersheds	1.01	1.07	0.82
🟦 ALJC001 [Mixed Industrial]	0.67	0.83	0.52
🟨 ALJC002 [Mixed Industrial]	1.20	1.24	0.61
🟥 ALJC009 [Mixed Residential]	0.55	0.37	0.69
🟪 ALJC010 [Mixed Residential]	0.82	0.68	0.54
🟩 ALJC012 [Mixed Commercial]	0.67	0.77	0.43

Fig. 74. Total Suspended Solids – Seasonal Coefficients of Variation (Real Space Data) for Alabama Jefferson Co. Watersheds

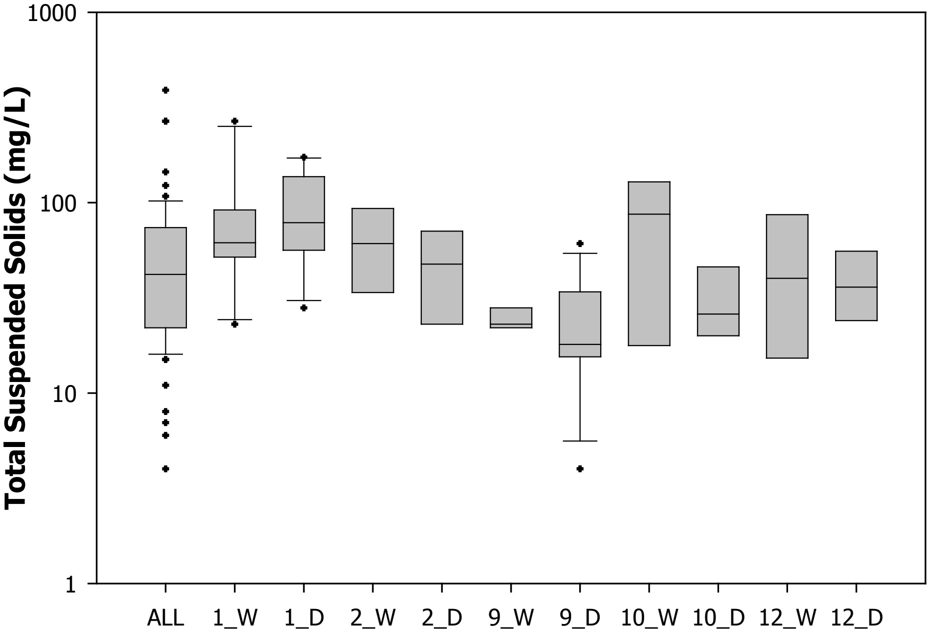
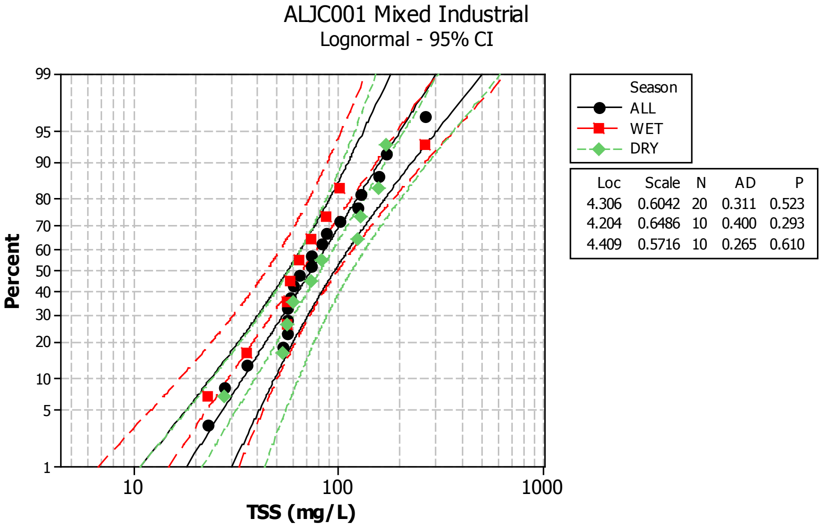
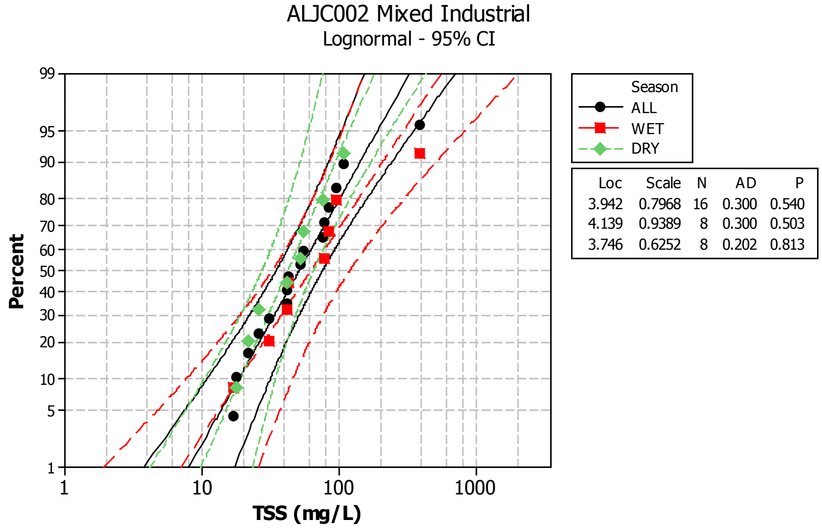


Fig. 75. Total Suspended Solids – Seasons for Alabama Jefferson Co. Watersheds (W = wet and warm; D = dry and cold)



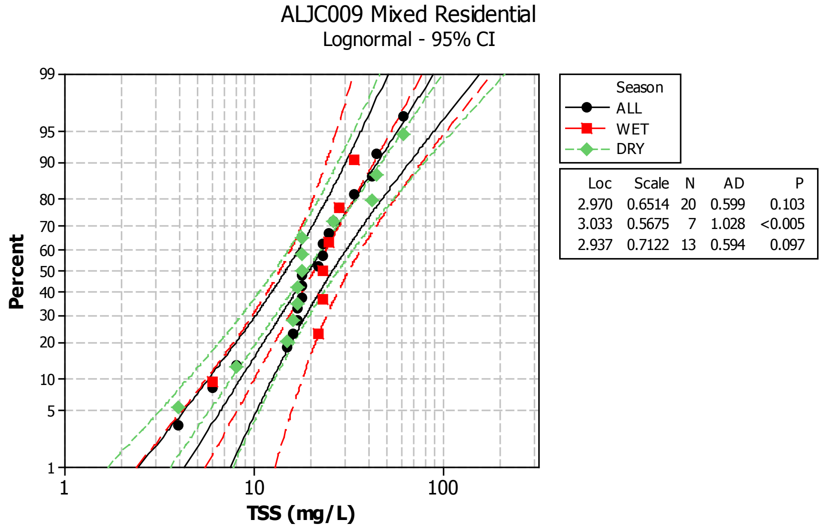
One –Way ANOVA ALJC001 Log TSS	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
Between Seasons	0.040	1	0.040	0.561	0.463
Within Seasons	1.269	18	0.070		
Total	1.308	19			

Fig. 76. Total Suspended Solids – ALJC001 Watershed Checks for Normality and Seasonal Differences



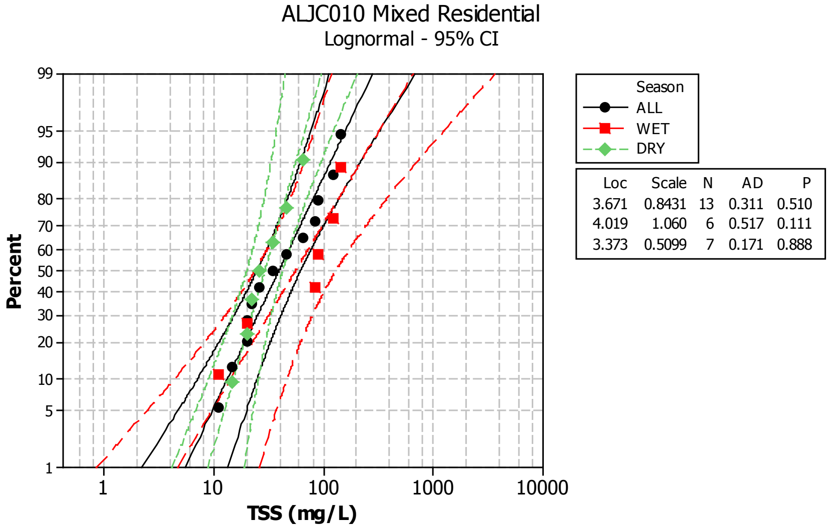
One-Way ANOVA ALJC002 Log TSS	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.116	1	0.116	0.969	0.342
Within Seasons	1.680	14	0.120		
Total	1.796	15			

Fig. 77. Total Suspended Solids – ALJC002 Watershed Checks for Normality and Seasonal Differences



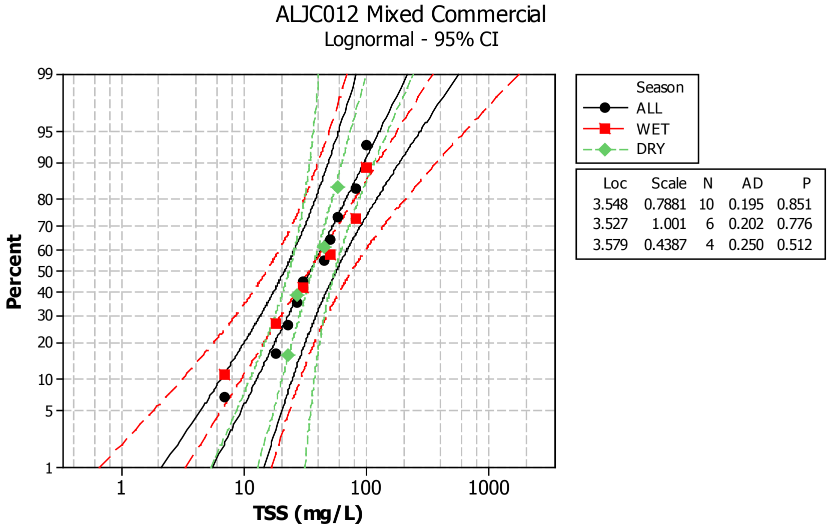
One-Way ANOVA ALJC009 Log TSS	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.008	1	0.008	0.095	0.761
Within Seasons	1.513	18	0.084		
Total	1.521	19			

Fig. 78. Total Suspended Solids – ALJC009 Watershed Checks for Normality and Seasonal Differences



One-Way ANOVA ALJC010 Log TSS	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.254	1	0.254	2.065	0.179
Within Seasons	1.355	11	0.123		
Total	1.609	12			

Fig. 79. Total Suspended Solids – ALJC010 Watershed Checks for Normality and Seasonal Differences



One-Way ANOVA ALJC012 Log TSS	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.001	1	0.001	0.009	0.926
Within Seasons	1.053	8	0.132		
Total	1.054	9			

Fig. 80. Total Suspended Solids – ALJC012 Watershed Checks for Normality and Seasonal Differences

Table 75. Power of the Test for Total Suspended Solids –
Jefferson County Watersheds Separated by Seasons

ALJC001 Log TSS	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	10	1.92	0.25
WET	10	1.83	0.28
Pooled Standard Deviation			0.27
Obtained Effect Size			0.17

α level	**Power (%)**
0.20	31.0
0.15	25.0
0.10	18.4
0.05	***10.9***
0.01	2.9

ALJC002 Log TSS	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	8	1.63	0.27
WET	8	1.80	0.41
Pooled Standard Deviation			0.35
Obtained Effect Size			0.24

α level	**Power (%)**
0.20	38.0
0.15	31.6
0.10	24.1
0.05	***14.8***
0.01	4.4

ALJC009 Log TSS	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	13	1.28	0.31
WET	7	1.32	0.25
Pooled Standard Deviation			0.29
Obtained Effect Size			0.07

α level	**Power (%)**
0.20	22.0
0.15	16.8
0.10	11.5
0.05	***6.0***
0.01	1.3

ALJC010 Log TSS	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	7	1.47	0.22
WET	6	1.75	0.46
Pooled Standard Deviation			0.35
Obtained Effect Size			0.40

α level	**Power (%)**
0.20	54.4
0.15	47.5
0.10	38.5
0.05	***26.0***
0.01	9.0

ALJC012 Log TSS	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	4	1.55	0.19
WET	6	1.53	0.44
Pooled Standard Deviation			0.36
Obtained Effect Size			0.03

α level	**Power (%)**
0.20	20.2
0.15	15.2
0.10	10.1
0.05	***5.1***
0.01	1.0

The available sample sizes for each watershed were very small and were not able to detect the effect size present between seasonal mean concentrations (very small power of the test) (Table 77). This table also shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the two seasons (calculations performed for real space data).

Table 76. Summary Statistics for Total Suspended Solids –
Jefferson County Watersheds Separated by Seasons

Watershed	Seasons	N	Mean	p-value	Power (%)	Significant (?)	Results
ALJC001	DRY WET	10 10	1.915 1.826	0.463	11	No	No seasonal influence
ALJC002	DRY WET	8 8	1.627 1.797	0.342	15	No	No seasonal influence
ALJC009	DRY WET	13 7	1.275 1.317	0.761	6	No	No seasonal influence
ALJC010	DRY WET	7 6	1.465 1.745	0.179	26	No	No seasonal influence
ALJC012	DRY WET	4 6	1.554 1.532	0.926	5	No	No seasonal influence

Table 77. Total Suspended Solids – Required Number of Samples to
Detect Seasonal Mean Differences

Watershed	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
ALJC001	20	23	84	290
ALJC002	16	48	150	136
ALJC009	20	10	92	1800
ALJC010	13	91	195	52
ALJC012	10	5	157	10500

The ANOVA results did not show enough evidence to conclude that significant differences between the season's mean concentrations were present. It was concluded that for total suspended solids, there were no seasonal influences in the local watersheds.

The next step was to verify if the total suspended solids concentrations were similar for the five Jefferson Co. watersheds. One-way ANOVA and Scheffe post hoc tests were used to identify any differences among the concentration means (Table 78). The retrospective power analysis (Table 79) revealed that the effect size present among the total suspended solids mean values were very large. Consequently, the available sample size could detect this effect size, so the study was well powered. It was concluded that total suspended solids concentrations coming from watershed ALJC009 (high density residential) were different from the concentrations coming from the other four watersheds (Table 78). The statistical results indicated that the total suspended solids concentrations for the two mixed industrial watersheds were related. Also, the concentrations for the mostly low density residential watershed and predominantly commercial watershed were also similar.

Table 78. Analyses of Variance, Multiple Comparisons and Data Groups for Total Suspended Solids – Jefferson County Watershed Groups

ANOVA (Watersheds: Log TSS)

P = 0.00

Log TSS	**Sum of Squares**	**DF**	**Mean Square**	**F**
Between Watersheds	3.62	4	0.904	9.2
Within Watersheds	7.29	74	0.098	
Total	10.9	78		

Multiple Comparisons
(Scheffe Test,
Equal Variances Assumed)

(I) ALJC	**(J) ALJC**	**p-value**
1	2	0.690
	9	0.000*
	10	0.205
	12	0.131
2	9	0.005*
	10	0.907
	12	0.766
9	10	0.128
	12	0.380
10	12	0.997

Watersheds
Log TSS Groups

ALJC	**Gr. A**	**Gr. B**	**Gr. C**
9	1.290		
10		1.594	
12		1.541	
1			1.870
2			1.712

*Significant P-value

Table 79. Power of the Test for Total Suspended Solids – Jefferson County Watershed Groups

Watersheds	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	20	1.87	0.26
ALJC002	16	1.71	0.35
ALJC009	20	1.29	0.28
ALJC010	13	1.59	0.37
ALJC012	10	1.54	0.34
Pooled Standard Deviation			0.31
Obtained Effect Size			0.69

α level	**Power (%)**
0.20	99.9
0.15	99.9
0.10	99.9
0.05	***99.9***
0.01	99.4

The Scheffe post hoc test failed to find significant differences among the total suspended solids concentrations from the industrial watersheds and the residential-commercial watersheds. Due to the obvious differences in mean value concentrations, the total suspended solids were separated by watershed as followed: industrial watersheds (ALJC001 and ALJC002), low-density residential and commercial watersheds (ALJC010 and ALJC012), and high-density residential watershed (ALJC009) (Figure 81). Those three groups were also checked for significant differences in means (Table 80). The Scheffe post hoc test and the power analysis showed that the groups were significantly different (Table 80 and 81). One possible explanation for this grouping was that the mostly commercial watershed (ALJC012) is about 34% pervious, areas that can generate large suspended solid concentrations during heavy rains. Table 82 shows the summary statistics of the clustered homogeneous groups.

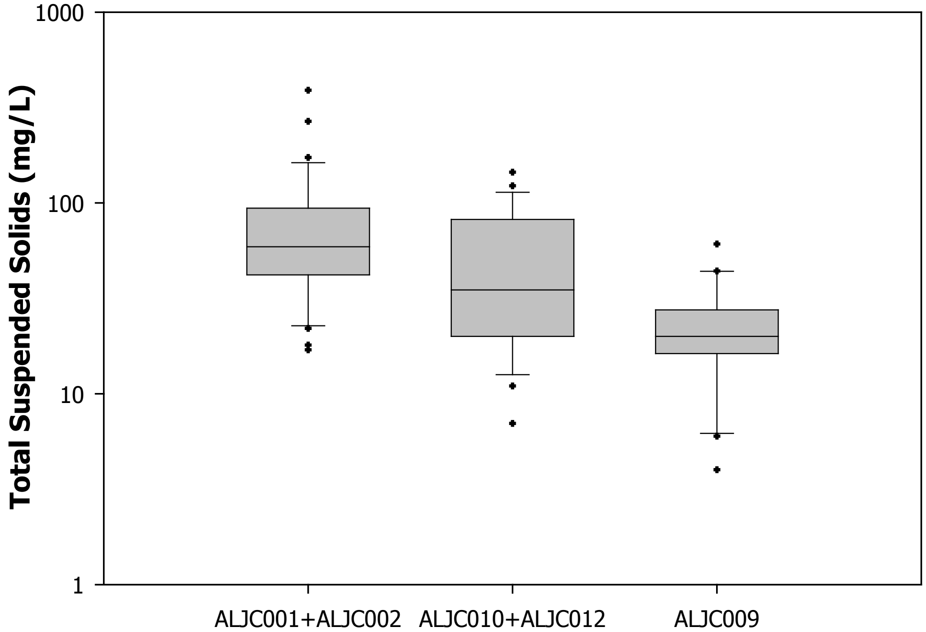


Fig. 81. Total Suspended Solids – Jefferson County Watershed Homogeneous Groups

Table 80. Statistical Analyses for Total Suspended Solids –
Jefferson County Watershed Homogeneous Groups

ANOVA (Watershed Groups: Log TSS)

P = 0.00

Log TSS	**Sum of Squares**	**DF**	**Mean Square**	**F**
Between Groups	3.378	2	1.689	17
Within Groups	7.526	76	0.099	
Total	10.91	78		

*Significant P-value

Multiple Comparisons
(Scheffe Test,
Equal Variances Assumed)

(I) Group	**(J) Group**	**p-value**
A	B	0.029*
	C	0.000*
B	C	0.018*

**Watersheds Log TSS
Homogeneous Groups**

Groups	**Gr. A**	**Gr. B**	**Gr. C**
AL01 AL02	1.799		
AL10 AL12		1.571	
AL09			1.290

Table 81. Power of the Test for Total Suspended Solids –
Jefferson County Watershed Homogeneous Groups

Homogeneous Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001 , ALJC002	36	1.80	0.31
ALJC010 , ALJC012	23	1.54	0.35
ALJC009	20	1.29	0.28
Pooled Standard Deviation			0.32
Obtained Effect Size			0.66

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***99.9***
0.01	99.7

Table 82. Basic Statistics for Jefferson County Watersheds - Total Suspended Solids
Homogeneous Groups (Real Space Data) (mg/L)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	ALJC001 , ALJC002	36	82	73	0.89	17	59	390
B	ALJC010 , ALJC012	23	50	38	0.76	7	35	145
C	ALJC009	20	23	14	0.59	4	20	61

Similar analyses were performed for total zinc, total copper, total lead, total and dissolved phosphorous, total nitrogen, Total Kjeldahl Nitrogen, and fecal coliform (Appendix D). Figures 82 to 89 and Tables 84, 86, 88, 90, 92, 94, 96, and 98 show the clustered homogeneous groups along with their basic statistics.

Statistical analyses showed that Jefferson County's total zinc concentrations were not represented with enough samples to detect seasonal influences among the watershed's mean concentrations at any reasonable significance level (Table 83). Table 83 also shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the two seasons (calculations performed for real space data). Analyses of variance and power of the test showed that the total zinc concentrations were significantly different for the three watersheds that had data measurements (Figure 82 and Table 84).

Table 83. Total Zinc – Required Number of Samples to Detect Seasonal Mean Differences

Watershed	**Available Sample Size**	**Maximum Difference in Seasonal Means (%)**	**Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)**	**Sample Size Required to Detect the Maximum Difference in Seasonal Means**
ALJC001	19	62	89	38
ALJC002	15	35	86	78
ALJC012	10	35	145	145

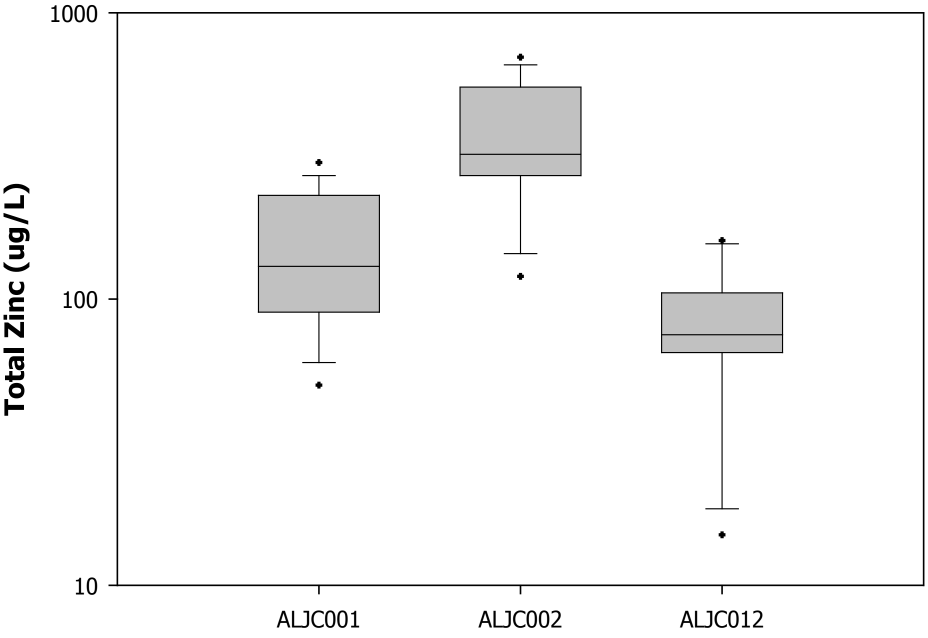


Fig. 82. Total Zinc – Jefferson County Watershed Homogeneous Groups

Table 84. Basic Statistics for Jefferson County Watersheds - Total Zinc Homogeneous Groups (Real Space Data) (μg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001	19	155	78	0.50	50	130	300
B	ALJC002	15	376	172	0.46	120	320	700
C	ALJC012	10	82	39	0.48	15	75	160

Jefferson County's total copper data were not represented by enough samples to detect seasonal differences among the watersheds mean concentrations at any significance level (Table 85). Table 85 also shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the two seasons (calculations performed for real space data).

Statistical analyses showed that the total copper concentrations were statistically significant for the two watersheds that had copper measurements (Figure 83 and Table 86).

Table 85. Total Copper – Required Number of Samples to Detect Seasonal Mean Differences

Watershed	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
ALJC001	19	32	105	185
ALJC002	16	10	105	1770

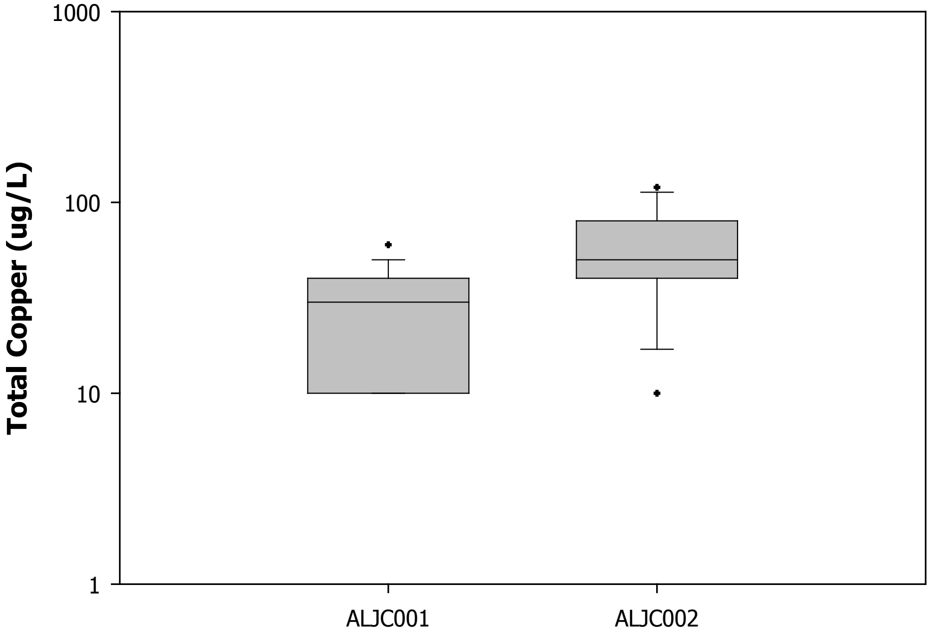


Fig. 83. Total Copper – Jefferson County Watershed Homogeneous Groups

Table 86. Basic Statistics for Jefferson County Watersheds - Total Copper Homogeneous Groups (Real Space Data) (µg/L)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	ALJC001	19	26	16	0.61	10	30	60
B	ALJC002	16	59	33	0.56	10	50	120

Local total lead sample numbers were not sufficiently large to detect seasonal differences among the watersheds mean concentrations at any significance level (Table 87). This table also shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the two seasons (calculations performed for real space data). Statistical analyses did not find significant differences between the total lead concentrations for the two mixed industrial watersheds. In addition, the concentrations for the high-density residential watershed and predominantly commercial watershed were found to be similar. The low-density residential watershed had too many samples with undetected concentrations, and therefore was not evaluated (Figure 84 and Table 88).

Table 87. Total Lead – Required Number of Samples to Detect Seasonal Mean Differences

Watershed	**Available Sample Size**	**Maximum Difference in Seasonal Means (%)**	**Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)**	**Sample Size Required to Detect the Maximum Difference in Seasonal Means**
ALJC001	20	2	78	16600
ALJC002	16	51	95	50
ALJC009	20	10	130	2800
ALJC012	10	51	160	76

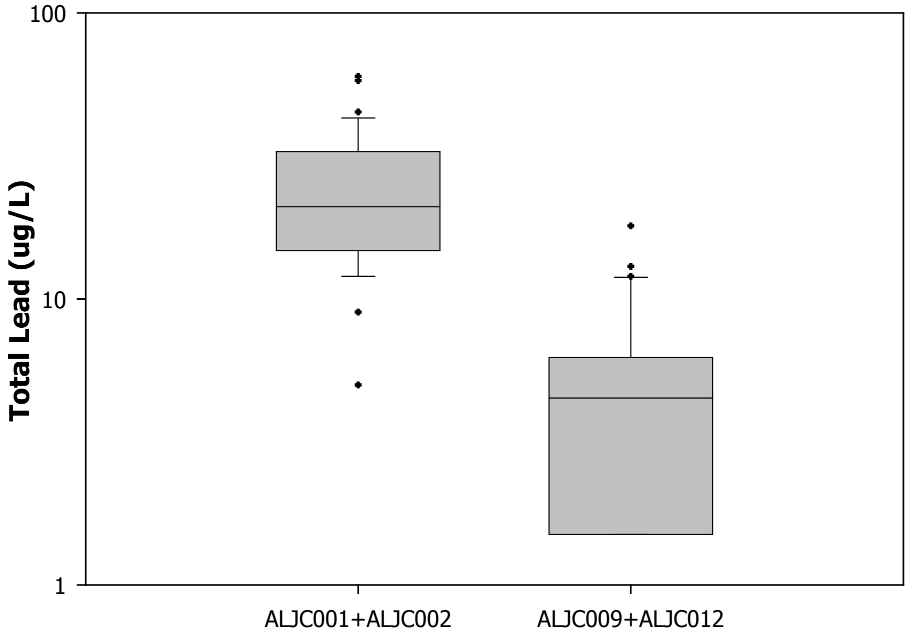


Fig. 84. Total Lead – Jefferson County Watershed Homogeneous Groups

Table 88. Basic Statistics for Jefferson County Watersheds - Total Lead Homogeneous Groups (Real Space Data) (μg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001 , ALJC002	36	25	13	0.52	5.0	21	60
B	ALJC009 , ALJC012	30	5.2	4.0	0.78	1.5	4.5	18

Local total phosphorous and dissolved phosphorous samples were not sufficiently large to detect seasonal differences among the watersheds' mean concentrations at any significance level considered (Tables 89 and 91). In addition, these tables show the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the two seasons (calculations performed for real space data). Statistical analyses showed that ALJC001 watershed (light industrial land use - scrap yards, manufacturing, and railroad tracks) is statistically different from the other four watersheds for both constituents (Figures 85 and 86, Tables 90 and 92).

Table 89. Total Phosphorous – Required Number of Samples to Detect Seasonal Mean Differences

Watershed	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
ALJC001	20	51	96	64
ALJC002	16	15	75	350
ALJC009	19	26	69	120
ALJC010	13	17	140	620
ALJC012	10	0	n/a	n/a

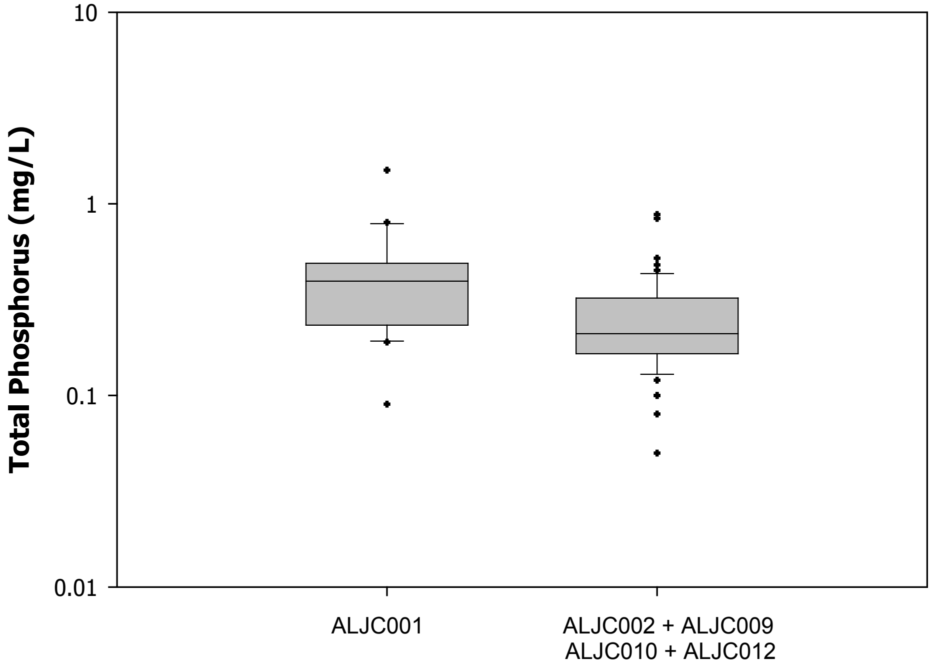


Fig. 85. Total Phosphorous – Jefferson County Watershed Homogeneous Groups

Table 90. Basic Statistics for Jefferson County Watersheds - Total Phosphorous Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001	20	0.44	0.30	0.68	0.09	0.40	1.5
B	ALJC002, ALJC009 ALJC010, ALJC012	58	0.25	0.15	0.60	0.05	0.21	0.88

Table 91. Dissolved Phosphorous – Required Number of Samples to Detect Seasonal Mean Differences

Watershed	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
ALJC001	20	26	115	345
ALJC002	16	23	70	130
ALJC009	19	26	94	210
ALJC010	13	55	100	40
ALJC012	10	7	120	1925

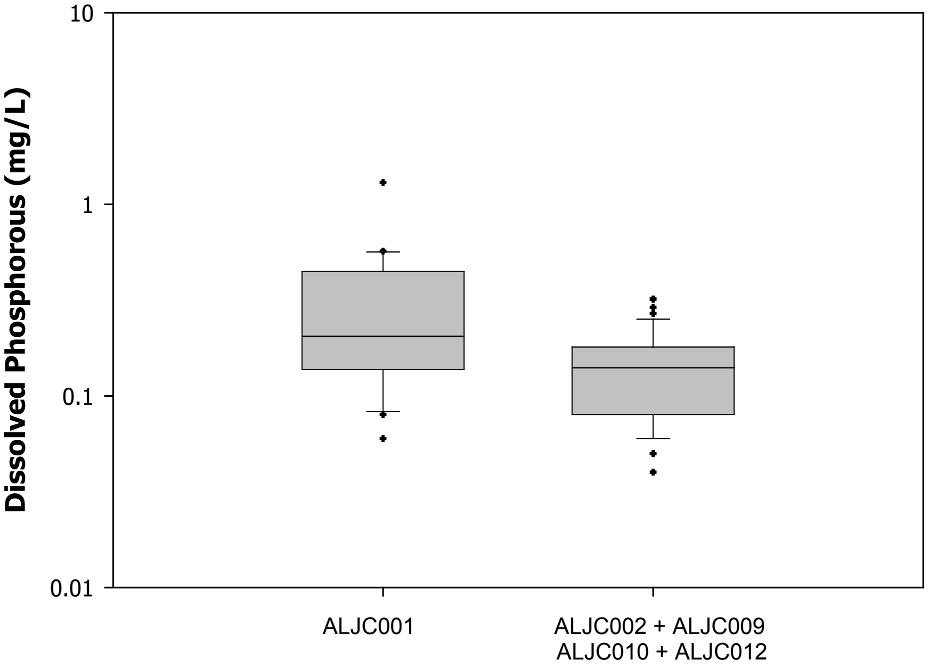


Fig. 86. Dissolved Phosphorous – Jefferson County Watershed Homogeneous Groups

Table 92. Basic Statistics for Jefferson County Watersheds – Dissolved Phosphorous Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC01	20	0.31	0.28	0.88	0.06	0.21	1.3
B	ALJC002 , ALJC009 ALJC010 , ALJC012	58	0.15	0.07	0.49	0.04	0.14	0.32

Local total nitrogen sample numbers were not sufficiently large to detect seasonal differences among the watersheds' mean concentrations at any significance level examined (Table 93). The table also shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the two seasons (calculations performed for real space data). Statistical analyses showed that ALJC012 watershed (commercial land use) is statistically different from the other four watersheds (Figure 87 and Table 94).

Table 93. Total Nitrogen – Required Number of Samples to Detect Seasonal Mean Differences

Watershed	**Available Sample Size**	**Maximum Difference in Seasonal Means (%)**	**Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)**	**Sample Size Required to Detect the Maximum Difference in Seasonal Means**
ALJC001	20	12	100	1200
ALJC002	16	17	47	130
ALJC009	20	2	160	37600
ALJC010	13	26	86	115
ALJC012	10	35	165	190

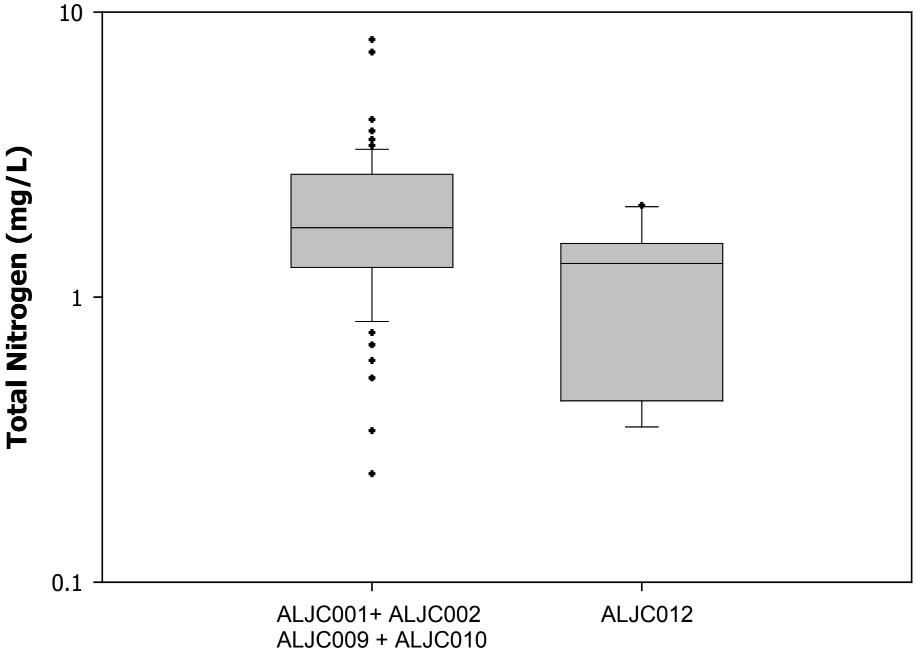


Fig. 87. Total Nitrogen – Jefferson County Watershed Homogeneous Groups

Table 94. Basic Statistics for Jefferson County Watersheds **-** Total Nitrogen Homogeneous Groups (Real Space Data)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	ALJC001, ALJC002 ALJC009, ALJC010	69	2.1	1.3	0.63	0.24	1.8	8.0
B	ALJC012	10	1.2	0.61	0.53	0.35	1.3	2.1

Local Total Kjeldahl Nitrogen samples were not sufficiently large to detect seasonal differences among the watersheds’ mean concentrations at any significance level examined

(Table 95). Table 95 also shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the two seasons (calculations performed for real space data). Statistical analyses showed that the watersheds form two statistically different groups (1) commercial and low-density residential watersheds, and (2) two industrial and the high-density residential watersheds (Figure 88 and Table 96).

Table 95. Total Kjeldahl Nitrogen – Required Number of Samples to Detect Seasonal Mean Differences

Watershed	**Available Sample Size**	**Maximum Difference in Seasonal Means (%)**	**Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)**	**Sample Size Required to Detect the Maximum Difference in Seasonal Means**
ALJC001	20	10	110	2550
ALJC002	16	12	70	460
ALJC009	20	7	27	1250
ALJC010	13	23	140	380
ALJC012	10	45	180	125

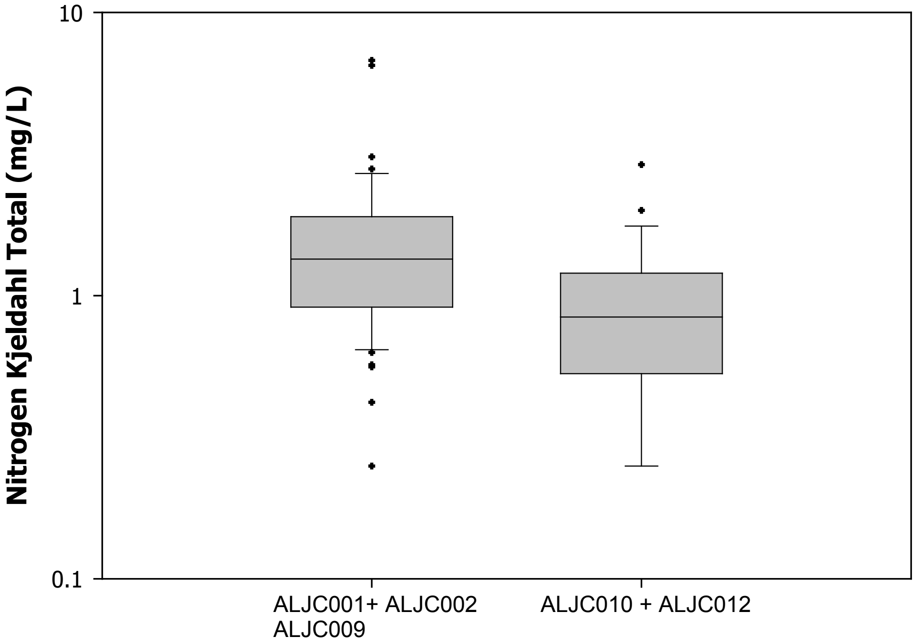


Fig. 88. Total Kjeldahl Nitrogen – Jefferson County Watershed Homogeneous Groups

Table 96. Basic Statistics for Jefferson County Watersheds –
Total Kjeldahl Nitrogen Homogeneous Groups (Real Space Data)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001, ALJC002 ALJC009	56	1.6	1.2	0.73	0.25	1.3	6.8
B	ALJC010, ALJC012	23	0.93	0.61	0.66	0.25	0.84	2.9

Local fecal coliform sample numbers were not sufficiently large enough to detect seasonal differences among the watersheds' mean concentrations at any significance level examined (Table 97). Table 97 also shows the minimum difference in seasonal means that can be detected with the available sample sizes, and the number of samples required to detect the maximum difference in seasonal means of the two seasons (calculations performed for real space data). Further statistical analyses did not find significant differences among the fecal coliform levels for the five watersheds. Therefore, the five Jefferson County watersheds were lumped together (Figure 89 and Table 98).

Table 97. Fecal Coliform Bacteria – Required Number of Samples to
Detect Seasonal Mean Differences

Watershed	Available Sample Size	Maximum Difference in Seasonal Means (%)	Minimum Difference in Seasonal Means that Could be Detected with the Available Sample Size (%)	Sample Size Required to Detect the Maximum Difference in Seasonal Means
ALJC001	13	100	370	140
ALJC002	11	300	900	86
ALJC009	14	100	430	230
ALJC010	10	210	680	78
ALJC012	8	26	520	2040

Fig. 89. Fecal Coliform Bacteria – Jefferson County Watershed Homogeneous Group

Table 98. Basic Statistics for Jefferson County Watersheds –
Fecal Coliform Bacteria Homogeneous Group (Real Space Data) (Colonies/100mL)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001, ALJC002 ALJC009, ALJC010 ALJC012	55	1975	3922	2.0	10	600	21400

The analyses of local stormwater constituents showed that the watersheds did not have sufficient sample numbers to prove that seasonal influence affected the stormwater mean concentrations in the five studied watersheds for any of the constituents. As expected, the two mixed industrial watersheds (ALJC001 and ALJC002) had similar mean concentrations for total suspended solids, total lead, total nitrogen, and Total Kjeldahl Nitrogen. However, they had statistically significant differences in concentrations for total zinc, total copper, and for total and dissolved phosphorous). These differences are assumed to be related to the activities in the watersheds - ALJC001 has mostly industrial, commercial and freeways land uses which produce more metals and less nutrients, while ALJC002 has industrial, residential and open space land uses (Table 72 and Table 99). In addition, the analyses found that total and dissolved phosphorous concentrations were similar for the ALJC002, the mixed residential, and the mixed commercial watershed (25% of the area is residential land use).

Table 99. Summary of Jefferson County, AL Stormwater Constituents Groups (Watersheds and Predominant Land Uses)

TSS	**Zn**	**Cu**	**Pb**	**TP**	**DP**	**N**	**TKN**	**FC**
ALJC001 (ID,CO,FW) ALJC002 (ID,RE,CO)	ALJC001 (ID,CO,FW)	ALJC001 (ID,CO,FW)	ALJC001 (ID,CO,FW) ALJC002 (ID,RE,CO)	ALJC001 (ID,CO,FW)	ALJC001 (ID,CO,FW)	ALJC001 (ID,CO,FW) ALJC002 (ID,RE,CO) ALJC009 (RE,IS,CO) ALJC010 (RE,OP)	ALJC001 (ID,CO,FW) ALJC002 (ID,RE,CO) ALJC009 (RE,IS,CO)	ALJC001 (ID,CO,FW) ALJC002 (ID,RE,CO) ALJC009 (RE,IS,CO) ALJC010 (RE,OP) ALJC012 (CO,RE)
ALJC010 (RE,OP) ALJC012 (CO,RE)	ALJC002 (ID,RE,CO)	ALJC002 (ID,RE,CO)	ALJC009 (RE,IS,CO) ALJC012 (CO,RE)	ALJC002 (ID,RE,CO) ALJC009 (RE,IS,CO) ALJC010 (RE,OP) ALJC012 (CO,RE)	ALJC002 (ID,RE,CO) ALJC009 (RE,IS,CO) ALJC010 (RE,OP) ALJC012 (CO,RE)	ALJC012 (CO,RE)	ALJC010 (RE,OP) ALJC012 (CO,RE)	
ALJC009 (RE,IS,CO)	ALJC012 (CO,RE)							

It was expected to find similarities in pollutant mean concentrations for the two mixed residential watersheds. This assumption was true for total phosphorous, dissolved phosphorous, and total nitrogen, but could not be tested for total zinc, total copper and total lead due to lack of data. Analyses showed that the mixed commercial watershed (75% commercial, 25% residential) tended to pair with the residential watersheds in stormwater characteristics. Furthermore, it was shown that it had very different concentrations from the mixed industrial watersheds. In addition, it was expected that significant seasonal differences and differences among watersheds for fecal coliforms would be identified. However, due to the limited number of samples, the statistical tests could not detect any significance differences in these categories.

4.5 Results and Discussions

The NSQD version 3 represents sites throughout the US for most land uses and for many constituents. It is the most comprehensive stormwater quality database currently available. However, only EPA Rain Zone 2 single land uses had enough numbers of samples to confidently evaluate stormwater pollutant concentrations variability for seasonal effects for all land uses. Local stormwater data analyzed for this research were from Jefferson County, Alabama, watersheds (EPA Rain Zone 3), and had mixed land uses.

Table 100 shows the final stormwater constituent clusters for all EPA Rain Zones, EPA Rain Zone 2, and Jefferson County watersheds along with their coefficients of variation. The parametric analyses on means performed for all nine geographical regions showed no seasonal differences for most of the constituents, except for fecal colifoms (in all rain zones) and occasionally for total lead, dissolved phosphorous, and TKN (only in EPA Rain Zone 7), and total nitrogen (only in EPA Rain Zone 3).

The detailed analysis of EPA Rain Zone 2 indicated that land use variations affect all stormwater pollutant concentrations, except for total nitrogen (few data available). The stormwater constituent concentrations for open space (total suspended solids, total zinc, total copper and Total Kjeldahl Nitrogen), and freeway (total lead and total phosphorous) land uses were very different. Seasonal effects were observed in EPA Rain Zone 2 (analyzed separately due to its large data set) for almost all pollutants (except for total zinc, total lead, and total nitrogen), but were not as obvious as the land use variations. Constituent concentration variations in the residential land use areas seemed to be mostly affected by the seasonal differences.

Table 100. Summary Table of Homogeneous Land Uses and Seasonal Clusters

Stormwater Constituent	All EPA Rain Zones Land Use	Mean (COV)	EPA Rain Zone 2 Land Use (Season)	Mean (COV)	Jefferson County Land Uses (Watershed)	Mean (COV)
Total Suspended Solids	1-RE,CO,ID 4-RE,CO,ID 6-RE,CO 9-CO,ID	199 (1.9)	RE(FA,WI) IS(SU,WI)	60 (1.7)	ID, CO, FW (ALJC001) ID, RE, CO (ALJC002)	82 (0.89)
			RE(SP,SU) FW	82 (1.5)		
	2-RE 3-RE,CO,ID	76 (1.6)	CO ID	86 (1.7)	RE, OP(ALJC010) CO, RE(ALJC012)	50 (0.76)
	2-CO,ID 5- RE,CO,ID 7- RE,CO,ID 9-RE	78 (1.9)	IS(FA,SP)	110 (0.68)	RE, IS, CO (ALJC009)	23 (0.59)
			OP	32 (1.2)		
Total Zinc	1-RE	59 (1.9)	RE	87 (1.6)	ID, CO, FW (ALJC001)	78 (0.50)
	1-CO,ID 2-RE 3-RE,CO,ID 5-RE,CO,ID	92 (1.6)	CO IS	268 (1.2)	ID, RE, CO (ALJC002)	172 (0.46)
	2-ID 7-RE,CO,ID 9-RE,CO,ID	163 (2.3)	ID FW	169 (1.2)	CO, RE(ALJC012)	39 (0.48)
	2-CO 4-RE,CO,ID 6-RE,CO	261 (1.2)	OP	21 (0.98)		
Total Copper	1-RE,ID 3-RE,CO,ID 5-RE,CO,ID 6-RE,CO	11 (2.3)	RE(FA,SP,WI) FW(FA,SP), ID	22 (2.0)	ID, CO, FW (ALJC001)	26 (0.61)
	2-RE,ID 7-RE,CO,ID	25 (1.9)	RE(SU)	35 (1.9)	ID, RE, CO (ALJC002)	59 (0.56)
	1-CO 2-CO 9-RE,CO,ID	36 (1.2)	CO, IS, FW(SU,WI)	33 (1.5)		
	4-RE,CO,ID	86 (1.9)	OP	8.2 (1.3)		
Total Lead	1-RE, CO,ID 2-RE,ID 3-CO,ID 5-RE 7-(RE,CO) (SP,SU)	17 (2.3)	RE ID OP	16 (2.4)	ID, CO, FW (ALJC001) ID, RE, CO (ALJC002)	25 (0.52)
	3-RE	8.4 (4.7)	CO IS	38 (1.6)	RE, IS, CO (ALJC009) CO, RE(ALJC012)	5.2 (0.78)
	2-CO 4-RE,CO,ID 5-CO,ID 6-RE,CO 7-(RE,CO) (FA,WI),ID 9-RE,CO,ID	44 (1.9)	FW	57 (0.78)		

Table 100. - *Continued*

Stormwater Constituent	All EPA Rain Zones Land Use	Mean (COV)	EPA Rain Zone 2 Land Use (Season)	Mean (COV)	Jefferson County Land Uses (Watershed)	Mean (COV)
Total Phosphorous	1-CO 3-RE,ID 5-CO	0.17 (1.2)	RE(FA,SU)	0.45 (1.5)	ID, CO, FW (ALJC001)	0.44 (0.68)
	1-RE,ID 2-RE,CO,ID 3-CO 4-RE,CO,ID 5-RE,ID	0.38 (1.7)	RE(SP,WI) CO ID	0.35 (2.0)	ID, RE, CO (ALJC002) RE, IS, CO (ALJC009) RE, OP(ALJC010) CO, RE(ALJC012)	0.25 (0.60)
	7-RE,CO,ID	0.3 (1.2)	IS OP	0.24 (0.79)		
	6-RE,CO 9-RE,CO,ID	0.52 (0.67)	FW	0.95 (1.3)		
Dissolved Phosphorous	1-ID 3-RE,CO,ID 5-CO 7-(RE,CO,ID) (SP,WI)	0.11 (1.5)	RE(FA,SU,WI) ID(FA)	0.26 (1.3)	ID, CO, FW (ALJC001)	0.31 (0.88)
	1-RE,CO 2-RE,CO,ID 4-RE,CO,ID 5-RE,ID 6-RE 9-RE,CO,ID	0.22 (1.1)	RE(SP) CO IS	0.19 (1.0)	ID, RE, CO (ALJC002) RE, IS, CO (ALJC009) RE, OP(ALJC010) CO, RE(ALJC012)	0.15 (0.49)
	7-(RE,CO,ID) (FA)	0.94 (0.71)	ID(SP,SU,WI) OP FW	0.14 (0.97)		
Total Nitrogen	1-RE,CO,ID 3-(RE,CO,ID) (FA,SP)	1.7 (0.79)	RE CO ID	4.3 (0.99)	ID, CO, FW (ALJC001) ID, RE, CO (ALJC002) RE, IS, CO (ALJC009) RE, OP(ALJC010)	2.1 (0.63)
	3-(RE,CO,ID) (SU,WI)	0.98 (0.98)				
	2-RE,CO,ID 4-RE,CO,ID 9-RE,CO,ID	3.2 (0.78)			CO, RE(ALJC012)	1.2 (0.53)
Total Kjeldahl Nitrogen	1-RE,CO,ID 2-RE,CO,ID 3-CO,ID 4-RE,CO,ID 5-RE,CO,ID 7-(RE,CO) (FA,SU), ID	1.8 (0.99)	RE(FA,SP,SU) CO(FA,SP,WI) IS	1.9 (1.0)	ID, CO, FW (ALJC001) ID, RE, CO (ALJC002) RE, IS, CO (ALJC009)	1.6 (0.73)
	3-RE 7-(RE,CO) (SP,WI)	0.97 (0.90)	RE(WI) ID	1.5 (1.2)		
	6-RE,CO 9-RE,CO,ID	3.6 (0.73)	CO(SU) FW	2.4 (1.0)	RE, OP(ALJC010) CO, RE(ALJC012)	0.93 (0.66)
			OP	0.59 (0.29)		

Table 100. - *Continued*

Stormwater Constituent	All EPA Rain Zones Land Use	Mean (COV)	EPA Rain Zone 2 Land Use (Season)	Mean (COV)	Jefferson County Land Uses (Watershed)	Mean (COV)
Fecal Colifom	1-(RE,CO,ID) (FA,SP,WI) 2-(RE,CO,ID) (SP,WI) 3-(RE,CO,ID) (SP,WI) 4-ID 7-RE,CO,ID 9-(RE,CO,ID) (SP)	29120 (8.2)	RE(SP, WI) CO(SP, WI) ID FW	13635 (2.6)	ID, CO, FW (ALJC001) ID, RE, CO (ALJC002) RE, IS, CO (ALJC009) RE, OP(ALJC010) CO, RE(ALJC012)	1975 (2.0)
	1-(RE,CO,ID) (SU) 2-(RE,CO,ID) (FA,SU) 3-(RE,CO,ID) (FA,SU) 4-RE,CO 5-RE,CO,ID 6-RE 9-(RE,CO,ID) (FA,SU)	40286 (3.0)	RE(FA, SU) CO(FA, SU) OP	25344 (2.4)		

The analyses of Jefferson County watershed data (EPA Rain Zone 3) indicated that seasons did not influence local stormwater pollutant concentrations, likely due to the fewer data available. However, land use influences were observed for all constituents, except for fecal coliforms. The two mainly industrial watersheds (ALJC001 and ALJC002) appeared to have similar concentration values for total suspended solids, total lead, and total nitrogen, but dissimilar concentrations for the rest of the analyzed constituents. In addition, the two predominant residential watersheds (ALJC009 and ALJC010) had similar concentration values for total and dissolved phosphorous, and total nitrogen, but different concentrations for total suspended solids. These residential watersheds had many non-detected values for total zinc, total copper, and total lead (only ALJC010). Therefore, they were not evaluated for these analyses.

The national data (Table 14) showed that the coefficient of variation values ranged from 0.3 to 4.0 for the majority of pollutants across all major land uses and rain zones. The residential, commercial, and industrial land use concentration variability behavior was studied from the general perspective of all geographical regions and from the more detailed analysis of EPA Rain Zone 2. The coefficients of variation for the comparable homogeneous clusters for each stormwater constituent are presented in Table 101. The data show similar variations for the studied land uses when taken at the national level compared to the EPA Rain Zone 2 data alone.

Table 101. Coefficients of Variation for the Comparable Homogeneous Clusters

Stormwater Constituent	**All EPA Rain Zones**	**COV**	**EPA Rain Zone 2**	**COV**
Total Suspended Solids	**2-RE** 3-RE,CO,ID	1.6	**RE(FA,WI)** IS(SU,WI)	1.7
			RE(SP,SU) FW	1.5
	2-CO,ID 5- RE,CO,ID 7- RE,CO,ID 9-RE	1.9	**CO** **ID**	1.7
Total Zinc	1-CO,ID **2-RE** 3-RE,CO,ID 5-RE,CO,ID	1.6	**RE**	1.6
	2-ID 7-RE,CO,ID 9-RE,CO,ID	2.3	**ID** FW	1.2
	2-CO 4-RE,CO,ID 6-RE,CO	1.2	**CO** IS	1.2
Total Copper	**2-RE,ID** 7-RE,CO,ID	1.9	**RE(FA,SP,WI)** FW(FA,SP), **ID**	2.0
	1-CO **2-CO** 9-RE,CO,ID	1.2	**CO**, IS, FW(SU,WI)	1.5
Total Lead	1-RE, CO,ID **2-RE,ID** 3-CO,ID 5-RE 7-(RE,CO)(SP,SU)	2.3	**RE** **ID** OP	2.4
	2-CO 4-RE,CO,ID 5-CO,ID 6-RE,CO 7-(RE,CO) (FA,WI),ID 9-RE,CO,ID	1.9	**CO** IS	1.6
Total Phosphorous	1-RE,ID **2-RE,CO,ID** 3-CO 4-RE,CO,ID 5-RE,ID	1.7	**RE(SP,WI)** **CO** **ID**	2.0

Table 101. - *Continued*

Stormwater Constituent	All EPA Rain Zones	COV	EPA Rain Zone 2	COV
Dissolved Phosphorous	1-RE,CO **2-RE,CO,ID** 4-RE,CO,ID 5-RE,ID 6-RE 9-RE,CO,ID	1.1	**RE(FA,SU,WI)** **ID(FA)**	1.3
			RE(SP) **CO** IS	1.0
Total Nitrogen	**2-RE,CO,ID** 4-RE,CO,ID 9-RE,CO,ID	0.78	**RE** **CO** **ID**	0.99
Total Kjeldahl Nitrogen	1-RE,CO,ID **2-RE,CO,ID** 3-CO,ID 4-RE,CO,ID 5-RE,CO,ID 7-(RE,CO) (FA,SU), ID	0.99	**RE(FA,SP,SU)** **CO(FA,SP,WI)** IS	1.0
			RE(WI) **ID**	1.2
Fecal Colifom	1-(RE,CO,ID)(FA,SP,WI) **2-(RE,CO,ID)(SP,WI)** 3-(RE,CO,ID)(SP,WI) 4-ID 7-RE,CO,ID 9-(RE,CO,ID)(SP)	8.2	**RE (SP, WI)** **CO (SP, WI)** ID, FW	2.6
	1-(RE,CO,ID)(SU) **2-(RE,CO,ID)(FA,SU)** 3-(RE,CO,ID)(FA,SU) 4-RE,CO 5-RE,CO,ID 6-RE 9-(RE,CO,ID)(FA,SU)	3.0	**RE (FA, SU)** **CO (FA, SU)** OP	2.4

*The studied land use were in bold letters

It was observed that the local Jefferson County concentration clusters had much lower coefficients of variation for all analyzed parameter concentrations compared to the other data, meaning that the local concentrations were less dispersed and more concentrated near their means.

4.6 Chapter Summary

This chapter describes stormwater variability for nine selected pollutants using data from the National Stormwater Quality Database (NSQD) version 3. The analyses were performed for total suspended solids, total zinc, total copper, total lead, total and dissolved phosphorous, total nitrogen, Total Kjeldahl Nitrogen, and fecal coliforms, for watersheds without stormwater controls. This chapter examines the effect of geographical region, land use, and season on stormwater constituent concentrations to determine if grouping of the constituents with statistically comparable concentrations was possible, resulting in a reasonable subset of data groups covering the wide range of national conditions.

Due to lack of complete sample coverage, only data for residential, commercial, and industrial land uses were used to detect geographical, land use, and seasonal influences on stormwater concentrations. A more detailed analysis was performed using only EPA Rain Zone 2 due to the availability of complete data. In addition, the local (Alabama) stormwater variability was examined by using data collected by the Storm Water Management Authority Inc. of Jefferson County, AL, data that are included in the NSQD database.

The normal approach to classify urban sites for estimating stormwater characteristics is based on land use. This approach is generally accepted because it is related to the activities in the watershed and many site features are generally consistent within each land use. However, this chapter showed that stormwater concentrations for different land uses were not always significantly different, and that other features may also need to be considered (especially geographical area, and to a lesser extent, season).

When the study was performed at the geographical region level, the analyses failed to show that seasonal samples were statistically significantly different for each season, but this was likely caused by lack of sufficient data. Exception were noted for EPA Rain Zone 7 for some nutrients (dissolved phosphorous and TKN) and total lead, EPA Rain Zone 3 for total nitrogen, and all rain zones (except EPA Rain Zones 4 and 5) for fecal coliforms. However, the two detailed analyses at the rain zone level gave different results:

(a) The detailed analysis of EPA Rain Zone 2 data showed that land uses and seasons had an effect on some stormwater constituent concentrations, especially for residential land uses.

(b) In contrast, the detailed analysis of Jefferson County watersheds (mixed land uses in EPA Rain Zone 3) found no seasonal influences on the stormwater pollutant concentrations. This was probably because the seasons were grouped in warm-wet and cold-dry instead of the traditional four seasons, and the sample sizes were much smaller.

The analyses presented in this chapter will be used in conjunction with analyses presented in the next chapter (Chapter 5) to build a model of stormwater characteristics variability to effectively predict receiving water responses to stormwater controls for an area.

Chapter 5
Alabama Jefferson County Watersheds
Land Development Characteristics

The dissertation work uses the field data collected for Little Shades Creek watershed and the five Jefferson County drainage basins (Figure 7) to examine the variability in land development characteristics for the study area and to explain how this variability (especially impervious cover) affects the variability in stormwater characteristics. It is known that there is considerable variability in runoff quantity and quality between different locations in a region due to rainfall spatial variability. Runoff characteristics can also be significantly different between nearby locations, even if they receive similar rains. This variability in runoff between sites may be associated with differences in land uses (and activities on going in those areas) and variability in surface covers within similar land uses.

The current research found that there was considerable variability in total impervious cover (TIA) for all six watersheds investigated. The box plot in Figure 90 and information summarized in Table 102 shows the total impervious cover variability within the study watersheds, also reflecting the differences in watersheds' land uses and surface covers. The total impervious cover values were based on detailed surveys conducted on about 170 individual homogeneous neighborhoods within the watersheds. It was also found that the variability of the surface covers between the land uses was greater than the variability of the surface covers within the land uses. It was therefore important that the land surface cover within each land use category be examined to determine if the runoff quality variability could be due to differences in the surface covers.

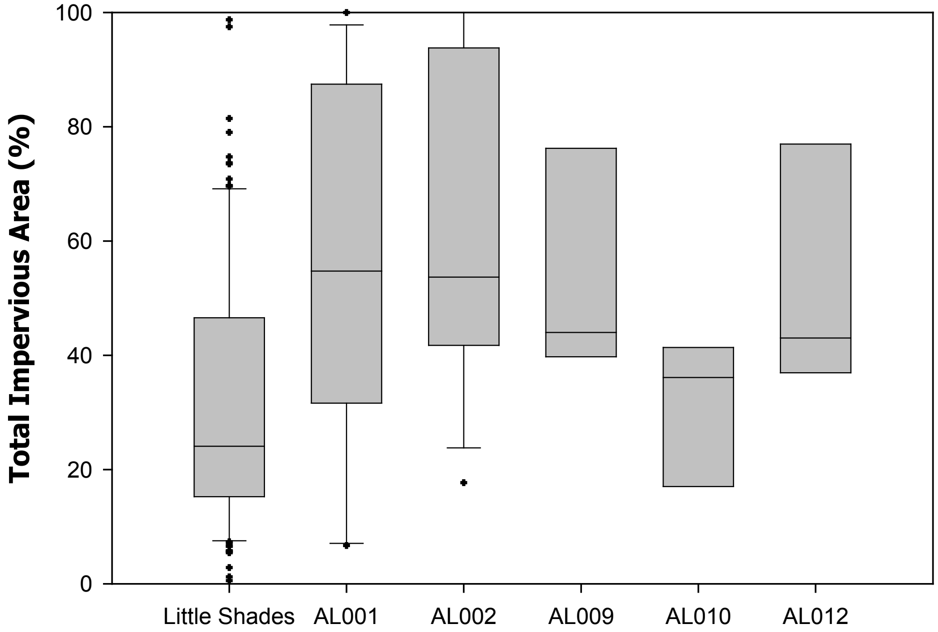


Fig. 90. Total Impervious Area for the Study Watersheds (Bochis and Pitt 2010)

The watershed surveys conducted during the field data collection activities revealed the existence of eleven distinct sub-categories of land uses in the Birmingham area. Residential land uses were separated based on housing densities, into high (> 6 units/acre), medium (2-6 units/acre), low density (< 2 units/acre), and apartments/multiple families (> 3 stories on height and two, or more, housing units in the same building) categories. In contrast, commercial and institutional land uses were separated according to the primary functionality of the property: commercial land uses were separated into shopping center and office park categories, while institutional land uses were separated in school and church categories. The industrial, freeway, and open space land uses were not separated based on the sites investigated during this research, although separate categories for these land uses would be appropriate in other areas having a wider range of activities being investigated.

Table 102. Percentage of Land Use for Alabama Jefferson County Watersheds Investigated as Part of this Research*

Land Uses	**Little Shades Creek** Medium Density Residential	**ALJC001** Industrial	**ALJC002** Industrial	**ALJC009** High Density Residential	**ALJC010** Low Density Residential	**ALJC012** Commercial
Area(ac/ha)	**5120 (2072)**	**341 (138)**	**721 (292)**	**102 (41)**	**133 (54)**	**228 (92)**
High Density Residential	4.1	0	5.1	**86**	0	0
Medium Density Residential	**27**	0.73	9.3	0	0	0
Low Density Residential	8.5	7.7	0	0	**88**	0
Apartments & Multi Family	13	0	0	0	0	25
Commercial (Shopping Centers)	4.0	12	2.5	6.3	0	**75**
Commercial (Offices)	2.1	0	0	0	0	0
Industrial	1.7	**62**	**76**	0	0	0
Institutional (Schools)	7.5	0	0.64	6.2	0	0
Institutional (Churches)	1.5	0	0.12	1.4	0	0
Open Space	**24**	6.4	6.7	0	12	0
Freeways	6.8	11	0	0	0	0

*Only the predominant land use is noted with the watershed name

Source: Bochis, Celina. 2007. Magnitude of Impervious Surfaces in Urban Areas. Master Thesis. The University of Alabama, Tuscaloosa.

5.1 Land Cover Characteristics

Regardless of the methods used to estimate imperviousness, field verification is necessary because it is the only accurate method that can be used to estimate the directly connected portion of the impervious cover (Gregory et al. 2005; Bochis 2007). Aerial photographs and satellite images were used to assist in the measurement of the actual coverage of each type of surface in each neighborhood studied, and were used to supplement the field collection information. The individual land covers were originally measured in square feet units from aerial photographs/satellite images. For easier handling of the data, ability of comparison with other watersheds, and better accounting for minor rounding errors, the actual area measurements were normalized as percentages of each the total area. Land cover percentages were used for all the analyses related to this chapter.

Table 103 shows the percentage impervious and pervious coverage for the land uses found in the Jefferson County, AL study areas. This table and Figure 91 show that impervious areas in the six watersheds are almost entirely directly connected. However, Figure 91 shows that there are large variabilities in the directly connected impervious fractions among and within the land uses. Table 103 shows the land uses' directly connected impervious areas (DCIA), with their averages and the corresponding coefficients of variation. These areas had most of their impervious surfaces directly connected to the drainage systems. Commercial land use areas have the greatest fraction of their impervious covers directly connected, with little variability. There is a large amount of impervious covers in the freeway land uses, but the sites studied have zero connectivity since they were drained by grass swales.

Table 103. Land Cover for Jefferson County, AL Land Uses

Land Use	**Total Pervious Area (TPA) (% of land use)**		**Total Impervious Area (TIA)* (% of land use)**		**Disconnected Impervious Area (DSIA) (% of land use)**		**Directly Connected Impervious Area (DCIA) (% of land use)**		**Impervious Area that is Directly Connected** (% of TIA)**	
	Avg.	**COV**	**Avg.**	**COV**	**Avg.**	**COV**	**Avg.**	**COV**	**Avg.**	**COV**
High Density Residential	70	0.16	30	0.37	11	0.44	19	0.51	62	0.25
Medium Density Residential	78	0.13	22	0.47	8.9	0.75	13	0.64	58	0.45
Low Density Residential	78	0.19	23	0.63	8.7	0.69	14	0.82	58	0.48
Apartments/ Multi Family	62	0.22	38	0.36	14	0.97	24	0.64	64	0.48
Commercial (Shopping Centers)	24	0.72	76	0.23	0.36	4.0	76	0.24	99	0.03
Commercial (Offices)	39	0.52	61	0.33	2.8	2.1	58	0.39	94	0.13
Industrial	41	0.69	59	0.49	8.5	2.3	50	0.66	82	0.43
Institutional (Schools)	73	0.19	27	0.50	3.9	0.89	23	0.62	83	0.15
Institutional (Churches)	35	0.52	65	0.29	3.2	1.2	61	0.27	96	0.05
Open Space	87	0.19	13	1.2	4.6	1.9	8.7	1.2	68	0.65
Freeways	42	0.18	58	0.13	58	0.13	0	NA	0	NA
Study Area	**61**	**0.43**	**39**	**0.67**	**9.2**	**1.5**	**30**	**0.95**	**70**	**0.47**

*TIA = DCIA + DSIA; Total land use area = TIA + TPA = 100

** Impervious area that is directly connected is calculated for each site and averaged by land use

Source: Bochis, Celina. 2007. Magnitude of Impervious Surfaces in Urban Areas. Master Thesis. The University of Alabama, Tuscaloosa.

As shown in the literature review, it is generally recognized when examining the effects of urbanization on stormwater quantity and quality that the main focus should be on DCIA and not total impervious cover alone. Because DCIA is site-specific and complicated to measure, the literature review also described how empirical equations for determining DCIA from the TIA measurement have been developed for different regions of the country. However, these equations seldom account for, nor describe, the large variations in this relationship. The local data were fitted with power and linear equations, the most common forms used in the literature for the prior investigations of DCIA. The goal of the regressions was to find the line that best predicts DCIA from TIA.

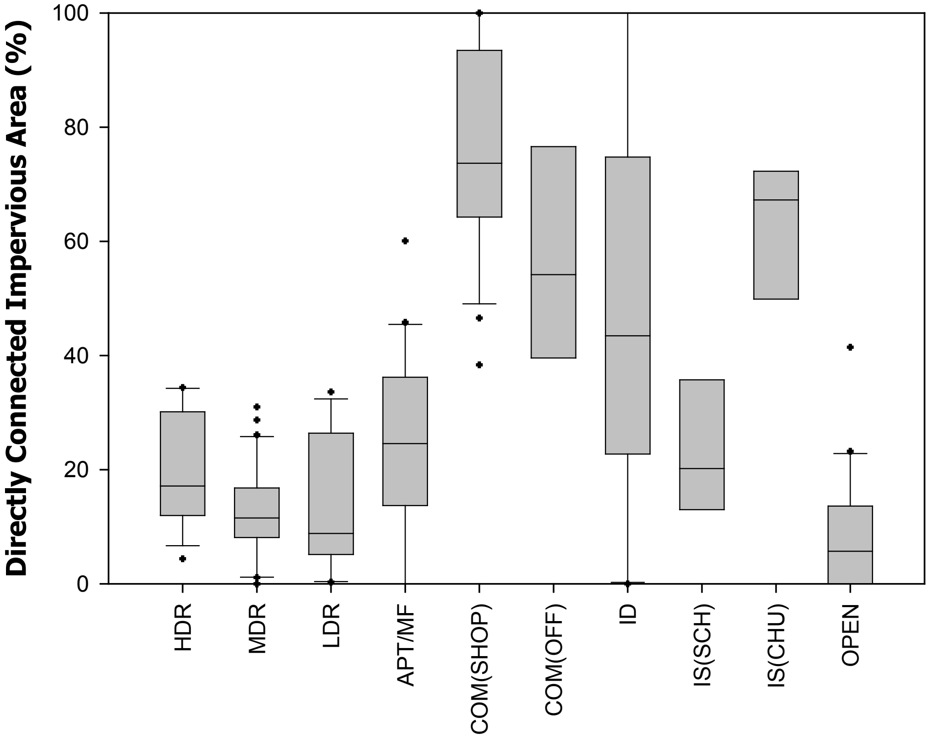


Fig. 91. Directly Connected Impervious Area by Land Use for Little Shades Creek and Jefferson County, AL Watersheds (Bochis and Pitt 2010)

Figures 92 and 93 relates the percent directly connected impervious areas to the total impervious areas for all of the individual homogeneous land use sites investigated, except freeway sites. Displayed on each graph are the empirical equation, the coefficient of determination, the fitted line, and the 95% confidence interval of the fitted line.

The plot from Figure 92 shows that the combined study areas' DCIA might be a power function of TIA, as suggested by Sutherland (highly connected basin, 2000), and Alley and Veenhuis (1983). As noted above, these drainage basins have most of the impervious surfaces directly connected to the drainage system. The fitted equation for the entire study areas was comparable to one of the Sutherland equations used for highly connected areas, where the drainage collector was a storm sewer with curb and gutters, and the roofs are connected.

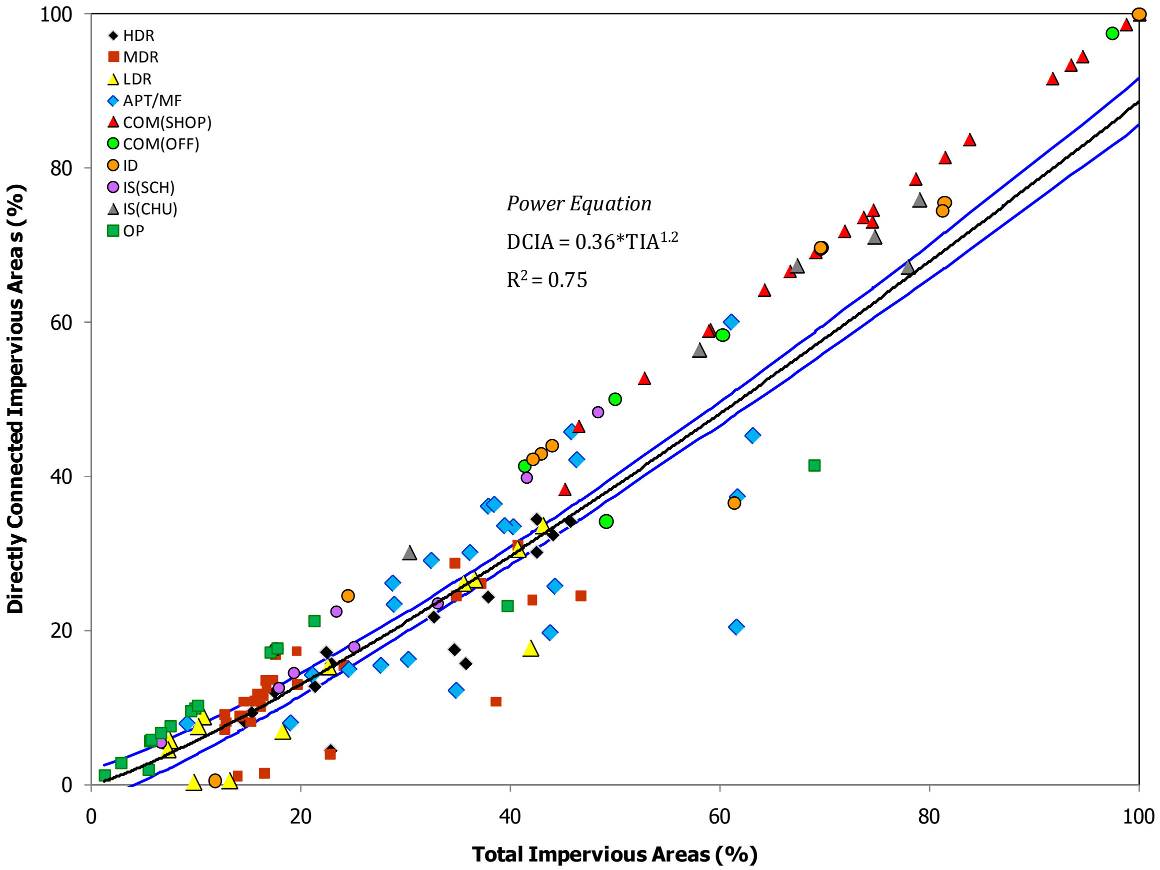


Fig. 92. Empirical Estimation (Power Equation) of DCIA based on TIA for Jefferson County, AL Study Area

The linear regression presented in Figure 93 shows a better fit of the data as it is associated with a larger coefficient of determination. The validation of the power and linear models was performed by checking the significance of the regressions coefficients (using ANOVA for the regression models) and by examining the behavior of the residuals (normality and random distribution checks).

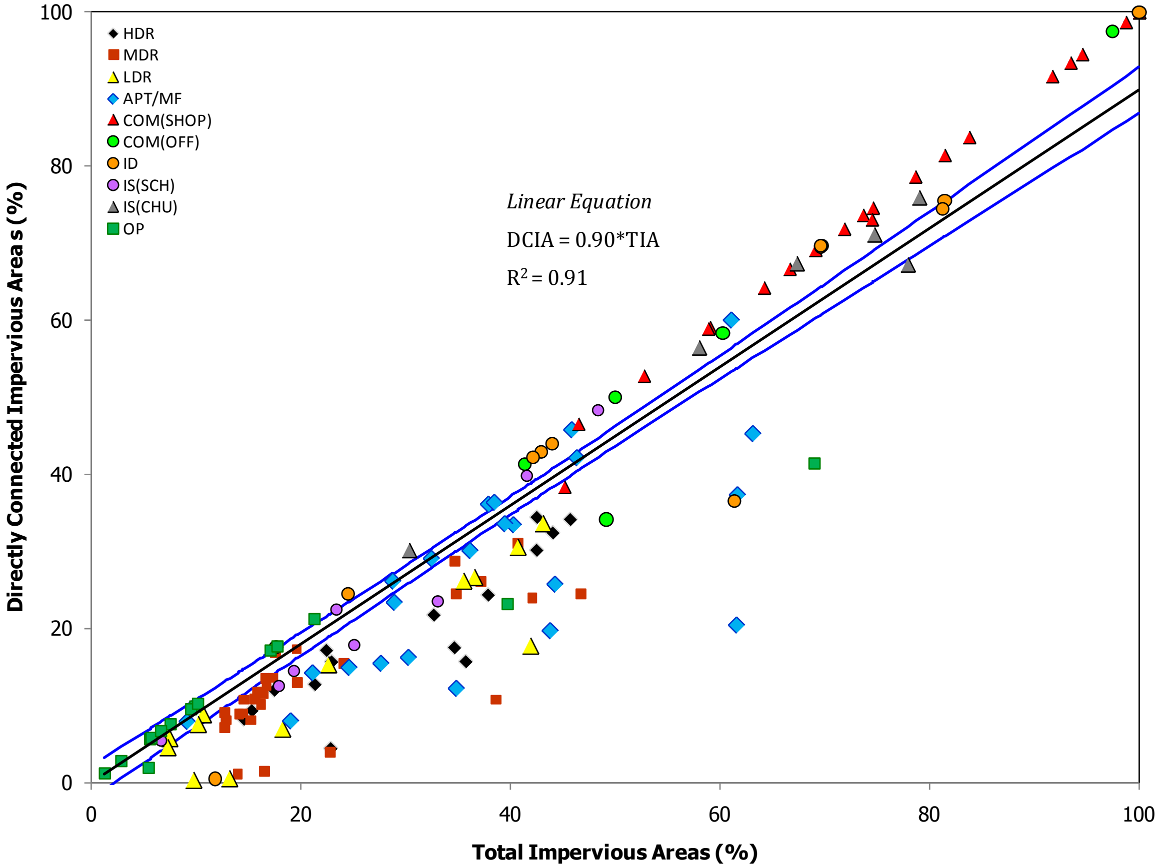


Fig. 93. Empirical Estimation (Linear Equation) of DCIA based on TIA for Jefferson County, AL Study Area

The ANOVA table for the power regression is shown in Table 104. The probability of observing a value greater than or equal to F statistics is less than 0.0001, therefore there is strong evidence that the regression coefficients are not equal to zero.

Table 104. ANOVA Results for the Nonlinear Regression Analysis

Source	Sum of Squares	DF	Mean Squares	F	p-value
Regression	276705	2	138353	2957	<0.0001
Residual	6972	149	47		
Uncorrected Total	283677	151			
Corrected Total	116411	150			

Dependent variable: DCIA

The primary tool for model validation is a graphical analysis of the residuals (NIST/SEMATECH 2003*)*. The residuals have to be normally distributed and randomly dispersed around the horizontal axis for the regression model to be appropriate for the data we want to predict. Figure 94 and Figure 95 show the normality and scatter plots of the residuals from the power regression. The graphs reveal that the residuals are not normally distributed (based on the Anderson Darling test statistic showing that the probability plot of the residuals is significantly different from a normal distribution plot) and do not have a random behavior about the mean. Therefore, the power model that takes into account all land uses from Jefferson County, AL does not fit the data well, even though the regression model is highly significant.

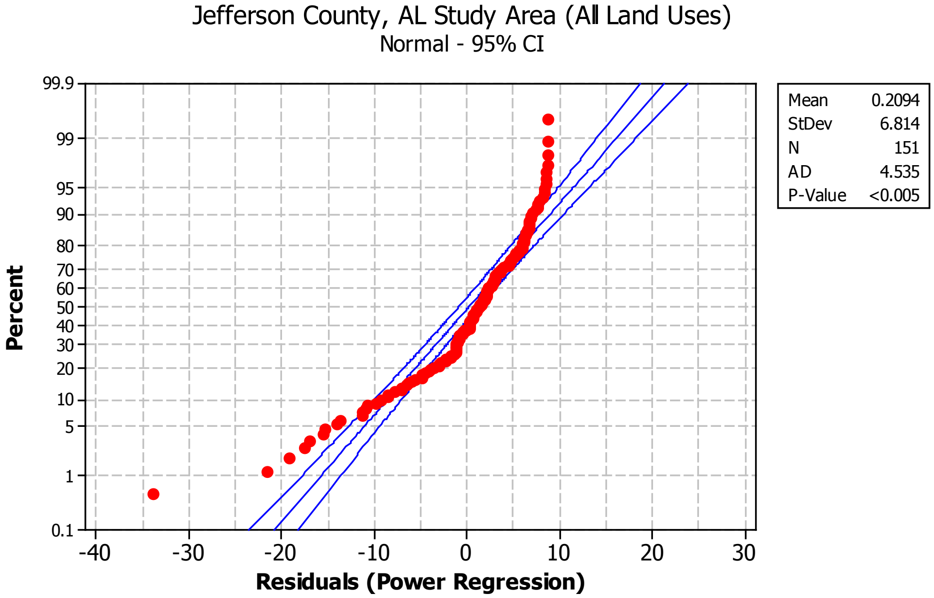


Fig. 94. Normal Probability Plot of the Power Regression Residuals – Jefferson County, AL Overall Land Uses

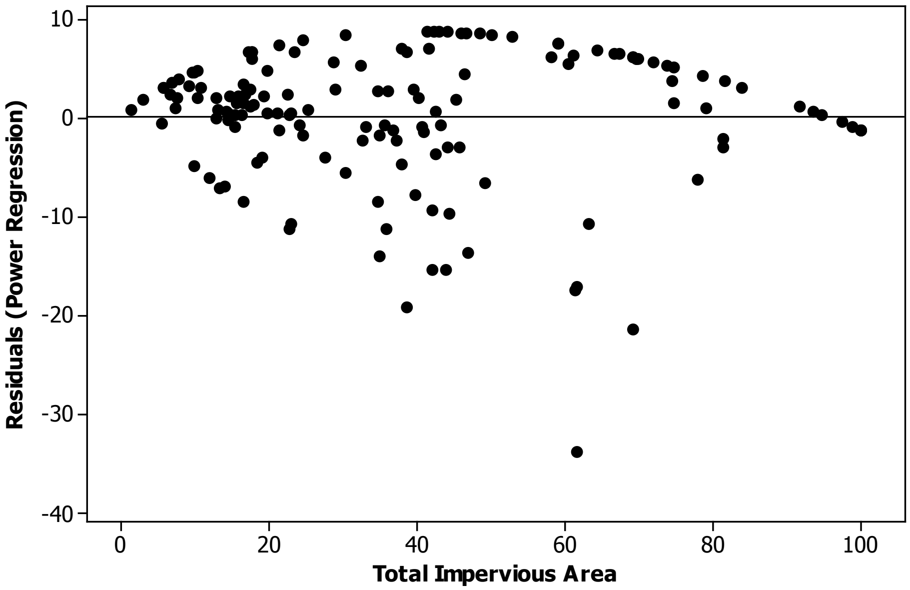


Fig. 95. Scatter Plot for the Power Regression Residuals –
Jefferson County, AL Overall Land Uses

The ANOVA table for the linear regression is shown in Table 105. The regression probability of observing a value greater than or equal to F statistics is also very small (<0.0001), therefore there is strong evidence that the regression coefficients are not equal to zero.

Table 105. ANOVA Results for the Linear Regression Analysis

Model	Sum of Squares	DF	Mean Square	F	p-value
Regression	273186	1	273186	3906	<0.0001
Residual	10492	150	70		
Total	283677	151			

Predictors: TIA; Dependent Variable: DCIA; Intercept not used

Figure 96 and Figure 97 show the normality and scatter plots of the residuals from the linear regression, revealing that the residuals are not normally distributed and do not have a random behavior. Therefore, the linear model that takes into account all land uses from Jefferson County, AL also is not a good fit for the data.

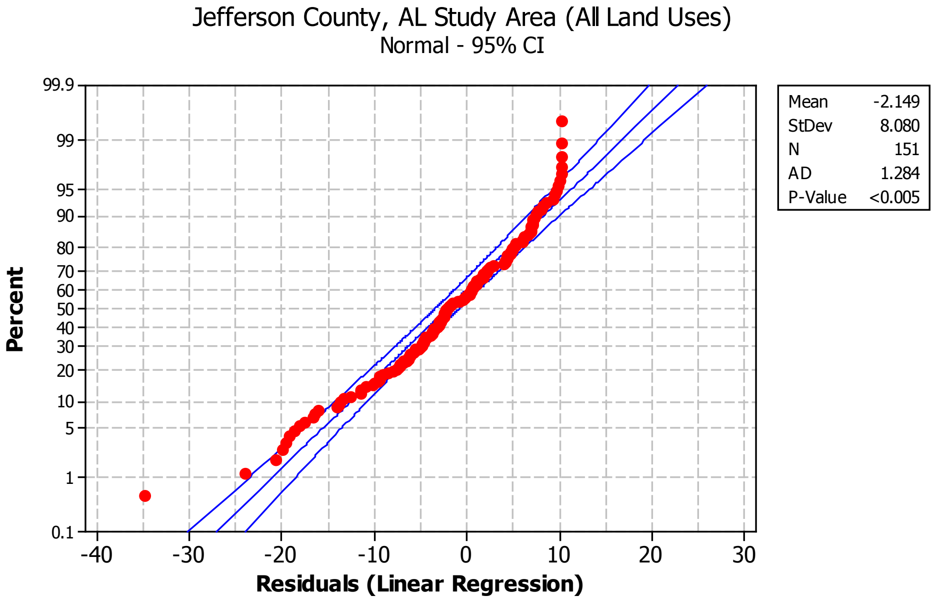


Fig. 96. Normal Probability Plot of the Linear Regression Residuals – Jefferson County, AL Overall Land Uses

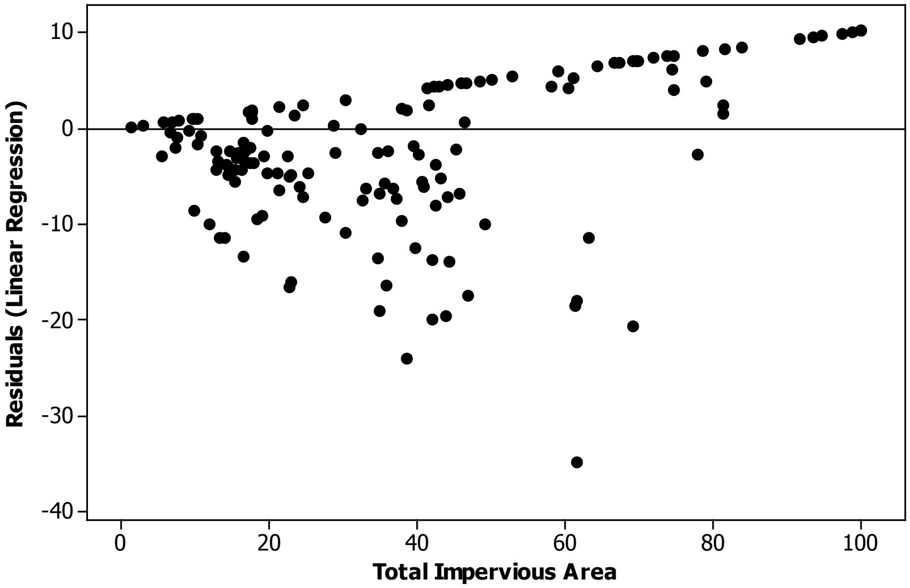


Fig. 97. Scatter Plot of the Linear Regression Residuals – Jefferson County, AL Overall Land Uses

Since there was high variability and scatter in the data, as the box plot of DCIA shows in Figure 91, the overall fitted equations shown on Figures 92 and 93 did not give satisfactory results. Therefore, to better explain the variability, it was more appropriate to subcategorize the DCIA relationships by land use and evaluate each land use separately.

The linear [$DCIA = m(TIA)$] and power [$DCIA = m(TIA)^n$] equations were fitted separately for each individual land use in the study area. The *m,* and respectably $n,$ equation coefficients along with the equation's coefficients of determination are presented in Table 106. Figure 98 to Figure 101 show the probability and residual plots used to test the robustness of the power and linear models. The p-values associated with the Anderson-Darling goodness-of-fit statistic (measures how well the data follow the normal distribution) were summarized in Table 106 (should be >0.05 indicating that they are not significantly different from a normal distribution of the data).

Table 106. Equation Coefficients for Each Land Use Existent in Jefferson County, AL Study Area

	Power Equation $DCIA = m(TIA)^n$				**Linear Equation** $DCIA = m(TIA)$		
Land Use	***m*** **coeff.**	***n*** **coeff.**	**R^2 value**	**Residuals p-value**	***m*** **coeff.**	**R^2 value**	**Residuals p-value**
High Density Residential	0.31	1.2	0.66	0.006*	0.66	0.79	0.169
Medium Density Residential	0.45	1.1	0.34	0.217	0.61	0.62	0.180
Low Density Residential	0.11	1.5	0.47	<0.005*	0.65	0.82	0.085
Apartments/ Multi Family	0.73	0.98	0.63	0.723	0.72	0.54	0.656
Commercial (Shopping Centers)	0.75	1.1	0.99	0.105	1.0	0.99	0.370
Commercial (Offices)	0.53	1.1	0.86	0.582	0.97	0.92	0.865
Industrial	0.04	1.8	0.75	<0.005*	0.95	0.94	0.382
Institutional (Schools)	0.63	1.1	0.96	0.512	0.89	0.92	0.817
Institutional (Churches)	1.3	0.92	0.98	0.901	0.95	0.95	0.194
Open Space	1.1	0.92	0.91	0.053	0.67	0.87	0.373

*Significant P-value

Source: Bochis, Celina, and Robert Pitt. 2010. Impervious Cover Variability in Urban Watersheds. In: *Dynamic Modeling of Urban Water Systems*, *Monograph 18,* Edited by W. James, K. N. Irvine, J. Li, E.A. McBean, R.E. Pitt and S.J. Wright, 131 - 146. Guelph, ON Canada: CHI Publisher.

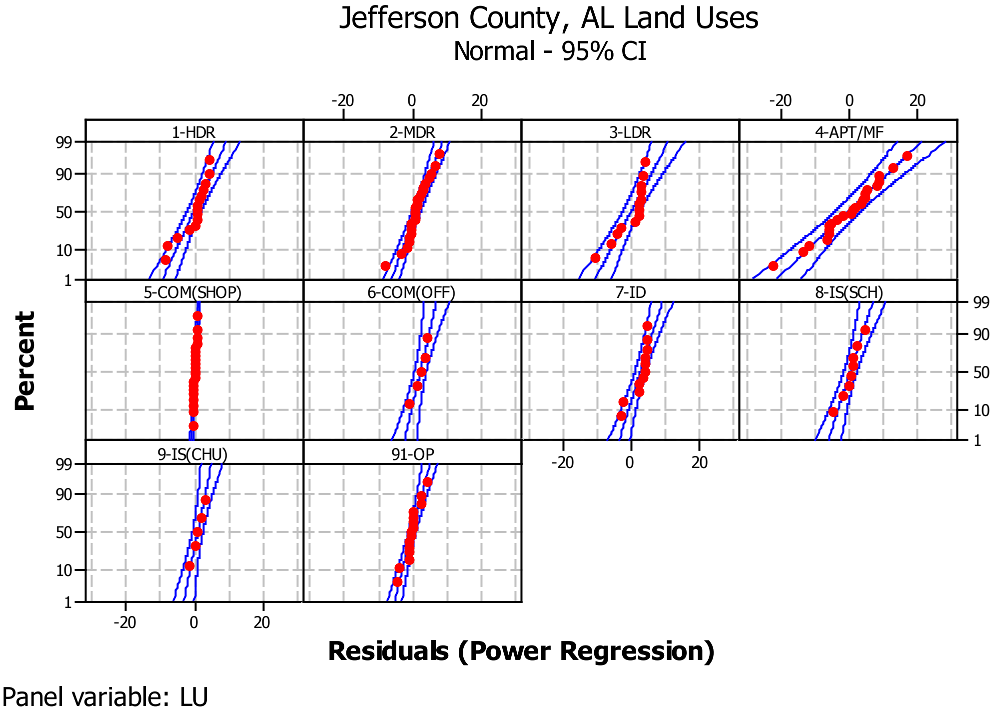


Fig. 98. Normal Probability Plots of the Power Regression Residuals by Land Use – Jefferson County, AL

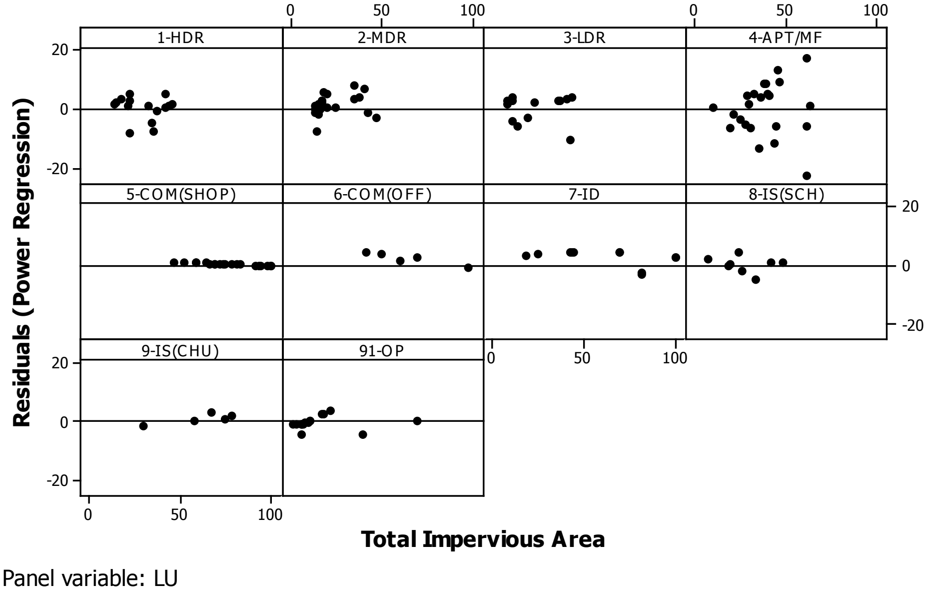


Fig. 99. Scatter Plots of the Power Regression Residuals by Land Use – Jefferson County, AL

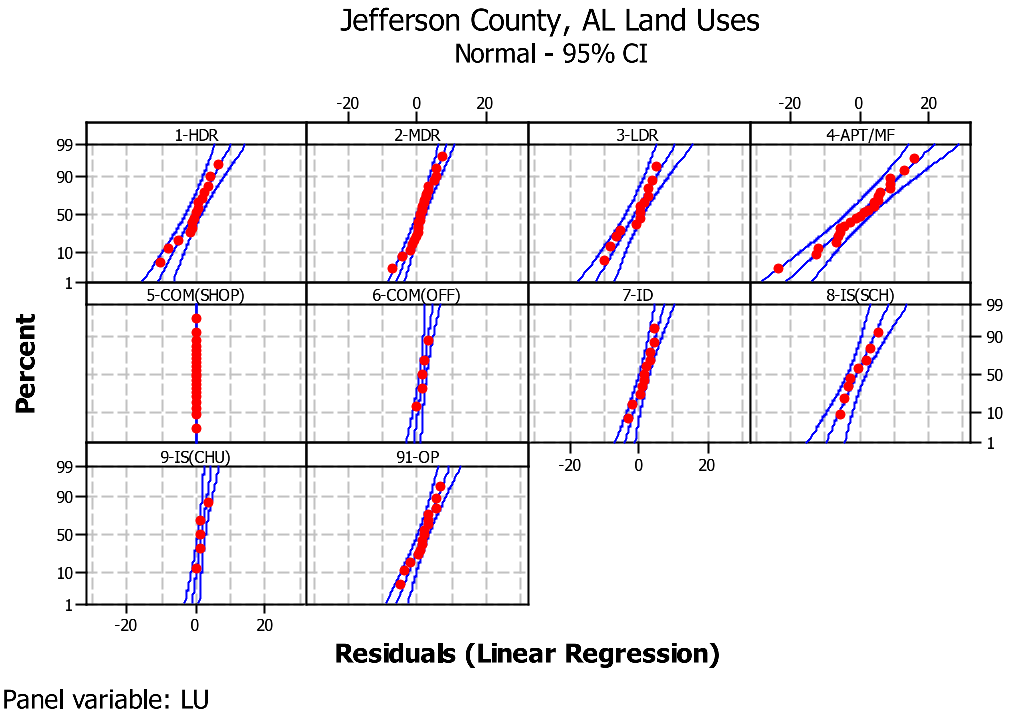


Fig. 100. Normal Probability Plots of the Linear Regression Residuals by Land Use – Jefferson County, AL

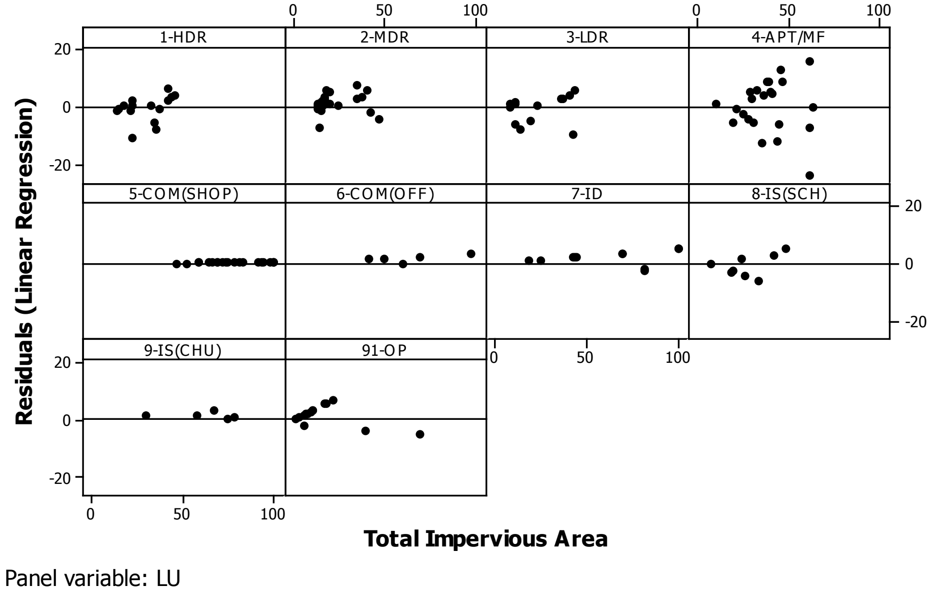


Fig. 101. Scatter Plots of the Linear Regression Residuals by Land Use – Jefferson County, AL

These data show that DCIA of each land use was not always best described by using a power function of TIA. It was found that the linear equations better fit these local data based on generally higher R^2 values, statistically significant fitted linear equations when the intercepts were not used (ANOVA p-values were zero for the intercept terms), and acceptable residual behaviors (the residual p-values were not significantly different from random, normal distributions)(Figures 98 to 101).

Other reported literature impervious cover relationships were also not very accurate when applied to local conditions (Table 2, Literature Review Chapter). These over/under estimates can lead to large errors in the predicted runoff volume as runoff volume is closely related to the DCIA values.

During field surveys, the important characteristics of the study areas were recorded and the actual land coverage (roofs, parking areas, street areas, driveways, landscaping, etc.) were measured for each neighborhood studied. Table 107 shows the average percentages and coefficients of variation of the major land coverage surfaces for the land uses found in the Jefferson County, AL study area.

Table 107. Major Surface Land Covers for Jefferson County, AL Land Uses

Land Use	**Connected Paved Street Area**		**Disconnected Paved Street Area**		**Connected Paved Driveways Area**		**Disconnected Paved Driveways Area**	
	Avg. (%)	**COV**	**Avg. (%)**	**COV**	**Avg. (%)**	**COV**	**Avg.(%)**	**COV**
High Density Residential	12	0.70	0.38	3.9	1.8	0.69	2.0	0.59
Medium Density Residential	7.9	0.90	1.0	2.4	1.1	0.88	1.5	0.66
Low Density Residential	9.3	0.88	1.3	1.9	1.4	1.2	1.7	0.94
Apartments/ Multi Family	6.9	0.65	1.8	2.0	0.45	1.1	0.63	1.1
Commercial (Shopping Centers)	19	0.32	0	NA	0.59	1.7	0.06	4.8
Commercial (Offices)	16	0.79	0	NA	1.1	1.0	0.62	2.4
Industrial	10	0.83	2.6	2.1	0.31	0.85	0.11	2.6
Institutional (Schools)	6.6	1.0	0	NA	0.30	2.0	0.30	2.0
Institutional (Churches)	21	0.69	0	NA	2.5	1.9	2.5	1.9
Open Space	8.7	0.77	6.5	0.93	0.07	1.0	0.07	1.0
Freeways	0	NA	47	0.13	0	NA	0	NA
Study Area	**11**	**0.79**	**2.9**	**3.2**	**0.92**	**1.5**	**0.98**	**1.4**

Source: Bochis, Celina. 2007. Magnitude of Impervious Surfaces in Urban Areas. Master Thesis. The University of Alabama, Tuscaloosa.

Table 107. - *Continued*

Land Use	**Connected Paved Parking Area**		**Disconnected Paved Parking Area**		**Connected Roof Area**		**Disconnected Roof Area**	
	Avg. (%)	**COV**	**Avg. (%)**	**COV**	**Avg. (%)**	**COV**	**Avg.(%)**	**COV**
High Density Residential	0.09	3.9	5.2	0.48	5.2	0.48	8.4	0.47
Medium Density Residential	0	NA	3.8	1.1	3.8	1.1	6.4	0.90
Low Density Residential	0	NA	3.1	1.0	3.1	1.0	5.8	1.0
Apartments/ Multi Family	9.0	1.0	8.0	1.0	8.0	1.0	10	0.88
Commercial (Shopping Centers)	36	0.37	17	0.70	17	0.70	1.4	3.9
Commercial (Offices)	25	0.81	17	0.67	17	0.67	0.33	2.4
Industrial	18	1.1	10	0.79	10	0.79	4.3	2.3
Institutional (Schools)	8.2	0.63	8.0	0.66	8.0	0.66	3.6	1.0
Institutional (Churches)	26	0.33	12	0.67	12	0.67	1.2	1.3
Open Space	8.2	1.2	0	NA	0	NA	0.2	3.2
Freeways	0	NA	0	NA	0	NA	0	NA
Study Area	**12**	**1.4**	**1.1**	**3.6**	**7.5**	**1.2**	**4.8**	**1.4**

Table 107. - *Continued*

Land Use	**Connected Paved Storage Area**		**Disconnected Paved Playground Area**		**Small Landscaped Area**		**Undeveloped/ Turf Area**	
	Avg.(%)	**COV**	**Avg.(%)**	**COV**	**Avg. (%)**	**COV**	**Avg. (%)**	**COV**
High Density Residential	0	NA	0	NA	64	0.30	5.5	2.6
Medium Density Residential	0	NA	0	NA	76	0.18	2.4	2.6
Low Density Residential	0	NA	0	NA	73	0.23	4.5	3.0
Apartments/ Multi Family	0	NA	0.37	1.8	46	0.57	4.3	3.1
Commercial (Shopping Centers)	1.1	2.7	0	NA	14	1.3	9.0	1.7
Commercial (Offices)	0	NA	0	NA	39	0.52	0	NA
Industrial	27	1.3	0	NA	25	1.1	17	1.5
Institutional (Schools)	0	NA	5.2	2.8	38	0.59	30	0.45
Institutional (Churches)	0	NA	0	NA	31	0.31	4.7	2.4
Open Space	0	NA	0.82	4.4	88	0.13	66	0.56
Freeways	0	NA	0	NA	34	0.26	7.3	0.52
Study Area	**2.5**	**5.1**	**0.42**	**8.4**	**53**	**0.59**	**15**	**1.9**

The 170 neighborhoods studied were separated in eleven land use sub-categories and are listed in Table F1 (Appendix F). Figure 102 shows the average land cover distributions for the medium density residential land use, the predominant land use in the study area. For a typical medium density residential land use in this region that was studied (having 2-6 units/acre), the major land cover were the landscaped areas. About 22% of this land use area is covered by impervious surfaces broken down into three major subcategories: roofs, streets, and driveways, with small amounts as parking and storage areas and playgrounds. Also, for a typical medium density residential land use examined, the total amount of impervious area for each category does not vary greatly (Figure 103). The pervious cover front and back yard components vary due to position of the house on a lot, but that does not affect the total pervious cover value. There is a similarity in the land cover distribution for all residential areas (high, medium, and low density), but this trend is not obvious for other land uses such as commercial, industrial or institutional where the major land covers are parking lots, streets and connected roofs (Figures 104 and 105).

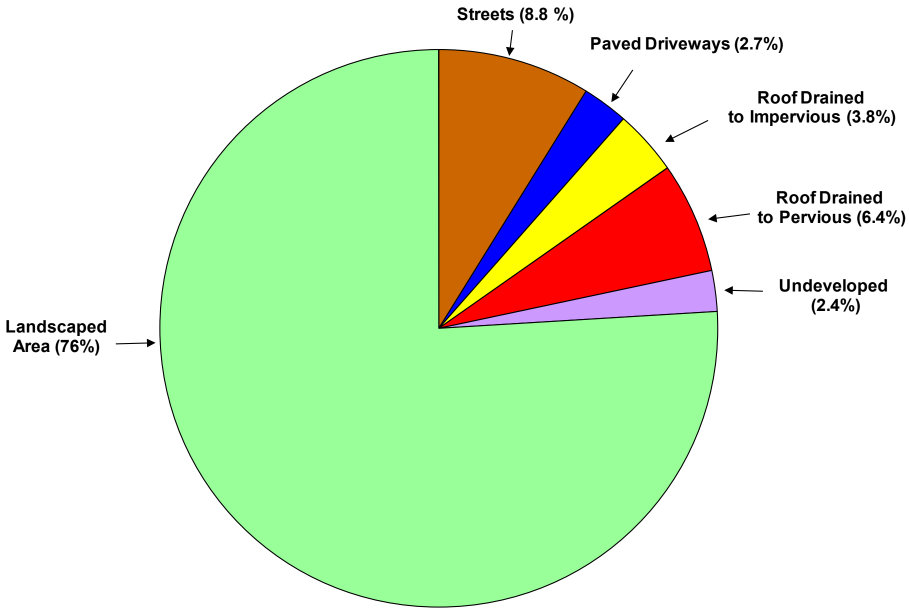


Fig. 102. Medium Density Residential Land Use – Average Land Cover Distribution (Bochis 2007)

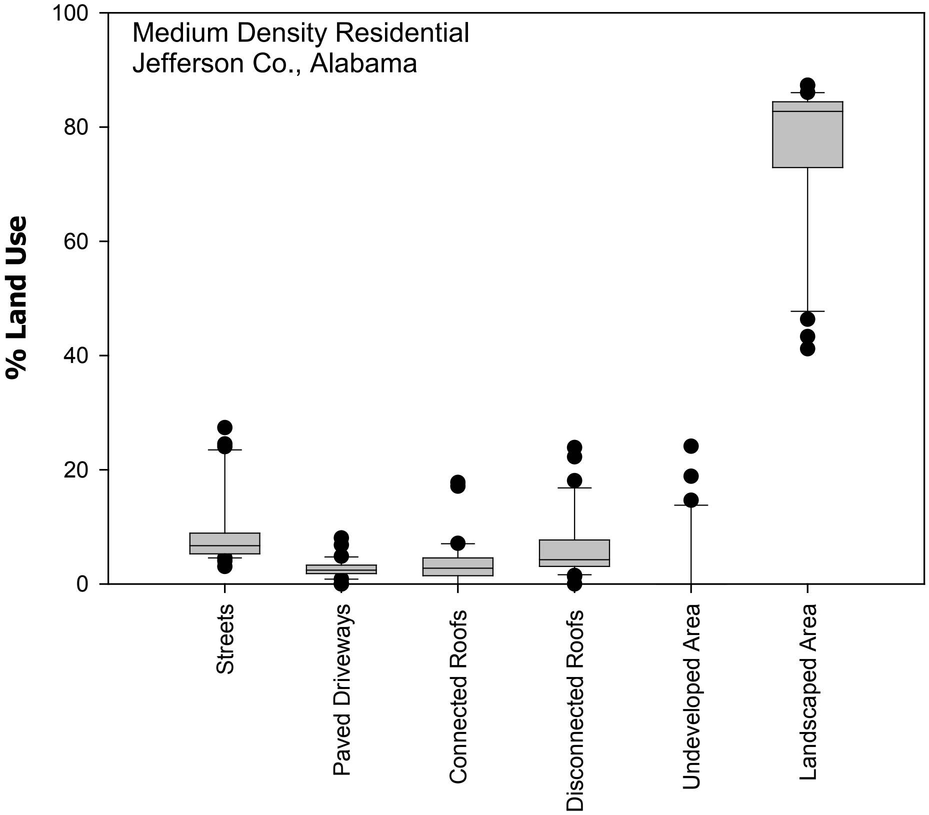


Fig. 103. Medium Density Residential Land Use -Land Cover Variations (Bochis 2007)

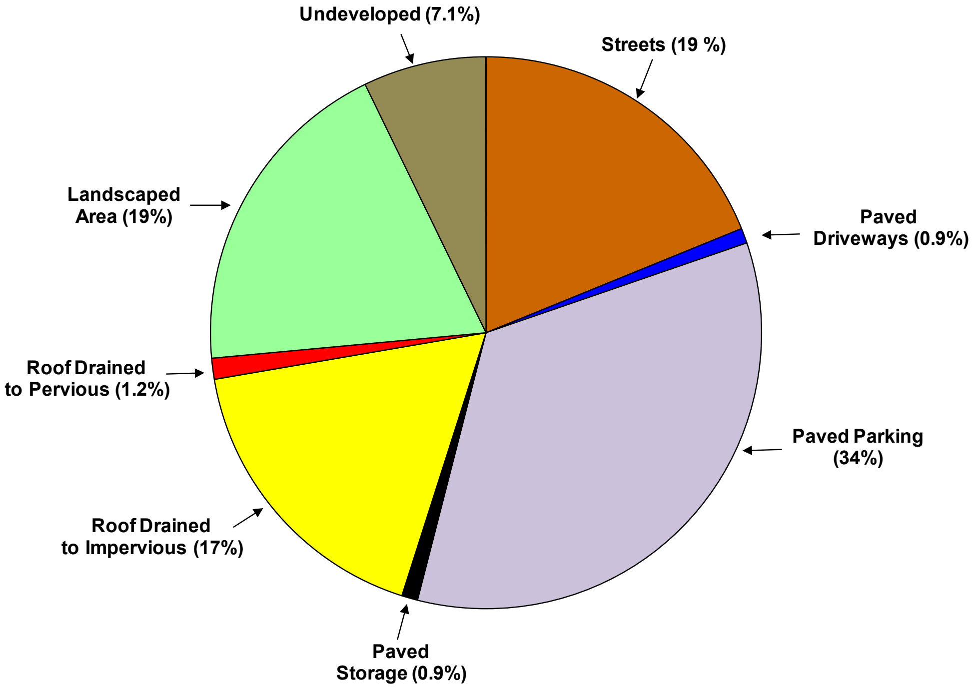


Fig. 104. Commercial Land Use –
Average Land Cover Distribution (Bochis 2007)

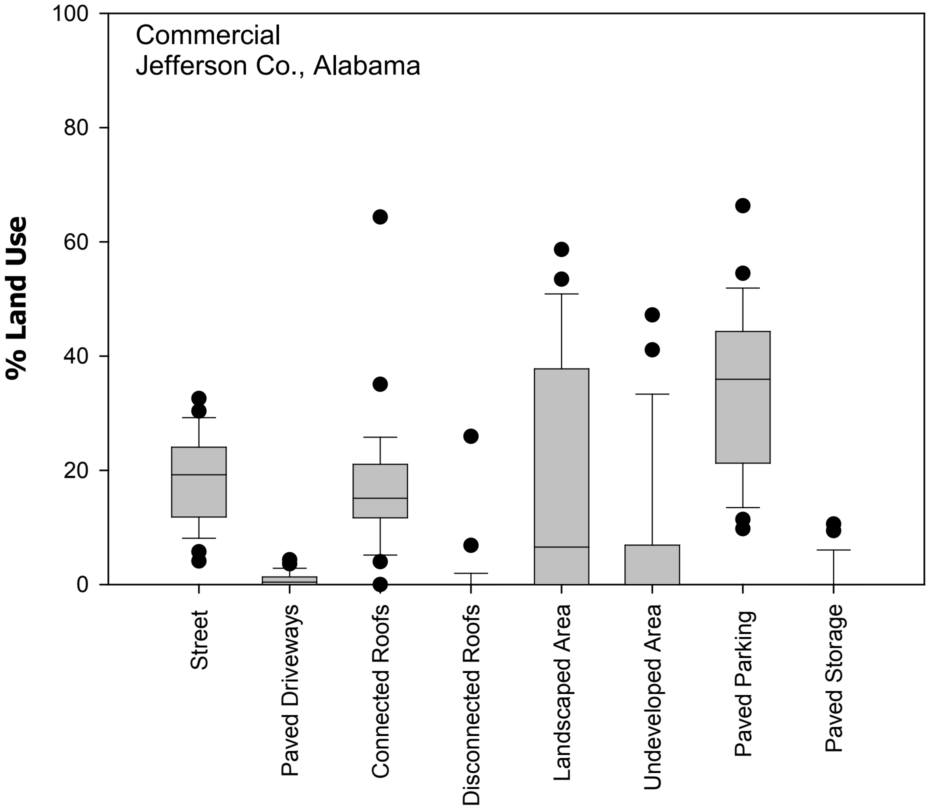


Fig. 105. Commercial Land Use - Land Cover Variation (Bochis 2007)

5.2 Land Cover Variation in Jefferson County, AL Watersheds

Any type of land use modification in a watershed can have a direct impact on the stormwater runoff volume and pollutant concentrations. Land use modifications that have the greatest impact on stormwater quantity and quality are the modifications to the land covers related to urbanization, especially as impervious covers are increased and if they are directly connected to the drainage system.

The previous chapter (Chapter 4) related the geographical areas with land uses and pollutant loadings. This chapter attempts to relate the land use/land cover with stormwater characteristics. In order to examine the effect of land use/land cover on stormwater constituent concentrations, several land covers (directly connected impervious area, disconnected impervious area, total pervious area, paved streets, paved parking lots, connected and disconnected roofs, and small landscaped area) were analyzed in order to establish if land cover similarities exist among land uses and among watersheds. A series of univariate and multivariate statistical analyses were undertaken to identify linkages between pollutant parameters and correlations with land use/land cover.

As shown in the literature search, such as by Arnold and Gibbons (1996), and the USEPA (1994), directly connected impervious area values are commonly used as an indicator of the impacts of land development on urban receiving waters. Therefore, the directly connected impervious cover is presented in the text as an example of the detailed analyses conducted, while the detailed analyses for the other land covers are presented in Appendix F.

5.2.1 Evaluation of Land Cover Variation by Land Use

This section takes into consideration all of the 170 individual homogeneous neighborhoods that were contained in the six watersheds examined in the vicinity of Birmingham, AL. As noted, the individual neighborhoods studied were separated in eleven land use sub-categories as listed in Table F1 (Appendix F).

Figure 106 is a box and whisker plot of directly connected impervious areas for the Jefferson County, AL areas studied and illustrates the DCIA variability among the land uses examined. As mentioned above, all of the freeway land use sites examined are drained by grass swales, so this category has no direct connectivity to the drainage system. Figure 107 is a probability plot used to check for the normality of the data.

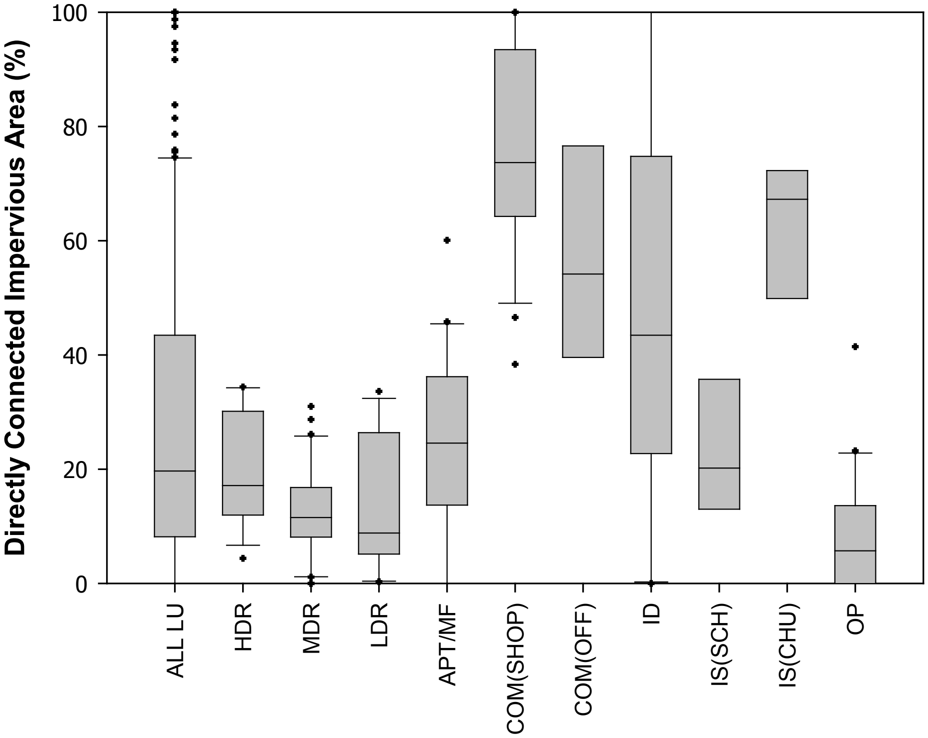
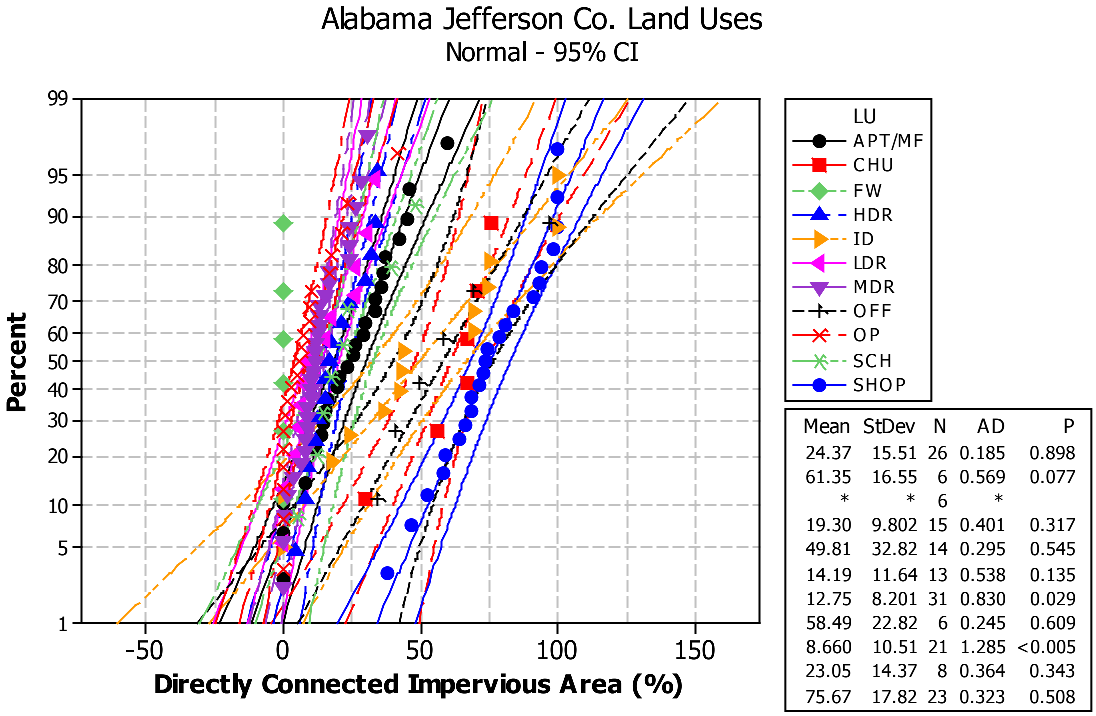


Fig. 106. Directly Connected Impervious Area – Jefferson County Land Uses

The DCIA percentage data were not consistently normally distributed (the freeways were all of the same value, and the medium density residential and open space distributions were found to be statistically different from normal distributions) and the sample sizes were rather variable (with 6 to 31 neighborhoods in each land use category). Therefore, the Kruskal-Wallis one-way analysis of variance by ranks was performed (Table 108). These analyses showed that significant differences were present among some of the land use sub-categories. Therefore, multiple comparisons (Mann-Whitney *U* test) were performed to assess all combinations of the land uses to determine whether any two independent DCIA sets came from the same population (Table 109). The Mann-Whitney test showed that the median differences between at least one of the total possible two distinct DCIA groupings were significant at the 0.05 level, so the land uses were separated according to their homogeneity and significance (Figure 108 and Table 109).



Mean	StDev	N	AD	P
24.37	15.51	26	0.185	0.898
61.35	16.55	6	0.569	0.077
*	*	6	*	
19.30	9.802	15	0.401	0.317
49.81	32.82	14	0.295	0.545
14.19	11.64	13	0.538	0.135
12.75	8.201	31	0.830	0.029
58.49	22.82	6	0.245	0.609
8.660	10.51	21	1.285	<0.005
23.05	14.37	8	0.364	0.343
75.67	17.82	23	0.323	0.508

Fig. 107. Probability Distributions of Directly Connected Impervious Areas by Land Uses Examined in Jefferson County and Checks for Normality

Table 108. Nonparametric Analyses of Variance and Power Analyses for Directly Connected Impervious Areas – Jefferson County Land Uses

Kruskal-Wallis Test (Land Uses: % DCIA)

H = 104.08 DF = 10 P = 0.00
H = 104.20 DF = 10 P = 0.00 (adjusted for ties)

Land Use	N	Median	Ave Rank	Z
HDR	15	17	78	-1
MDR	31	12	59	-3
LDR	13	8.8	61	-2
APT/MF	26	25	85	0
CO(SHOP)	23	74	150	7
CO(OFF)	6	54	136	3
ID	14	43	117	3
IS(SCH)	8	20	85	0
IS(CHU)	6	67	139	3
OP	21	5.7	42	-4
FW	6	0	10	-4
Overall	169		85	

Power of the Test (Land Uses: % DCIA)

Land Use	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
HDR	15	19	9.8
MDR	31	13	8.2
LDR	13	14	12
APT/MF	26	24	16
CO(SHOP)	23	76	18
CO(OFF)	6	58	23
ID	14	50	33
IS(SCH)	8	23	14
IS(CHU)	6	61	17
OP	21	8.7	11
FW	6	0	0

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 15.8
Obtained
Effect Size = 1.5

Table 109. Multiple Comparisons and Data Groups for Directly Connected Impervious Areas – Jefferson County Land Uses

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value	(I) LU	(J) LU	p-value
HDR	MDR	0.023*	APT/MF	CO (SHOP)	0.000*
	LDR	0.167		CO (OFF)	0.002*
	APT/MF	0.334		ID	0.011*
	CO (SHOP)	0.000*		IS (SCH)	0.823
	CO (OFF)	0.001*		IS (CHU)	0.001*
	ID	0.005*		OP	0.001*
	IS(SCH)	0.583	COM (SHOP)	CO (OFF)	0.063
	IS(CHU)	0.001		ID	0.057
	OP	0.003*		IS (SCH)	0.000*
				IS (CHU)	0.112
				OP	0.000*

*Significant P-value

Land Use
%DCIA Groups (medians)

Land Use	Gr. A	Gr. B	Gr. C	Gr. D
HDR	17			
APT/MF	25			
IS(SCH)	20			
MDR		12		
LDR		8.8		
CO (SHOP)			74	
CO (OFF)			54	
IS(CHU)			67	
ID			43	
OP				5.7

Table 109. - *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	**(J) LU**	**p-value**	**(I) LU**	**(J) LU**	**p-value**	**(I) LU**	**(J) LU**	**p-value**
MDR	LDR	0.959	LDR	APT/MF	0.067	CO(OFF)	ID	0.773
	APT/MF	0.002*		CO (SHOP)	0.000*		IS (SCH)	0.008*
	CO (SHOP)	0.000*		CO (OFF)	0.001*		IS (CHU)	0.689
	CO (OFF)	0.000*		ID	0.006*		OP	0.000*
	ID	0.000*		IS (SCH)	0.205	ID	IS (SCH)	0.061
	IS(SCH)	0.046*		IS (CHU)	0.001*		IS (CHU)	0.536
	IS(CHU)	0.000*		OP	0.103		OP	0.000*
	OP	0.022*	IS(CHU)	OP	0.000*	IS(SCH)	IS (CHU)	0.006*
							OP	0.008*

*Significant P-value

A retrospective power analysis was performed to help decide how accurate the statistical test was in detecting the effect size present in the available sample data, or to give an estimate of how large the sample size is needed to enable accurate and reliable statistical judgments. These power tests are described in more detail in the Experimental Design section (Chapter 3).

The power test (Table 108) revealed that the analysis of variance was performed on an adequate sample size and it was well-powered (100%) at the study alpha level to detect the large effect size (1.5, corresponding to about 750% maximum difference between any two DCIA means) present among Jefferson County's DCIA by land use. The results were acceptable, resulting in four DCIA homogeneous groups (Figure 108), each group including only samples that are not statistically significant from each other.

The next step was to verify that the four DCIA groups were statistically different from each other. Figure 108 shows the box-and-whisker plots of the four groups, while Table 110 shows the analysis of variance and the power test that confirmed the DCIA medians were not the same across the four groups (p-value = 0, power 100%). Table 111 presents the multiple comparison procedures performed to determine which medians differ. The box-and-whisker plots show large separations in the boxes (median values ranging from 6% to 69%), so the number of samples in each group was adequate to detect significant differences. Therefore, the results of the statistical test were accepted with confidence.

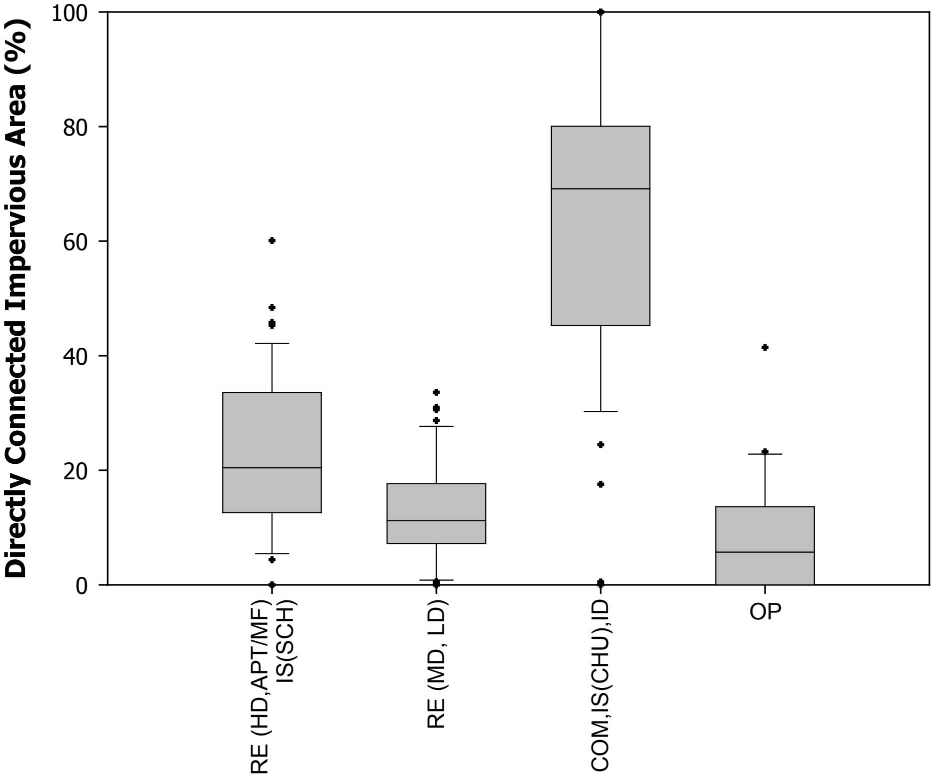


Fig. 108. Directly Connected Impervious Areas –
Jefferson County Land Uses Homogeneous Groups

Table 110. Nonparametric Analyses of Variance and Power Analyses for Directly Connected Impervious Areas Homogeneous Groups – Jefferson County Land Uses

Kruskal-Wallis Test
(Homogeneous Groups: % DCIA)

H = 90.59 DF = 3 P = 0.00
H = 94.62 DF = 3 P = 0.00 (adjusted for ties)

Land Use Groups	N	Median	Ave Rank	Z
RE(HD, APT/MF) IS(SCH)	49	20	77	-1
RE(MD, LD)	44	11	53	-5
CO, IS(CHU), ID	49	69	132	9
OP	21	5.7	37	-5
Overall	163		82	

Power of the Test
(Homogeneous Groups: % DCIA)

Land Use Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(HD, APT/MF) IS(SCH)	49	23	14
RE(MD, LD)	44	13	9.2
CO, IS(CHU), ID	49	64	25
OP	21	8.7	11

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 17.0

Obtained Effect Size = 1.3

Table 111. Multiple Comparisons for Directly Connected Impervious Areas Homogeneous Groups – Jefferson County Land Uses

Multiple Comparisons
(Mann-Whitney U Test)

(I)LU	(J)LU	p-value
RE(HD,APT/MF) IS(SCH)	RE(MD, LD)	0.000*
	CO, IS(CHU), ID	0.000*
	OP	0.000*
RE(MD, LD)	CO, IS(CHU), ID	0.000*
	OP	0.017*
CO, IS(CHU)	OP	0.000*

*Significant P-value

Homogeneous Groups:
% DCIA (medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE(HD,APT/MF) IS(SCH)	20			
RE(MD, LD)		11		
CO, IS(CHU), ID			69	
OP				5.7

Based on the outcome of post hoc multiple comparison, the DCIA data were kept in the originally four distinct DCIA groups: (1) high density residential, apartment/multiple families, and institutional schools; (2) medium and low density residential; (3) commercial (shopping centers and offices), institutional churches, and industrial; (4) open space land use. Table 112 shows the basic statistics for these homogeneous groups, based on DCIA measurements.

Table 112. Basic Statistics for Jefferson County Land Uses –
Directly Connected Impervious Area Homogeneous Groups (%)

Groups	**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
RE(HD,APT/MF),IS(SCH)	49	23	14	0.61	0.0	20	60
RE(MD, LD)	44	13	9.2	0.70	0.0	11	34
CO, IS(CHU), ID	49	64	25	0.40	0.0	69	100
OP	21	8.7	11	1.2	0.0	5.7	41

Similar analyses were performed for disconnected impervious areas (DSIA), total pervious area, paved streets, paved parking lots, connected roofs, disconnected roofs, and small landscaped areas, with the full analyses shown in Appendix F. Figures 109 to 115 and Tables 113 to F119 show the clustered homogeneous groups along with their basic statistics for these other land covers.

For the Jefferson County watersheds examined, the land covers included in the disconnected impervious area category (the runoff from these surfaces is directed to a pervious area that allows infiltration and increased time of concentration) were mostly disconnected roofs, disconnected driveways, and streets drained by grass swales. For this land cover, there were no statistically significant differences found between the land use sub-categories. Commercial, industrial, and open space land uses grouped together since their disconnected impervious area was mainly composed of a few disconnected streets, as shown in Figure 109 and Table 113.

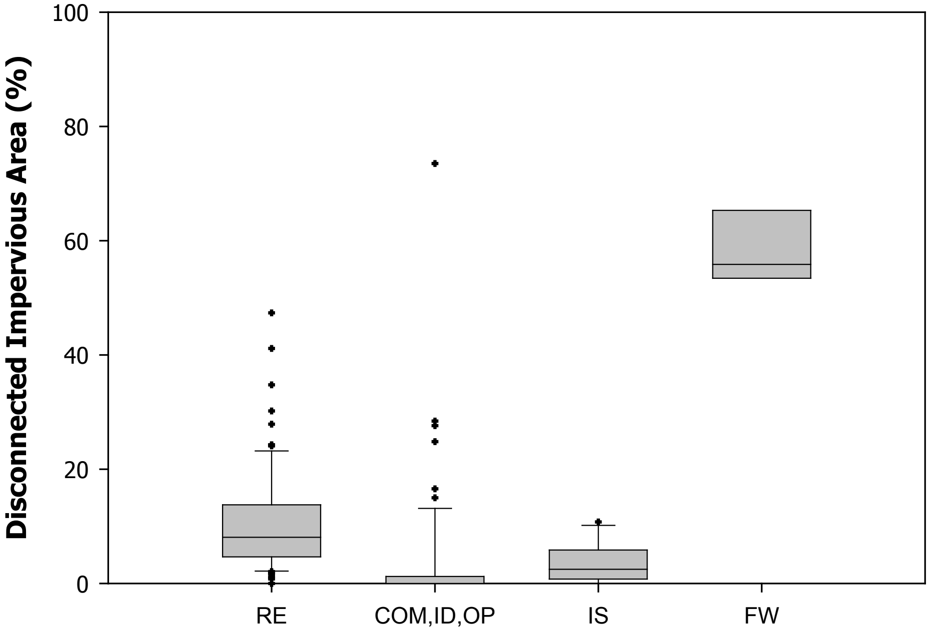


Fig. 109. Disconnected Impervious Areas –
Jefferson County Land Uses Homogeneous Groups

Table 113. Basic Statistics for Jefferson County Land Uses –
Disconnected Impervious Areas Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE	85	11	9.0	0.84	0.0	8.1	47
CO, ID,OP	64	3.8	11	2.9	0.0	0.0	74
IS	14	3.6	3.5	0.99	0.0	2.5	11
FW	6	58	7.6	0.13	49	56	71

Total pervious areas are mostly associated with small landscaped areas adjacent to buildings, unpaved streets, unpaved parking lots, unpaved storage areas, unpaved playgrounds, and the large turf/undeveloped areas that might exist between properties. Since total imperviousness for the areas studied in the Jefferson County watersheds is mostly directly connected, the total pervious area and directly connected impervious areas were approximately complementary. As expected, the land uses for those two land covers were similarly grouped

(Figure 110 and Table 114). The exception was the freeway land use which was totally disconnected impervious area, but had some pervious area in the form of landscaped area and grass at the median.

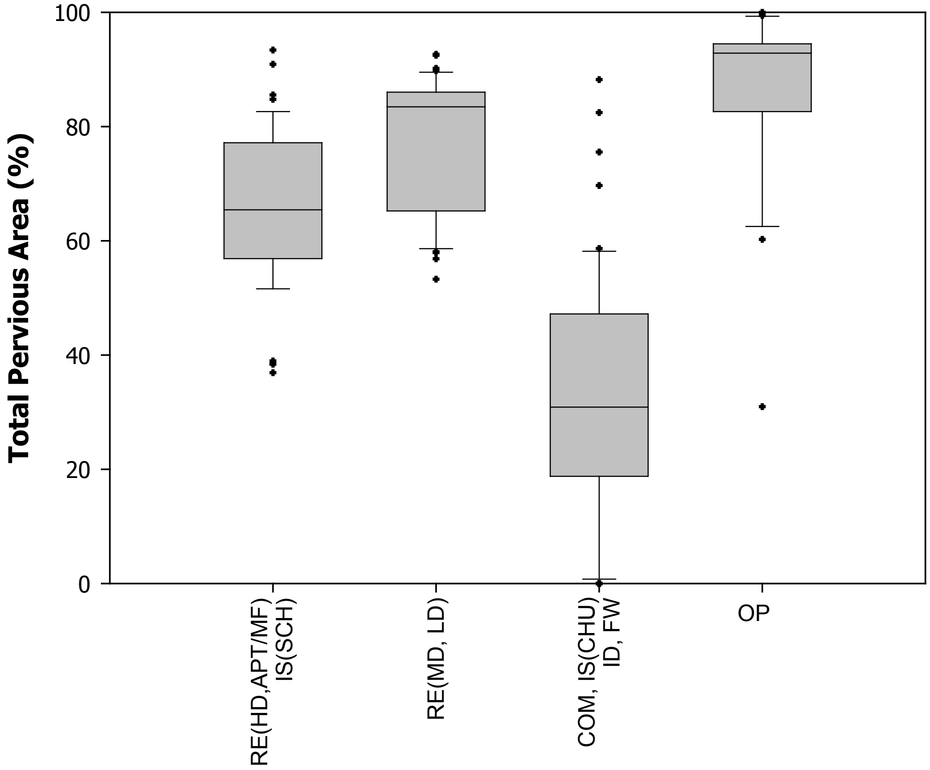


Fig. 110. Total Pervious Area – Jefferson County Land Uses Homogeneous Groups

Table 114. Basic Statistics for Jefferson County Land Uses – Total Pervious Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE(HD,APT/MF), IS(SCH)	49	66	13	0.20	37	65	93
RE(MD, LD)	44	78	12	0.15	53	83	93
CO, IS(CHU), ID, FW	55	33	21	0.65	0.0	31	88
OP	21	87	16	0.19	31	93	100

Paved streets land cover includes connected and disconnected street areas. It was found that all residential land use sub-categories, industrial, and open space (parks, cemeteries, golf courses) land uses from the Jefferson County watersheds examined had similar amounts of paved street areas. Also, the institutional church sub-category and the commercial land uses (shopping centers and office parks) had similar amounts of streets (Figure 111 and Table 115).

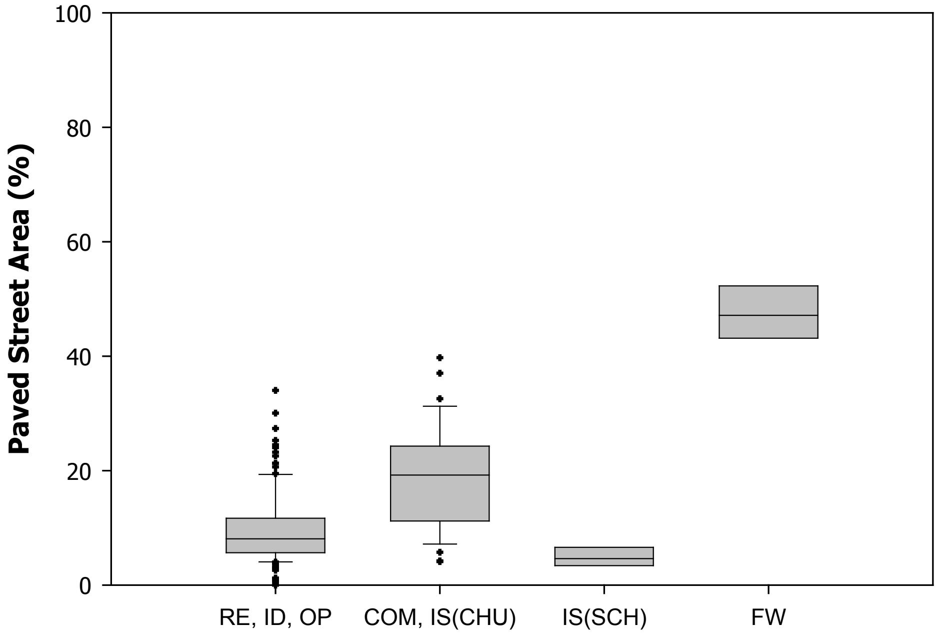


Fig. 111. Paved Street Areas - Jefferson County Land Uses Homogeneous Groups

Table 115. Basic Statistics for Jefferson County Land Uses –
Paved Street Areas Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE, ID, OP	120	10	6.3	0.65	0.0	8.1	34
CO, IS(CHU)	35	19	9.0	0.47	4.1	19	40
IS(SCH)	8	6.6	6.7	1.0	0.6	4.6	23
FW	6	47	6.3	0.13	35	47	53

Figure 112 and Table 116 show the final groups for paved parking lot areas. Once again, it was found that commercial land uses were similar in land cover to institutional church land uses. A very small amount of parking areas was found in high-density residential land uses, but they were missing from residential medium and low-density land uses. Shoulders were considered parking areas for freeway land uses and were found to be similar in quantity to industrial, schools, and apartment/multiple family land uses.

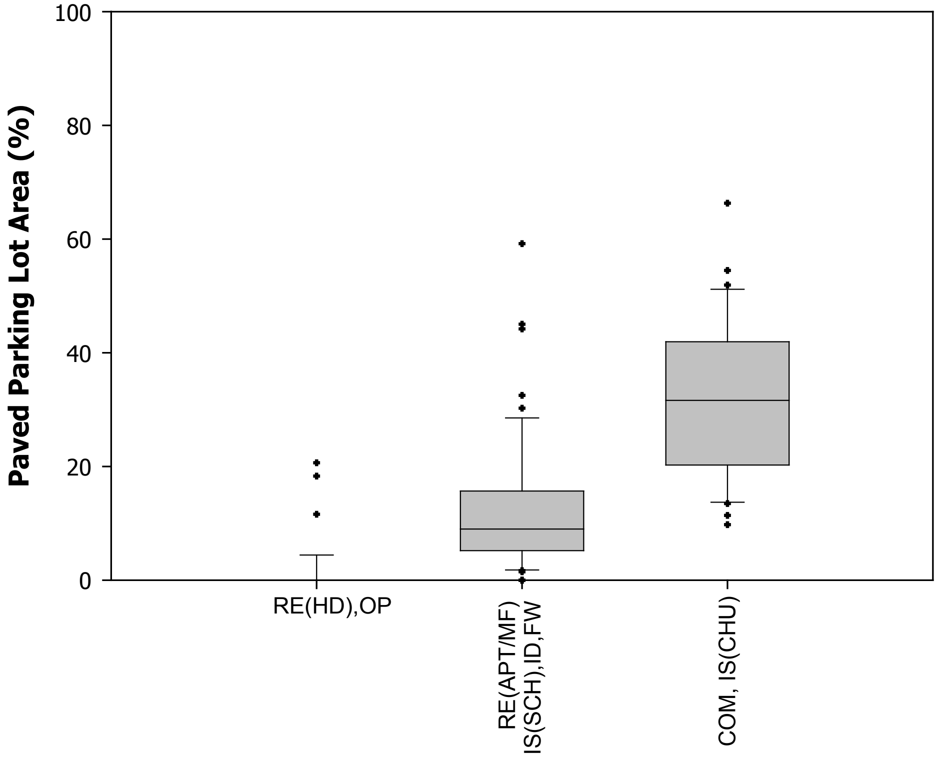


Fig. 112. Paved Parking Lot Areas – Jefferson County Land Uses Homogeneous Groups

Table 116. Basic Statistics for Jefferson County Land Uses –
Paved Parking Lot Areas Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE(HD), OP	36	1.5	4.8	3.3	0.0	0.0	21
RE (APT/MF) IS(SCH), ID, FW	54	12	12	0.95	0.0	9.0	59
CO, IS(CHU)	35	33	14	0.42	10	32	66

Figure 113 and Table 117 show the final groups for connected roof tops land cover. Connected roofs were obviously not present in the freeway and open space land uses. Statistical analyses showed that connected roofs from institutional and industrial land uses had comparable quantities, but they were different from commercial and residential land uses. Statistically significant differences were found among residential land use sub-categories. High-density residential land uses seems to be more related to apartments/multifamily land uses, while medium and low-density residential group together.

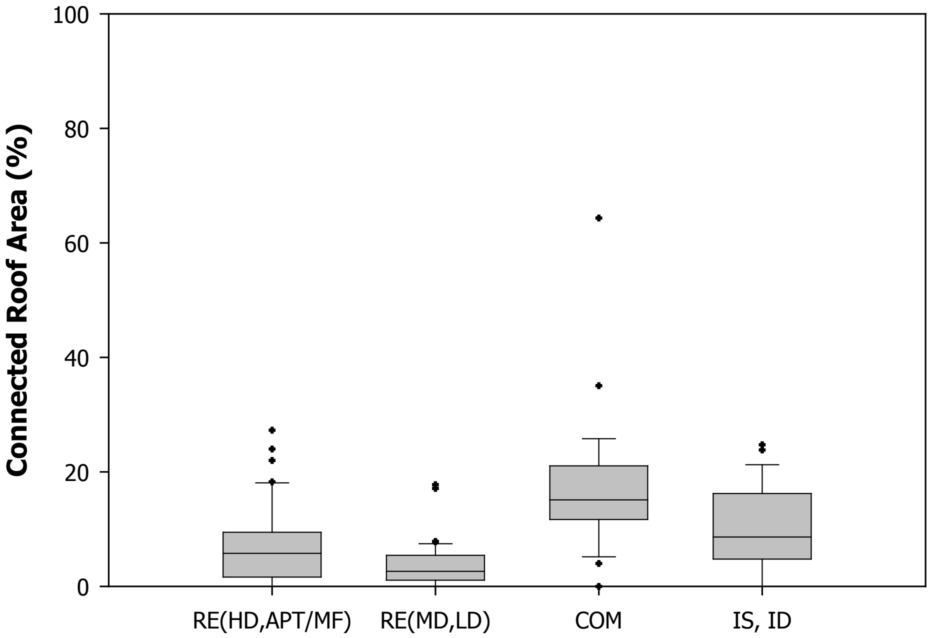


Fig. 113. Connected Roof Areas – Jefferson County Land Uses Homogeneous Groups

Table 117. Basic Statistics for Jefferson County Land Uses – Connected Roof Areas Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE(HD, APT/MF)	41	7.0	6.9	0.99	0.0	5.8	27
RE(MD, LD)	44	3.6	3.9	1.1	0.0	2.6	18
CO	29	17	12	0.69	0.0	15	64
IS, ID	28	10	7.2	0.73	0.0	8.6	25

Disconnected and connected roofs land uses were complementary, so the land uses grouped in the same fashion. The exception was the existence of disconnected roofs in open space land uses which group with commercial land uses (Figure 114 and Table 118).

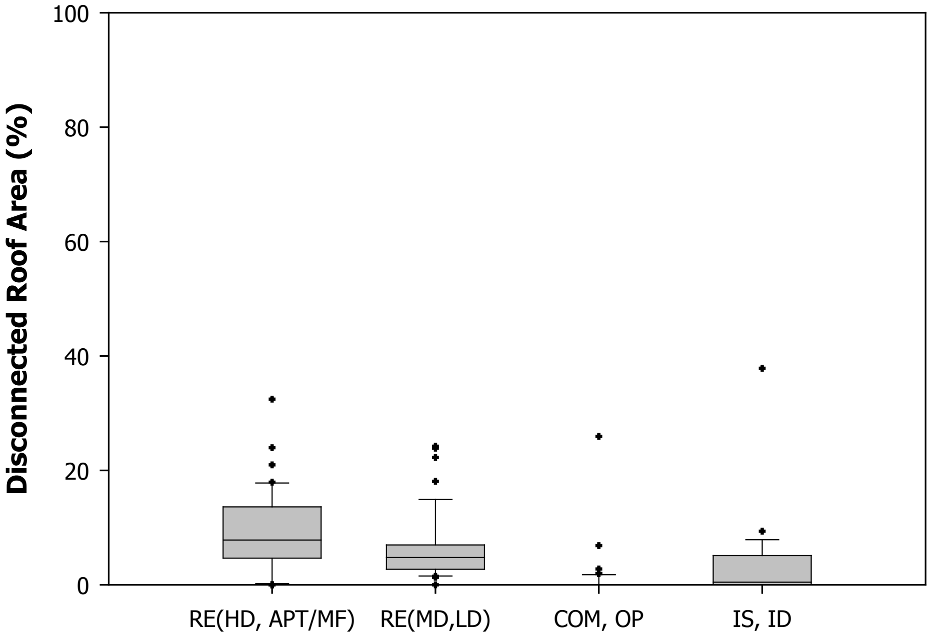


Fig. 114. Disconnected Roof Areas – Jefferson County Land Uses Homogeneous Groups

Table 118. Basic Statistics for Jefferson County Land Uses –
Disconnected Roof Areas Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE(HD, APT/MF)	41	9.1	7.0	0.77	0.0	7.8	32
RE(MD, LD)	44	6.2	5.7	0.92	0.0	4.7	24
CO, OP	50	0.8	3.8	4.8	0.0	0.0	26
IS, ID	28	3.4	7.3	2.1	0.0	0.5	38

Small landscaped area land cover includes the back and front landscape adjacent to the residential buildings and the landscaped areas found in public areas. It was found that medium and low-density residential land uses from the Jefferson County watersheds examined had similar amounts of landscaped areas. This group was found to be statistically different from high-density residential or apartment/multiple families land uses. The apartment/multiple families land use groups with commercial offices, institutional, and freeways land uses. In addition, it was determined that commercial shopping and office parks had statistically different amounts of landscaped areas. It was not a surprise to find that shopping centers group with industrial and open space land uses concerning small landscaped areas, giving that these land uses all have very little land cover allocated for landscape areas. Their major land cover consists mostly of streets and parking lots (commercial, industrial), and undeveloped land (open space) (Figure 115 and Table 119).

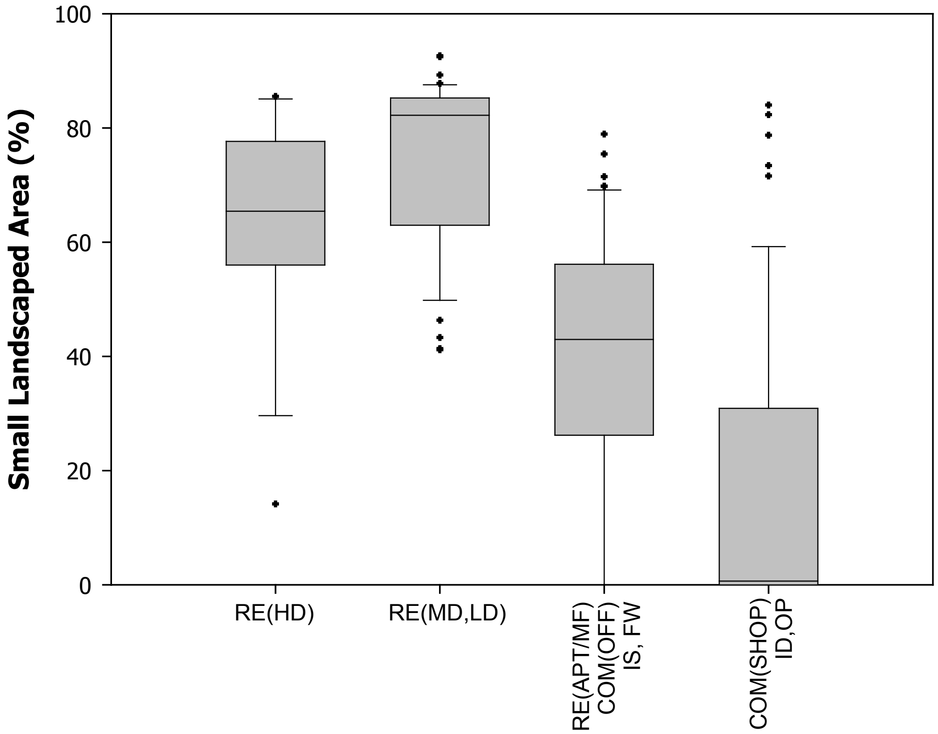


Fig. 115. Small Landscaped Areas - Jefferson County Land Uses Homogeneous Groups

Table 119. Basic Statistics for Jefferson County Land Uses –
Small Landscaped Areas Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE(HD)	15	64	19	0.30	14	65	86
RE(MD, LD)	44	75	15	0.19	41	82	93
RE(APT/MF) CO(OFF), IS, FW	52	41	22	0.54	0.0	43	79
CO(SHOP), ID, OP	58	19	26	1.3	0.0	0.64	84

Table 120 shows the final land cover groups and their coefficients of variation for the land uses examined in the test areas in Jefferson County, AL. The analyses on medians for those land covers showed differences among land uses, especially for residential and institutional land use sub-categories. Generally, high-density residential areas grouped with the apartment/multiple family areas, and medium density residential areas grouped with low-density residential areas. Also, for most of the land covers, it was found that institutional school characteristics were statistically different than institutional church characteristics, which was closely related with the commercial area characteristics. For all land covers, except for the small landscaped areas, there were no statistical differences between the two commercial sub-categories. As expected, directly connected impervious areas and total pervious areas formed identical groupings of land uses. Also, connected and disconnected roofs resulted in the same land use groupings. In the study areas, commercial land uses had similar amounts of street and parking lots as institutional churches.

Table 120. Summary Table of Homogeneous Land Covers
for Jefferson County, AL Land Uses

Land Cover	Land Use	COV	Land Cover	Land Use	COV
Directly Connected Impervious Area	RE(HD,APT/MF),IS(SCH)	0.61	Paved Parking Lot Area	RE(HD), OP	3.3
	RE(MD, LD)	0.70		RE(APT/MF) IS(SCH), ID, FW	0.95
	CO, IS(CHU), ID	0.40		CO, IS(CHU)	0.42
	OP	1.2	Connected Roof Area	RE(HD, APT/MF)	0.99
Disconnected Impervious Area	RE	0.84		RE(MD, LD)	1.1
	CO, ID,OP	2.9		CO	0.69
	IS	0.99		IS, ID	0.73
	FW	0.13	Disconnected Roof Area	RE(HD, APT/MF)	0.77
Total Pervious Area	RE(HD,APT/MF), IS(SCH)	0.20		RE(MD, LD)	0.92
	RE(MD, LD)	0.15		CO, OP	4.8
	CO, IS(CHU), ID, FW	0.65		IS, ID	2.1
	OP	0.19	Small Landscaped Area	RE(HD)	0.30
Paved Street Area	RE, ID, OP	0.65		RE(MD, LD)	0.19
	CO, IS(CHU)	0.47		RE(APT/MF) CO(OFF), IS, FW	0.54
	IS(SCH)	1.0		CO(SHOP) ID, OP	1.3
	FW	0.13			

Data correlations, data reductions, and clustering were also used to find patterns and associations among the land covers and calculated runoff volume for the investigated land use categories. First, Pearson correlation matrices were used to measure the degree of association between land covers and calculated runoff volumes for the 170 neighborhoods representing eleven land use sub-categories found in the study areas. Next, cluster analyses were used to identify patterns that are more complex and associations in the data as a supplement to the simple correlations found using the Pearson matrix analyses. Parameters with short branches linking them are more closely correlated than parameters linked by longer branches. The advantage of a cluster analysis is the ability to identify complex correlations that cannot be observed using a simple correlation matrix, as summarized in the following paragraphs. SYSTAT10 (SPSS Inc., Chicago, IL) statistical software was used to carry out both the Pearson correlation matrices and the cluster analyses.

Runoff volume for each studied neighborhood was modeled using the Source Loading and Management Model (WinSLAMM) (Pitt and Voorhees 1995; 2002). The detailed land development characteristics of the 170 individual neighborhoods along with the pre-built runoff and rain files were used to generate runoff volumes for the study area. The RUNOFF.RSV and BHAM76.RAN files incorporated in the model were used for all runs. The runoff file is used by WinSLAMM to calculate the runoff volumes for each rain for each source area in each land use. It was initially developed based on extensive rainfall and runoff monitoring data collected in Toronto, Ontario, and in Milwaukee, WI, (as reported by Pitt 1987). The file was developed and verified using independent data sets collected over a broad range of conditions and for many rains. The model has also been verified using data collected from throughout the US, mainly during the EPA's Nationwide Urban Runoff Program (EPA 1983) and other stormwater research projects. The representative rain file was created using National Oceanic and Atmospheric Administration (NOAA) data as presented on EarthInfo, Inc. CD ROMs. This file includes the rain events for the entire 1976 year, which has been previously determined to be a representative rain year for the area, based on comparisons with long-term (about 52 year) rain records. Birmingham's rains are reasonably well distributed throughout the year. However, some of the wetter winter months, plus March and July, have twice the rainfall of October, the driest month. Summer rainfall is almost entirely from scattered afternoon and early evening thunderstorms. Serious droughts are rare and most dry spells are not severe.

It was found that for the Jefferson County, AL, study areas, the parking lots, connected rooftops, and streets were the major source areas of runoff (Table 121 and Figure 116). They were also the main directly connected impervious areas in the region. It was also found that the landscaped areas were the major pervious surfaces, while the disconnected rooftops were the major disconnected impervious surfaces. The analyses also showed that the pervious surfaces, especially landscape areas, had little influence on runoff volumes (Table 121 and Figure 116).

Table 121. Pearson's Correlation Matrix of Land Covers
for Jefferson County, AL Land Uses
(bold values are high correlations between pairs of parameters)

	DCIA	DSIA	PERVIOUS	STREET	PARKING	CONROOF	DISROOF	LANDSCAPE
DCIA	1.00							
DSIA	-0.39	1.00						
PERVIOUS	**-0.88**	-0.10	1.00					
STREET	0.35	0.41	**-0.60**	1.00				
PARKING	**0.84**	-0.13	**-0.84**	0.35	1.00			
CONROOF	**0.73**	-0.31	**-0.63**	0.12	0.51	1.00		
DISROOF	-0.23	0.48	0.00	-0.11	-0.21	-0.24	1.00	
LANDSCAPE	**-0.75**	-0.01	**0.82**	-0.48	**-0.72**	-0.57	0.06	1.00
RUNVOL	**0.89**	-0.16	**-0.88**	0.48	**0.83**	**0.68**	-0.30	**-0.79**

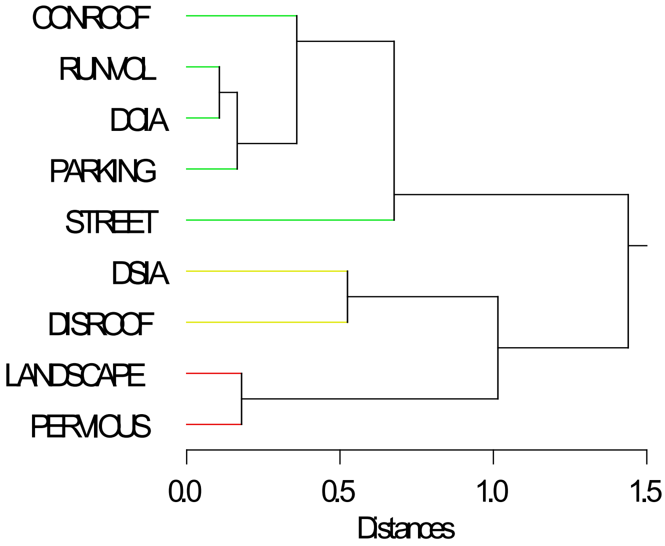


Fig. 116. Dendrogram from Cluster Analyses for Jefferson County, AL Land Covers
(Distance metric: 1-Pearson correlation coefficient. The linkage method: average)

These results were all as expected, as the modeling of runoff characteristics from urban areas has long been known to be closely related to the directly connected impervious source areas, and that, by definition, impervious areas are inversely related to pervious areas. These analyses also showed how the disconnected impervious areas are more strongly associated with the pervious areas than to the directly connected impervious areas. The following analyses take these relationships further by examining associations and differences between different land use categories in the overall objective of testing whether land use categories are an appropriate way of describing urban areas for stormwater analyses, instead of the simpler use of DCIA alone. As noted previously, land uses are expected to have unique patterns and mixtures of these surfaces, while activities taking place within the land use categories may further affect the runoff quality and its variability from these areas.

Cluster analyses were also used to identify similarities among land uses when land cover and runoff volume were the variables of interest. Figure 117 is a dendrogram showing the association of the Jefferson County land uses studied. This dendrogram confirmed the previous finding that the commercial shopping center and commercial office park land use sub-categories are not statistically significant based on the number of available samples. Statistical software G*Power 3.1.2 (Faul et al. 2009) was used to estimate the minimum required number of samples needed to enable accurate and reliable statistical judgments about the commercial land use sub-categories' significance (65 samples required versus 29 samples that the study had available). The land cover patterns in the institutional church land use category resemble the patterns seen in the commercial land use category, although the institutional schools land use category are similar to the high-density residential land uses. It was also confirmed that high-density residential land uses have similar land cover patterns to the apartment/multifamily category. Medium and low-density residential land uses are similar to the open space land uses.

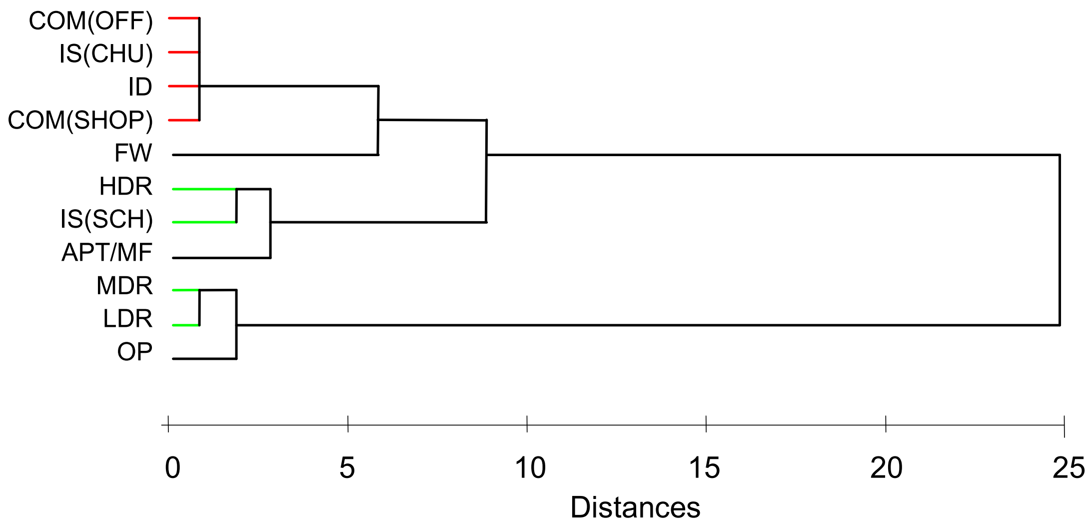


Fig. 117. Dendrogram from Cluster Analyses for Jefferson County, AL Land Uses (Distance metric: 1-Pearson correlation coefficient. The linkage method: average)

Figure 118 shows another approach to finding similarities among land uses. This figure plots the directly connected impervious area percentages (DCIA %) vs. the calculated volumetric runoff coefficients (Rv) for each of the 170 neighborhoods studied, color-coded by land use (excluding freeways, as the investigated freeways are all drained by grass swales).

A large body of research, some of which was described in the literature search, shows that in urban areas, as the runoff volume increases, the impacts on the receiving water also increase. The DCIA is the most single important parameter predicting this hydromodification, but the land use, and the activities that take place within the land use, are shown to affect the receiving water quality. As anticipated, the areas having the least expected impacts on water quality (those having the smallest Rv values, as indicated in the many references noted in the literature review) are the open space and low density residential land uses, while the greatest impacts are associated with commercial, industrial, and institutional land uses.

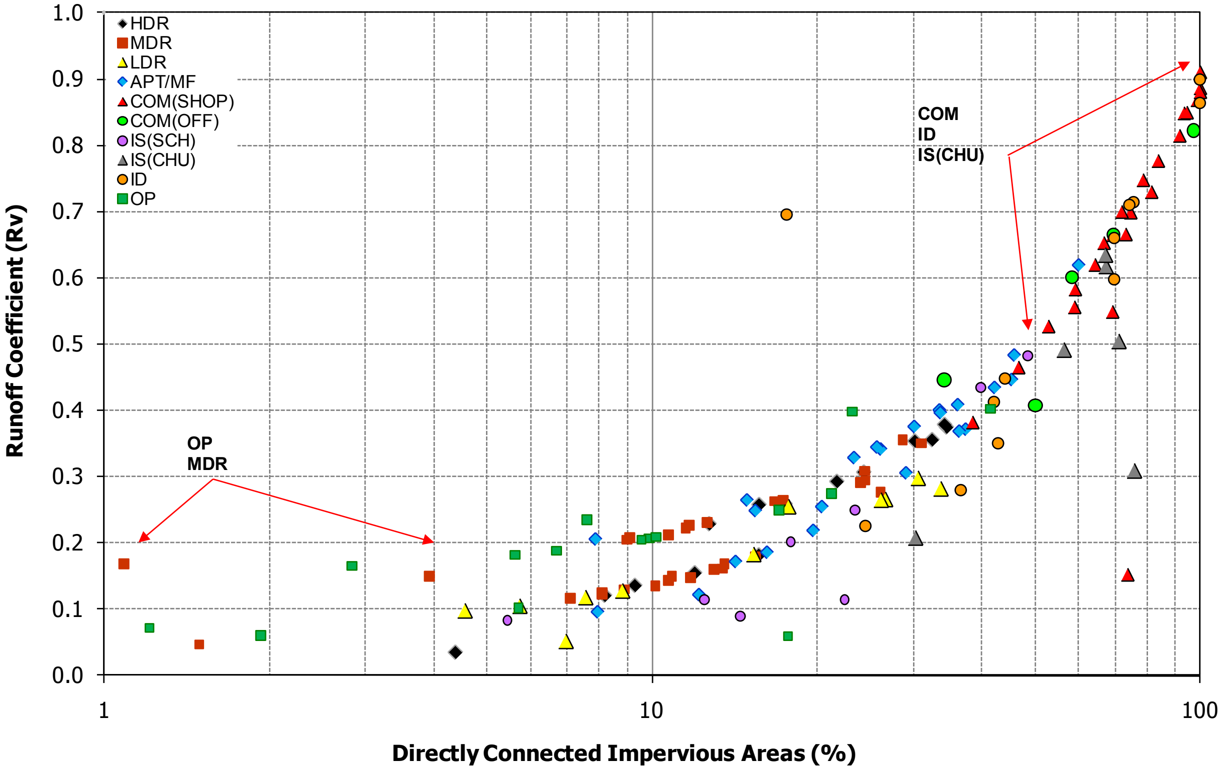


Fig.118. Relationships between the DCIA (%) and the Calculated Volumetric Runoff Coefficients (Rv) for Each Site Surveyed by Land Use

Figure 118 also shows the amount of stormwater volume control an area needs in order to reduce impacts on receiving waters. By reducing the effect of DCIA in an area, it is possible to change the effective land use characteristics and reduce the associated water quality impact

Principal component analyses (PCA), a variable reduction procedure, was conducted using SYSTAT 10 (SPSS Inc., Chicago, IL) to identify complex groupings of parameters by factors, so variables within each factor were more highly correlated with variables in that factor than with variables in other factors. The PCA procedure was used because of the large numbers of measured variables that might be redundant, meaning that the variables are correlated with each other possibly because they are measuring the same factor. In this case, the observed variables are reduced into a smaller number of uncorrelated variables (principal components) that account for most of the variability in the data set. Principal component analysis was used to identify relationships and natural groupings of the major land development characteristics and runoff volumes for the Jefferson County land uses studied.

Figure 119 and Table 122 display the eigenvalues of the correlation matrix for the nine land cover variables. The eigenvalues indicate that the first three components provide a reasonable summary of the data, accounting for 87% of the total variance. Subsequent components each contribute 5% or less. Figure 119 is a scree plot that shows the sorted eigenvalues from large to small and helps visualize the relative importance of the factors. The sharp drop in the plot signals that subsequent factors (those with eigenvalues under 1) can safely be ignored.

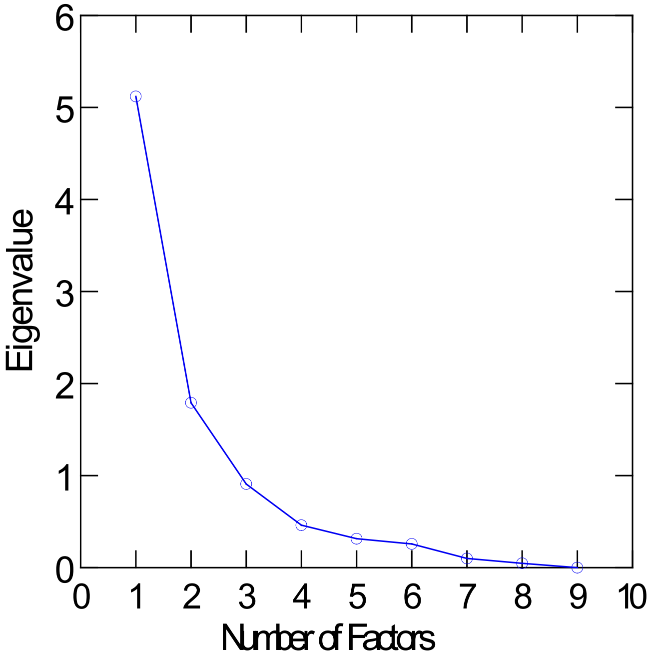


Fig. 119. Principal Components - Scree Plot of Land Covers for Jefferson County, AL

Table 122. Variance Explained by the Principal Components for Jefferson County, AL Land Covers Examined

Factor	**Variance Explained by Component**	**Percent of Total Variance Explained**	**Percent Cumulative Variance Explained**
PC1	5.1	57	57
PC2	1.8	20	77
PC3	0.91	10	87
PC4	0.46	5.1	92
PC5	0.31	3.5	96

Figure 120 and Table 123 show that the first component has large loadings associated with all impervious surfaces and the runoff volumes, suggesting that the first component is primarily a measure of directly connected impervious areas. The second component has high positive loadings on the pervious surface areas. The third component is not easily identified, but seems to account for disconnected impervious surfaces.

Figure 121 is a scatterplot of the values of the first two principal components for the eight land covers and runoff volumes of all 170 sites. The first two principal components account for 77% of the total variation in the data set, showing several groupings corresponding to neighborhoods having similar land covers. The first principal component, interpreted as a measure of the DCIA (Table 123), helped separate the 170 neighborhoods and explained 57% of the total variation in the data set (Table 122)

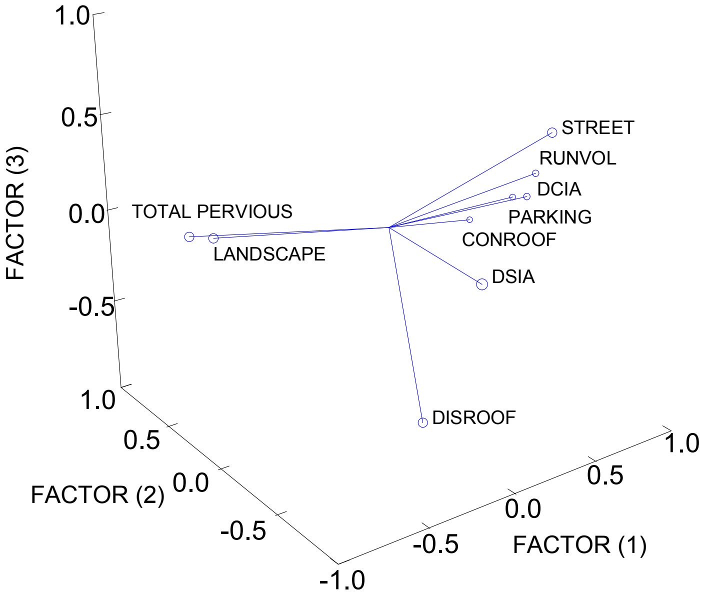


Fig. 120. Principal Components Loadings for Land Covers and Runoff Volume for Jefferson County, AL

Table 123. Factor Component Loadings by Land Cover Variable for Jefferson County, AL

Variables	Factor 1	Factor 2	Factor 3
Directly Connected Impervious Area	**0.948**	0.189	-0.125
Disconnected Impervious Area	-0.163	-0.919	**0.083**
Total Pervious Area	-0.941	**0.279**	0.091
Street Area	**0.514**	-0.576	0.546
Parking Lot Area	**0.880**	0.002	-0.046
Connected Roof Tops	**0.740**	0.290	-0.238
Disconnected Roof Tops	-0.253	-0.615	**-0.713**
Small Landscaped Area	-0.861	**0.194**	0.093
Runoff Volume	**0.957**	0.027	0.058

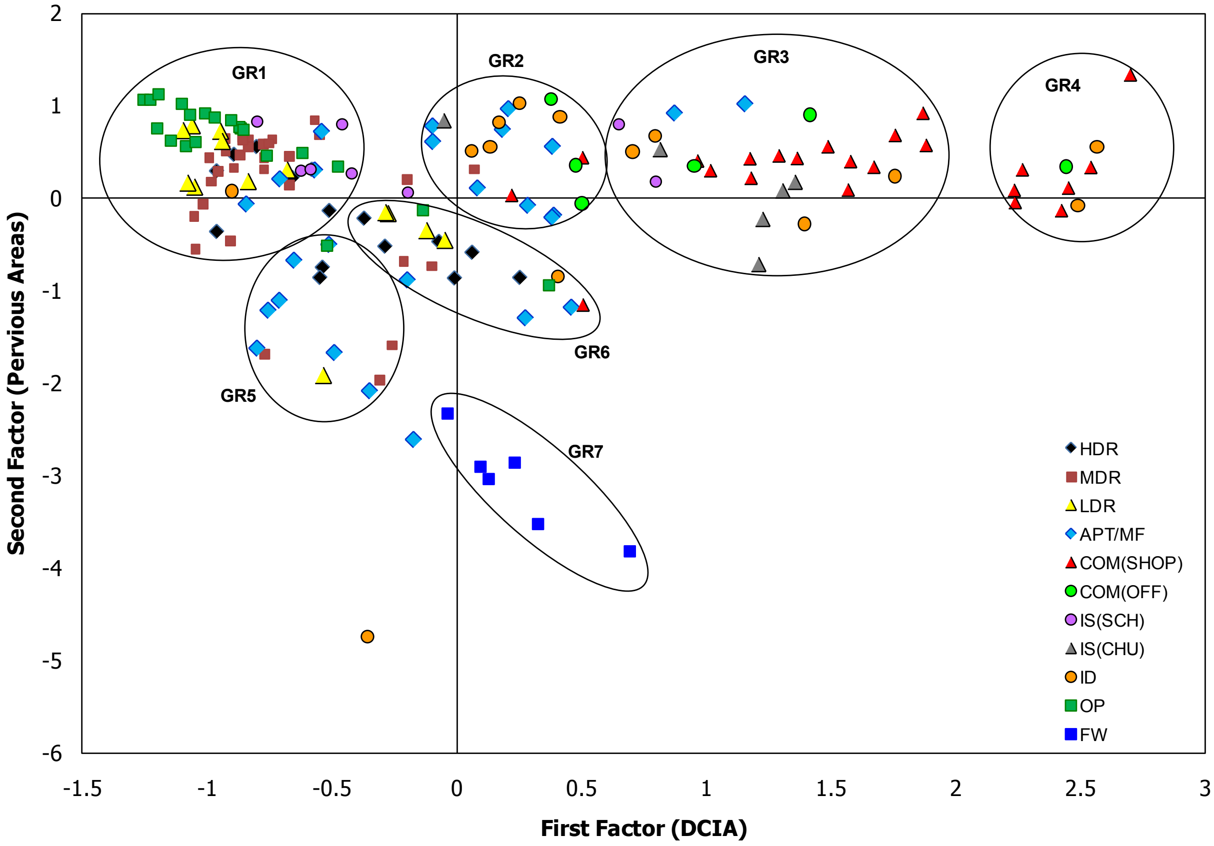


Fig. 121. Score Plot of Principal Components for Land Covers and Runoff Volume for Jefferson County, AL Land Uses Studied

Table 124 shows the land use percentages in each group: group 1 has mostly residential (medium and low density) and open space sites, group 3 has commercial, institutional church and industrial sites, and group 4 has again commercial and industrial sites, while group 7 is made up exclusively of freeways sites. Therefore, the land development characteristics in each of these major groups are consistent in explaining large portions of the variance.

Table 124. Land Use Percentages for Each Group

Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
HDR	10	MDR	4.8	APT/MF	7.1	**COM(SHOP)**	**70**	**HDR**	**14**	**HDR**	**32**	**FW**	**100**
MDR	**36**	**APT/MF**	**43**	**COM(SHOP)**	**46**	**COM(OFF)**	**10**	**MDR**	**21**	MDR	11		
LDR	**12**	**COM(SHOP)**	**9.5**	**COM(OFF)**	**7.1**	ID	20	LDR	7.1	**LDR**	**21**		
APT/MF	7.5	**COM(OFF)**	**14**	ID	14			**APT**	**43**	**APT**	**16**		
IS(SCH)	7.5	**ID**	**24**	IS(SCH)	7.1			OP	14	SHOP	5.3		
ID	1.5	IS(CHU)	4.8	**IS(CHU)**	**18**					ID	5.3		
OP	**25**									OP	11		
	100		100		100		100		100		100		100

5.2.2 Evaluation of Land Cover Variation by Watersheds

This section focuses only on the five urban watersheds from Jefferson County, AL, which are part of the local monitoring NPDES Phase 1 Stormwater Permit. Figure 122 is a box and whisker plot of directly connected impervious areas for the five Jefferson County urban drainage areas and illustrates the DCIA's variability among the watersheds examined. These variabilities are large likely because they each contain multiple land uses. Figure 123 is a probability plot used to check for the normality of the data.

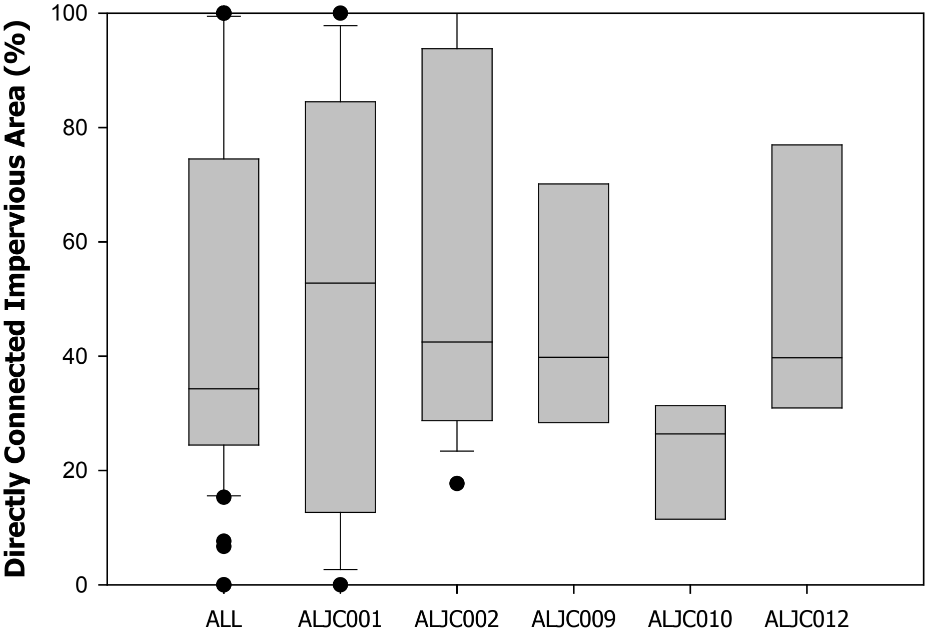
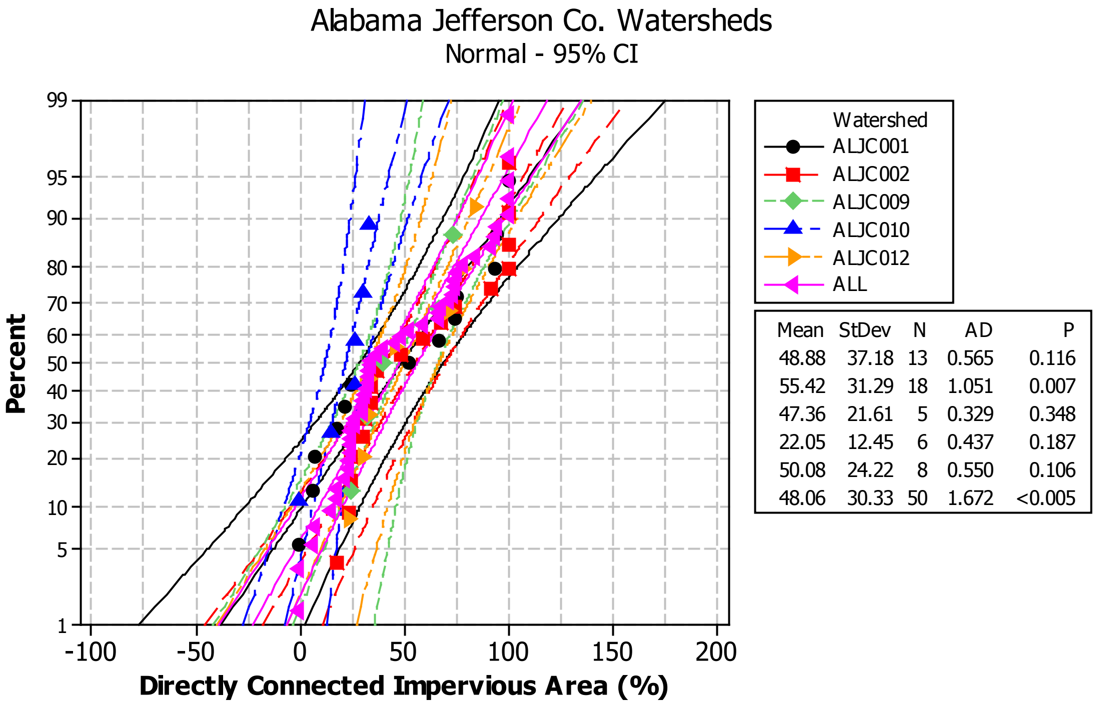


Fig. 122. Directly Connected Impervious Area – Jefferson County Watersheds



Mean	StDev	N	AD	P
48.88	37.18	13	0.565	0.116
55.42	31.29	18	1.051	0.007
47.36	21.61	5	0.329	0.348
22.05	12.45	6	0.437	0.187
50.08	24.22	8	0.550	0.106
48.06	30.33	50	1.672	<0.005

Fig. 123. Probability Distributions of Directly Connected Impervious Areas by Watersheds Examined in Jefferson County and Checks for Normality

The DCIA percentage data were not consistently normally distributed (the ALJC002 watershed was found to be statistically different from the normal distribution) and the sample sizes were small (with 5 to 13 homogeneous neighborhoods in each watershed). Therefore, the Kruskal-Wallis one-way analysis of variance by ranks was performed (Table 125). This analysis showed that no significant differences were present among the watersheds. The retrospective power analysis (Table 125) revealed that the available sample sizes were not large enough to detect differences in the DCIA land cover for the study watersheds. Increasing the alpha level did not adequately increase the power of the test to be able to conclude otherwise. The maximum difference between any two watersheds' mean DCIA is about 150%. This difference requires a minimum of 110 samples (at 5% significance level and 80% power) to facilitate accurate statistical judgments about DCIA significance. The available sample size (50) could detect differences among watersheds only if the differences in the DCIA's mean would be at least 230%. Since the differences in the watersheds' DCIA were smaller than the critical value, the DCIA data were lumped together in one homogeneous group based on the outcome of these analyses (Figure 124). Table 126 shows the basic statistics for the DCIA group.

Table 125. Nonparametric Analyses of Variance and Power Analyses for Directly Connected Impervious Areas - Jefferson County Watersheds

Kruskal-Wallis Test (Watersheds: % DCIA)

H = 5.52 DF = 4 P = 0.238
H = 5.53 DF = 4 P = 0.237 (adjusted for ties)

Watershed	N	Median	Ave Rank	Z
ALJC001	13	52.8	24.5	-0.3
ALJC002	18	42.5	29.3	1.4
ALJC009	5	39.8	26.2	0.1
ALJC010	6	26.4	13.4	-2.2
ALJC012	8	39.7	27.4	0.4
Overall	50		25.5	

Power of the Test (Watersheds: % DCIA)

Watershed	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	13	48.9	37.2
ALJC002	18	55.4	31.3
ALJC009	5	47.4	21.6
ALJC010	6	22.1	12.5
ALJC012	8	50.1	24.2

α level	Power (%)
0.20	69.5
0.15	63.0
0.10	54.2
0.05	***40.6***
0.01	18.6

Pooled Standard Deviation	29.8
Obtained Effect Size	0.34

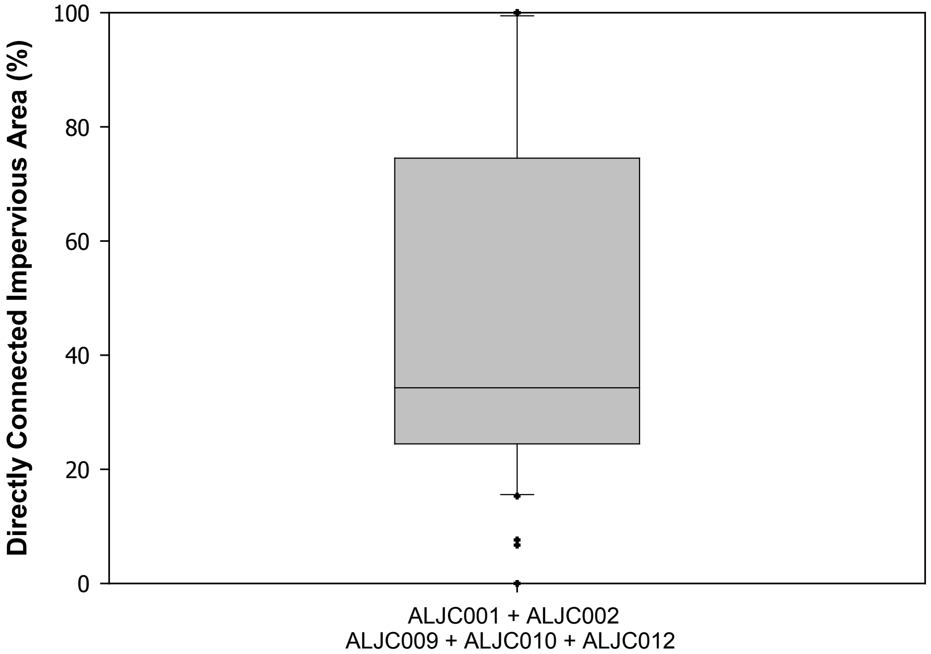


Fig. 124. Directly Connected Impervious Areas – Jefferson County Watersheds Homogeneous Group

Table 126. Basic Statistics for Jefferson County Watersheds –
Directly Connected Impervious Areas Homogeneous Group (%)

Groups (Predominant Land Use)	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001(ID) ALJC002(ID) ALJC009(HDR) ALJC010(LDR) ALJC012(CO)	50	48	30	0.63	0	34	100

Similar analyses were performed for disconnected impervious areas (DSIA), total pervious areas, paved streets, paved parking lots, connected roofs, disconnected roofs, and small landscaped areas, with the full analyses shown in (Appendix E). Figures 125 to 131 and Tables 127 to 133 show the clustered homogeneous groups along with their basic statistics for these other land covers.

For the disconnected impervious areas land cover, there were no statistically significant differences found among the five Jefferson County watersheds examined due to limited sample size. The maximum difference found among watersheds' DCIA means is about 170%. This difference requires a minimum sample size of 95 (at 5% significance level and 80% power) to give confidence about the statistical results. The available sample size (50) could detect differences among DCIA means only if the difference would be at least 250% for the study watersheds. Based on the outcome of these analyses the watersheds' disconnected impervious areas were grouped into a single homogeneous category (Figure 125 and Table 127).

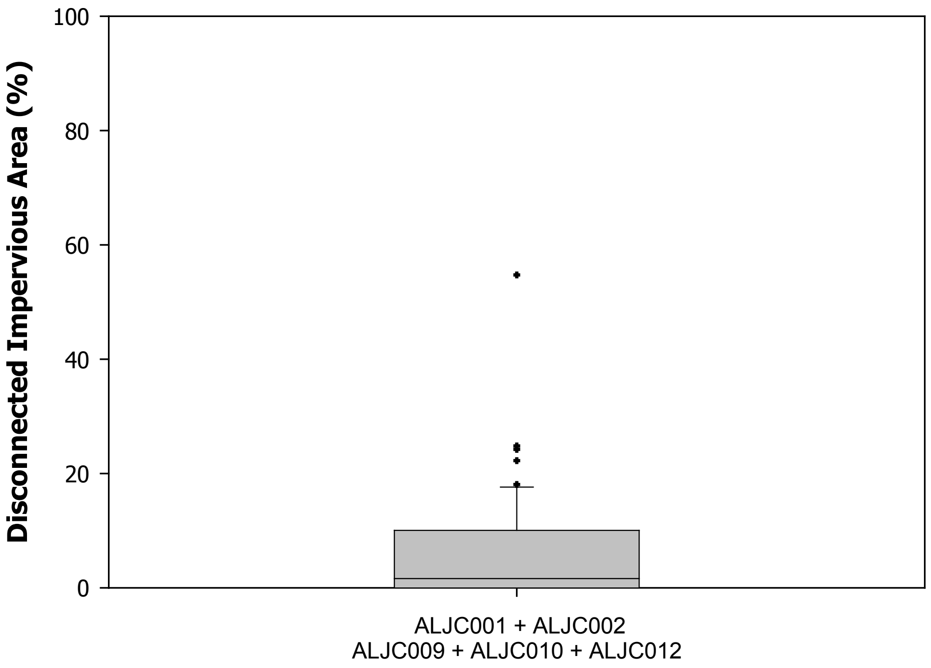


Fig. 125. Disconnected Impervious Areas –
Jefferson County Watersheds Homogeneous Group

Table 127. Basic Statistics for Jefferson County Watersheds –
Disconnected Impervious Areas Homogeneous Group (%)

Groups (Predominant Land Use)	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001(ID) ALJC002 (ID) ALJC009 (HDR) ALJC010 (LDR) ALJC012 (CO)	50	6.4	10	1.5	0	1.6	55

Since the investigation of directly connected impervious cover and disconnected impervious cover did not detect statistically significant differences among the Jefferson County watersheds examined, it was predicted that no significant difference would be found for total pervious areas. As expected, the analyses did not find statistically significant differences among the watersheds for total pervious areas land cover most likely because of limited sample size.

The actual difference found among pervious cover means is about 80% and requires a minimum sample size of 100 (at 5% significance level and 80% power) to offer confidence about the statistical results. The available sample size (50) could detect differences among pervious cover means only if the difference would be at least 160% for the study watersheds. Based on the outcome of these analyses, pervious cover data were lumped together in one homogeneous group (Figure 126 and Table 128).

Fig. 126. Total Pervious Areas –
Jefferson County Watersheds Homogeneous Group

Table 128. Basic Statistics for Jefferson County Watersheds –
Total Pervious Areas Homogeneous Group (%)

Groups (Predominant Land Use)	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001(ID) ALJC002 (ID) ALJC009 (HDR) ALJC010 (LDR) ALJC012 (CO)	50	46	27	0.59	0	54	100

However, the statistical analyses of paved street areas identified some significant differences among the five watersheds. It was found that the mostly industrial watersheds are similar with respect to the paved street area land cover, while mostly residential and commercial watersheds form a different group (Figure 127 and Table 129).

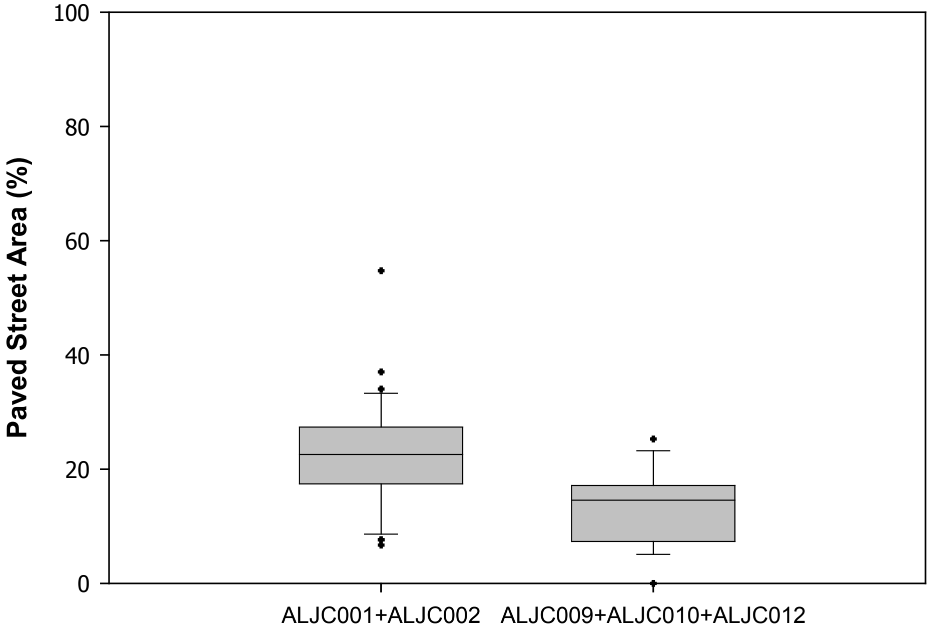


Fig. 127. Paved Street Areas –
Jefferson County Watersheds Homogeneous Groups

Table 129. Basic Statistics for Jefferson County Watersheds –
Paved Street Areas Homogeneous Groups (%)

Groups (Predominant Land Use)	**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
ALJC001(ID) ALJC002 (ID)	31	22	10	0.42	6.7	23	55
ALJC009 (HDR) ALJC010 (LDR) ALJC012 (CO)	19	13	6.7	0.50	0	15	25

For paved parking lot areas land cover, the statistical analyses failed to detect significant differences among the examined watersheds at the study's alpha level. No parking lot areas are present in the low-density residential watershed (ALJC010). The predominant high-density residential watershed (ALJC009) has a small commercial shopping center and an elementary school, so the watershed has a small amount of parking area. The maximum difference between any two watersheds for paved parking area means is about 80%. This difference requires a minimum of 590 samples (at 5% significance level and 80% power) to allow accurate statistical decisions about the watersheds' significance. The available sample size (44) could detect differences among paved parking lot area means only if the difference would be at least 300% for the study watersheds. Based on the outcome of these analyses, all parking lot data were grouped into one homogeneous category (Figure 128 and Table 130).

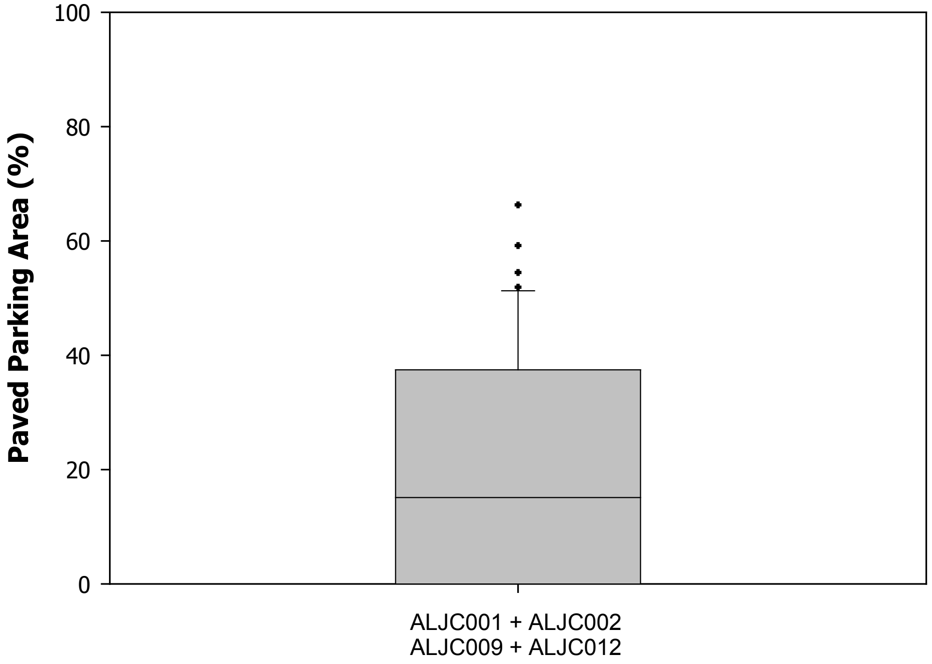


Fig. 128. Paved Parking Lot Areas –
Jefferson County Watersheds Homogeneous Group

Table 130. Basic Statistics for Jefferson County Watersheds –
Paved Parking Lot Areas Homogeneous Group (%)

Groups (Predominant Land Use)	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001(ID) ALJC002 (ID) ALJC009 (HDR) ALJC012 (CO)	44	20	20	1.0	0	15	66

The statistical analyses also failed to detect significant differences among watersheds when examining connected roof land covers. The maximum difference between any two watersheds for connected roof land cover means is about 160%. This difference requires a minimum of 130 samples (at 5% significance level and 80% power) to provide confidence about the statistical results. The available sample size (50) could detect differences among connected rooftop area means only if the difference would be at least 260% for the study watersheds. Based on the outcome of these analyses, all connected roof data were grouped together into one homogeneous category (Figure 129 and Table 131).

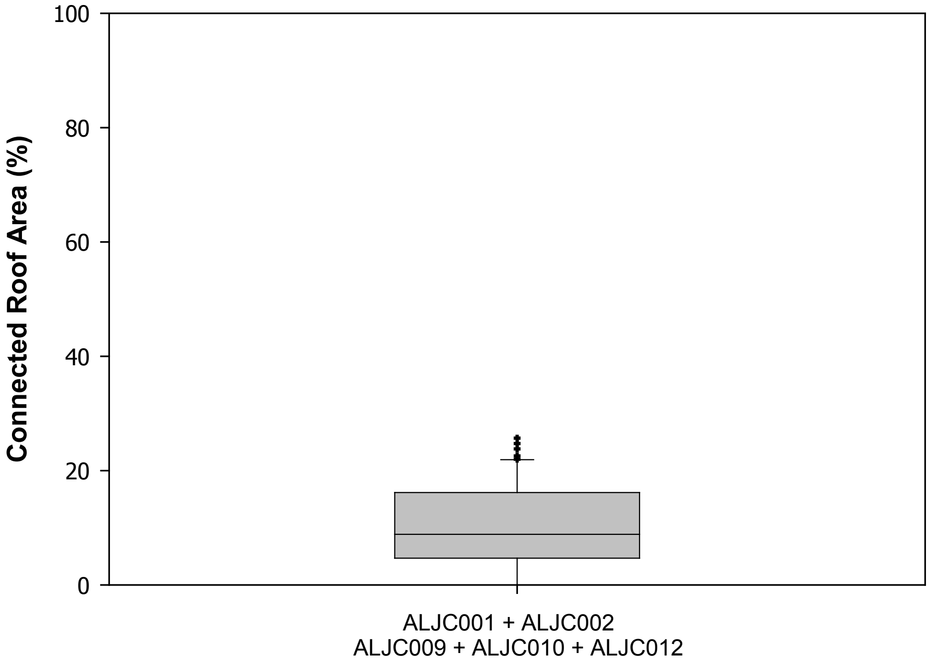


Fig. 129. Connected Roof Areas – Jefferson County Watersheds Homogeneous Group

Table 131. Basic Statistics for Jefferson County Watersheds –
Connected Roof Areas Homogeneous Group (%)

Groups (Predominant Land Use)	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001(ID) ALJC002 (ID) ALJC009 (HDR) ALJC010 (LDR) ALJC012 (CO)	50	10	7.7	0.76	0	8.8	26

For disconnected roof areas, it was expected that the five watersheds would group in a similar fashion to connected rooftop areas. As expected, the statistical analyses did not find significant differences among the watersheds for disconnected roofs land cover either. The maximum difference between any two watersheds for disconnected roof land cover means is about 70% (less than half the difference found for connected rooftop areas). This difference requires about 1300 samples (5% significance level and 80% power) to facilitate accurate statistical judgments about disconnected rooftop areas significance. The available sample size (50) could detect differences among disconnected roof area means only if the difference would be at least 350% for the study watersheds. As a result, all disconnected roof data were clustered into one homogeneous group (Figure 130 and Table 132).

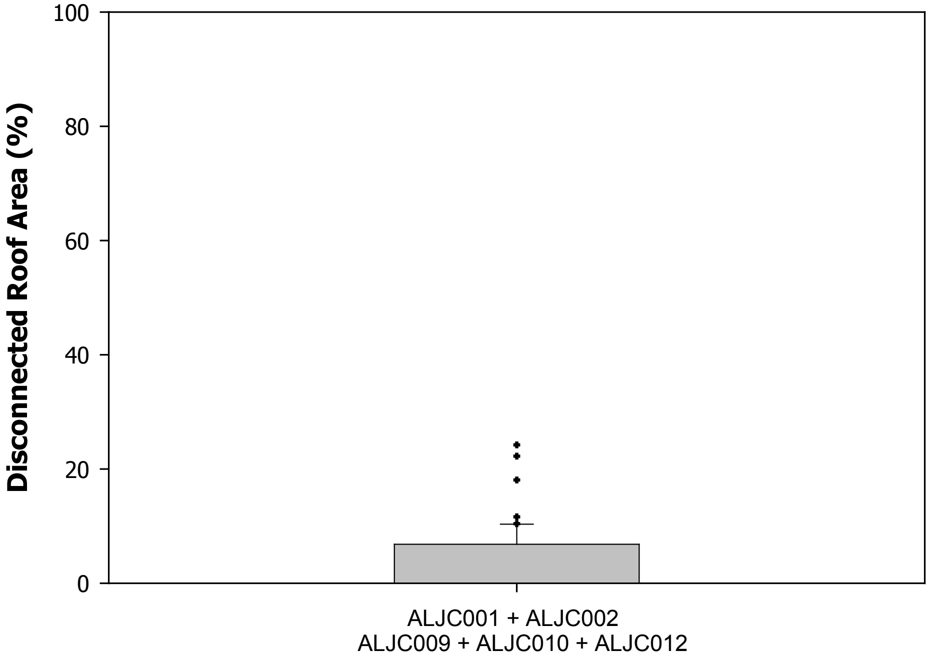


Fig. 130. Disconnected Roof Areas –
Jefferson County Watersheds Homogeneous Group

Table 132. Basic Statistics for Jefferson County Watersheds –
Disconnected Roof Areas Homogeneous Group (%)

Groups (Predominant Land Use)	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001(ID) ALJC002 (ID) ALJC009 (HDR) ALJC010 (LDR) ALJC012 (CO)	50	4.0	5.8	1.5	0	0	24

The statistical analyses found differences among watersheds for small landscaped area land cover. The ALJC012 watershed is mostly composed of commercial land uses without landscaped areas around buildings. The apartment portion of this watershed has no landscaped areas, but does have large undeveloped/forested areas. The landscaped area land cover for the Jefferson County watersheds examined was grouped in two categories: industrial and high-density residential watersheds, and low-density residential watersheds (Figure 131 and Table 133).

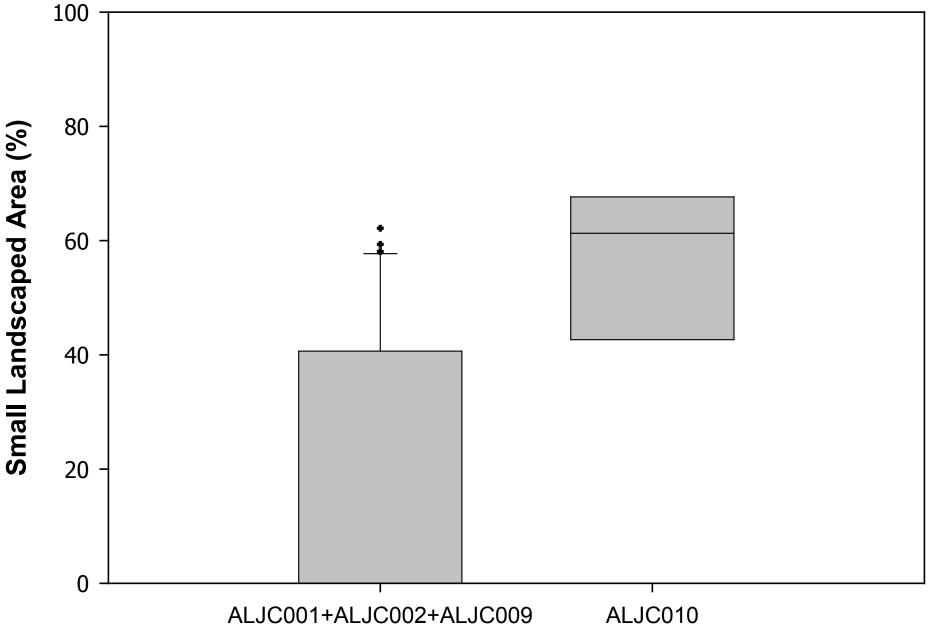


Fig. 131. Small Landscaped Areas –
Jefferson County Watersheds Homogeneous Groups

Table 133. Basic Statistics for Jefferson County Watersheds –
Small Landscaped Areas Homogeneous Groups (%)

Groups (Predominant Land Use)	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001(ID) ALJC002 (ID) ALJC009 (HDR)	36	17	23	1.4	0	0	62
ALJC010 (LDR)	6	54	27	0.51	0	61	77

The land covers analyses for the five urban drainage areas revealed that the available sample sizes were not large enough to detect differences among the watersheds. The only exceptions were the streets and landscape areas land covers, where the industrial watersheds were clearly different from residential watersheds.

Statistics such as data correlations, data reductions, and clustering were used as weight of evidence to demonstrate the correlations among the land covers, the rain depth, the calculated runoff volume, and the measured stormwater quality constituents for the investigated watersheds. Pearson correlation coefficients were used to relate the degree of associations among the above-mentioned variables for the five urban drainage areas from Jefferson County, AL. Pearson matrix is a good tool to show simple and linear relationships.

The runoff volume at the outfall was not monitored during the NPDES sampling process, thus this information had to be estimated through modeling. Rain files were created for each of the SWMA monitoring watersheds using the actual rain depth information gathered during the sampling events, along with rainfall data recorded at nearby stations and at the Birmingham International Airport that correspond to the actual monitored events. The rain files construction is described in detail in Appendix A. The watersheds' detailed development characteristics and local rain events were used as input for the Source Loading and Management Model (WinSLAMM) (Pitt and Voorhees 1995; 2002) to generate runoff volumes associated with each rain monitored at each outfall (Table D1 to D5 in Appendix D).

Table 134 shows the Pearson correlation coefficients that relate the associations of land covers and pollutant variables for the five urban drainage areas. The matrix shows several high correlations between pairs of parameters (>0.5). As an example, high correlations are seen between runoff volume and parking lot areas. These are also strong negative correlations between runoff volume, landscape areas, and disconnected rooftops. The matrix also shows high correlations among stormwater pollutants (except TSS and fecal coliforms) and street area land cover, suggesting that street area is a major source of major pollutants to the stormwater.

Table 134. Pearson's Correlation Matrix of Land Covers and Pollutant Concentrations for Jefferson County, AL Watersheds Studied (bold values are high correlations between pairs of parameters)

	DCIA	DSIA	Total Perv.	Street	P'king	Con. Roof	Dis. Roof	L'scape	Rain Depth	Run Vol.	TSS	Zn	Cu	Pb	TP	DP	N	TKN
DCIA	1.00																	
DSIA	-0.40	1.00																
Total Perv.	**-0.99**	0.25	1.00															
Street	0.43	0.48	**-0.55**	1.00														
P'king	**0.93**	**-0.52**	**-0.89**	0.30	1.00													
Con. Roof	**0.64**	-0.21	**-0.63**	-0.08	0.46	1.00												
Dis. Roof	**-0.70**	**0.76**	**0.60**	0.17	**-0.88**	-0.40	1.00											
L'scape	**-0.86**	**0.62**	**0.80**	-0.10	**-0.98**	-0.49	**0.96**	1.00										
Rain Depth	0.15	-0.20	-0.11	-0.24	0.46	0.05	**-0.65**	**-0.57**	1.00									
Run. Vol.	0.41	-0.35	-0.36	-0.05	**0.70**	0.08	**-0.81**	**-0.77**	**0.94**	1.00								
TSS	-0.01	-0.11	0.02	0.42	0.15	**-0.77**	-0.05	-0.07	0.00	0.18	1.00							
Zn	**0.60**	-0.27	**-0.60**	**0.65**	0.49	-0.06	-0.18	-0.34	-0.42	-0.10	**0.60**	1.00						
Cu	0.49	-0.04	**-0.52**	**0.69**	0.25	0.04	0.11	-0.08	**-0.69**	-0.42	0.39	**0.93**	1.00					
Pb	**0.51**	0.22	**-0.58**	**0.92**	**0.51**	-0.22	-0.12	-0.33	0.02	0.25	**0.66**	**0.72**	**0.61**	1.00				
TP	0.06	0.44	-0.14	**0.73**	0.19	**-0.57**	0.07	-0.06	0.26	0.35	**0.72**	0.32	0.19	**0.84**	1.00			
DP	0.44	0.28	**-0.51**	**0.67**	**0.57**	-0.09	-0.33	-0.48	**0.56**	**0.67**	0.39	0.22	0.05	**0.80**	**0.84**	1.00		
N	0.15	**0.50**	-0.26	**0.89**	-0.05	-0.26	0.49	0.26	**-0.62**	-0.46	0.46	**0.69**	**0.82**	**0.74**	**0.56**	0.29	1.00	
TKN	0.48	0.37	**-0.59**	**0.95**	0.26	0.06	0.22	-0.05	-0.49	-0.28	0.31	**0.76**	**0.86**	**0.81**	0.49	0.42	**0.93**	1.00
FC	**-0.52**	**0.53**	0.46	-0.17	**-0.78**	0.14	**0.80**	**0.79**	**-0.65**	**-0.85**	**-0.60**	-0.39	-0.03	**-0.53**	-0.48	**-0.64**	0.13	-0.01

Legend:

DCIA = directly connected impervious area
DSIA = disconnected impervious area
Total PERV = total pervious area (landscape, turf, undeveloped, etc)
Street = paved street area
P'king = paved parking lot area
Con. roof = connected roof tops
Dis. roof = disconnected roof tops
L'scape = small landscape area
Rain Depth = rain depth (in)
Run. Vol. = runoff volume (cu. ft)

TSS = total suspended solids (mg/L)
Zn = total zinc (ug/L)
Cu = total copper (ug/L)
Pb = total lead (ug/L)
TP = total phosphorous (mg/L)
DP = dissolved phosphorous (mg/L)
N = total nitrogen (mg/L)
TKN = Total Kjeldahl Nitrogen (mg/L)
FC = Fecal Coliform (Col/100mL)

The negative correlation between stormwater pollutants and total pervious areas also supports this finding. The major sources of fecal coliforms in stormwater seem to be the landscaped areas and disconnected impervious areas such as disconnected rooftops.

It is also interesting to note that TSS is only strongly correlated with total zinc, total lead and total phosphorus (and negatively correlated with fecal coliforms), indicating that TSS may not be as universal of a stormwater quality indicator of other stormwater contaminants as often assumed

Cluster analyses were used to identify complex patterns and associations between land covers and pollutant concentrations. First, cluster analyses were used to examine the correlations between land development characteristics and water quality parameters. Next, the clusters were used to find relationships between the individual urban drainage areas.

Figure 132 is a dendrogram produced by statistical software SYSTAT 10 (SPSS, Inc., Chicago, IL) using the same land development characteristics and stormwater quality data for these Jefferson County watersheds as used for the earlier Pearson correlation matrix analysis.

The two pairs of variables, runoff volume - rain depth and landscape areas - disconnected rooftops, which had high correlations in the Pearson matrix, are also seen to have strong simple relationships in the cluster analyses. In addition, it was found that water quality parameters were associated with each other and were in the same major branch as the directly connected impervious areas (except for fecal coliforms that are associated with the pervious area branch).

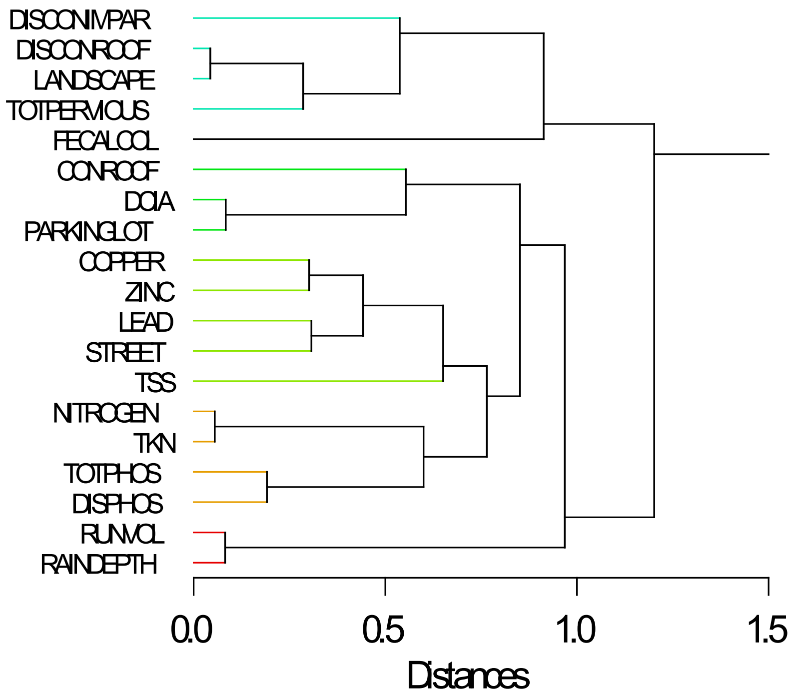


Fig. 132. Dendrogram from Cluster Analyses of Land Covers
and Water Quality Parameters for Jefferson County, AL Watersheds Studied
(Distance metric: 1-Pearson correlation coefficient. The linkage method: average)

Figure 133 shows another dendrogram from a cluster analyses used to identify relationships among the individual urban drainage areas when the land covers, the runoff volume, and the stormwater pollutant concentrations were the variables of interest. It was found that the two residential watersheds (ALJC009 and ALJC010) and the two industrial watersheds (ALJC001 and ALJC002), respectively form strong relationships and separate branches in the cluster analysis. The mostly commercial watershed (ALJC012) does not have a very strong relationship with any watershed, but it is more closely associated with the residential areas than with the industrial areas. This cluster analyses is a confirmation that similar land uses have similar land development and stormwater characteristics.

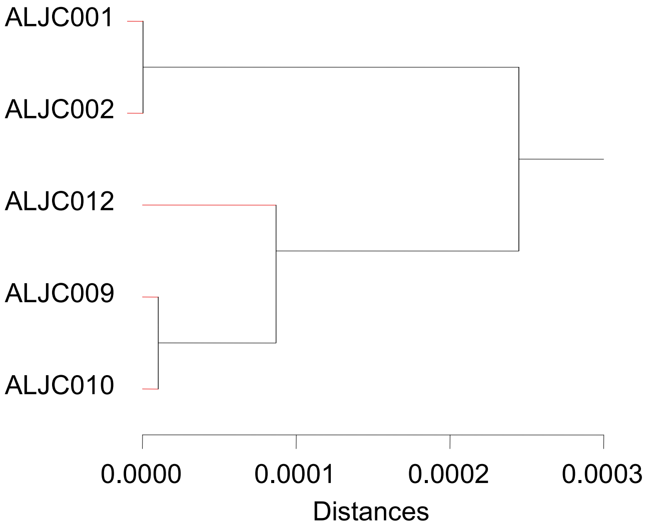


Fig. 133. Dendrogram from Cluster Analyses for Jefferson County, AL Watersheds (Distance metric: 1-Pearson correlation coefficient. The linkage method: average)

Principal component analyses (PCA) were used to identify complex groupings of parameters by factors, with variables within each factor being highly correlated. PCA also were used to identify similar watersheds. Figure 134 and Table 135 display the eigenvalues of the correlation matrix for the 19 variables (land covers and pollutant concentrations). The eigenvalues indicate that the first four components provide a reasonable summary of the data, accounting for 71% of the total variance in the data set. Figure 134 is a scree plot showing the sorted eigenvalues that help to visualize the relative importance of the factors.

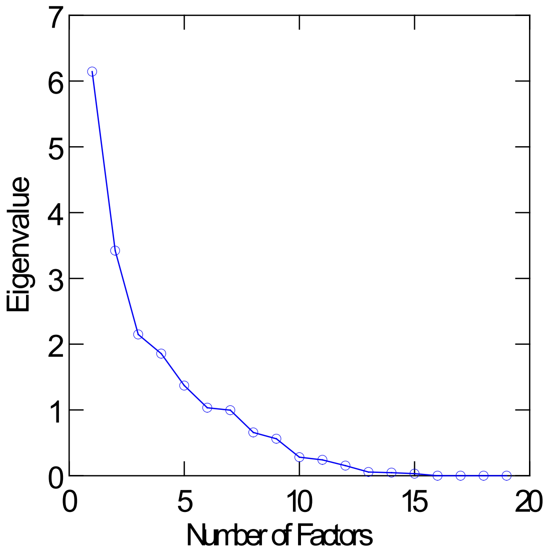


Fig. 134. Principal Components - Scree Plot of Land Covers and Stormwater Pollutant Concentrations for Jefferson County, AL Watersheds

Table 135. Variance Explained by the Principal Components for Jefferson County, AL Watersheds

Factor	**Variance Explained by Component**	**Percent of Total Variance Explained**	**Percent Cumulative Variance Explained**
PC1	6.1	32	32
PC2	3.4	18	50
PC3	2.1	11	62
PC4	1.9	9.8	71
PC5	1.4	7.2	79
PC6	1.0	5.4	84

Figure 135 and Table 136 show the first three principal components of the analysis. It can be seen that the first principal component has large loadings for street areas, parking lot areas, runoff volume, and the stormwater pollutants such as zinc, copper, and lead. This suggests that the first factor is primarily a measure of directly connected impervious surfaces, which are the major contributor of these metals in stormwater.

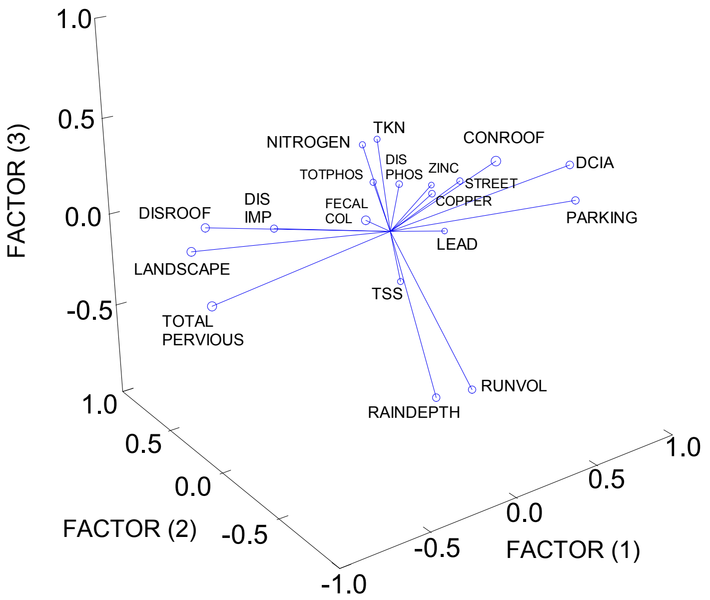


Fig. 135. Principal Components Loadings of Land Covers and Stormwater Pollutant Concentrations for Jefferson County, AL Watersheds

Table 136. Component Loadings by Variable for Jefferson County, AL Watersheds

Variables	**PC1**	**PC2**	**PC3**
Directly Connected Impervious Area	**0.909**	-0.265	0.223
Disconnected Impervious Area	-0.309	**0.566**	-0.101
Total Pervious Area	-0.901	**0.179**	-0.218
Street Area	**0.624**	0.487	-0.054
Parking Lot Area	**0.932**	-0.294	0.037
Connected Roof Tops	**0.267**	-0.462	0.444
Disconnected Roof Tops	-0.719	**0.533**	0.015
Small Landscaped Area	-0.865	**0.418**	-0.033
Rain Depth	**0.115**	-0.230	-0.847
Runoff Volume	**0.295**	-0.290	-0.833
TSS	0.334	**0.368**	-0.495
Total Zinc	**0.663**	0.296	0.019
Total Copper	**0.474**	0.287	-0.005
Total Lead	**0.669**	0.423	-0.309
Total Phosphorous	0.295	**0.557**	0.014
Dissolved Phosphorous	0.360	**0.417**	0.033
Total Nitrogen	0.323	**0.693**	0.176
TKN	0.385	**0.647**	0.207
Fecal Coliform	-0.152	-0.010	**0.099**

The second principal component has high positive loadings for the pervious surface areas, disconnected impervious areas, TSS, and the nutrient variables. The groupings of the third and subsequent components are difficult to identify.

Figure 136 is a scatterplot of the scores of the first two principal components for all of the 50 surveyed neighborhoods that were in the five Jefferson County watersheds studied. The score matrix contains information about the watersheds and the two-dimensional graph represents the relative position of the watersheds in the space of the principal components. The purpose of the score plot was to determine watersheds with similar behavior.

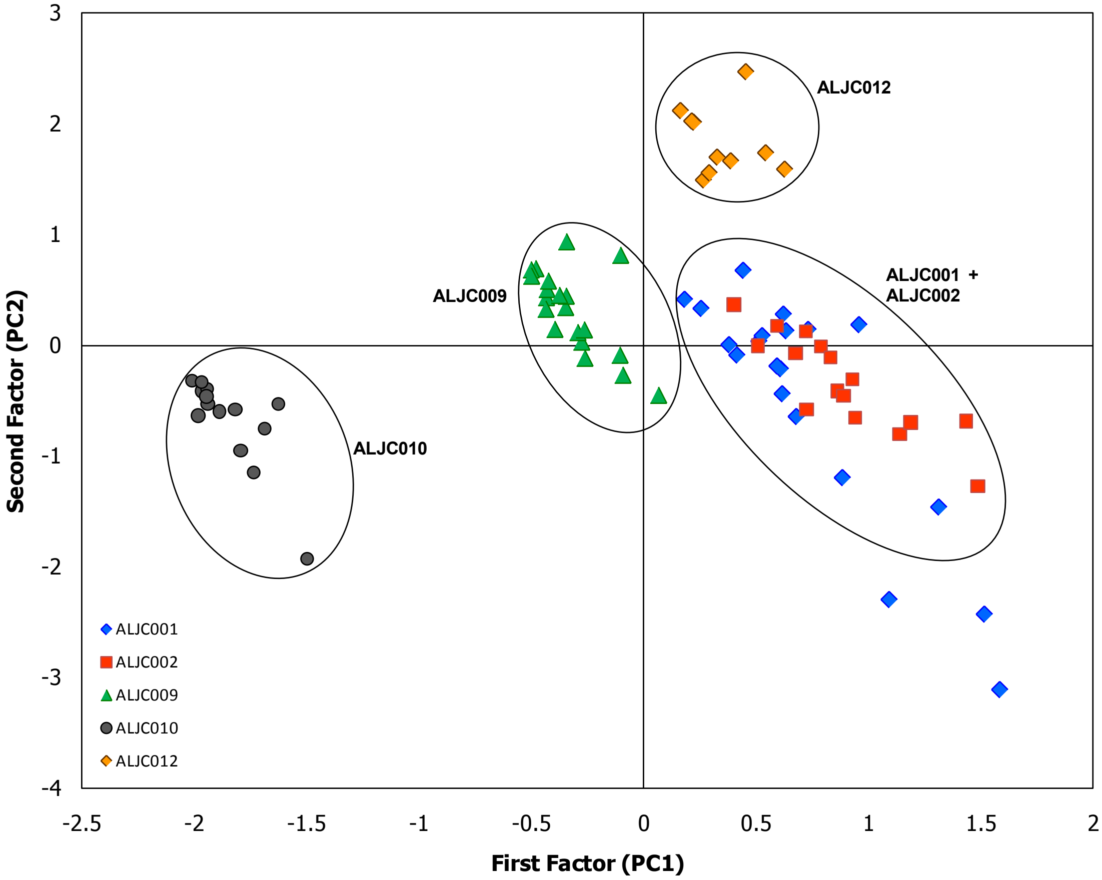


Fig. 136. Score Plot of Principal Components for Land Covers and Stormwater Pollutant Concentrations for Jefferson County, AL Watersheds Studied

Figure 136 shows groupings of samples corresponding to neighborhoods having similar land uses and stormwater pollutant concentrations.

Figure 137 is a biplot that overlays the scores and loadings for the first two components. The loading of a variable (DCIA, TSS, etc) indicates how much this variable participates in defining the principal components. Therefore, the biplot from Figure 137 shows the common features that the watersheds have. It can be observed from the plot that the industrial watersheds have the same loadings on the first and second principal component, meaning that they have very similar land covers (DCIA represented by streets and parking lots) and similar pollutant concentrations at the outfall. The dominant land cover in the commercial watershed seems to be the connected rooftops that generate large quantities of runoff. Even if the graph from Figure 136 shows that the two residential watersheds are highly separated from each other, Figure 137 shows that they actually have many common features, such as their major land covers: the disconnected impervious areas and pervious areas, and higher values of fecal coliforms. The residential watersheds have similar loadings on the second principal component (represented by pervious surfaces and disconnected impervious areas), but have dissimilar loadings on the first component represented by DCIA. This finding is expected since ALJC009 watershed (mostly high-density residential with some commercial and institutional land uses) has less pervious and more impervious cover than the ALJC010 watershed (low-density residential with a large portion of undeveloped/forestland).

Principal component analysis was used as a part of the weight of evidence to demonstrate the more complex correlations between land development and stormwater characteristics. In contrast, the cluster analyses did not show this depth of distinction among the watersheds.

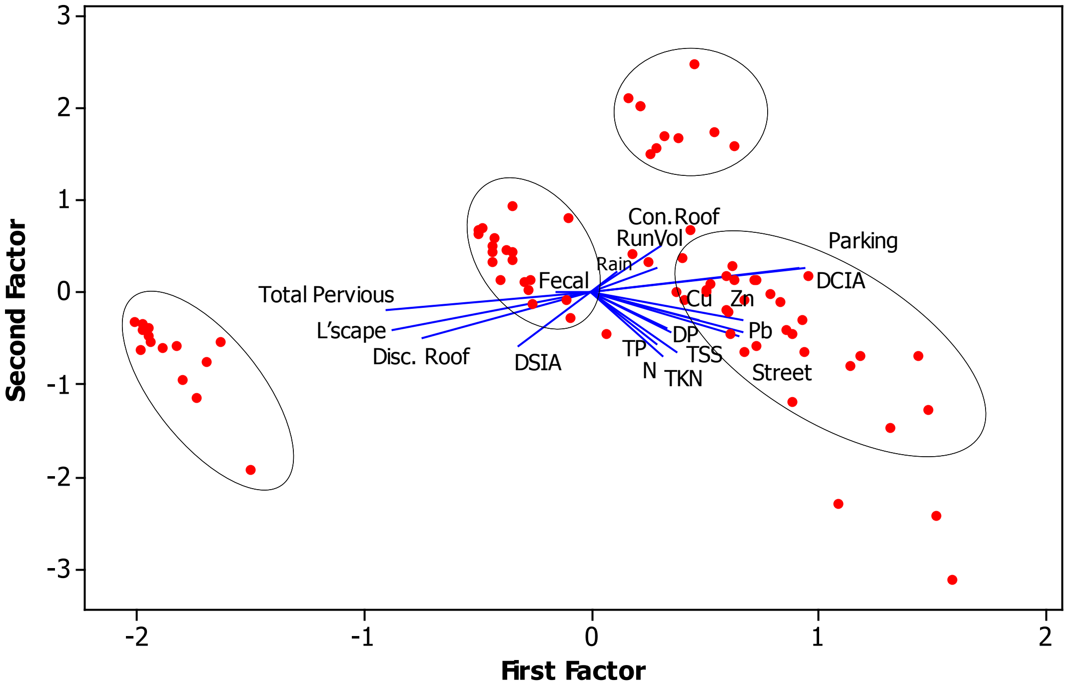


Fig. 137. Biplot (Scores and Loadings) of Principal Components for Land Covers and Stormwater Pollutant Concentrations for Jefferson County, AL Watersheds Studied (watershed labels are the same as on Fig. 136)

Another method used to check if the land uses' physical characteristics (aka land covers) have an influence on the pollutant concentrations involved more detailed investigations of EPA Rain Zone 2 in the NSQD, made possible by the increased data in this area, and by comparing those relationships to the final stormwater constituent clusters using the local Jefferson County, AL data. The Pearson's correlation matrix of land covers and pollutant concentrations for Jefferson County, AL watersheds related the local land covers with the pollutant concentrations. Therefore, each pollutant was compared only with the land cover that was previously determined to influence its concentrations (Table 137).

It was found that the commercial and institutional land use groupings for metals (total zinc, total copper, total lead), nutrients (dissolved phosphorous, and TKN), directly connected impervious areas, and street areas (which are the major land covers contributors of these pollutants) were significant. Residential and industrial land use groupings for total copper, total lead, total and dissolved phosphorous, total nitrogen, TKN, and also for street areas also were significant.

Table 137. Land Development Characteristics Association with Land Uses and Pollutant Concentrations

Total Zinc		DCIA		Street Areas	
Land Use	**COV**	**Land Use**	**COV**	**Land Use**	**COV**
RE	1.6	RE(HD,APT/MF) IS(SCH)	0.61	RE ID OP	0.65
CO **IS**	1.2	RE(MD, LD)	0.70	**CO** **IS**(CHU)	0.47
ID FW	1.2	**CO** **IS**(CHU) ID	0.40	IS(SCH)	1.0
OP	0.98	**OP**	1.2	FW	0.13

Total Copper		Street Area	
Land Use	**COV**	**Land Use**	**COV**
RE(FA,SP,WI) **ID** FW(FA,SP)	2.0	**RE** **ID** OP	0.65
RE(SU)	1.9	**CO** **IS**(CHU)	0.47
CO, IS FW(SU,WI)	1.5	IS(SCH)	1.0
OP	1.3	FW	0.13

Total Lead		DCIA		Street Area		Parking Area	
Land Use	**COV**	**Land Use**	**COV**	**Land Use**	**COV**	**Land Use**	**COV**
RE **ID** OP	2.4	RE(HD,APT/MF) IS(SCH)	0.61	**RE** **ID** OP	0.65	**RE** (APT/MF) **ID** IS(SCH) FW	0.95
CO **IS**	1.6	RE(MD, LD)	0.70	**CO** **IS**(CHU)	0.47	RE(HD), OP	3.3
FW	0.78	**CO** **IS**(CHU) ID	0.40	IS(SCH)	1.0	**CO** **IS**(CHU)	0.42
		OP	1.2	**FW**	0.13		

*Colored codes represent significant pollutant concentrations and land use/land cover groups

Table 137. – *Continued*

Total Phosphorous		Street Area	
Land Use	**COV**	**Land Use**	**COV**
RE(FA,SU)	1.5	**RE** **ID** OP	0.65
RE(SP,WI) CO **ID**	2.0	CO IS(CHU)	0.47
IS OP	0.79	IS(SCH)	1.0
FW	1.3	**FW**	0.13

Dissolved Phosphorous		Street Area		Parking Area	
Land Use	**COV**	**Land Use**	**COV**	**Land Use**	**COV**
RE(FA,SU,WI) **ID**(FA)	1.3	**RE** **ID** **OP**	0.65	RE(HD) OP	3.3
RE(SP) **CO** **IS**	1.0	**CO** **IS**(CHU)	0.47	**RE**(APT/MF) IS(SCH) **ID** FW	0.95
		IS(SCH)	1.0		
ID(SP,SU,WI) **OP** FW	0.97	FW	0.13	**CO** **IS**(CHU)	0.42

Total Nitrogen		DSIA		Street Area	
Land Use	**COV**	**Land Use**	**COV**	**Land Use**	**COV**
RE **CO** **ID**	0.99	RE	0.84	**RE** **ID** OP	0.65
		IS	0.99		
		FW	0.13	CO IS(CHU)	0.47
		CO **ID** OP	2.9	IS(SCH)	1.0
				FW	0.13

Total Kjeldahl Nitrogen		Street Area	
Land Use	**COV**	**Land Use**	**COV**
RE(FA,SP,SU) **CO**(FA,SP,WI) **IS**	1.0	**RE** **ID** OP	0.65
RE(WI) **ID**	1.2	**CO** **IS**(CHU)	0.47
CO(SU) FW	1.0	IS(SCH)	1.0
OP	0.29	FW	0.13

Fecal Colifoms		DSIA		Disconnected Roof Area		Small Landscaped Area	
Land Use	**COV**	**Land Use**	**COV**	**Land Use**	**COV**	**Land Use**	**COV**
RE(SP, WI) **CO**(SP, WI) **ID** FW	2.6	RE	0.84	RE(HD, APT/MF)	0.77	RE(HD)	0.30
		CO **ID** **OP**	2.9	RE(MD, LD)	0.92	RE(MD, LD)	0.19
RE(FA, SU) **CO**(FA, SU) **OP**	2.4	IS	0.99	**CO** **OP**	4.8	RE(APT/MF) CO(OFF) IS FW	0.54
		FW	0.13	IS ID	2.1	**CO**(SHOP) **ID** **OP**	1.3

*Colored codes represent significant pollutant concentrations and land use/land cover groups

In addition, commercial and industrial land use groupings for disconnected impervious area land cover and for both total nitrogen and fecal coliforms were significant.

5.3 Chapter Summary

This chapter examines the variability in land development characteristics for the Jefferson County, AL land uses studied, plus the five urban drainage areas that are part of the NPDES Phase 1 stormwater permit.

Estimation of stormwater characteristics is usually performed based on land use since many site features are consistent within each land use category. This approach is widely accepted since the stormwater quality parameters are related to the activities in the watershed, and on the types and magnitude of land covers in each land use. However, it is hypothesized that the major land uses (residential, commercial, institutional, industrial, open space, freeways) could be further divided into subcategories to better account for observed variabilities in stormwater characteristics (runoff volumes and pollutant concentrations), enabling more accurate predictions of stormwater discharges in unmonitored areas.

This chapter shows that it is beneficial to subdivide some, but not all, of the major land uses examined. Table 138 is a summary of the chapter findings showing the final land cover groups and their coefficients of variation for the land uses and watersheds examined in the Jefferson County, AL study area.

It was found that there are differences among the major land uses, especially for residential and institutional land uses, when comparing the land covers of the eleven land use subcategories from the Jefferson County, AL study area. In this area, high-density residential land uses have physical characteristics comparable to apartment/multiple family and institutional school land uses. Furthermore, medium density residential, low-density residential and open space land uses have similar physical characteristics.

Table 138. Summary Table of Homogeneous Land Covers for Jefferson County, AL Land Uses and Watersheds

Land Cover	Land Use	COV	Watersheds	COV
Directly Connected Impervious Area	RE(HD,APT/MF) IS(SCH)	0.61	ALJC001(ID, CO, FW) ALJC002 (ID, RE, CO) ALJC009 (HDR, IS, CO) ALJC010 (LDR,OP) ALJC012 (CO, APT)	0.63
	RE(MD, LD)	0.70		
	CO, IS(CHU), ID	0.40		
	OP	1.2		
Disconnected Impervious Area	RE	0.84	ALJC001(ID, CO, FW) ALJC002 (ID, RE, CO) ALJC009 (HDR, IS, CO) ALJC010 (LDR,OP) ALJC012 (CO, APT)	1.5
	CO, ID,OP	2.9		
	IS	0.99		
	FW	0.13		
Total Pervious Area	RE(HD,APT/MF) IS(SCH)	0.20	ALJC001(ID, CO, FW) ALJC002 (ID, RE, CO) ALJC009 (HDR, IS, CO) ALJC010 (LDR,OP) ALJC012 (CO, APT)	0.59
	RE(MD, LD)	0.15		
	CO, IS(CHU), ID, FW	0.65		
	OP	0.19		
Paved Street Area	RE, ID, OP	0.65	ALJC001(ID, CO, FW) ALJC002 (ID, RE, CO)	0.42
	CO, IS(CHU)	0.47		
	IS(SCH)	1.0	ALJC009 (HDR, IS, CO) ALJC010 (LDR,OP) ALJC012 (CO, APT)	0.50
	FW	0.13		
Paved Parking Lot Area	RE(HD), OP	3.3	ALJC001(ID, CO, FW) ALJC002 (ID, RE, CO) ALJC009 (HDR, IS, CO) ALJC012 (CO, APT)	1.0
	RE(APT/MF) IS(SCH), ID, FW	0.95		
	CO, IS(CHU)	0.42		
Connected Roof Area	RE(HD, APT/MF)	0.99	ALJC001(ID, CO, FW) ALJC002 (ID, RE, CO) ALJC009 (HDR, IS, CO) ALJC010 (LDR,OP) ALJC012 (CO, APT)	0.76
	RE(MD, LD)	1.1		
	CO	0.69		
	IS, ID	0.73		
Disconnected Roof Area	RE(HD, APT/MF)	0.77	ALJC001(ID, CO, FW) ALJC002 (ID, RE, CO) ALJC009 (HDR, IS, CO) ALJC010 (LDR,OP) ALJC012 (CO, APT)	1.5
	RE(MD, LD)	0.92		
	CO, OP	4.8		
	IS, ID	2.1		
Small Landscaped Area	RE(HD)	0.30	ALJC001(ID, CO, FW) ALJC002 (ID, RE, CO) ALJC009 (HDR, IS, CO)	1.4
	RE(MD, LD)	0.19		
	RE(APT/MF) CO(OFF), IS, FW	0.54		
	CO(SHOP) ID, OP	1.3	ALJC010 (LDR,OP)	0.51

It was also found that institutional schools are significantly different from institutional churches for the study areas. In this region, church land uses are closely related to commercial areas. The analyses did not find significant differences between the two commercial sub-categories (shopping centers and office parks) likely due to the limited number of samples for office parks sub-category.

The land cover analyses for the five urban drainage areas revealed that the available sample sizes were not large enough to detect significant differences among the watersheds. The only exceptions were for the street area and landscape area land covers, where the industrial watersheds are clearly different from residential watersheds. In addition, it was found that water quality parameters were associated with each other and their concentrations were largely influenced by the presence of the directly connected impervious areas, especially streets areas, and to a lesser extent parking lot areas. The only exception was for fecal coliforms bacteria that are associated with the pervious areas and disconnected rooftop areas.

The land development characteristics in conjunction with stormwater quantity/quality data were also analyzed for the five urban watersheds. It was found that the two residential watersheds (ALJC009 and ALJC010) and the two industrial watersheds (ALJC001 and ALJC002) were closely related, respectively to each other but not between the groups, indicating that the watersheds' physical characteristics have an influence on the pollutant concentrations at the outfall, along with likely differences in activities occurring within the land uses. The mostly commercial watershed (ALJC012) does not have a very strong relationship with any watershed, but it is more closely associated with the residential areas than with the industrial areas.

Chapter 6
Conclusions

6.1 Introduction

The purpose of this dissertation is to analyze the variability in land development characteristics and to examine how this can affect the variability in stormwater characteristics. Specifically, is “land use” an appropriate way to categorize these land development characteristics, in contrast to simpler descriptors such as directly connected impervious cover alone? Historically, land development characteristics for each land use have been assumed to be relatively consistent for an area. This research has shown that the manner land develops in an area can vary and this variability can affect stormwater characteristics. This dissertation tested the hypothesis using locally collected stormwater quality data, a calibrated stormwater model, and much information concerning local land development characteristics obtained during detailed site surveys. Information from throughout the nation was also used to verify these findings.

This research could assist communities and local governments understand the role land use/land cover has in impairing stormwater quality, therefore helping them make the investment in stormwater management and monitoring more effective. The stormwater managers’ concern with the high variability in stormwater quality and the associated uncertainty of being able to meet discharge requirements, even with extensive use of stormwater control practices, could be diminished by a better understanding of this variability. More appropriate discharge regulations that recognize this variability could also assist these decision makers to better use their limited financial resources and to maximize receiving water quality improvements. In addition, this research finding can assist the stakeholders, developers, or local governments in estimating pollutant loadings from land uses. These pollutant values could be use as a first estimate of the impact a proposed development project will have on the health of the watershed and waterbodies.

The stormwater characterization data are stored in the National Stormwater Quality Database (NSQD) version 3, which contains separate stormwater system outfall quality data for 8,602 separate events from 104 agencies and municipalities from 29 states, representing all of the nine EPA Rain Zones (not to be confused with EPA administrative regions). Unfortunately, a large number of the observations have non-detected values, or belong to “unknown”, or to mixed land use areas, and were therefore not available for use with this research. About 4,750 events represent single land use areas and were regarded as potentially useful. In order to have sufficient numbers of observations in each category, only the single land use data from the residential, commercial, and industrial areas were used to test the research hypothesis.

The selected stormwater constituent data from NSQD version 3 that were evaluated as part of this dissertation were: total suspended solids (mg/L), total zinc (µg/L), total copper (µg/L), total lead (µg/L), total phosphorous (mg/L), dissolved phosphorous (mg/L), total nitrogen (mg/L), Total Kjeldahl Nitrogen (mg/L), and fecal coliform (colonies/100mL). These constituents are a small fraction of all that are available in the NSQD and were selected as representative of stormwater quality constituents commonly monitored by regional authorities. These also have relatively large amounts of available data from throughout the US with usually few detection limit problems, and cover a range of concentration variabilities. Total nitrogen and

Total Kjeldahl Nitrogen were selected to compare conclusions for two very similar constituents that had greatly differing amounts of available data.

The data were originally separated into individual land use groups for each rain zone to check the variability of stormwater pollutants between land uses for each geographical area, but it was determined that the database did not have enough samples to achieve the desired 80% power for all of the planned statistic tests with this level of categorization. Even if the preliminary analyses found significant differences among the pollutant means for the three major land uses (residential, commercial, and industrial areas), the tests were not powerful enough (at the chosen alpha level) for the given differences to be accepted. Therefore, the data groupings could not be kept separate for all land use and geographical area subcategories. As an example (with 95% confidence and 80% power):

- Total copper subcategories in Rain Zone 5 would need to total at least 60 samples, ideally evenly divided among land uses, to statistically detect the largest 70% difference observed in the land use means. The overall 34 samples combined for all subcategories can only detect differences greater than about 95%.
- Total copper subcategories in Rain Zone 6 would need at least a total of 58 samples equally separated among land uses to statistically detect the largest 180% difference observed in the land use means. The total 37 available sample for all land uses combined can only detect differences greater than about 230%.
- Total lead subcategories in Rain Zone 1 would need at least 111 total samples to statistically detect the largest 120% difference observed in the land use means. The actual total of 93 samples can only detect differences greater than about 130%.

This research was conducted in two stages covering different spatial scales: (1) the first stage of the research examined the variabilities in stormwater characteristics at national, regional (EPA Rain Zone 2), and local (Jefferson County, AL) levels and related the land uses to pollutant loadings; (2) the second stage of the study examined the land use development characteristics based on actual local field measurements and explained how this variability (especially impervious cover) affects the variability in stormwater characteristics.

The examination of the stormwater characteristics' variability was performed by statistically evaluating the stormwater pollutant concentrations observed at single land use areas (residential, commercial, industrial) that have no controls at outfall or in the watershed, for all seasons, and for all EPA Rain Zones (except Rain Zone 8 which has no data) for selected constituents contained in the NSQD. In addition, EPA Rain Zone 2 (the Chesapeake Bay area) data were chosen for further detailed analyses due to the availability of large amounts of data in this one area of the country as contained in the NSQD. Local stormwater data from five urban watersheds located in Jefferson County, AL were also analyzed in detail. The results of the local data analyses were compared to the results obtained from the national and EPA Rain Zone 2 analyses to examine the transferability of findings from different scales, and for different amounts of data.

The assessment of the land use development characteristics was completed by statistically evaluating field data collected from the Little Shades Creek watershed and five Jefferson County drainage basins. About 170 individual homogeneous neighborhoods within the watersheds were evaluated in detail to compare the variabilities of development characteristics within different land use categories. The land development characteristics studied during this research included: directly connected impervious areas, disconnected impervious areas, total pervious areas, paved streets, paved parking lots, connected and disconnected roofs, and small landscaped areas. These characteristics were examined using different association and pattern recognition statistical tools to establish if land cover similarities (or significant differences) exist among land uses and among watersheds, and if these relationships were also similar for stormwater quality characteristics.

6.2 Dissertation Research Hypothesis

The hypothesis for this dissertation states that ***the variability of development characteristics for different land uses explains an important portion of the variability of observed stormwater characteristics. Activities conducted in the land uses also significantly affect observed stormwater quality.***

This hypothesis was evaluated by testing the following three assumptions, listed below along with the observations constituting the weight-of-evidence obtained during this research:

Assumption 1: ***Variability in stormwater quality characteristics is less within each land use category than between the land use categories.***

Many factors can be considered when examining the quality of stormwater. These factors include, but are not limited to land use, geographical region (EPA rain zone), and season. This research tested if these three factors, individually or in combination (3 main land uses; 8 regions; and 4 seasons corresponding to 96 separate categories), had significant influences on the stormwater constituents' concentrations. The research also showed the importance of having large sample sizes when dealing with stormwater pollutant concentrations at the national level.

When the 2-way interactions between the geographical regions and the land use categories were examined, it was found that the national data could be combined into a reasonable number of significantly different subsets having similar characteristics. These groups of data have concentrations that are more similar within the group than between the groups. These groupings of the data can be used to assist local stormwater managers in estimating likely stormwater concentrations for similar local conditions. Examining 3-way interactions, by adding seasonal data to the geographical regions and land use information, did not result in many additional category distinctions associated with seasonal effects on stormwater concentrations. Table 139 shows the combined categorical groupings of the national data, with the limited seasonal distinctions.

Table 139. Summary Table of National, Regional, and Local Homogeneous Groups

Stormwater Constituent	All EPA Rain Zones Land Use	Mean (COV)	EPA Rain Zone 2 Land Use (Season)	Mean (COV)	Jefferson County Land Uses (Watershed)	Mean (COV)
Total Suspended Solids	1-RE,CO,ID 4-RE,CO,ID 6-RE,CO 9-CO,ID	199 (1.9)	RE(FA,WI) IS(SU,WI)	60 (1.7)	ID, CO, FW (ALJC001) ID, RE, CO (ALJC002)	82 (0.89)
			RE(SP,SU) FW	82 (1.5)		
	2-RE 3-RE,CO,ID	76 (1.6)	CO ID	86 (1.7)	RE, OP(ALJC010) CO, RE(ALJC012)	50 (0.76)
	2-CO,ID 5- RE,CO,ID 7- RE,CO,ID 9-RE	78 (1.9)	IS(FA,SP)	110 (0.68)	RE, IS, CO (ALJC009)	23 (0.59)
			OP	32 (1.2)		
Total Zinc	1-RE	59 (1.9)	RE	87 (1.6)	ID, CO, FW (ALJC001)	78 (0.50)
	1-CO,ID 2-RE 3-RE,CO,ID 5-RE,CO,ID	92 (1.6)	CO IS	268 (1.2)	ID, RE, CO (ALJC002)	172 (0.46)
	2-ID 7-RE,CO,ID 9-RE,CO,ID	163 (2.3)	ID FW	169 (1.2)	CO, RE(ALJC012)	39 (0.48)
	2-CO 4-RE,CO,ID 6-RE,CO	261 (1.2)	OP	21 (0.98)		

Table 139. – *Continued*

Stormwater Constituent	**All EPA Rain Zones Land Use**	**Mean (COV)**	**EPA Rain Zone 2 Land Use (Season)**	**Mean (COV)**	**Jefferson County Land Uses (Watershed)**	**Mean (COV)**
Total Copper	1-RE,ID 3-RE,CO,ID 5-RE,CO,ID 6-RE,CO	11 (2.3)	RE(FA,SP,WI) FW(FA,SP), ID	22 (2.0)	ID, CO, FW (ALJC001)	26 (0.61)
	2-RE,ID 7-RE,CO,ID	25 (1.9)	RE(SU)	35 (1.9)	ID, RE, CO (ALJC002)	59 (0.56)
	1-CO 2-CO 9-RE,CO,ID	36 (1.2)	CO, IS, FW(SU,WI)	33 (1.5)		
	4-RE,CO,ID	86 (1.9)	OP	8.2 (1.3)		
Total Lead	1-RE, CO,ID 2-RE,ID 3-CO,ID 5-RE 7-(RE,CO) (SP,SU)	17 (2.3)	RE ID OP	16 (2.4)	ID, CO, FW (ALJC001) ID, RE, CO (ALJC002)	25 (0.52)
	3-RE	8.4 (4.7)	CO IS	38 (1.6)	RE, IS, CO (ALJC009) CO, RE(ALJC012)	5.2 (0.78)
	2-CO 4-RE,CO,ID 5-CO,ID 6-RE,CO 7-(RE,CO) (FA,WI),ID 9-RE,CO,ID	44 (1.9)	FW	57 (0.78)		
Total Phosphorous	1-CO 3-RE,ID 5-CO	0.17 (1.2)	RE(FA,SU)	0.45 (1.5)	ID, CO, FW (ALJC001)	0.44 (0.68)
	1-RE,ID 2-RE,CO,ID 3-CO 4-RE,CO,ID 5-RE,ID	0.38 (1.7)	RE(SP,WI) CO ID	0.35 (2.0)	ID, RE, CO (ALJC002) RE, IS, CO (ALJC009) RE, OP(ALJC010) CO, RE(ALJC012)	0.25 (0.60)
	7-RE,CO,ID	0.3 (1.2)	IS OP	0.24 (0.79)		
	6-RE,CO 9-RE,CO,ID	0.52 (0.67)	FW	0.95 (1.3)		
Dissolved Phosphorous	1-ID 3-RE,CO,ID 5-CO 7-(RE,CO,ID) (SP,WI)	0.11 (1.5)	RE(FA,SU,WI) ID(FA)	0.26 (1.3)	ID, CO, FW (ALJC001)	0.31 (0.88)
	1-RE,CO 2-RE,CO,ID 4-RE,CO,ID 5-RE,ID 6-RE 9-RE,CO,ID	0.22 (1.1)	RE(SP) CO IS	0.19 (1.0)	ID, RE, CO (ALJC002) RE, IS, CO (ALJC009) RE, OP(ALJC010) CO, RE(ALJC012)	0.15 (0.49)
	7-(RE,CO,ID) (FA)	0.94 (0.71)	ID(SP,SU,WI) OP FW	0.14 (0.97)		

Table 139. – *Continued*

Stormwater Constituent	**All EPA Rain Zones Land Use**	**Mean (COV)**	**EPA Rain Zone 2 Land Use (Season)**	**Mean (COV)**	**Jefferson County Land Uses (Watershed)**	**Mean (COV)**
Total Nitrogen	1-RE,CO,ID 3-(RE,CO,ID) (FA,SP)	1.7 (0.79)	RE CO ID	4.3 (0.99)	ID, CO, FW (ALJC001) ID, RE, CO (ALJC002) RE, IS, CO (ALJC009) RE, OP(ALJC010)	2.1 (0.63)
	3-(RE,CO,ID) (SU,WI)	0.98 (0.98)				
	2-RE,CO,ID 4-RE,CO,ID 9-RE,CO,ID	3.2 (0.78)			CO, RE(ALJC012)	1.2 (0.53)
Total Kjeldahl Nitrogen	1-RE,CO,ID 2-RE,CO,ID 3-CO,ID 4-RE,CO,ID 5-RE,CO,ID 7-(RE,CO) (FA,SU), ID	1.8 (0.99)	RE(FA,SP,SU) CO(FA,SP,WI) IS	1.9 (1.0)	ID, CO, FW (ALJC001) ID, RE, CO (ALJC002) RE, IS, CO (ALJC009)	1.6 (0.73)
	3-RE 7-(RE,CO) (SP,WI)	0.97 (0.90)	RE(WI) ID	1.5 (1.2)		
	6-RE,CO 9-RE,CO,ID	3.6 (0.73)	CO(SU) FW	2.4 (1.0)	RE, OP(ALJC010) CO, RE(ALJC012)	0.93 (0.66)
			OP	0.59 (0.29)		
Fecal Colifom	1-(RE,CO,ID) (FA,SP,WI) 2-(RE,CO,ID) (SP,WI) 3-(RE,CO,ID) (SP,WI) 4-ID 7-RE,CO,ID 9-(RE,CO,ID) (SP)	29120 (8.2)	RE(SP, WI) CO(SP, WI) ID FW	13635 (2.6)	ID, CO, FW (ALJC001) ID, RE, CO (ALJC002) RE, IS, CO (ALJC009) RE, OP(ALJC010) CO, RE(ALJC012)	1975 (2.0)
	1-(RE,CO,ID) (SU) 2-(RE,CO,ID) (FA,SU) 3-(RE,CO,ID) (FA,SU) 4-RE,CO 5-RE,CO,ID 6-RE 9-(RE,CO,ID) (FA,SU)	40286 (3.0)	RE(FA, SU) CO(FA, SU) OP	25344 (2.4)		

At the national level (Figure 22, Chapter 4), EPA Rain Zones 1, 3, and 5 were found to have statistically significant differences in land use categories only for total suspended solids. There were no data for total nitrogen in EPA Rain Zone 5 and 6, therefore these comparisons could not be performed. However, EPA Rain Zone 1 and 3 did not have statistically significant differences in land use categories for total nitrogen. EPA Rain Zones 1 and 2 were found to also have statistically significant differences in land use categories only for total suspended solids. Also, EPA Rain Zones 2 and 5 were not found to have statistically significant differences in land use categories, except for total copper. In addition, EPA Rain Zones 6 and 9 were not found to have statistically significant differences in land use groups, except for metals (total zinc and total copper).

Table 140 is a summary of the coefficients of variation separated by land uses and rain zones, compared to the overall variations. The pollutant concentration variabilities within each land use category were generally lower than the overall variabilities, and separating the data by geographical area also reduced the variations in each subcategory. The land uses with the most exceptions to this were the residential and freeways land uses.

Table 140. Coefficients of Variation Summary by EPA Rain Zone and Land Use

Stormwater Pollutant	**Land Use**	**RZ 1**	**RZ 2**	**RZ 3**	**RZ 4**	**RZ 5**	**RZ 6**	**RZ 7**	**RZ 9**	**ALL Rain Zones**
Total Suspended Solids	ALL LUs	1.3	1.6	1.8	1.7	1.0	2.6	1.0	1.4	**2.2**
	Residential	1.2	1.6	2.0	1.8	0.87	0.76	0.89	1.5	2.2
	Commercial	1.2	1.8	1.9	1.4	1.0	1.0	1.1	1.5	1.8
	Industrial	1.4	1.1	1.4	1.4	0.46		1.2	1.1	1.5
	Institutional	0.69	0.97							0.92
	Open Space	0.56	1.2		0.97					1.8
	Freeways		1.6	1.4			2.8*	0.86		2.6
Total Zinc	ALL LUs	1.8	1.5	1.4	1.3	1.2	1.1	2.7	1.4	**3.3**
	Residential	1.9	1.6	1.1	1.6	1.0	1.2	0.67	0.95	1.6
	Commercial	1.7	1.2	1.5	1.0	0.76	0.44	1.2	0.62	1.4
	Industrial	1.1	1.0	1.2	1.1	0.33		2.9	1.3	2.3
	Institutional	0.24	0.92							0.90
	Open Space		1.0		0.74					1.0
	Freeways		1.3	1.0		1.3	1.1	0.78		1.4
Total Copper	ALL LUs	1.4	1.8	4.3	1.9	1.5	1.6	0.95	1.0	**2.1**
	Residential	2.3*	2.0	3.3*	1.8	0.28	1.5	1.0	0.83	2.2
	Commercial	0.86	1.4	1.6	1.1	0.81	0.40	0.80	0.70	1.4
	Industrial	1.7	1.8	1.1	1.9	0.37		0.74	1.1	2.8
	Institutional	0.39	0.74							0.67
	Open Space	0.14	1.3		0.69					1.2
	Freeways		2.0	3.7*		1.8	1.4	0.81		2.2

Table 140. - *Continued*

Stormwater Pollutant	**Land Use**	**RZ 1**	**RZ 2**	**RZ 3**	**RZ 4**	**RZ 5**	**RZ 6**	**RZ 7**	**RZ 9**	**ALL Rain Zones**
Total Lead	ALL LUs	0.94	1.9	3.6	2.1	0.94	1.5	1.3	2.9	**2.0**
	Residential	1.0	2.4*	4.7*	1.7	1.7	1.2	1.6	0.99	2.3
	Commercial	1.1	1.7	1.6	0.86	0.83	0.74	1.6	0.57	1.7
	Industrial	0.78	2.3*	1.2	1.8	0.38		0.73	1.2	2.6
	Institutional	0.78	1.5							1.5
	Open Space		1.7							1.8
	Freeways		0.78			0.76	1.5	1.3		1.1
Total Phosphorous	ALL LUs	0.95	1.8	1.3	1.2	9.0	1.5	1.2	0.69	**2.8**
	Residential	0.92	2.0	1.4	0.93	0.65	0.50	1.2	0.68	1.8
	Commercial	0.92	1.0	1.1	0.85	0.74	0.94	1.5	0.67	1.2
	Industrial	0.76	1.7	1.1	0.54	0.47		0.88	0.50	1.4
	Institutional	0.42	0.80							0.76
	Open Space	0.32	0.81		0.60					0.73
	Freeways		1.3	0.74		9.3*	1.6	0.57		5.3
Dissolved Phosphorous	ALL LUs	1.1	1.2	1.6	0.81	0.86	2.3	1.7	0.89	**1.6**
	Residential	1.1	1.1	1.5	0.68	0.29	0.56	1.7*	0.94	1.1
	Commercial	0.44	1.0	1.7*	0.96	0.66		1.9*	0.63	1.2
	Industrial	0.94	1.9*	1.3	0.69	0.60		0.83	0.99	1.8
	Institutional	0.64	0.49							0.60
	Open Space		1.1		0.65					1.1
	Freeways		0.78	1.3			2.1*			2.8
Total Nitrogen	ALL LUs	0.54	0.96	0.94	0.55				0.56	**1.7**
	Residential	0.43	0.39	1.0	0.48				0.59	0.73
	Commercial	0.52	1.0	1.0	0.54				0.60	1.2
	Industrial	0.44	0.55	0.79	0.56				0.55	0.78
	Institutional	0.39								0.39
	Open Space	0.47	0.20		0.41					0.68
	Freeways			0.64						0.64
Total Kjeldahl Nitrogen	ALL LUs	0.64	1.1	0.95	0.67	0.88	1.2	0.93	0.79	**1.2**
	Residential	0.68	1.0	1.0	0.59	0.87	0.66	1.0	0.79	1.1
	Commercial	0.61	1.0	0.57	0.63	0.65	0.71	0.93	0.63	0.91
	Industrial	0.60	1.4*	0.80	0.58	0.39		0.58	0.56	1.1
	Institutional	0.74	0.82							0.84
	Open Space		0.29		0.57					0.39
	Freeways		1.1			0.86	1.4*	0.58		1.2
Fecal Coliform	ALL LUs	5.8	2.6	5.7	3.9	2.3	1.9	3.9	1.1	**5.0**
	Residential	4.5	2.9	4.2	0.98	1.1	1.5	2.6	0.80	5.5
	Commercial	2.2	2.1	0.95	2.1	2.4		3.9	1.5	3.1
	Industrial	5.7	2.3	1.9	4.6	0.92		2.6	1.3	7.2
	Institutional	0.44								0.44
	Open Space		0.77		1.1					1.2
	Freeways		3.3				2.1	1.8		2.7

*Larger variability within the land use compared to the complete data set combined

The detailed analyses of the EPA Rain Zone 2 and Jefferson County, AL data indicated that land use variations affect all stormwater pollutant concentrations examined, except for total nitrogen (EPA Rain Zone 2) and fecal coliforms (Alabama). The fewer data available for these constituents did not allow significant land use patterns to be detected. Table 141 shows the numbers of data observations available for these two study areas. The most data are available for the national NSQD database, with less data for the EPA Rain Zone 2 area (but with the most data for any one geographical area), and relatively few data for the Jefferson County sites. Evaluations using these varying amounts of data are shown to result in different levels of significant categories and resulting conclusions. The different observations based on the different data set sizes confirm the trade-offs associated with collecting fewer data, and the limitations in extrapolating results. Table 139 data show similar variations for the studied land uses when taken at the national level compared to the EPA Rain Zone 2 data alone. It was observed that the local Jefferson County concentration clusters had much lower coefficients of variation for all analyzed parameter concentrations compared to the other data, likely because they were from individual monitoring locations and not from groups of similar monitoring areas.

Table 141. Number of Data Available for EPA Rain Zone 2 and Jefferson County, AL Study Areas

Land Uses/Watersheds		**TSS**	**ZN**	**Cu**	**Pb**	**TP**	**DP**	**N**	**TKN**	**FC**
EPA Rain Zone 2 Land Uses	Residential	1000	783	714	557	1003	392	7	948	205
	Commercial	398	350	315	222	375	148	7	387	88
	Industrial	190	152	120	105	186	113	7	179	67
	Institutional	45	46	35	42	44	14	ND	46	ND
	Open Space	23	14	18	16	19	17	ND	13	5
	Freeways	225	200	96	92	181	9	ND	100	18
Jefferson Co., AL Watersheds	ALJC001	20	19	19	20	20	20	20	20	12
	ALJC002	16	15	16	16	16	16	16	16	11
	ALJC009	20	ND	ND	20	19	19	20	20	14
	ALJC010	13	ND	ND	ND	13	13	13	13	10
	ALJC012	10	10	ND	10	10	10	10	10	8

In the EPA Rain Zone 2 region, differences between the commercial and institutional land use concentrations were not statistically detected for total zinc, total copper, total lead, dissolved phosphorous, and Total Kjeldahl Nitrogen. Total suspended solids, total phosphorous, total nitrogen, and fecal coliform concentration differences also could not be statistically detected between the commercial and industrial land use categories. Differences in stormwater concentrations from the residential and industrial land use areas could not be detected based on the available numbers of data for most of the studied constituents, except for total suspended solids and total zinc. As expected, differences between the total zinc and total copper data sets for the industrial and freeway land use groups also could not be statistically detected, while open space land use data were usually found to be statistically different from the other land use data. Table 139 shows the final land use groups for EPA Rain Zone 2 along with their mean and coefficients of variation.

It was determined that the variability of the pollutant concentrations within each land use was generally lower than the variabilities shown for the complete data set. Table 142 shows the p-values from Levene's test for equality of variances performed for the pollutant concentrations of the six individual land uses and the complete data set (all land uses together). The tests check whether the variance of the different data sets are homogeneous, and is not restricted to normal distributions or independent data. The analyses showed that 65% of the combinations were not statistically significant at the 0.05 significance level, and the number of available data could not determine if they are of different data distributions. However, about 70% of these not significant combinations have land use standard deviation values smaller than the standard deviation of the complete data set. About 90% of the statistically significant combination groups showed smaller land use variations. The exceptions are in the freeways land use for total phosphorous and open space land use for dissolved phosphorous.

Table 142. P-values from Levene's Test for Equality of Variances (Individual Land Use vs. All Land Uses) for EPA Rain Zone 2

LU	TSS		Zn		Cu		Pb		TP		DP		N		TKN		FC	
RE	0.068	≥	0.003	<	0.201	≥	0.008	<	0.413	≤	0.242	≤	0.709	≤	0.452	≤	0.759	≤
CO	0.008	<	0.001	<	0.096	≤	0.018	<	0.002	<	0.302	≥	0.482	≥	0.184	≥	0.910	≥
ID	0.001	<	0.717	≤	0.003	<	0.010	<	0.026	<	0.178	≤	0.903	≤	0.063	≤	0.214	≥
IS	0.658	≤	0.000	<	0.012	<	0.057	≤	0.202	≤	0.214	≤	ND		0.273	≥	ND	
OP	0.906	≤	0.118	≤	0.360	≤	0.519	≥	0.069	≥	0.001	>	0.454	≤	0.020	<	0.123	≤
FW	0.916	≤	0.000	<	0.041	<	0.575	≥	0.000	>	0.138	≤	ND		0.037	<	0.180	≤

Note: Barlett test compared if the variability of the land use is greater (>), smaller (<), or not statistically significant (≤ , ≥) but with individual standard deviation smaller or larger than the standard deviation for all land uses combined.

The six land uses were grouped in sets of statistically comparable concentrations (one set for total nitrogen up to five sets for total suspended solids, Table 139).Table 143 shows the coefficients of variation (real space data) and the p-values from Levene's test for equality of variances performed on these land use groups vs. all land uses combined. These analyses indicated that 55% of the possible combinations were not statistically significant at the 0.05 significance level. However, 75% of the not significant combinations have the standard deviation of the grouped sets smaller than the standard deviation for the all land uses combined. About 85% of the statistically significant combinations showed lower variability for the grouped land use sets. The groups showing larger variation are the sets containing freeways land use data for total suspended solids and total phosphorous, and the set containing institutional land use for TKN.

Table 143. Coefficients of Variation and P-values from Levene's Test for Equality of Variances (Grouped Sets of Land Uses vs. All Land Uses) for EPA Rain Zone 2

Groups	**TSS**			**Zn**			**Cu**		
	COV	**p-value**		**COV**	**p-value**		**COV**	**p-value**	
ALL LUs	**1.6**			**1.5**			**1.8**		
Group 1	1.7	0.957	≤	1.6	0.003	<	2.0	0.361	≤
Group 2	1.5	0.027	>	1.2	0.000	<	1.9	0.218	≥
Group 3	1.7	0.000	<	1.2	0.001	<	1.5	0.008	<
Group 4	0.68	0.160	≤	0.98	0.118	≤	1.3	0.360	≤
Group 5	1.2	0.906	≤						

Groups	**Pb**			**TP**			**DP**		
	COV	**p-value**		**COV**	**p-value**		**COV**	**p-value**	
ALL LUs	**1.9**			**1.8**			**1.2**		
Group 1	2.4	0.003	<	1.5	0.914	≤	1.3	0.344	≤
Group 2	1.6	0.005	<	2.0	0.001	<	1.0	0.886	≤
Group 3	0.78	0.575	≥	0.79	0.984	≤	0.97	0.108	≤
Group 4				1.3	0.000	>			

Groups	**N**			**TKN**			**FC**		
	COV	**p-value**		**COV**	**p-value**		**COV**	**p-value**	
ALL LUs	**0.99**			**1.1**			**2.6**		
Group 1	0.99	NA		1.0	0.227	≥	2.4	0.728	≥
Group 2				1.2	0.000	<	2.6	0.281	≤
Group 3				1.0	0.020	<			
Group 4				0.29	0.020	<			

The analyses of Jefferson County watershed data (EPA Rain Zone 3) also identified land use influences on constituent concentration groupings for all constituents, except for fecal coliforms. The two mostly industrial watersheds (ALJC001 and ALJC002) did not have sufficient data to detect any significant differences in their concentration groupings for total suspended solids, total lead, and total nitrogen, but significant differences were detected for the concentration groupings for the other analyzed constituents.

Also, the two predominantly residential watershed (ALJC009 and ALJC010) concentration groups could not be separated with the available data for total and dissolved phosphorous and total nitrogen, but were found to have significant different concentration groupings for total suspended solids. These residential watersheds had many non-detected values for total zinc, total copper, and total lead (only observed in ALJC010) and were therefore not evaluated. Table 139 shows the final land use groupings for the different constituents and their coefficients of variation for the Jefferson County watersheds. Table 144 presents the p-values from the Bartlett's test for equality of variances performed for land use groupings vs. all land uses combined. Jefferson County constituent concentrations data were normally distributed, therefore Bartlett's test has better performance than Levene's test. These analyses did not detect significant differences between the groups' variance, except for total zinc and total lead. However, for the rest of the constituents the standard deviations of the land use groups were smaller than the standard deviation of the complete set of data. The only exceptions were for total and dissolved phosphorous in the group containing ALJC001 watershed data.

Table 144. Coefficients of Variation and P-values from Bartlett's Test for Equality of Variances (Grouped Sets of Land Uses vs. All Land Uses) for Jefferson County, AL

Groups	**TSS**			**Zn**			**Cu**		
	COV	**p-value**		**COV**	**p-value**		**COV**	**p-value**	
ALL Watersheds	**1.0**			**0.77**			**0.73**		
Group 1	0.89	0.219	≤	0.50	0.001	<	0.61	0.399	≤
Group 2	0.76	0.681	≤	0.46	0.001	<	0.56	0.536	≤
Group 3	0.59	0.179	≤	0.48	0.046	<			

Groups	**Pb**			**TP**			**DP**		
	COV	**p-value**		**COV**	**p-value**		**COV**	**p-value**	
ALL Watersheds	**0.88**			**0.72**			**0.89**		
Group 1	0.52	0.000	<	0.68	0.822	≥	0.88	0.335	≥
Group 2	0.78	0.020	<	0.60	0.364	≤	0.49	0.090	≤

Groups	**N**			**TKN**			**FC**		
	COV	**p-value**		**COV**	**p-value**		**COV**	**p-value**	
ALL Watersheds	**0.65**			**0.77**			**2.0**		
Group 1	0.63	0.623	≤	0.73	0.393	≤	2.0	NA	
Group 2	0.53	0.732	≥	0.66	0.954	≤			

At the geographical region level, the statistical analyses were not powerful enough to demonstrate that seasonal sample groups were significantly different for each season, but this was likely caused by insufficient data needed to detect the relatively small differences in the means for the seasonal groupings. Exceptions were: in EPA Rain Zone 7 for some nutrients (dissolved phosphorous and TKN) and total lead, in EPA Rain Zone 3 for total nitrogen, and all rain zones (except EPA Rain Zones 4 and 5) for fecal coliforms.

However, the detailed analyses of EPA Rain Zone 2 data showed that the interactions of land uses and seasons significantly affected some stormwater constituent concentrations, especially for residential land uses where the most data were available. It was concluded that seasonal effects were overwhelmed by the geographical effects. Therefore, when the geographical region influences were removed, the seasonal effects were more visible and could be detected at the regional level.

For EPA Rain Zone 2, it was observed that seasonal mean differences were usually small (less than 20-30%), therefore large sample sizes would be required to show that these differences were significant (1,000 samples required versus 190 available for TSS concentrations in the industrial land use category; 2,600 samples required versus 780 available for total zinc concentrations in the residential land use category; and 2,200 samples required versus 560 available for total lead concentrations in the residential land use category). It is unlikely that gathering this number of samples would be feasible for any stormwater management program and the relatively minor seasonal differences observed are not very useful. Therefore, the seasonal effects were not considered to be significant or important for most situations.

The detailed analysis of Jefferson County watersheds (mixed land uses in EPA Rain Zone 3) found no seasonal influences on the stormwater pollutant concentrations. The data were subdivided in only two seasons (warm-wet and cold-dry) instead of the traditional four seasons, because there is not much distinction among the four calendar based seasons and to prevent the already small sample size from being further reduced. The local stormwater pollutant database has about 80 samples for each analyzed constituent, divided among the five watersheds. This sample size enabled land use influences on stormwater constituent groupings to be detected (except for fecal coliforms), but there were too few samples to detect seasonal differences among the watersheds, even though the measured differences were in many cases quite large (TSS in ALJC010, 91% maximum seasonal difference, requires 52 samples, only 13 available; total zinc in ALJC001, 62% maximum seasonal difference, requires 38 samples, only 19 available; and total lead in ALJC002, 51% maximum seasonal difference, requires 50 samples, only 16 available for example).

For EPA Rain Zone 2 and Jefferson County watersheds, the concentration variations between the seasonal pollutant groupings were usually lower than the concentration variations within the land use groupings. Figure 138 is an example of the seasonal concentration variations for total phosphorous in the commercial land use category in EPA Rain Zone 2, showing the large overlaps in concentration values for the different seasons.

It was concluded that stormwater concentrations collected from different land uses, geographical regions, and/or seasons are not always significantly different and the many individual subcategories (96 separate categories) can be pooled into many fewer categorical groups (Table 139) of statistically comparable concentrations. Scaling evaluations affect the amount of available data in each category making identical evaluations difficult due to varying power. However, different data perspectives are possible when examining information from city to regional to national scales

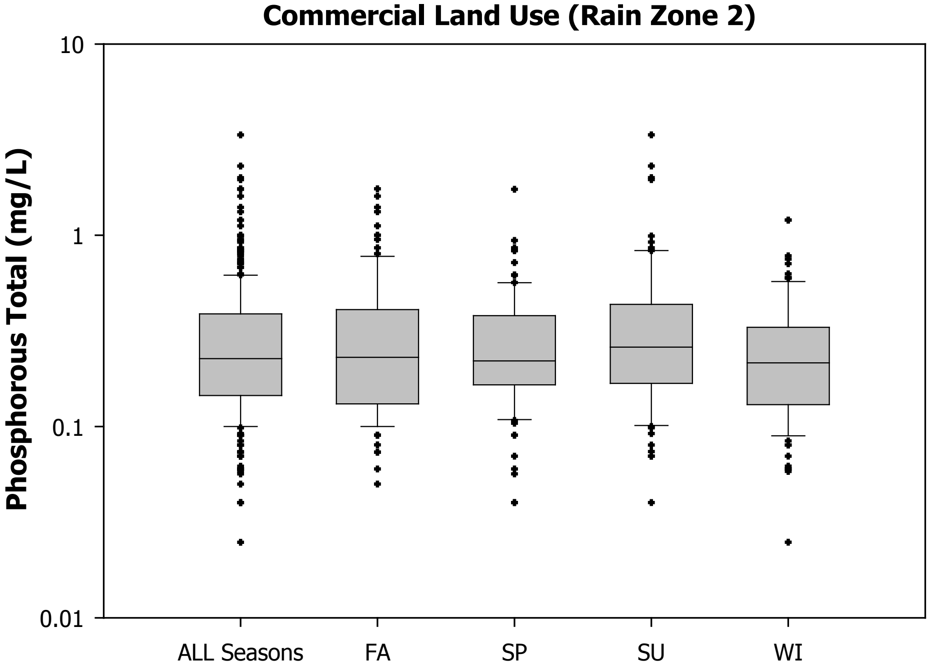


Fig. 138. Box-and-wisher Plot Showing Seasonal Variability for
Total Phosphorous Concentrations in Commercial Land Use Areas

The first assumption of the dissertation hypothesis was substantiated since it was shown that there is less variability in stormwater quality characteristics within each land use category compared to the variability between the land use categories. Yet, because of the relatively large variability in the concentrations in these data sets, large amounts of data are necessary to statistically demonstrate and identify these separate categories. In many cases, geographical location also affected the identifications of separate land use categories of stormwater concentrations, but seasonal effects were much less common.

Assumption 2: ***Variability in land use development characteristics is less within each land use category than between the land use categories***.

This research studied 170 homogeneous neighborhoods separated into eleven land use sub-categories in order to examine the variability of development characteristics in each of these land uses. These areas were located in the Little Shades Creek watershed and five urban drainage areas in Jefferson County, AL. Those areas were field surveyed and their actual land coverage (roofs, parking areas, street areas, driveways, landscaping, etc) were measured and statistically evaluated.

Table 145 shows the average percentage surface areas for each land use, and their corresponding coefficients of variation. All three of the residential land use categories (high, medium, and low density) have landscape areas as the major land cover, and have about 25% to 30% of the land as impervious surfaces (Table 145).

Table 145. Summary of the Land Cover Means (%) and Coefficients of Variation for Each Land Use in Jefferson County, AL

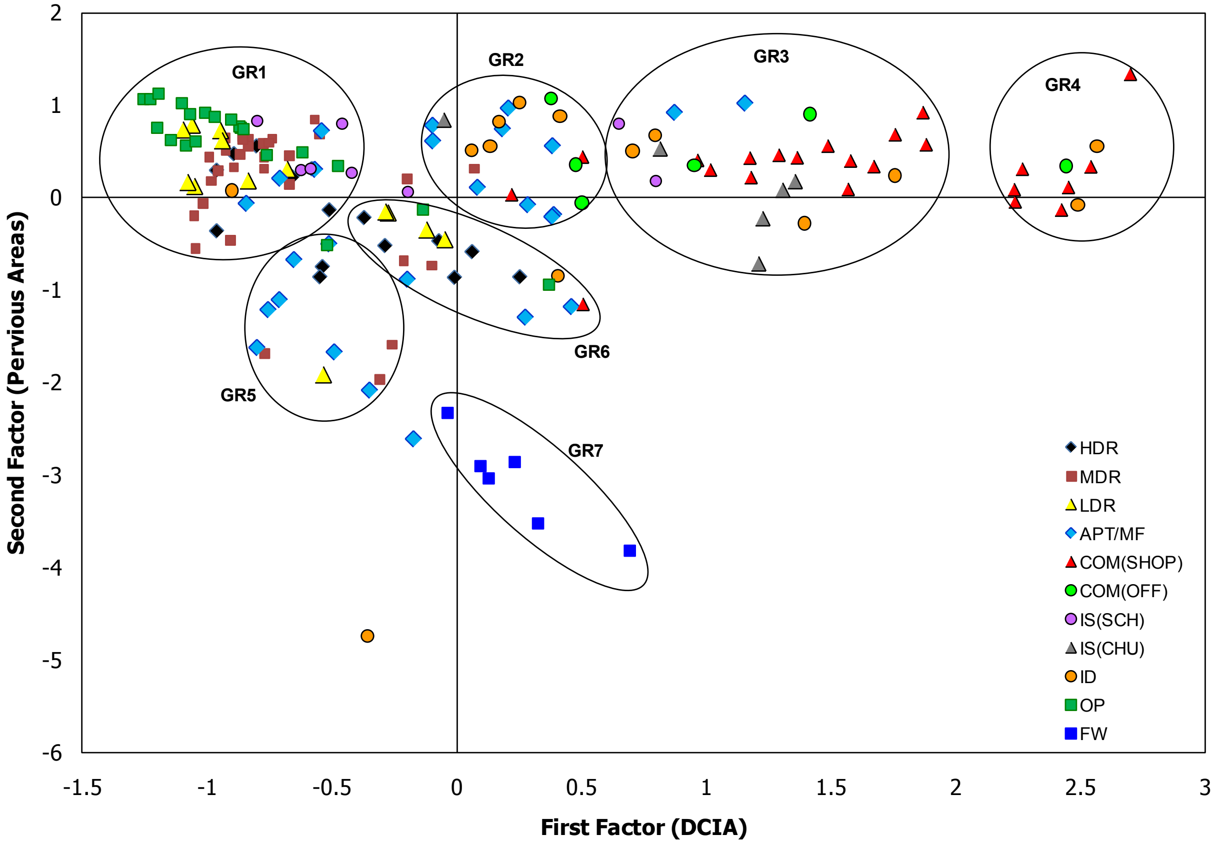
Land Use/ Land Cover	**Directly Connected Impervious Area**	**Disconnected Impervious Area**	**Total Pervious Area**	**Paved Street Area**	**Paved Parking Area**	**Connected Roof Area**	**Disconnected Roof Area**	**Small Landscaped Area**
High Density Residential	19 (0.51)	11 (0.44)	70 (0.16)	13 (0.64)	0.09 (3.9)*	5.2 (0.48)	8.4 (0.47)	64 (0.30)
Medium Density Residential	13 (0.64)	8.9 (0.75)	78 (0.13)	8.8 (0.72)	ND	3.8 (1.1)	6.4 (0.90)	76 (0.18)
Low Density Residential	14 (0.82)	8.7 (0.69)	78 (0.19)	11 (0.65)	ND	3.1 (1.0)	5.8 (1.)	73 (0.23)
Apartments/ Multi Family	24 (0.64)	14 (0.97)	62 (0.22)	8.6 (0.37)	10 (0.83)	8.0 (1.1)	9.5 (0.88)	46 (0.57)
Commercial (Shopping Centers)	76 (0.24)	0.36 (4.0)*	24 (0.72)	19 (0.32)	36 (0.37)	17 (0.70)	1.4 (3.9)*	14 (1.3)*
Commercial (Offices)	59 (0.39)	2.8 (2.1)*	39 (0.52)	16 (0.79)	27 (0.66)	17 (0.67)	0.3 (2.5)*	39 (0.52)
Industrial	50 (0.66)	8.5 (2.4)*	42 (0.68)	12 (0.64)	19 (0.96)	10 (0.79)	4.3 (2.3)*	25 (1.1)
Institutional (Schools)	23 (0.62)	3.9 (0.89)	73 (0.19)	6.6 (1.02)	8.2 (0.63)	8.0 (0.66)	3.6 (1.0)	38 (0.59)
Institutional (Churches)	61 (0.27)	3.2 (1.2)	36 (0.52)	21 (0.69)	26 (0.33)	12 (0.67)	1.2 (1.3)*	31 (0.31)
Open Space	8.7 (1.2)	4.6 (1.9)*	87 (0.19)	8.4 (0.75)	2.4 (2.6)*	ND	0.22 (3.2)*	88 (0.13)
Freeways	ND	58 (0.13)	42 (0.18)	47 (0.13)	12 (0.35)	ND	ND	34 (0.26)
ALL LUs	**30 (0.95)**	**9.2 (1.5)**	**61 (0.43)**	**13 (0.80)**	**11 (1.4)**	**7.5 (1.2)**	**4.8 (1.4)**	**53 (0.59)**

*Land use/land cover with high levels of variation

In the case of apartment complexes/multifamily housing units, the landscape areas still represent the main land cover areas, but parking lots, streets and roofs comprise larger fractions of the total area than for the other residential areas. In commercial land use areas (strip commercial and office parks) land cover areas are about equally divided among impervious surfaces and landscaped areas. However, for institutional land use (schools and churches) there is an evident distinction between the two land use sub-categories. For the school areas, the predominant land cover is landscaped areas, followed by streets and parking areas. In contrast, in the church land use area, the dominant impervious surfaces are parking lots and streets, which are slightly larger in area than the total pervious areas. In the industrial land use area, the major land covers are the landscaped areas, followed by hard surfaces (such as parking lots, streets, and paved storage areas). In freeway lands use areas, the impervious surfaces (street and shoulder areas) make up more than half of the land cover areas. As expected, in open space land use areas, pervious areas are the predominant surface cover.

It was found that there are significant differences in the land covers among the major land uses. Residential land uses were originally separated based on housing density (high, medium, and low density), and commercial (shopping centers vs. office parks) and institutional areas (schools vs. churches) were separated based on functionally of the land use. Figure 139 is a scatter plot of the first two principal components for the land covers and runoff volumes of all 170 sites and illustrates the groupings of these different areas using principal component analyses. The first principal component interpreted as a measure of the DCIA, helped separate the 170 neighborhoods and explained 57% of the data variability. The second principal component, which is a measure of pervious areas, explained the next 20% of the total variation.

The statistical analyses showed that in the Jefferson County, AL study area, high-density residential land uses have physical characteristics similar to apartment/multifamily and institutional school land uses.



Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
HDR	10	MDR	4.8	APT/MF	7.1	**COM(SHOP)**	**70**	**HDR**	**14**	**HDR**	**32**	**FW**	**100**
MDR	**36**	**APT/MF**	**43**	**COM(SHOP)**	**46**	**COM(OFF)**	**10**	**MDR**	**21**	MDR	11		
LDR	**12**	**COM(SHOP)**	**9.5**	**COM(OFF)**	**7.1**	**ID**	**20**	LDR	7.1	**LDR**	**21**		
APT/MF	7.5	**COM(OFF)**	**14**	ID	14			**APT**	**43**	**APT**	**16**		
IS(SCH)	7.5	**ID**	**24**	IS(SCH)	7.1			OP	14	SHOP	5.3		
ID	1.5	IS(CHU)	4.8	**IS(CHU)**	**18**					ID	5.3		
OP	**25**									OP	11		
	100		100		100		100		100		100		100

Fig. 139. Score Plot and Loadings of Principal Components for Land Covers for Jefferson County, AL Land Uses Studied (Table: Land Use Percentages for Each Group)

This similarity is better observed on the dendrogram from cluster analyses in Figure 140. In the dendrogram, the length of the branches represents the strength of the relationship among land uses. The shorter the branch, the more correlated the land uses are. Furthermore, medium density residential, low-density residential, and open space land uses have similar physical characteristics. It was also found that institutional schools are significantly different from institutional churches for the study areas (Figure 140). In this area, church land uses are closely related to commercial areas. The analyses did not find significant differences between the two commercial sub-categories (shopping centers and office parks) likely due to the limited number of samples for the office parks sub-category.

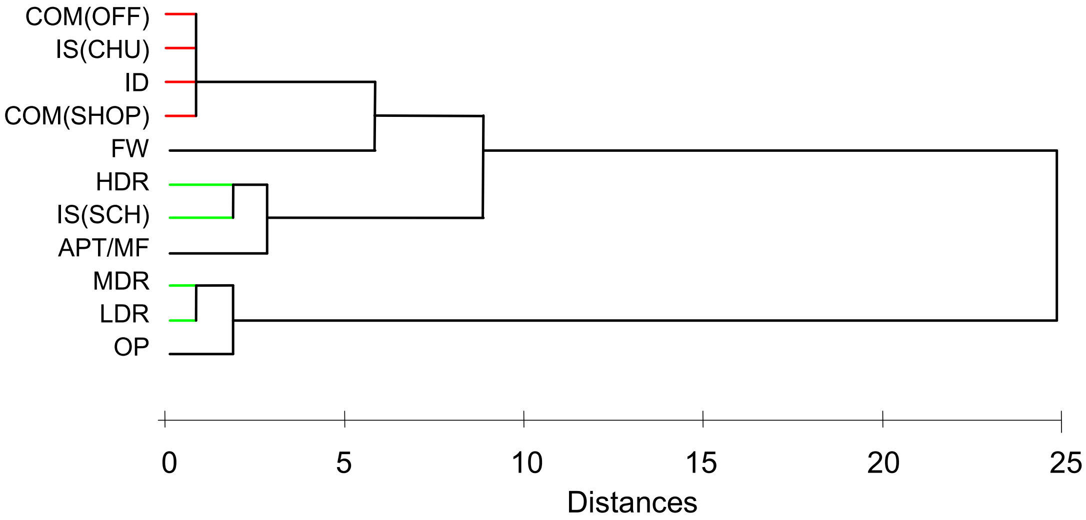


Fig. 140. Clusters of Land Uses for Jefferson County, AL Watersheds

The variabilities of the land development characteristics within and between land uses were examined by comparing the coefficients of variation and the whole variance for the major land covers. It was determined that the land cover areas within each land use have low and medium levels of variation (76% of the land use/land cover combinations studied had the coefficients of variation below 1), and were usually smaller than the variation between the land uses. However, the study found large levels of variation (coefficients of variation larger than 1.25) for disconnected impervious areas and disconnected roofs (commercial land use for both shopping areas and office parks, industrial, and open space land uses), parking lot areas (high density residential and open space land uses), and small landscape areas (commercial shopping center areas) (Tables 103 and 107, Chapter 5). These large variations were associated with surfaces that comprised small portions of these land uses.

The eleven categories of land uses were grouped in sets of statistically comparable areas for each land cover. Table 146 shows the coefficients of variation and the p-values from Levene's test for equality of variances performed on these land use groups vs. all land uses combined.

Table 146. Coefficients of Variation and P-values from Levene's Test for Equality of Variances (Grouped Sets of Land Uses vs. All Land Uses) for Jefferson County, AL

Groups	**DCIA**			**DSIA**			**Pervious Areas**		
	COV	**p-value**		**COV**	**p-value**		**COV**	**p-value**	
ALL LUs	**0.95**			**1.5**			**0.43**		
Group 1	0.61	0.001	<	0.84	0.001	<	0.20	0.000	<
Group 2	0.70	0.000	<	2.9	0.059	<	0.15	0.000	<
Group 3	0.40	0.475	≤	0.99	0.000	<	0.65	0.045	<
Group 4	1.2	0.002	<	0.13	0.561	≤	0.19	0.001	<

Groups	**Street Areas**			**Parking Areas**			**Connected Roofs**		
	COV	**p-value**		**COV**	**p-value**		**COV**	**p-value**	
ALL LUs	**0.80**			**1.4**			**1.2**		
Group 1	0.65	0.002	<	3.3	0.000	<	0.99	0.314	≤
Group 2	0.47	0.942	≤	0.95	0.030	<	1.1	0.001	<
Group 3	1.0	0.239	≤	0.42	0.986	≤	0.69	0.384	≥
Group 4	0.13	0.408	≤				0.73	0.774	≤

Groups	**Disconnected Roofs**			**Landscape Areas**		
	COV	**p-value**		**COV**	**p-value**	
ALL LUs	**1.4**			**0.59**		
Group 1	0.77	0.335	≥	0.30	0.008	<
Group 2	0.92	0.329	≤	0.19	0.000	<
Group 3	4.8	0.000	<	0.54	0.001	<
Group 4	2.1	0.426	≥	1.3	0.001	>

The analyses show that about 40% of the land use/land cover group combinations did not have statistically significant differences, but the majority of the combinations have small standard deviation values. However, 95% of the combinations that were found to be statistically significantly different showed lower variabilities for the grouped land use/land cover sets. The second assumption of the dissertation was therefore supported by these multiple tests in that land cover characteristics had greater similarities for sites grouped within individual land use categories than for sites in different land use categories.

Assumption 3: ***The variability in development and stormwater characteristics are correlated and this correlation can be used to more effectively predict receiving water responses to stormwater controls for an area.***

To test the third assumption, this research used a series of univariate and multivariate statistical analyses to identify the possible linkages between pollutant parameters and associations with land use/land cover in the overall objective of testing whether land use categories are an appropriate way of describing urban areas for stormwater analyses, instead of the simpler use of DCIA alone.

For the Jefferson County, AL study areas, the parking lots, connected rooftops, and streets were the major source areas of runoff, such as the example shown in Figure 141. These areas were also the main directly connected impervious areas for these areas studied. It was also noted that the landscaped areas were the major pervious surfaces, as expected, while the disconnected rooftops were the major disconnected impervious surfaces. The analyses also found that the directly connected surfaces (parking lot areas and connected roofs) are more significant in runoff generation for the small rain events, while the pervious surfaces, especially landscape areas, can became important for larger events. These analyses also showed how the disconnected impervious areas are more strongly associated with the pervious areas than to the directly connected impervious areas.

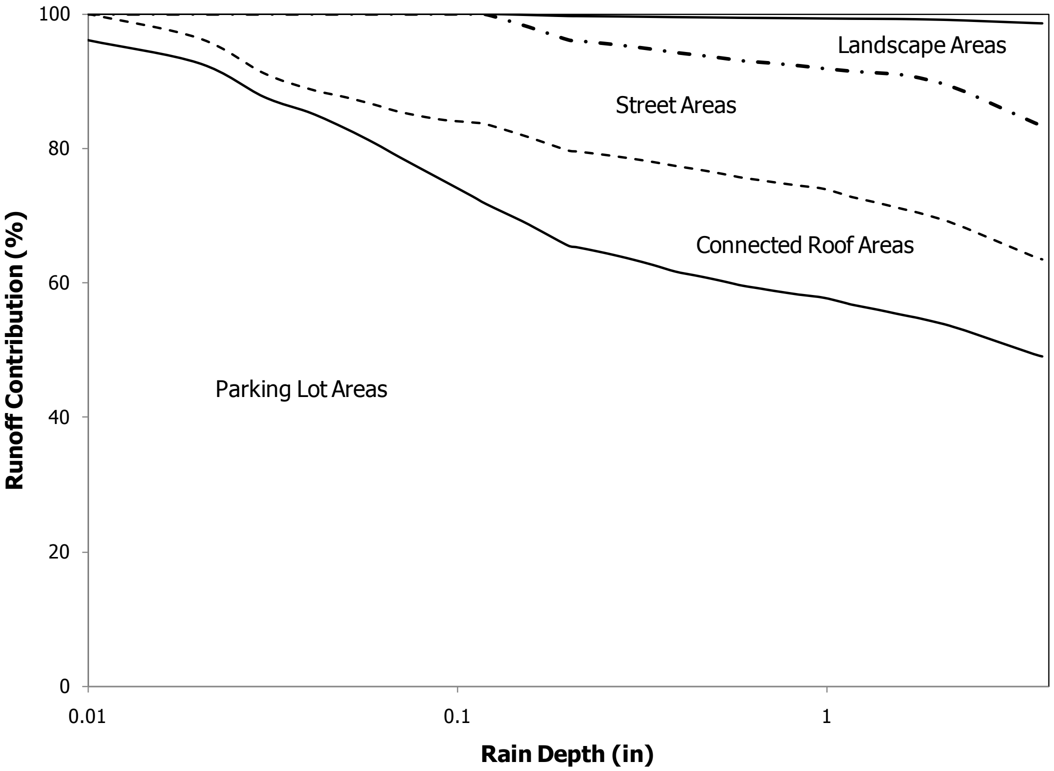


Fig. 141. Land Cover Runoff Volume (%) Contribution for 0.01 to 4 Inch Rains in ALJC012 Watershed (Bochis 2007)

The investigation of local land covers and local monitored stormwater pollutants revealed significant correlations among some stormwater pollutants (especially for metals, but not for fecal coliforms), street area land cover, and parking lot areas suggesting that DCIA (especially street area) is a potentially major source of pollutants to the stormwater (Figure 142). Cluster analyses used to identify associations between land covers and pollutant concentrations revealed that water quality parameters were associated with each other and were in the same major branch as the directly connected impervious areas (Figure 142). This finding was also supported by the negative Pearson correlations between stormwater pollutants and total pervious areas for most contaminants. The major sources of fecal coliforms in stormwater seem to be the landscaped areas and disconnected impervious areas, especially disconnected rooftops. The total suspended solids concentrations were only strongly correlated with zinc, lead and phosphorus (and negatively correlated with fecal coliforms), indicating that TSS may not be as universal of a stormwater quality surrogate as often assumed.

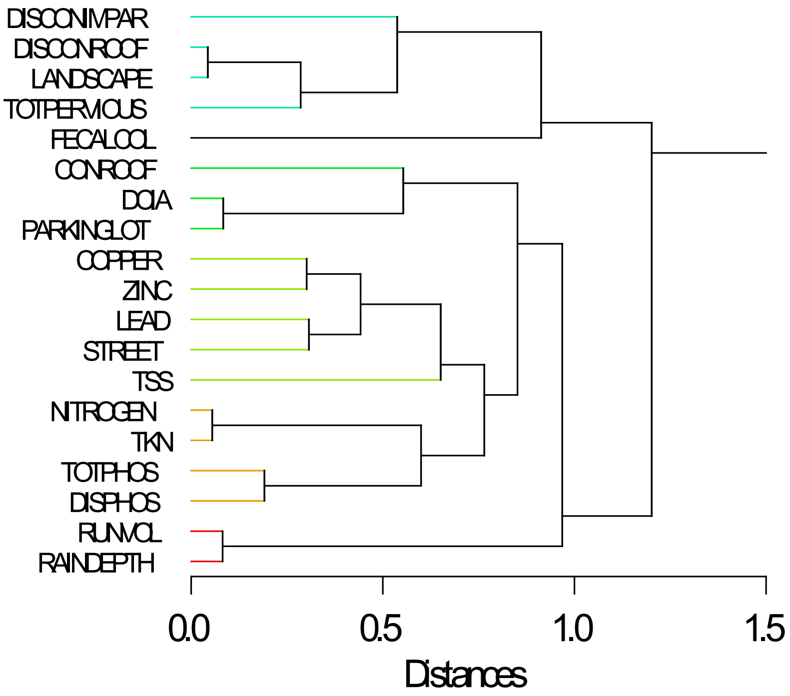


Fig. 142. Cluster of Land Covers and Water Quality Parameters
for Jefferson County, AL Watersheds Studied

The investigation of local watersheds (land covers) and pollutant concentrations showed that the two industrial watersheds (ALJC001 and ALJC002) have comparable land covers (DCIA represented by streets and parking lots) and similar pollutant concentrations at the outfall.

Additionally, it was determined that the two mostly residential watersheds (ALJC009 and ALJC010) also have many common features, such as their major land covers: the disconnected impervious areas and pervious areas. The mostly commercial watershed (ALJC012) did not form very strong relationships with any watershed, but it was more closely associated with the residential areas than with the industrial areas (Figure 143). These associations indicate that the watersheds' physical characteristics (major land cover) in association with the activities occurring within the watershed (land uses) influence the pollutant concentrations at the outfall. Therefore, the cluster analysis in Figure 143 is a confirmation that similar land uses have similar land development and stormwater characteristics.

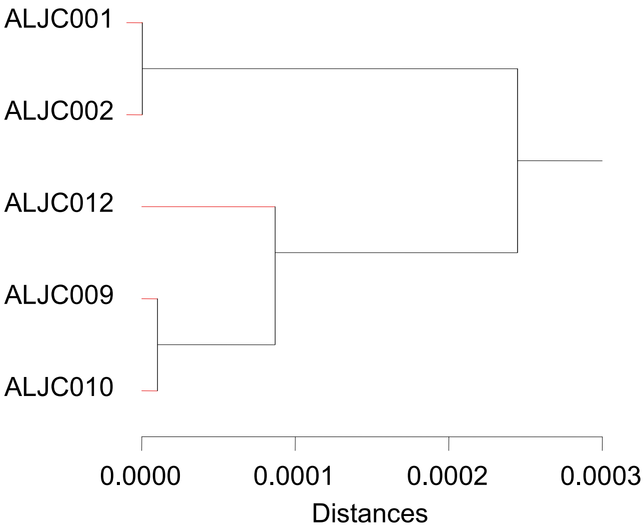


Fig. 143. Cluster of Jefferson County, AL Watersheds

Another method used to check if the land uses' physical characteristics (land covers) have an influence on the pollutant concentrations involved a comparison between the final groups of stormwater constituent concentrations from EPA Rain Zone 2 in the NSQD and the final groups of land covers from the local Jefferson County, AL data. Each pollutant was compared only with the land cover that was previously determined to influence its concentrations. It was found that the commercial and institutional land use groupings for metals (total zinc, total copper, total lead), nutrients (dissolved phosphorous and TKN), directly connected impervious areas, and street areas (which are the major land covers contributors of these pollutants) were significant (example Table 147). Residential and industrial land use groupings for total copper, total lead, total and dissolved phosphorous, total nitrogen, TKN, and also for street areas were also significant. In addition, commercial and industrial land use groupings for disconnected impervious area land cover and for both total nitrogen and fecal coliforms were significant.

Table 147. Example - Land Development Characteristic Association with Land Uses and Pollutant Concentrations (from EPA Rain Zone 2)

Total Lead		**DCIA**		**Street Area**		**Parking Area**	
Land Use	**COV**	**Land Use**	**COV**	**Land Use**	**COV**	**Land Use**	**COV**
*__RE__ __ID__ OP	2.4	RE(HD,APT/MF) IS(SCH)	0.61	*__RE__ __ID__ OP	0.65	*__RE__ (APT/MF) __ID__ IS(SCH) FW	0.95
*__CO__ __IS__	1.6	RE(MD, LD)	0.70	*__CO__ __IS__(CHU)	0.47	RE(HD), OP	3.3
*__FW__	0.78	*__CO__ __IS__(CHU) ID	0.40	IS(SCH)	1.0	*__CO__ __IS__(CHU)	0.42
		OP	1.2	*__FW__	0.13		

*Significant pollutant concentrations and land use/land cover groups

Each major land use was expected to have unique patterns and mixtures of surfaces, while activities taking place within the land uses might further affect the runoff quality and its variability from these areas. Those expectations were confirmed during this research with the help of national and local pollutant data, and local land development characteristics data. Therefore, the research's third assumption was also substantiated.

6.3 Future Research Needs

The NSQD is an important tool for the analysis of stormwater discharges at outfalls and contains separate stormwater system outfall quality data for 8,602 separate events. Most of the analyses in this dissertation were performed for residential, commercial and industrial land uses due to the lack of complete datasets for other land uses (institutional, open space, and freeways). The EPA Rain Zone 2 has the most observations for any region of the country, but the majority of this data is also concentrated in residential, commercial, and industrial land uses. The sample sizes in the institutional, open space, and freeways land uses are too small to provide sufficient power to distinguish any subcategories of data in these land uses at the conservative data quality objectives desired for this research and used for the other areas (alpha of 0.05 and beta of 0.2, or a confidence of 95% and a power of 80%). Therefore, the majority of the analyses efforts during this dissertation research focused on the three major land use categories: residential, commercial, and industrial areas. Further studies using the existing sample set in the NSQD version 3 database could be conducted using less conservative test statistics associated with using a larger significance criterion (larger alpha and correspondingly smaller confidence level), therefore, increasing the power of the tests. The most recent NSQD update focused on expanding the data set for better geographical coverage, which was reasonably successful. A better approach than reducing the data quality objectives would be to continue to expand the NSQD by collecting additional data from the available monitoring efforts associated with the NPDES stormwater permit program, especially focusing on these underrepresented land uses.

The results from these dissertation analyses can also be used as guidance for local stormwater quality monitoring efforts. In order to have sufficient data to conduct many of the basic statistical analyses of interest for a local stormwater management program, it is suggested that a monitoring program be conducted until at least 30 to 40 events have been monitored for each site. This relatively large amount of data is necessary because of the large variability associated with stormwater characteristics, as indicated during this and other research. Typical current NPDES monitoring requirements only specify three events per year from each location, requiring many years before a statistically adequate numbers of observations are obtained. Due to the minimum ten years necessary to collect the data at this slow rate, major changes in laboratory technology and large turn-over in field and laboratory personnel occur, increasing the difficulties needed for ensuring continuity in sampling and contaminant detection methods.

In addition, it is important that a sufficient range of constituents be monitored, based on local objectives. Changing constituents also cause problems during excessively long monitoring periods. During this research, problems were noted as some sites were migrating to total nitrogen analyses instead of TKN, and the increasing emphasis on E-coli and enterococci decreased the amount of recent fecal coliform bacteria observations. In addition, some analytes have much greater variabilities (especially the bacteria measurements), and larger amounts of data will be needed for these constituents if they are of primary interest. Also, flow monitoring needs to be included as a critical component of all stormwater characterization monitoring (lacking for most of the NPDES monitoring locations) along with on-site rainfall information (regional rainfall is usually reported during NPDES monitoring). This additional information, along with increased amounts of the water quality data collected in a shorter period of time, will greatly enhance the usefulness of the water quality monitoring data for watershed managers and better direct the very large expenditures that municipalities are investing in improving urban receiving water quality.

The execution of this project and the results obtained indicate that there are avenues for further improvements in related areas. Some of these are listed below:

- Stormwater quality models need to integrate the relationships between land use/land cover - rainfall – runoff volume – pollutant loads. Increases in runoff volumes are directly associated with increases in impervious cover and therefore in pollutant mass discharges. The use of simplified modeling approaches that only consider directly connected impervious cover can be improved by considering the types of the different land surfaces and the activities that are on-going in the different land use areas.
- Stormwater quality models need to be expanded to also address the variability in the monitoring data.
- Simplified calculations are useful for preliminary evaluations and these can be improved by considering the separate subcategories and combinations of conditions (interactions of geographical area and land use mostly, with limited seasonal effects) that affect stormwater quality, as presented in this research. The use of rainfall – runoff – pollutant mass loading curves using the entire NSQD database (much expanded compared to the NURP (1983) data which were originally used to build similar curves and which are still being used) can be easily accomplished based on the results presented in this dissertation. The Table 139 (both concentrations and coefficients of variation) can be used as a first estimate of pollutant loadings from land uses.

- The variabilities inherent in stormwater quality need to be better recognized in regulations. As more numeric discharge limits become established, the uncertainty of meeting these limits because of this variability, even with extensive stormwater controls, causes great concern for the regulated community.
- The analytical methods used for the detection of constituents should be reported and investigated if they affect the stormwater quality variability.

6.4 Summary of the Dissertation Research Findings

- Stormwater analyses should use the land use categories and information about the surface covers in the area (such as the percentage of impervious areas and knowledge of the different impervious cover types) in order to reduce and explain the variability of the predicted stormwater concentrations.
- DCIA is the most important characteristic affecting hydro-modification effects in urban receiving waters. However more complete land cover/land use information is needed to better understand stormwater quality characteristics.
- The large variability in pollutant discharge characteristics from different land uses requires a much greater amount of data than typically is collected in order to identify and measure the differences between important data subsets.
- Stormwater concentrations collected from different land uses, geographical regions, and/or seasons are not always significantly different. During this research, 2 to 5 significant subcategories per pollutant were identified, out of 96 total possible combinations. The main reason for these few significant subcategories was insufficient data.

- Examinations of stormwater characteristics and land development at different scales provided additional insights, but affected the amount of available data in each category making similar evaluations difficult due to varying power of the analyses. However, some important data perspectives are possible when examining information from city to regional to national scales.
- Evaluations using varying amounts of data showed different levels of significant categories and resulting conclusions. The different observations based on the different data set sizes confirm the trade-offs associated with collecting fewer data, and the limitations in extrapolating results.
- Removing the effects of geographical location enabled more detailed seasonal and land use interactions to be identified.
- Detailed local information allowed close correlations between land development and stormwater characteristics to be identified.
- The examination of EPA Rain Zone 2 and Jefferson Co. data illustrated the advantages of examining the data on smaller scales, but the specific results from these smaller areas are not expected to be generally applicable elsewhere.
- It was found that:
    - The pollutant concentration variabilities within each land use category were generally lower compared to the variability between the land use categories.
    - Land cover areas within each land use have lower levels of variation than the variation between the land uses.
    - Each major land use had unique patterns and mixtures of surfaces.

  - The activities taking place within the land uses affect the runoff quality and its associated variability.
- The major findings from the national data analyses were found to be generally applicable for these local analyses (land use distinctions are important), therefore the results from this dissertation analyses can be used as guidance for local stormwater quality monitoring efforts.
- Future research needs to expand the database for many regions and local areas to allow for more accurate analyses of local problems, considering the large expenses associated with improving the receiving water quality.

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Appendix A
WinSLAMM Model Calibration and Verification

A.1. WinSLAMM Data Files

Data from the NSQD (National Stormwater Quality Database) MS4 (municipal separate storm sewer system) database (Maestre and Pitt 2005) for Jefferson County, Alabama, was used to conduct a re-validation of the WinSLAMM model before it was used to calculate the expected runoff conditions used for this dissertation.

In order to construct the WinSLAMM files, several types of information about the site were needed, such as describing the drainage system (grass swales, curb and gutter in good/fair/poor condition, undeveloped roadside) and the fraction of each type of drainage system serving the study area; the soil type (sandy, silty, clayey); site development characteristics (such as the roof type, street texture, etc.); and measurements of the different source areas. Except for the soil type, all of the other information was obtained during field surveys, or during the aerial photograph measurements.

A separate evaluation was performed to determine the site's general soil type. Field maps showing the exact site locations were used in conjunction with Alabama topographic maps (scale 1:24000, published by US Geological Survey in 1988) and the *Soil Survey of Jefferson County*, Alabama, maps (scale 1:24000, published by US Department of Agriculture Soil Conservation Service in 1975) to identify the site locations on the county soil maps. The information necessary to perform a WinSLAMM model run was stored in a WinSLAMM data file and its associated parameter files. This information included a description of land uses and source areas, the time period and corresponding rainfall events, the pollutant control devices applied to the site, and the pollutants to be analyzed

Several parameter files were needed when conducting a WinSLAMM analysis. The most important file used with the model was the rain file (*.RAN) which describes the rain series during the study period. To better evaluate the conditions in the five different Jefferson County drainage areas, a separate rain file was created for each area based on the nearest rain gage data. Each file described the rains that occurred during the field sampling, including several rains before and after the sampling period started and ended. Separate rain files were used for each watershed in order to best represent the actual rains that occurred at each site, as there was substantial variability in the rain characteristics (depth and duration) over the entire area. The rain files contain the start and end dates and times for each rain, and the total rain depth for the rain. A six hour dry period separated each rain event. The model calculated the antecedent rain period before each event, and the average rain intensity.

For the Little Shades Creek watershed analyses, the typical Birmingham area rain file (BHAM76.RAN) was used. This file includes the rains for the entire 1976 year which has been previously determined to be a representative rain year for the area, based on comparisons with long term (about 45 year) rain records. Birmingham's rains are reasonably well distributed throughout the year. However, some of the wetter winter months, plus March and July, have twice the rainfall of October, the driest month. Summer rainfall is almost entirely from scattered afternoon and early evening thunderstorms. Serious droughts are rare and most dry spells are not severe.

There are mandatory and optional parameter files required to run WinSLAMM. The runoff file (*.RSV), a required file, contains volumetric runoff coefficients for each surface type that generates surface runoff for the rains. For this study, the RUNOFF.RSV file supplied with the model was used for all runs. The file was developed based on extensive monitoring data collected in Toronto and Milwaukee (as reported by Pitt 1987). It has been verified using additional independent data representing a wide range of land development and rain conditions. The current NSQD MS4 database for Jefferson County Alabama does not include runoff data, so it was not possible to re-verify this file for local conditions.

Four additional files were previously created based on Birmingham area regional research and include:

1. Particulate solids concentration file (BHAM.PSC) that describes the particulate residue (particulate solids) concentrations for each source area (except for roads) and land use, for several rain categories;
2. Particulate residue reduction file (DELIVERY.PRR) that accounts for the deposition of particulate pollutants in the storm drainage system, before the outfall, or before outfall controls (the delivery file was calibrated for swales, curb and gutters, undeveloped roadsides, or combinations of drainage conditions);
3. The pollutant file (BHAM.PPD) was needed when examining pollutants besides particulate solids, and was used to describe the particulate pollutant strengths related to particulate residue (in units such as mg pollutant / kg particulate solids) and the filterable pollutant concentrations (in units such as mg/L) for each source area for each land use (this file also contains the coefficient of variation (COV) values for each pollutant for Monte Carlo simulations in WinSLAMM in order to account for the random nature of stormwater pollutants); and

4. The street delivery file (STREET.STD) was used to define the limits of the street dirt washoff routines in the model based on rain characteristics (energy limitations).

These four files (*.PSC, *.PRR, *.PPD, *.STD) were re-validated using the NSQD MS4 monitoring information for Jefferson County prior to their use in examining the Little Shades Creek data. The Jefferson County MS4 data were not affected by any stormwater source area or outfall control measures.

A.2 Rain File Construction

The first step in the construction of the rain files was the collection of hourly rainfall data for the Birmingham, AL, area. The local rain data for the Birmingham Municipal Airport Weather Observation Station was obtained through its internet site maintained by NCDC (National Climatic Data Center). The hourly precipitation data (measured in hundredths of inches, stored and observed to the same accuracy) from January 01, 2001 to April 11, 2005 were downloaded as a text file (.TXT) and used to create the MASTER.RAN file, covering the same time period as the local MS4 data collection.

This rain file, which served as the basic rain file for all of the five individual rain files for each of the five monitoring locations, had some missing data. Periods of missing data were added manually and labeled “no record” for the start/end date and time of the rain and rain depth. The “no record” rain depth values were replaced using estimated values obtained by averaging the values obtained from four Birmingham Water Works (BWW) Rainfall Stations (Lake Purdy, Putnam, Shades and Western) for that particular day. Carson and Inland Lake stations (also part of the BWW network) were not used due to their remote location from the study watersheds. The BHAMSRCE.RAN rain file, supplied with WinSLAMM, was used as a reference to estimate the durations of the rain events. BHAMSRCE.RAN was created using long-term rainfall records. It includes 12 rain events from 0.01 to 4 inches and corresponding typical rain durations.

A rain file was created for each MS4 station using this master rain file. The rain files include the start/end date and time of the rain event, along with the total rain depth. The final individual rain files start and end approximately 1 month before and after the monitoring dates.

A.3 WinSLAMM Re-Calibration Process

The verification and calibration procedures for WinSLAMM were the same as for any other stormwater quality model: local data has to be collected to check the accuracy of the calculated results produced by the model. The data needed included outfall quality and quantity measurements and watershed information.

A good approach to calibrate a model is to collect all the necessary information from one watershed and to use that data to adjust the necessary parameters to obtain the best agreement between the calculated and observed conditions. Verification then uses independent data from another watershed to compare the calculated and observed conditions. Another common method used to calibrate and verify a model is to collect information for a series of events and use that data for adjusting the model parameters to obtain the best fit. Verification is then accomplished using additional data from the same watershed. During this re-calibration and re-verification of WinSLAMM, the first approach was used because of the available monitoring data from five independent drainage areas.

The process of calibrating WinSLAMM for this project used the following order:

- Runoff quantity (*.rsv file)
- Particulate solids loading (*psc and delivery files)
- Total pollutant loading (*.ppd file)

The runoff quantity file had to be examined before any of the additional parameter files were evaluated. The particulate solids files was then calibrated, followed by the other pollutants. It was very important to be completely satisfied with the calibration at each step before proceeding to the next one. As already mentioned, the NSQD MS4 Jefferson County monitoring information did not include runoff data, so the RUNOFF.RSV could not be re-validated, therefore the re-calibration process started with particulate solids and delivery files and the initial runoff calibration data for Jefferson County was used.

Data from five drainage areas were available for the re-calibration and verification process. Therefore, the calibration process started with data from the simplest and most uniform drainage area (one that has only a single land use); these areas were calibrated first before moving on to more complex areas, such as areas having a mixture of land uses and areas having both connected and disconnected roofs.

One single data file (*.dat) that stores the information necessary to perform a WinSLAMM model run was created for each drainage area based on the field data and the surface areas measured from the aerial photographs. Each data file was modeled twice, once using the rain file for the specific monitoring event, and again using the BHAMSRCE rain file. The model output included the percentage contribution of runoff volume and pollutants of interest for each rain and for each source area, indicating the main source areas that generate runoff for the different rain depths. The use of BHAMSRCE rain file (containing only 12 sorted rains) was important because it revealed the rain depth at which each source area generated runoff and pollutants, and helped focus on certain areas that needed to have their parameters modified. The monitored rain events covered a smaller range of rain depths.

A.4 Re-validation of Particulate Solids Concentration (*.PSC) file

WinSLAMM uses the mandatory PARTICULATE.PSC file to describe particulate solids concentrations for each source area (except for streets) and all land uses (except freeway), for several rain categories. The model also uses the DELIVERY.PRR file to adjust the source predictions for outfall conditions because the larger particulates will accumulate in the storm drainage system during the smaller rains. This file is used for swales, curb and gutters, undeveloped roadsides, or combinations of drainage components.

The washoff of particulates from streets is directly calculated using explicit accumulation and washoff algorithms based on land use, street texture, and rain conditions. Freeway paved lane and shoulder areas are also directly predicted and have explicit algorithms that calculates the washoff of particulate solids based on traffic volumes and rain conditions. The street and highway predictions for particulate solids are modified by the STREET.STD file to account for reduced rainfall energy during the smaller rains. Concentrations of particulate solids at the beginning of the rains at some source area (especially paved parking areas) are much greater than later in the same rain ("first flush" conditions). This variation is highly dependent on rain energy and WinSLAMM uses a similar relationship to describe particulate solids variations for different rain depths.

The re-calibration process was started by running the WinSLAMM files for the monitored drainage areas using their own rain file, and the delivery, street and particulate files without any additional pollutants selected. The predicted and observed particulate solids concentrations for the monitored events were compared by creating a double probability plot of observed and predicted values (Figure A1). The data were plotted using a log- normal distribution so that the points should form approximately straight lines. Departures from this straight line indicated departures from the anticipated log-normal distributions of the data. The desired pattern for the observed and predicted particulate solids concentration plots was to have two overlapping lines of points with minimal deviation. The desired pattern for the residual error plot was an even, narrow band over the range of observed rain depths, centered on the zero residual error horizontal line (Figure A2). Also, the sum of the observed and predicted particulate solids concentration (mg/L) for all monitored events had to be calculated. The percentage difference in the sum of concentrations should be small. It was likely that the largest difference in the particulate solids concentrations were associated with small rain depths (WinSLAMM probably over-estimated the concentrations, unless the delivery files were correctly used), while the differences for the larger rains were smaller. WinSLAMM calibration for particulate solids concentrations and loadings was accomplished by modifying the DELIVERY.PRR, STREET.STD and BHAM.PSC files.

The *.PRR file adjusts the delivery of the particulate solids for the whole watershed (based on the drainage system type) and usually has a greater effect on small rains, with minimum effects on large rains. The DELIVERY.PRR file data was smoothened by modifying almost all of the delivery fractions by the same amount (Figure A3).

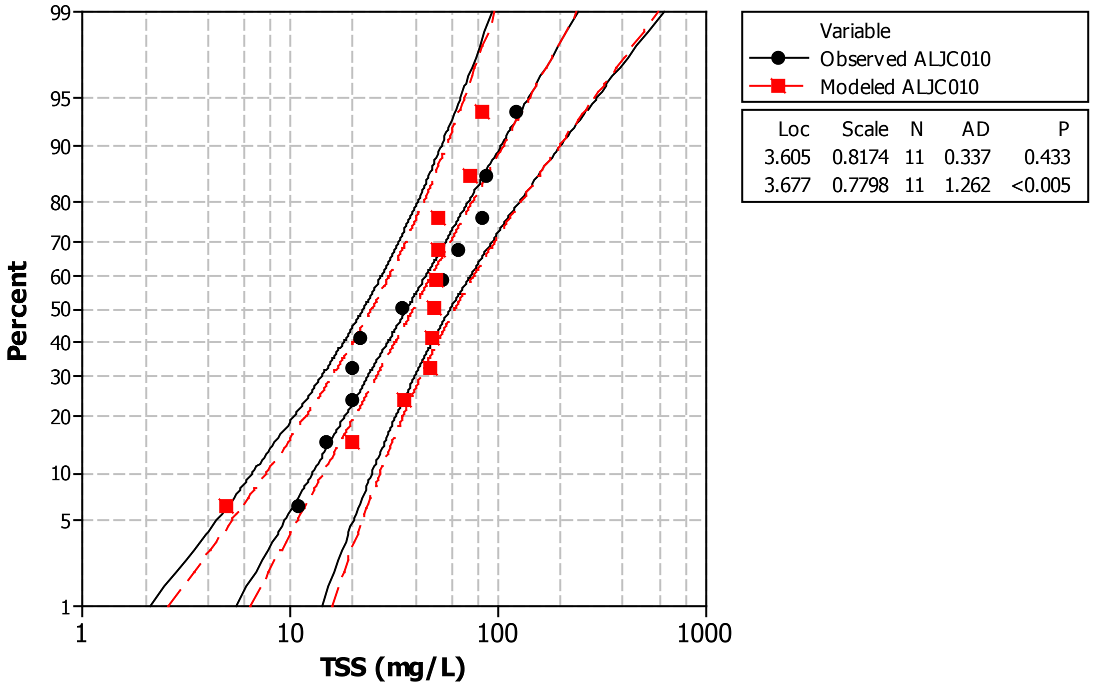


Fig. A1. Example of Log-Normal Probability Plot for Site ALJC010 (Residential Land Use)

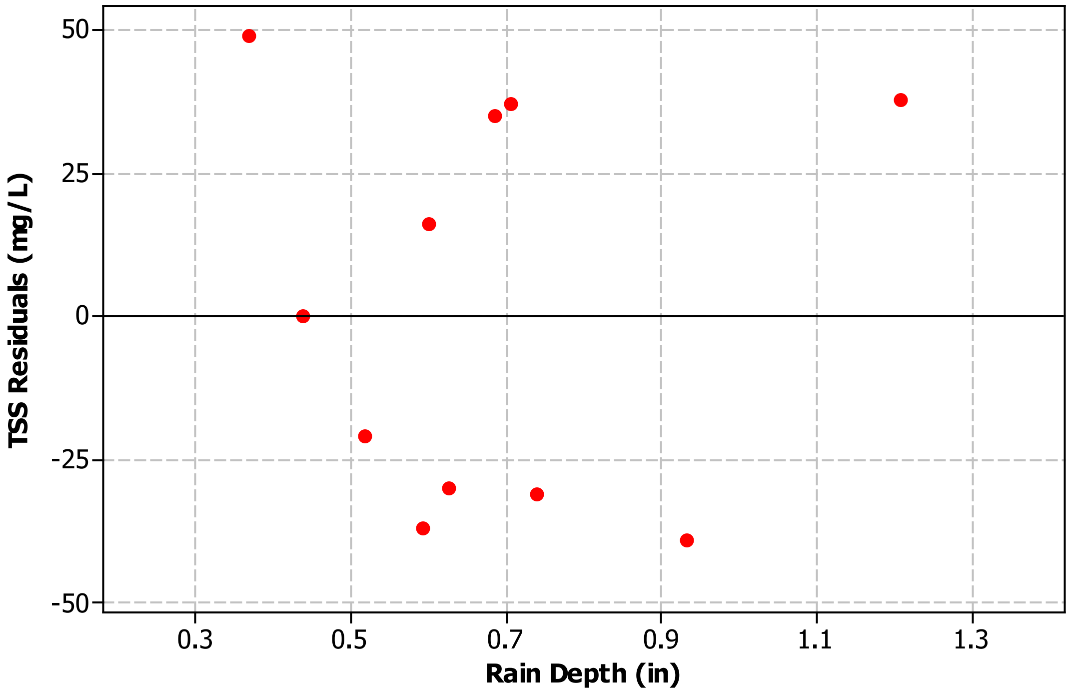


Fig. A2. Example of Residual Plot for Site ALJC010 (Residential Land Use)

Grass swales, undeveloped roadsides, and flat curbs and gutters have slow runoff velocities and lower carrying capacities of sediment than flows in steeper areas or smoother gutters. The differences are the most pronounced for the smaller rains than for larger rains where the velocities are all much greater, corresponding too much greater sediment carrying capacities.

The street delivery file (*.STD) only affects predicted particulate concentrations associated with the street areas and is based on limited runoff energy availability. It was the next file to be calibrated. Separate street delivery files were created for each land use (Figure A4). The *.PSC file describes the particulate solids concentrations (mg/L) for each rain for each source area, showing where WinSLAMM is generating the particulate solids for different rain depths.

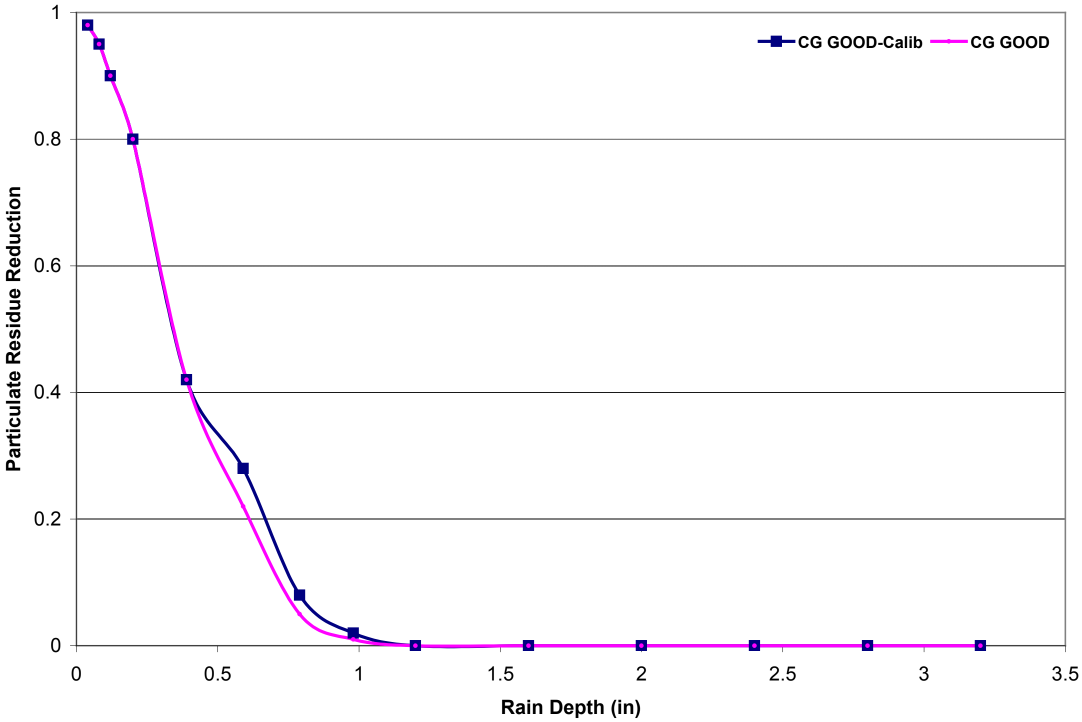


Fig. A3. Example of Smoothed Delivery File (for Curbs and Gutters in Good Conditions or Very Steep Drainage System)

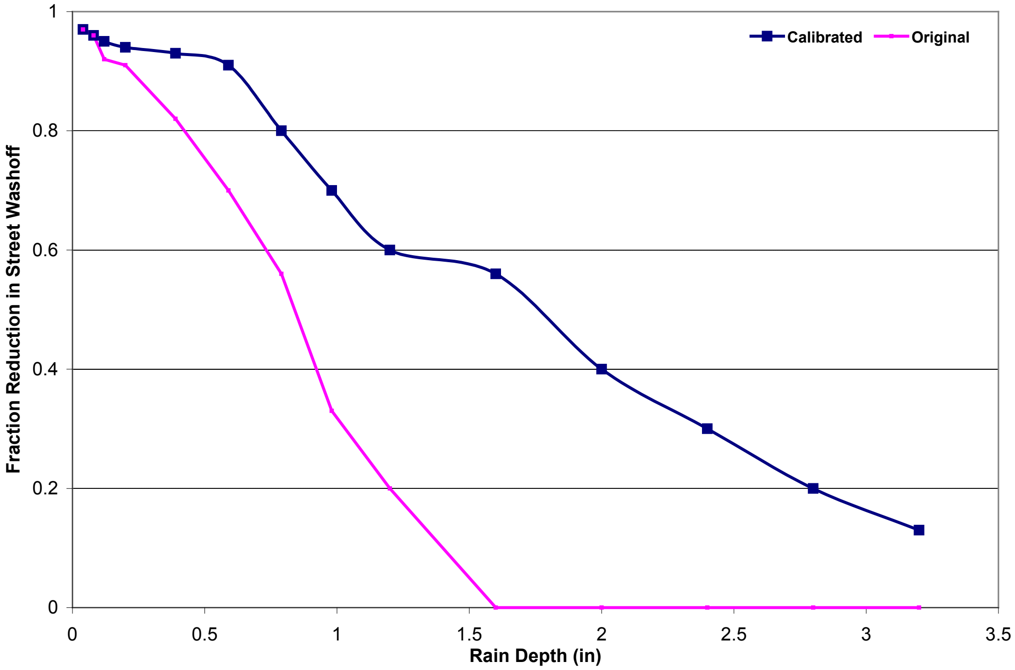


Fig. A4. Example of Street Delivery File (for Residential Land Uses)

The calibration process for the *.PSC file began by first focusing on the larger storms and trying to bring the medians of the observed and calculated values close together. For some land uses the PSC values were increased or decreased more for the larger storms than for the smaller storms (Figure A5 and A6).

After each change was made, the program was re-run using the new parameter file and the results were reviewed. It was necessary to repeat this process a few times to become satisfied that no further improvements were possible.

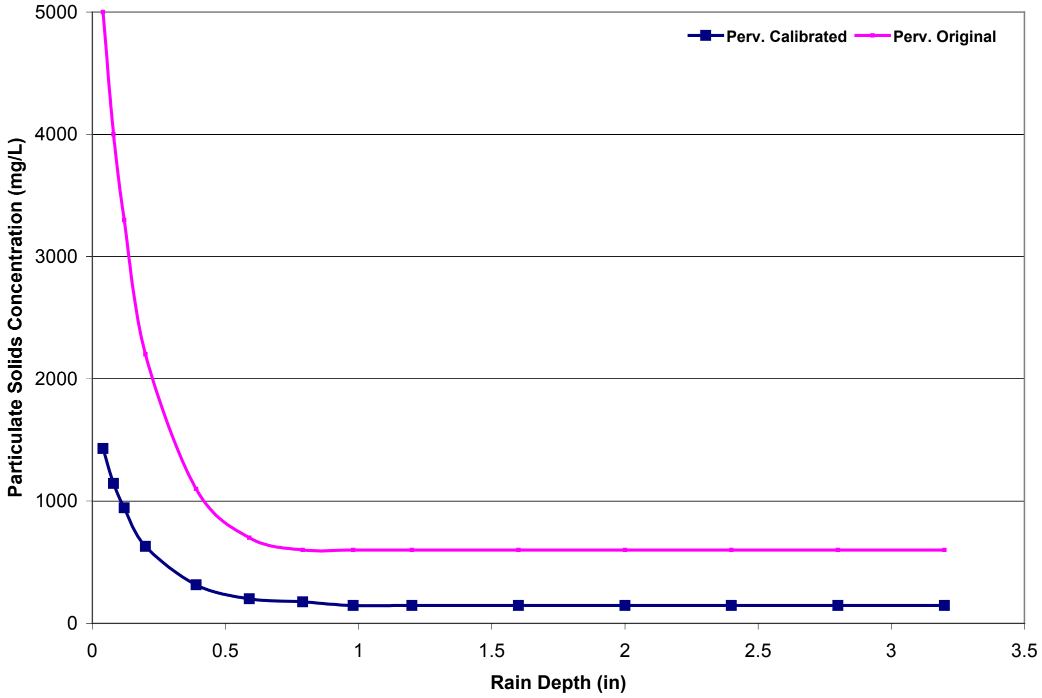


Fig. A5. Example of Particulate Solids Concentration File for Residential Land Use - Pervious Surfaces

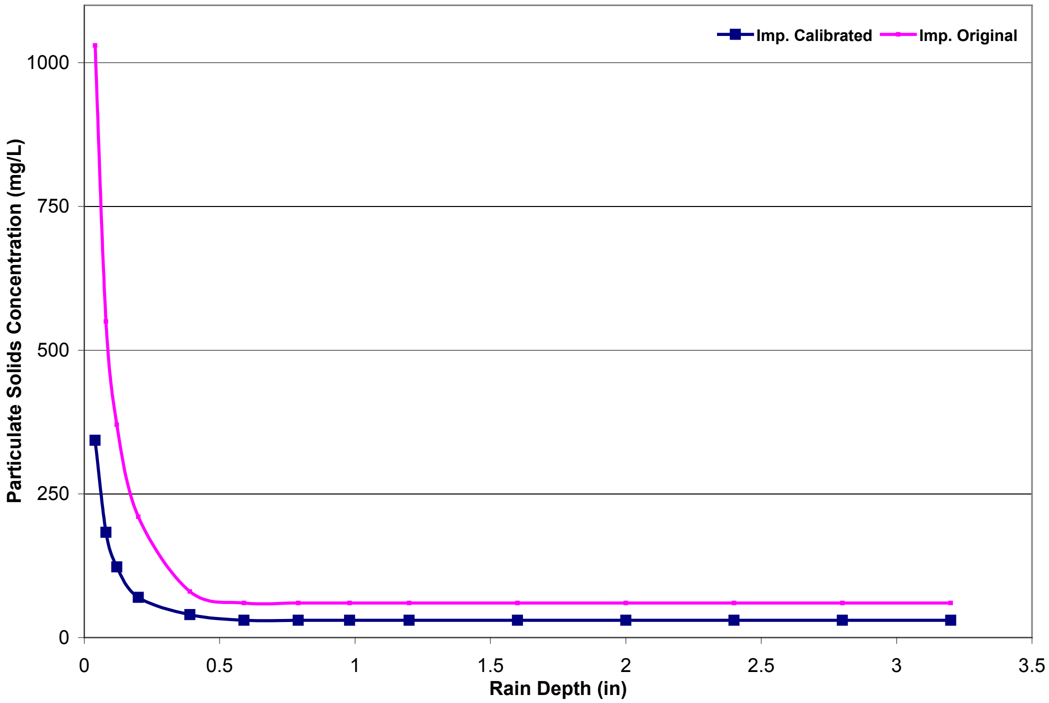


Fig. A6. Example of Particulate Solids Concentration File for Residential Land Use - Impervious Surfaces

A.5 Re-validation of Pollutants Concentration (*.PPD) file

The pollutant file BHAM.PPD describes the particulate pollutant strengths associated with the particulate solids (mg pollutant/kg particulate solids) and the filterable pollutant concentrations (mg/L) for each land use for each source area. This file is not needed if the watershed analysis includes only runoff volume and particulate solids calculations. This file also contains the COV values for each pollutant for Monte Carlo simulations in WinSLAMM, an option that can be turned off by the model user default (seed of -42).

For this study, only phosphorus, COD, copper, and zinc were calibrated. The procedure for calibrating the total pollutants followed the same pattern as for calibrating the *.PSC file, with one exception: the total pollutant value is the sum of the particulate and filterable pollutant values. Therefore, the calibration was performed for particulate and filterable pollutants by increasing and decreasing the values by the same amount for one particular pollutant (Figure A7 and A8).

Once again, after each change was made to the pollutant file, the program was re-run using the new *.PPD parameter file and the already calibrated particulate solids concentrations files. The results were reviewed and the process was repeated multiple times until satisfied that no further improvements were possible.

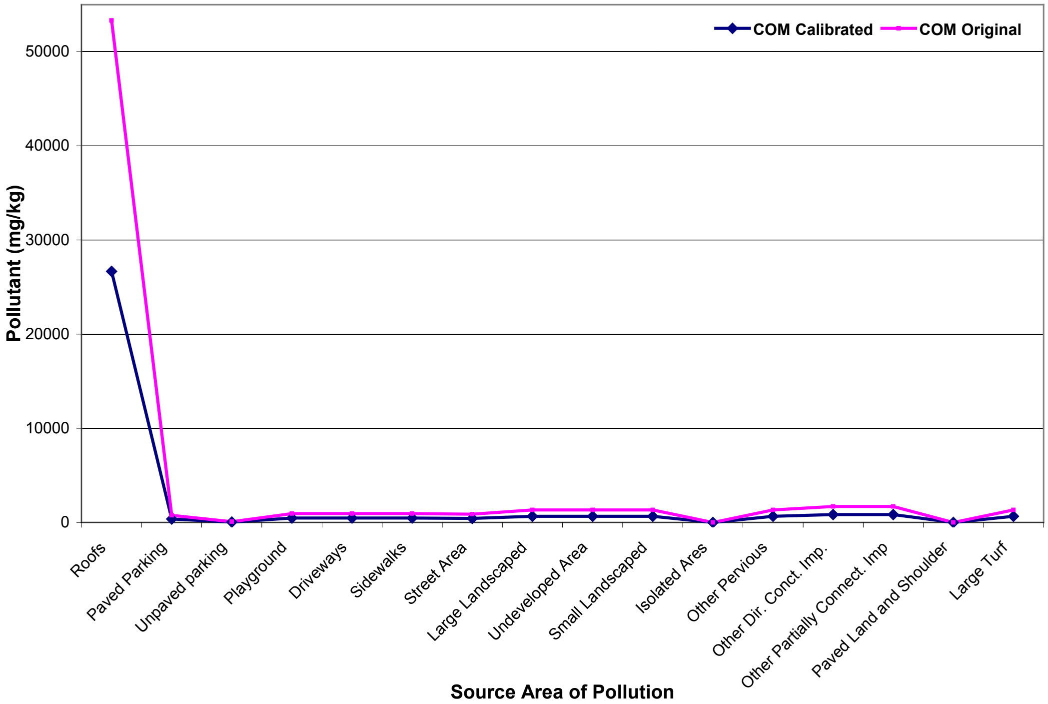


Fig. A7. Example of Particulate Zinc for Commercial Land Use

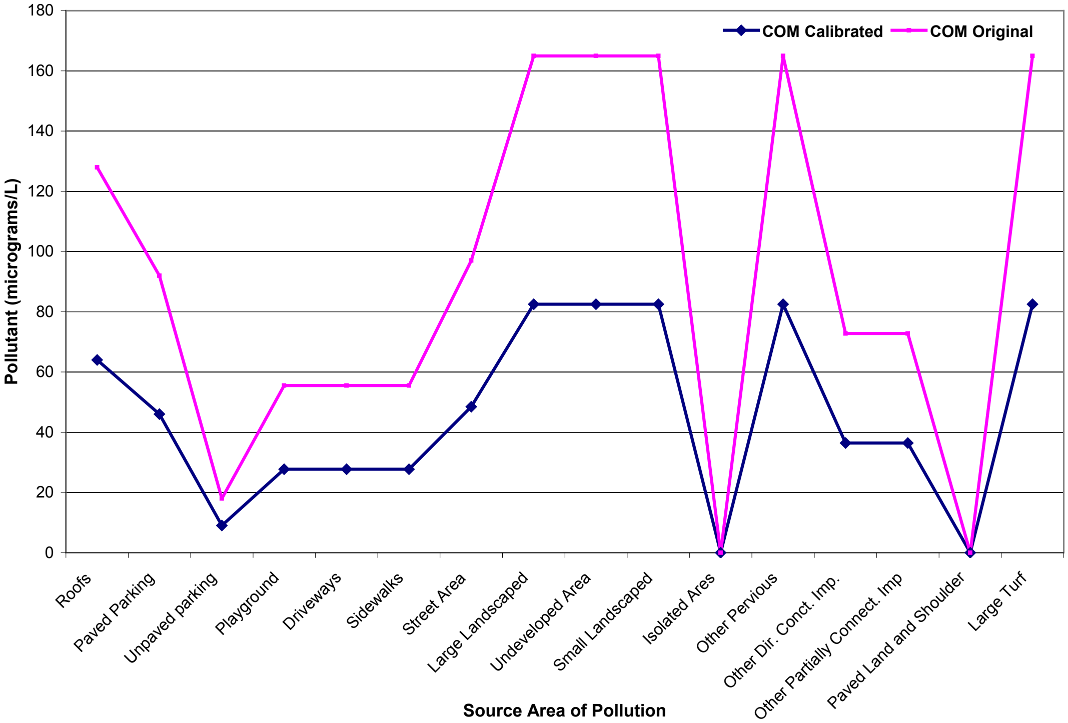


Fig. A8. Example of Filterable Zinc Concentration for Commercial Land Use

Appendix B
All EPA Rain Zones – Detailed Analyses of Selected Pollutants

B.1. Total Zinc

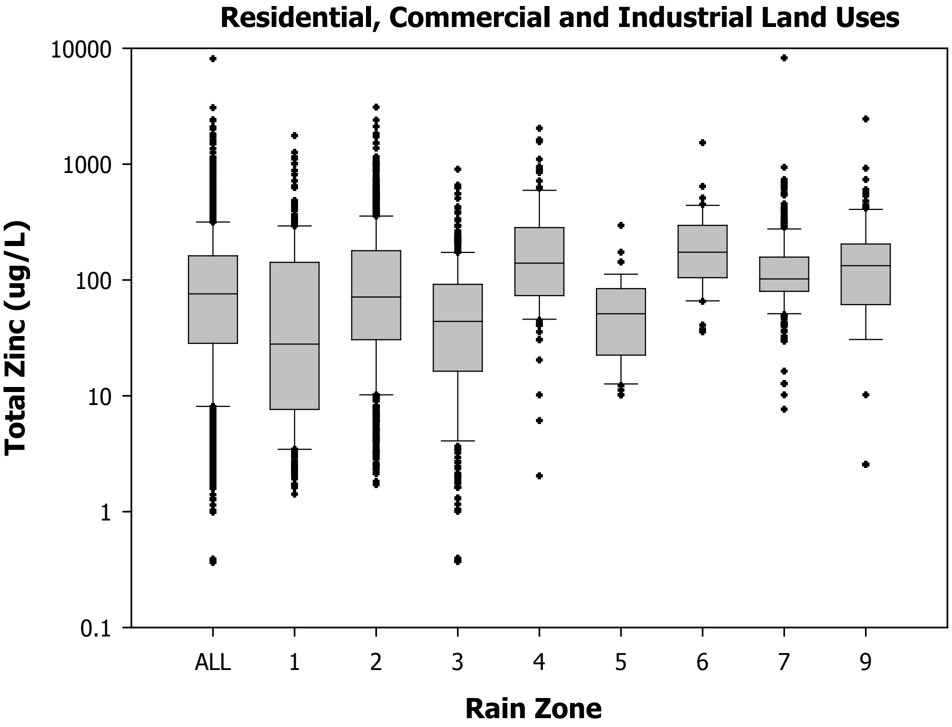
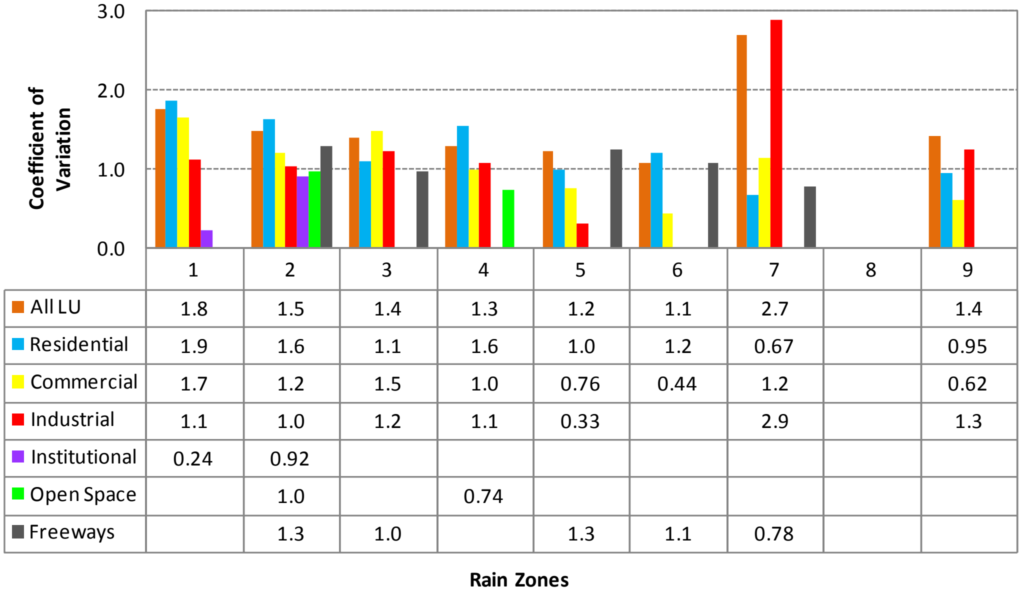
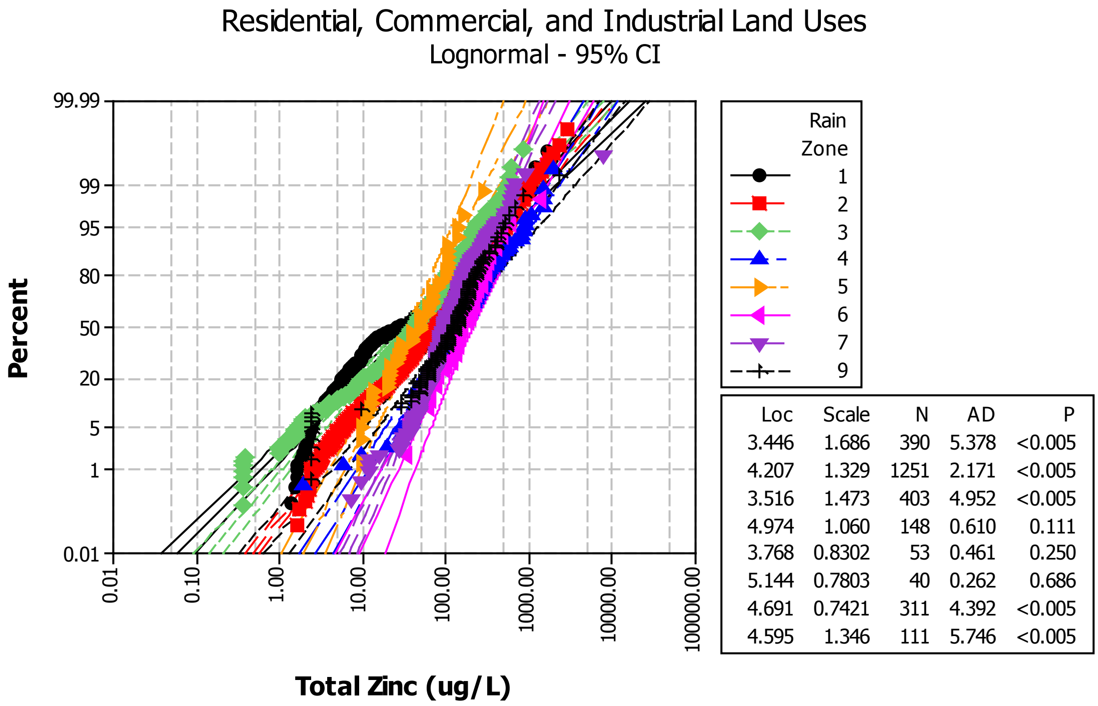


Fig. B1. Total Zinc – Residential, Commercial, and Industrial Land Uses
in the Contiguous United States



	1	2	3	4	5	6	7	8	9
🟧 All LU	1.8	1.5	1.4	1.3	1.2	1.1	2.7		1.4
🟦 Residential	1.9	1.6	1.1	1.6	1.0	1.2	0.67		0.95
🟨 Commercial	1.7	1.2	1.5	1.0	0.76	0.44	1.2		0.62
🟥 Industrial	1.1	1.0	1.2	1.1	0.33		2.9		1.3
🟪 Institutional	0.24	0.92							
🟩 Open Space		1.0		0.74					
⬛ Freeways		1.3	1.0		1.3	1.1	0.78		

Fig. B2. Total Zinc - Regional Coefficients of Variation for Single Land Uses in the Contiguous United States



Loc	Scale	N	AD	P
3.446	1.686	390	5.378	<0.005
4.207	1.329	1251	2.171	<0.005
3.516	1.473	403	4.952	<0.005
4.974	1.060	148	0.610	0.111
3.768	0.8302	53	0.461	0.250
5.144	0.7803	40	0.262	0.686
4.691	0.7421	311	4.392	<0.005
4.595	1.346	111	5.746	<0.005

Fig. B3. Total Zinc – Residential, Commercial, and Industrial Land Uses in the Contiguous United State (Checks for Normality)

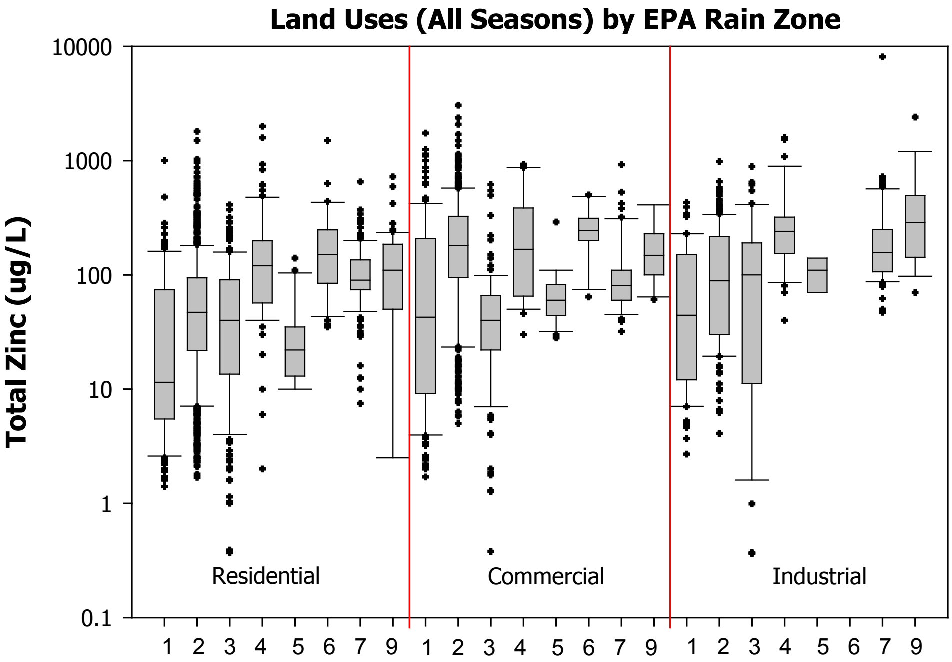


Fig. B4. Total Zinc – Land Uses by EPA Rain Zone

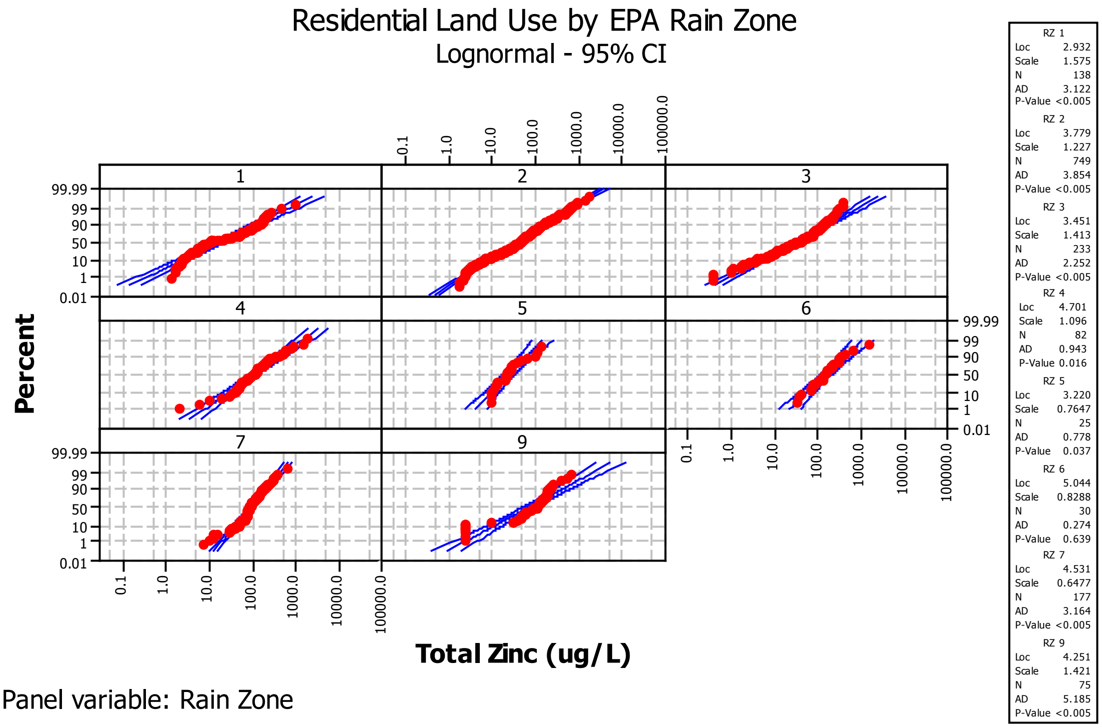


Fig. B5. Total Zinc – Residential Land Use by EPA Rain Zone (Checks for Normality)

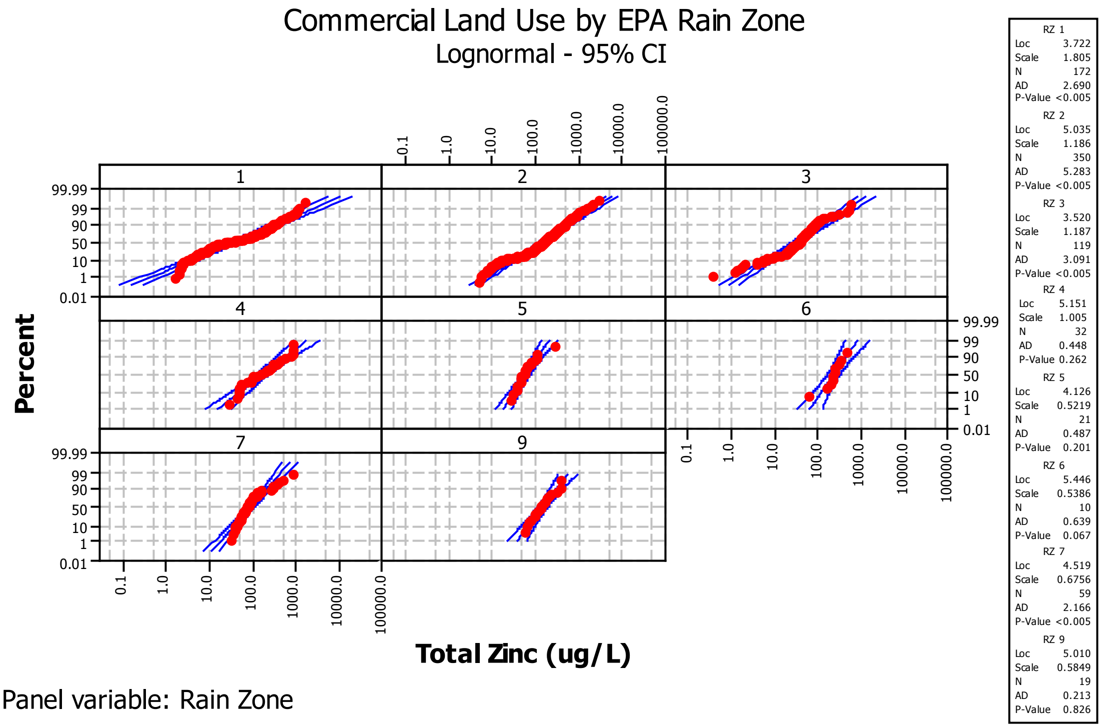


Fig. B6. Total Zinc – Commercial Land Use by EPA Rain Zone (Checks for Normality)

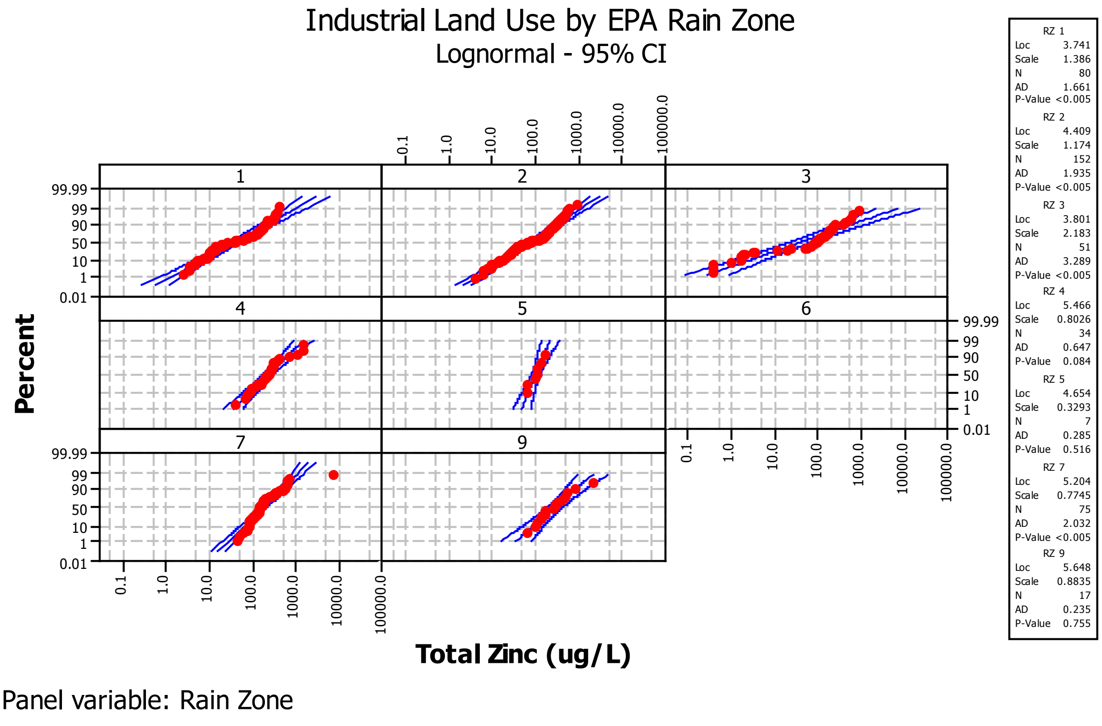


Fig. B7. Total Zinc – Industrial Land Use by EPA Rain Zone (Checks for Normality)

Table B1. Total Zinc – Univariate 3-way ANOVA Tests of Between-Subjects Effects

Dependent Variable: Log Zinc

	Source	Type III Sum of Squares	DF	Mean Square	F	P-value
	Corrected Model*	258*	90	2.9	9.8	0.000
	Intercept	1953	1	1953	6717	0.000
Main Effects	Rain Zone (8 levels)	97	7	14	48	0.000*
	Land Use (3 levels)	14	2	7.2	25	0.000*
	Season (4 levels)	0.62	3	0.21	0.72	0.542
Two-way Interactions	Rain Zone * Land Use	23	13	1.8	6.0	0.000*
	Rain Zone * Season	23	21	1.1	3.7	0.000*
	Land Use * Season	1.7	6	0.28	0.97	0.446
Three-way Interaction	Rain Zone * Land Use * Season	10	38	0.26	0.91	0.628
	Error	761	2616	0.29		
	Total	9656	2707			
	Corrected Total	1018	2706			

*R Squared = 0.253 (Adjusted R Squared = 0.227)

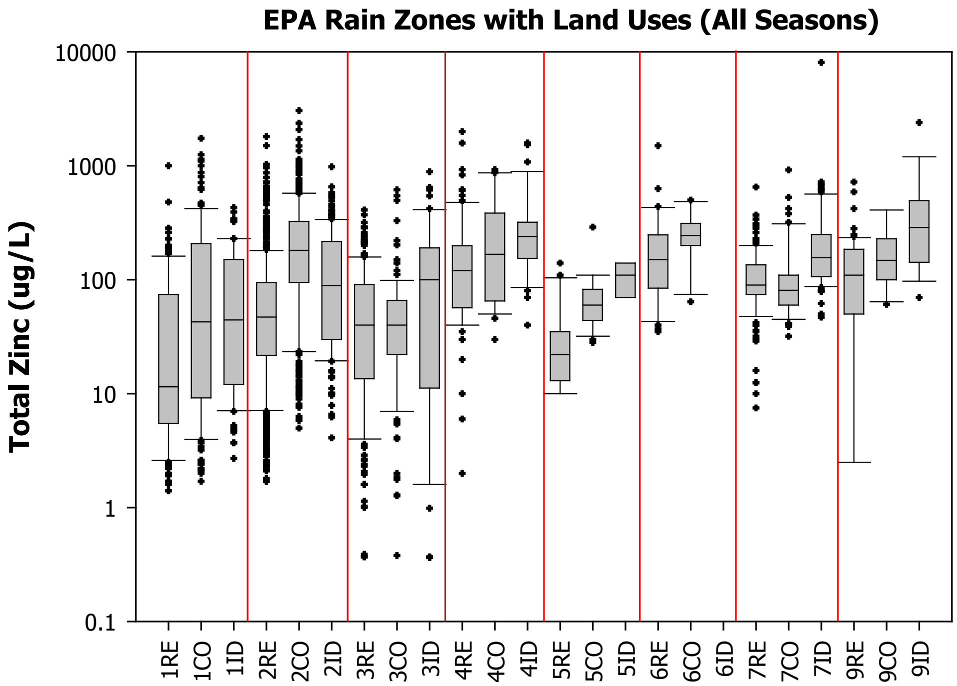


Fig. B8. Total Zinc – EPA Rain Zones with Land Uses

Table B2. Total Zinc **-** MANOVA Test for Significance of Land Use within Rain Zone using Unique Sum of Squares

Source of Variation	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
WITHIN CELLS	761	2616	0.29		
Land Use WITHIN Rain Zone (1)	17	2	8.4	29	0.000*
Land Use WITHIN Rain Zone (2)	65	2	32	111	0.000*
Land Use WITHIN Rain Zone (3)	17	2	8.4	29	0.000*
Land Use WITHIN Rain Zone (4)	0.47	2	0.24	0.81	0.443
Land Use WITHIN Rain Zone (5)	4.6	2	2.3	8.0	0.000*
Land Use WITHIN Rain Zone (6)	6.5	2	3.3	11	0.000*
Land Use WITHIN Rain Zone (7)	4.6	2	2.3	7.8	0.000*
Land Use WITHIN Rain Zone (9)	1.1	2	0.57	2.0	0.142

Table B3. Total Zinc - Test of Significance: Land Use within Rain Zone

Rain Zone	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Zinc					**Power Analysis**	
		(I) LU	**(J) LU**	**p-value**	**LU**	**N**	**Gr. 1**	**Gr. 2**	**Gr. 3**	**α level**	**Power (%)**
1	0.000*	RE	CO	0.000*	RE	138	1.273			0.20	99.8
			ID	0.002*	CO	172		1.616		0.15	99.7
		CO	ID	0.996	ID	80		1.625		0.10	99.5
					Pooled St. Dev = 0.715					***0.05***	***98.8***
					Obtained Effect Size = 0.23					0.01	95.0
2	0.000*	RE	CO	0.000*	RE	749	1.641			0.20	100
			ID	0.000*	CO	350		2.187		0.15	100
		CO	ID	0.000*	ID	152			1.915	0.10	100
					Pooled St. Dev = 0.525					***0.05***	***100***
					Obtained Effect Size = 0.46					0.01	100
3	0.308	RE	CO	0.919	RE	233	1.499			0.20	52.6
			ID	0.308	ID	119	1.529			0.15	45.9
		CO	ID	0.521	CO	51	1.651			0.10	37.4
					Pooled St. Dev = 0.639					***0.05***	***25.9***
					Obtained Effect Size = 0.08					0.01	10.2
5	0.000*	RE	CO	0.000*	RE	25	1.398			0.20	99.9
			ID	0.000*	CO	21		1.792		0.15	99.9
		CO	ID	0.173	ID	7		2.021		0.10	99.9
					Pooled St. Dev = 0.276					***0.05***	***99.9***
					Obtained Effect Size = 0.86					0.01	99.8
6	0.161	-	-	-	RE	30	2.191			0.20	55.5
					CO	10	2.365			0.15	48.9
					ID	-	-			0.10	40.5
					Pooled St. Dev = 0.334					***0.05***	***28.5***
					Obtained Effect Size = 0.23					0.01	11.3

Table B3. - *Continued*

Rain Zone	1-Way ANOVA p-value	Multiple Comparison (Scheffe Post-Hoc Test)			Homogeneous Groups Dependent Variable: Log Zinc					Power Analysis	
		(I) LU	(J) LU	p-value	LU	N	Gr. 1	Gr. 2	Gr. 3	α level	Power (%)
7	0.000*	RE	CO	0.993	RE	177	1.968			0.20	100
			ID	0.000*	CO	59	1.963			0.15	100
		CO	ID	0.000*	ID	75		2.260		0.10	100
					Pooled St. Dev = 0.298					***0.05***	***99.9***
					Obtained Effect Size = 0.42					0.01	99.9

Table B4. Total Zinc **-** MANOVA Test for Significance of Season within Rain Zone using Unique Sum of Squares

Source of Variation	Sum of Squares	DF	Mean Square	F	p-value
WITHIN CELLS	761	2616	0.29		
Season WITHIN Rain Zone (1)	12	3	3.9	14	0.000*
Season WITHIN Rain Zone (2)	2.5	3	0.83	2.9	0.036*
Season WITHIN Rain Zone (3)	11	3	3.7	13	0.000*
Season WITHIN Rain Zone (4)	1.2	3	0.40	1.4	0.251
Season WITHIN Rain Zone (5)	0.03	3	0.01	0.03	0.991
Season WITHIN Rain Zone (6)	1.8	3	0.61	2.1	0.099
Season WITHIN Rain Zone (7)	6.5	3	2.2	7.4	0.000*
Season WITHIN Rain Zone (9)	2.0	3	0.68	2.3	0.071

Table B5. Total Zinc – Test of Significance: Land Use and Season within Rain Zone

Rain Zone	Land Use	1-Way ANOVA p-value	Multiple Comparison (Scheffe Post-Hoc Test)			Homogeneous Groups Dependent Variable: Log Zinc				Power Analysis	
			(I) Season	(J) Season	p-value	Season	N	Gr. 1	Gr. 2	α level	Power (%)
1	RE	0.144	-	-	-	FA	60	1.194		0.20	73.8
						SP	28	1.193		0.15	68.0
						SU	35	1.506		0.10	59.9
						WI	15	1.197		***0.05***	***46.9***
										0.01	24.1
						Pooled St. Dev = 0.678, Obtained Effect Size = 0.20					
	CO ID	0.000*	FA	SP	0.919	FA	94	1.554		0.20	99.5
				SU	0.034*	SP	44	1.645		0.15	99.2
				WI	0.276	SU	71	1.884		0.10	98.7
			SP	SU	0.380	WI	43		1.297	***0.05***	***97.1***
				WI	0.156					0.01	90.1
			SU	WI	0.000*	Pooled St. Dev = 0.707, Obtained Effect Size = 0.28					

Table B5. - *Continued*

Rain Zone	Land Use	1-Way ANOVA p-value	Multiple Comparison (Scheffe Post-Hoc Test)			Homogeneous Groups Dependent Variable: Log Zinc				Power Analysis	
			(I) Season	(J) Season	p-value	Season	N	Gr. 1	Gr. 2	α level	Power (%)
2	RE	0.263	-	-	-	FA	207	1.610		0.20	63.3
						SP	211	1.630		0.15	56.8
						SU	147	1.718		0.10	48.2
						WI	184	1.627		***0.05***	***35.6***
										0.01	16.1
						Pooled St. Dev = 0.533, Obtained Effect Size = 0.07					
	CO	0.069	-	-	-	FA	100	2.077		0.20	82.8
						SP	84	2.258		0.15	78.2
						SU	79	2.243		0.10	71.4
						WI	87	2.193		***0.05***	***59.7***
										0.01	35.6
						Pooled St. Dev = 0.512, Obtained Effect Size = 0.14					
	ID	0.079	-	-	-	FA	42	1.762		0.20	81.2
						SP	41	1.939		0.15	76.3
						SU	32	1.922		0.10	69.2
						WI	37	2.056		***0.05***	***57.0***
										0.01	32.7
						Pooled St. Dev = 0.503, Obtained Effect Size = 0.21					
3	RE ID CO	0.001*	FA	SP	0.004*	FA	131	1.463		0.20	99.0
				SU	0.998	SU	113	1.479		0.15	98.5
				WI	0.995	WI	80	1.440		0.10	97.5
			SP	SU	0.010*	SP	79		1.790	***0.05***	***95.0***
				WI	0.007*					0.01	85.1
			SU	WI	0.981	Pooled St. Dev = 0.629, Obtained Effect Size = 0.21					
7	RE CO	0.000*	FA	SP	0.000*	FA	50	2.143		0.20	99.9
				SU	0.044*	SP	66		1.890	0.15	99.9
				WI	0.000*	SU	35		1.972	0.10	99.9
			SP	SU	0.539	WI	85		1.920	***0.05***	***99.8***
				WI	0.921					0.01	98.7
			SU	WI	0.819	Pooled St. Dev = 0.269, Obtained Effect Size = 0.35					
	ID	0.505	-	-	-	FA	35	2.278		0.20	47.3
						SP	19	2.253		0.15	40.4
						SU	3	1.972		0.10	32.0
						WI	18	2.280		***0.05***	***21.0***
										0.01	7.4
						Pooled St. Dev = 0.338, Obtained Effect Size = 0.18					

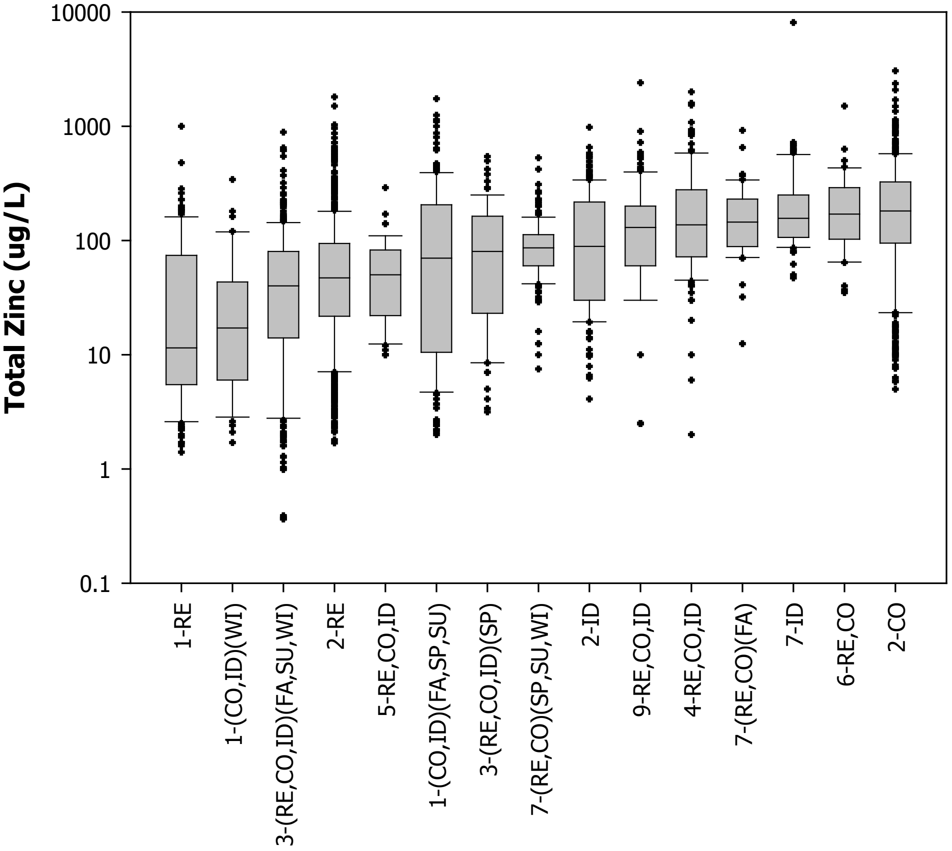


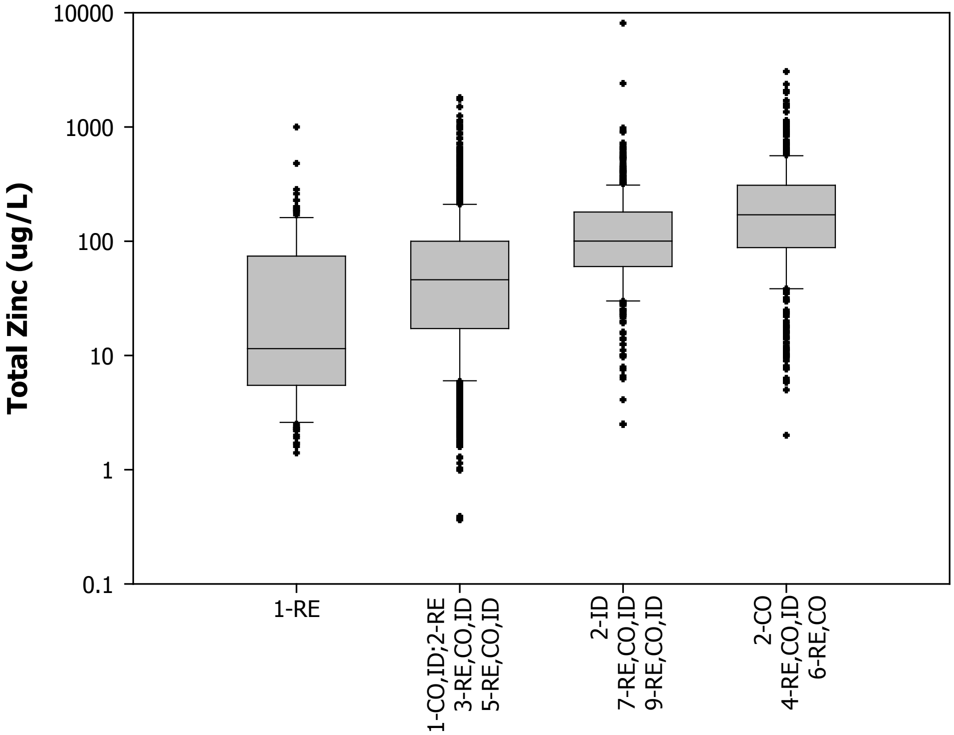
Fig. B9. Total Zinc – Rain Zone Groups

Table B6. Total Zinc – Homogeneous Groups

Groups	**N**	**Homogeneous Groups** Dependent Variable: Log Zinc			
		A	**B**	**C**	**D**
1-RE	138	1.273			
1-(CO,ID)(FA,SP,SU)	209		1.685		
1-(CO,ID)(WI)	43		1.297		
2-RE	749		1.641		
3-(RE,CO,ID)(FA,SU,WI)	324		1.462		
3-(RE,CO,ID)(SP)	79		1.790		
5-RE,CO,ID	53		1.637		
2-ID	152			1.915	
7-(RE,CO)(FA)	50			2.142	
7-(RE,CO)(SP,SU,WI)	186			1.919	
7-ID	75			2.260	
9-RE,CO,ID	111			1.996	
2-CO	350				2.187
4-RE,CO,ID	148				2.160
6-RE,CO,ID	40				2.234

Table B7. Total Zinc – Rain Zone Groups Multiple Comparisons

(I) Group	(J) Group	p-value
4-RE,CO,ID	5-RE,CO,ID	0.001
	6-RE,CO,ID	1.000
	9-RE,CO,ID	0.972
	1-RE	0.000
	1-(CO,ID)(FA,SP,SU)	0.000
	1-(CO,ID)(WI)	0.000
	2-RE	0.000
	2-CO	1.000
	2-ID	0.369
	3-(RE,CO,ID)(FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.050
	7-(RE,CO)(FA)	1.000
	7-(RE,CO)(SP,SU,WI)	0.304
	7-ID	1.000
5-RE,CO,ID	6-RE,CO,ID	0.018
	9-RE,CO,ID	0.341
	1-RE	0.254
	1-(CO,ID)(FA,SP,SU)	1.000
	1-(CO,ID)(WI)	0.816
	2-RE	1.000
	2-CO	0.000
	2-ID	0.744
	3-(RE,CO,ID)(FA,SU,WI)	0.990
	3-(RE,CO,ID)(SP)	1.000
	7-(RE,CO)(FA)	0.077
	7-(RE,CO)(SP,SU,WI)	0.683
	7-ID	0.000
1-(CO,ID)(WI)	1-(CO,ID)(FA,SP,SU)	0.205
	2-RE	0.303
	2-CO	0.000
	2-ID	0.000
	3-(RE,CO,ID)(FA,SU,WI)	0.998
	3-(RE,CO,ID)(SP)	0.065
	7-(RE,CO)(FA)	0.000
	7-(RE,CO)(SP,SU,WI)	0.000
	7-ID	0.000
9-RE,CO,ID	1-RE	0.000
	1-(CO,ID)(FA,SP,SU)	0.052
	1-(CO,ID)(WI)	0.000
	2-RE	0.000
	2-CO	0.737
	2-ID	1.000
	3-(RE,CO,ID)(FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.949
	7-(RE,CO)(FA)	1.000
	7-(RE,CO)(SP,SU,WI)	1.000
	7-ID	0.725
1-RE	1-(CO,ID)(FA,SP,SU)	0.000
	1-(CO,ID)(WI)	1.000
	2-RE	0.000
	2-CO	0.000
	2-ID	0.000
	3-(RE,CO,ID)(FA,SU,WI)	0.632
	3-(RE,CO,ID)(SP)	0.000
	7-(RE,CO)(FA)	0.000
	7-(RE,CO)(SP,SU,WI)	0.000
	7-ID	0.000
1-(CO,ID)(FA,SP,SU)	1-(CO,ID)(WI)	0.205
	2-RE	1.000
	2-CO	0.000
	2-ID	0.332
	3-(RE,CO,ID)(FA,SU,WI)	0.099
	3-(RE,CO,ID)(SP)	1.000
	7-(RE,CO)(FA)	0.013
	7-(RE,CO)(SP,SU,WI)	0.202
	7-ID	0.000
3-(RE,CO,ID)(FA,SU,WI)	3-(RE,CO,ID)(SP)	0.062
	7-(RE,CO)(FA)	0.000
	7-(RE,CO)(SP,SU,WI)	0.000
	7-ID	0.000
7-(RE,CO)(SP,SU,WI)	7-ID	0.104
6-RE,CO,ID	9-RE,CO,ID	0.975
	1-RE	0.000
	1-(CO,ID)(FA,SP,SU)	0.002
	1-(CO,ID)(WI)	0.000
	2-RE	0.000
	2-CO	1.000
	2-ID	0.699
	3-(RE,CO,ID)(FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.226
	7-(RE,CO)(FA)	1.000
	7-(RE,CO)(SP,SU,WI)	0.685
	7-ID	1.000
2-RE	2-CO	0.000
	2-ID	0.004
	3-(RE,CO,ID)(FA,SU,WI)	0.044
	3-(RE,CO,ID)(SP)	0.980
	7-(RE,CO)(FA)	0.000
	7-(RE,CO)(SP,SU,WI)	0.000
	7-ID	0.000
2-CO	2-ID	0.024
	3-(RE,CO,ID)(FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.002
	7-(RE,CO)(FA)	1.000
	7-(RE,CO)(SP,SU,WI)	0.010
	7-ID	1.000
2-ID	3-(RE,CO,ID)(FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.999
	7-(RE,CO)(FA)	0.952
	7-(RE,CO)(SP,SU,WI)	1.000
	7-ID	0.128
3-(RE,CO,ID)(SP)	7-(RE,CO)(FA)	0.545
	7-(RE,CO)(SP,SU,WI)	0.999
	7-ID	0.012
7-(RE,CO)(FA)	7-(RE,CO)(SP,SU,WI)	0.949
	7-ID	1.000



Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	57 (2.4)	93 (1.6)	52 (1.2)	103 (0.68)	19 (0.65)	425 (1.1)	160 (0.73)	118 (0.62)
	SP	57 (1.8)	74 (1.2)	74 (1.0)	256 (1.4)	41 (0.83)	124 (0.27)	86 (0.45)	97 (0.94)
	SU	72 (1.0)	118 (1.7)	73 (1.2)	251 (1.7)	44 (1.0)	170 (0.59)	127 (0.45)	141 (1.04)
	WI	34 (1.3)	77 (1.8)	63 (1.1)	182 (1.3)	16 (0.63)	157 (0.88)	97 (0.54)	ND
Commercial	FA	187 (1.8)	216 (1.0)	44 (0.79)	187 (0.56)	109 (0.84)	287 (0.19)	279 (0.95)	101 (0.56)
	SP	131 (1.5)	303 (1.3)	165 (0.84)	461 (0.86)	65 (0.57)	ND	104 (1.1)	167 (0.64)
	SU	189 (0.99)	287 (1.2)	71 (1.8)	233 (0.74)	53 (0.29)	276 (0.65)	92 (1.1)	216 (0.55)
	WI	31 (1.5)	283 (1.2)	36 (0.85)	150 (1.0)	54 (0.16)	205 (0.24)	93 (0.54)	ND
Industrial	FA	66 (1.5)	127 (1.4)	159 (1.2)	407 (0.74)	ND	ND	446 (3.0)	361 (1.3)
	SP	96 (1.3)	14 (0.98)	190 (0.77)	345 (1.3)	127 (0.3)	ND	212 (0.69)	290 (0.55)
	SU	141 (0.70)	137 (0.93)	161 (1.9)	468 (1.2)	93 (0.43)	ND	130 (1.0)	613 (1.5)
	WI	63 (1.3)	178 (0.8)	81 (0.62)	187 (0.52)	ND	ND	224 (0.61)	453 (0.05)

Fig. B10. Total Zinc – Rain Zone Homogeneous Groups: Mean (CV)

Table B8. Basic Statistics for Total Zinc –
Rain Zone Homogeneous Groups (Real Space Data) (μg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	1-RE	138	59	109	1.9	1.4	11	1000
B	1-CO,ID; 2-RE 3-RE,CO,ID 5-RE,CO,ID	1457	92	151	1.6	0.36	46	1807
C	2-ID 7-RE,CO,ID 9-RE,CO,ID	574	163	371	2.3	2.5	100	8100
D	2-CO; 4-RE,CO,ID 6-RE,CO	538	261	317	1.2	2.0	170	3051

B.2. Total Copper

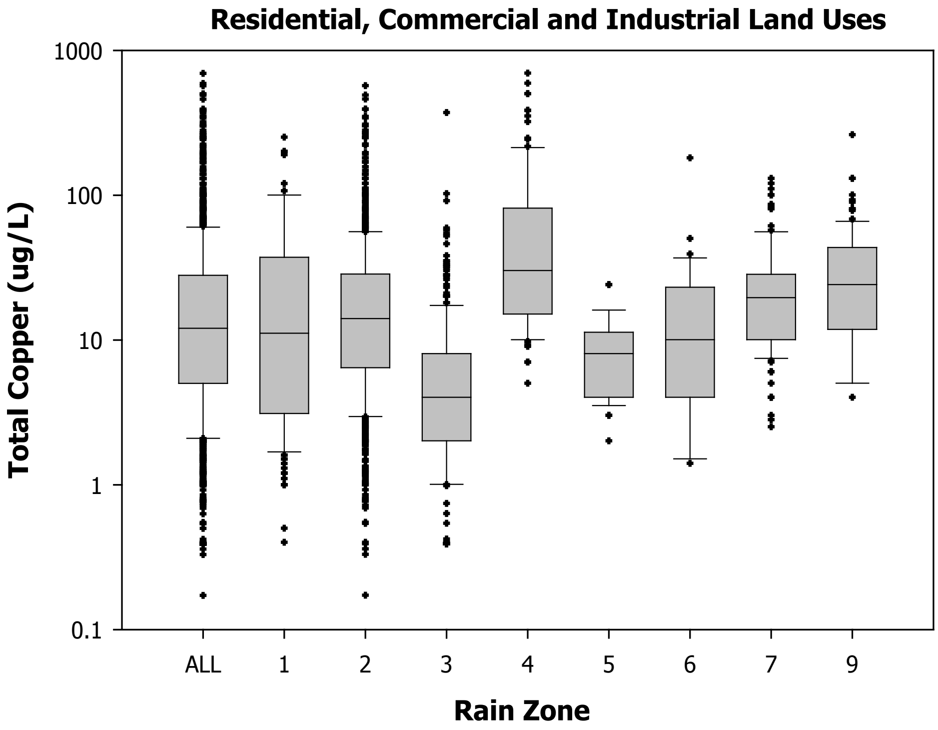


Fig. B11. Total Copper – Residential, Commercial, and Industrial Land Uses
in the Contiguous United States

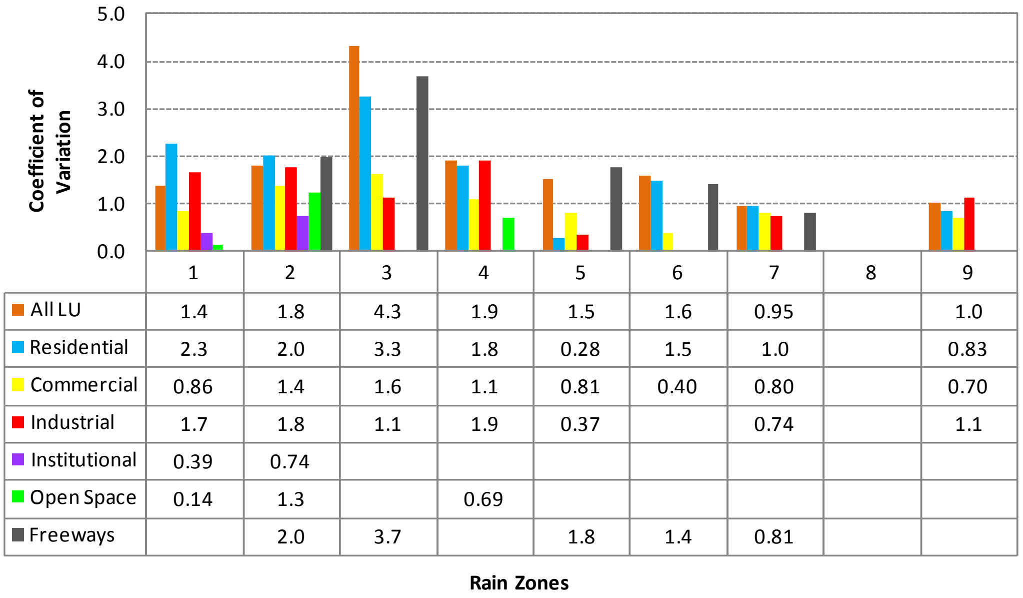


Fig. B12. Total Copper - Regional Coefficients of Variation for Single Land Uses in the Contiguous United States

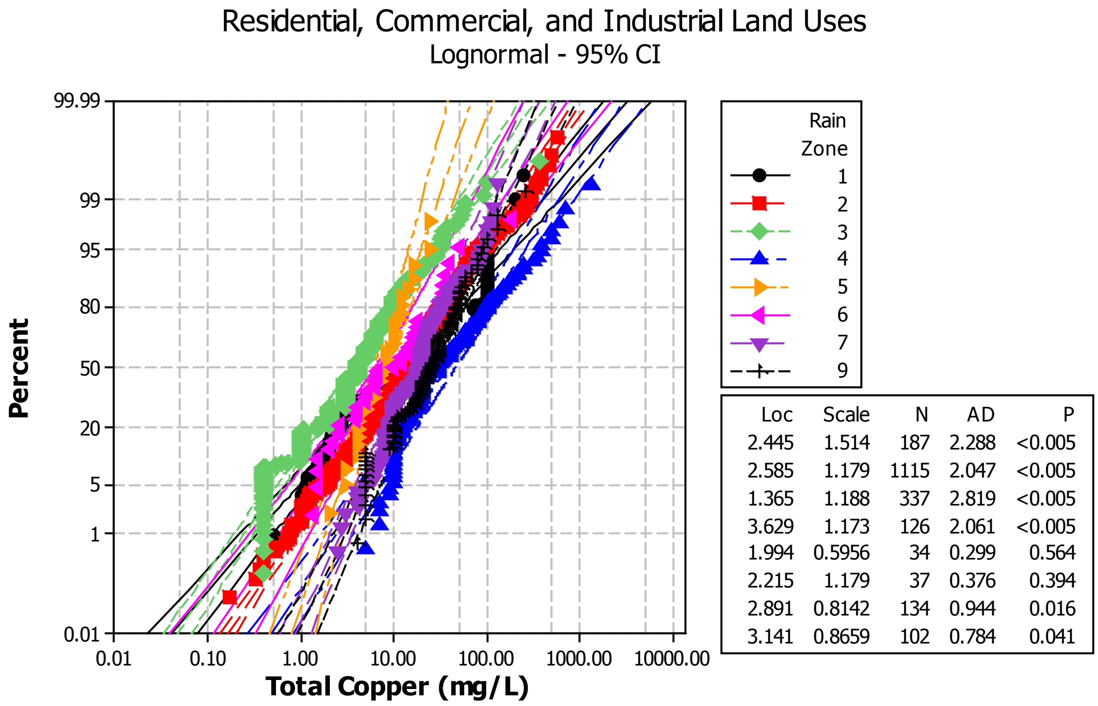


Fig. B13. Total Copper – Residential, Commercial, and Industrial Land Uses in the Contiguous United State (Checks for Normality)

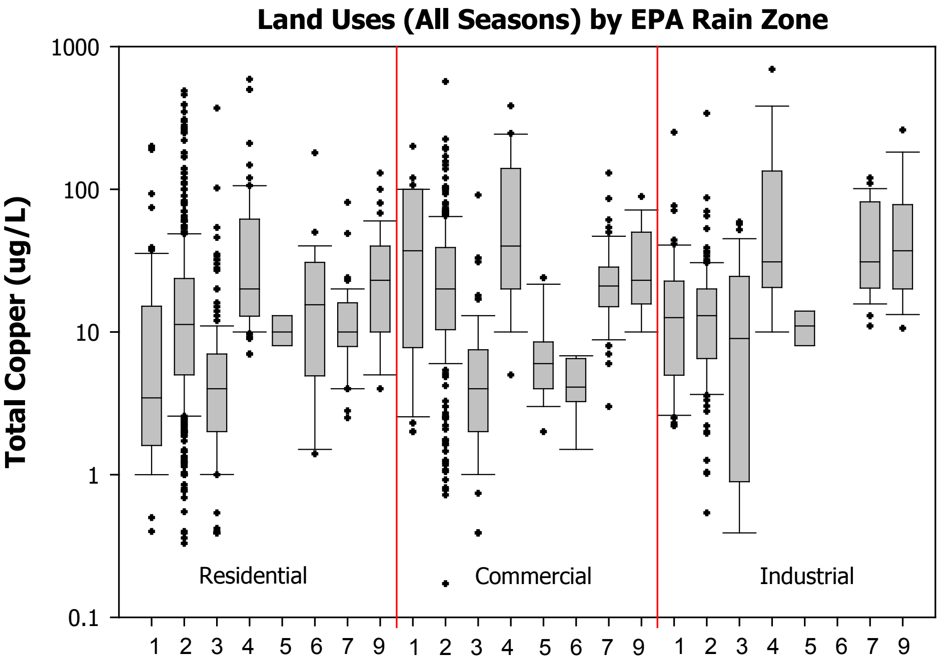
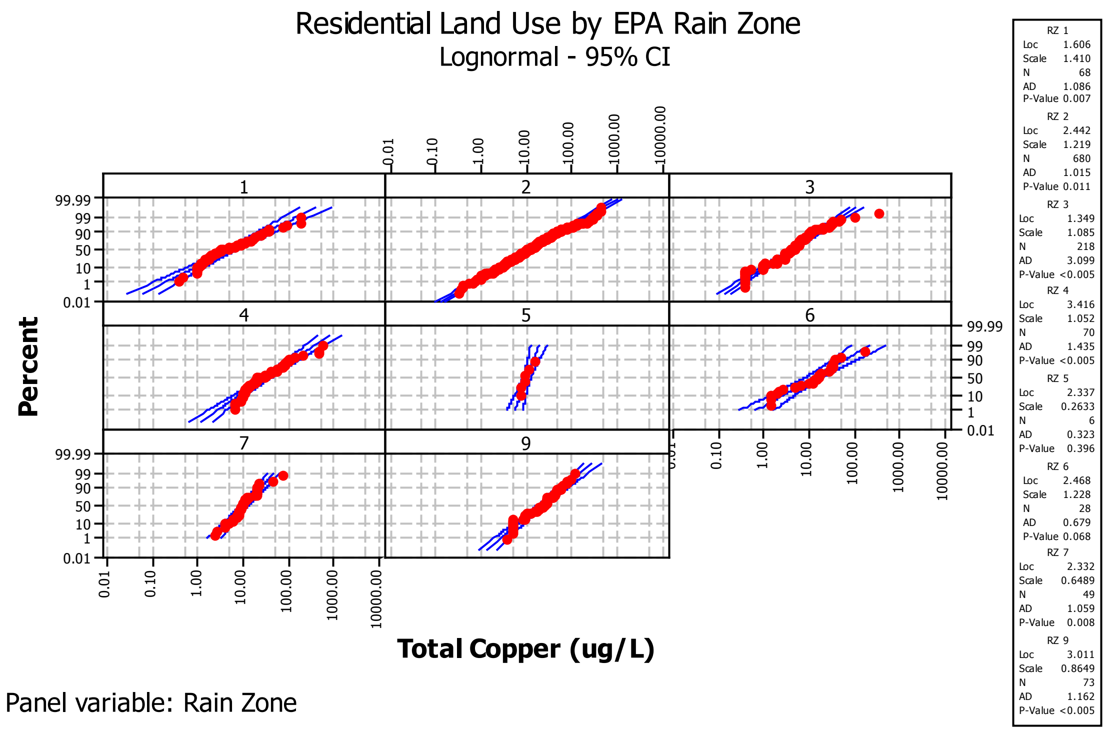


Fig. B14. Total Copper – Land Uses by EPA Rain Zone



RZ 1	
Loc	1.606
Scale	1.410
N	68
AD	1.086
P-Value	0.007
RZ 2	
Loc	2.442
Scale	1.219
N	680
AD	1.015
P-Value	0.011
RZ 3	
Loc	1.349
Scale	1.085
N	218
AD	3.099
P-Value	<0.005
RZ 4	
Loc	3.416
Scale	1.052
N	70
AD	1.435
P-Value	<0.005
RZ 5	
Loc	2.337
Scale	0.2633
N	6
AD	0.323
P-Value	0.396
RZ 6	
Loc	2.468
Scale	1.228
N	28
AD	0.679
P-Value	0.068
RZ 7	
Loc	2.332
Scale	0.6489
N	49
AD	1.059
P-Value	0.008
RZ 9	
Loc	3.011
Scale	0.8649
N	73
AD	1.162
P-Value	<0.005

Fig. B15. Total Copper – Residential Land Use by EPA Rain Zone (Checks for Normality)

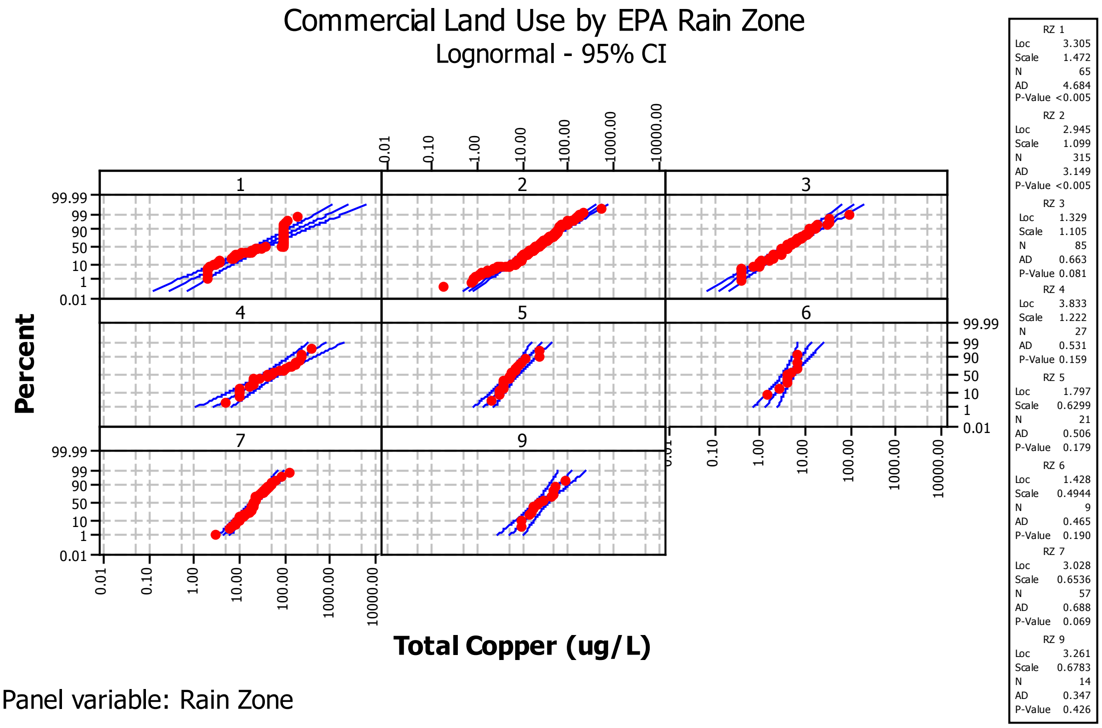


Fig. B16. Total Copper – Commercial Land Use by EPA Rain Zone (Checks for Normality)

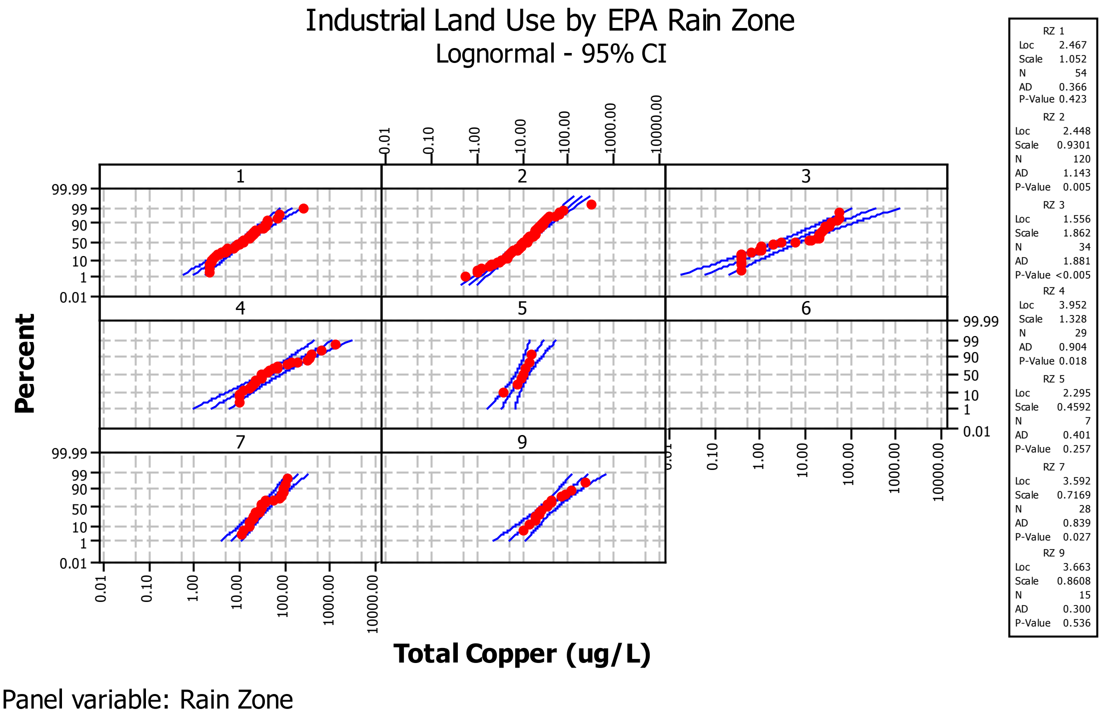


Fig. B17. Total Copper – Industrial Land Use by EPA Rain Zone (Checks for Normality)

Table B9. Total Copper – Univariate 3-way ANOVA Tests of Between-Subjects Effects

Dependent Variable: Log Copper

	Source	Type III Sum of Squares	DF	Mean Square	F	P-value
	Corrected Model*	207	89	2.3	10	0.000
	Intercept	494	1	494	2141	0.000
Main Effects	Rain Zone (8 levels)	73	7	10	45	0.000*
	Land Use (3 levels)	2.1	2	1.1	4.7	0.010*
	Season (4 levels)	3.2	3	1.1	4.7	0.003*
Two-way Interactions	Rain Zone * Land Use	13	13	1.0	4.3	0.000*
	Rain Zone * Season	21	21	1.0	4.3	0.000*
	Land Use * Season	0.88	6	0.15	0.64	0.701
Three-way Interaction	Rain Zone * Land Use * Season	15	37	0.39	1.7	0.005*
	Error	457	1982	0.23		
	Total	3045	2072			
	Corrected Total	664	2071			

*R Squared = 0.312 (Adjusted R Squared = 0.281)

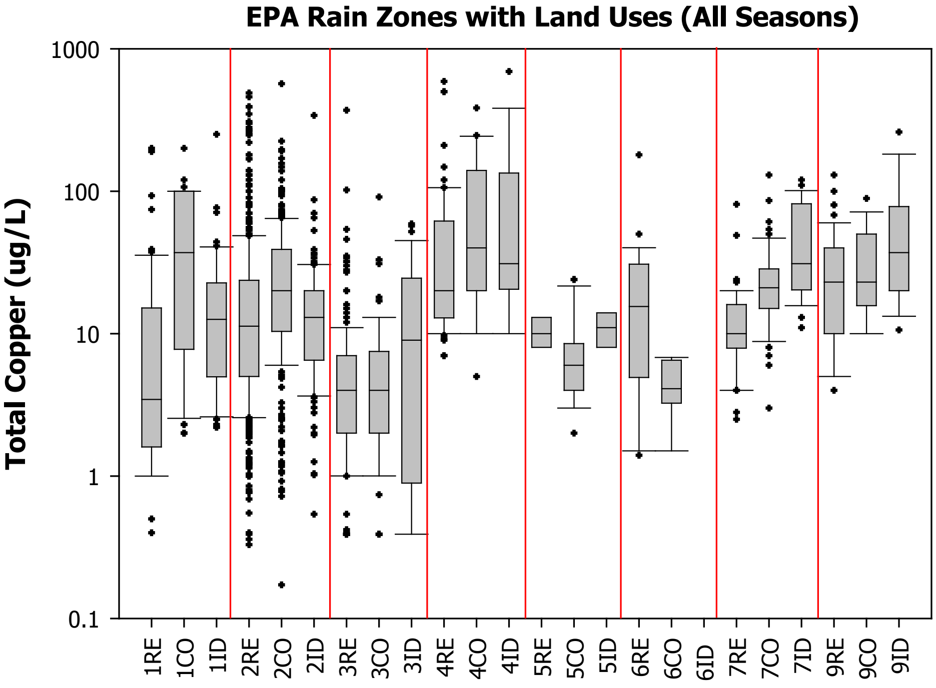


Fig. B18. Total Copper – EPA Rain Zones with Land Uses

Table B10. Total Copper - MANOVA Test for Significance of Land Use within Rain Zone using Unique Sum of Squares

Source of Variation	Sum of Squares	DF	Mean Square	F	p-value
WITHIN CELLS	457	1982	0.23		
Land Use WITHIN Rain Zone(1)	18	2	9.1	39	0.000*
Land Use WITHIN Rain Zone (2)	11	2	5.3	23	0.000*
Land Use WITHIN Rain Zone (3)	38	2	19	83	0.000*
Land Use WITHIN Rain Zone (4)	1.3	2	0.63	2.7	0.066
Land Use WITHIN Rain Zone (5)	1.6	2	0.81	3.5	0.030*
Land Use WITHIN Rain Zone (6)	2.2	2	1.1	4.8	0.009*
Land Use WITHIN Rain Zone (7)	4.3	2	2.2	9.4	0.000*
Land Use WITHIN Rain Zone (9)	1.2	2	0.60	2.6	0.075

Table B11. Total Copper - Test of Significance: Land Use within Rain Zone

Rain Zone	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Copper					**Power Analysis**	
		(I) LU	**(J) LU**	**p-value**	**LU**	**N**	**Gr. 1**	**Gr. 2**	**Gr. 3**	**α level**	**Power (%)**
1	0.000*	RE	CO	0.000*	RE	68	0.698			0.20	100
			ID	0.002*	CO	65		1.435		0.15	100
		CO	ID	0.004*	ID	54			1.071	0.10	99.9
					Pooled St. Dev = 0.582					***0.05***	***99.9***
					Obtained Effect Size = 0.53					0.01	99.9
2	0.000*	RE	CO	0.000*	RE	680	1.060			0.20	99.9
			ID	0.999*	ID	120	1.063			0.15	99.9
		CO	ID	0.000*	CO	315		1.279		0.10	99.9
					Pooled St. Dev = 0.503					***0.05***	***99.9***
					Obtained Effect Size = 0.20					0.01	99.9
3	0.608	-	-	-	RE	218	0.586			0.20	35.1
					ID	85	0.577			0.15	28.8
					CO	34	0.676			0.10	21.7
					Pooled St. Dev = 0.517					***0.05***	***13.2***
					Obtained Effect Size = 0.05					0.01	4.0
5	0.043*	RE	CO	0.015*	RE	6	1.015			0.20	84.9
			ID	0.977	ID	7	0.997			0.15	80.4
		CO	ID	0.097	CO	21		0.780		0.10	73.6
					Pooled St. Dev = 0.241					***0.05***	***61.2***
					Obtained Effect Size = 0.45					0.01	34.9
6	0.019*	-	-	-	RE	28	1.072			0.20	87.4
					CO	9		0.620		0.15	83.7
					ID	-				0.10	77.8
					Pooled St. Dev = 0.480					***0.05***	***66.6***
					Obtained Effect Size = 0.40					0.01	40.7

Table B11. - *Continued*

Rain Zone	1-Way ANOVA p-value	Multiple Comparison (Scheffe Post-Hoc Test)			Homogeneous Groups Dependent Variable: Log Copper					Power Analysis	
		(I) LU	(J) LU	p-value	LU	N	Gr. 1	Gr. 2	Gr. 3	α level	Power (%)
7	0.000*	RE	CO	0.000*	RE	49	1.013			0.20	100
			ID	0.000*	CO	57		1.315		0.15	100
		CO	ID	0.002*	ID	28			1.560	0.10	100
					Pooled St. Dev = 0.289					***0.05***	***100***
					Obtained Effect Size = 0.71					0.01	99.9

Table B12. Total Copper - MANOVA Test for Significance of Season within Rain Zone using Unique Sum of Squares

Source of Variation	Sum of Squares	DF	Mean Square	F	p-value
WITHIN CELLS	457	1982	0.23		
Season WITHIN Rain Zone (1)	8.2	3	2.8	12	0.000*
Season WITHIN Rain Zone (2)	3.1	3	1.0	4.4	0.004*
Season WITHIN Rain Zone (3)	19	3	6.3	27	0.000*
Season WITHIN Rain Zone (4)	2.8	3	0.94	4.1	0.007*
Season WITHIN Rain Zone (5)	0.26	3	0.09	0.38	0.766
Season WITHIN Rain Zone (6)	0.82	3	0.27	1.2	0.314
Season WITHIN Rain Zone (7)	1.9	3	0.62	2.7	0.044*
Season WITHIN Rain Zone (9)	6.5	3	2.2	9.3	0.000*

Table B13. Total Copper – Test of Significance: Land Use and Season within Rain Zone

Rain Zone	**Land Use**	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Copper				**Power Analysis**	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
1	RE	0.131*	-	-	-	FA	24	0.506		0.20	75.2
						SP	16	0.843		0.15	69.4
						SU	22	0.861		0.10	61.2
						WI	6	0.476		***0.05***	***48.1***
										0.01	24.5
						Pooled St. Dev = 0.599, Obtained Effect Size = 0.29					
	CO	0.000*	FA	SP	0.630	FA	25	1.506		0.20	99.9
				SU	0.743	SP	9	1.225		0.15	99.8
				WI	0.001*	SU	25	1.678		0.10	99.7
			SP	SU	0.220	WI	6		0.443	***0.05***	***99.3***
				WI	0.071					0.01	96.31
			SU	WI	0.000*	Pooled St. Dev = 0.547, Obtained Effect Size = 0.64					
	ID	0.001*	FA	SP	0.805	FA	12	1.061		0.20	99.4
				SU	0.208	SP	12	0.900		0.15	98.9
				WI	0.416	WI	12	0.784		0.10	98.1
			SP	SU	0.021*	SU	18		1.384	***0.05***	***95.9***
				WI	0.917					0.01	85.8
			SU	WI	0.003*	Pooled St. Dev = 0.399, Obtained Effect Size = 0.60					
2	RE ID	0.009*	FA	SP	0.998	FA	224	1.039		0.20	95.1
				SU	0.077	SP	225	1.049		0.15	93.2
				WI	0.885	WI	187	0.999		0.10	89.9
			SP	SU	0.116	SU	164		1.177	***0.05***	***83.3***
				WI	0.801					0.01	64.0
			SU	WI	0.014*	Pooled St. Dev = 0.509, Obtained Effect Size = 0.12					
	CO	0.021*	FA	SP	0.372	FA	89	1.153		0.20	91.5
				SU	0.030*	SP	76		1.284	0.15	88.6
				WI	0.027*	SU	73		1.353	0.10	84.0
			SP	SU	0.831	WI	77		1.350	***0.05***	***75.0***
				WI	0.839					0.01	52.4
			SU	WI	1.000	Pooled St. Dev = 0.472, Obtained Effect Size = 0.18					
3	RE CO ID	0.000*	FA	SP	0.000*	FA	110	0.503		0.20	99.9
				SU	0.994	SU	98	0.522		0.15	99.9
				WI	0.845	WI	67	0.573		0.10	99.9
			SP	SU	0.000*	SP	62		0.884	***0.05***	***99.8***
				WI	0.006*					0.01	98.9
			SU	WI	0.939	Pooled St. Dev = 0.499, Obtained Effect Size = 0.31					

Table B13. - *Continued*

Rain Zone	**Land Use**	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Copper				**Power Analysis**	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
4	RE CO ID	0.364	-	-	-	FA	37	1.604		0.20	56.1
						SP	35	1.494		0.15	49.2
						SU	32	1.690		0.10	40.5
						WI	22	1.493		***0.05***	***28.4***
										0.01	11.5
						Pooled St. Dev = 0.509, Obtained Effect Size = 0.16					
7	RE	0.001*	FA	SP	0.066	FA	10	1.286		0.20	99.1
				SU	0.142	SP	17		1.016	0.15	98.6
				WI	0.001*	SU	4		0.940	0.10	97.6
			SP	SU	0.958	WI	18		0.874	***0.05***	***94.8***
				WI	0.410					0.01	82.9
			SU	WI	0.970	Pooled St. Dev = 0.245, Obtained Effect Size = 0.62					
	CO	0.045*	FA	SP	0.882	FA	8	1.464		0.20	86.9
				SU	0.824	SP	17	1.370		0.15	82.9
				WI	0.099	SU	14	1.350		0.10	76.7
			SP	SU	0.998	WI	18	1.169		***0.05***	***65.2***
				WI	0.199					0.01	39.8
			SU	WI	0.327	Pooled St. Dev = 0.271, Obtained Effect Size = 0.39					
	ID	0.001*	FA	SP	0.048*	FA	8	1.884		0.20	99.5
				SU	0.038*	SP	7		1.509	0.15	99.2
				WI	0.003*	SU	3		1.375	0.10	98.5
			SP	SU	0.880	WI	10		1.392	***0.05***	***96.3***
				WI	0.801					0.01	84.9
			SU	WI	1.000	Pooled St. Dev = 0.239, Obtained Effect Size = 0.88					
9	RE CO ID	0.625	-	-	-	FA	25	1.378		0.20	41.3
						SP	21	1.338		0.15	34.5
						SU	52	1.386		0.10	26.6
						WI	4	1.136		***0.05***	***16.8***
										0.01	5.5
						Pooled St. Dev = 0.378, Obtained Effect Size = 0.13					

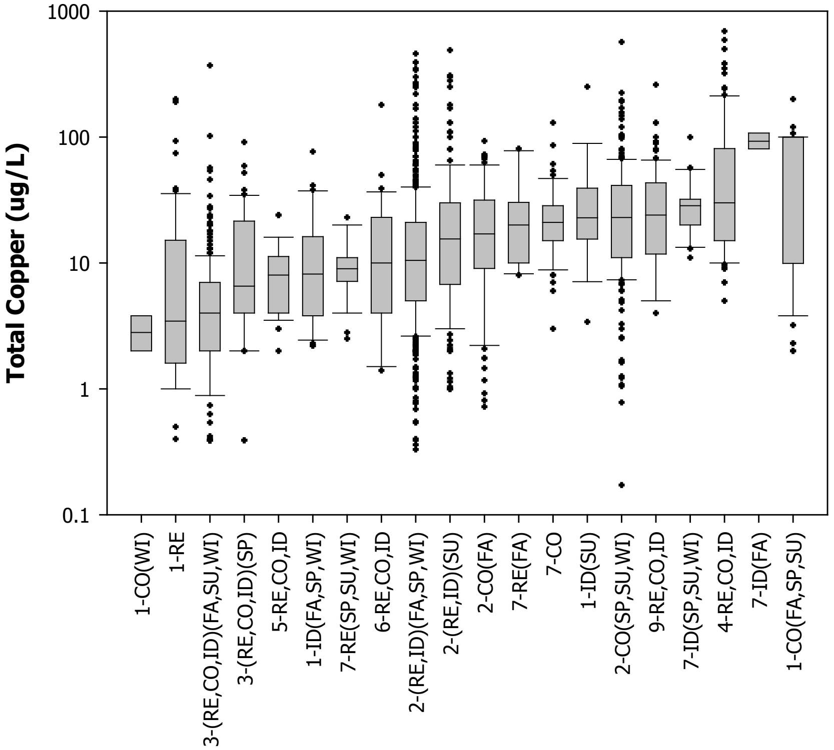


Fig. B19. Total Copper – Rain Zone Groups

Table B14. Total Copper – Homogeneous Groups

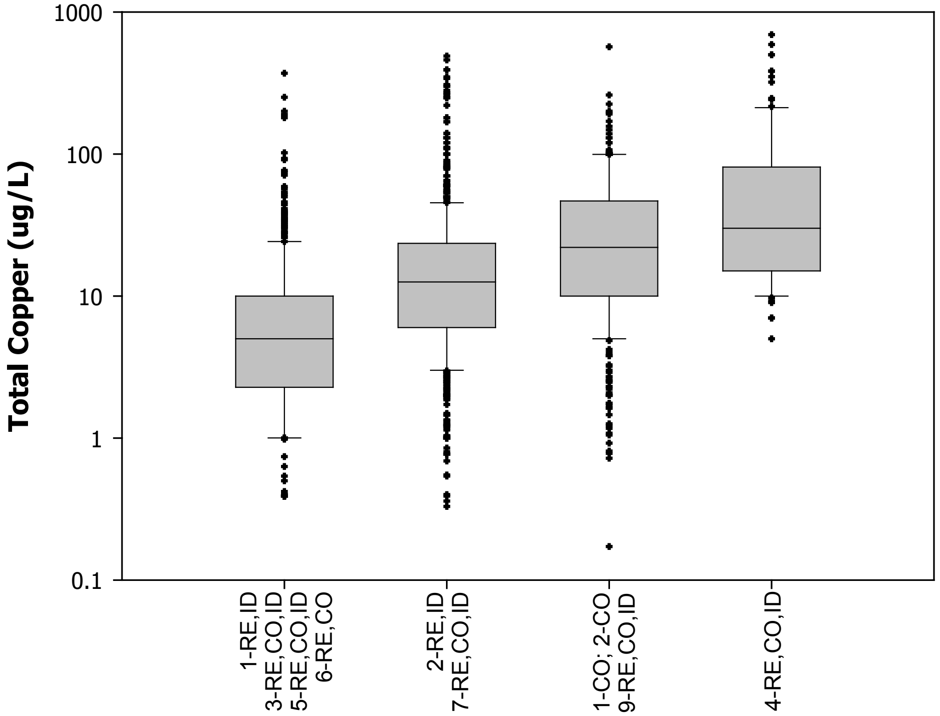
Groups	**N**	**Homogeneous Groups** Dependent Variable: Log Copper			
		A	**B**	**C**	**D**
1-RE	68	0.698			
1-ID(FA,SP,WI)	36	0.915			
1-ID(SU)	18	1.384			
3-(RE,CO,ID)(FA,SU,WI)	275	0.527			
3-(RE,CO,ID)(SP)	62	0.884			
5-RE,CO,ID	34	0.866			
6-RE,CO	37	0.962			
2-(RE,ID)(FA,SP,WI)	636		1.031		
2-(RE,ID)(SU)	164		1.177		
7-CO	57		1.315		
7-ID(FA)	20		1.43		
7-ID(SP,SU,WI)	8		1.884		
7-RE(FA)	10		1.286		
7-RE(SP,SU,WI)	39		0.942		
1-CO(FA,SP,SU)	59			1.536	
1-CO(WI)	6			0.443	
2-CO(FA)	89			1.153	
2-CO(SP,SU,WI)	226			1.329	
9-RE,CO,ID	102			1.364	
4-RE,CO,ID	126				1.576

Table B15. Total Copper – Rain Zone Groups Multiple Comparisons

(I) Group	(J) Group	p-value
1-RE	1-CO(FA,SP,SU)	0.000
	1-CO(WI)	1.000
	1-ID(FA,SP,WI)	1.000
	1-ID(SU)	0.073
	2-(RE,ID)(FA,SP,WI)	0.065
	2-(RE,ID)(SU)	0.000
	2-CO(FA)	0.018
	2-CO(SP,SU,WI)	0.000
	3-(RE,CO,ID)(FA,SU,WI)	0.995
	3-(RE,CO,ID)(SP)	1.000
	4-RE,CO,ID	0.000
	5-RE,CO,ID	1.000
	6-RE,CO,ID	0.993
	7-RE(FA)	0.842
	7-RE(SP,SU,WI)	0.997
	7-CO	0.000
	7-ID(FA)	0.001
	7-ID(SP,SU,WI)	0.013
	9-RE,CO,ID	0.000
1-CO (FA,SP,SU)	1-CO(WI)	0.088
	1-ID(FA,SP,WI)	0.009
	1-ID(SU)	1.000
	2-(RE,ID)(FA,SP,WI)	0.000
	2-(RE,ID)(SU)	0.199
	2-CO(FA)	0.272
	2-CO(SP,SU,WI)	0.979
	3-(RE,CO,ID) (FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.000
	4-RE,CO,ID	1.000
	5-RE,CO,ID	0.002
	6-RE,CO,ID	0.032
	7-RE(FA)	1.000
	7-RE(SP,SU,WI)	0.013
	7-CO	0.998
	7-ID(FA)	1.000
	7-ID(SP,SU,WI)	1.000
	9-RE,CO,ID	1.000
1-CO(WI)	1-ID(FA,SP,WI)	0.999
	1-ID(SU)	0.586
	2-(RE,ID)(FA,SP,WI)	0.976
	2-(RE,ID)(SU)	0.820
	2-CO(FA)	0.879
	2-CO(SP,SU,WI)	0.418
	3-(RE,CO,ID)(FA,SU,WI)	1.000
	3-(RE,CO,ID)(SP)	1.000
	4-RE,CO,ID	0.037
	5-RE,CO,ID	1.000
	6-RE,CO,ID	0.998
	7-RE(FA)	0.908
	7-RE(SP,SU,WI)	0.999
	7-CO	0.545
	7-ID(FA)	0.047
	7-ID(SP,SU,WI)	0.441
	9-RE,CO,ID	0.361
1-ID(FA,SP,WI)	1-ID(SU)	0.913
	2-(RE,ID)(FA,SP,WI)	1.000
	2-(RE,ID)(SU)	0.979
	2-CO(FA)	0.997
	2-CO(SP,SU,WI)	0.251
	3-(RE,CO,ID)(FA,SU,WI)	0.365
	3-(RE,CO,ID)(SP)	1.000
	4-RE,CO,ID	0.000
	5-RE,CO,ID	1.000
	6-RE,CO,ID	1.000
	7-RE(FA)	1.000
	7-RE(SP,SU,WI)	1.000
	7-CO	0.716
	7-ID(FA)	0.124
	7-ID(SP,SU,WI)	0.747
	9-RE,CO,ID	0.241
1-ID(SU)	2-(RE,ID)(FA,SP,WI)	0.967
	2-(RE,ID)(SU)	1.000
	2-CO(FA)	1.000
	2-CO(SP,SU,WI)	1.000
	3-(RE,CO,ID)(FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.729
	4-RE,CO,ID	1.000
	5-RE,CO,ID	0.812
	6-RE,CO,ID	0.969
	7-RE(FA)	1.000
	7-RE(SP,SU,WI)	0.946
	7-CO	1.000
	7-ID(FA)	0.998
	7-ID(SP,SU,WI)	1.000
	9-RE,CO,ID	1.000
2-(RE,ID)(FA,SP,WI)	2-(RE,ID)(SU)	0.891
	2-CO(FA)	0.999
	2-CO(SP,SU,WI)	0.000
	3-(RE,CO,ID)(FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.999
	4-RE,CO,ID	0.000
	5-RE,CO,ID	1.000
	6-RE,CO,ID	1.000
	7-RE(FA)	1.000
	7-RE(SP,SU,WI)	1.000
	7-CO	0.520
	7-ID(FA)	0.176
	7-ID(SP,SU,WI)	0.826
	9-RE,CO,ID	0.002

Table B15. - *Continued*

(I) Group	(J) Group	p-value
2-(RE,ID)(SU)	2-CO(FA)	1.000
	2-CO(SP,SU,WI)	0.966
	3-(RE,CO,ID)(FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.628
	4-RE,CO,ID	0.000
	5-RE,CO,ID	0.901
	6-RE,CO,ID	0.998
	7-RE(FA)	1.000
	7-RE(SP,SU,WI)	0.992
	7-CO	1.000
	7-ID(FA)	0.636
	7-ID(SP,SU,WI)	0.999
	9-RE,CO,ID	0.965
2-CO(FA)	2-CO(SP,SU,WI)	0.981
	3-(RE,CO,ID)(FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.914
	4-RE,CO,ID	0.004
	5-RE,CO,ID	0.979
	6-RE,CO,ID	1.000
	7-RE(FA)	1.000
	7-RE(SP,SU,WI)	0.999
	7-CO	1.000
	7-ID(FA)	0.605
	7-ID(SP,SU,WI)	0.999
	9-RE,CO,ID	0.972
7-CO	7-ID(FA)	0.959
	7-ID(SP,SU,WI)	1.000
	9-RE,CO,ID	1.000
7-ID(FA)	7-ID(SP,SU,WI)	0.999
	9-RE,CO,ID	0.980
7-ID (SP,SU,WI)	9-RE,CO,ID	1.000
2-CO(SP,SU,WI)	3-(RE,CO,ID) (FA,SU,WI)	0.000
	3-(RE,CO,ID)(SP)	0.003
	4-RE,CO,ID	0.331
	5-RE,CO,ID	0.105
	6-RE,CO,ID	0.503
	7-RE(FA)	1.000
	7-RE(SP,SU,WI)	0.325
	7-CO	1.000
	7-ID(FA)	0.948
	7-ID(SP,SU,WI)	1.000
	9-RE,CO,ID	1.000
3-(RE,CO,ID) (FA,SU,WI)	3-(RE,CO,ID)(SP)	0.092
	4-RE,CO,ID	0.000
	5-RE,CO,ID	0.729
	6-RE,CO,ID	0.121
	7-RE(FA)	0.205
	7-RE(SP,SU,WI)	0.155
	7-CO	0.000
	7-ID(FA)	0.000
	7-ID(SP,SU,WI)	0.000
	9-RE,CO,ID	0.000
3-(RE,CO,ID)(SP)	4-RE,CO,ID	0.000
	5-RE,CO,ID	1.000
	6-RE,CO,ID	1.000
	7-RE(FA)	0.998
	7-RE(SP,SU,WI)	1.000
	7-CO	0.216
	7-ID(FA)	0.050
	7-ID(SP,SU,WI)	0.441
	9-RE,CO,ID	0.006
5-RE,CO,ID	6-RE,CO,ID	1.000
	7-RE(FA)	0.998
	7-RE(SP,SU,WI)	1.000
	7-CO	0.500
	7-ID(FA)	0.073
	7-ID (SP,SU,WI)	0.581
	9-RE,CO,ID	0.105
4-RE,CO,ID	5-RE,CO,ID	0.000
	6-RE,CO,ID	0.001
	7-RE(FA)	1.000
	7-RE (SP,SU,WI)	0.000
	7-CO	0.908
	7-ID(FA)	1.000
	7-ID (SP,SU,WI)	1.000
	9-RE,CO,ID	0.930
6-RE,CO,ID	7-RE(FA)	1.000
	7-RE (SP,SU,WI)	1.000
	7-CO	0.887
	7-ID(FA)	0.201
	7-ID (SP,SU,WI)	0.877
	9-RE,CO,ID	0.471
7-RE(FA)	7-RE (SP,SU,WI)	1.000
	7-CO	1.000
	7-ID(FA)	0.995
	7-ID (SP,SU,WI)	1.000
	9-RE,CO,ID	1.000
7-RE (SP,SU,WI)	7-CO	0.798
	7-ID(FA)	0.157
	7-ID (SP,SU,WI)	0.814
	9-RE,CO,ID	0.313



Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	5.4 (1.0)	28 (2.1)	5.2 (2.4)	56 (2.0)	ND	43 (1.3)	25 (0.90)	28 (0.62)
	SP	15 (1.3)	22 (1.8)	8.7 (1.0)	31 (1.0)	9.3 (0.12)	13 (0.51)	12 (0.49)	15 (0.68)
	SU	31 (1.9)	36 (1.8)	10 (4.4)	84 (1.5)	14 (0.20)	17 (0.88)	9.0 (0.29)	33 (0.85)
	WI	3.2 (0.40)	19 (2.2)	9.0 (1.3)	73 (1.9)	ND	14 (0.96)	8.4 (0.53)	ND
Commercial	FA	59 (0.77)	23 (0.90)	5.4 (0.83)	52 (1.0)	10 (0.71)	6.1 (0.12)	41 (0.98)	ND
	SP	51 (1.3)	34 (1.0)	28 (1.0)	147 (0.93)	8.8 (0.93)	ND	25 (0.43)	41 (0.69)
	SU	69 (0.61)	35 (1.1)	4.7 (0.6)	68 (0.74)	5.7 (0.27)	3.6 (0.77)	26 (0.72)	30 (0.57)
	WI	2.9 (0.28)	38 (1.8)	3.8 (1.1)	56 (1.2)	4.5 (0.44)	4.0 (0.04)	19 (0.71)	ND
Industrial	FA	13 (0.42)	14 (0.69)	18 (1.2)	191 (1.2)	ND	ND	87 (0.37)	56 (0.91)
	SP	19 (1.3)	24 (2.3)	27 (0.69)	71 (1.8)	11 (0.18)	ND	39 (0.76)	60 (0.76)
	SU	38 (1.4)	15 (0.81)	5.4 (1.7)	312 (1.9)	12 (0.33)	ND	27 (0.53)	67 (1.4)
	WI	7.3 (0.65)	18 (1.1)	7.9 (0.98)	51 (1.3)	ND	ND	26 (0.31)	26 (0.08)

Fig. B20. Total Copper – Rain Zone Homogeneous Groups: Mean (CV)

Table B16. Basic Statistics for Total Copper –
Rain Zone Homogeneous Groups (Real Space Data) (μg/L)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	1-RE,ID; 3-RE,CO,ID 5-RE,CO,ID; 6-RE,CO	530	11	26	2.3	0.39	5.0	370
B	2-RE,ID; 7-RE,CO,ID	934	25	47	1.9	0.33	13	490
C	1-CO; 2-CO 9-RE,CO,ID	482	36	43	1.2	0.17	22	569
D	4-RE,CO,ID	126	86	164	1.9	5.0	30	1360

B.3. Total Lead

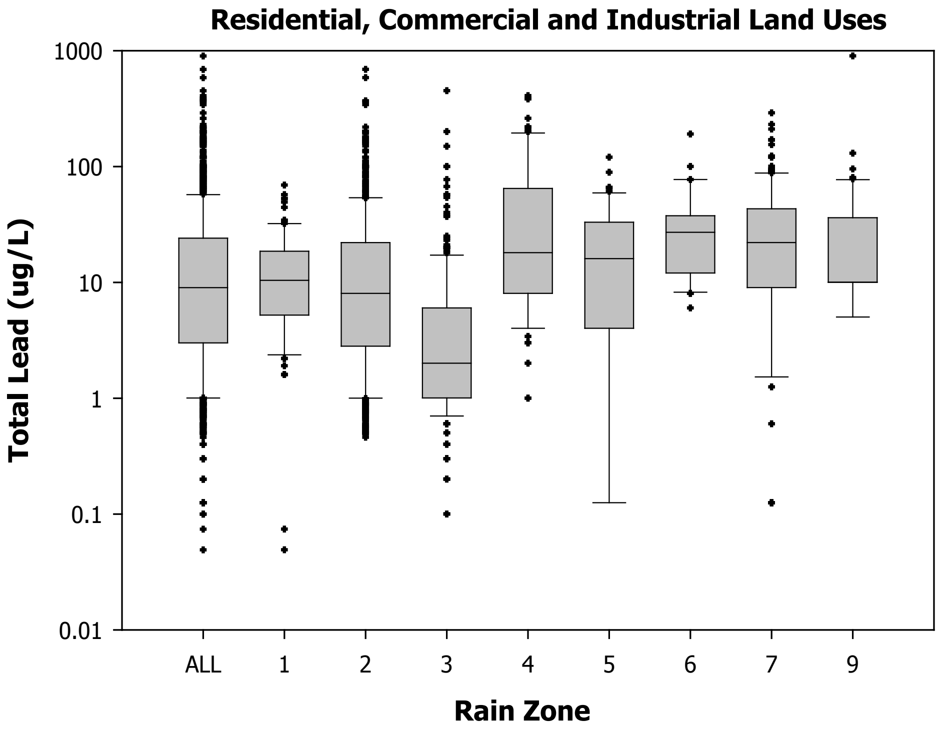
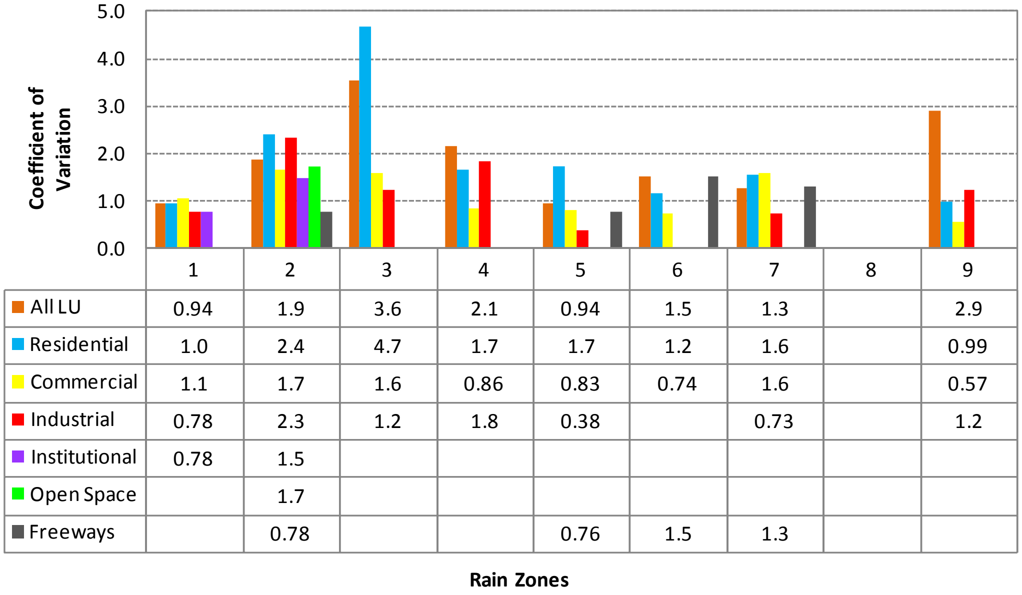
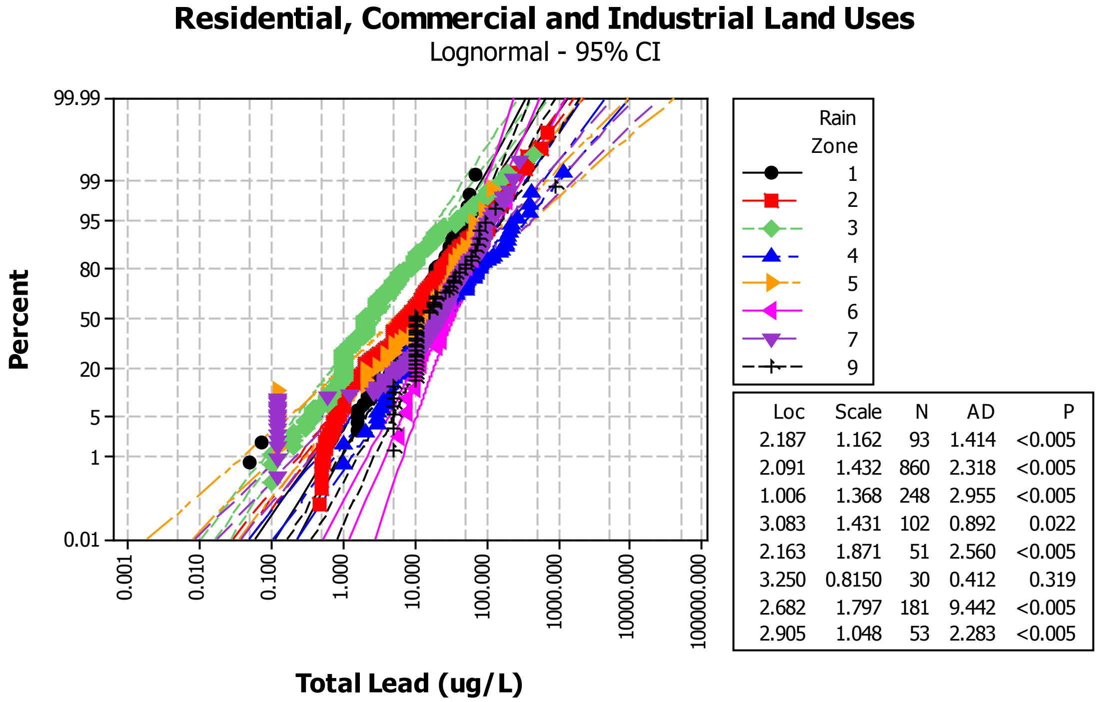


Fig. B21. Total Lead – Residential, Commercial, and Industrial Land Uses
in the Contiguous United States



	1	2	3	4	5	6	7	8	9
🟧 All LU	0.94	1.9	3.6	2.1	0.94	1.5	1.3		2.9
🟦 Residential	1.0	2.4	4.7	1.7	1.7	1.2	1.6		0.99
🟨 Commercial	1.1	1.7	1.6	0.86	0.83	0.74	1.6		0.57
🟥 Industrial	0.78	2.3	1.2	1.8	0.38		0.73		1.2
🟪 Institutional	0.78	1.5							
🟩 Open Space		1.7							
⬛ Freeways		0.78			0.76	1.5	1.3		

Fig. B22. Total Lead - Regional Coefficients of Variation for Single Land Uses in the Contiguous United States



Loc	Scale	N	AD	P
2.187	1.162	93	1.414	<0.005
2.091	1.432	860	2.318	<0.005
1.006	1.368	248	2.955	<0.005
3.083	1.431	102	0.892	0.022
2.163	1.871	51	2.560	<0.005
3.250	0.8150	30	0.412	0.319
2.682	1.797	181	9.442	<0.005
2.905	1.048	53	2.283	<0.005

Fig. B23. Total Lead – Residential, Commercial, and Industrial Land Uses in the Contiguous United State (Checks for Normality)

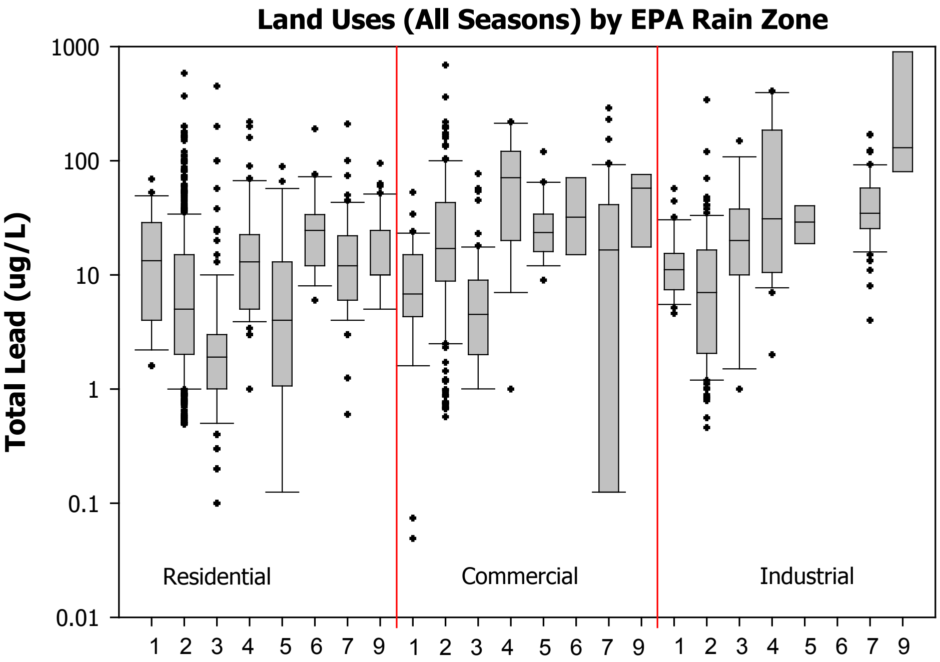


Fig. B24. Total Lead – Land Uses by EPA Rain Zone

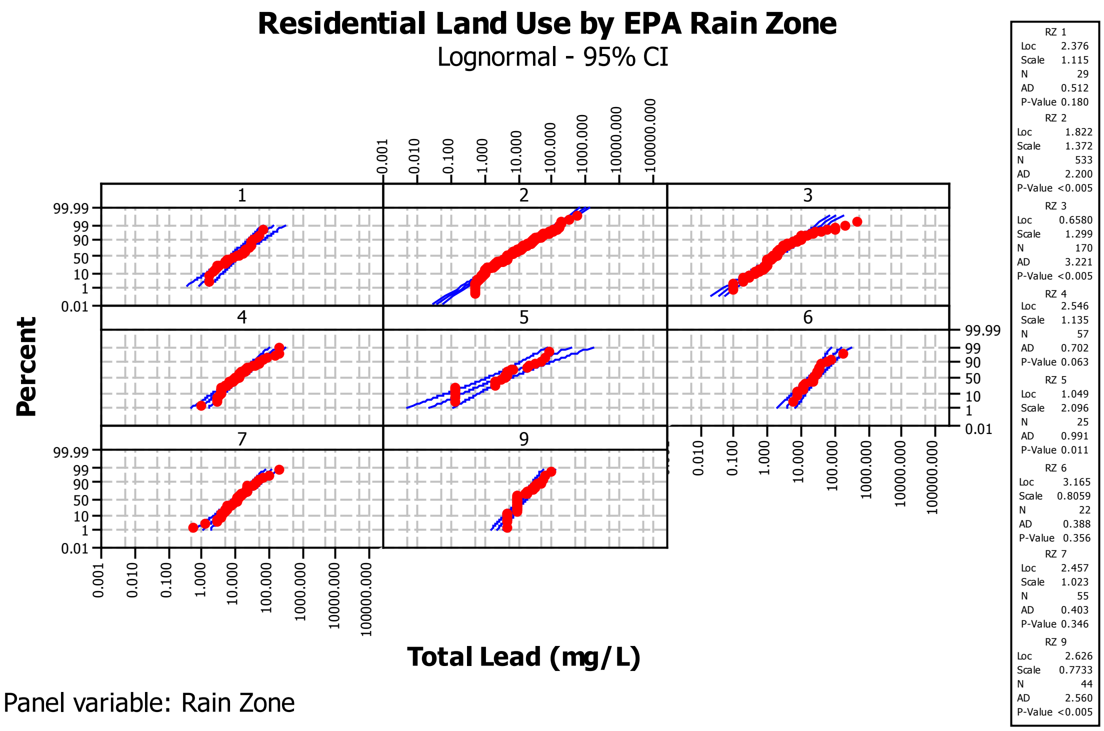


Fig. B25. Total Lead – Residential Land Use by EPA Rain Zone (Checks for Normality)

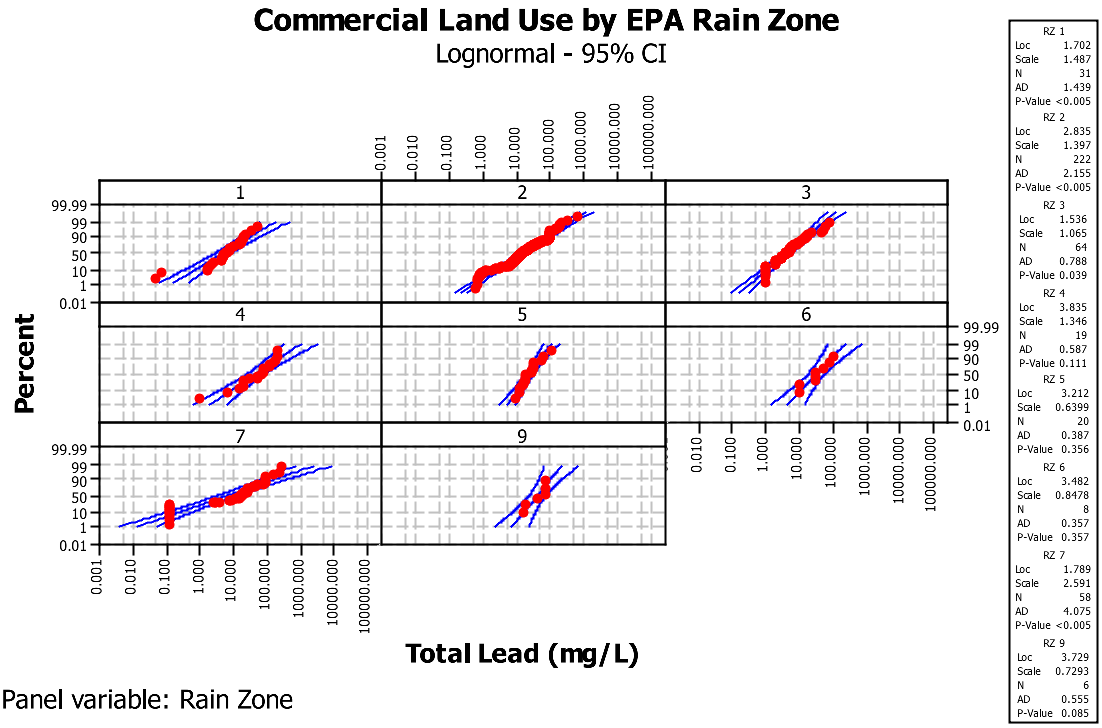


Fig. B26. Total Lead – Commercial Land Use by EPA Rain Zone (Checks for Normality)

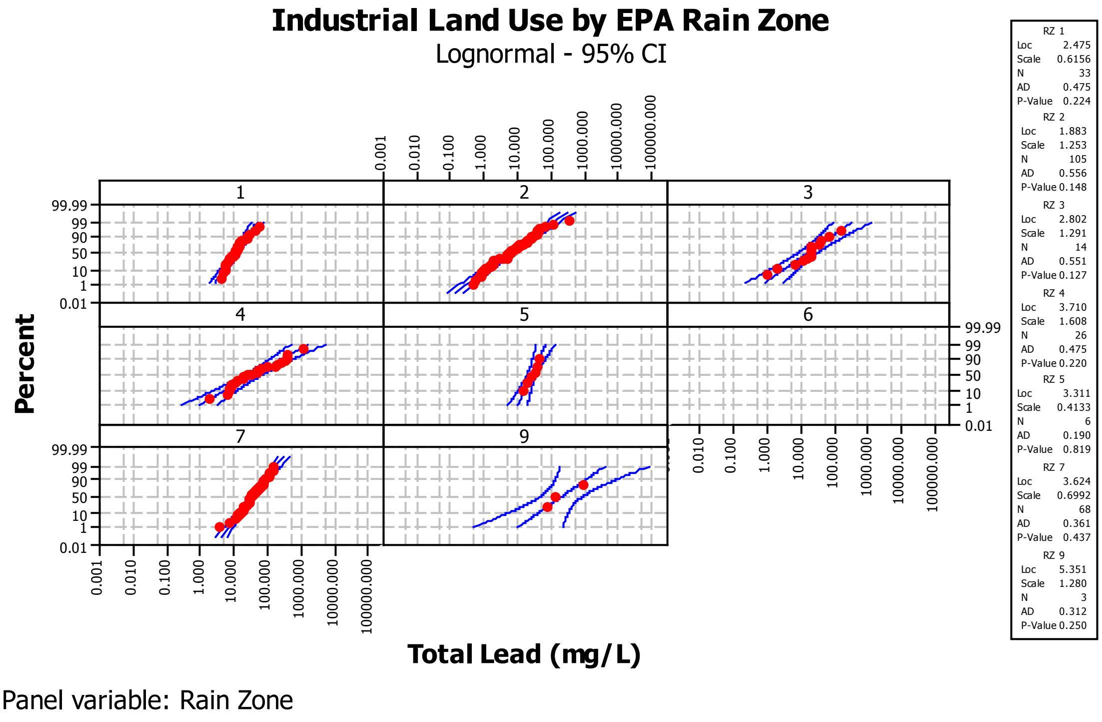


Fig. B27. Total Lead – Industrial Land Use by EPA Rain Zone (Checks for Normality)

Table B17. Total Lead – Univariate 3-way ANOVA Tests of Between-Subjects Effects

Dependent Variable: Log Lead

	Source	Type III Sum of Squares	DF	Mean Square	F	P-value
	Corrected Model*	230	83	3	8	0.000
	Intercept	411	1	411	1237	0.000
Main Effects	Rain Zone (8 levels)	36	7	5.1	15	0.000*
	Land Use (3 levels)	15	2	7.6	23	0.000*
	Season (4 levels)	1.3	3	0.42	1.3	0.286
Two-way Interactions	Rain Zone * Land Use	31	13	2.4	7.2	0.000*
	Rain Zone * Season	17	20	0.87	2.6	0.000*
	Land Use * Season	1.3	6	0.22	0.66	0.686
Three-way Interaction	Rain Zone * Land Use * Season	12	32	0.37	1.1	0.319
	Error	509	1534	0.33		
	Total	2097	1618			
	Corrected Total	739	1617			

*R Squared = 0.311 (Adjusted R Squared = 0.274)

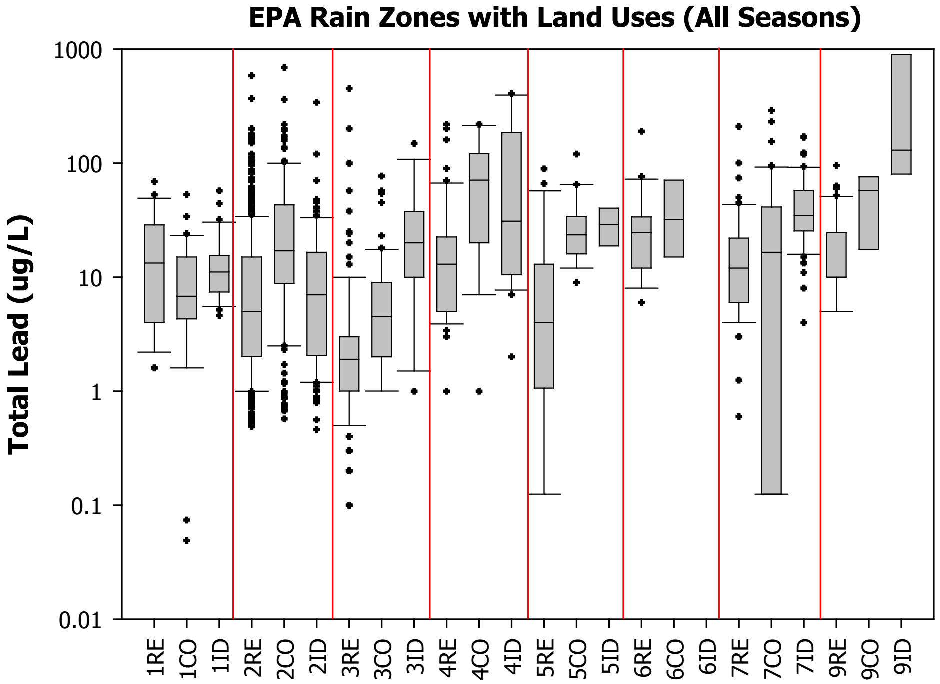


Fig. B28. Total Lead – EPA Rain Zones with Land Uses

Table B18. Total Lead - MANOVA Test for Significance of Land Use within Rain Zone using Unique Sum of Squares

Source of Variation	Sum of Squares	DF	Mean Square	F	p-value
WITHIN CELLS	509	1534	0.33		
Land Use WITHIN Rain Zone(1)	2.1	2	1.0	3.1	0.044*
Land Use WITHIN Rain Zone (2)	36	2	18	55	0.000*
Land Use WITHIN Rain Zone (3)	80	2	40	120	0.000*
Land Use WITHIN Rain Zone (4)	1.3	2	0.64	1.9	0.146
Land Use WITHIN Rain Zone (5)	12	2	5.8	17	0.000*
Land Use WITHIN Rain Zone (6)	4.7	2	2.3	7.0	0.001*
Land Use WITHIN Rain Zone (7)	22	2	11	33	0.000*
Land Use WITHIN Rain Zone (9)	0.07	2	0.03	0.1	0.902

Table B19. Total Lead - Test of Significance: Land Use within Rain Zone

Rain Zone	1-Way ANOVA p-value	Multiple Comparison (Scheffe Post-Hoc Test)			Homogeneous Groups Dependent Variable: Log Lead					Power Analysis	
		(I) LU	(J) LU	p-value	LU	N	Gr. 1	Gr. 2	Gr. 3	α level	Power (%)
1	0.015*	RE	CO	0.072	RE	29	1.032			0.20	91.5
			ID	0.942	ID	33	1.075			0.15	88.6
		CO	ID	0.026*	CO	31		0.739		0.10	83.9
					Pooled St. Dev = 0.487					***0.05***	***74.7***
					Obtained Effect Size = 0.31					0.01	51.2
2	0.000*	RE	CO	0.000*	RE	533	0.791			0.20	100
			ID	0.915	ID	105	0.818			0.15	100
		CO	ID	0.000*	CO	222		1.231		0.10	100
					Pooled St. Dev = 0.593					***0.05***	***100***
					Obtained Effect Size = 0.32					0.01	100
3	0.000*	RE	CO	0.000*	RE	170	0.286			0.20	100
			ID	0.000*	CO	64		0.667		0.15	100
		CO	ID	0.003*	ID	14			1.217	0.10	100
					Pooled St. Dev = 0.540					***0.05***	***99.9***
					Obtained Effect Size = 0.47					0.01	99.9
4	0.000*	RE	CO	0.002*	RE	57	1.106			0.20	99.9
			ID	0.001*	CO	19		1.666		0.15	99.8
		CO	ID	0.951	ID	26		1.611		0.10	99.6
					Pooled St. Dev = 0.568					***0.05***	***98.9***
					Obtained Effect Size = 0.46					0.01	95.2
5	0.000*	RE	CO	0.000*	RE	25	0.455			0.20	99.9
			ID	0.009*	CO	20		1.395		0.15	99.9
		CO	ID	0.991	ID	6		1.438		0.10	99.8
					Pooled St. Dev = 0.669					***0.05***	***99.5***
					Obtained Effect Size = 0.71					0.01	97.3

Table B19. – *Continued*

Rain Zone	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Lead					**Power Analysis**	
		(I) LU	**(J) LU**	**p-value**	**LU**	**N**	**Gr. 1**	**Gr. 2**	**Gr. 3**	**α level**	**Power (%)**
6	0.355	-	-	-	RE	22	1.375			0.20	37.3
					CO	8	1.512			0.15	31.0
					ID	-	-			0.10	23.7
					Pooled St. Dev = 0.355					***0.05***	***14.7***
					Obtained Effect Size = 0.17					0.01	4.5
7	0.000*	RE	CO	0.096	RE	55	1.067			0.20	99.9
			ID	0.001*	CO	58	0.777			0.15	99.9
		CO	ID	0.000*	ID	68		1.574		0.10	99.9
					Pooled St. Dev = 0.707					***0.05***	***99.9***
					Obtained Effect Size = 0.48					0.01	99.9

Table B20. Total Lead - MANOVA Test for Significance of Season within Rain Zone using Unique Sum of Squares

Source of Variation	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
WITHIN CELLS	509	1534	0.33		
Season WITHIN Rain Zone (1)	1.6	3	0.53	1.6	0.190
Season WITHIN Rain Zone (2)	0.99	3	0.33	0.99	0.395
Season WITHIN Rain Zone (3)	18	3	6.2	19	0.000*
Season WITHIN Rain Zone (4)	2.6	3	0.88	2.7	0.047*
Season WITHIN Rain Zone (5)	0.50	3	0.17	0.50	0.681
Season WITHIN Rain Zone (6)	2.0	3	0.66	2.0	0.116
Season WITHIN Rain Zone (7)	26	3	8.8	26	0.000*
Season WITHIN Rain Zone (9)	7.3	3	2.4	7.4	0.000*

Table B21. Total Lead – Test of Significance: Land Use and Season within Rain Zone

Rain Zone	**Land Use**	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Lead				**Power Analysis**	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
3	RE	0.002*	FA	SP	0.017*	FA	51	0.059		0.20	98.1
				SU	0.176	SP	39		0.435	0.15	97.2
				WI	0.017*	SU	55		0.296	0.10	95.6
			SP	SU	0.685	WI	25		0.491	***0.05***	***91.6***
				WI	0.984					0.01	77.6
			SU	WI	0.532	Pooled St. Dev = 0.545, Obtained Effect Size = 0.30					
	CO	0.000*	FA	SP	0.001*	FA	31	0.565		0.20	99.7
				SU	0.984	SU	14	0.617		0.15	99.5
				WI	1.000	WI	11	0.566		0.10	99.0
			SP	SU	0.006*	SP	8		1.289	***0.05***	***97.7***
				WI	0.004*					0.01	90.8
			SU	WI	0.992	Pooled St. Dev = 0.406, Obtained Effect Size = 0.58					
	ID	0.018*	-	-	Not possible because FALL has only one value	FA	1	0.845		0.20	94.7
						SP	10	1.459		0.15	92.1
						SU	-	-		0.10	87.5
						WI	3	0.534		***0.05***	***76.9***
										0.01	46.8
						Pooled St. Dev = 0.422, Obtained Effect Size = 0.92					
4	RE	0.183	-	-	-	FA	13	0.995		0.20	69.7
						SP	18	1.101		0.15	63.3
						SU	14	1.339		0.10	54.7
						WI	12	0.960		***0.05***	***41.4***
										0.01	19.4
						Pooled St. Dev = 0.484, Obtained Effect Size = 0.30					
	CO ID	0.512	-	-	-	FA	12	1.609		0.20	46.7
						SP	15	1.631		0.15	39.7
						SU	9	1.887		0.10	31.2
						WI	9	1.421		***0.05***	***20.3***
										0.01	6.9
						Pooled St. Dev = 0.651, Obtained Effect Size = 0.23					
9	RE CO ID	0.210	FA	SP		FA	15	1.124		0.20	60.6
				SU		SP	10	1.180		0.15	53.8
				WI		SU	28	1.365		0.10	45.1
			SP	SU		WI	-	-		***0.05***	***32.4***
				WI						0.01	13.6
			SU	WI		Pooled St. Dev = 0.450, Obtained Effect Size = 0.25					

Table B21. – *Continued*

Rain Zone	**Land Use**	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Lead				**Power Analysis**	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
7	RE CO	0.001*	FA	SP	0.024*	FA	20	1.430		0.20	98.6
				SU	0.006*	WI	41	1.047		0.15	97.9
				WI	0.409	SP	34		0.703	0.10	96.6
			SP	SU	0.801	SU	18		0.463	***0.05***	***93.3***
				WI	0.360					0.01	80.8
			SU	WI	0.105	Pooled St. Dev = 0.824, Obtained Effect Size = 0.38					
	ID	0.003*	FA	SP	0.679	FA	33	1.664		0.20	98.1
				SU	0.006*	SP	18	1.563		0.15	97.1
				WI	0.291	WI	14	1.490		0.10	95.3
			SP	SU	0.037*	SU	3		1.043	***0.05***	***91.1***
				WI	0.909					0.01	75.6
			SU	WI	0.106	Pooled St. Dev = 0.279, Obtained Effect Size = 0.48					

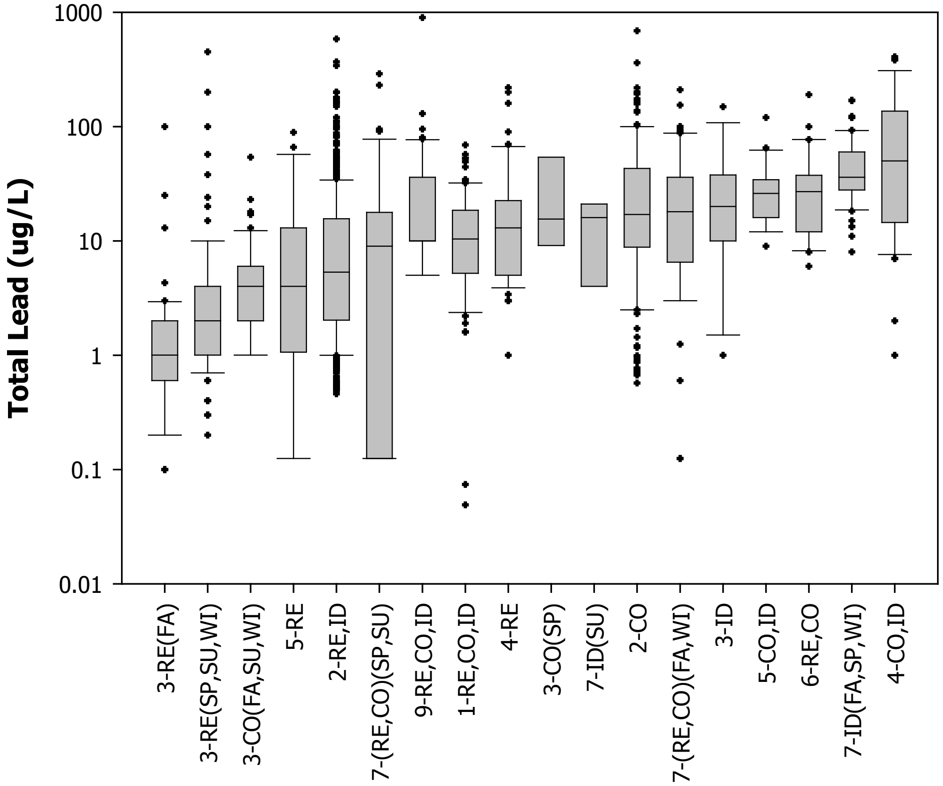


Fig. B29. Total Lead – Rain Zone Groups

Table B22. Total Lead – Rain Zone Groups Multiple Comparisons

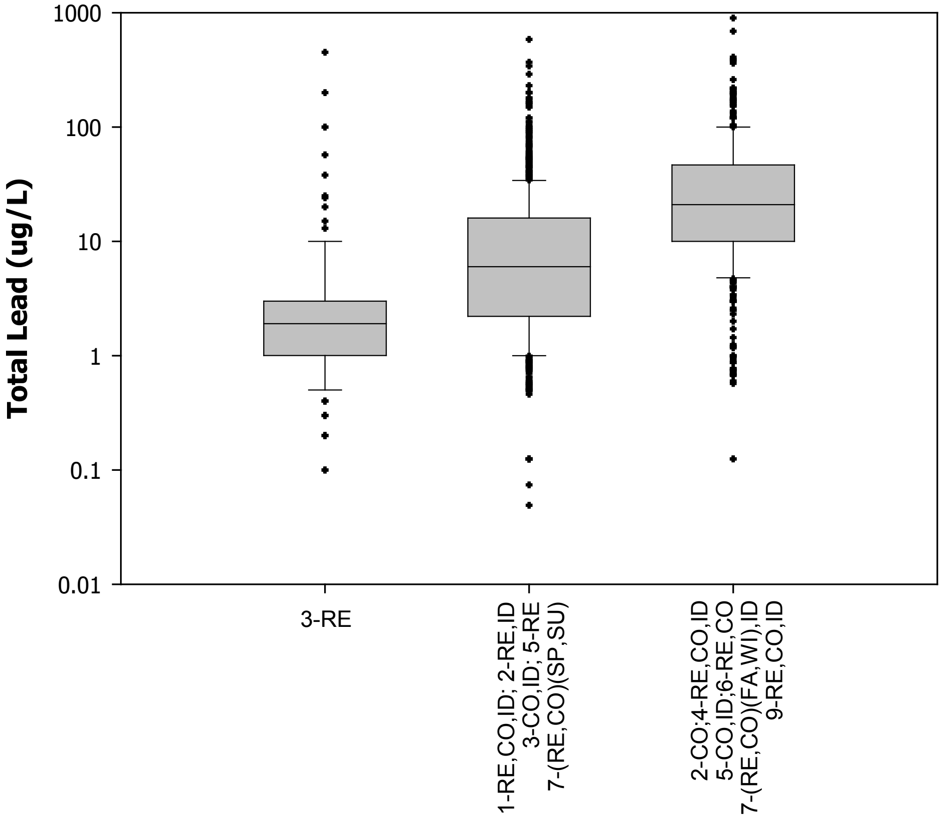
(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
1-RE,CO,ID	2-RE,ID	0.991	2-CO	3-RE(FA)	0.000	3-RE(SP,SU,WI)	3-CO(FA,SU,WI)	0.999
	2-CO	0.633		3-RE(SP,SU,WI)	0.000		3-CO(SP)	0.368
	3-RE(FA)	0.000		3-CO(FA,SU,WI)	0.000		3-ID	0.077
	3-RE(SP,SU,WI)	0.000		3-CO(SP)	1.000		4-RE	0.000
	3-CO(FA,SU,WI)	0.603		3-ID	1.000		4-CO,ID	0.000
	3-CO(SP)	1.000		4-RE	1.000		5-RE	1.000
	3-ID	1.000		4-CO,ID	0.385		5-CO,ID	0.000
	4-RE	1.000		5-RE	0.001		6-RE,CO	0.000
	4-CO,ID	0.001		5-CO,ID	1.000		7-(RE,CO)(FA,WI)	0.000
	5-RE	0.618		6-RE,CO	1.000		7-(RE,CO)(SP,SU)	0.993
	5-CO,ID	0.793		7-(RE,CO)(FA,WI)	1.000		7-ID(FA,SP,WI)	0.000
	6-RE,CO	0.675		7-(RE,CO)(SP,SU)	0.000		7-ID(SU)	1.000
	7-(RE,CO)(FA,WI)	0.998		7-ID(FA,SP,WI)	0.266		9-RE,CO,ID	0.000
	7-(RE,CO)(SP,SU)	0.842		7-ID(SU)	1.000	3-CO(FA,SU,WI)	3-CO(SP)	0.878
	7-ID(FA,SP,WI)	0.000		9-RE,CO,ID	1.000		3-ID	0.695
	7-ID(SU)	1.000	3-RE(FA)	3-RE(SP,SU,WI)	0.850		4-RE	0.140
	9-RE,CO,ID	0.931		3-CO(FA,SU,WI)	0.212		4-CO,ID	0.000
2-RE,ID	2-CO	0.000		3-CO(SP)	0.020		5-RE	1.000
	3-RE(FA)	0.000		3-ID	0.000		5-CO,ID	0.005
	3-RE(SP,SU,WI)	0.000		4-RE	0.000		6-RE,CO	0.001
	3-CO(FA,SU,WI)	0.980		4-CO,ID	0.000		7-(RE,CO)(FA,WI)	0.023
	3-CO(SP)	0.995		5-RE	0.969		7-(RE,CO)(SP,SU)	1.000
	3-ID	0.980		5-CO,ID	0.000		7-ID(FA,SP,WI)	0.000
	4-RE	0.598		6-RE,CO	0.000		7-ID(SU)	1.000
	4-CO,ID	0.000		7-(RE,CO)(FA,WI)	0.000		9-RE,CO,ID	0.003
	5-RE	0.961		7-(RE,CO)(SP,SU)	0.120	3-CO(SP)	3-ID	1.000
	5-CO,ID	0.051		7-ID(FA,SP,WI)	0.000		4-RE	1.000
	6-RE,CO	0.014		7-ID(SU)	0.964		4-CO,ID	1.000
	7-(RE,CO)(FA,WI)	0.134		9-RE,CO,ID	0.000		5-RE	0.766
	7-(RE,CO)(SP,SU)	0.999	6-RE,CO	7-(RE,CO)(FA,WI)	1.000		5-CO,ID	1.000
	7-ID(FA,SP,WI)	0.000		7-(RE,CO)(SP,SU)	0.006		6-RE,CO	1.000
	7-ID(SU)	1.000		7-ID(FA,SP,WI)	1.000		7-(RE,CO)(FA,WI)	1.000
	9-RE,CO,ID	0.017		7-ID(SU)	1.000		7-(RE,CO)(SP,SU)	0.931
7-(RE,CO)(SP,SU)	7-ID(FA,SP,WI)	0.000		9-RE,CO,ID	1.000		7-ID(FA,SP,WI)	1.000
	7-ID(SU)	1.000	7-(RE,CO)(FA,WI)	7-(RE,CO)(SP,SU)	0.085		7-ID(SU)	1.000
	9-RE,CO,ID	0.015		7-ID(FA,SP,WI)	0.457		9-RE,CO,ID	1.000
7-ID(FA,SP,WI)	7-ID(SU)	1.000		7-ID(SU)	1.000			
	9-RE,CO,ID	0.909		9-RE,CO,ID	1.000	7-ID(SU)	9-RE,CO,ID	1.000

Table B22. - *Continued*

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
3-ID	4-RE	1.000	4-RE	4-CO,ID	0.233	5-RE	5-CO,ID	0.009
	4-CO,ID	0.996		5-RE	0.194		6-RE,CO	0.004
	5-RE	0.563		5-CO,ID	0.998		7-(RE,CO)(FA,WI)	0.058
	5-CO,ID	1.000		6-RE,CO	0.996		7-(RE,CO)(SP,SU)	1.000
	6-RE,CO	1.000		7-(RE,CO)(FA,WI)	1.000		7-ID(FA,SP,WI)	0.000
	7-(RE,CO)(FA,WI)	1.000		7-(RE,CO)(SP,SU)	0.325		7-ID(SU)	1.000
	7-(RE,CO)(SP,SU)	0.817		7-ID(FA,SP,WI)	0.188		9-RE,CO,ID	0.013
	7-ID(FA,SP,WI)	0.998		7-ID(SU)	1.000	5-CO,ID	6-RE,CO	1.000
	7-ID(SU)	1.000		9-RE,CO,ID	1.000		7-(RE,CO)(FA,WI)	1.000
	9-RE,CO,ID	1.000	4-CO,ID	5-RE	0.000		7-(RE,CO)(SP,SU)	0.017
				5-CO,ID	1.000		7-ID(FA,SP,WI)	1.000
				6-RE,CO	1.000		7-ID(SU)	1.000
				7-(RE,CO)(FA,WI)	0.497		9-RE,CO,ID	1.000
				7-(RE,CO)(SP,SU)	0.000			
				7-ID(FA,SP,WI)	1.000			
				7-ID(SU)	1.000			
				9-RE,CO,ID	0.902			

Table B23. Total Lead – Homogeneous Groups

Groups	N	Homogeneous Groups Dependent Variable: Log Lead		
		A	B	C
3-RE(FA)	51	0.060		
3-RE(SP,SU,WI)	119	0.383		
3-CO(FA,SU,WI)	56		0.578	
3-CO(SP)	8		1.290	
3-ID	14		1.217	
2-RE,ID	638		0.796	
5-RE	25		0.456	
7-(RE,CO)(SP,SU)	52		0.620	
1-RE,CO,ID	93		0.958	
2-CO	222			1.231
4-RE	57			1.106
4-CO,ID	45			1.634
5-CO,ID	26			1.405
6-RE,CO	30			1.412
7-(RE,CO)(FA,WI)	61			1.173
7-ID(FA,SP,WI)	65			1.598
7-ID(SU)	3			1.040
9-RE,CO,ID	53			1.262



Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	14 (0.77)	18 (2.1)	3.9 (3.6)	16 (1.1)	6.0 (1.4)	51 (1.2)	39 (1.5)	15 (0.55)
	SP	22 (1.0)	18 (2.3)	12 (3.0)	27 (1.9)	15 (1.3)	18 (0.38)	11 (0.52)	11 (0.65)
	SU	21 (0.97)	23 (2.7)	2.7 (0.85)	48 (1.3)	20 (1.7)	37 (0.49)	15 (1.4)	25 (0.99)
	WI	ND	13 (1.8)	24 (3.7)	13 (1.0)	3.0 (0.58)	20 (0.61)	18 (1.2)	ND
Commercial	FA	16 (1.2)	48 (1.9)	6.7 (1.5)	43 (0.79)	46 (0.87)	40 (0.86)	53 (0.64)	ND
	SP	8.5 (0.77)	33 (1.8)	29 (0.92)	126 (0.68)	28 (0.71)	ND	30 (2.4)	46 (0.92)
	SU	10 (0.87)	32 (1.3)	5.4 (0.69)	68 (0.64)	12 (0.22)	62 (0.56)	35 (1.8)	53 (0.53)
	WI	7.2 (0.78)	41 (1.2)	4.7 (0.71)	53 (1.1)	28 (0.29)	ND	29 (1.3)	ND
Industrial	FA	12 (0.23)	7.0 (0.96)	ND	154 (1.2)	ND	ND	54 (0.61)	ND
	SP	27 (0.73)	25 (2.5)	40 (1.1)	71 (1.8)	39 (0.14)	ND	47 (0.86)	ND
	SU	13 (0.67)	12 (0.94)	ND	312 (1.6)	20 (0.25)	ND	14 (0.64)	515 (1.1)
	WI	10 (0.41)	16 (1.6)	7.7 (1.4)	58 (1.7)	ND	ND	40 (0.77)	ND

Fig. B30. Total Lead – Rain Zone Homogeneous Groups: Mean (CV)

Table B24. Basic Statistics for Total Lead –
Rain Zone Homogeneous Groups (Real Space Data) (μg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	3-RE	170	8.4	39	4.7	0.10	1.9	450
B	1-RE, CO,ID; 5-RE 2-RE,ID; 3-CO,ID; 7-(RE,CO)(SP,SU)	886	17	38	2.3	0.05	6.0	585
C	2-CO;4-RE,CO,ID 5-CO,ID; 6-RE,CO 7-(RE,CO)(FA,WI),ID 9-RE,CO,ID	562	44	85	1.9	0.13	21	1200

B.4. Total Phosphorous

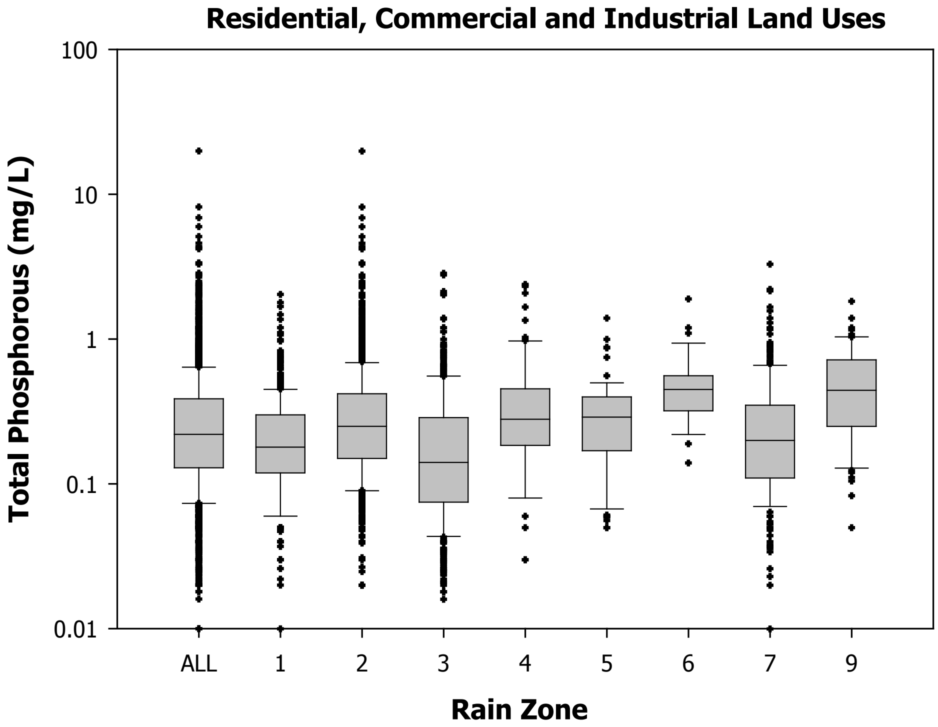
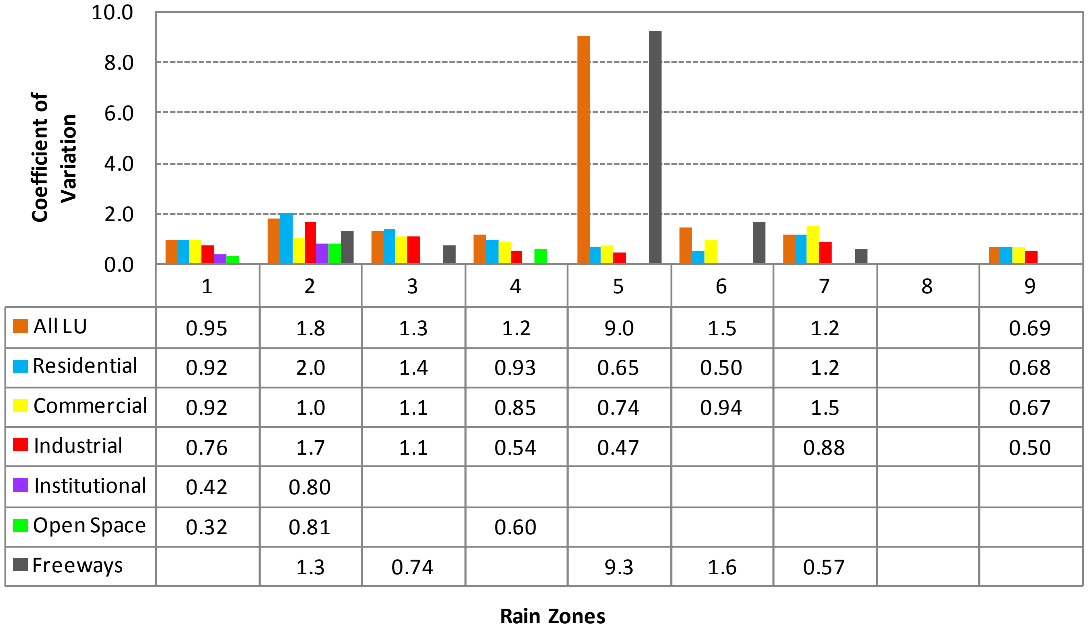
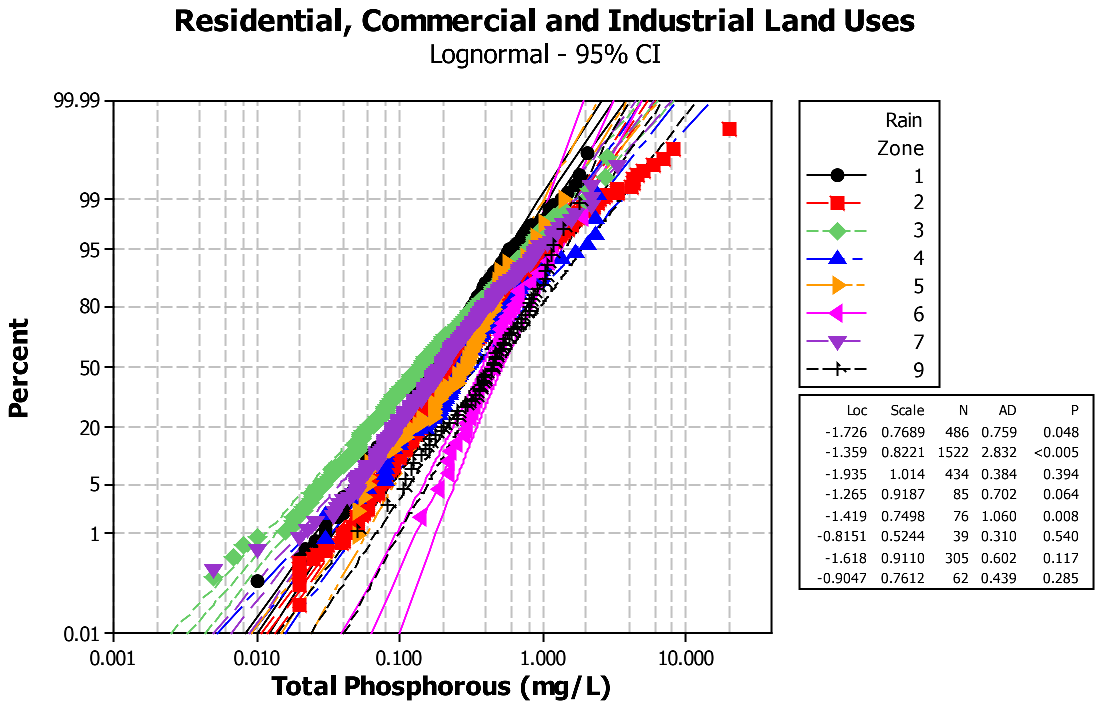


Fig. B31. Total Phosphorous – Residential, Commercial, and Industrial Land Uses in the Contiguous United States



	1	2	3	4	5	6	7	8	9
All LU	0.95	1.8	1.3	1.2	9.0	1.5	1.2		0.69
Residential	0.92	2.0	1.4	0.93	0.65	0.50	1.2		0.68
Commercial	0.92	1.0	1.1	0.85	0.74	0.94	1.5		0.67
Industrial	0.76	1.7	1.1	0.54	0.47		0.88		0.50
Institutional	0.42	0.80							
Open Space	0.32	0.81		0.60					
Freeways		1.3	0.74		9.3	1.6	0.57		

Fig. B32. Total Phosphorous - Regional Coefficients of Variation for Single Land Uses in the Contiguous United States



Loc	Scale	N	AD	P
-1.726	0.7689	486	0.759	0.048
-1.359	0.8221	1522	2.832	<0.005
-1.935	1.014	434	0.384	0.394
-1.265	0.9187	85	0.702	0.064
-1.419	0.7498	76	1.060	0.008
-0.8151	0.5244	39	0.310	0.540
-1.618	0.9110	305	0.602	0.117
-0.9047	0.7612	62	0.439	0.285

Fig. B33. Total Phosphorous – Residential, Commercial, and Industrial Land Uses in the Contiguous United State (Checks for Normality)

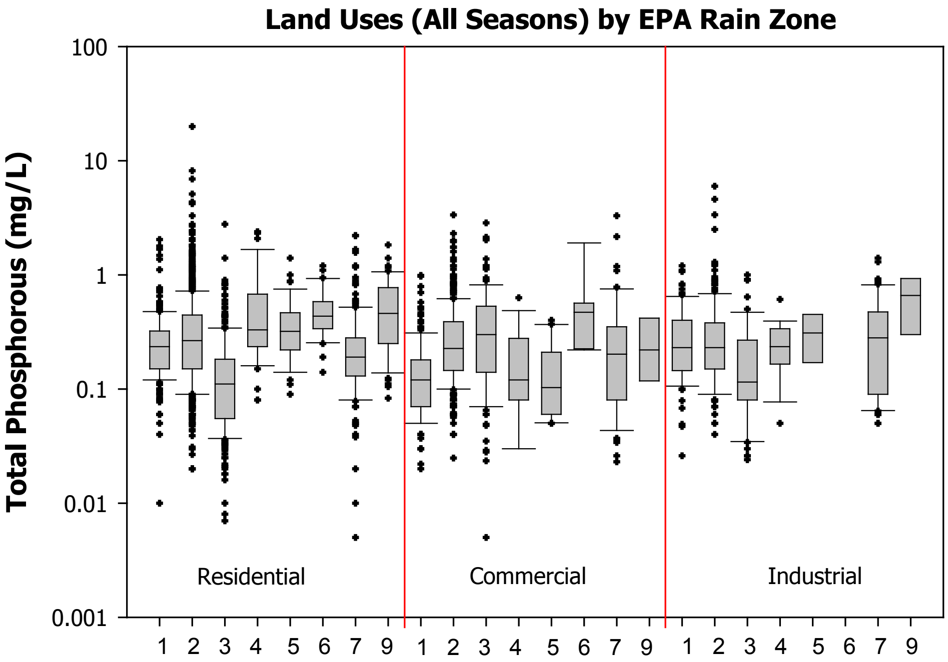


Fig. B34. Total Phosphorous – Land Uses by EPA Rain Zone

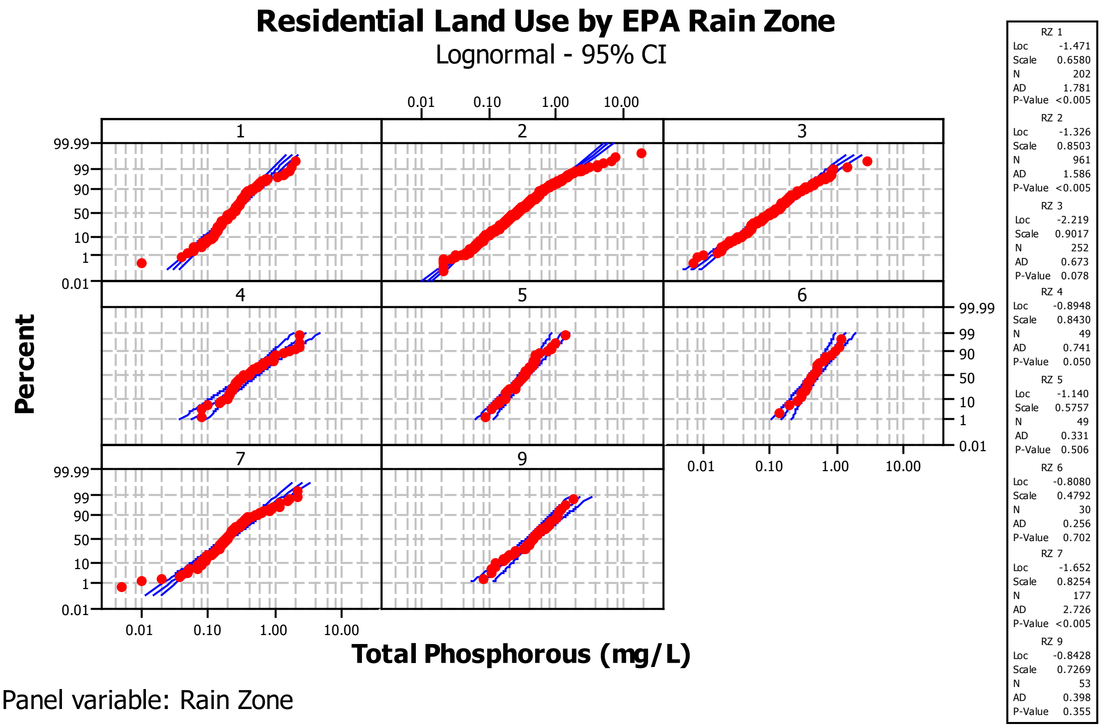


Fig. B35. Total Phosphorous – Residential Land Use by EPA Rain Zone (Checks for Normality)

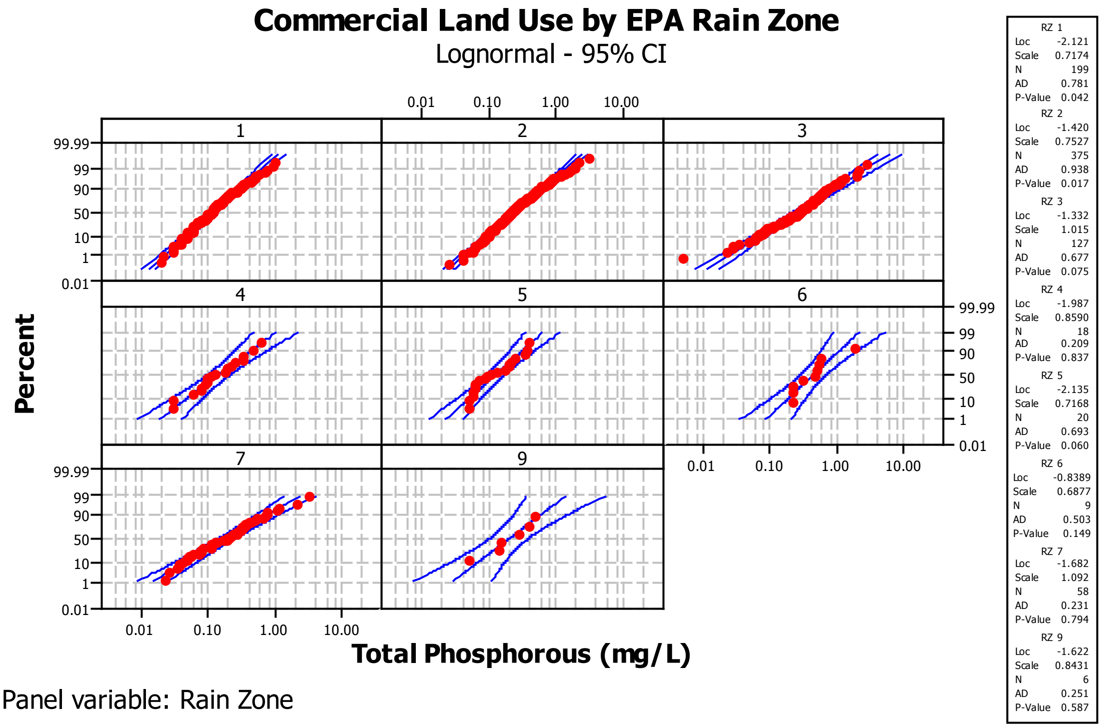


Fig. B36. Total Phosphorous – Commercial Land Use by EPA Rain Zone (Checks for Normality)

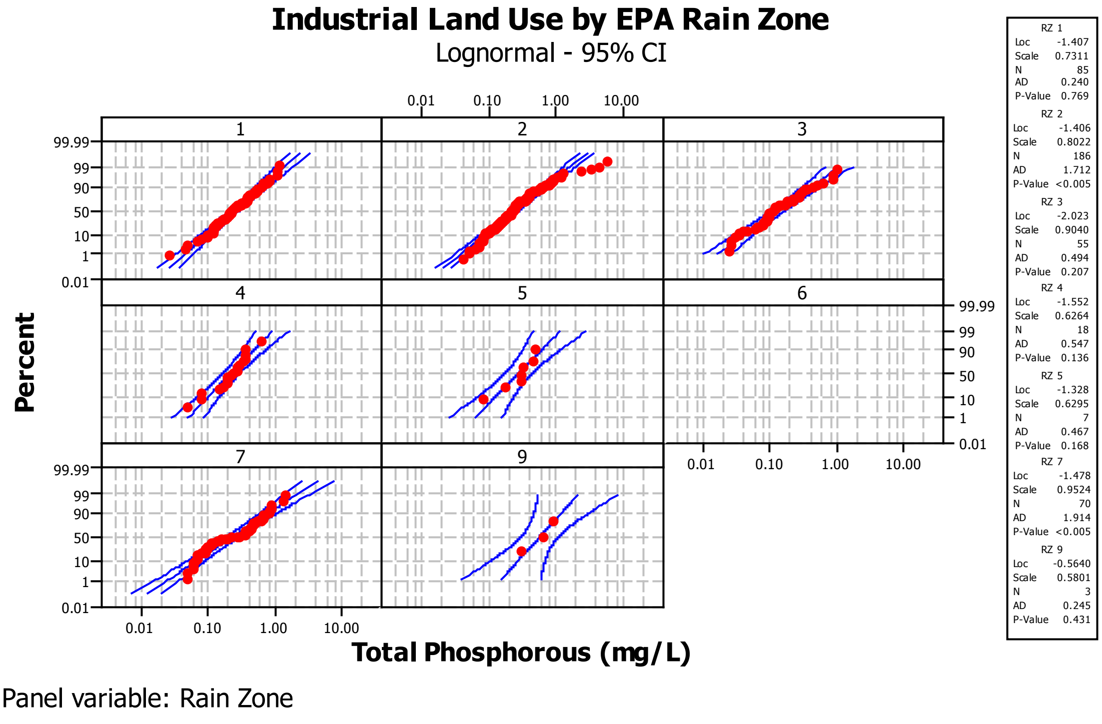


Fig. B37. Total Phosphorous – Industrial Land Use by EPA Rain Zone (Checks for Normality)

Table B25. Total Phosphorous – Univariate 3-way ANOVA Tests of Between-Subjects Effects

Dependent Variable: Log Total Phosphorous

	Source	Type III Sum of Squares	DF	Mean Square	F	P-value
	Corrected Model*	88	85	1.0	8	0.000
	Intercept	154	1	154	1265	0.000
Main Effects	Rain Zone (8 levels)	16	7	2.2	18	0.000*
	Land Use (3 levels)	2.4	2	1.2	10	0.000*
	Season (4 levels)	1.2	3	0.39	3.2	0.022*
Two-way Interactions	Rain Zone * Land Use	17	13	1.3	11	0.000*
	Rain Zone * Season	2.5	20	0.13	1.0	0.412
	Land Use * Season	1.2	6	0.21	1.7	0.121
Three-way Interaction	Rain Zone * Land Use * Season	14	34	0.41	3.3	0.000*
	Error	357	2923	0.12		
	Total	1739	3009			
	Corrected Total	445	3008			

*R Squared = 0.198 (Adjusted R Squared = 0.174)

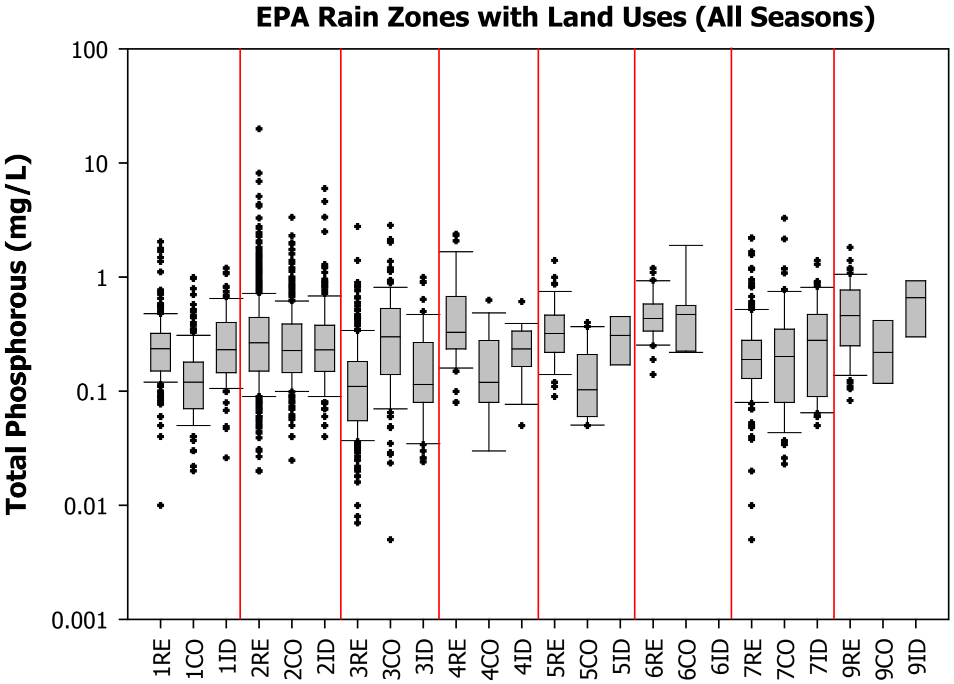


Fig. B38. Total Phosphorous – EPA Rain Zones with Land Uses

Table B26. Total Phosphorous **-** MANOVA Test for Significance of Land Use within Rain Zone using Unique Sum of Squares

Source of Variation	Sum of Squares	DF	Mean Square	F	p-value
WITHIN CELLS	357	2923	0.12		
Land Use WITHIN Rain Zone(1)	12	2	5.9	48	0.000*
Land Use WITHIN Rain Zone (2)	4.2	2	2.1	17	0.000*
Land Use WITHIN Rain Zone (3)	19	2	9.6	79	0.000*
Land Use WITHIN Rain Zone (4)	4.4	2	2.2	18	0.000*
Land Use WITHIN Rain Zone (5)	2.9	2	1.4	12	0.000*
Land Use WITHIN Rain Zone (6)	3.8	2	1.9	15	0.000*
Land Use WITHIN Rain Zone (7)	0.50	2	0.25	2.1	0.128
Land Use WITHIN Rain Zone (9)	4.4	2	2.2	18	0.000*

Table B27. Total Phosphorous - Test of Significance: Land Use within Rain Zone

Rain Zone	1-Way ANOVA p-value	Multiple Comparison (Scheffe Post-Hoc Test)			Homogeneous Groups Dependent Variable: Log Total Phosphorous				Power Analysis	
		(I) LU	(J) LU	p-value	LU	N	Gr. 1	Gr. 2	α level	Power (%)
1	0.000*	RE	CO	0.000*	RE	202	-0.639		0.20	100
			ID	0.778	ID	85	-0.611		0.15	100
		CO	ID	0.000*	CO	199		-0.921	0.10	100
					Pooled St. Dev = 0.302				***0.05***	***100***
					Obtained Effect Size = 0.47				0.01	100
2	0.124	-	-	-	RE	961	-0.576		0.20	70.7
					CO	375	-0.617		0.15	64.7
					ID	186	-0.611		0.10	56.6
					Pooled St. Dev = 0.357				***0.05***	***43.9***
					Obtained Effect Size = 0.05				0.01	22.1
3	0.000*	RE	CO	0.000*	RE	252	-0.964		0.20	100
			ID	0.374	ID	55	-0.879		0.15	100
		CO	ID	0.000*	CO	127		-0.578	0.10	100
					Pooled St. Dev = 0.407				***0.05***	***100***
					Obtained Effect Size = 0.42				0.01	100
4	0.000*	RE	CO	0.000	RE	49	-0.389		0.20	99.9
			ID	0.016	CO	18		-0.863	0.15	99.9
		CO	ID	0.277	ID	18		-0.674	0.10	99.9
					Pooled St. Dev = 0.350				***0.05***	***99.7***
					Obtained Effect Size = 0.56				0.01	98.4

Table B27. – *Continued*

Rain Zone	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Total Phosphorous				**Power Analysis**	
		(I) LU	**(J) LU**	**p-value**	**LU**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
5	0.000*	RE	CO	0.000*	RE	49	-0.495		0.20	99.9
			ID	0.756	ID	7	-0.577		0.15	99.9
		CO	ID	0.016*	CO	20		-0.927	0.10	99.9
					Pooled St. Dev = 0.269				***0.05***	***99.9***
					Obtained Effect Size = 0.70				0.01	99.8
6	0.879	-	-	-	RE	30	-0.351		0.20	20.5
					CO	9	-0.364		0.15	15.4
					ID	-	-		0.10	10.3
					Pooled St. Dev = 0.231				***0.05***	***5.2***
					Obtained Effect Size = 0.02				0.01	1.1
9	0.041*	RE	CO	0.055	RE	53	-0.366		0.20	84.5
			ID	0.815	CO	6	-0.704		0.15	80.1
		CO	ID	0.134	ID	3	-0.245		0.10	73.4
					Pooled St. Dev = 0.318				***0.05***	***61.6***
					Obtained Effect Size = 0.33				0.01	36.4

Table B28. Total Phosphorous - MANOVA Test for Significance of Season within Rain Zone using Unique Sum of Squares

Source of Variation	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
WITHIN CELLS	357	2923	0.12		
Season WITHIN Rain Zone (1)	1.4	3	0.47	3.9	0.009*
Season WITHIN Rain Zone (2)	2.2	3	0.73	6.0	0.000*
Season WITHIN Rain Zone (3)	0.81	3	0.27	2.2	0.084
Season WITHIN Rain Zone (4)	0.43	3	0.14	1.2	0.322
Season WITHIN Rain Zone (5)	1.1	3	0.36	3.0	0.030*
Season WITHIN Rain Zone (6)	0.67	3	0.22	1.8	0.141
Season WITHIN Rain Zone (7)	2.9	3	0.96	7.9	0.000*
Season WITHIN Rain Zone (9)	4.6	3	1.5	13	0.000*

Table B29. Total Phosphorous – Test of Significance: Land Use and Season within Rain Zone

Rain Zone	Land Use	1-Way ANOVA p-value	Multiple Comparison (Scheffe Post-Hoc Test)			Homogeneous Groups Dependent Variable: Log Total Phosphorous				Power Analysis	
			(I) Season	(J) Season	p-value	Season	N	Gr. 1	Gr. 2	α level	Power (%)
1	RE ID	0.340	-	-	-	FA	111	-0.624		0.20	57.6
						SP	57	-0.661		0.15	50.7
						SU	89	-0.597		0.10	42.1
						WI	30	-0.697		***0.05***	***29.9***
										0.01	12.5
						Pooled St. Dev = 0.295, Obtained Effect Size = 0.11					
	CO	0.141	-	-	-	FA	87	-0.970		0.20	73.7
						SP	34	-0.872		0.15	67.9
						SU	55	-0.917		0.10	59.8
						WI	23	-0.820		***0.05***	***46.9***
										0.01	24.2
						Pooled St. Dev = 0.310, Obtained Effect Size = 0.17					
2	RE CO ID	0.000*	FA	SP	0.022*	FA	392	-0.555		0.20	99.8
				SU	0.892	SU	319	-0.534		0.15	99.6
				WI	0.042*	SP	400		-0.63	0.10	99.3
			SP	SU	0.003*	WI	411		-0.63	***0.05***	***98.5***
				WI	0.995					0.01	94.2
			SU	WI	0.007*	Pooled St. Dev = 0.355, Obtained Effect Size = 0.12					
5	RE ID	0.513	-	-	-	FA	11	-0.543		0.20	46.9
						SP	18	-0.471		0.15	39.9
						SU	24	-0.536		0.10	31.5
						WI	3	-0.332		***0.05***	***20.6***
										0.01	7.1
						Pooled St. Dev = 0.253, Obtained Effect Size = 0.20					
	CO	0.010*	FA	SP	0.471	FA	4	-0.584		0.20	96.9
				SU	0.147	SP	6		-0.84	0.15	95.2
				WI	0.015*	SU	3		-1.04	0.10	92.1
			SP	SU	0.702	WI	7		-1.15	***0.05***	***84.4***
				WI	0.176					0.01	59.1
			SU	WI	0.926	Pooled St. Dev = 0.241, Obtained Effect Size = 0.88					

Table B29. – *Continued*

Rain Zone	**Land Use**	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Total Phosphorous				**Power Analysis**	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
7	RE CO ID	0.001*	FA	SP	0.250	FA	83	-0.590		0.20	98.5
				SU	0.952	SU	38	-0.634		0.15	97.8
				WI	0.002*	SP	83		-0.71	0.10	96.4
			SP	SU	0.789	WI	101		-0.81	***0.05***	***93.1***
				WI	0.379					0.01	80.8
			SU	WI	0.120	Pooled St. Dev = 0.387, Obtained Effect Size = 0.23					
9	RE CO ID	0.120	-	-	-	FA	17	-0.376		0.20	70.8
						SP	10	-0.587		0.15	64.7
						SU	35	-0.345		0.10	56.3
						WI	-	-		***0.05***	***43.2***
										0.01	20.9
						Pooled St. Dev = 0.324, Obtained Effect Size = 0.27					

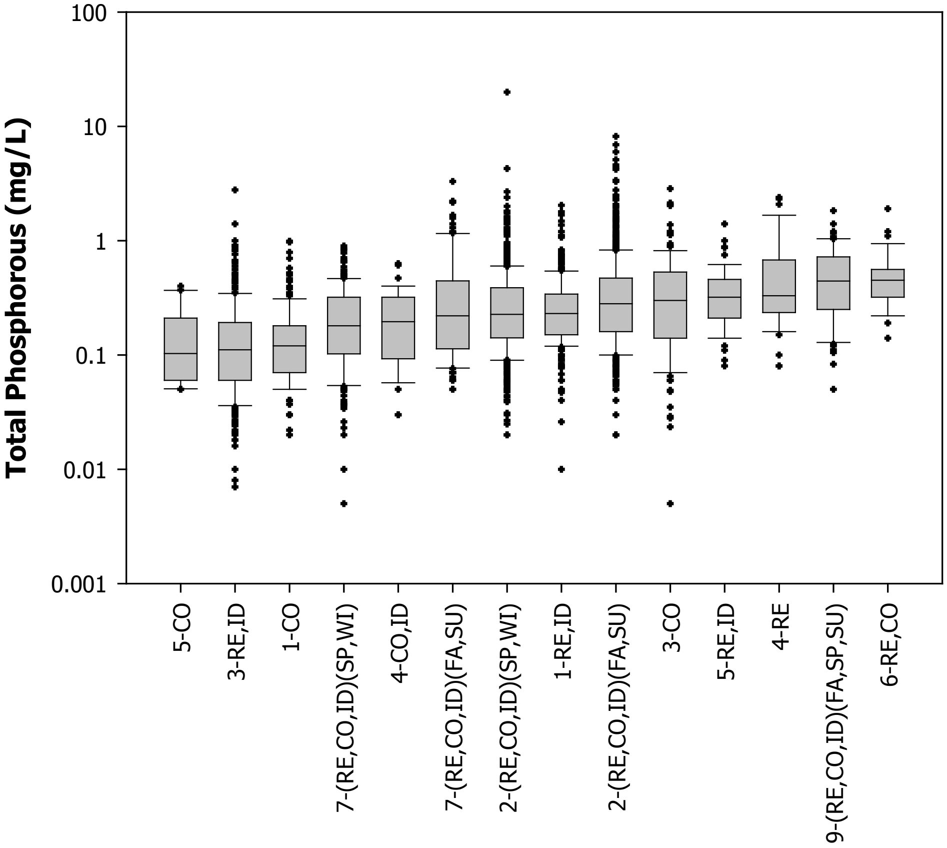


Fig. B39. Total Phosphorous – Rain Zone Groups

Table B30. Total Phosphorous – Rain Zone Groups Multiple Comparisons

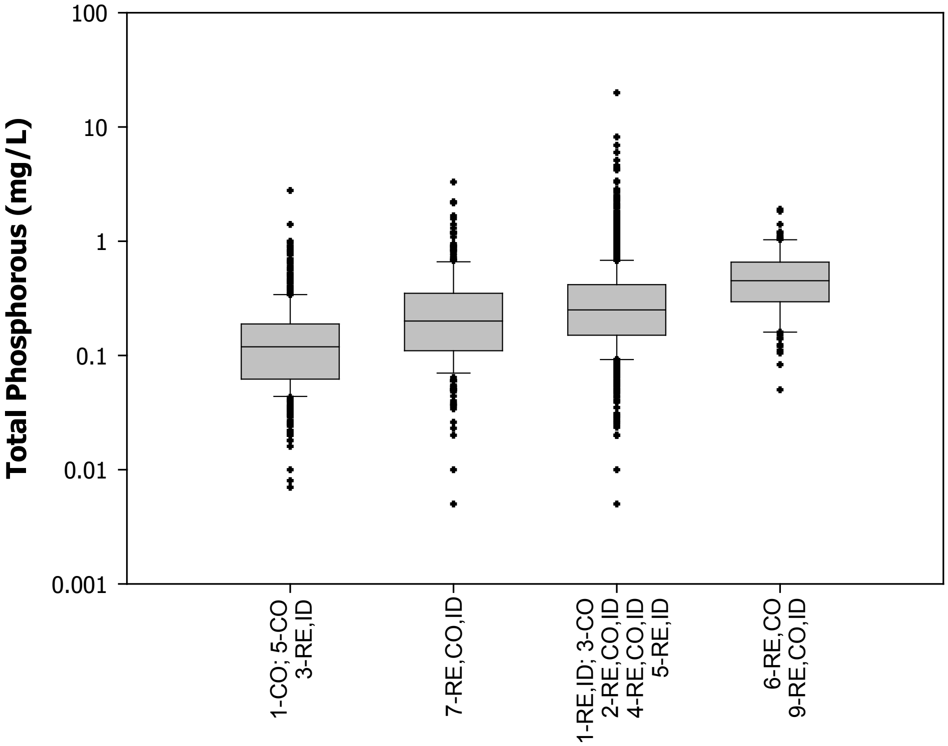
(I) Group	(J) Group	p-value
1-RE,ID	1-CO	0.000
	2-(RE,CO,ID) (FA,SU)	0.543
	2-(RE,CO,ID) (SP,WI)	1.000
	3-RE,ID	0.000
	3-CO	1.000
	4-RE	0.110
	4-CO,ID	0.979
	5-RE,ID	0.952
	5-CO	0.443
	6-RE,CO	0.077
	7-(RE,CO,ID) (FA,SU)	1.000
	7-(RE,CO,ID) (SP,WI)	0.214
	9-(RE,CO,ID)	0.044
1-CO	2-(RE,CO,ID) (FA,SU)	0.000
	2-(RE,CO,ID) (SP,WI)	0.000
	3-RE,ID	1.000
	3-CO	0.000
	4-RE	0.000
	4-CO,ID	0.958
	5-RE,ID	0.000
	5-CO	1.000
	6-RE,CO	0.000
	7-(RE,CO,ID) (FA,SU)	0.000
	7-(RE,CO,ID) (SP,WI)	0.159
	9-(RE,CO,ID)	0.000
4-RE	4-CO,ID	0.034
	5-RE,ID	0.998
	5-CO	0.002
	6-RE,CO	1.000
	7-(RE,CO,ID)(FA,SU)	0.460
	7-(RE,CO,ID)(SP,WI)	0.000
	9-(RE,CO,ID)	1.000
2-(RE,CO,ID) (SP,WI)	3-RE,ID	0.000
	3-CO	1.000
	4-RE	0.067
	4-CO,ID	0.969
	5-RE,ID	0.928
	5-CO	0.395
	6-RE,CO	0.049
	7-(RE,CO,ID)(FA,SU)	1.000
	7-(RE,CO,ID)(SP,WI)	0.047
	9-(RE,CO,ID)	0.019
3-RE,ID	3-CO	0.000
	4-RE	0.000
	4-CO,ID	0.823
	5-RE,ID	0.000
	5-CO	1.000
	6-RE,CO	0.000
	7-(RE,CO,ID)(FA,SU)	0.000
	7-(RE,CO,ID)(SP,WI)	0.005
	9-(RE,CO,ID)	0.000
3-CO	4-RE	0.683
	4-CO,ID	0.841
	5-RE,ID	1.000
	5-CO	0.215
	6-RE,CO	0.532
	7-(RE,CO,ID)(FA,SU)	1.000
	7-(RE,CO,ID)(SP,WI)	0.068
	9-(RE,CO,ID)	0.577
4-CO,ID	5-RE,ID	0.523
	5-CO	0.999
	6-RE,CO	0.020
	7-(RE,CO,ID)(FA,SU)	0.947
	7-(RE,CO,ID)(SP,WI)	1.000
	9-(RE,CO,ID)	0.020
5-RE,ID	5-CO	0.077
	6-RE,CO	0.989
	7-(RE,CO,ID)(FA,SU)	0.998
	7-(RE,CO,ID)(SP,WI)	0.037
	9-(RE,CO,ID)	0.998
5-CO	6-RE,CO	0.001
	7-(RE,CO,ID)(FA,SU)	0.357
	7-(RE,CO,ID)(SP,WI)	0.994
	9-(RE,CO,ID)	0.001
6-RE,CO	7-(RE,CO,ID)(FA,SU)	0.331
	7-(RE,CO,ID)(SP,WI)	0.000
	9-(RE,CO,ID)	1.000
7-(RE,CO,ID) (FA,SU)	7-(RE,CO,ID)(SP,WI)	0.277
	9-(RE,CO,ID)(FA,SP,SU)	0.340
7-(RE,CO,ID) (SP,WI)	9-(RE,CO,ID)	0.000
2-(RE,CO,ID) (FA,SU)	2-(RE,CO,ID) (SP,WI)	0.064
	3-RE,ID	0.000
	3-CO	1.000
	4-RE	0.778
	4-CO,ID	0.405
	5-RE,ID	1.000
	5-CO	0.048
	6-RE,CO	0.632
	7-(RE,CO,ID) (FA,SU)	0.998
	7-(RE,CO,ID) (SP,WI)	0.000
	9-(RE,CO,ID)	0.651

Table B31. Total Phosphorous – Homogeneous Groups

Groups	**N**	**Homogeneous Groups** Dependent Variable: Log Total Phosphorous			
		A	**B**	**C**	**D**
1-CO	199	-0.921			
3-RE,ID	307	-0.949			
5-CO	20	-0.927			
7-(RE,CO,ID)(SP,WI)	184		-0.767		
7-(RE,CO,ID)(FA,SU)	121		-0.604		
1-RE,ID	287			-0.631	
2-(RE,CO,ID)(FA,SU)	711			-0.545	
2-(RE,CO,ID)(SP,WI)	811			-0.630	
3-CO	127			-0.578	
4-RE	49			-0.389	
4-CO,ID	36			-0.768	
5-RE,ID	56			-0.505	
6-RE,CO	39				-0.354
9-RE,CO,ID	62				-0.393

Table B32. Basic Statistics for Total Phosphorous –
Rain Zone Homogeneous Groups (Real Space Data) (mg/L)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	1-CO; 3-RE,ID; 5-CO	526	0.17	0.20	1.2	0.01	0.12	2.8
B	7-RE,CO,ID	305	0.30	0.37	1.2	0.01	0.20	3.3
C	1-RE,ID; 2-RE,CO,ID 3-CO; 4-RE,CO,ID 5-RE,ID	2077	0.38	0.64	1.7	0.01	0.25	20
D	6-RE,CO; 9-RE,CO,ID	101	0.52	0.35	0.67	0.05	0.45	1.9



Land Use	**Season**	**EPA Rain Zones**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**9**
Residential	FA	0.30 (0.90)	0.41 (1.1)	0.13 (1.4)	0.61 (1.2)	0.33 (0.57)	0.64 (0.51)	0.52 (1.1)	0.52 (0.60)
	SP	0.27 (0.81)	0.42 (3.1)	0.22 (1.8)	0.49 (0.72)	0.40 (0.61)	0.42 (0.38)	0.21 (0.56)	0.5 (1.2)
	SU	0.3 (1.0)	0.54 (1.7)	0.17 (1.1)	0.85 (0.99)	0.36 (0.75)	0.45 (0.38)	0.29 (0.80)	0.57 (0.60)
	WI	0.23 (0.68)	0.32 (0.85)	0.18 (0.92)	0.46 (0.90)	0.52 (0.59)	0.46 (0.57)	0.17 (0.64)	ND
Commercial	FA	0.15 (1.1)	0.34 (0.96)	0.49 (1.1)	0.18 (0.63)	0.28 (0.40)	0.98 (0.81)	0.89 (1.2)	ND
	SP	0.18 (0.85)	0.30 (0.80)	0.27 (1.4)	0.15 (0.88)	0.19 (0.65)	ND	0.2 (1.2)	0.22 (1.1)
	SU	0.15 (0.83)	0.42 (1.2)	0.47 (0.77)	0.24 (0.92)	0.10 (0.39)	0.34 (0.37)	0.35 (1.1)	0.27 (0.62)
	WI	0.17 (0.54)	0.27 (0.79)	0.21 (1.0)	0.21 (1.0)	0.07 (0.28)	0.23 (0.03)	0.22 (0.73)	ND
Industrial	FA	0.29 (0.61)	0.63 (1.9)	0.16 (1.5)	0.31 (0.34)	ND	ND	0.25 (1.2)	ND
	SP	0.33 (0.81)	0.30 (0.74)	0.27 (0.91)	0.26 (1.0)	0.33 (0.48)	ND	0.48 (0.35)	ND
	SU	0.40 (0.81)	0.29 (0.75)	0.12 (0.63)	0.20 (0.16)	0.28 (0.67)	ND	0.65 (1.1)	0.80 (0.24)
	WI	0.22 (0.35)	0.29 (0.87)	0.23 (0.99)	0.23 (0.38)	ND	ND	0.34 (0.75)	ND

Fig. B40. Total Phosphorous – Rain Zone Homogeneous Groups: Mean (CV)

B.5. Dissolved Phosphorous

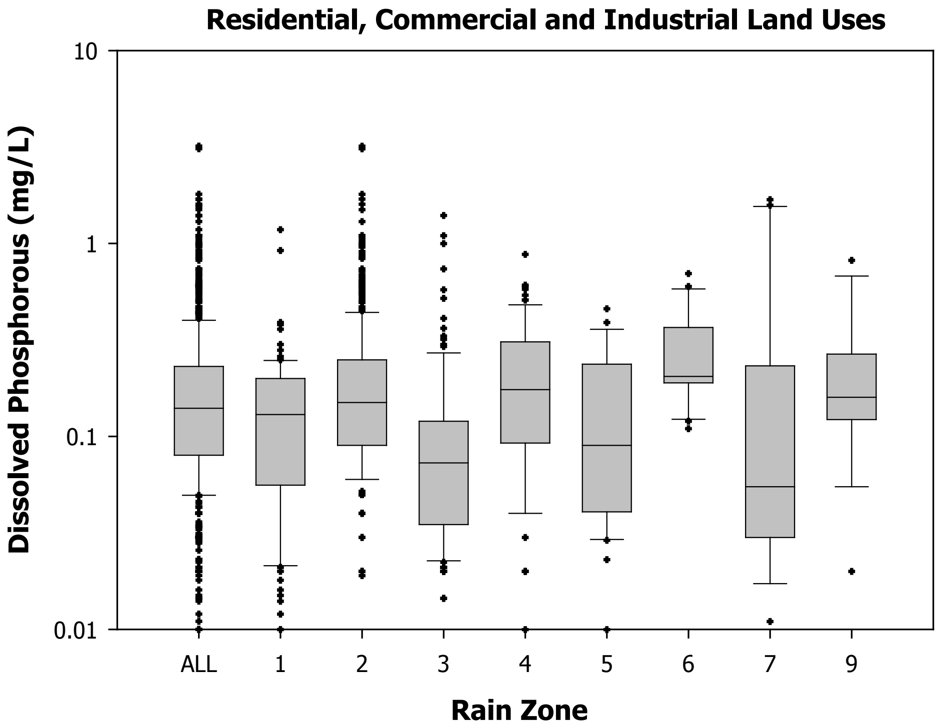
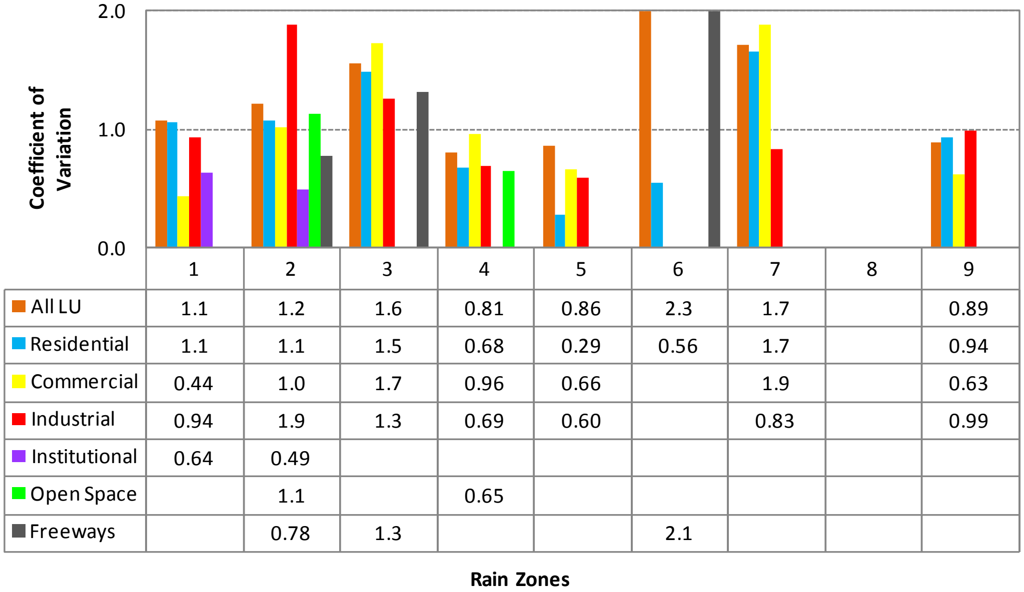


Fig. B41. Dissolved Phosphorous – Residential, Commercial, and Industrial Land Uses in the Contiguous United States



	1	2	3	4	5	6	7	8	9
🟧 All LU	1.1	1.2	1.6	0.81	0.86	2.3	1.7		0.89
🟦 Residential	1.1	1.1	1.5	0.68	0.29	0.56	1.7		0.94
🟨 Commercial	0.44	1.0	1.7	0.96	0.66		1.9		0.63
🟥 Industrial	0.94	1.9	1.3	0.69	0.60		0.83		0.99
🟪 Institutional	0.64	0.49							
🟩 Open Space		1.1		0.65					
⬛ Freeways		0.78	1.3			2.1			

Fig. B42. Dissolved Phosphorous - Regional Coefficients of Variation for Single Land Uses in the Contiguous United States

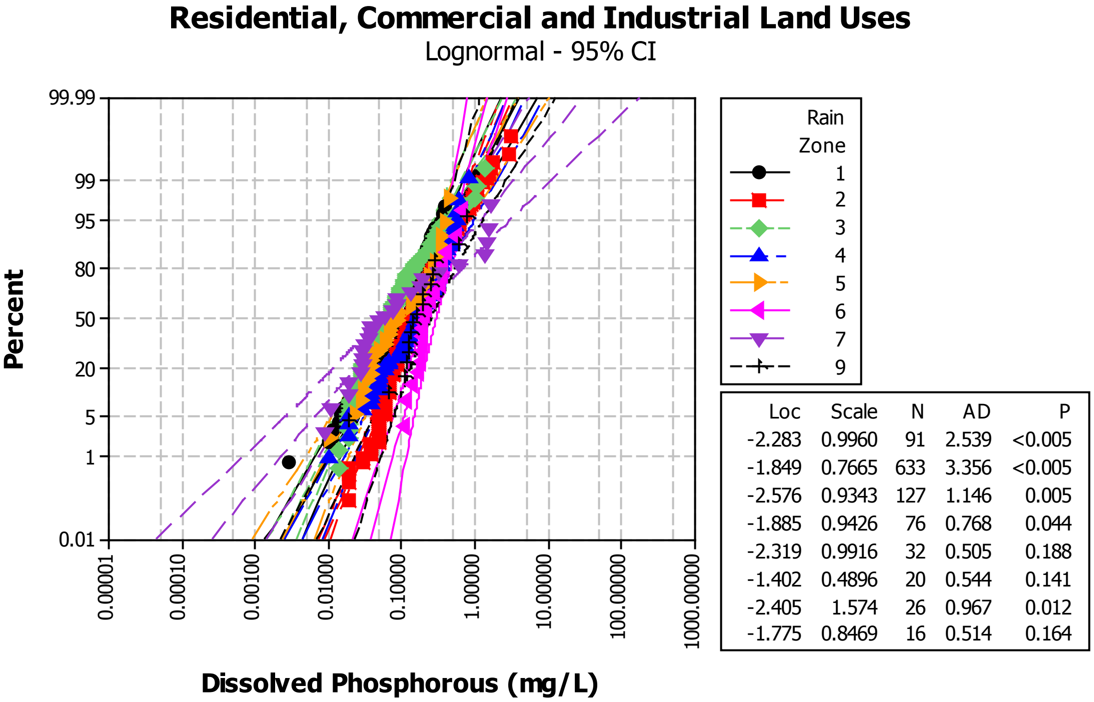


Fig. B43. Dissolved Phosphorous – Residential, Commercial, and Industrial Land Uses in the Contiguous United State (Checks for Normality)

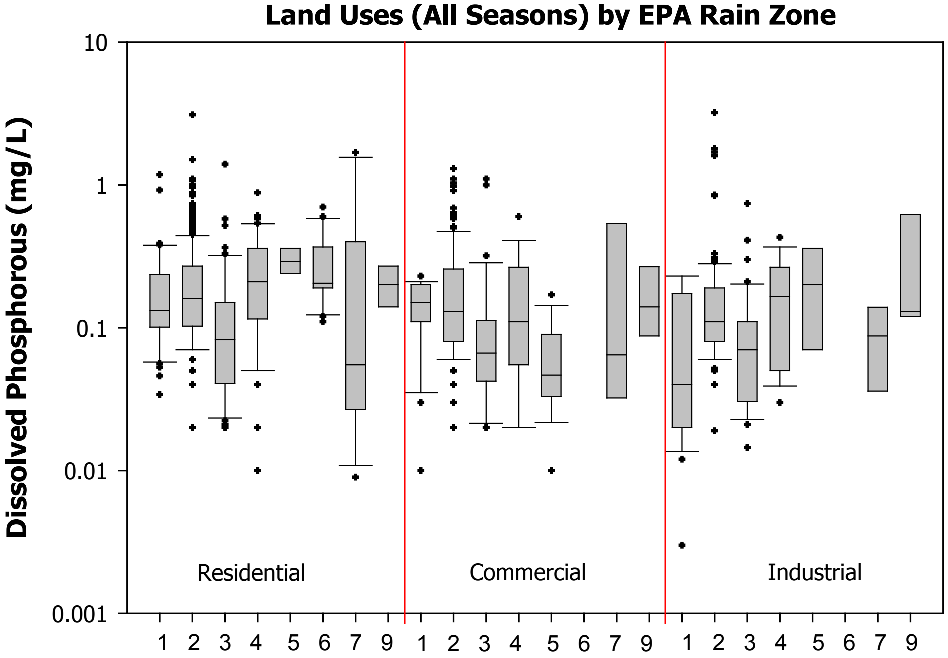


Fig. B44. Dissolved Phosphorous – Land Uses by EPA Rain Zone

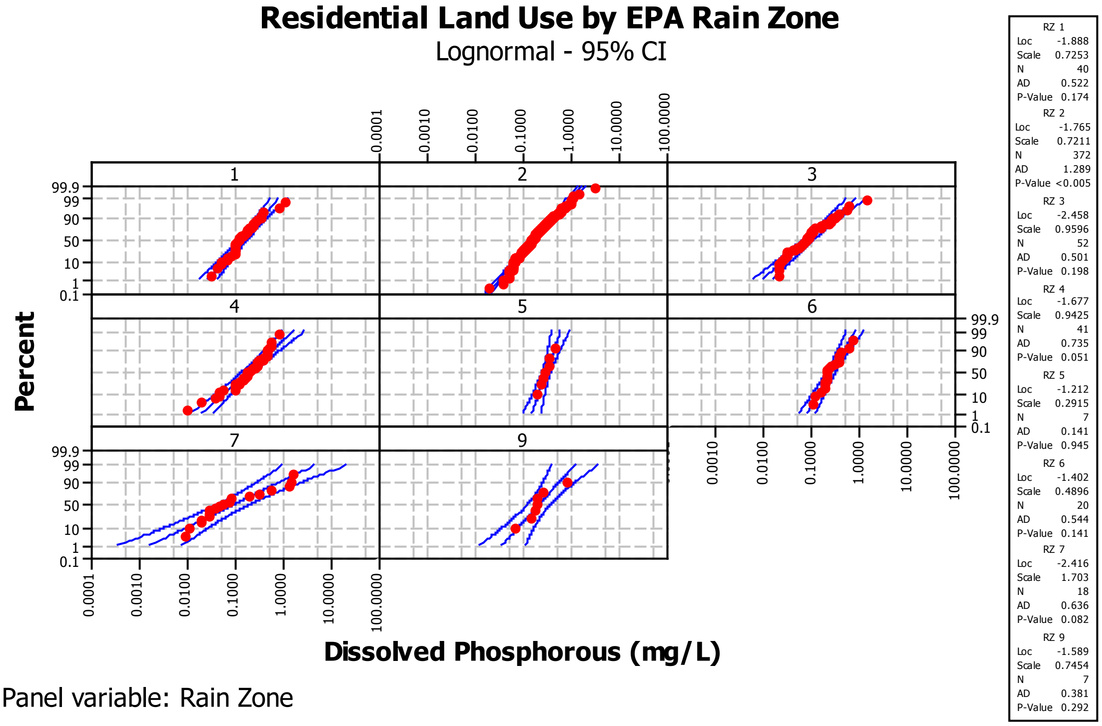


Fig. B45. Dissolved Phosphorous – Residential Land Use by EPA Rain Zone (Checks for Normality)

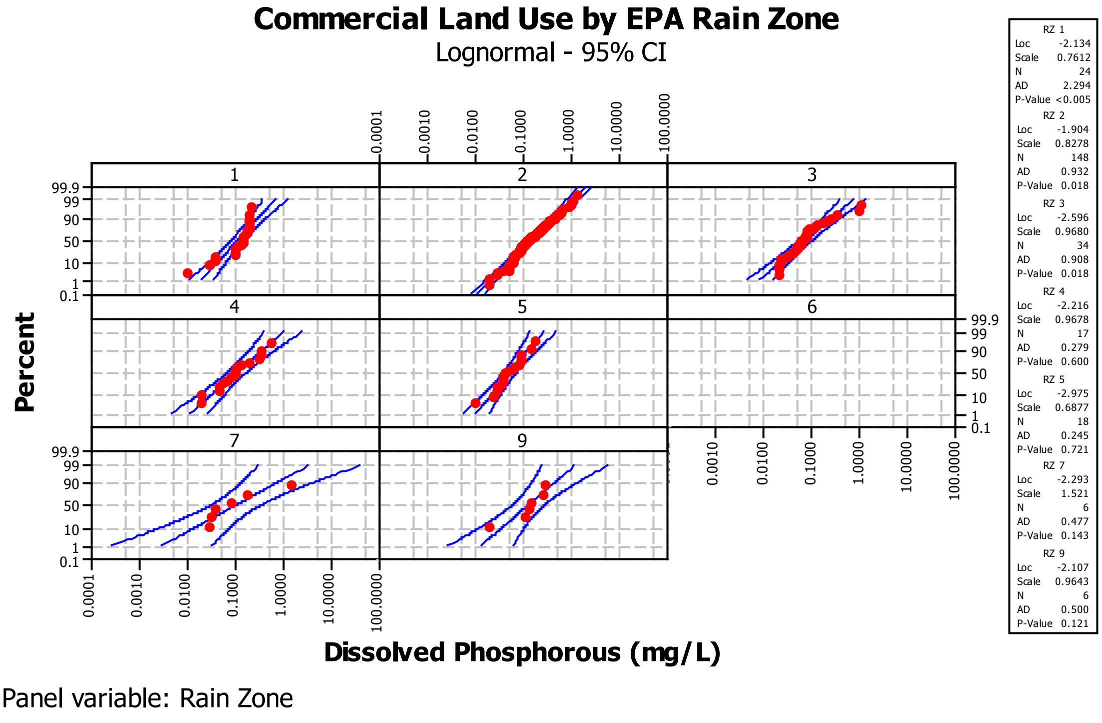


Fig. B46. Dissolved Phosphorous – Commercial Land Use by EPA Rain Zone (Checks for Normality)

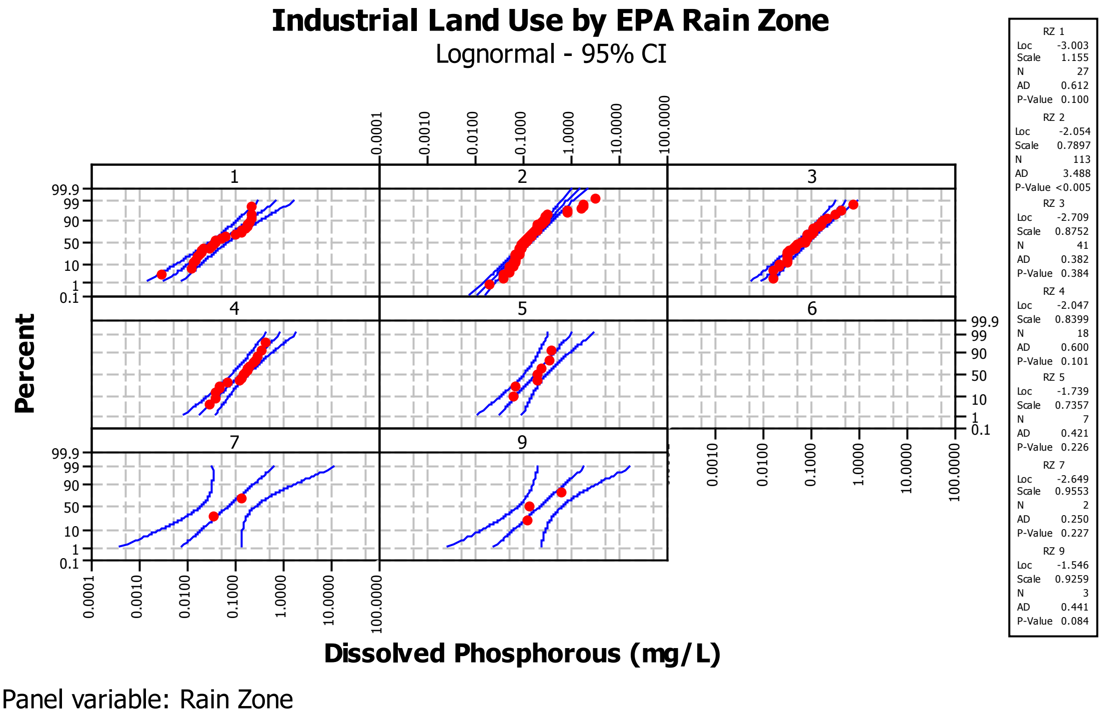


Fig. B47. Dissolved Phosphorous – Industrial Land Use by EPA Rain Zone (Checks for Normality)

Table B33. Dissolved Phosphorous – Univariate 3-way ANOVA Tests of Between-Subjects Effects

Dependent Variable: Log Dissolved Phosphorous

	Source	Type III Sum of Squares	DF	Mean Square	F	P-value
	Corrected Model*	45	76	0.59	5.1	0.000
	Intercept	177	1	177	1510	0.000
Main Effects	Rain Zone (8 levels)	10	7	1.5	13	0.000*
	Land Use (3 levels)	1.0	2	0.50	4.3	0.014*
	Season (4 levels)	3.1	3	1.0	8.8	0.000*
Two-way Interactions	Rain Zone * Land Use	3.7	12	0.31	2.7	0.002*
	Rain Zone * Season	7.5	19	0.40	3.4	0.000*
	Land Use * Season	1.0	6	0.17	1.4	0.196
Three-way Interaction	Rain Zone * Land Use * Season	3.4	27	0.12	1.1	0.375
	Error	111	944	0.12		
	Total	926	1021			
	Corrected Total	156	1020			

*R Squared = 0.289 (Adjusted R Squared = 0.232)

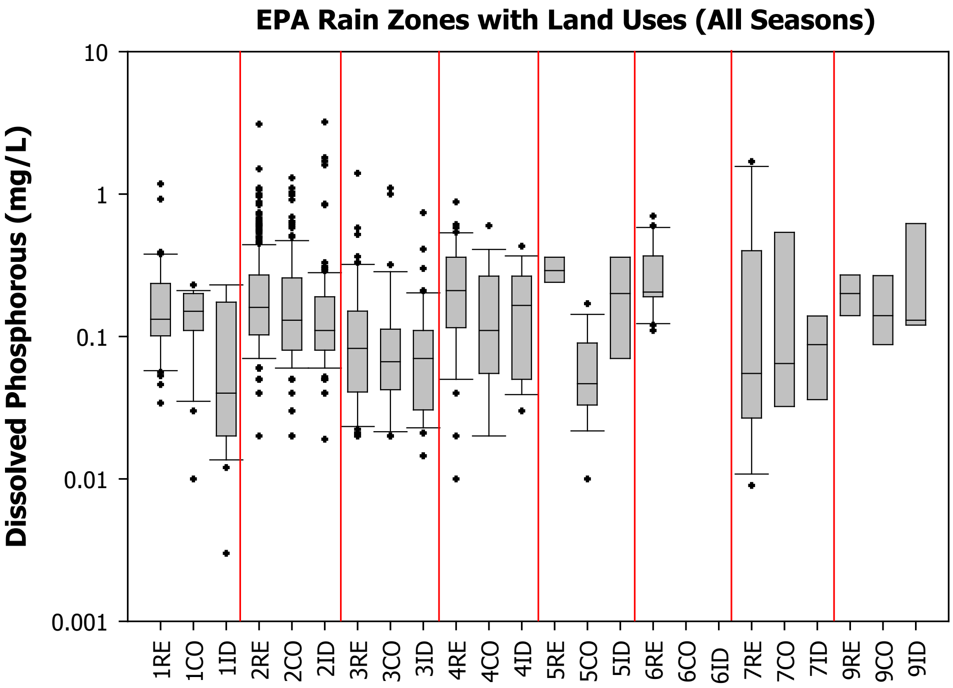


Fig. B48. Dissolved Phosphorous – EPA Rain Zones with Land Uses

Table B34. Dissolved Phosphorous - MANOVA Test for Significance of Land Use within Rain Zone using Unique Sum of Squares

Source of Variation	Sum of Squares	DF	Mean Square	F	p-value
WITHIN CELLS	111	944	0.12		
Land Use WITHIN Rain Zone(1)	3.5	2	1.7	15	0.000*
Land Use WITHIN Rain Zone (2)	3.9	2	1.9	16	0.000*
Land Use WITHIN Rain Zone (3)	0.18	2	0.09	0.78	0.460
Land Use WITHIN Rain Zone (4)	1.1	2	0.55	4.7	0.009*
Land Use WITHIN Rain Zone (5)	3.9	2	2.0	17	0.000*
Land Use WITHIN Rain Zone (6)	-	-	-	-	-
Land Use WITHIN Rain Zone (7)	0.27	2	0.13	1.1	0.322
Land Use WITHIN Rain Zone (9)	0.19	2	0.09	0.79	0.452

Table B35. Dissolved Phosphorous - Test of Significance: Land Use within Rain Zone

Rain Zone	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Dissolved Phosphorous				**Power Analysis**	
		(I) LU	**(J) LU**	**p-value**	**LU**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
1	0.000*	RE	CO	0.560	RE	40	-0.820		0.20	99.9
			ID	0.000*	CO	24	-0.927		0.15	99.9
		CO	ID	0.003*	ID	27		-1.304	0.10	99.9
					Pooled St. Dev = 0.383				***0.05***	***99.7***
					Obtained Effect Size = 0.54				0.01	98.3
2	0.001*	RE	CO	0.170	RE	372	-0.767		0.20	98.0
			ID	0.002*	CO	148		-0.827	0.15	97.1
		CO	ID	0.288	ID	113		-0.892	0.10	95.5
					Pooled St. Dev = 0.330				***0.05***	***91.6***
					Obtained Effect Size = 0.15				0.01	77.9
4	0.097				RE	41	-0.728		0.20	74.1
		-	-	-	ID	17	-0.963		0.15	68.3
					CO	18	-0.889		0.10	60.2
					Pooled St. Dev = 0.402				***0.05***	***47.2***
					Obtained Effect Size = 0.25				0.01	24.0
5	0.000*	RE	CO	0.000	RE	7	-0.526		0.20	99.9
			ID	0.317	ID	7	-0.755		0.15	99.9
		CO	ID	0.001	CO	18		-1.292	0.10	99.9
					Pooled St. Dev = 0.277				***0.05***	***99.9***
					Obtained Effect Size = 1.2				0.01	99.9

Table B36. Dissolved Phosphorous **-** MANOVA Test for Significance of Season within Rain Zone using Unique Sum of Squares

Source of Variation	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
WITHIN CELLS	111	944	0.12		
Season WITHIN Rain Zone (1)	1.5	3	0.51	4.4	0.005*
Season WITHIN Rain Zone (2)	3.6	3	1.2	10	0.000*
Season WITHIN Rain Zone (3)	0.43	3	0.14	1.2	0.301
Season WITHIN Rain Zone (4)	0.25	3	0.08	0.71	0.545
Season WITHIN Rain Zone (5)	1.6	3	0.53	4.5	0.004*
Season WITHIN Rain Zone (6)	0.54	3	0.18	1.5	0.204
Season WITHIN Rain Zone (7)	9.7	3	3.2	28	0.000*
Season WITHIN Rain Zone (9)	0.67	3	0.22	1.9	0.129

Table B37. Dissolved Phosphorous – Test of Significance: Land Use and Season within Rain Zone

Rain Zone	**Land Use**	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Dissolved Phosphorous				**Power Analysis**	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
1	RE CO	0.449	-	-	-	FA	31	-0.802		0.20	50.8
						SP	11	-0.957		0.15	43.8
						SU	12	-0.937		0.10	35.2
						WI	10	-0.840		***0.05***	***23.7***
										0.01	8.7
						Pooled St. Dev = 0.323, Obtained Effect Size = 0.21					
	ID	0.024*	FA	SP	0.997	FA	9	-1.277		0.20	92.6
				SU	0.383	SP	6	-1.330		0.15	89.6
				WI	0.326	SU	7	-1.670		0.10	84.6
			SP	SU	0.589	WI	5		-0.81	***0.05***	***74.3***
				WI	0.304					0.01	47.5
			SU	WI	0.025*	Pooled St. Dev = 0.436, Obtained Effect Size = 0.65					
2	RE	0.000*	FA	SP	0.000*	FA	111	-0.694		0.20	99.5
				SU	0.823	SU	75	-0.737		0.15	99.2
				WI	0.427	WI	95	-0.765		0.10	98.6
			SP	SU	0.031*	SP	91		-0.88	***0.05***	***97.0***
				WI	0.088					0.01	89.8
			SU	WI	0.951	Pooled St. Dev = 0.306, Obtained Effect Size = 0.23					
	CO ID	0.003*	FA	SP	0.011*	FA	70	-0.737		0.20	97.5
				SU	0.406	SP	62		-0.94	0.15	96.4
				WI	0.029*	SU	65		-0.84	0.10	94.3
			SP	SU	0.438	WI	64		-0.92	***0.05***	***89.7***
				WI	0.988					0.01	74.3
			SU	WI	0.639	Pooled St. Dev = 0.346, Obtained Effect Size = 0.23					
5	RE ID	0.935	-	-	-	FA	2	-0.603		0.20	21.9
						SP	7	-0.626		0.15	16.6
						SU	5	-0.677		0.10	11.3
						WI	-	-		***0.05***	***5.8***
										0.01	1.2
						Pooled St. Dev = 0.283, Obtained Effect Size = 0.10					
	CO	0.019*	FA	SP	0.989	FA	4	-1.122		0.20	95.1
				SU	0.970	SP	6	-1.174		0.15	92.7
				WI	0.049*	SU	3	-1.210		0.10	88.3
			SP	SU	0.997	WI	5		-1.62	***0.05***	***78.4***
				WI	0.051*					0.01	49.8
			SU	WI	0.171	Pooled St. Dev = 0.233, Obtained Effect Size = 0.88					

Table B37. – *Continued*

Rain Zone	**Land Use**	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Dissolved Phosphorous				**Power Analysis**	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
7	RE CO ID	0.000*	FA	SP	0.000	FA	8	-0.170		0.20	100
				WI	0.000	SP	11		-1.48	0.15	100
			SP	WI	0.789	SU	-	-	-	0.10	100
						WI	7		-1.36	***0.05***	***100***
										0.01	99.9
						Pooled St. Dev = 0.348, Obtained Effect Size = 1.68					

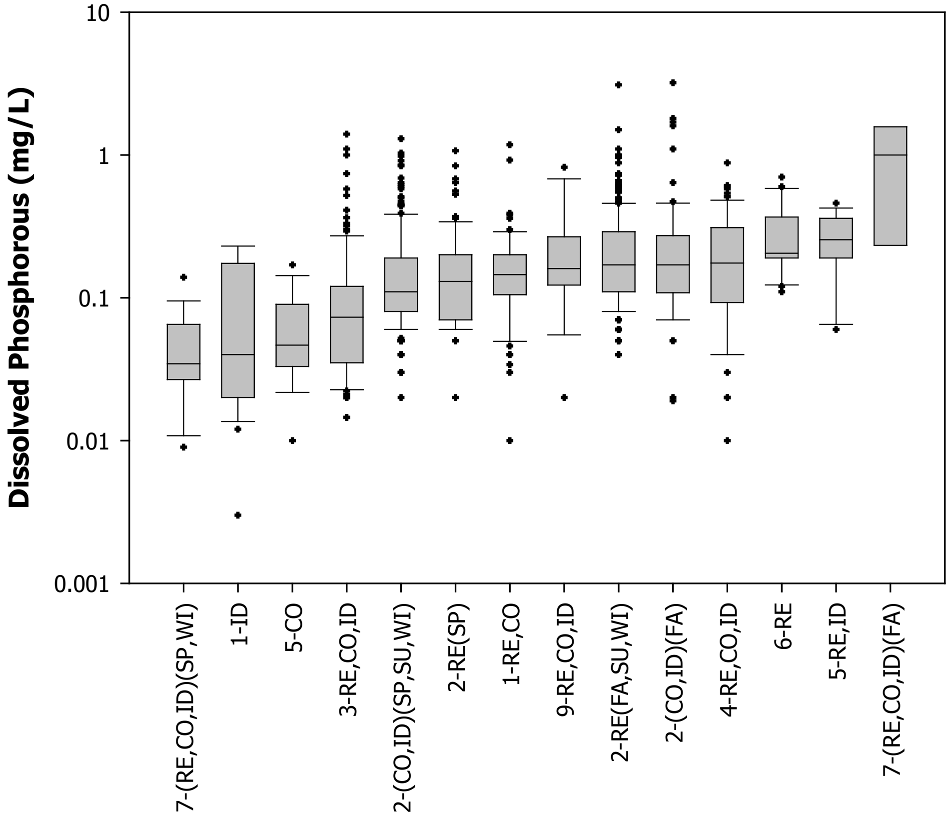


Fig. B49. Dissolved Phosphorous – Rain Zone Groups

Table B38. Dissolved Phosphorous – Rain Zone Groups Multiple Comparisons

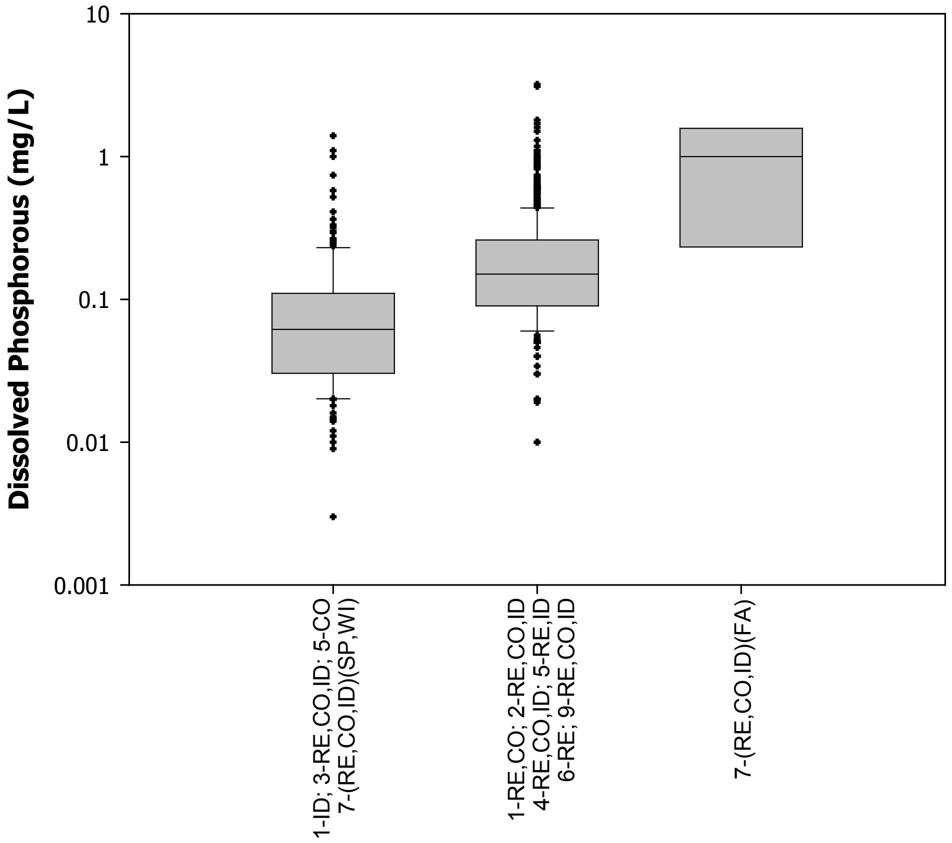
(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
1-RE,CO	1-ID	0.003	2-RE (FA,SU,WI)	2-RE(SP)	0.446	2-(CO,ID) (SP,SU,WI)	3-RE,CO,ID	0.004
	2-RE(FA,SU,WI)	0.881		2-(CO,ID)(FA)	1.000		4-RE,CO,ID	0.998
	2-RE(SP)	1.000		2-(CO,ID) (SP,SU,WI)	0.013		5-RE,ID	0.887
	2-(CO,ID)(FA)	0.988		3-RE,CO,ID	0.000		5-CO	0.068
	2-(CO,ID)(SP,SU,WI)	1.000		4-RE,CO,ID	0.992		6-RE	0.464
	3-RE,CO,ID	0.034		5-RE,ID	1.000		7-(RE,CO,ID)(FA)	0.001
	4-RE,CO,ID	1.000		5-CO	0.000		7-(RE,CO,ID)(SP,WI)	0.000
	5-RE,ID	0.982		6-RE	0.999		9-RE,CO,ID	1.000
	5-CO	0.057		7-(RE,CO,ID)(FA)	0.086	3-RE,CO,ID	4-RE,CO,ID	0.001
	6-RE	0.837		7-(RE,CO,ID)(SP,WI)	0.000		5-RE,ID	0.031
	7-(RE,CO,ID)(FA)	0.009		9-RE,CO,ID	1.000		5-CO	0.991
	7-(RE,CO,ID)(SP,WI)	0.000	2-RE(SP)	2-(CO,ID)(FA)	0.910		6-RE	0.000
	9-RE,CO,ID	1.000		2-(CO,ID)(SP,SU,WI)	1.000		7-(RE,CO,ID)(FA)	0.000
1-ID	2-RE(FA,SU,WI)	0.000		3-RE,CO,ID	0.023		7-(RE,CO,ID)(SP,WI)	0.442
	2-RE(SP)	0.004		4-RE,CO,ID	1.000		9-RE,CO,ID	0.354
	2-(CO,ID)(FA)	0.000		5-RE,ID	0.951	4-RE,CO,ID	5-RE,ID	0.997
	2-(CO,ID)(SP,SU,WI)	0.002		5-CO	0.068		5-CO	0.012
	3-RE,CO,ID	0.932		6-RE	0.679		6-RE	0.950
	4-RE,CO,ID	0.000		7-(RE,CO,ID)(FA)	0.004		7-(RE,CO,ID)(FA)	0.020
	5-RE,ID	0.001		7-(RE,CO,ID)(SP,WI)	0.000		7-(RE,CO,ID)(SP,WI)	0.000
	5-CO	1.000		9-RE,CO,ID	1.000		9-RE,CO,ID	1.000
	6-RE	0.000	2-(CO,ID) (FA)	2-(CO,ID) (SP,SU,WI)	0.592	5-RE,ID	5-CO	0.010
	7-(RE,CO,ID)(FA)	0.000		3-RE,CO,ID	0.000		6-RE	1.000
	7-(RE,CO,ID)(SP,WI)	1.000		4-RE,CO,ID	1.000		7-(RE,CO,ID)(FA)	0.735
	9-RE,CO,ID	0.035		5-RE,ID	1.000		7-(RE,CO,ID)(SP,WI)	0.000
6-RE	7-(RE,CO,ID)(FA)	0.755		5-CO	0.000		9-RE,CO,ID	1.000
	7-(RE,CO,ID)(SP,WI)	0.000		6-RE	1.000	5-CO	6-RE	0.000
	9-RE,CO,ID	1.000		7-(RE,CO,ID)(FA)	0.114		7-(RE,CO,ID)(FA)	0.000
7-(RE,CO,ID)(FA)	7-(RE,CO,ID)(SP,WI)	0.000		7-(RE,CO,ID) (SP,WI)	0.000		7-(RE,CO,ID) (SP,WI)	1.000
	9-RE,CO,ID	0.239		9-RE,CO,ID	1.000		9-RE,CO,ID	0.118
7-(RE,CO,ID) (SP,WI)	9-RE,CO,ID	0.004						

Table B39. Dissolved Phosphorous – Homogeneous Groups

Groups	N	**Homogeneous Groups** Dependent Variable: Log Dissolved Phosphorous		
		A	**B**	**C**
1-ID	27	-1.303		
3-RE,CO,ID	127	-1.119		
5-CO	18	-1.293		
7-(RE,CO,ID)(SP,WI)	18	-1.434		
1-RE,CO	64		-0.860	
2-RE(FA,SU,WI)	281		-0.730	
2-RE(SP)	91		-0.880	
2-(CO,ID)(FA)	70		-0.737	
2-(CO,ID)(SP,SU,WI)	191		-0.899	
4-RE,CO,ID	76		-0.819	
5-RE,ID	14		-0.641	
6-RE	20		-0.608	
9-RE,CO,ID	16		-0.772	
7-(RE,CO,ID)(FA)	8			-0.169

Table B40. Basic Statistics for Dissolved Phosphorous –
Rain Zone Homogeneous Groups (Real Space Data) (mg/L)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	1-ID; 5-CO 3-RE,CO,ID 7-(RE,CO,ID)(SP,WI)	190	0.11	0.17	1.5	0.003	0.06	1.4
B	1-RE,CO; 2-RE,CO,ID 4-RE,CO,ID; 5-RE,ID 6-RE; 9-RE,CO,ID	823	0.22	0.25	1.1	0.01	0.15	3.2
C	7-(RE,CO,ID)(FA)	8	0.94	0.67	0.71	0.19	1.0	1.7



Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	0.29 (1.0)	0.28 (1.2)	0.17 (2.0)	0.19 (0.66)	ND	0.35 (0.39)	0.96 (0.68)	0.22 (0.32)
	SP	0.12 (0.50)	0.18 (0.98)	0.11 (0.80)	0.31 (0.56)	0.32 (0.35)	0.19 (0.17)	0.04 (0.73)	ND
	SU	0.13 (0.54)	0.23 (0.79)	0.19 (1.1)	0.32 (0.78)	0.3 (0.28)	0.21 (0.17)	ND	0.34 (0.94)
	WI	0.14 (0.33)	0.23 (0.86)	0.11 (0.94)	0.20 (0.78)	ND	0.28 (0.79)	0.04 (0.61)	ND
Commercial	FA	0.14 (0.54)	0.22 (0.85)	0.25 (1.6)	0.10 (0.40)	0.08 (0.24)	ND	0.89 (1.11)	ND
	SP	0.13 (0.58)	0.17 (0.85)	0.08 (0.86)	0.10 (0.84)	0.08 (0.71)	ND	0.04 (0.14)	0.14 (1.2)
	SU	0.12 (0.12)	0.25 (1.1)	0.07 (0.54)	0.24 (0.79)	0.06 (0.38)	ND	ND	0.17 (0.48)
	WI	0.15 (0.17)	0.21 (1.1)	0.08 (0.80)	0.22 (0.98)	0.03 (0.42)	ND	0.06 (0.70)	ND
Industrial	FA	0.08 (0.91)	0.44 (1.7)	0.10 (1.1)	0.20 (0.67)	ND	ND	ND	ND
	SP	0.07 (0.95)	0.11 (0.38)	0.07 (0.81)	0.16 (1.1)	0.22 (0.76)	ND	ND	ND
	SU	0.03 (0.98)	0.15 (0.98)	0.06 (0.71)	0.18 (0.14)	0.21 (0.70)	ND	ND	0.37 (0.96)
	WI	0.18 (0.45)	0.14 (1.1)	0.18 (1.24)	0.15 (0.73)	ND	ND	ND	ND

Fig. B50. Dissolved Phosphorous – Rain Zone Homogeneous Groups: Mean (CV)

B.6. Total Nitrogen

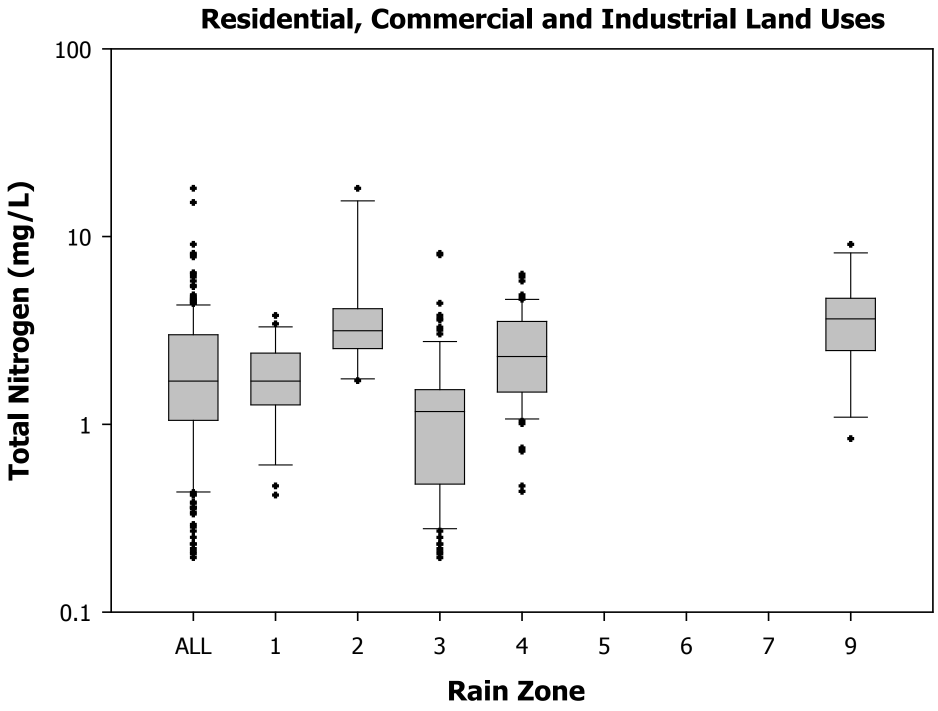
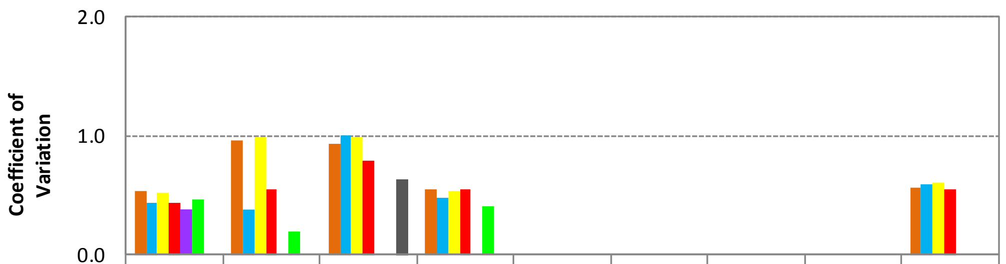
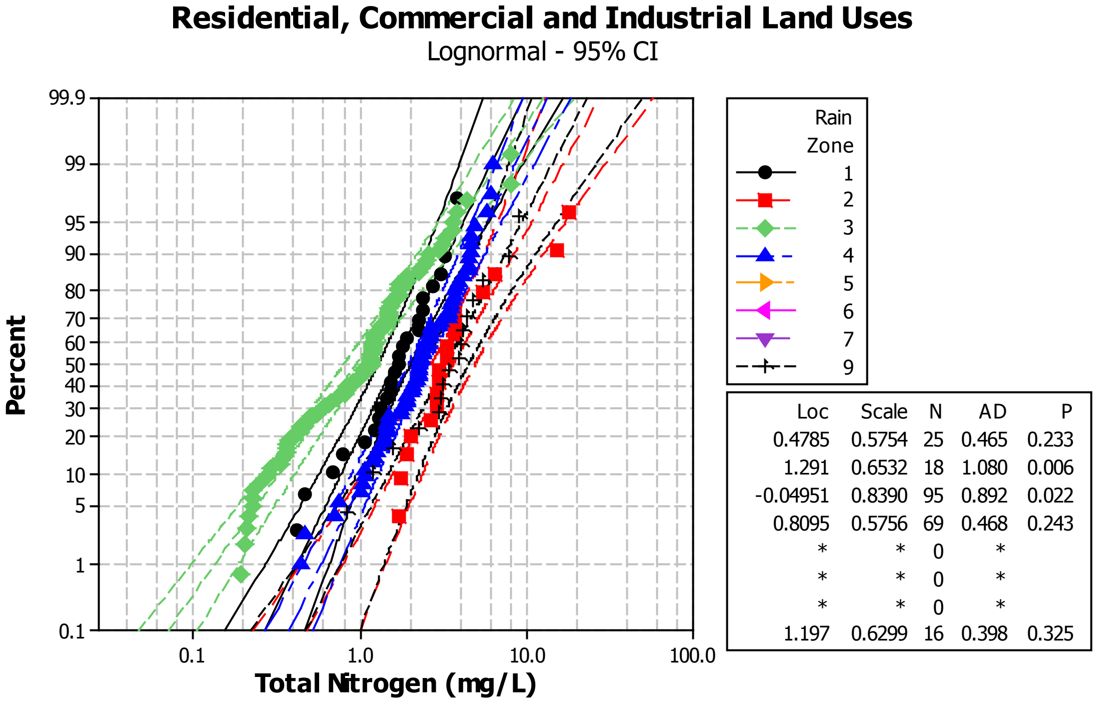


Fig. B51. Total Nitrogen – Residential, Commercial, and Industrial Land Uses in the Contiguous United States



	1	2	3	4	5	6	7	8	9
🟧 All LU	0.54	0.96	0.94	0.55					0.56
🟦 Residential	0.43	0.39	1.0	0.48					0.59
🟨 Commercial	0.52	1.0	1.0	0.54					0.60
🟥 Industrial	0.44	0.55	0.79	0.56					0.55
🟪 Institutional	0.39								
🟩 Open Space	0.47	0.20	0	0.41					
⬛ Freeways			0.64						

Fig. B52. Total Nitrogen - Regional Coefficients of Variation for Single Land Uses in the Contiguous United States



Loc	Scale	N	AD	P
0.4785	0.5754	25	0.465	0.233
1.291	0.6532	18	1.080	0.006
-0.04951	0.8390	95	0.892	0.022
0.8095	0.5756	69	0.468	0.243
*	*	0	*	
*	*	0	*	
*	*	0	*	
1.197	0.6299	16	0.398	0.325

Fig. B53. Total Nitrogen – Residential, Commercial, and Industrial Land Uses in the Contiguous United State (Checks for Normality)

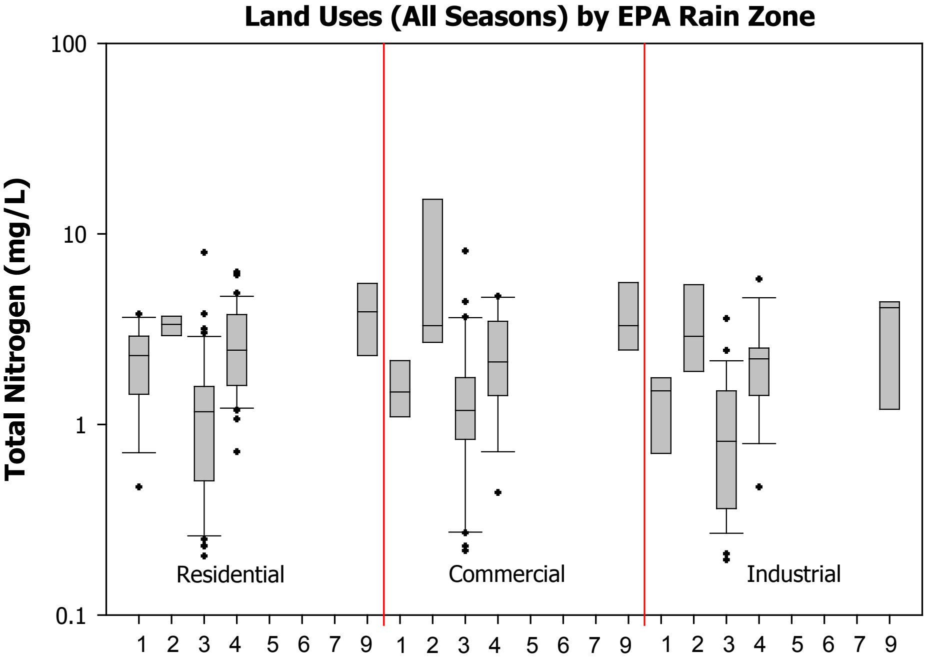


Fig. B54. Total Nitrogen – Land Uses by EPA Rain Zone

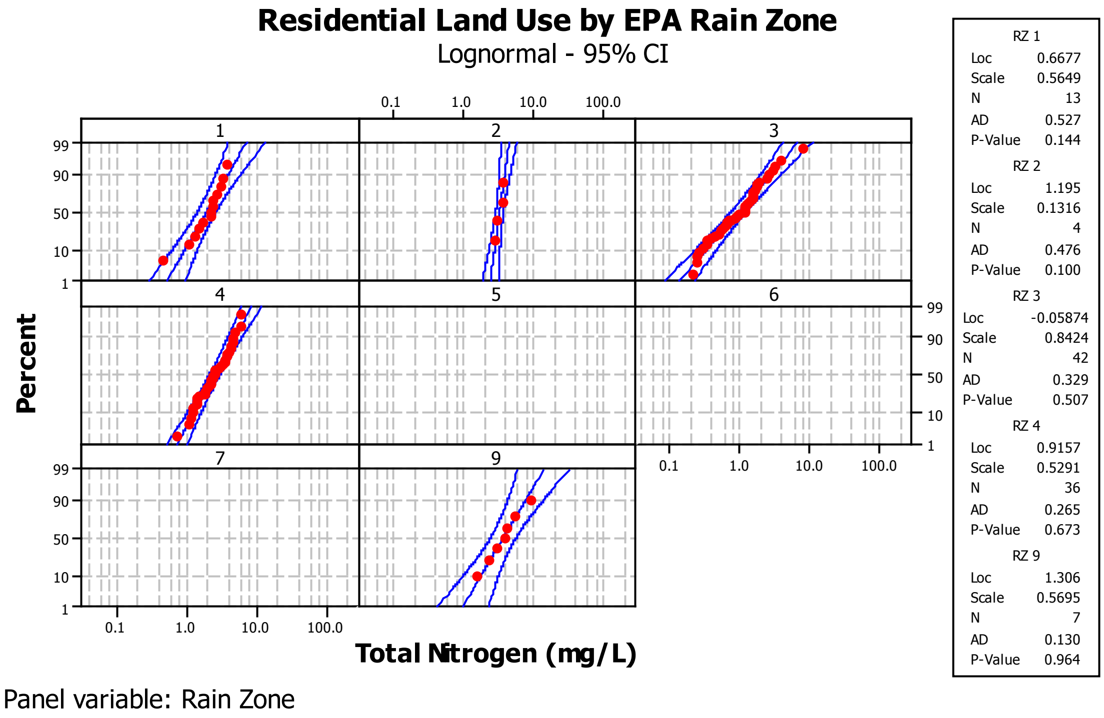


Fig. B55. Total Nitrogen – Residential Land Use by EPA Rain Zone (Checks for Normality)

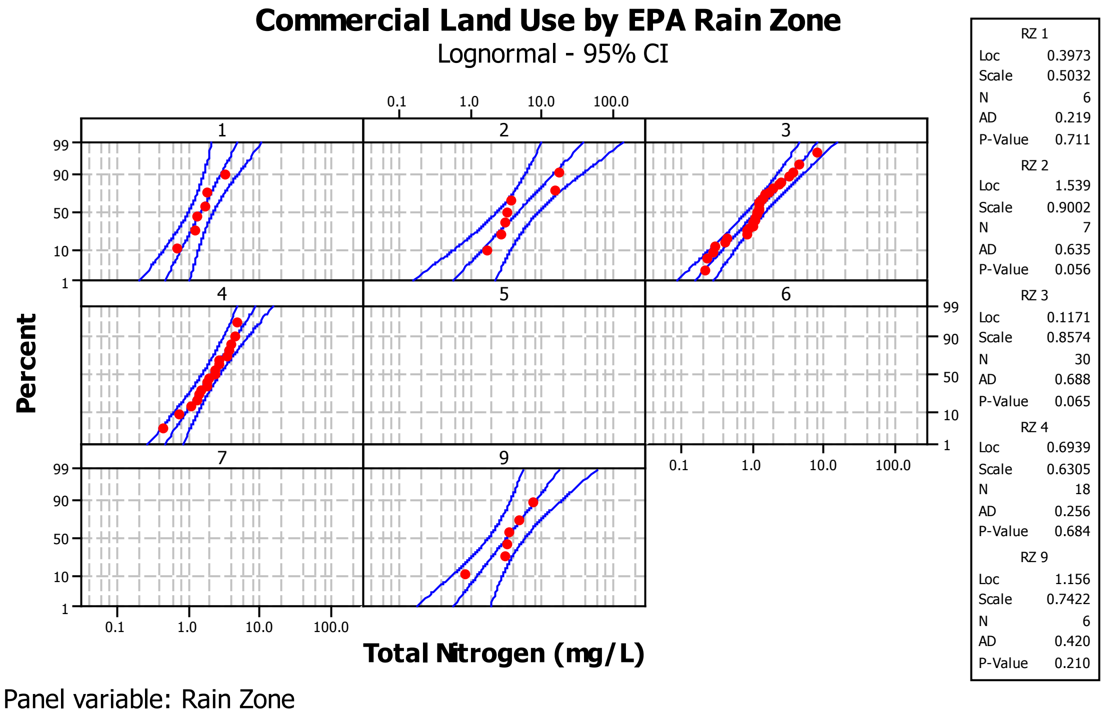


Fig. B56. Total Nitrogen – Commercial Land Use by EPA Rain Zone (Checks for Normality)

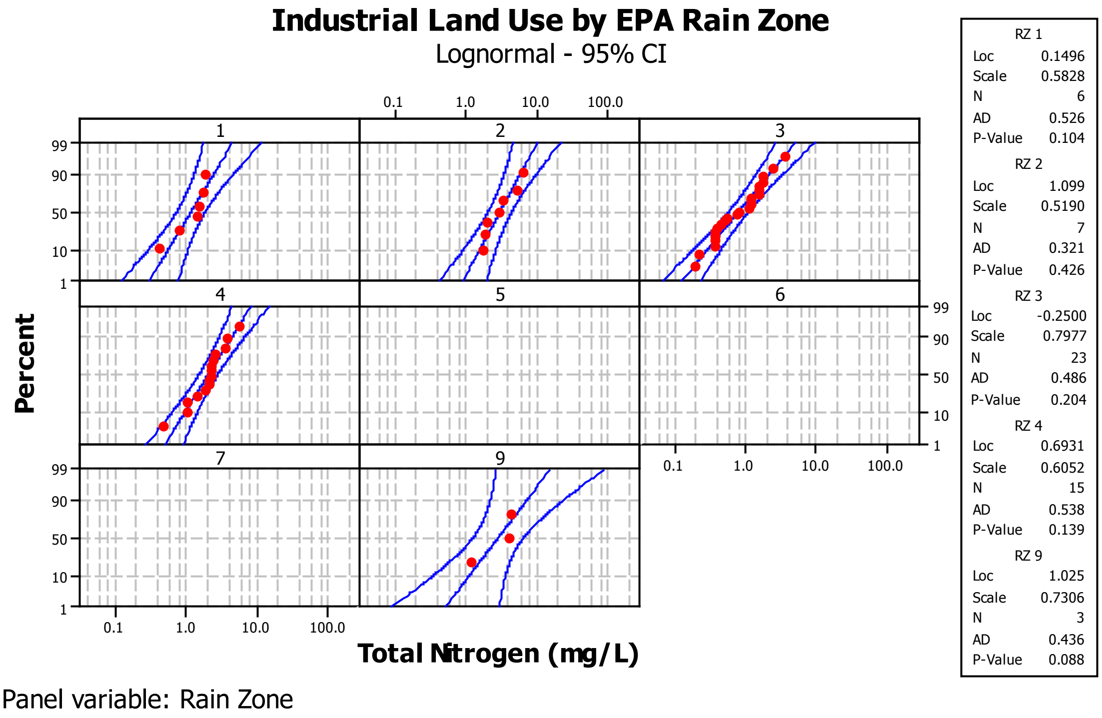


Fig. B57. Total Nitrogen – Industrial Land Use by EPA Rain Zone (Checks for Normality)

Table B41. Total Nitrogen – Univariate 3-way ANOVA Tests of Between-Subjects Effects

Dependent Variable: Log Nitrogen

	Source	Type III Sum of Squares	DF	Mean Square	F	P-value
	Corrected Model*	15	46	0.32	3.5	0.000
	Intercept	8.2	1	8.2	88	0.000
Main Effects	Rain Zone (8 levels)	7.6	4	1.9	20	0.000*
	Land Use (3 levels)	0.15	2	0.08	0.82	0.442
	Season (4 levels)	0.25	3	0.08	0.92	0.433
Two-way Interactions	Rain Zone * Land Use	0.43	8	0.05	0.58	0.793
	Rain Zone * Season	1.6	9	0.18	1.9	0.052*
	Land Use * Season	0.06	6	0.01	0.11	0.995
Three-way Interaction	Rain Zone * Land Use * Season	0.66	14	0.05	0.51	0.926
	Error	16	176	0.09		
	Total	40	223			
	Corrected Total	31	222			

*R Squared = 0.476 (Adjusted R Squared = 0.338)

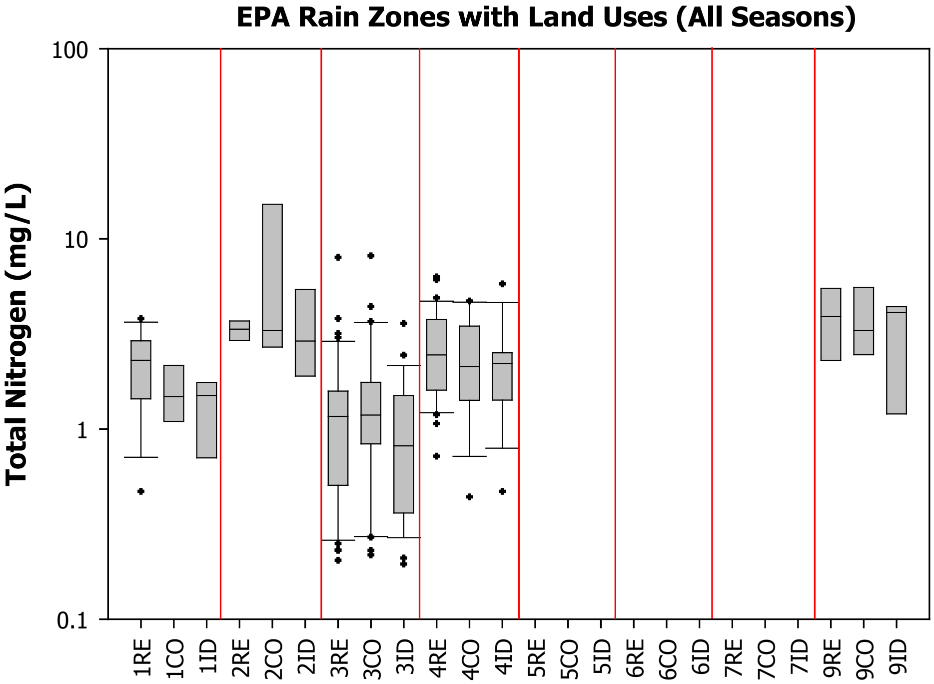


Fig. B58. Total Nitrogen – EPA Rain Zones with Land Uses

Table B42. Total Nitrogen **-** MANOVA Test for Significance of Season within Rain Zone using Unique Sum of Squares

Source of Variation	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
WITHIN CELLS	16	176	0.09		
Season WITHIN Rain Zone (1)	0.19	3	0.06	0.67	0.570
Season WITHIN Rain Zone (2)	3.2	3	1.1	11	0.000*
Season WITHIN Rain Zone (3)	1.6	3	0.52	5.6	0.001*
Season WITHIN Rain Zone (4)	0.27	3	0.09	0.97	0.410
Season WITHIN Rain Zone (9)	2.6	3	0.86	9.3	0.000*

Table B43. Total Nitrogen – Test of Significance: Land Use and Season within Rain Zone

Rain Zone	**Land Use**	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Nitrogen				**Power Analysis**	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
2	RE CO ID	0.330	-	-	-	FA	10	0.440		0.20	70.2
						SP	-	-		0.15	63.5
						SU	6	0.750		0.10	54.3
						WI	2	0.484		***0.05***	***40.0***
										0.01	16.8
						Pooled St. Dev = 0.281, Obtained Effect Size = 0.51					
3	RE CO ID	0.003*	FA	SP	0.518	FA	27	0.025		0.20	98.0
				SU	0.250	SP	25	0.168		0.15	97.0
				WI	0.424	SU	24		-0.17	0.10	95.3
			SP	SU	0.010*	WI	19		-0.15	***0.05***	***91.0***
				WI	0.032*					0.01	76.0
			SU	WI	0.997	Pooled St. Dev = 0.343, Obtained Effect Size = 0.40					
9	RE CO ID	0.060	-	-	-	FA	2	0.425		0.20	80.7
						SP	4	0.275		0.15	75.0
						SU	10	0.637		0.10	66.6
						WI	-	-		***0.05***	***52.1***
										0.01	24.6
						Pooled St. Dev = 0.245, Obtained Effect Size = 0.64					

Table B44. Total Nitrogen – Rain Zone Groups Multiple Comparisons

(I) Group	**(J) Group**	**p-value**	**(I) Group**	**(J) Group**	**p-value**
1-RE,CO,ID	2-RE,CO,ID	0.014	3-(RE,CO,ID) (FA,SP)	3-(RE,CO,ID)(SU,WI)	0.005
	3-(RE,CO,ID)(FA,SP)	0.777		4-RE,CO,ID	0.001
	3-(RE,CO,ID)(SU,WI)	0.000		9-RE,CO,ID	0.000
	4-RE,CO,ID	0.514	3-(RE,CO,ID) (SU,WI)	4-RE,CO,ID	0.000
	9-RE,CO,ID	0.063		9-RE,CO,ID	0.000
2-RE,CO,ID	3-(RE,CO,ID)(FA,SP)	0.000	4-RE,CO,ID	9-RE,CO,ID	0.536
	3-(RE,CO,ID)(SU,WI)	0.000			
	4-RE,CO,ID	0.219			
	9-RE,CO,ID	0.999			

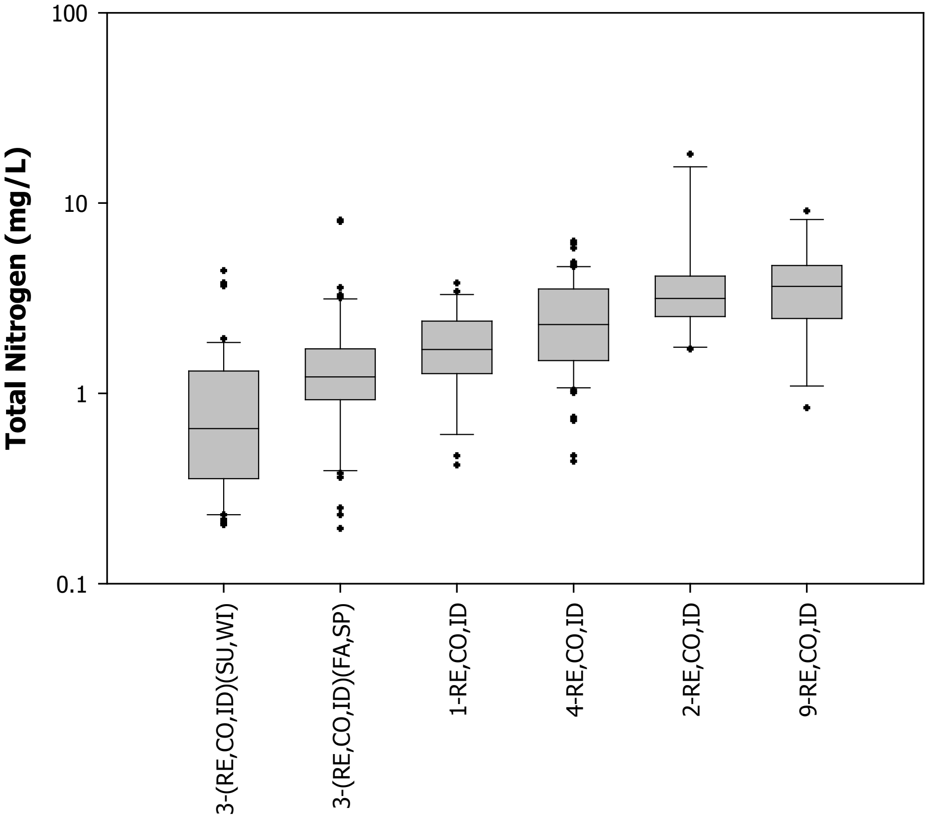
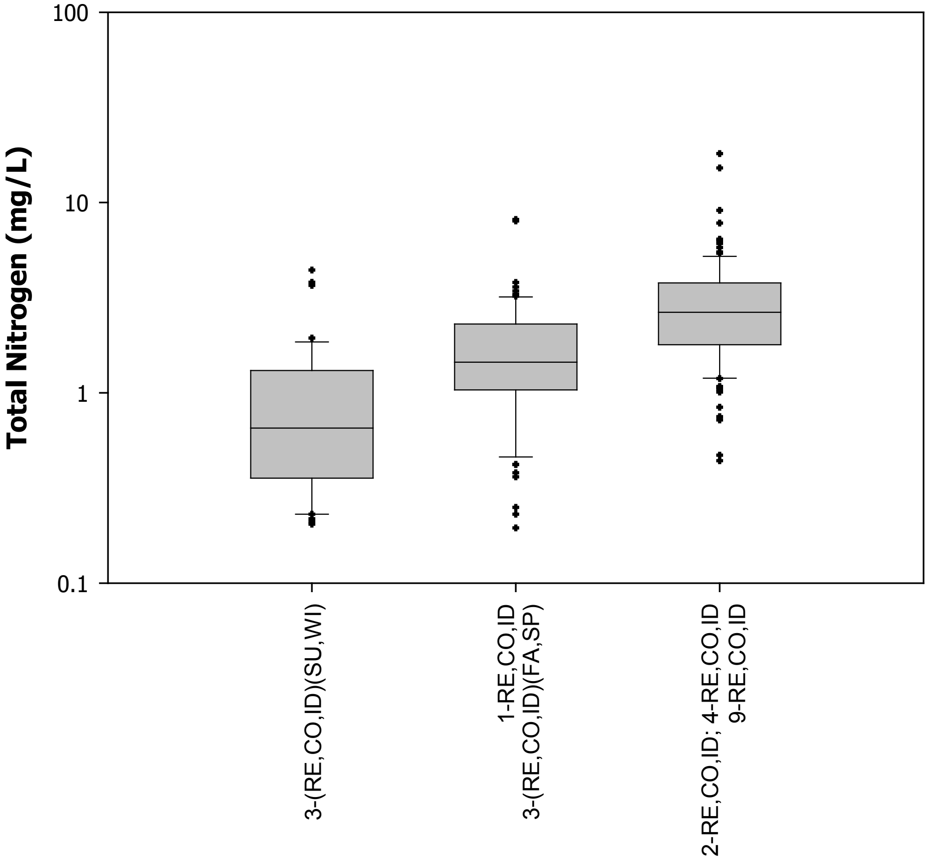


Fig. B59. Total Nitrogen – Rain Zone Groups

Table B45. Total Nitrogen – Homogeneous Groups

Groups	**N**	**Homogeneous Groups** Dependent Variable: Log Nitrogen		
		A	**B**	**C**
3-(RE,CO,ID)(SU,WI)	43	-0.161		
3-(RE,CO,ID)(FA,SP)	52		0.094	
1-RE,CO,ID	25		0.208	
4-RE,CO,ID	69			0.351
9-(RE,CO,ID)(FA,SP,SU)	16			0.519
2-RE,CO,ID	18			0.561



Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	2.2 (0.27)	3.4 (0.15)	1.7 (1.3)	2.7 (0.48)	ND	ND	ND	2.7 (0.21)
	SP	2.4 (0.57)	ND	1.6 (0.47)	3.3 (0.32)	ND	ND	ND	ND
	SU	2.1 (0.49)	3.3 (0.17)	1.2 (0.91)	3.2 (0.55)	ND	ND	ND	5.7 (0.42)
	WI	ND	ND	0.81 (0.69)	2.4 (0.65)	ND	ND	ND	ND
Commercial	FA	1.9 (0.69)	3.2 (0.13)	1.3 (0.49)	2.5 (0.26)	ND	ND	ND	ND
	SP	ND	ND	2.4 (1.0)	3.3 (0.47)	ND	ND	ND	4.3 (1.1)
	SU	1.6 (0.23)	11 (0.75)	1.6 (1.3)	1.9 (0.67)	ND	ND	ND	3.6 (0.23)
	WI	ND	ND	1.1 (0.55)	1.7 (0.66)	ND	ND	ND	ND
Industrial	FA	1.8 (0.07)	3.3 (0.64)	1.6 (0.83)	1.7 (0.34)	ND	ND	ND	ND
	SP	ND	ND	1.3 (0.34)	2.4 (0.06)	ND	ND	ND	ND
	SU	0.92 (0.62)	ND	0.59 (0.71)	3.9 (0.66)	ND	ND	ND	4.5 (0.05)
	WI	ND	3.6 (0.74)	0.73 (0.55)	2.2 (0.62)	ND	ND	ND	ND

Fig. B60. Total Nitrogen – Rain Zone Homogeneous Groups: Mean (CV)

Table B46. Basic Statistics for Total Nitrogen –
Rain Zone Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	3-(RE,CO,ID)(SU,WI)	43	0.98	0.96	0.98	0.20	0.65	4.4
B	1-RE,CO,ID; 3-(RE,CO,ID)(FA,SP)	77	1.7	1.4	0.79	0.20	1.5	8.1
C	2-RE,CO,ID 4-RE,CO,ID; 9-(RE,CO,ID)(FA,SP,SU)	103	3.2	2.5	0.78	0.44	2.7	18

B.7. Total Kjeldhal Nitrogen

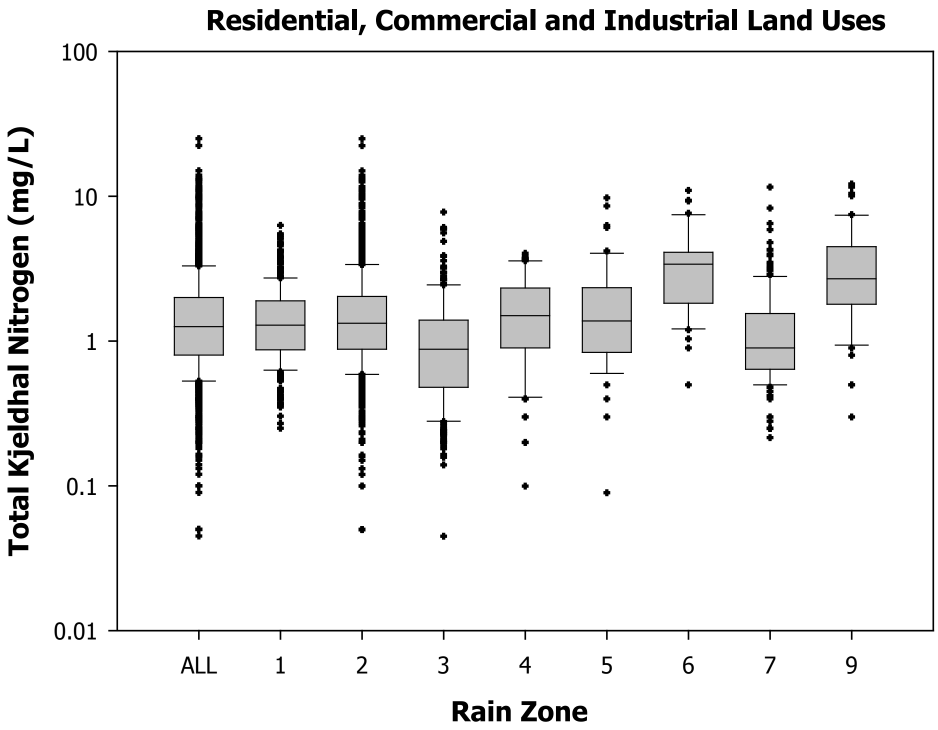
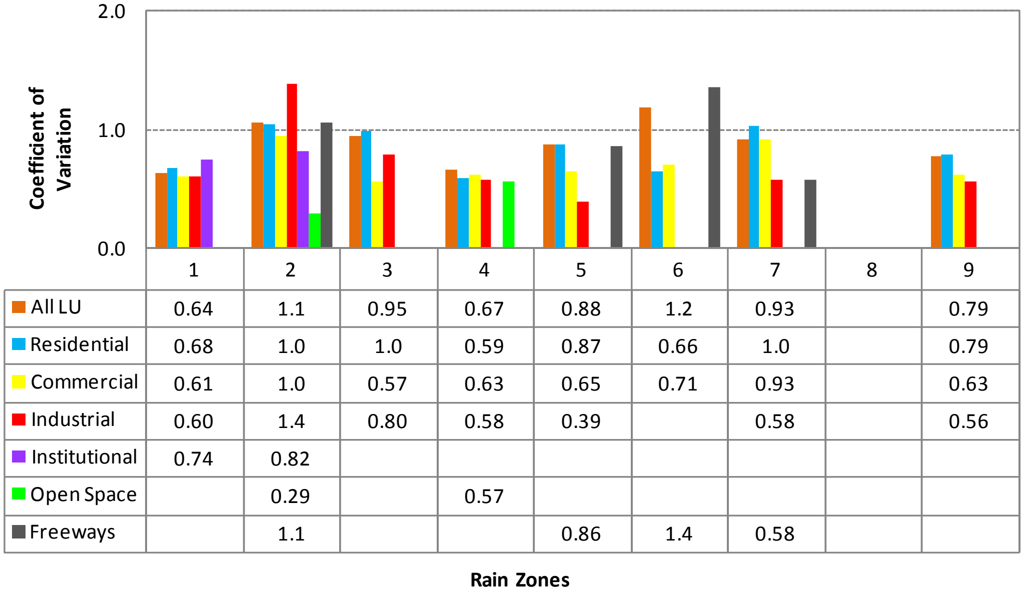
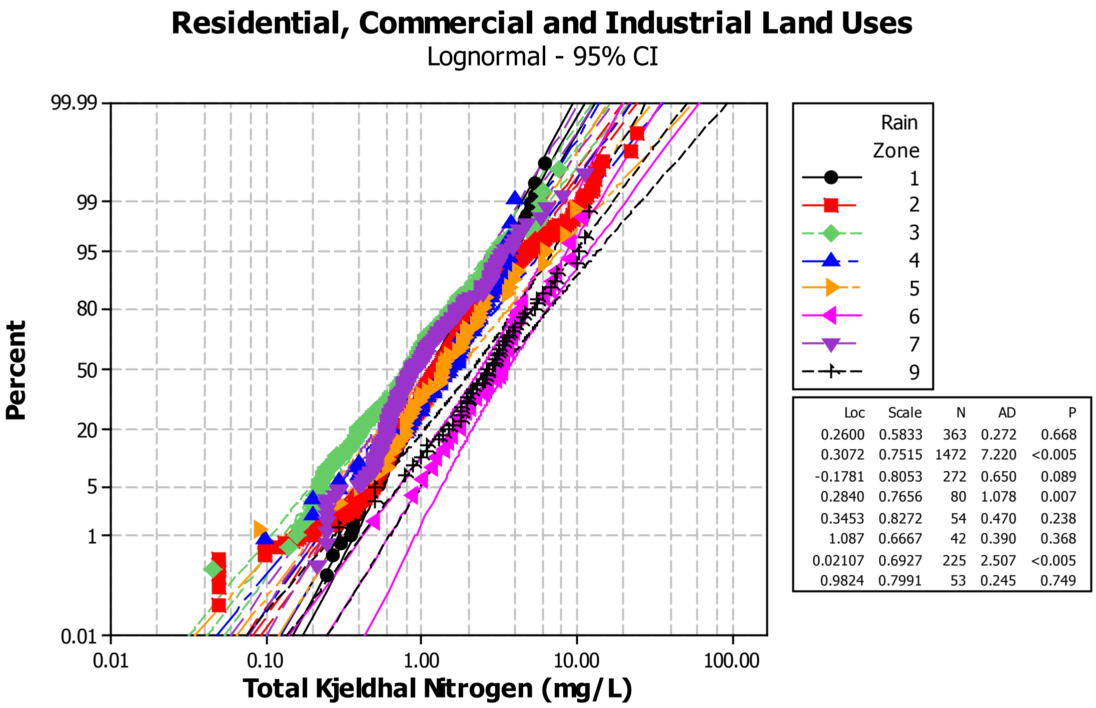


Fig. B61. Total Kjeldhal Nitrogen – Residential, Commercial, and Industrial Land Uses in the Contiguous United States



	1	2	3	4	5	6	7	8	9
🟧 All LU	0.64	1.1	0.95	0.67	0.88	1.2	0.93		0.79
🟦 Residential	0.68	1.0	1.0	0.59	0.87	0.66	1.0		0.79
🟨 Commercial	0.61	1.0	0.57	0.63	0.65	0.71	0.93		0.63
🟥 Industrial	0.60	1.4	0.80	0.58	0.39		0.58		0.56
🟪 Institutional	0.74	0.82							
🟩 Open Space		0.29		0.57					
⬛ Freeways		1.1			0.86	1.4	0.58		

Fig. B62. Total Kjeldhal Nitrogen - Regional Coefficients of Variation for Single Land Uses in the Contiguous United States



Loc	Scale	N	AD	P
0.2600	0.5833	363	0.272	0.668
0.3072	0.7515	1472	7.220	<0.005
-0.1781	0.8053	272	0.650	0.089
0.2840	0.7656	80	1.078	0.007
0.3453	0.8272	54	0.470	0.238
1.087	0.6667	42	0.390	0.368
0.02107	0.6927	225	2.507	<0.005
0.9824	0.7991	53	0.245	0.749

Fig. B63. Total Kjeldhal Nitrogen – Residential, Commercial, and Industrial Land Uses in the Contiguous United State (Checks for Normality)

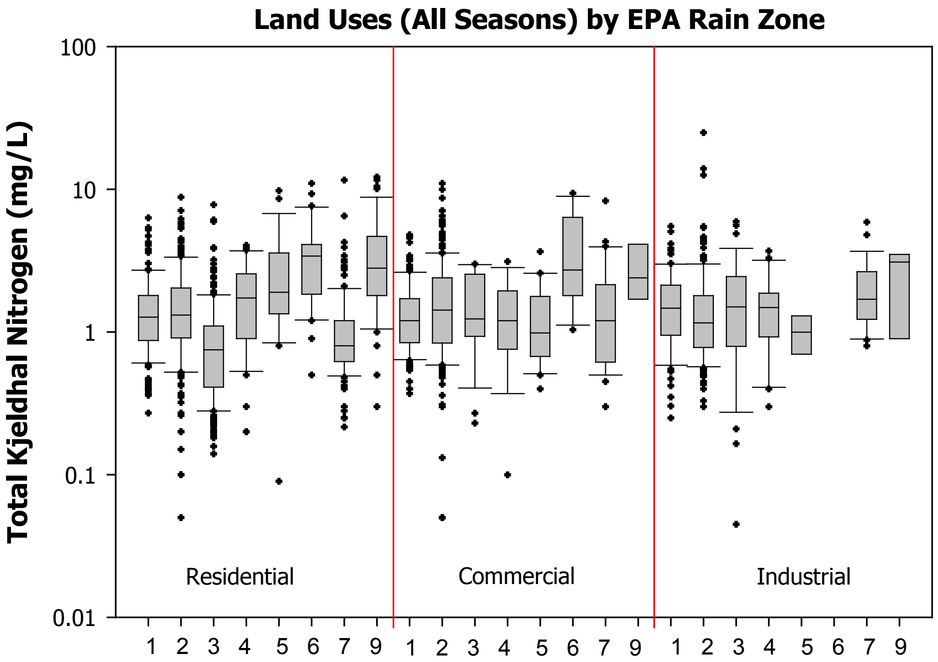


Fig. B64. Total Kjeldhal Nitrogen – Land Uses by EPA Rain Zone

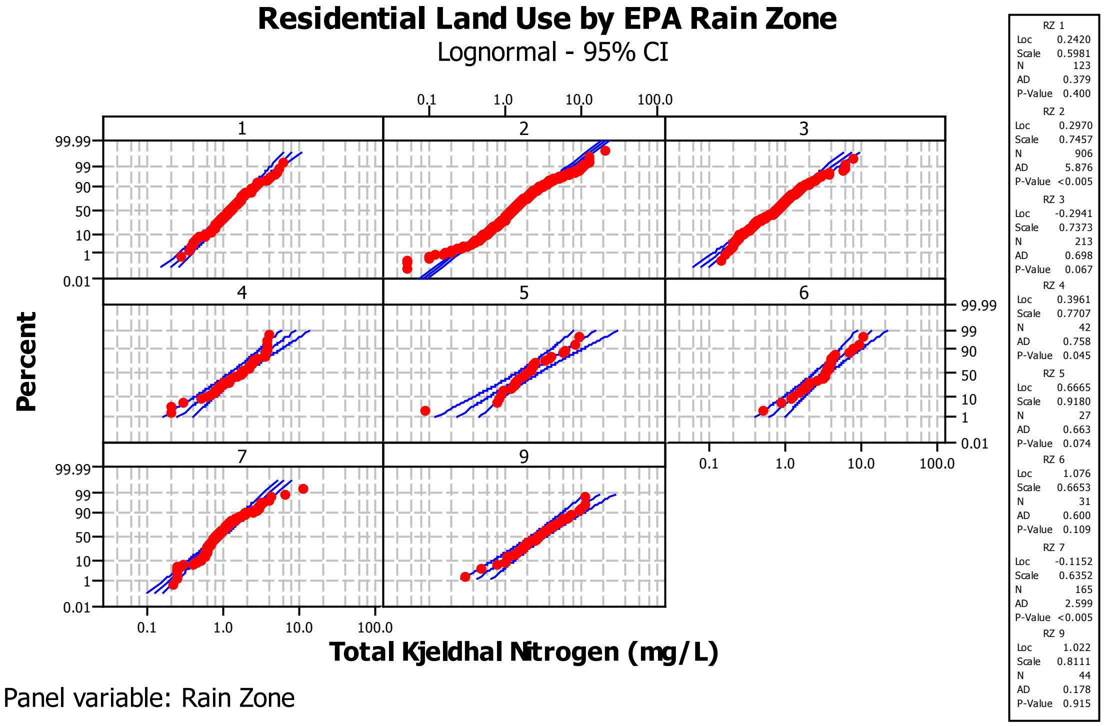


Fig. B65. Total Kjeldhal Nitrogen – Residential Land Use by EPA Rain Zone
(Checks for Normality)

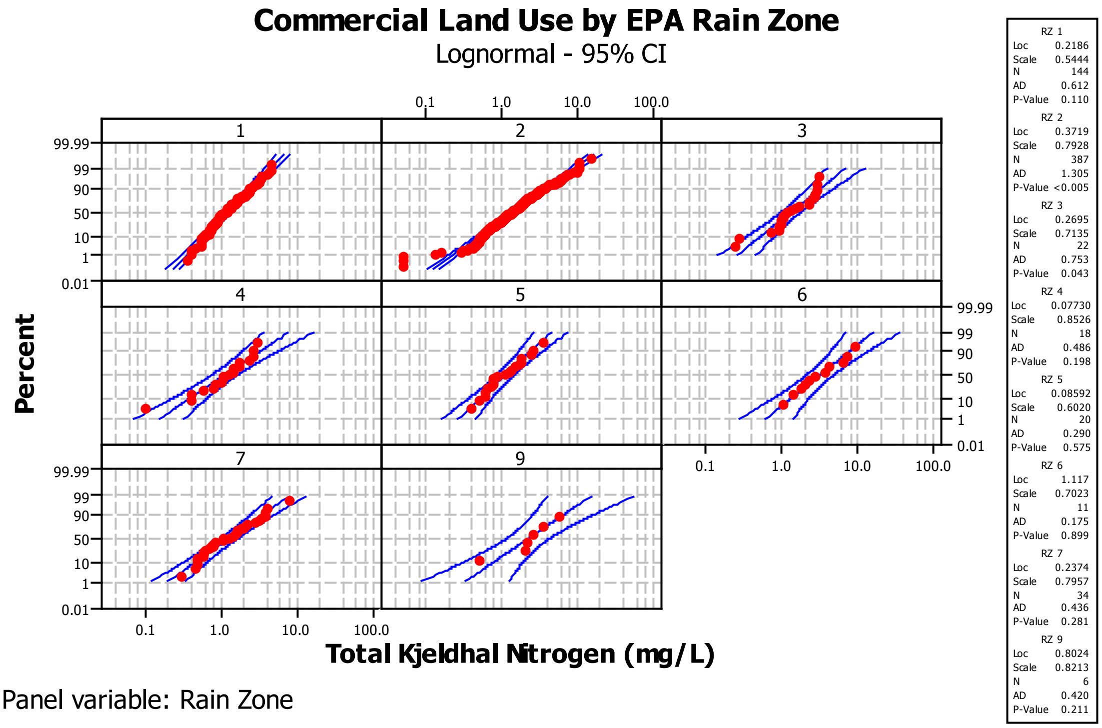


Fig. B66. Total Kjeldhal Nitrogen – Commercial Land Use by EPA Rain Zone
(Checks for Normality)

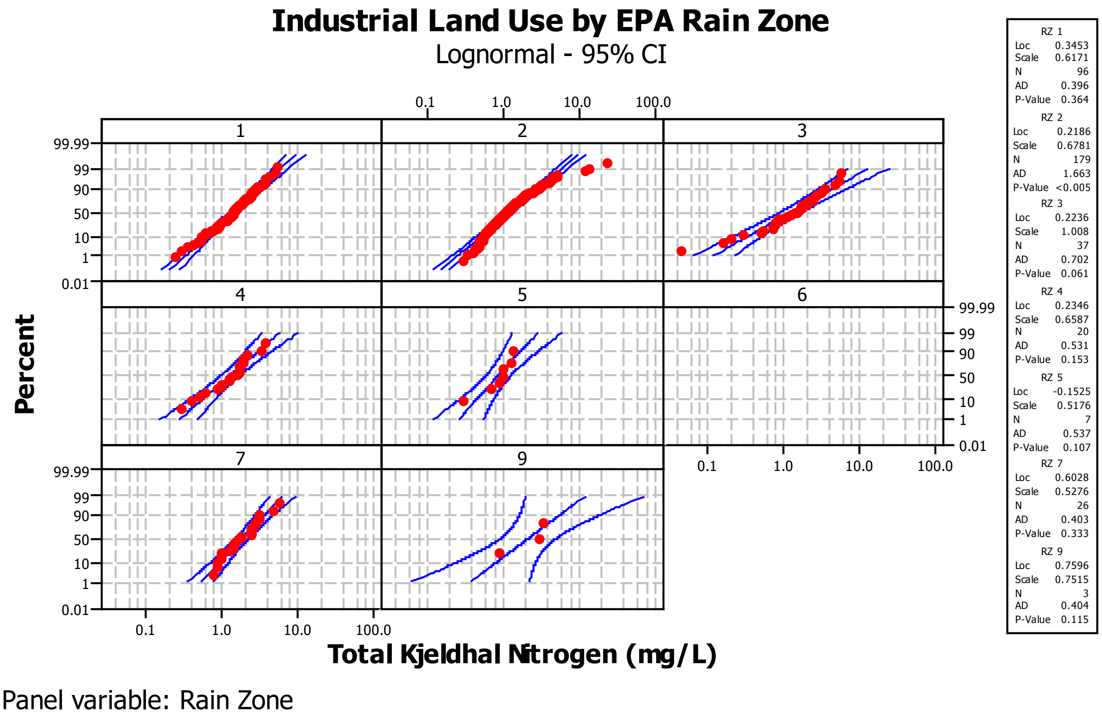


Fig. B67. Total Kjeldhal Nitrogen – Industrial Land Use by EPA Rain Zone
(Checks for Normality)

Table B47. Total Kjeldhal Nitrogen – Univariate 3-way ANOVA Tests of Between-Subjects Effects

Dependent Variable: Log Total Kjeldhal Nitrogen

	Source	**Type III Sum of Squares**	**DF**	**Mean Square**	**F**	**P-value**
	Corrected Model*	45	84	0.54	5.6	0.000
	Intercept	9.3	1	9.3	97	0.000
Main Effects	Rain Zone (8 levels)	5.0	7	0.72	7.5	0.000*
	Land Use (3 levels)	0.02	2	0.01	0.11	0.899
	Season (4 levels)	0.77	3	0.26	2.7	0.046*
Two-way Interactions	Rain Zone * Land Use	4.4	13	0.34	3.6	0.000*
	Rain Zone * Season	5.8	20	0.29	3.0	0.000*
	Land Use * Season	0.42	6	0.07	0.74	0.620
Three-way Interaction	Rain Zone * Land Use * Season	4.5	33	0.14	1.4	0.061
	Error	237	2476	0.10		
	Total	313	2561			
	Corrected Total	282	2560			

* R Squared = 0.159 (Adjusted R Squared = 0.131)

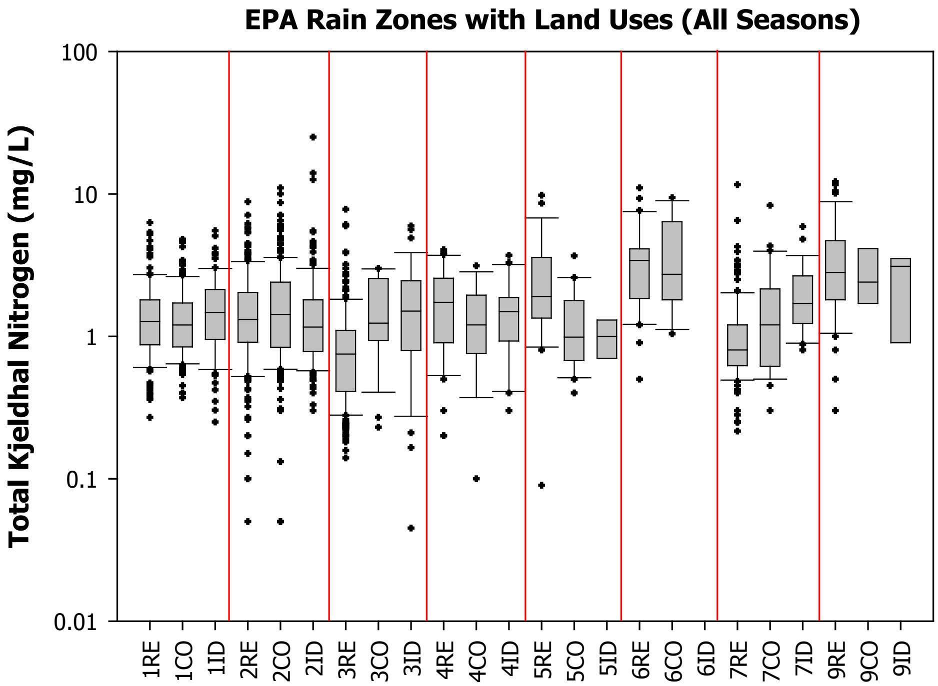


Fig. B68. Total Kjeldhal Nitrogen – EPA Rain Zones with Land Uses

Table B48. Total Kjeldhal Nitrogen - MANOVA Test for Significance of Land Use within Rain Zone using Unique Sum of Squares

Source of Variation	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
WITHIN CELLS	237	2476	0.10		
Land Use WITHIN Rain Zone(1)	0.19	2	0.10	1.0	0.365
Land Use WITHIN Rain Zone (2)	0.76	2	0.38	4.0	0.019*
Land Use WITHIN Rain Zone (3)	11	2	5.5	57	0.000*
Land Use WITHIN Rain Zone (4)	0.24	2	0.12	1.2	0.289
Land Use WITHIN Rain Zone (5)	1.1	2	0.56	5.8	0.003*
Land Use WITHIN Rain Zone (6)	5.2	2	2.6	27	0.000*
Land Use WITHIN Rain Zone (7)	4.9	2	2.4	26	0.000*
Land Use WITHIN Rain Zone (9)	3.9	2	2.0	20	0.000*

Table B49. Total Kjeldhal Nitrogen - Test of Significance: Land Use within Rain Zone

Rain Zone	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log TKN				**Power Analysis**	
		(I) LU	**(J) LU**	**p-value**	**LU**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
2	0.063	-	-	-	RE	906	0.129		0.20	79.7
					CO	387	0.162		0.15	74.7
					ID	179	0.095		0.10	67.5
					Pooled St. Dev = 0.326				***0.05***	***55.4***
					Obtained Effect Size = 0.06				0.01	31.7
3	0.000*	RE	CO	0.006*	RE	213	-0.128		0.20	99.9
			ID	0.001*	CO	22		0.117	0.15	99.8
		CO	ID	0.976	ID	37		0.097	0.10	99.6
					Pooled St. Dev = 0.338				***0.05***	***99.1***
					Obtained Effect Size = 0.28				0.01	95.9
5	0.011*	RE	CO	0.047*	RE	27	0.289		0.20	93.4
			ID	0.052*	CO	20		0.037	0.15	90.9
		CO	ID	0.782	ID	7		-0.066	0.10	86.8
					Pooled St. Dev = 0.335				***0.05***	***78.3***
					Obtained Effect Size = 0.43				0.01	55.2
6	0.864	-	-	-	RE	31	0.468		0.20	20.6
					CO	11	0.485		0.15	15.5
					ID	-	-		0.10	10.4
					Pooled St. Dev = 0.293				***0.05***	***5.3***
					Obtained Effect Size = 0.03				0.01	1.1

Table B49. - *Continued*

Rain Zone	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log TKN				**Power Analysis**	
		(I) LU	**(J) LU**	**p-value**	**LU**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
		RE	CO	0.017*	RE	165	-0.050		0.20	99.9
7	0.000*		ID	0.000*	CO	34	0.103		0.15	99.9
		CO	ID	0.100	ID	26		0.262	0.10	99.9
					Pooled St. Dev = 0.283				***0.05***	***99.9***
					Obtained Effect Size = 0.45				0.01	99.9
		RE	CO		RE	44	0.444		0.20	29.5
9	0.731		ID		CO	6	0.348		0.15	23.6
		CO	ID		ID	3	0.330		0.10	17.1
					Pooled St. Dev = 0.352				***0.05***	***9.7***
					Obtained Effect Size = 0.11				0.01	2.6

Table B50. Total Kjeldhal Nitrogen **-** MANOVA Test for Significance of Season within Rain Zone using Unique Sum of Squares

Source of Variation	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
WITHIN CELLS	237	2476	0.10		
Season WITHIN Rain Zone (1)	1.1	3	0.37	3.8	0.009*
Season WITHIN Rain Zone (2)	2.6	3	0.85	8.9	0.000*
Season WITHIN Rain Zone (3)	1.4	3	0.46	4.8	0.002*
Season WITHIN Rain Zone (4)	0.92	3	0.31	3.2	0.022*
Season WITHIN Rain Zone (5)	1.3	3	0.42	4.4	0.004*
Season WITHIN Rain Zone (6)	0.40	3	0.13	1.4	0.243
Season WITHIN Rain Zone (7)	4.1	3	1.4	14	0.000*
Season WITHIN Rain Zone (9)	5.8	3	1.9	20	0.000*

Table B51. Total Kjeldhal Nitrogen – Test of Significance: Land Use and Season within Rain Zone

Rain Zone	**Land Use**	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log TKN				**Power Analysis**	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
1	RE CO ID	0.000*	FA	SP	0.302	FA	143	0.047		0.20	99.5
				SU	0.001*	SP	64		0.118	0.15	99.2
				WI	0.047*	SU	89		0.187	0.10	98.7
			SP	SU	0.413	WI	67		0.151	***0.05***	***97.1***
				WI	0.904					0.01	90.2
			SU	WI	0.846	Pooled St. Dev = 0.248, Obtained Effect Size = 0.23					
2	RE CO ID	0.000*	FA	SP	0.660	FA	381	0.123		0.20	99.9
				SU	0.048*	WI	362	0.072		0.15	99.8
				WI	0.205	SP	415		0.152	0.10	99.7
			SP	SU	0.423	SU	314		0.192	***0.05***	***99.3***
				WI	0.008*					0.01	96.9
			SU	WI	0.000*	Pooled St. Dev = 0.324, Obtained Effect Size = 0.13					
3	RE	0.136	-	-	-	FA	70	-0.186		0.20	74.9
						SP	48	-0.052		0.15	69.2
						SU	62	-0.141		0.10	61.3
						WI	33	-0.089		***0.05***	***48.5***
										0.01	25.5
						Pooled St. Dev = 0.318, Obtained Effect Size = 0.16					
	CO ID	0.030*	FA	SP	0.840	FA	18	0.252		0.20	89.9
				SU	0.139	SP	25	0.147		0.15	86.6
				WI	0.129	SU	5	-0.198		0.10	81.1
			SP	SU	0.320	WI	11	-0.094		***0.05***	***70.8***
				WI	0.370					0.01	45.9
			SU	WI	0.965	Pooled St. Dev = 0.372, Obtained Effect Size = 0.40					
4	RE CO ID	0.033*	FA	SP	0.190	FA	15	0.065		0.20	89.1
				SU	0.971	SP	19	0.309		0.15	85.6
				WI	0.991	SU	18	0.119		0.10	80.0
			SP	SU	0.361	WI	28		0.032	***0.05***	***69.6***
				WI	0.044*					0.01	45.0
			SU	WI	0.846	Pooled St. Dev = 0.320, Obtained Effect Size = 0.34					

Table B51. – *Continued*

Rain Zone	**Land Use**	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log TKN				**Power Analysis**	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
5	RE CO ID	0.023*	FA	SP	0.959	FA	8	0.270		0.20	33.9
				SU	0.731	SP	20	0.228		0.15	27.5
				WI	0.045*	SU	20	0.142		0.10	20.4
			SP	SU	0.880	WI	6		-0.24	***0.05***	***12.0***
				WI	0.039*					0.01	3.4
			SU	WI	0.127	Pooled St. Dev =0.337, Obtained Effect Size = 0.15					
7	RE CO	0.000*	FA	SP	0.015*	FA	48	0.143		0.20	99.9
				SU	0.629	SU	25	0.054		0.15	99.9
				WI	0.000*	SP	53		-0.04	0.10	99.9
			SP	SU	0.608	WI	73		-0.15	***0.05***	***99.9***
				WI	0.132					0.01	99.7
			SU	WI	0.015*	Pooled St. Dev =0.272, Obtained Effect Size = 0.43					
	ID	0.088	-	-	-	FA	7	0.446		0.20	80.9
						SP	7	0.194		0.15	75.5
						SU	3	0.240		0.10	67.5
						WI	9	0.179		***0.05***	***53.8***
										0.01	27.3
						Pooled St. Dev = 0.211, Obtained Effect Size = 0.54					
9	RE CO ID	0.138	-	-	-	FA	16	0.444		0.20	68.6
						SP	8	0.204		0.15	62.3
						SU	29	0.478		0.10	53.7
						WI	-	-		***0.05***	***40.6***
										0.01	18.9
						Pooled St. Dev = 0.340, Obtained Effect Size = 0.28					

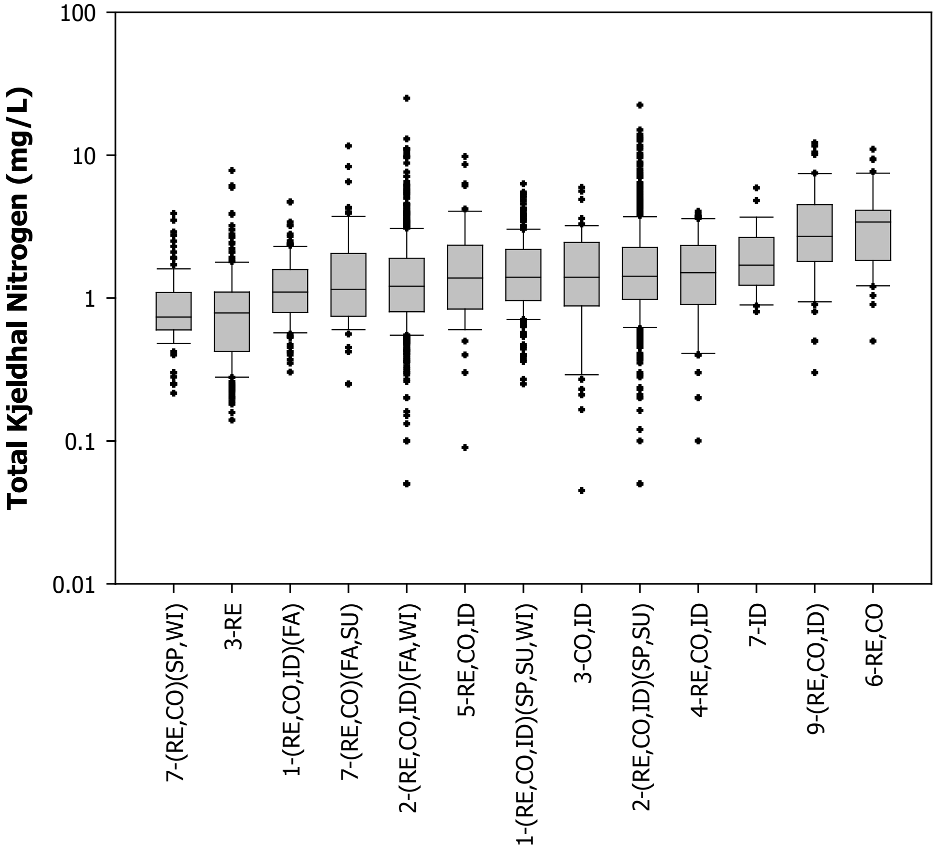


Fig. B69. Total Kjeldhal Nitrogen – Rain Zone Groups

Table B52. Total Kjeldhal Nitrogen – Rain Zone Groups Multiple Comparisons

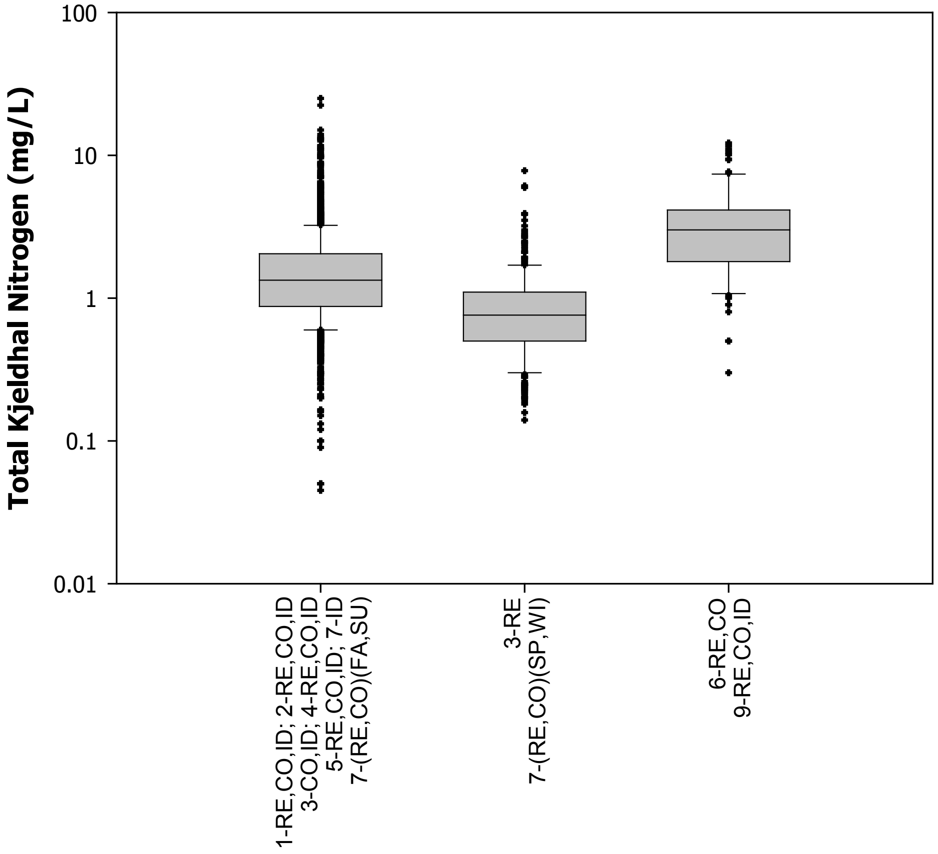
(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
1-(RE,CO,ID)(FA)	1-(RE,CO,ID)(SP,SU,WI)	0.641	2-(RE,CO,ID)(FA,WI)	2-(RE,CO,ID)(SP,SU)	0.083	3-CO,ID	4-RE,CO,ID	1.000
	2-(RE,CO,ID)(FA,WI)	0.997		3-RE	0.000		5-RE,CO,ID	1.000
	2-(RE,CO,ID)(SP,SU)	0.149		3-CO,ID	1.000		6-RE,CO	0.001
	3-RE	0.006		4-RE,CO,ID	1.000		7-(RE,CO)(FA,SU)	1.000
	3-CO,ID	1.000		5-RE,CO,ID	1.000		7-(RE,CO)(SP,WI)	0.130
	4-RE,CO,ID	0.997		6-RE,CO	0.000		7-ID	0.969
	5-RE,CO,ID	0.985		7-(RE,CO)(FA,SU)	1.000		9-(RE,CO,ID)	0.003
	6-RE,CO	0.000		7-(RE,CO)(SP,WI)	0.000	4-RE,CO,ID	5-RE,CO,ID	1.000
	7-(RE,CO)(FA,SU)	1.000		7-ID	0.861		6-RE,CO	0.001
	7-(RE,CO)(SP,WI)	0.186		9-(RE,CO,ID)	0.000		7-(RE,CO)(FA,SU)	1.000
	7-ID	0.613	2-(RE,CO,ID)(SP,SU)	3-RE	0.000		7-(RE,CO)(SP,WI)	0.012
	9-(RE,CO,ID)	0.000		3-CO,ID	0.999		7-ID	0.986
1-(RE,CO,ID)(SP,SU,WI)	2-(RE,CO,ID)(FA,WI)	0.923		4-RE,CO,ID	1.000		9-(RE,CO,ID)	0.003
	2-(RE,CO,ID)(SP,SU)	1.000		5-RE,CO,ID	1.000	5-RE,CO,ID	6-RE,CO	0.015
	3-RE	0.000		6-RE,CO	0.000		7-(RE,CO)(FA,SU)	1.000
	3-CO,ID	1.000		7-(RE,CO)(FA,SU)	0.999		7-(RE,CO)(SP,WI)	0.017
	4-RE,CO,ID	1.000		7-(RE,CO)(SP,WI)	0.000		7-ID	0.999
	5-RE,CO,ID	1.000		7-ID	0.999		9-(RE,CO,ID)	0.052
	6-RE,CO	0.000		9-(RE,CO,ID)	0.001	6-RE,CO	7-(RE,CO)(FA,SU)	0.000
	7-(RE,CO)(FA,SU)	1.000	3-RE	3-CO,ID	0.014		7-(RE,CO)(SP,WI)	0.000
	7-(RE,CO)(SP,WI)	0.000		4-RE,CO,ID	0.000		7-ID	0.845
	7-ID	0.997		5-RE,CO,ID	0.001		9-(RE,CO,ID)	1.000
	9-(RE,CO,ID)	0.001		6-RE,CO	0.000	7-(RE,CO)(FA,SU)	7-(RE,CO)(SP,WI)	0.041
1-(RE,CO,ID)(FA)	1-(RE,CO,ID)(SP,SU,WI)	0.641		7-(RE,CO)(FA,SU)	0.002		7-ID	0.974
	2-(RE,CO,ID)(FA,WI)	0.997		7-(RE,CO)(SP,WI)	1.000		9-(RE,CO,ID)	0.002
	2-(RE,CO,ID)(SP,SU)	0.149		7-ID	0.000	7-(RE,CO)(SP,WI)	7-ID	0.004
	3-RE	0.006		9-(RE,CO,ID)	0.000		9-(RE,CO,ID)	0.000
	3-CO,ID	1.000				7-ID	9-(RE,CO,ID)	0.964
	4-RE,CO,ID	0.997						

Table B53. Total Kjeldhal Nitrogen – Homogeneous Groups

Groups	N	Homogeneous Groups Dependent Variable: Log TKN		
		A	B	C
1-(RE,CO,ID)(FA)	143	0.051		
1-(RE,CO,ID)(SP,SU,WI)	220	0.156		
2-(RE,CO,ID)(FA,WI)	743	0.098		
2-(RE,CO,ID)(SP,SU)	729	0.169		
3-CO,ID	59	0.104		
4-RE,CO,ID	80	0.124		
5-RE,CO,ID	54	0.150		
7-(RE,CO)(FA,SU)	73	0.112		
7-ID	26	0.262		
3-RE	213		-0.127	
7-(RE,CO)(SP,WI)	126		-0.103	
6-RE,CO	42			0.471
9-RE,CO,ID	53			0.427

Table B54. Basic Statistics for Total Kjeldhal Nitrogen –
Rain Zone Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	1-RE,CO,ID 2-RE,CO,ID 3-CO,ID; 4-RE,CO,ID 5-RE,CO,ID; 7-ID 7-(RE,CO)(FA,SU)	2127	1.8	1.8	0.99	0.05	1.3	25
B	3-RE 7-(RE,CO)(SP,WI)	339	0.97	0.87	0.90	0.14	0.76	7.8
C	6-RE,CO; 9-RE,CO,ID	95	3.6	2.6	0.73	0.30	3.0	12



Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	1.4 (0.54)	1.9 (0.90)	0.96 (1.3)	1.9 (0.70)	3.9 (0.90)	4.5 (0.69)	1.8 (1.1)	3.4 (0.71)
	SP	1.4 (0.76)	1.9 (1.1)	1.2 (0.92)	2.5 (0.40)	3.1 (0.88)	3.5 (0.66)	0.97 (0.59)	2.3 (0.75)
	SU	2.0 (0.75)	2.1 (1.1)	0.94 (0.76)	1.7 (0.54)	2.3 (0.89)	3.6 (0.73)	1.3 (0.68)	4.3 (0.80)
	WI	1.4 (0.44)	1.4 (0.88)	0.92 (0.47)	1.6 (0.78)	ND	2.8 (0.41)	0.74 (0.43)	ND
Commercial	FA	1.3 (0.66)	1.9 (0.90)	1.8 (0.46)	1.0 (0.45)	1.9 (0.53)	2.3 (0.57)	2.7 (0.91)	ND
	SP	1.6 (0.62)	1.9 (0.87)	1.7 (0.49)	2.2 (0.45)	1.5 (0.56)	ND	1.8 (0.61)	3.1 (1.2)
	SU	1.7 (0.60)	2.4 (0.98)	0.25 (0.11)	1.2 (0.80)	1.3 (0.39)	5.2 (0.72)	1.9 (0.91)	2.6 (0.26)
	WI	1.3 (0.43)	1.8 (1.0)	ND	1.1 (0.65)	0.58 (0.20)	5.0 (0.37)	1.1 (0.76)	ND
Industrial	FA	1.1 (0.48)	1.5 (0.70)	2.3 (0.69)	1.0 (0.56)	ND	ND	3.2 (0.53)	ND
	SP	1.9 (0.47)	1.9 (1.4)	1.7 (0.74)	1.7 (0.16)	0.87 (0.18)	ND	1.8 (0.51)	ND
	SU	1.8 (0.63)	1.6 (0.71)	1.9 (0.80)	1.8 (0.59)	1.0 (0.61)	ND	1.8 (0.34)	3.3 (0.09)
	WI	2.4 (0.48)	1.7 (2.0)	1.5 (1.1)	1.5 (0.73)	ND	ND	1.6 (0.37)	ND

Fig. B70. Total Kjeldhal Nitrogen – Rain Zone Homogeneous Groups: Mean (CV)

B.8. Fecal Coliform Bacteria

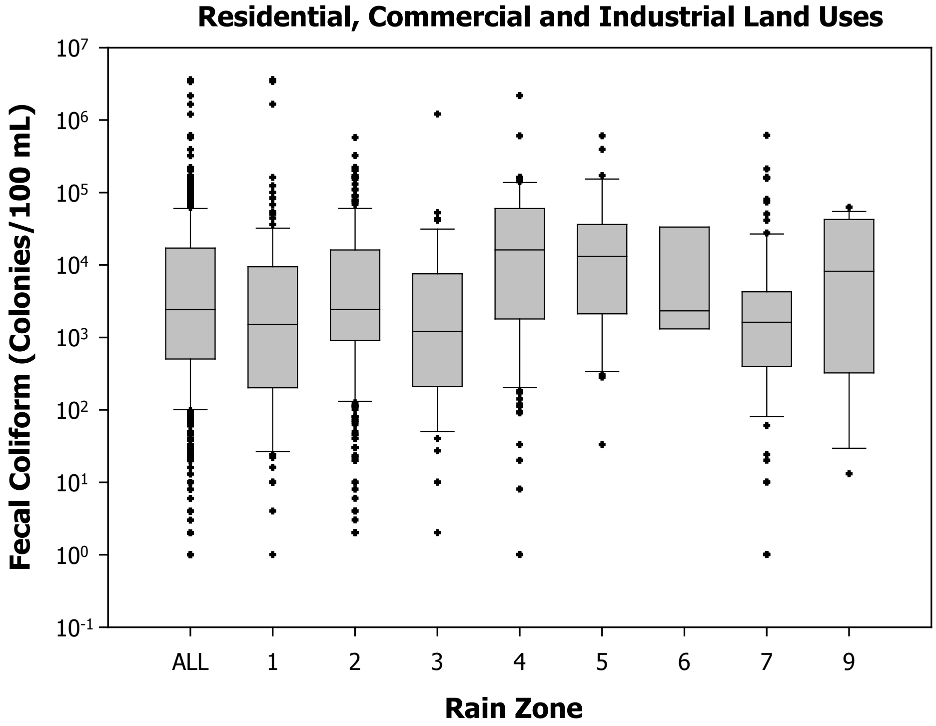
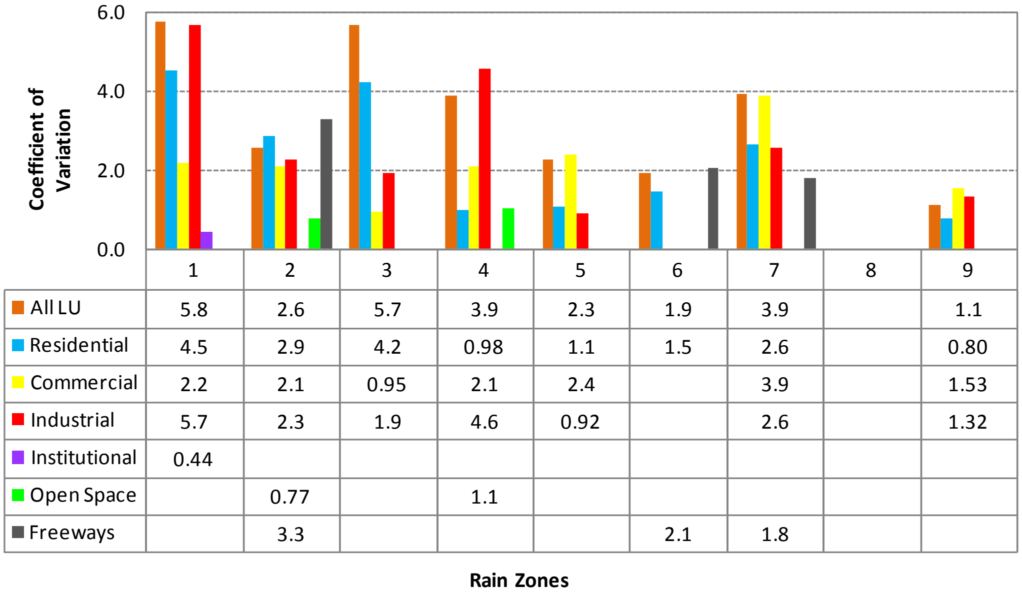


Fig. B71. Fecal Coliform Bacteria – Residential, Commercial, and Industrial Land Uses in the Contiguous United States



	1	2	3	4	5	6	7	8	9
🟧 All LU	5.8	2.6	5.7	3.9	2.3	1.9	3.9		1.1
🟦 Residential	4.5	2.9	4.2	0.98	1.1	1.5	2.6		0.80
🟨 Commercial	2.2	2.1	0.95	2.1	2.4		3.9		1.53
🟥 Industrial	5.7	2.3	1.9	4.6	0.92		2.6		1.32
🟪 Institutional	0.44								
🟩 Open Space		0.77		1.1					
⬛ Freeways		3.3				2.1	1.8		

Fig. B72. Fecal Coliform Bacteria - Regional Coefficients of Variation for Single Land Uses in the Contiguous United States

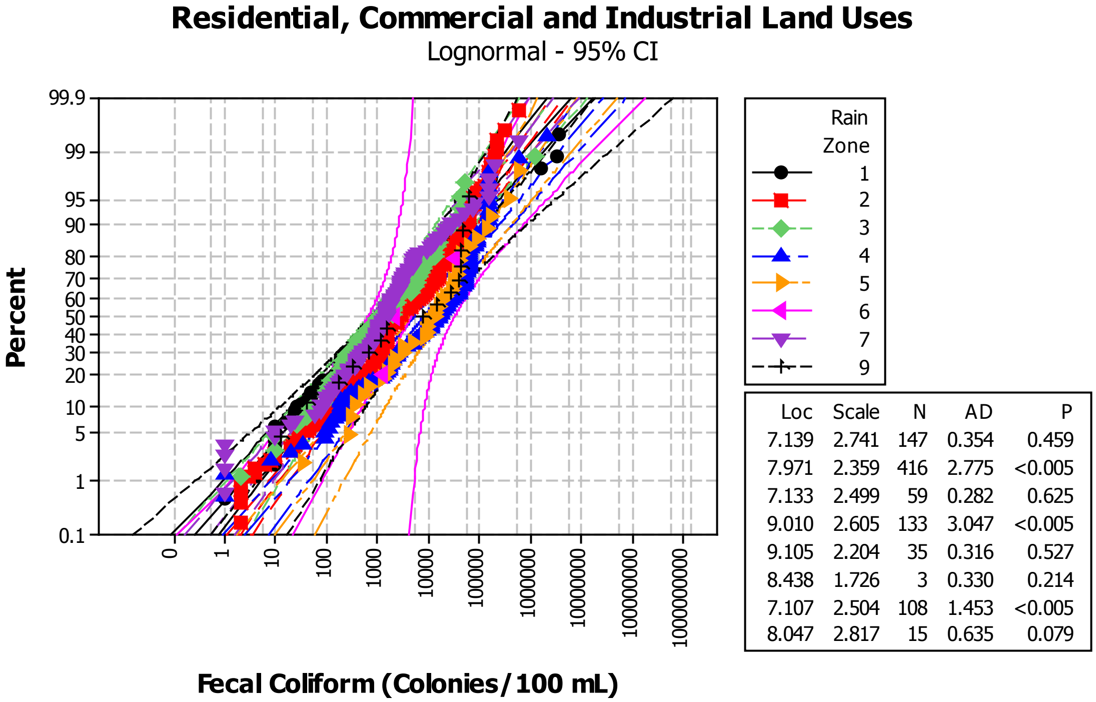


Fig. B73. Fecal Coliform Bacteria – Residential, Commercial, and Industrial Land Uses in the Contiguous United State (Checks for Normality)

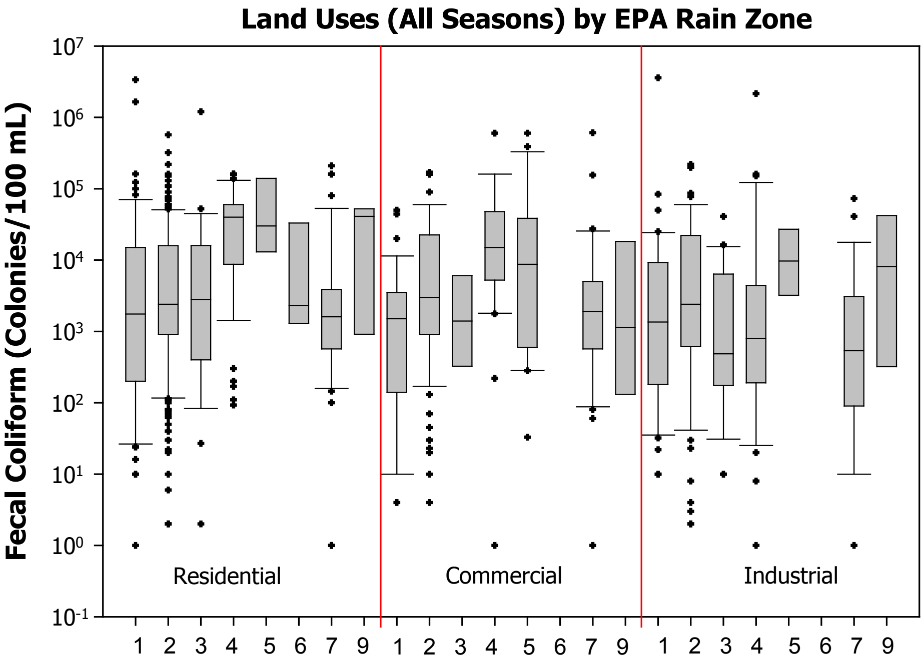


Fig. B74. Fecal Coliform Bacteria – Land Uses by EPA Rain Zone

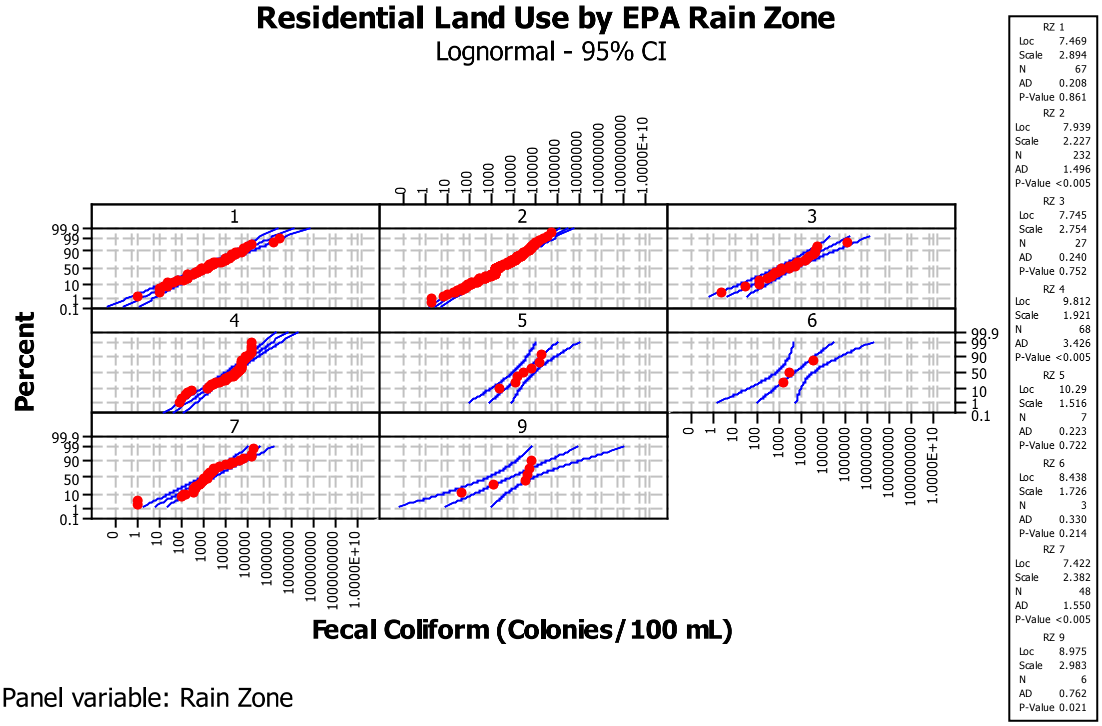


Fig. B75. Fecal Coliform Bacteria – Residential Land Use by EPA Rain Zone (Checks for Normality)

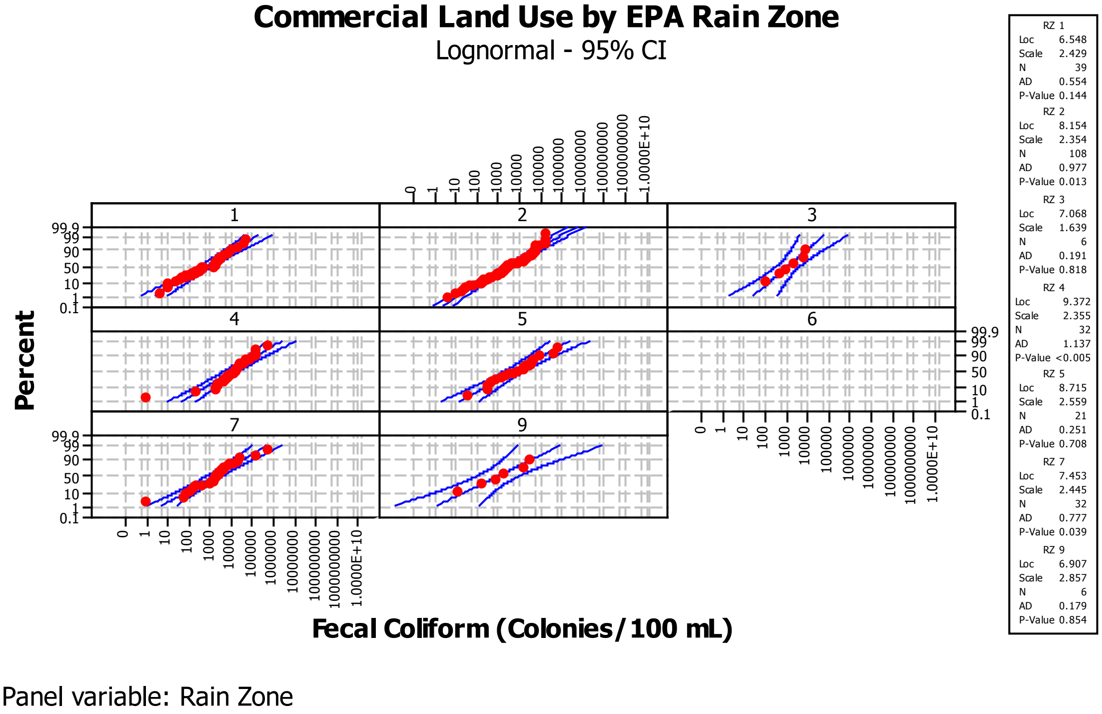


Fig. B76. Fecal Coliform Bacteria – Commercial Land Use by EPA Rain Zone (Checks for Normality)

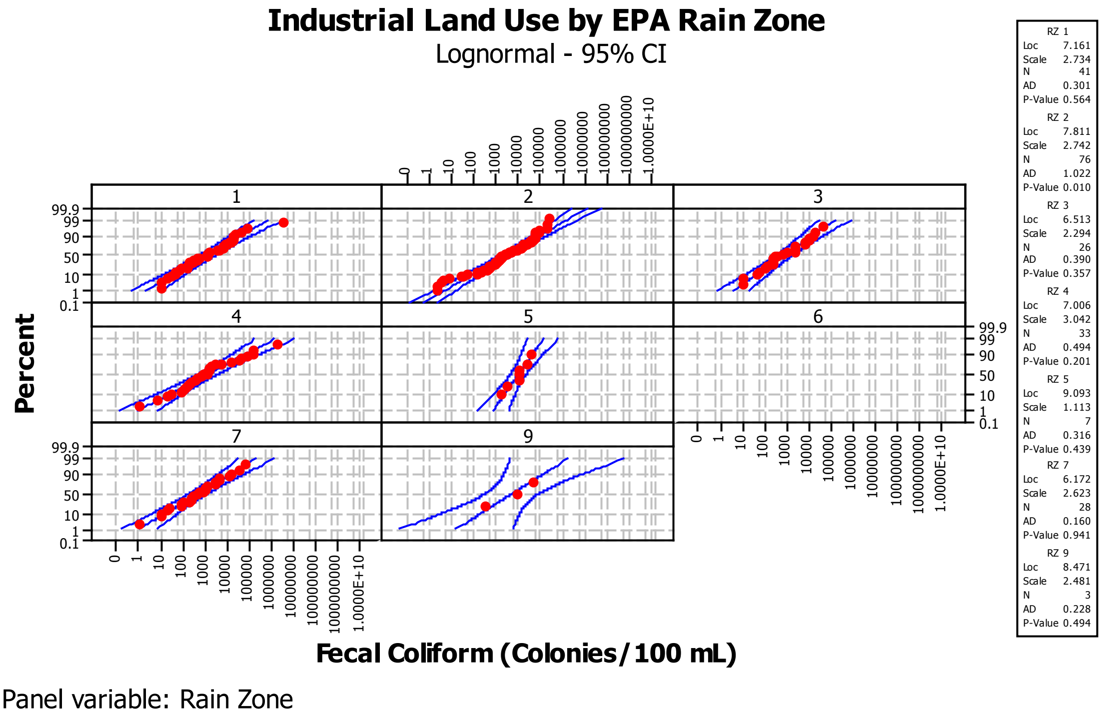


Fig. B77. Fecal Coliform Bacteria – Industrial Land Use by EPA Rain Zone (Checks for Normality)

Table B55. Fecal Coliform Bacteria – Univariate 3-way ANOVA Tests of Between-Subjects Effects

Dependent Variable: Log Fecal Coliform

	Source	Type III Sum of Squares	DF	Mean Square	F	P-value
	Corrected Model*	302	76	4.0	4.0	0.000
	Intercept	2197	1	2197	2211	0.000
Main Effects	Rain Zone (8 levels)	51	7	7.2	7.3	0.000*
	Land Use (3 levels)	6.9	2	3.4	3.5	0.032*
	Season (4 levels)	69	3	23	23	0.000*
Two-way Interactions	Rain Zone * Land Use	27	12	2.2	2.3	0.008*
	Rain Zone * Season	39	18	2.1	2.2	0.003*
	Land Use * Season	2.0	6	0.34	0.34	0.914
Three-way Interaction	Rain Zone * Land Use * Season	26	28	0.94	0.95	0.543
	Error	834	839	1.0		
	Total	11860	916			
	Corrected Total	1136	915			

*R Squared = 0.266 (Adjusted R Squared = 0.199)

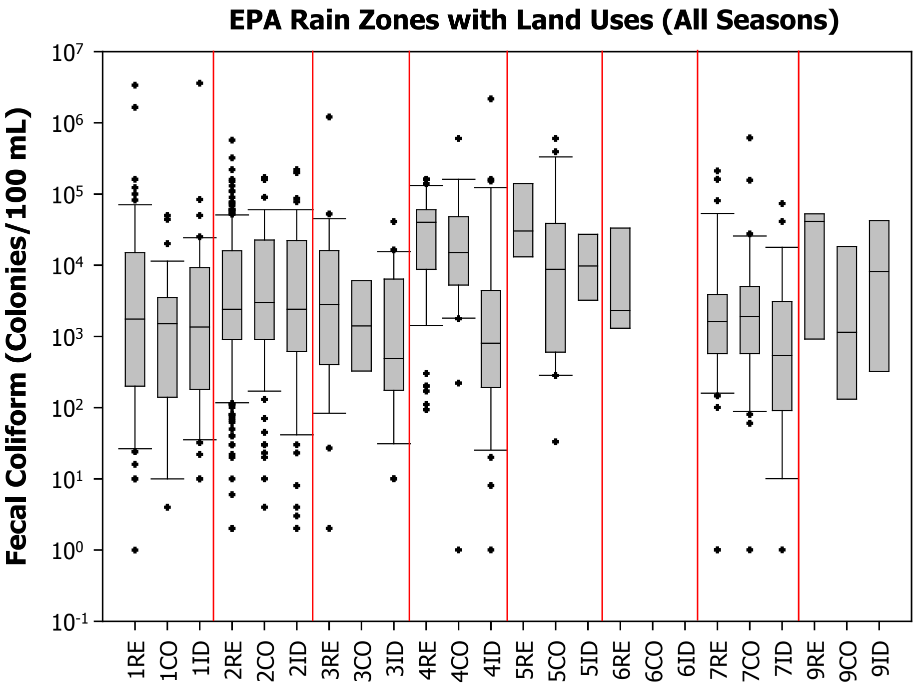


Fig. B78. Fecal Coliform Bacteria – EPA Rain Zones with Land Uses

Table B56. Fecal Coliform- MANOVA Test for Significance of Land Use within Rain Zone using Unique Sum of Squares

Source of Variation	Sum of Squares	DF	Mean Square	F	p-value
WITHIN CELLS	834	839	0.99		
Land Use WITHIN Rain Zone(1)	1.7	2	0.85	0.86	0.424
Land Use WITHIN Rain Zone (2)	1.5	2	0.76	0.76	0.467
Land Use WITHIN Rain Zone (3)	5.4	2	2.7	2.7	0.067
Land Use WITHIN Rain Zone (4)	51	2	25	26	0.000*
Land Use WITHIN Rain Zone (5)	1.2	2	0.60	0.61	0.546
Land Use WITHIN Rain Zone (6)	-	-	-	-	-
Land Use WITHIN Rain Zone (7)	4.1	2	2.1	2.1	0.128
Land Use WITHIN Rain Zone (9)	2.5	2	1.2	1.2	0.290

Table B57. Fecal Coliform Bacteria - Test of Significance: Land Use within Rain Zone

Rain Zone	**1-Way ANOVA p-value**	**Multiple Comparison** (Scheffe Post-Hoc Test)			**Homogeneous Groups** Dependent Variable: Log Fecal Coliform				**Power Analysis**	
		(I) LU	**(J) LU**	**p-value**	**LU**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
4	0.000*	RE	CO	0.684	RE	68	4.261		0.20	99.9
			ID	0.000*	CO	32	4.070		0.15	99.9
		CO	ID	0.000*	ID	33		3.043	0.10	99.9
					Pooled St. Dev = 1.02				***0.05***	***99.9***
					Obtained Effect Size = 0.50				0.01	99.6

Table B58. Fecal Coliform Bacteria **-** MANOVA Test for Significance of Season within Rain Zone using Unique Sum of Squares

Source of Variation	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
WITHIN CELLS	834	839	0.99		
Season WITHIN Rain Zone (1)	42	3	14	14	0.000*
Season WITHIN Rain Zone (2)	39	3	13	13	0.000*
Season WITHIN Rain Zone (3)	22	3	7.4	7.5	0.000*
Season WITHIN Rain Zone (4)	15	3	5.2	5.2	0.001*
Season WITHIN Rain Zone (5)	8.4	3	2.8	2.8	0.038*
Season WITHIN Rain Zone (6)					
Season WITHIN Rain Zone (7)	14	3	4.7	4.7	0.003*
Season WITHIN Rain Zone (9)	12	3	4.2	4.2	0.006*

Table B59. Fecal Coliform Bacteria – Test of Significance: Land Use and Season within Rain Zone

Rain Zone	Land Use	1-Way ANOVA p-value	Multiple Comparison (Scheffe Post-Hoc Test)			Homogeneous Groups Dependent Variable: Log Fecal Coliform					Power Analysis	
			(I) Season	(J) Season	p-value	Season	N	Gr. 1	Gr. 2	Gr. 3	α level	Power (%)
1	RE CO ID	0.000*	FA	SP	0.804	FA	53	3.169			0.20	99.9
				SU	0.017*	SP	41	2.950			0.15	99.9
				WI	0.001*	SU	30		3.955		0.10	99.9
			SP	SU	0.002*	WI	23			2.095	***0.05***	***99.9***
				WI	0.025*						0.01	99.9
			SU	WI	0.000*	Pooled St. Dev = 1.06, Obtained Effect Size = 0.53						
2	RE CO ID	0.000*	FA	SP	0.002*	FA	129	3.731			0.20	99.9
				SU	0.895	SU	74	3.842			0.15	99.9
				WI	0.000*	SP	100		3.224		0.10	99.9
			SP	SU	0.001*	WI	113		3.116		***0.05***	***99.9***
				WI	0.885						0.01	99.9
			SU	WI	0.000*	Pooled St. Dev = 0.981, Obtained Effect Size = 0.31						
3	RE CO ID	0.003*	FA	SP	0.037*	FA	13	3.589			0.20	98.2
				SU	0.806	SU	6	4.069			0.15	97.3
				WI	0.617	SP	23		2.563		0.10	95.6
			SP	SU	0.016*	WI	17		3.103		***0.05***	***91.5***
				WI	0.406						0.01	76.1
			SU	WI	0.244	Pooled St. Dev = 0.981, Obtained Effect Size = 0.52						
4	RE CO	0.000*	FA	SP		FA	26	4.648			0.20	99.8
				SU		SU	24	4.495			0.15	99.6
				WI		SP	29		3.720		0.10	99.2
			SP	SU		WI	20		3.963		***0.05***	***98.2***
				WI							0.01	92.7
			SU	WI		Pooled St. Dev = 0.826, Obtained Effect Size = 0.47						
	ID	0.472	-	-	-	FA	9	3.649			0.20	48.7
						SP	8	2.729			0.15	41.6
						SU	7	3.074			0.10	32.9
						WI	10	2.831			***0.05***	***21.5***
											0.01	7.3
						Pooled St. Dev = 1.32, Obtained Effect Size = 0.28						
5	RE CO ID	0.004*	FA	SP	0.037*	FA	7	4.626			0.20	98.3
				SU	0.999	SU	8	4.573			0.15	97.4
				WI	0.104	SP	13		3.452		0.10	95.6
			SP	SU	0.038*	WI	7		3.507		***0.05***	***91.1***
				WI	0.999						0.01	73.9
			SU	WI	0.112	Pooled St. Dev = 0.808, Obtained Effect Size = 0.69						

Table B59. – *Continued*

Rain Zone	Land Use	1-Way ANOVA p-value	Multiple Comparison (Scheffe Post-Hoc Test)			Homogeneous Groups Dependent Variable: Log Fecal Coliform				Power Analysis	
			(I) Season	**(J) Season**	**p-value**	**Season**	**N**	**Gr. 1**	**Gr. 2**	**α level**	**Power (%)**
7	RE CO ID	0.257	-	-	-	FA	28	3.345		0.20	63.7
						SP	26	3.045		0.15	57.1
						SU	8	3.455		0.10	48.4
						WI	46	2.889		***0.05***	***35.5***
										0.01	15.8
						Pooled St. Dev = 1.08, Obtained Effect Size = 0.20					
9	RE CO ID	0.004*	-	-	Not possible because FALL has only one value	FA	1	*		0.20	99.4
						SP	4	2.012		0.15	98.9
						SU	10		3.968	0.10	97.9
										0.05	***94.9***
										0.01	78.9
						Pooled St. Dev = 0.841, Obtained Effect Size = 1.1					

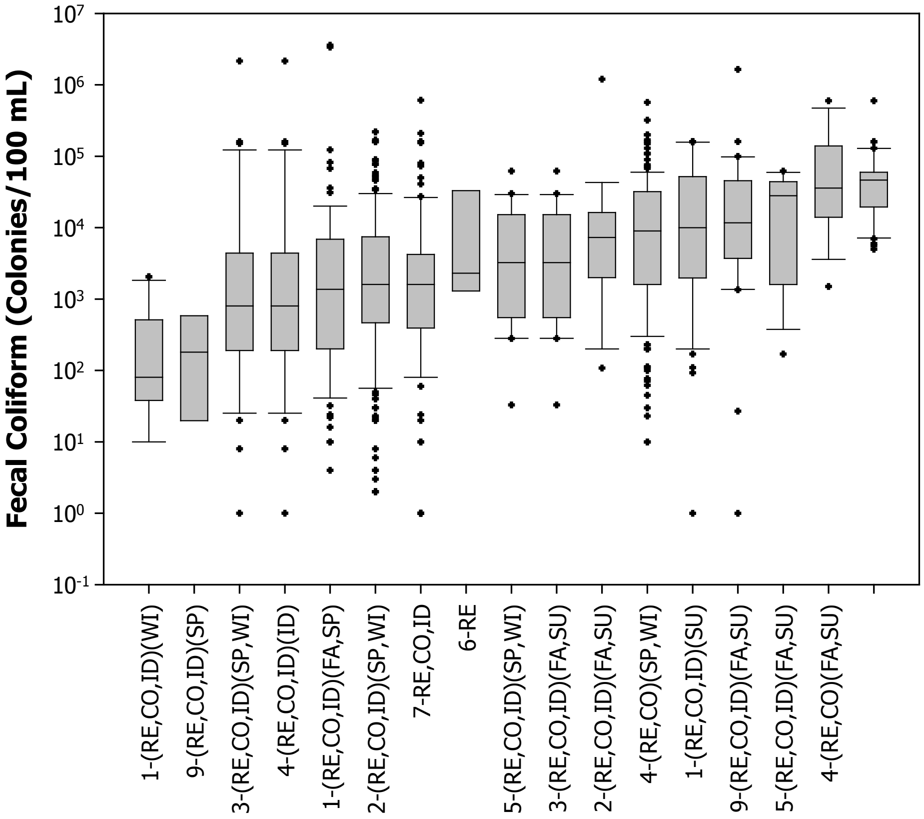


Fig. B79. Fecal Coliform Bacteria – Rain Zone Groups

Table B60. Fecal Coliform Bacteria – Rain Zone Groups Multiple Comparisons

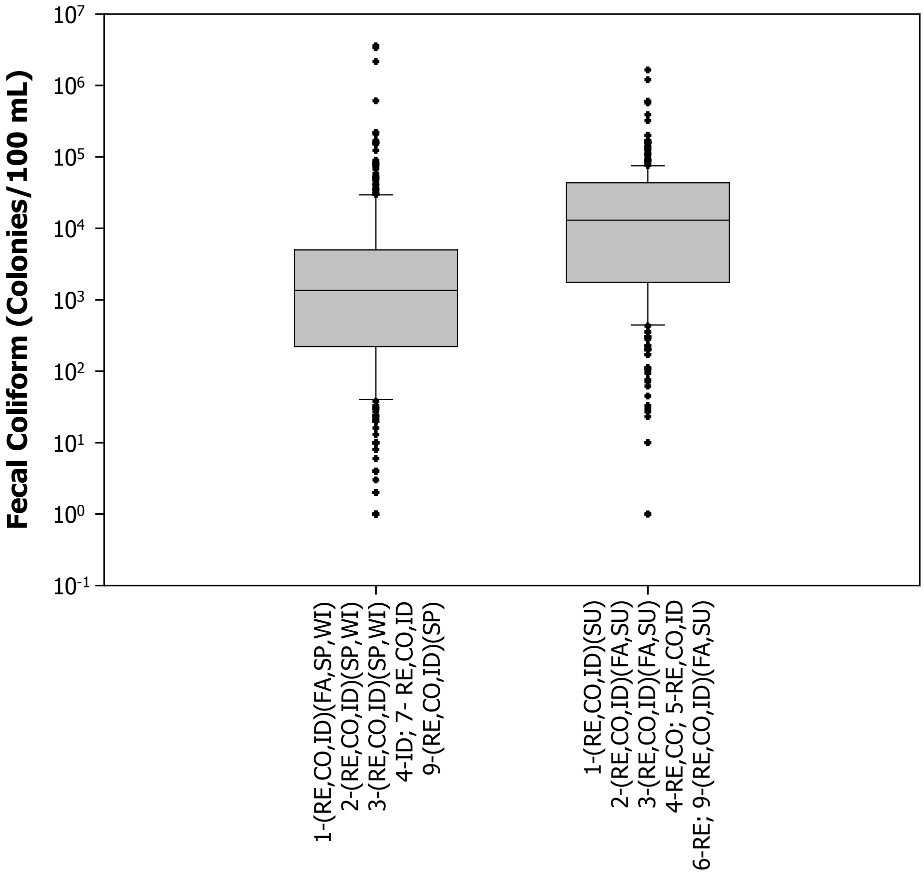
(I) Group	(J) Group	p-value
1-FA,SP	1-SU	0.276
	1-WI	0.279
	2-FA,SU	0.009
	2-SP,WI	1.000
	3-FA,SU	0.956
	3-SP,WI	1.000
	4-(RE,CO)(FA,SU)	0.000
	4-(RE,CO)(SP,WI)	0.265
	4-ID	1.000
	5-FA,SU	0.012
	5-SP,WI	1.000
	6	1.000
	7	1.000
	9-SP	0.996
	9-FA,SU	0.869
1-SU	1-WI	0.000
	2-FA,SU	1.000
	2-SP,WI	0.353
	3-FA,SU	1.000
	3-SP,WI	0.081
	4-(RE,CO)(FA,SU)	0.950
	4-(RE,CO)(SP,WI)	1.000
	4-ID	0.644
	5-FA,SU	0.997
	5-SP,WI	1.000
	6	1.000
	7	0.274
	9-SP	0.572
	9-FA,SU	1.000
1-WI	2-FA,SU	0.000
	2-SP,WI	0.069
	3-FA,SU	0.022
	3-SP,WI	0.953
	4-(RE,CO)(FA,SU)	0.000
	4-(RE,CO)(SP,WI)	0.000
	4-ID	0.588
	5-FA,SU	0.000
	5-SP,WI	0.161
	6	0.968
	7	0.231
	9-SP	1.000
	9-FA,SU	0.022
2-FA,SU	2-SP,WI	0.001
	3-FA,SU	1.000
	3-SP,WI	0.007
	4-(RE,CO)(FA,SU)	0.059
	4-(RE,CO)(SP,WI)	1.000
	4-ID	0.510
	5-FA,SU	0.841
	5-SP,WI	1.000
	6	1.000
	7	0.005
	9-SP	0.665
	9-FA,SU	1.000
2-SP,WI	3-FA,SU	0.983
	3-SP,WI	0.994
	4-(RE,CO)(FA,SU)	0.000
	4-(RE,CO)(SP,WI)	0.317
	4-ID	1.000
	5-FA,SU	0.018
	5-SP,WI	1.000
	6	1.000
	7	1.000
	9-SP	0.990
	9-FA,SU	0.926
3-FA,SU	3-SP,WI	0.709
	4-(RE,CO)(FA,SU)	0.839
	4-(RE,CO)(SP,WI)	1.000
	4-ID	0.988
	5-FA,SU	0.975
	5-SP,WI	1.000
	6	1.000
	7	0.959
	9-SP	0.825
	9-FA,SU	1.000
3-SP,WI	4-(RE,CO)(FA,SU)	0.000
	4-(RE,CO)(SP,WI)	0.081
	4-ID	1.000
	5-FA,SU	0.002
	5-SP,WI	0.976
	6	1.000
	7	1.000
	9-SP	1.000
	9-FA,SU	0.575
4-(RE,CO)(FA,SU)	4-(RE,CO)(SP,WI)	0.510
	4-ID	0.000
	5-FA,SU	1.000
	5-SP,WI	0.295
	6	1.000
	7	0.000
	9-SP	0.060
	9-FA,SU	1.000
4-(RE,CO)(SP,WI)	4-ID	0.737
	5-FA,SU	0.956
	5-SP,WI	1.000
	6	1.000
	7	0.255
	9-SP	0.669
	9-FA,SU	1.000

Table B60. - *Continued*

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
4-ID	5-FA,SU	0.062	5-SP,WI	6	1.000
	5-SP,WI	1.000		7	1.000
	6	1.000		9-SP	0.953
	7	1.000		9-FA,SU	1.000
	9-SP	0.998	6	7	1.000
	9-FA,SU	0.934		9-SP	0.994
5-FA,SU	5-SP,WI	0.756		9-FA,SU	1.000
	6	1.000	7	9-SP	0.996
	7	0.012		9-FA,SU	0.876
	9-SP	0.133	9-SP	9-FA,SU	0.675
	9-FA,SU	1.000			

Table B61. Fecal Coliform Bacteria – Homogeneous Groups

Groups	N	**Homogeneous Groups** Dependent Variable: Log Fecal Coliform Bacteria	
		A	B
1-(RE,CO,ID)(FA,SP)	94	3.073	
1-(RE,CO,ID)(WI)	23	2.096	
2-(RE,CO,ID)(SP,WI)	213	3.166	
3-(RE,CO,ID)(SP,WI)	40	2.793	
4-ID	34	3.074	
7-RE,CO,ID	108	3.086	
9-(RE,CO,ID)(SP)	4	2.013	
1-SU	30		3.955
2-(RE,CO,ID)(FA,SU)	203		3.770
3-(RE,CO,ID)(FA,SU)	19		3.739
4-(RE,CO)(FA,SU)	50		4.575
4-(RE,CO)(SP,WI)	49		3.819
5-(RE,CO,ID)(FA,SU)	15		4.599
5-(RE,CO,ID)(SP,WI)	20		3.472
6-RE,CO,ID	3		3.663
9-(RE,CO,ID)(FA,SU)	11		4.034



Land Use	Season	EPA Rain Zones							
		1	2	3	4	5	6	7	9
Residential	FA	145241 (4.6)	16556 (1.9)	17279 (1.1)	63765 (0.74)	ND	ND	36881 (1.7)	ND
	SP	3735 (2.3)	11987 (2.7)	2918 (1.5)	27402 (1.1)	26825 (0.97)	1800 (0.39)	16651 (3.2)	ND
	SU	148277 (2.9)	51533 (2.1)	603750 (1.4)	45212 (0.61)	155000 (0.14)	ND	3200 (0.59)	36300 (0.70)
	WI	201 (1.2)	7264 (1.8)	12051 (1.5)	52219 (1.3)	ND	ND	6965 (2.6)	ND
Commercial	FA	3190 (1.7)	23139 (1.5)	6450 (0.19)	109289 (1.7)	214600 (1.2)	ND	4683 (0.94)	ND
	SP	3403 (1.2)	22960 (2.1)	825 (1.0)	5168 (0.89)	4012 (2.1)	ND	94797 (2.4)	342 (1.4)
	SU	20960 (1.1)	23149 (1.1)	ND	34214 (1.1)	53667 (0.60)	ND	4233 (0.61)	11193 (1.2)
	WI	661 (1.3)	13876 (3.1)	ND	65000 (1.2)	6786 (1.1)	ND	12367 (3.3)	ND
Industrial	FA	281493 (3.5)	37625 (1.6)	7030 (1.1)	21224 (2.5)	ND	ND	5350 (2.5)	ND
	SP	3099 (2.1)	9056 (2.1)	1841 (2.5)	13793 (2.0)	7633 (0.50)	ND	4209 (1.3)	ND
	SU	20255 (1.3)	16530 (1.4)	5000 (0.67)	22154 (2.6)	21500 (0.83)	ND	2950 (1.0)	25050 (0.96)
	WI	265 (1.8)	18158 (2.7)	6170 (2.3)	276558 (2.8)	ND	ND	7225 (2.8)	ND

Fig. B80. Fecal Coliform Bacteria – Rain Zone Homogeneous Groups: Mean (CV)

Table B62. Basic Statistics for Fecal Coliform Bacteria –
Rain Zone Homogeneous Groups (Real Space Data) (Colonies/100mL)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	1-(RE,CO,ID)(FA,SP,WI) 2-(RE,CO,ID)(SP,WI) 3-(RE,CO,ID)(SP,WI) 4-ID 7-RE,CO,ID 9-(RE,CO,ID)(SP)	515	29120	239500	8.2	1.0	1350	3600000
B	1-(RE,CO,ID)(SU) 2-(RE,CO,ID)(FA,SU) 3-(RE,CO,ID)(FA,SU) 4-RE,CO 5-RE,CO,ID; 6-RE 9-(RE,CO,ID)(FA,SU)	401	40286	119279	3.0	1.0	13000	1650000

Appendix C
EPA Rain Zone 2 – Detailed Analyses of Selected Pollutants

C.1. Total Zinc

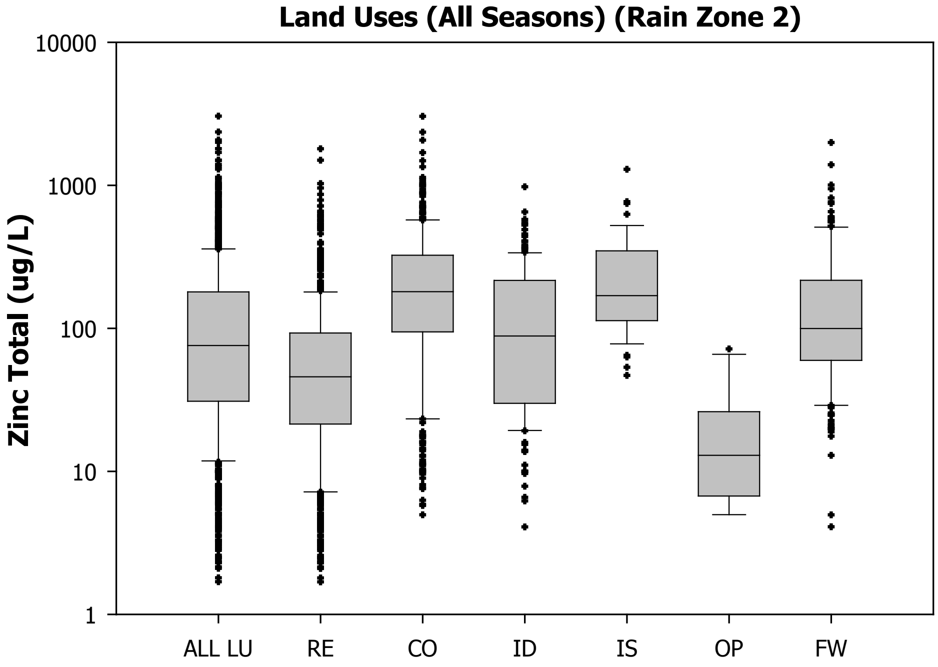
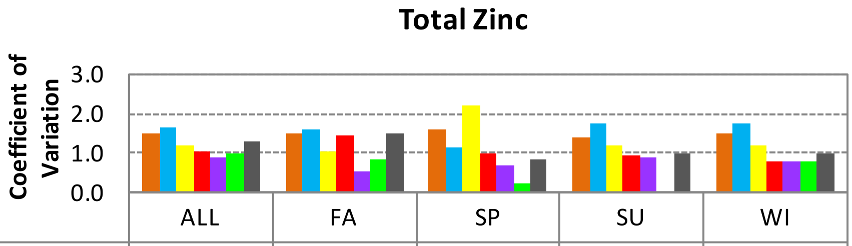


Fig. C1. Total Zinc - Single Land Uses in EPA Rain Zone 2



	ALL	FA	SP	SU	WI
🟧 All LU	1.49	1.48	1.60	1.39	1.50
🟦 Residential	1.64	1.60	1.17	1.76	1.76
🟨 Commercial	1.20	1.03	2.21	1.18	1.22
🟥 Industrial	1.04	1.45	0.98	0.93	0.80
🟪 Institutional	0.92	0.55	0.68	0.91	0.80
🟩 Open Space	0.98	0.86	0.25		0.80
⬛ Freeways	1.29	1.49	0.83	0.98	1.01

Fig. C2. Total Zinc – EPA Rain Zone 2 Seasonal Coefficients of Variation

C.1.1 Total Zinc - All Single Land Uses

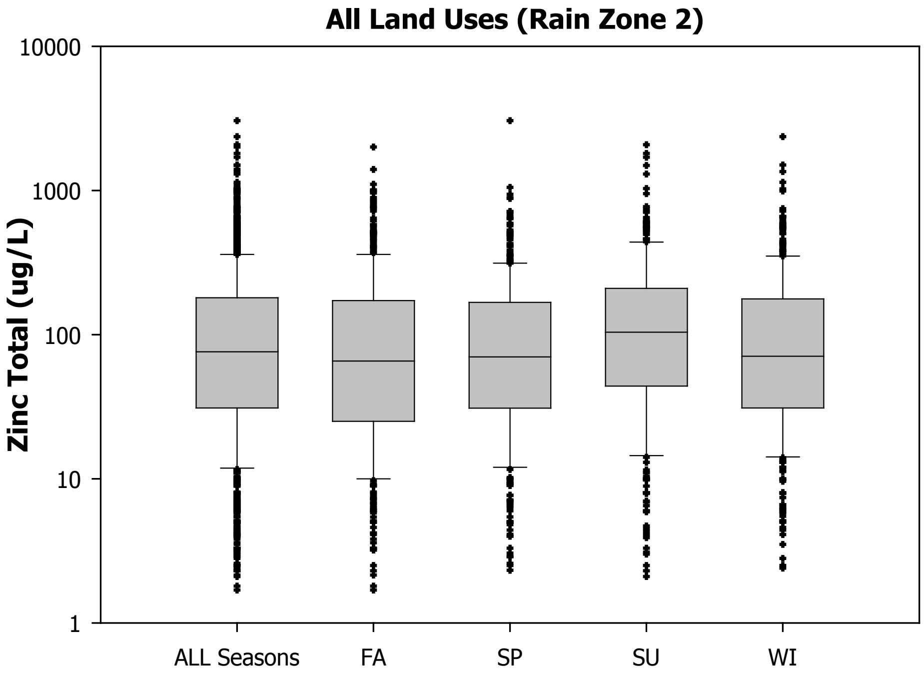


Fig. C3. Total Zinc – All Single Land Uses by Season

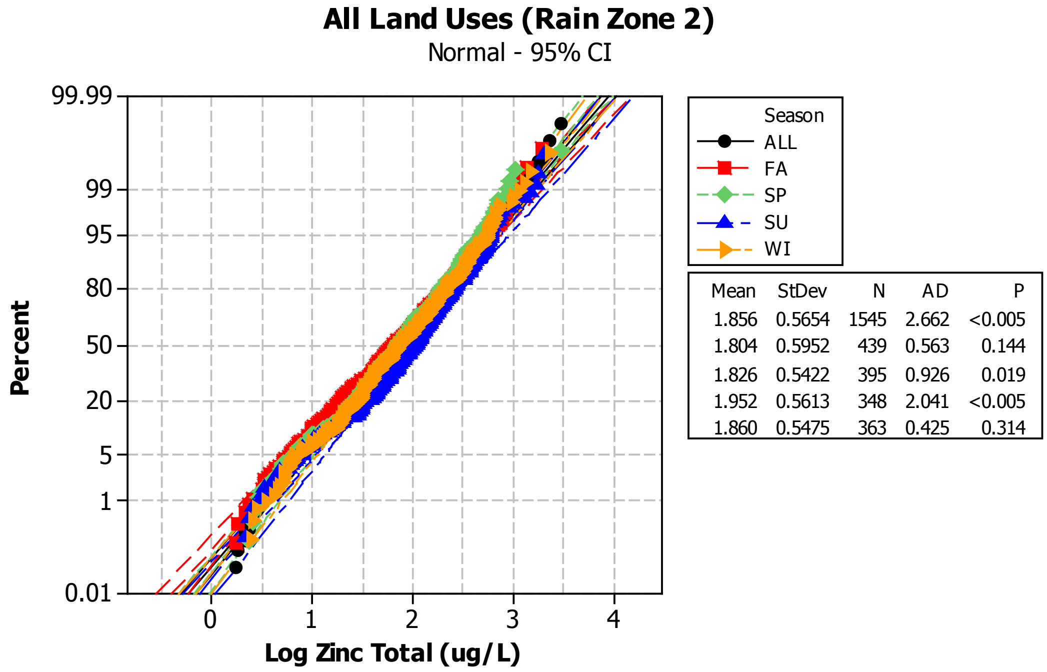


Fig. C4. Total Zinc – All Single Land Uses (Checks for Normality)

Table C1. Statistical Analyses for Total Zinc - All Single Land Uses

Kruskal-Wallis Test
(All Land Uses: Log Total Zinc)

H = 17.17 DF = 3 P = 0.001
H = 17.17 DF = 3 P = 0.001(adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	439	1.816	733	-2.2
SP	395	1.845	746	-1.4
SU	348	2.016	857	3.98
WI	363	1.849	769	-0.2
Overall	1545		773	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.616
	SU	0.000*
	WI	0.227
SP	SU	0.001*
	WI	0.494
SU	WI	0.009*

All Land Uses
Log Total Zinc
Groups (medians)

Season	Gr. 1	Gr. 2
FA	1.816	
SP	1.845	
WI	1.849	
SU		2.016

Table C2. Power of the Test for Total Zinc - All Single Land Uses

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	439	1.80	0.595
SP	395	1.83	0.542
SU	348	1.95	0.561
WI	363	1.86	0.548
Pooled Standard Deviation			0.562
Obtained Effect Size			0.10

α level	Power (%)
0.20	98.0
0.15	97.1
0.10	95.4
0.05	***91.5***
0.01	78.0

C.1.2 Total Zinc - Residential Land Use

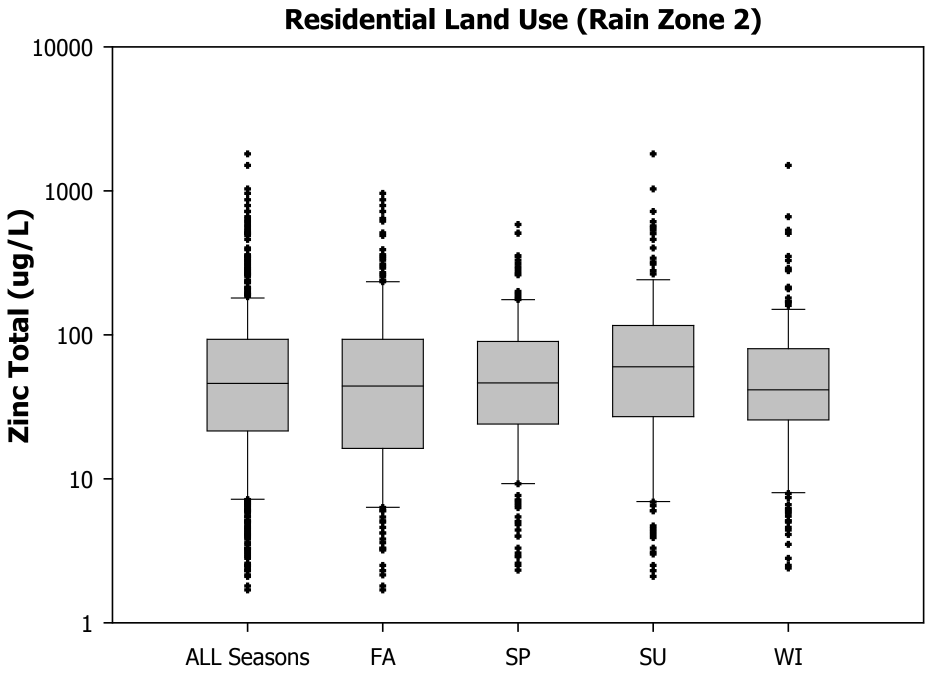


Fig. C5. Total Zinc – Residential Land Use by Season

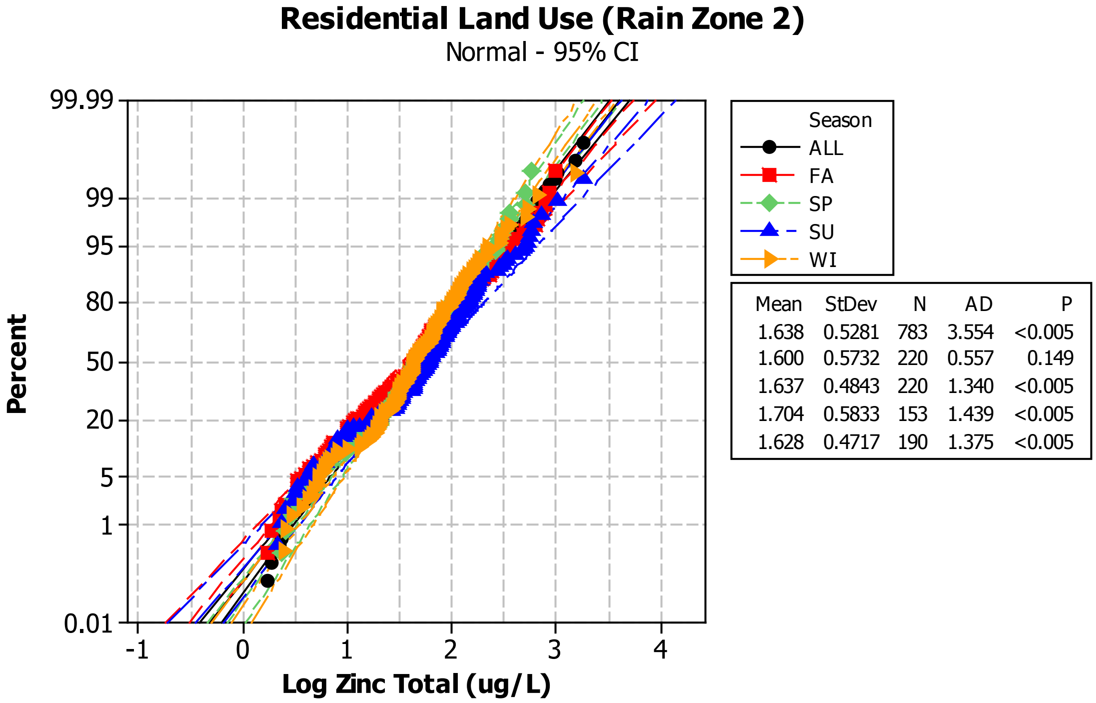


Fig. C6. Total Zinc – Residential Land Use (Checks for Normality)

Table C3. Statistical Analyses for Total Zinc – Residential Land Use

Kruskal-Wallis Test
(Residential: Log Total Zinc)

H = 5.39 DF = 3 P = 0.145
H = 5.39 DF = 3 P = 0.145 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	220	1.644	376	-1
SP	220	1.666	393	0.1
SU	153	1.778	428	2.2
WI	190	1.618	381	0
Overall	783		392	

Power of the Test (Residential: Log Total Zinc)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	220	1.60	0.573
SP	220	1.64	0.484
SU	153	1.70	0.583
WI	190	1.63	0.472
Pooled Standard Deviation			0.528
Obtained Effect Size			0.06

α level	Power (%)
0.20	57.4
0.15	50.6
0.10	41.9
0.05	***29.8***
0.01	12.5

C.1.3 Total Zinc - Commercial Land Use

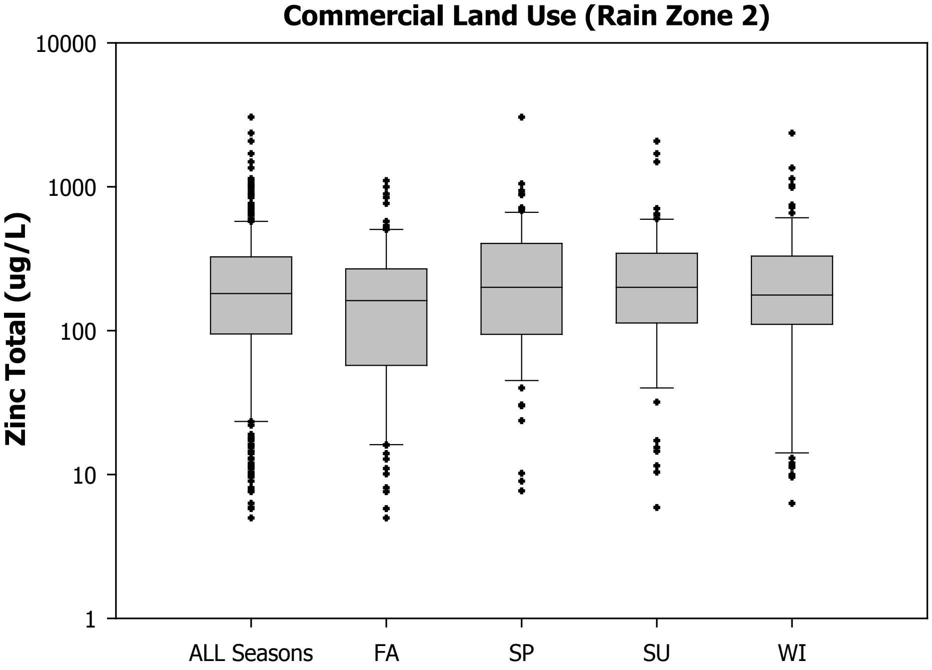


Fig. C7. Total Zinc – Commercial Land Use by Season

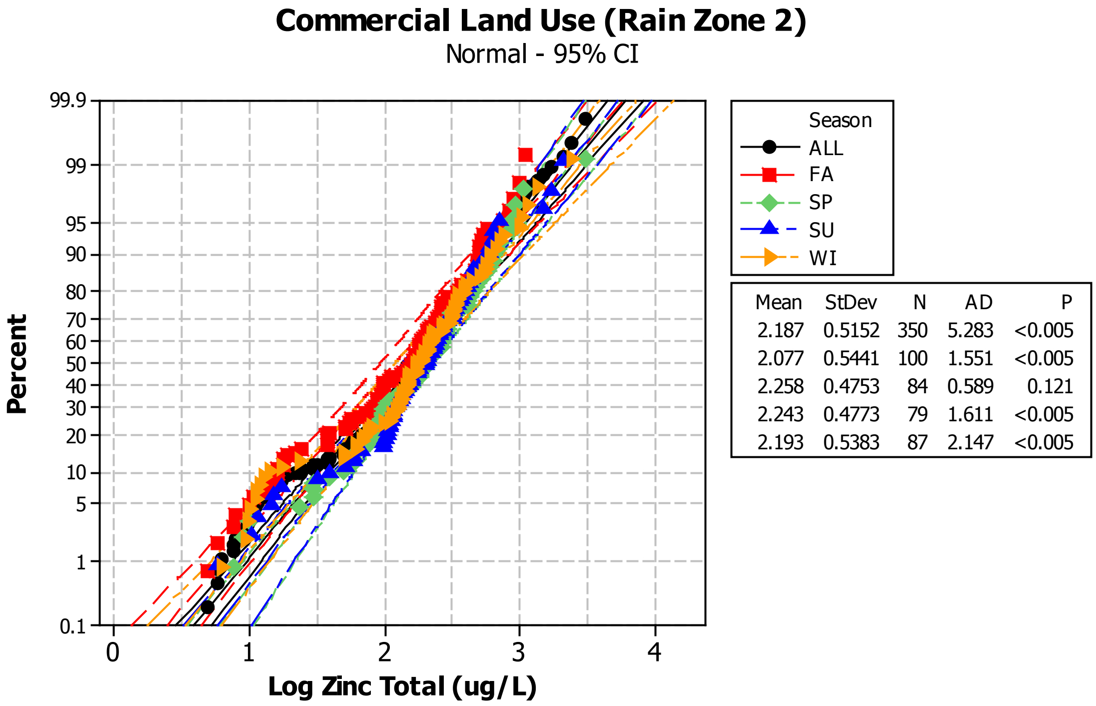


Fig. C8. Total Zinc – Commercial Land Use (Checks for Normality)

Table C4. Statistical Analyses for Total Zinc – Commercial Land Use

Kruskal-Wallis Test
(Commercial: Log Total Zinc)

H = 5.74 DF = 3 P = 0.125
H = 5.74 DF = 3 P = 0.125 (adjusted for ties)

Season	**N**	**Median**	**Ave Rank**	**Z**
FA	100	2.208	156	-2
SP	84	2.301	187	1.2
SU	79	2.301	186	1.0
WI	87	2.248	178	0.3
Overall	350		175.5	

Power of the Test (Commercial: Log Total Zinc)

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	100	2.08	0.544
SP	84	2.26	0.475
SU	79	2.24	0.477
WI	87	2.19	0.538
Pooled Standard Deviation			0.509
Obtained Effect Size			0.14

α level	**Power (%)**
0.20	82.0
0.15	77.3
0.10	70.4
0.05	***58.5***
0.01	34.4

C.1.4 Total Zinc - Industrial Land Use

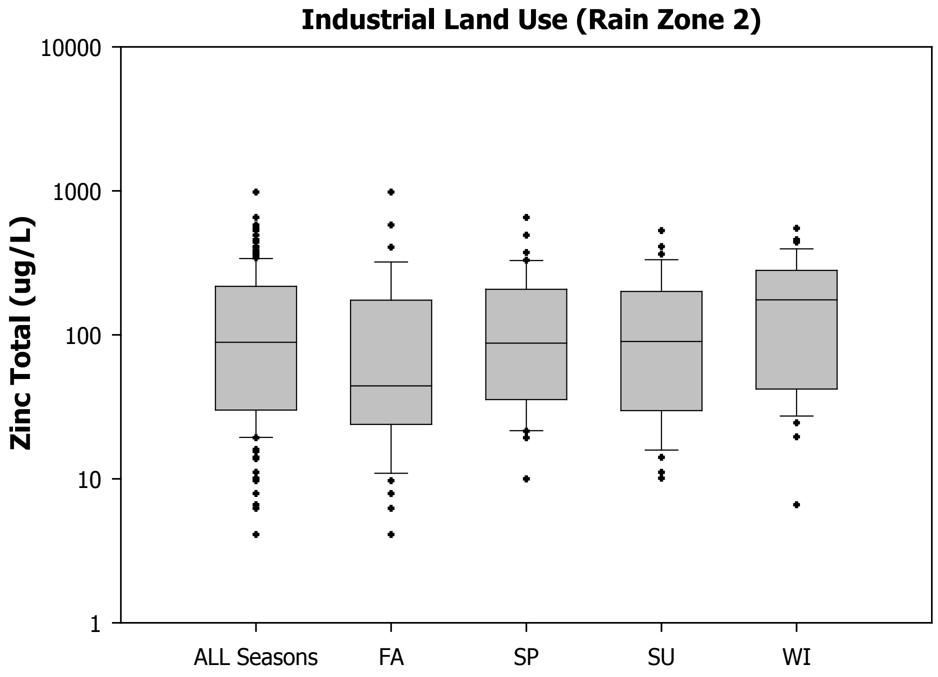
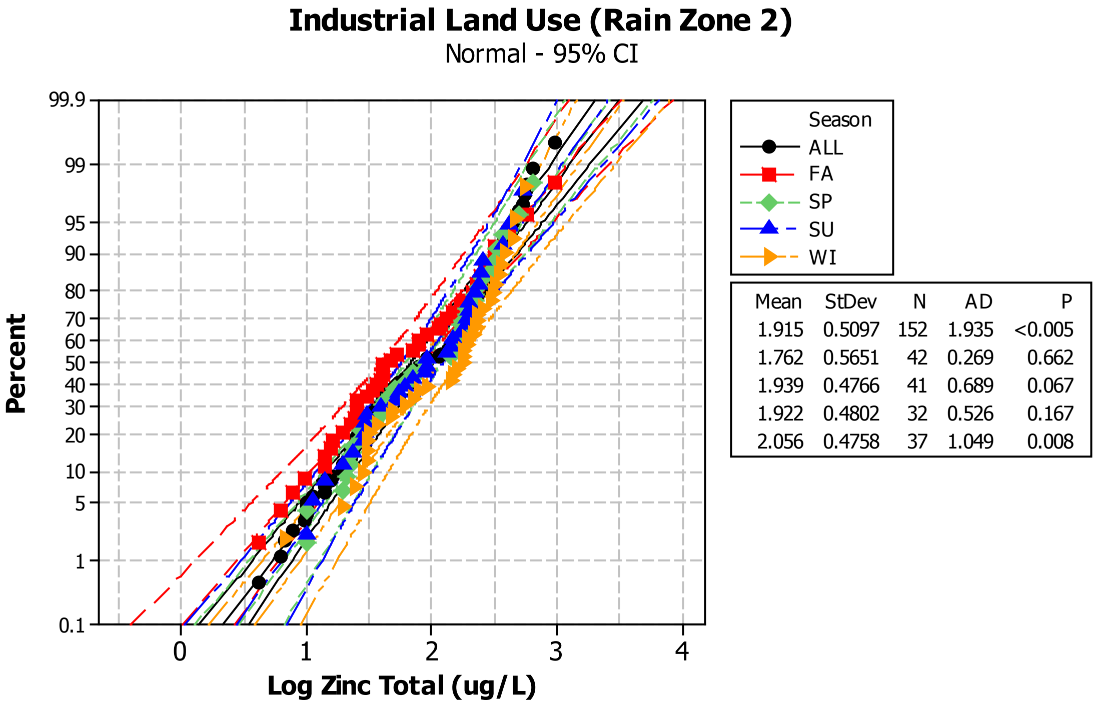


Fig. C9. Total Zinc – Industrial Land Use by Season



Mean	StDev	N	AD	P
1.915	0.5097	152	1.935	<0.005
1.762	0.5651	42	0.269	0.662
1.939	0.4766	41	0.689	0.067
1.922	0.4802	32	0.526	0.167
2.056	0.4758	37	1.049	0.008

Fig. C10. Total Zinc – Industrial Land Use (Checks for Normality)

Table C5. Statistical Analyses for Total Zinc – Industrial Land Use

Kruskal-Wallis Test
(Industrial: Log Total Zinc)

H = 6.72 DF = 3 P = 0.081
H = 6.72 DF = 3 P = 0.081 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	42	1.645	64	-2
SP	41	1.942	78	0.2
SU	32	1.954	77	0.1
WI	37	2.243	89	2.1
Overall	152		76.5	

Power of the Test (Industrial: Log Total Zinc)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	42	1.76	0.565
SP	4	1.94	0.477
SU	32	1.92	0.480
WI	37	2.06	0.476

Pooled Standard Deviation 0.500
Obtained Effect Size 0.22

α level	Power (%)
0.20	82.8
0.15	78.2
0.10	71.3
0.05	***59.4***
0.01	35.0

C.1.5 Total Zinc - Institutional Land Use

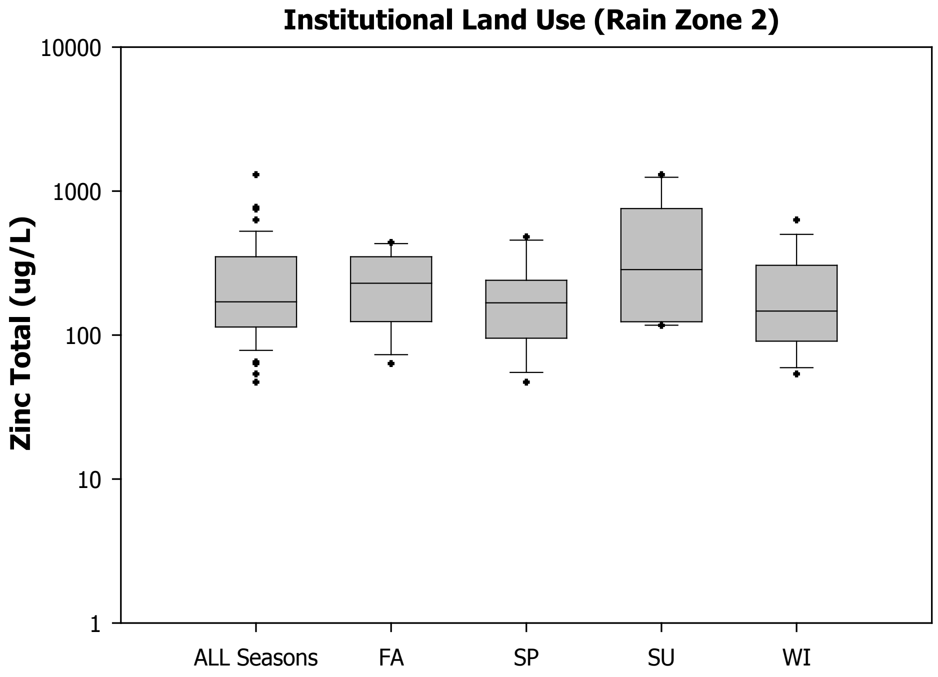


Fig. C11. Total Zinc – Institutional Land Use by Season

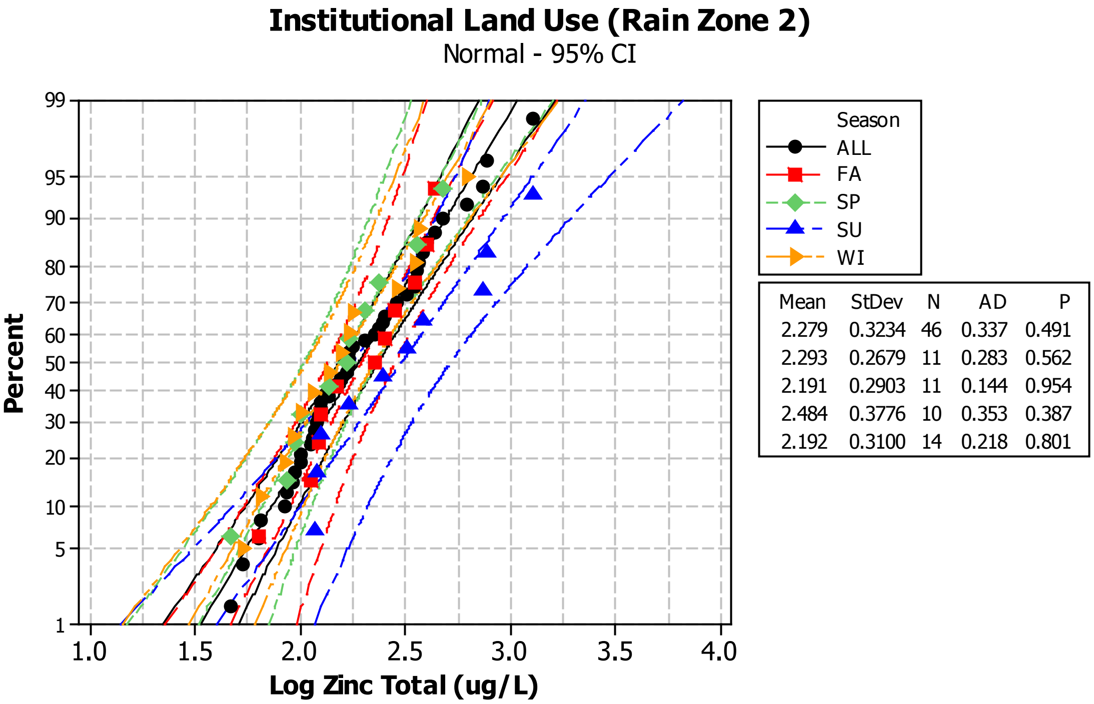


Fig. C12. Total Zinc – Institutional Land Use (Checks for Normality)

Table C6. Statistical Analyses for Total Zinc – Institutional Land Use

Kruskal-Wallis Test
(Institutional: Log Total Zinc)

H = 4.47 DF = 3 P = 0.215
H = 4.47 DF = 3 P = 0.215 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	11	2.359	24.8	0.37
SP	11	2.223	20.3	-0.9
SU	10	2.452	30.6	1.9
WI	14	2.166	19.9	-1.2
Overall	46		23.5	

Power of the Test (Institutional: Log Total Zinc)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	11	2.29	0.268
SP	11	2.19	0.290
SU	10	2.48	0.378
WI	14	2.19	0.310

Pooled Standard Deviation 0.312
Obtained Effect Size 0.37

α level	Power (%)
0.20	76.4
0.15	70.7
0.10	62.5
0.05	***49.1***
0.01	24.9

C.1.6 Total Zinc – Open Space Land Use

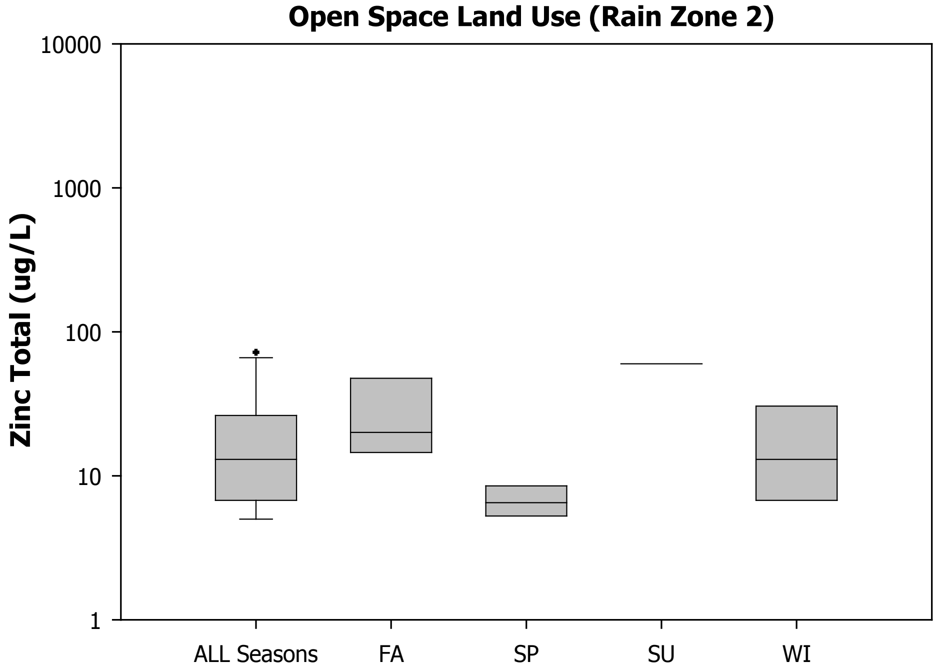


Fig. C13. Total Zinc – Open Space Land Use by Season

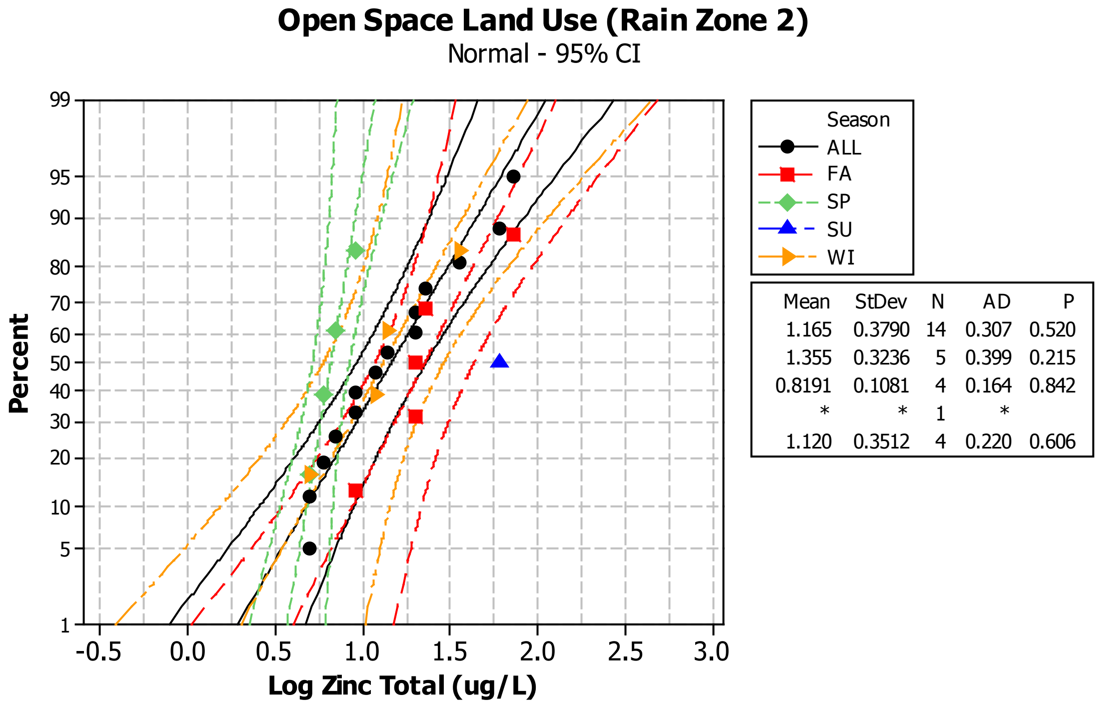


Fig. C14. Total Zinc – Open Space Land Use (Checks for Normality)

Table C7. Statistical Analyses for Total Zinc – Open Space Land Use

Kruskal-Wallis Test
(Open Space: Log Total Zinc)

H = 7.06 DF = 3 P = 0.070
H = 7.11 DF = 3 P = 0.068 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	5	1.301	9.9	1.6
SP	4	0.812	3.5	-2.3
SU	1	1.778	13	1.4
WI	4	1.113	7.1	-0.2
Overall	14		7.5	

Power of the Test (Open Space: Log Total Zinc)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	5	1.36	0.324
SP	4	0.819	0.108
SU	1	-	-
WI	4	1.12	0.351

Pooled Standard Deviation 0.261
Obtained Effect Size 0.86

α level	Power (%)
0.20	89.9
0.15	85.8
0.10	79.1
0.05	***65.6***
0.01	34.2

C.1.7 Total Zinc - Freeways Land Use

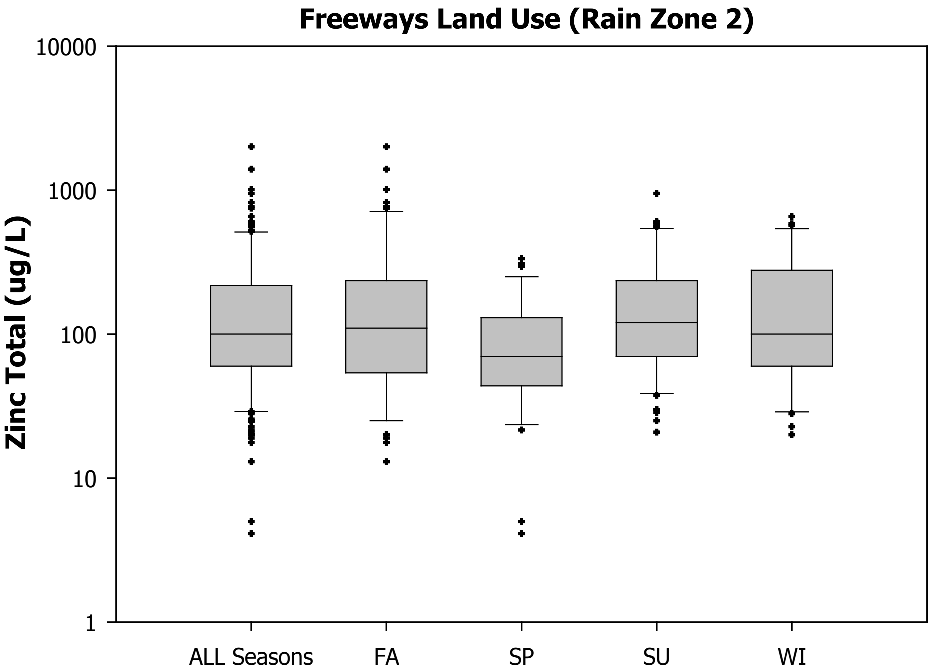
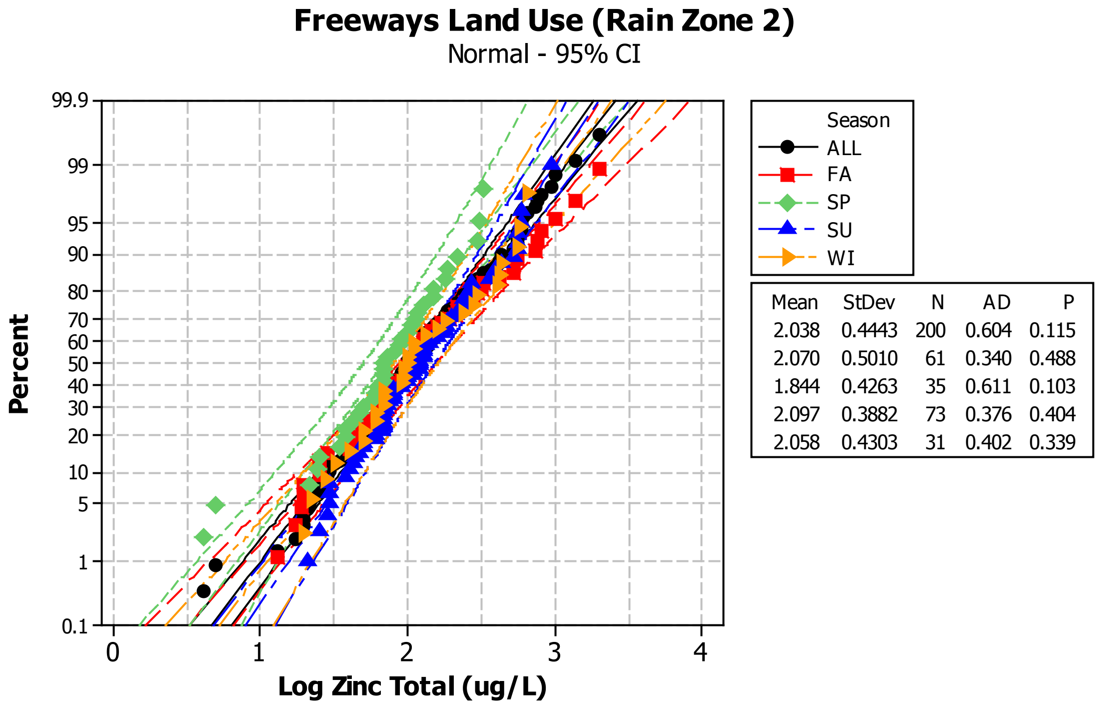


Fig. C15. Total Zinc – Freeways Land Use by Season



Mean	StDev	N	AD	P
2.038	0.4443	200	0.604	0.115
2.070	0.5010	61	0.340	0.488
1.844	0.4263	35	0.611	0.103
2.097	0.3882	73	0.376	0.404
2.058	0.4303	31	0.402	0.339

Fig. C16. Total Zinc – Freeways Land Use (Checks for Normality)

Table C8. Statistical Analyses for Total Zinc – Freeways Land Use

Kruskal-Wallis Test
(Freeways: Log Total Zinc)

H = 6.75 DF = 3 P = 0.080
H = 6.75 DF = 3 P = 0.080 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	61	2.041	103	0.4
SP	35	1.845	78	-3
SU	73	2.079	109	1.5
WI	31	2.0	102	0.1
Overall	200		101	

Power of the Test (Freeways: Log Total Zinc)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	61	2.07	0.501
SP	35	1.84	0.426
SU	73	2.□0	0.388
WI	31	2.06	0.430
Pooled Standard Deviation			0.436
Obtained Effect Size			0.21

α level	Power (%)
0.20	89.4
0.15	86.0
0.10	80.7
0.05	***70.7***
0.01	47.1

C.1.8 Total Zinc Land Use and Season Groups

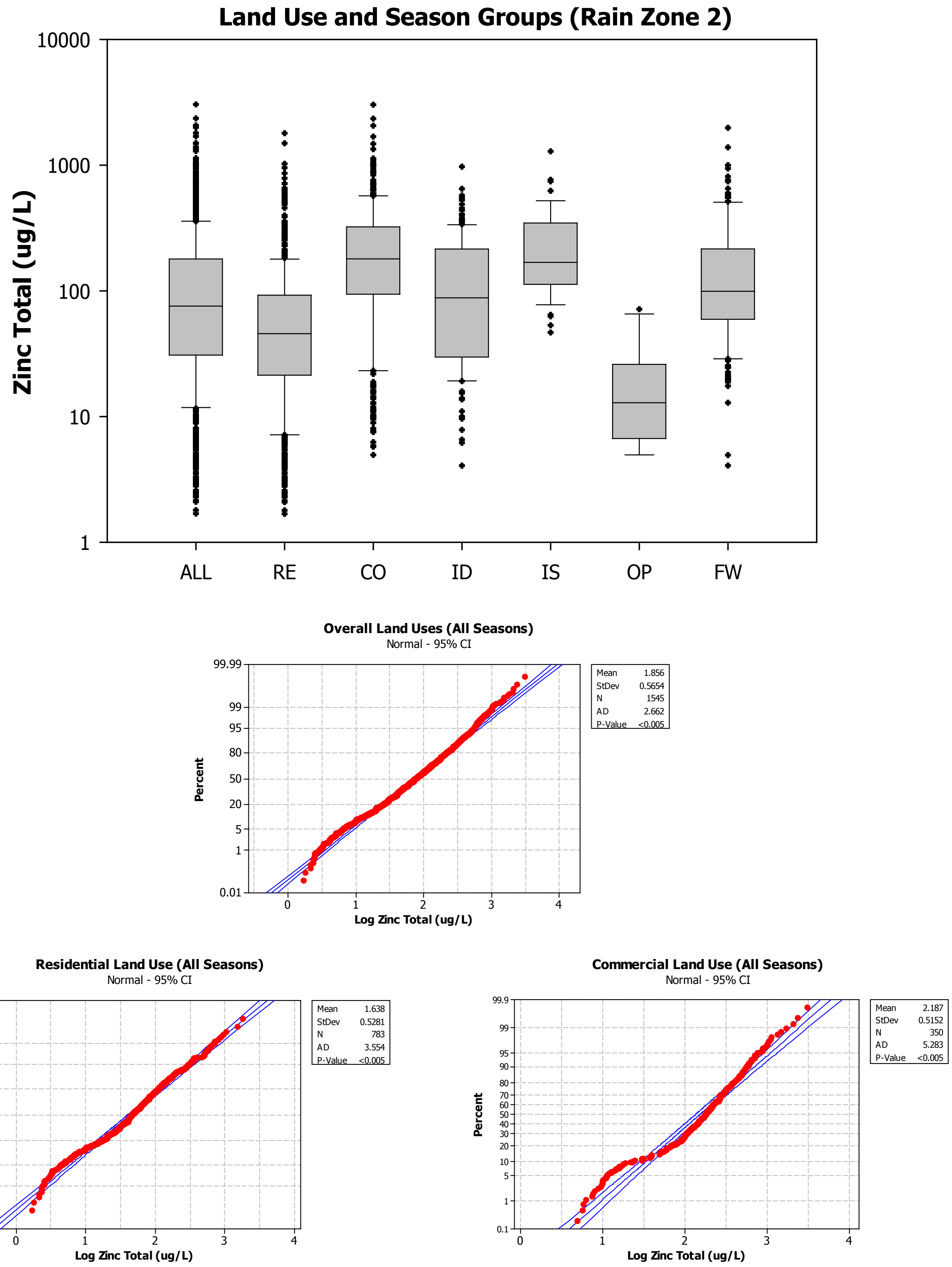


Fig. C17. Total Zinc – Land Use and Season Groups

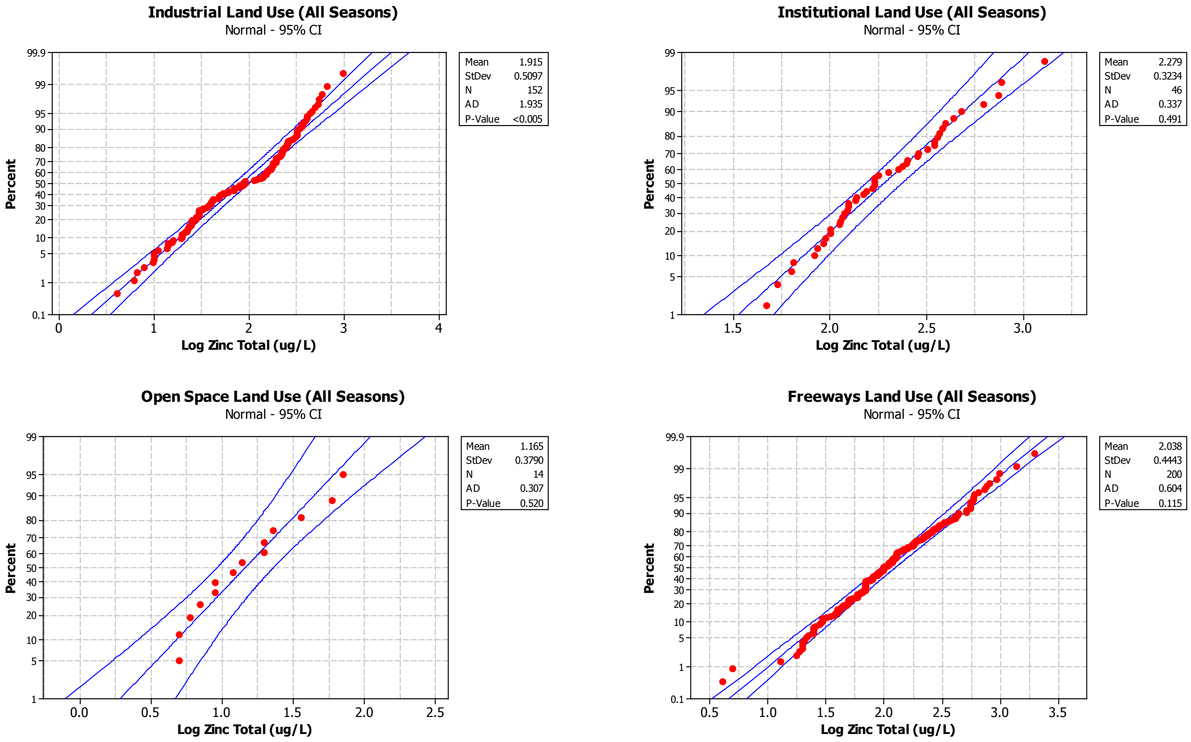


Fig. C17. – *Continued*

Table C9. Statistical Analyses for Total Zinc – Land Use and Season Groups

Kruskal-Wallis Test
(Log Total Zinc: Land Use and Season Groups)

H = 330.38 DF = 5 P = 0.000
H = 330.39 DF = 5 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE	783	1.663	594	-16
CO	350	2.258	1050	13
ID	152	1.948	816	1.3
IS	46	2.23	1134	5.6
OP	14	1.113	245	-4.5
FW	200	2.00	909	4.6
Overall	1545		773	

Land Use and Season Groups
(medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE	1.663			
CO		2.258		
IS		2.230		
ID			1.948	
FW			2.00	
OP				1.113

Table C10. Land Use and Season Multiple Comparisons for Total Zinc

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
RE	CO	0.000*	CO	ID	0.000*	ID	IS	0.000*
	ID	0.000*		IS	0.661		OP	0.000*
	IS	0.000*		OP	0.000*		FW	0.066
	OP	0.000*		FW	0.000*			
	FW	0.000*				IS	OP	0.000*
			OP	FW	0.000*		FW	0.000*

Table C11. All Possible Land Use and Season Combinations for Total Zinc

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE	1.663			
CO		2.258		
IS		2.230		
ID			1.948	
FW			2.000	
OP				1.113

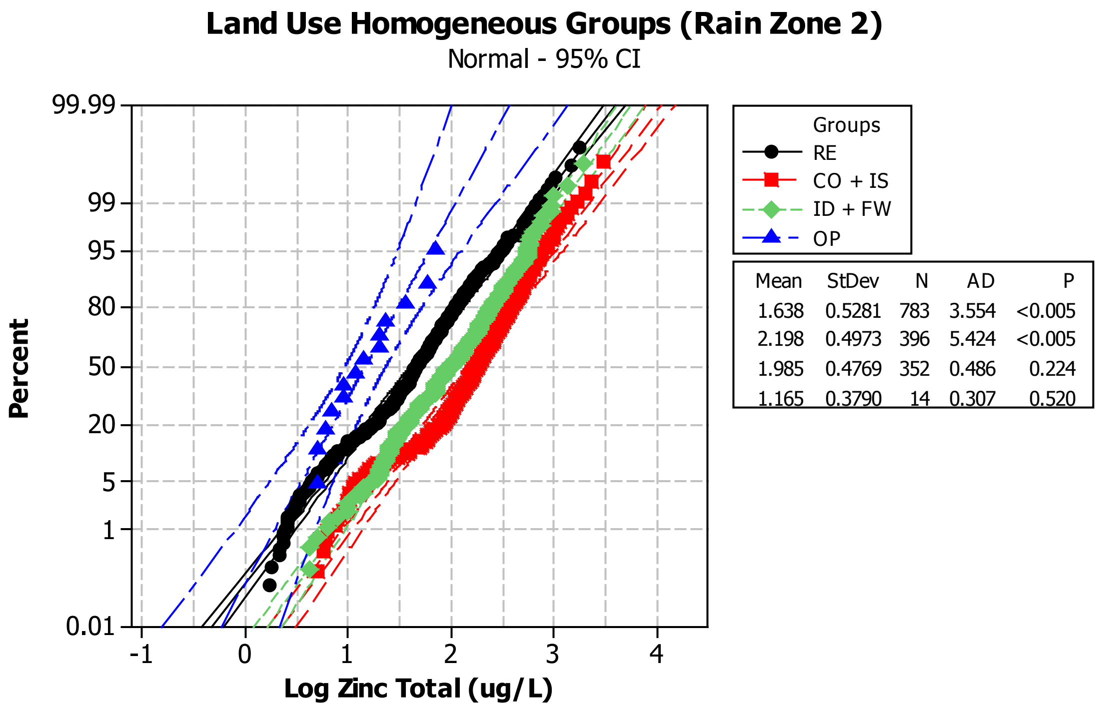
Table C12. Power of the Test for Total Zinc - Land Use and Season Groups

Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE	783	1.64	0.528
CO	350	2.19	0.515
ID	152	1.92	0.510
IS	46	2.28	0.323
OP	14	1.17	0.379
FW	200	2.04	0.444

Pooled Standard Deviation 0.450

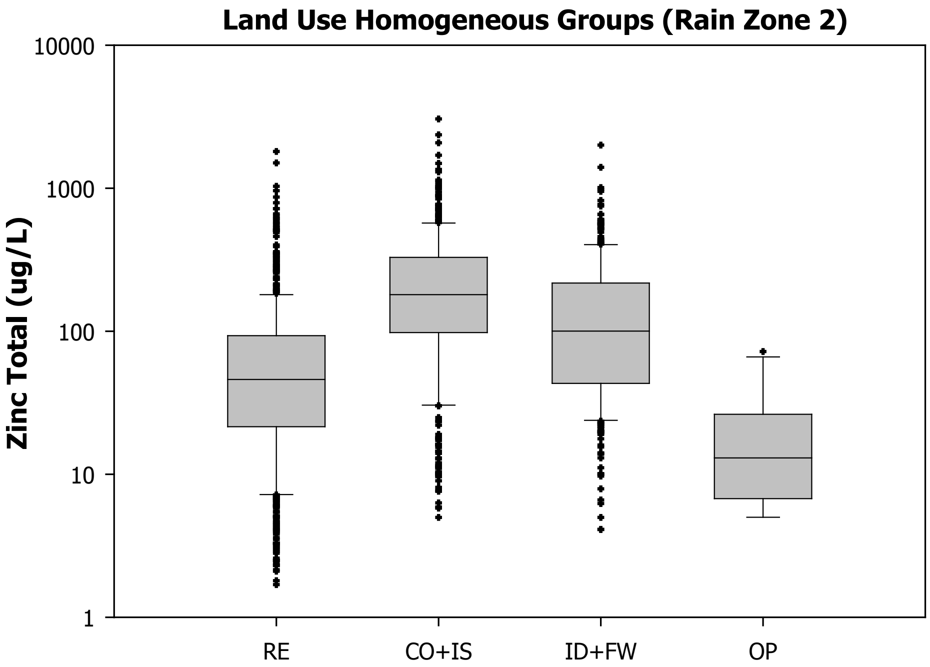
Obtained Effect Size 0.56

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100



Mean	StDev	N	AD	P
1.638	0.5281	783	3.554	<0.005
2.198	0.4973	396	5.424	<0.005
1.985	0.4769	352	0.486	0.224
1.165	0.3790	14	0.307	0.520

Fig. C18. Total Zinc – Land Use Homogeneous Groups (Checks for Normality)



Land Uses	FALL	SPRING	SUMMER	WINTER
Residential	90(1.6)	74(1.2)	114(1.8)	77(1.8)
Commercial	216(1.0)	303(1.3)	287(1.2)	283(1.2)
Industrial	127(1.5)	145(0.98)	137(0.93)	178(0.80)
Institutional	230(0.55)	190(0.68)	431(0.91)	200(0.80)
Open Space	29(0.86)	6.8(0.25)	ND	17(0.80)
Freeways	235(1.5)	101(0.82)	186(0.98)	182(1.0)

Fig. C19. Total Zinc – Land Use Homogeneous Groups: Mean (CV)

Table C13. Statistical Analyses for Total Zinc – Land Use Homogeneous Groups

Kruskal-Wallis Test (Log Total Zinc: Homogeneous Groups)

H = 325.23 DF = 3 P = 0.000
H = 325.23 DF = 3 P = 0.000
(adjusted for ties)

Groups		N	Median	Ave Rank	Z
1	RE	783	1.663	594	-16
2	CO , IS	396	2.255	1060	15
3	ID , FW	352	2.000	869	4.6
4	OP	14	1.113	245	-5
Overall		1545		773	

Multiple Comparisons

(Mann-Whitney U Test)

(I) Group	(J) Group	p-value
1	2	0.000*
	3	0.000*
	4	0.001*
2	3	0.000*
	4	0.000*
3	4	0.000*

Log Total Zinc Homogeneous Groups (medians)

Groups	Gr.A	Gr.B	Gr.C	Gr.D
1	1.663			
2		2.255		
3			2.000	
4				1.113

Table C14. Power of the Test for Total Zinc - Land Use Homogeneous Groups

Homogeneous Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE	783	1.64	0.528
CO , IS	396	2.20	0.497
ID , FW	352	1.99	0.477
OP	14	1.17	0.379
Pooled Standard Deviation			0.470
Obtained Effect Size			0.53

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Table C15. Basic Statistics for Total Zinc Homogeneous Groups (Real Space Data)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	RE	783	87.3	143	1.6	1.69	46	1807
B	CO , IS	396	268	315	1.2	4.99	180	3050
C	ID , FW	352	169	207	1.2	4.10	100	2000
D	OP	14	21.3	21	0.98	5.00	13	72

C.2. Total Copper

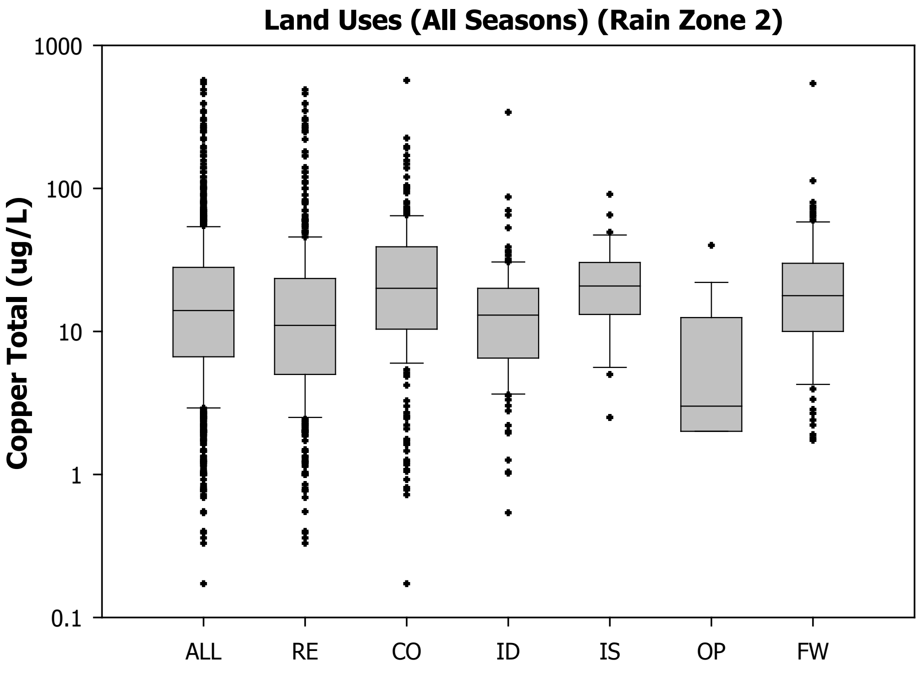
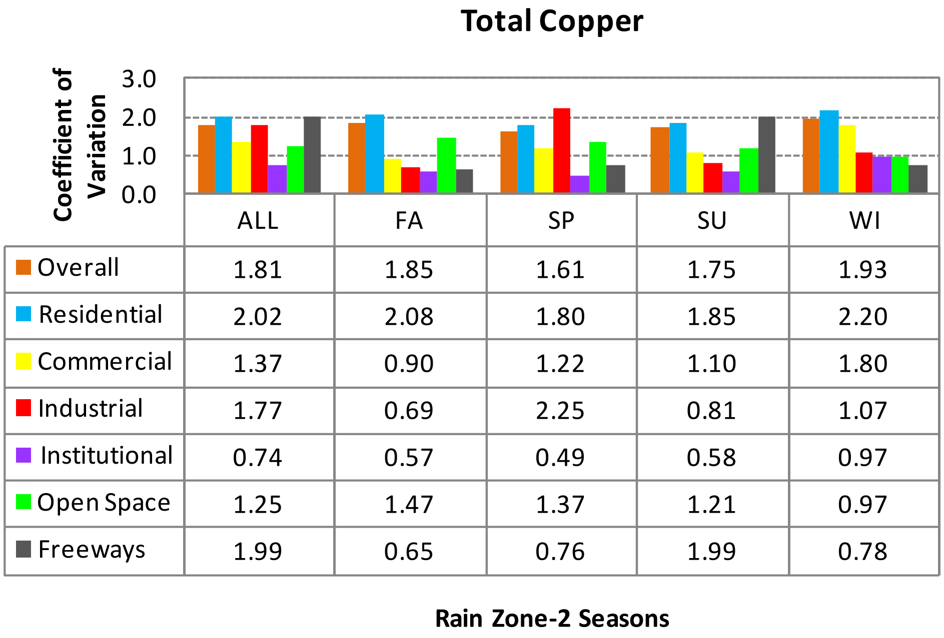


Fig. C20. Total Copper - Single Land Uses in EPA Rain Zone 2



	ALL	FA	SP	SU	WI
🟧 Overall	1.81	1.85	1.61	1.75	1.93
🟦 Residential	2.02	2.08	1.80	1.85	2.20
🟨 Commercial	1.37	0.90	1.22	1.10	1.80
🟥 Industrial	1.77	0.69	2.25	0.81	1.07
🟪 Institutional	0.74	0.57	0.49	0.58	0.97
🟩 Open Space	1.25	1.47	1.37	1.21	0.97
⬛ Freeways	1.99	0.65	0.76	1.99	0.78

Fig. C21. Total Copper - EPA Rain Zone 2 Seasonal Coefficients of Variation

C.2.1 Total Copper - All Land Uses

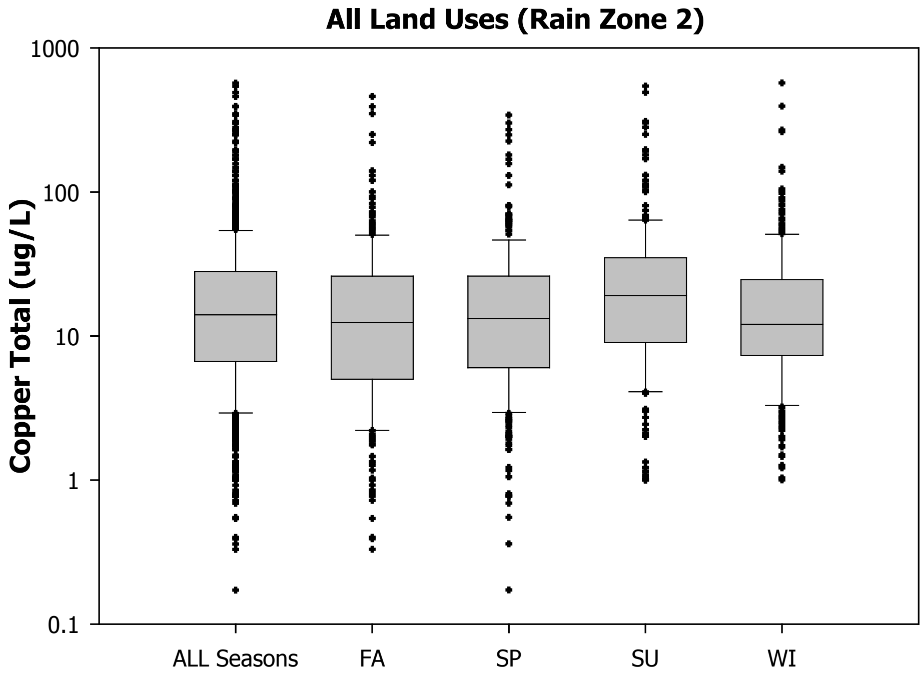


Fig. C22. Total Copper – All Single Land Uses by Season

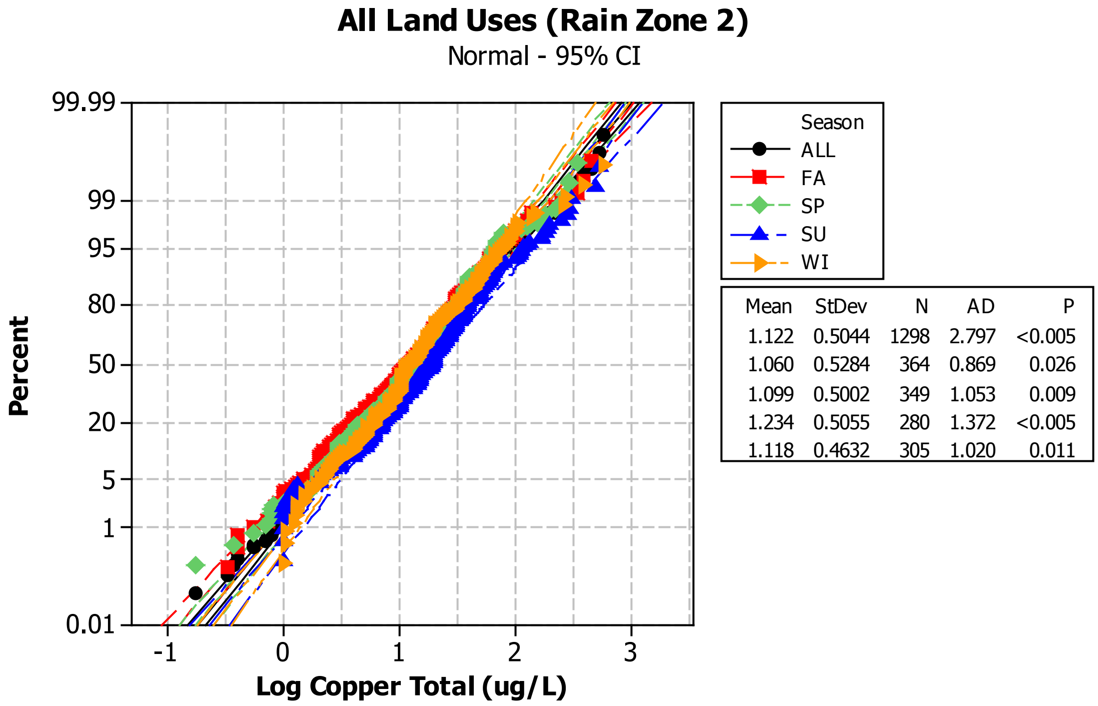


Fig. C23. Total Copper – All Single Land Uses (Checks for Normality)

Table C16. Statistical Analyses for Total Copper - All Single Land Uses

Kruskal-Wallis Test
(All Land Uses: Log Total Copper)

H = 20.12 DF = 3 P = 0.000
H = 20.13 DF = 3 P = 0.000 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	364	1.094	608.8	-2.4
SP	349	1.119	635.8	-0.8
SU	280	1.279	735.9	4.4
WI	305	1.079	634.5	-0.8
Overall	1298		649.5	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.323
	SU	0.000*
	WI	0.343
SP	SU	0.001*
	WI	0.993
SU	WI	0.001*

All Land Uses
Log Total Copper
Groups (medians)

Season	Gr. 1	Gr. 2
FA	1.094	
WI	1.079	
SP	1.119	
SU		1.279

Table C17. Power of the Test for Total Copper - All Single Land Uses

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	
FA	364	1.06	0.528	
SP	349	1.10	0.500	
SU	280	1.23	0.506	
WI	305	1.12	0.463	

Pooled Standard Deviation 0.499

Obtained Effect Size 0.12

α level	**Power (%)**
0.20	99.5
0.15	99.2
0.10	98.6
0.05	***97.1***
0.01	90.2

C.2.2 Total Copper - Residential Land Use

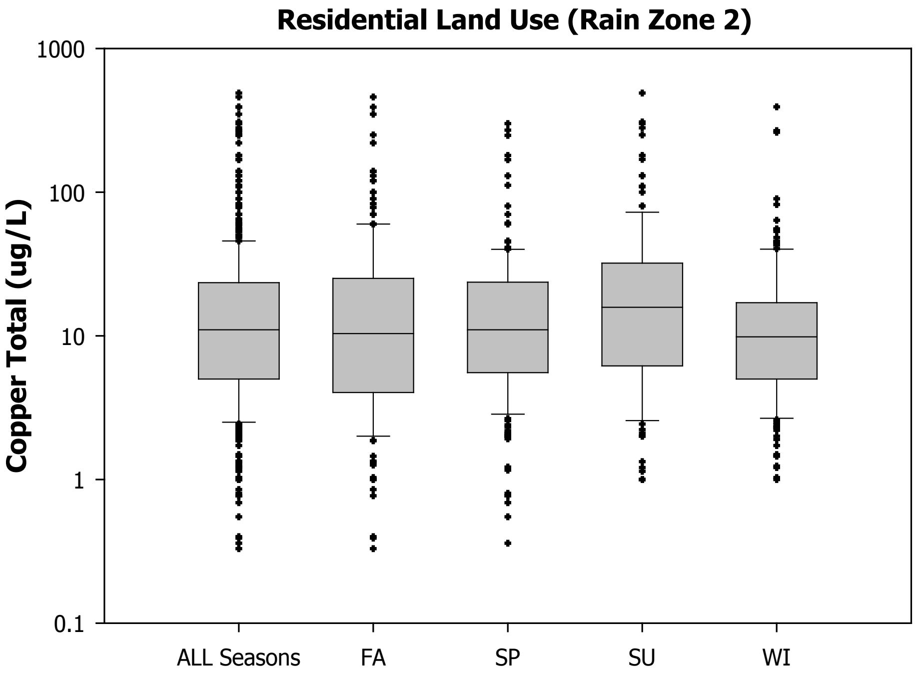


Fig. C24. Total Copper – Residential Land Use by Season

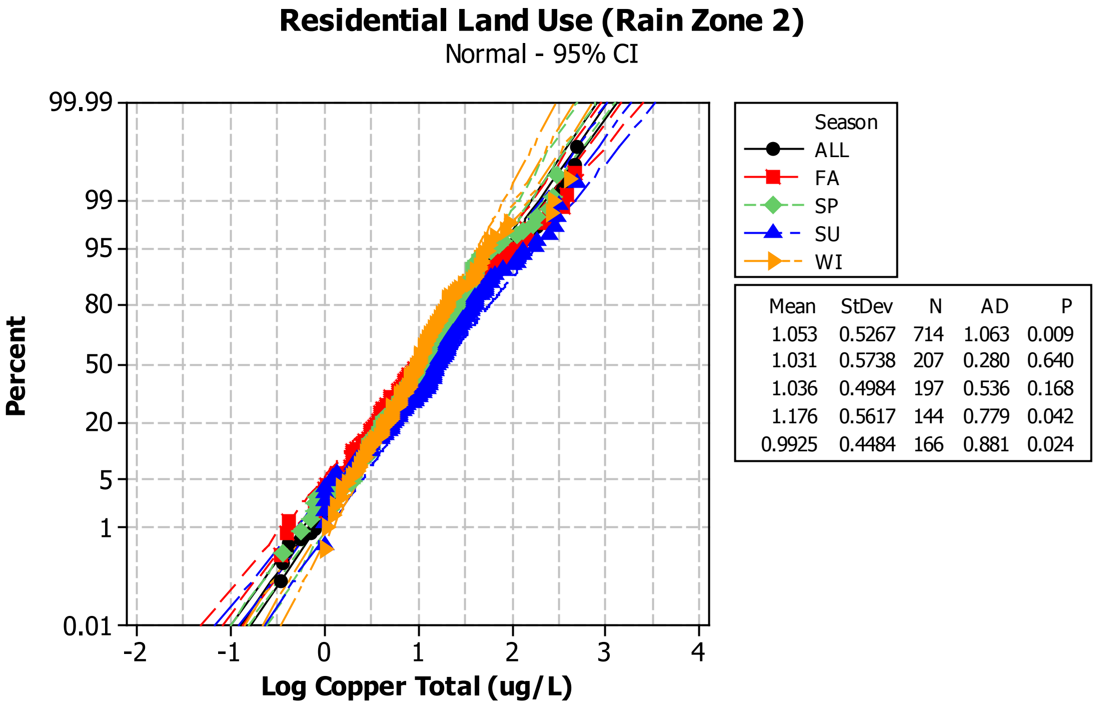


Fig. C25. Total Copper – Residential Land Use (Checks for Normality)

Table C18. Statistical Analyses for Total Copper - Residential Land Use

Kruskal-Wallis Test
(Residential: Log Total Copper)

H = 12.99 DF = 3 P = 0.005
H = 13.00 DF = 3 P = 0.005(adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	207	1.016	348.1	-0.78
SP	197	1.041	353.9	-0.29
SU	144	1.199	409.6	3.39
WI	166	0.993	328.3	-2.08
Overall	714		357.5	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.761
	SU	0.012*
	WI	0.461
SP	SU	0.012*
	WI	0.230
SU	WI	0.000*

Residential
Log Total Copper
Groups (medians)

Season	Gr. 1	Gr. 2
FA	1.016	
SP	1.041	
WI	0.993	
SU		1.199

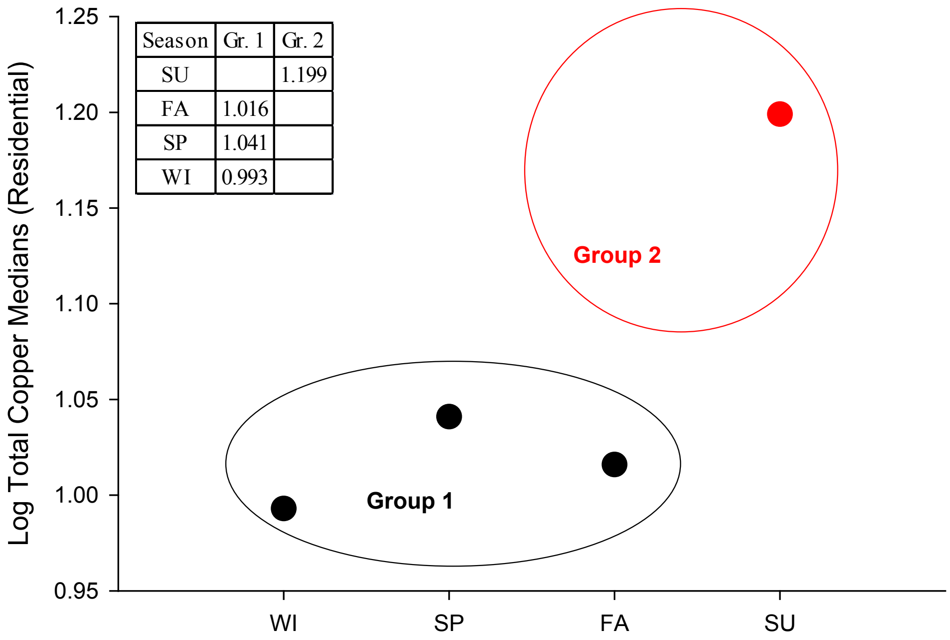


Fig. C26. All Possible Seasonal Combinations for Total Copper – Residential Land Use

Table C19. Power of the Test for Total Copper - Residential Land Use

Season	**n**	**$\mu_{\bar{x}}$**	**$\sigma_{\bar{x}}$**
FA	207	1.03	0.574
SP	197	1.04	0.498
SU	144	1.18	0.562
WI	166	0.993	0.448
Pooled Standard Deviation			0.521
Obtained Effect Size			0.13

α level	**Power (%)**
0.20	94.3
0.15	92.1
0.10	88.5
0.05	***81.2***
0.01	61.0

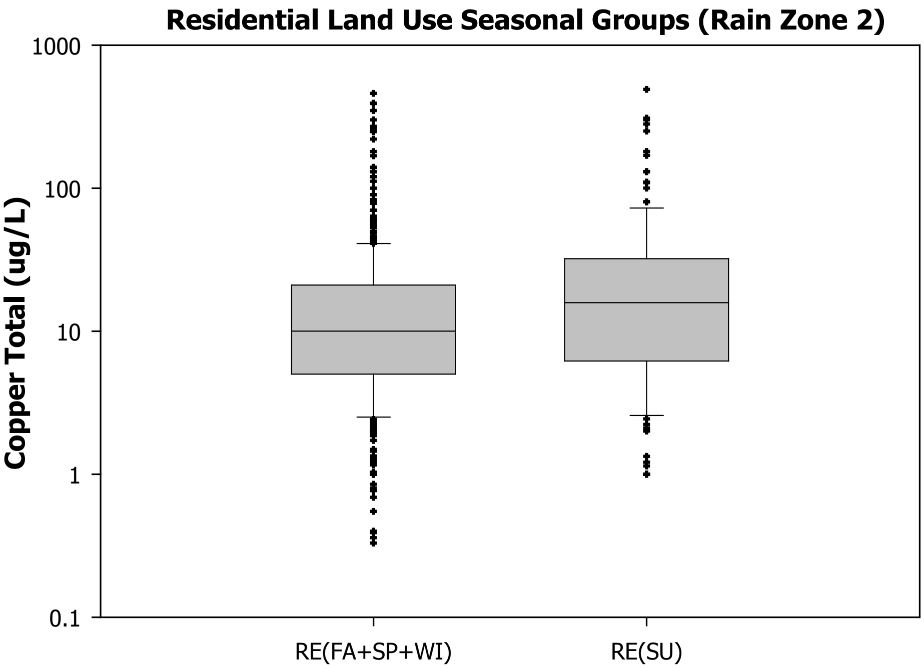


Fig. C27. Total Copper – Residential Land Use Seasonal Groups

Table C20. Statistical Analyses for Total Copper – Residential Land Use Seasonal Groups

Kruskal-Wallis Test
(Residential: Log Total Copper Groups)

H = 11.49 DF = 1 P = 0.001
H = 11.50 DF = 1 P = 0.001
(adjusted for ties)

Groups	**N**	**Median**	**Ave Rank**	**Z**
RE(FA, SP,WI)	570	1.00	344	-3.4
RE(SU)	144	1.199	410	3.39
Overall	714		358	

Power of the Test (Residential: Log Total Copper Groups)

Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,SP,WI)	570	1.02	0.513
RE(SU)	144	1.18	0.562

Pooled Standard Deviation 0.538
Obtained Effect Size 0.12

α level	**Power (%)**
0.20	97.2
0.15	96.0
0.10	93.8
0.05	***89.0***
0.01	72.7

C.2.3 Total Copper - Commercial Land Use

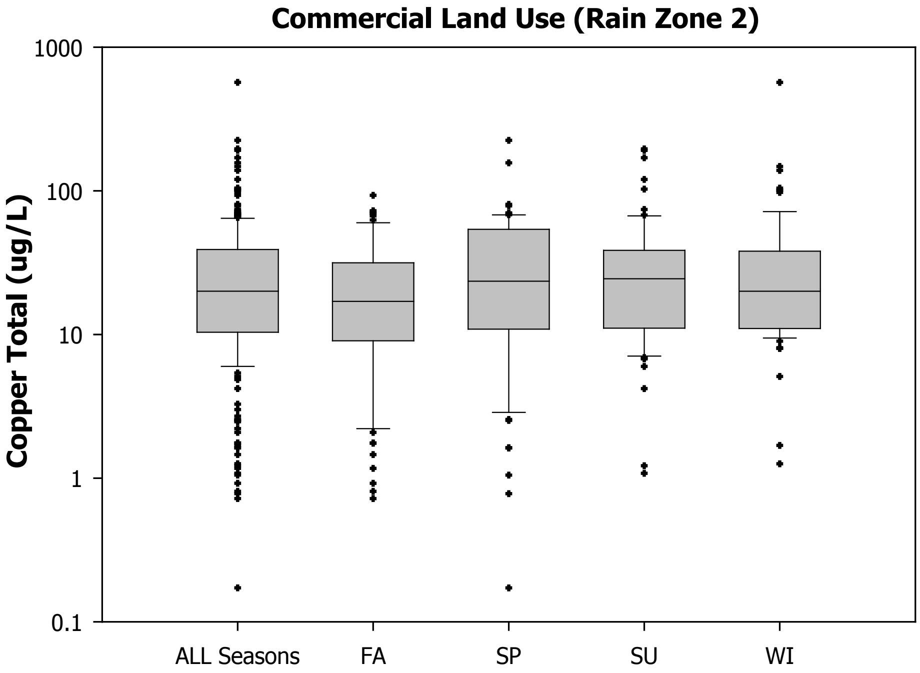
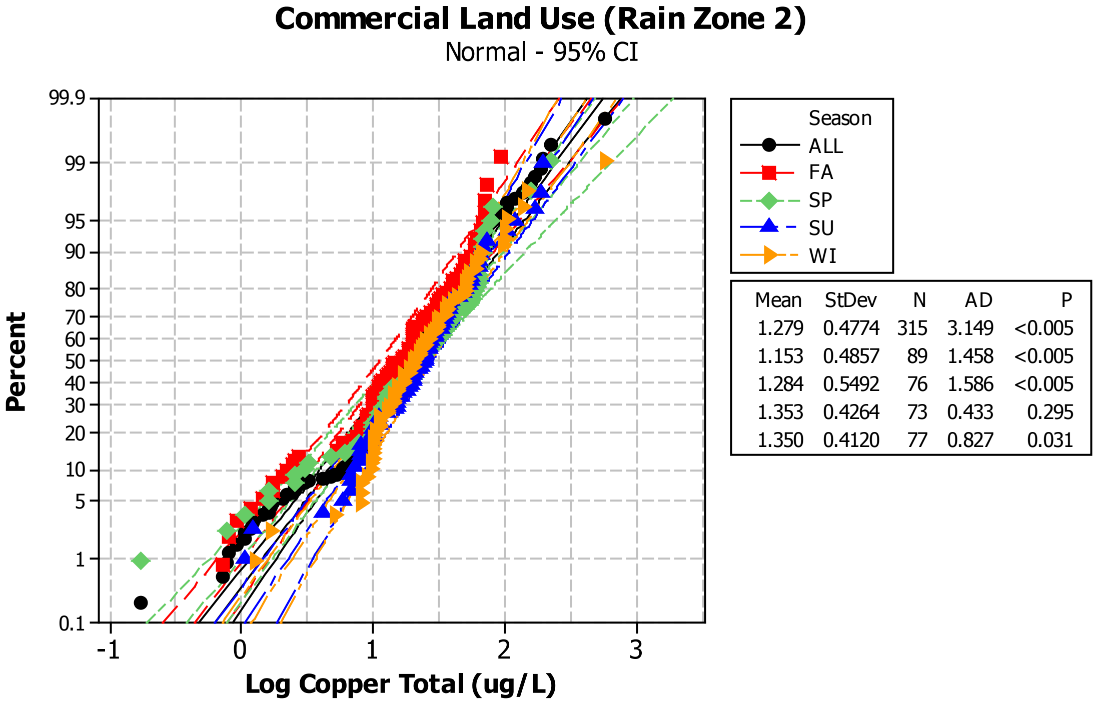


Fig. C28. Total Copper – Commercial Land Use by Season



Mean	StDev	N	AD	P
1.279	0.4774	315	3.149	<0.005
1.153	0.4857	89	1.458	<0.005
1.284	0.5492	76	1.586	<0.005
1.353	0.4264	73	0.433	0.295
1.350	0.4120	77	0.827	0.031

Fig. C29. Total Copper – Commercial Land Use (Checks for Normality)

Table C21. Statistical Analyses for Total Copper - Commercial Land Use

Kruskal-Wallis Test
(Commercial: Log Total Copper)

H = 7.73 DF = 3 P = 0.052
H = 7.74 DF = 3 P = 0.052(adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	89	1.230	13	-3
SP	76	1.371	167	1.0
SU	73	1.388	169	1.2
WI	77	1.301	165	0.8
Overall	315		158	

Power of the Test (Commercial: Log Total Copper)

Season	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
FA	89	1.15	0.486
SP	76	1.28	0.549
SU	73	1.35	0.426
WI	77	1.35	0.412

Pooled Standard Deviation 0.468

Obtained Effect Size 0.18

α level	Power (%)
0.20	91.2
0.15	89.5
0.10	85.1
0.05	***76.5***
0.01	54.3

C.2.4 Total Copper - Industrial Land Use

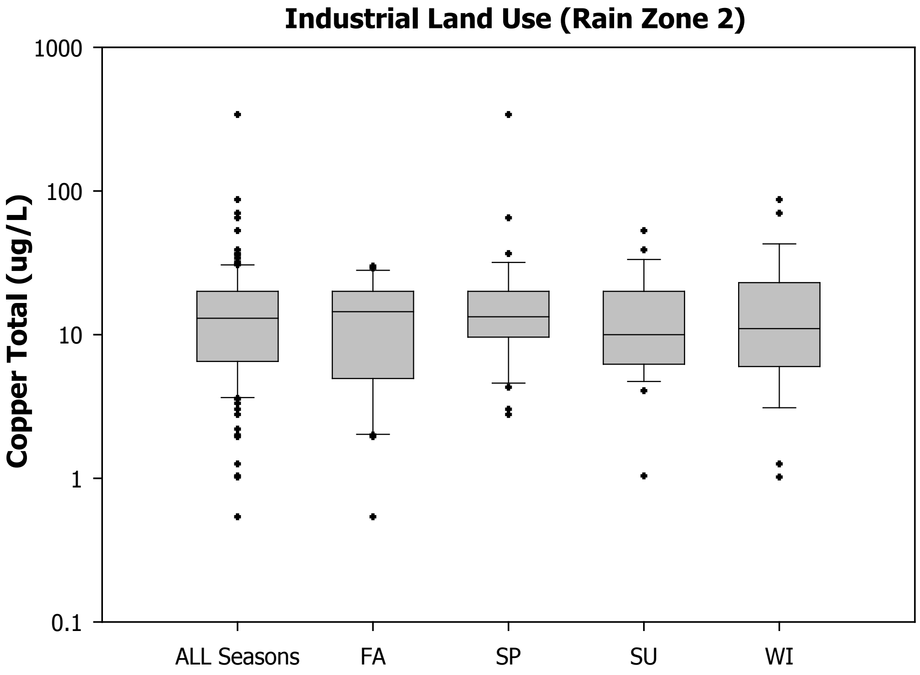


Fig. C30. Total Copper – Industrial Land Use by Season

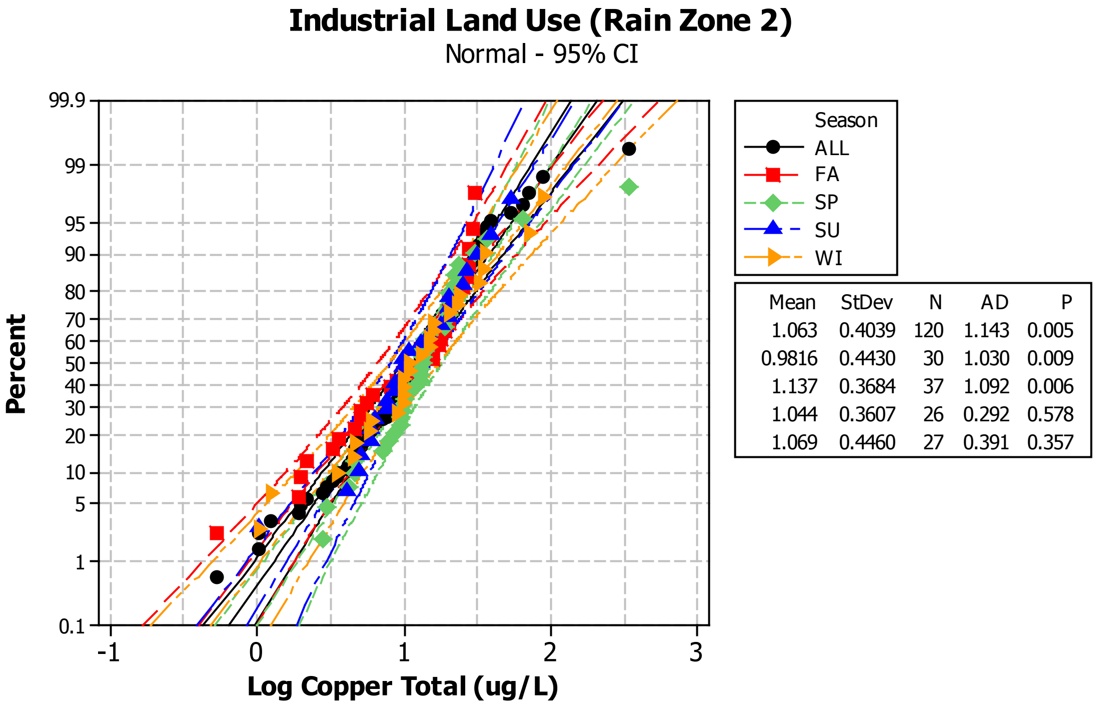


Fig. C31. Total Copper – Industrial Land Use (Checks for Normality)

Table C22. Statistical Analyses for Total Copper - Industrial Land Use

Kruskal-Wallis Test (Industrial: Log Total Copper)

H = 0.84 DF = 3 P = 0.839
H = 0.84 DF = 3 P = 0.839 (adjusted for ties)

Season	**N**	**Median**	**Ave Rank**	**Z**
FA	30	1.156	57.5	-0.55
SP	37	1.124	64.3	0.79
SU	26	1.00	57.7	-0.46
WI	27	1.041	61.4	0.15
Overall	120		60.5	

Power of the Test (Industrial: Log Total Copper)

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	30	0.9□2	0.443
SP	37	1.14	0.368
SU	26	1.04	0.361
WI	27	1.07	0.446

Pooled Standard Deviation 0.405

Obtained Effect Size 0.15

α level	**Power (%)**
0.20	50.5
0.15	43.5
0.10	35.0
0.05	***24.1***
0.01	8.8

C.2.5 Total Copper - Institutional Land Use

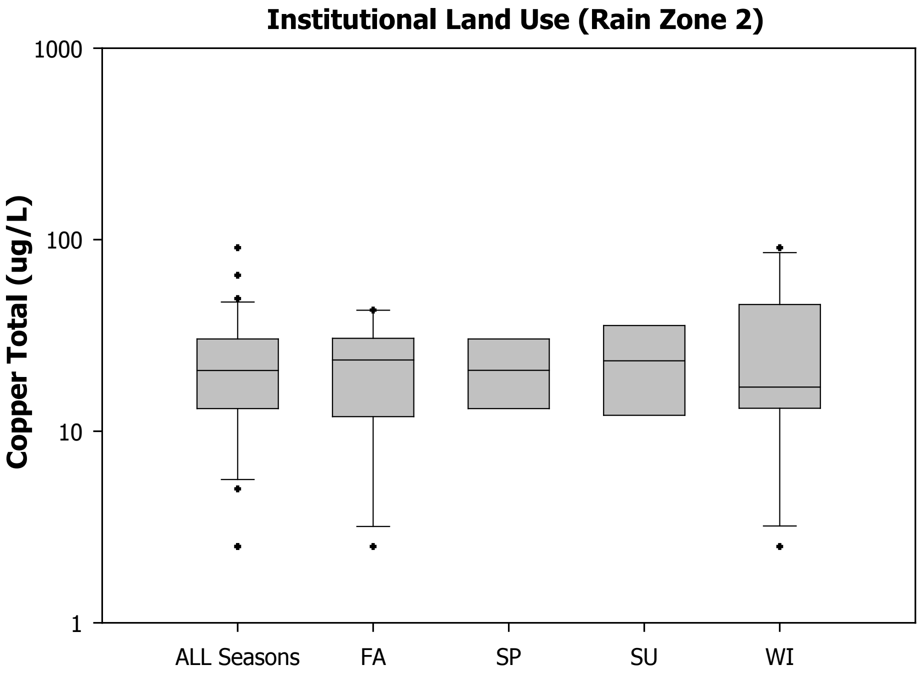
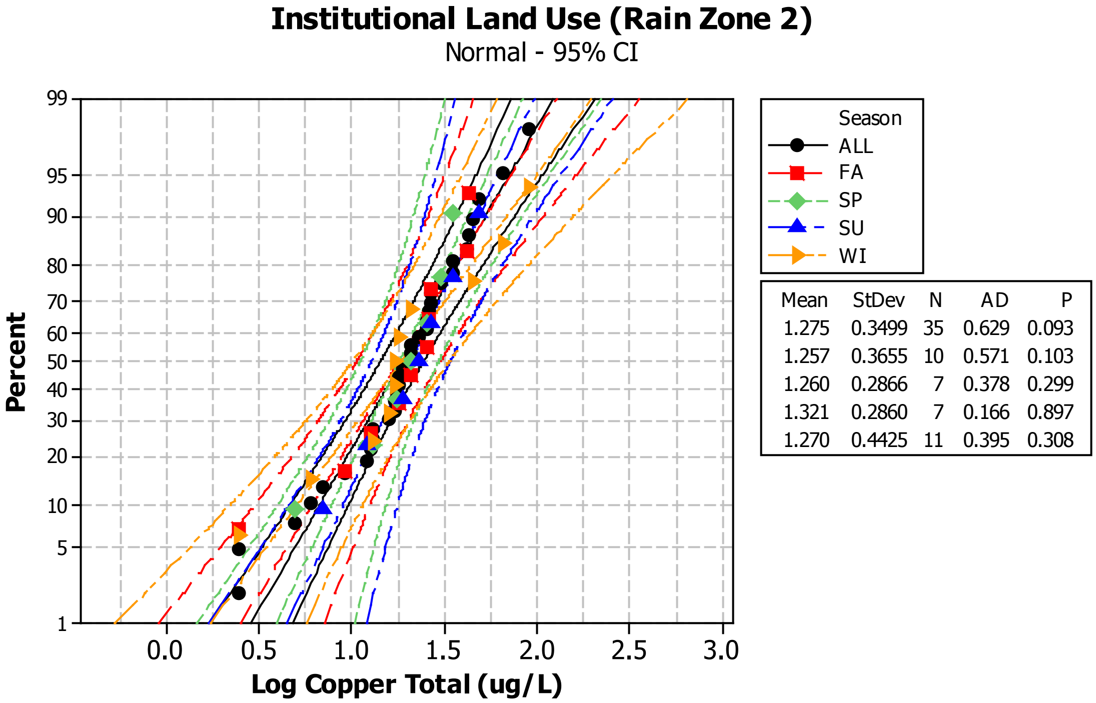


Fig. C32. Total Copper – Institutional Land Use by Season



Mean	StDev	N	AD	P
1.275	0.3499	35	0.629	0.093
1.257	0.3655	10	0.571	0.103
1.260	0.2866	7	0.378	0.299
1.321	0.2860	7	0.166	0.897
1.270	0.4425	11	0.395	0.308

Fig. C33. Total Copper – Institutional Land Use (Checks for Normality)

Table C23. Statistical Analyses for Total Copper - Institutional Land Use

Kruskal-Wallis Test
(Institutional: Log Total Copper)

H = 0.34 DF = 3 P = 0.952
H = 0.34 DF = 3 P = 0.952 (adjusted for ties)

Season	**N**	**Median**	**Ave Rank**	**Z**
FA	10	1.369	18.4	0.13
SP	7	1.318	17.4	-0.16
SU	7	1.367	19.7	0.49
WI	11	1.23	17	-0.41
Overall	35		18	

Power of the Test (Institutional: Log Total Copper)

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	10	1.26	0.366
SP	7	1.26	0.287
SU	7	1.32	0.286
WI	11	1.27	0.443

Pooled Standard Deviation 0.346

Obtained Effect Size 0.07

α level	**Power (%)**
0.20	21.8
0.15	16.6
0.10	11.2
0.05	***5.8***
0.01	1.2

C.2.6 Total Copper – Open Space Land Use

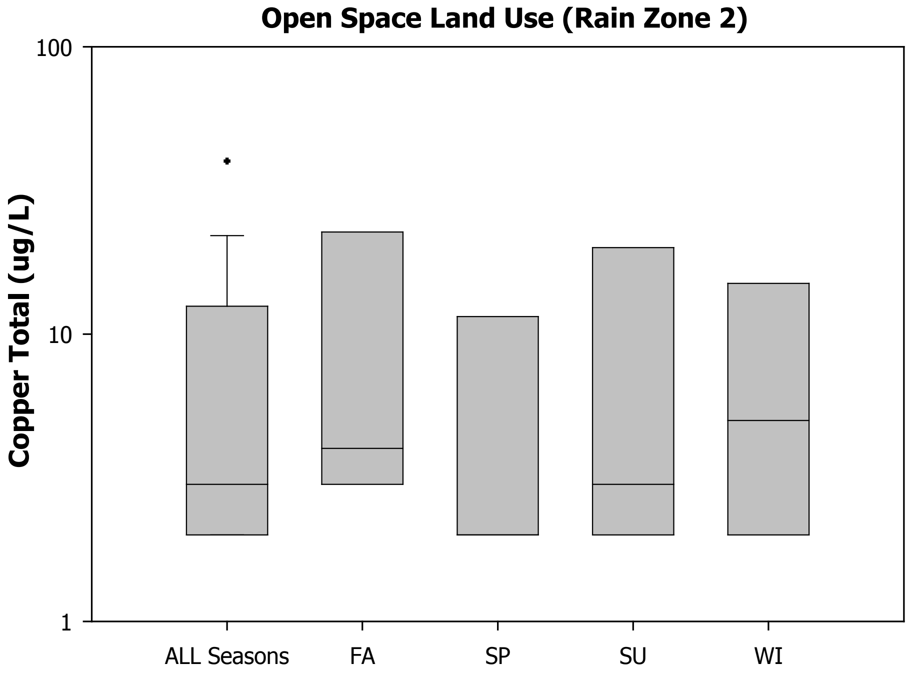
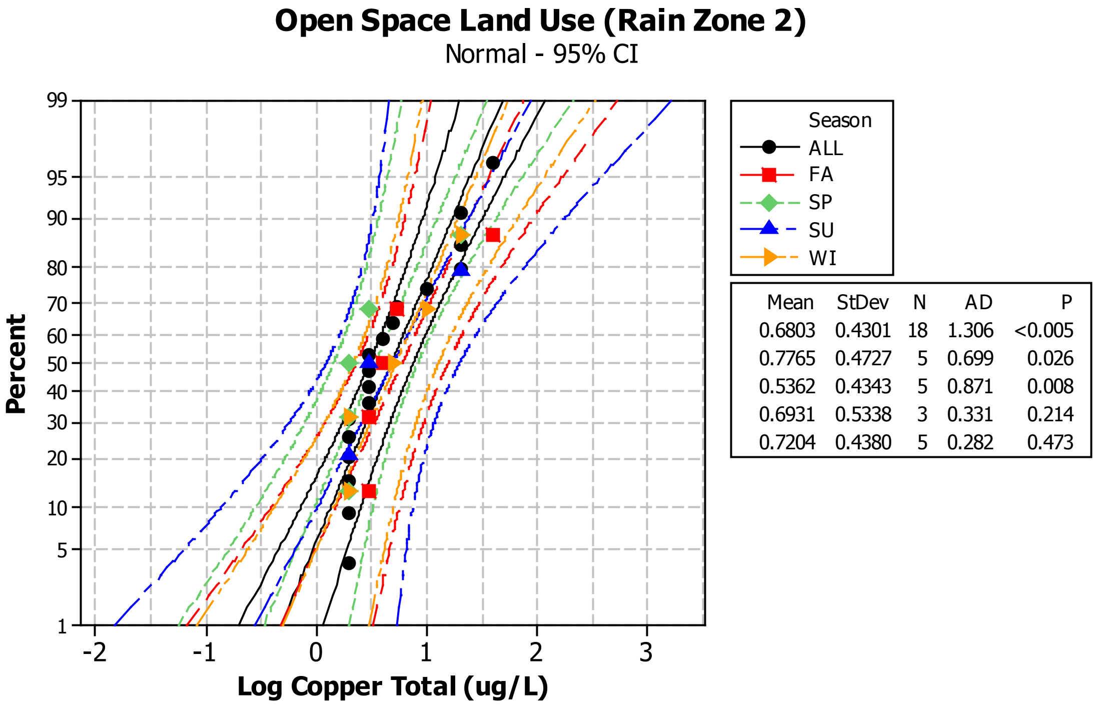


Fig. C34. Total Copper – Open Space Land Use by Season



Mean	StDev	N	AD	P
0.6803	0.4301	18	1.306	<0.005
0.7765	0.4727	5	0.699	0.026
0.5362	0.4343	5	0.871	0.008
0.6931	0.5338	3	0.331	0.214
0.7204	0.4380	5	0.282	0.473

Fig. C35. Total Copper – Open Space Land Use (Checks for Normality)

Table C24. Statistical Analyses for Total Copper - Open Space Land Use

Kruskal-Wallis Test
(Open Space: Log Total Copper)

H = 2.04 DF = 3 P = 0.563
H = 2.15 DF = 3 P = 0.541 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	5	0.602	12	1.13
SP	5	0.301	7	-1.23
SU	3	0.477	9.3	-0.06
WI	5	0.699	9.8	0.15
Overall	18		9.5	

Power of the Test (Open Space: Log Total Copper)

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	5	0.777	0.473
SP	5	0.536	0.434
SU	3	0.693	0.534
WI	5	0.720	0.438

Pooled Standard Deviation 0.470
Obtained Effect Size 0.20

α level	**Power (%)**
0.20	27.9
0.15	21.9
0.10	15.5
0.05	***8.5***
0.01	2.0

C.2.7 Total Copper - Freeways Land Use

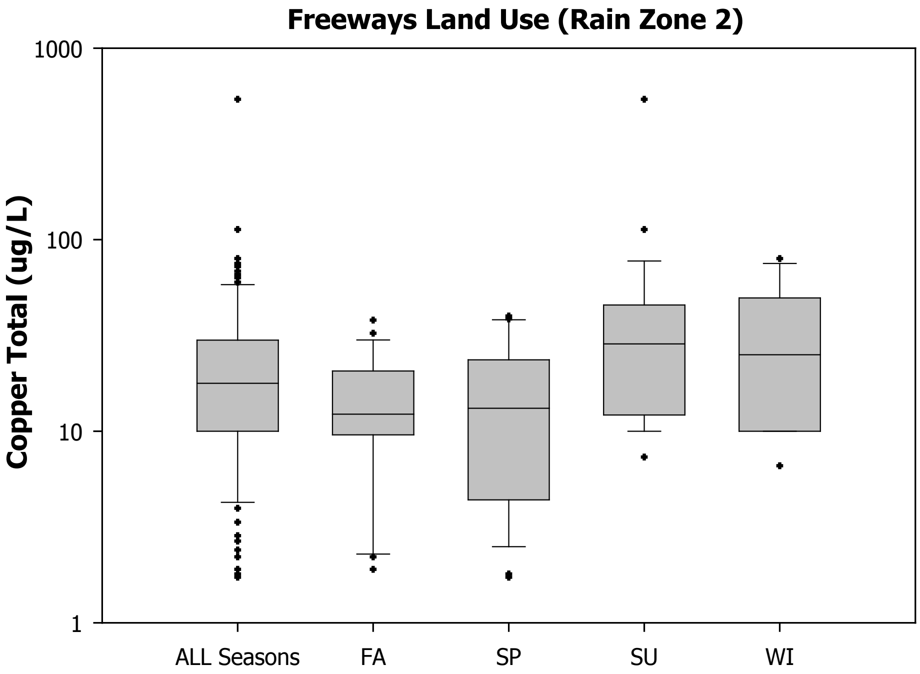
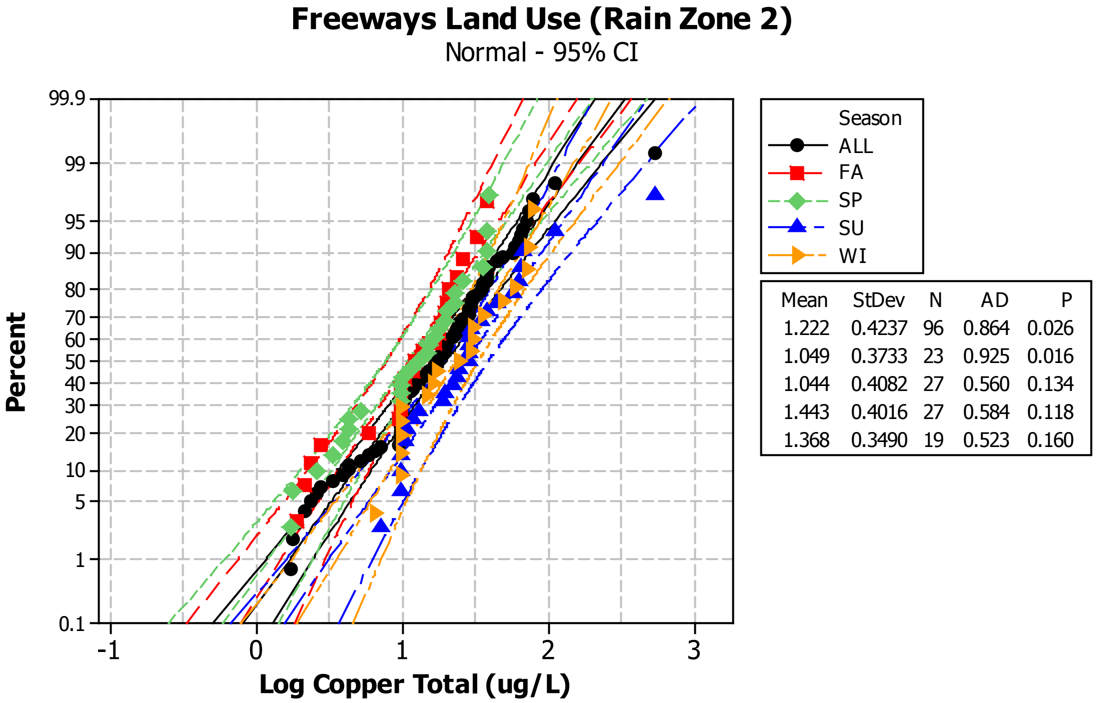


Fig. C36. Total Copper – Freeways Land Use by Season



Mean	StDev	N	AD	P
1.222	0.4237	96	0.864	0.026
1.049	0.3733	23	0.925	0.016
1.044	0.4082	27	0.560	0.134
1.443	0.4016	27	0.584	0.118
1.368	0.3490	19	0.523	0.160

Fig. C37. Total Copper – Freeways Land Use (Checks for Normality)

Table C25. Statistical Analyses for Total Copper - Freeways Land Use

Kruskal-Wallis Test
(Freeways: Log Total Copper)

H = 14.67 DF = 3 P = 0.002
H = 14.72 DF = 3 P = 0.002 (adjusted for ties)

Season	**N**	**Median**	**Ave Rank**	**Z**
FA	23	1.089	37.7	-2.1
SP	27	1.119	38.6	-2.2
SU	27	1.456	61.6	2.88
WI	19	1.399	57.1	1.51
Overall	96		48.5	

Multiple Comparisons

(Mann-Whitney U Test)

(I) Season	**(J) Season**	**p-value**
FA	SP	0.953
	SU	0.002*
	WI	0.035*
SP	SU	0.003*
	WI	0.033*
SU	WI	0.730

Freeways Log Total Copper Groups (medians)

Season	**Gr. 1**	**Gr. 2**
FA	1.089	
SP	1.119	
WI		1.399
SU		1.456

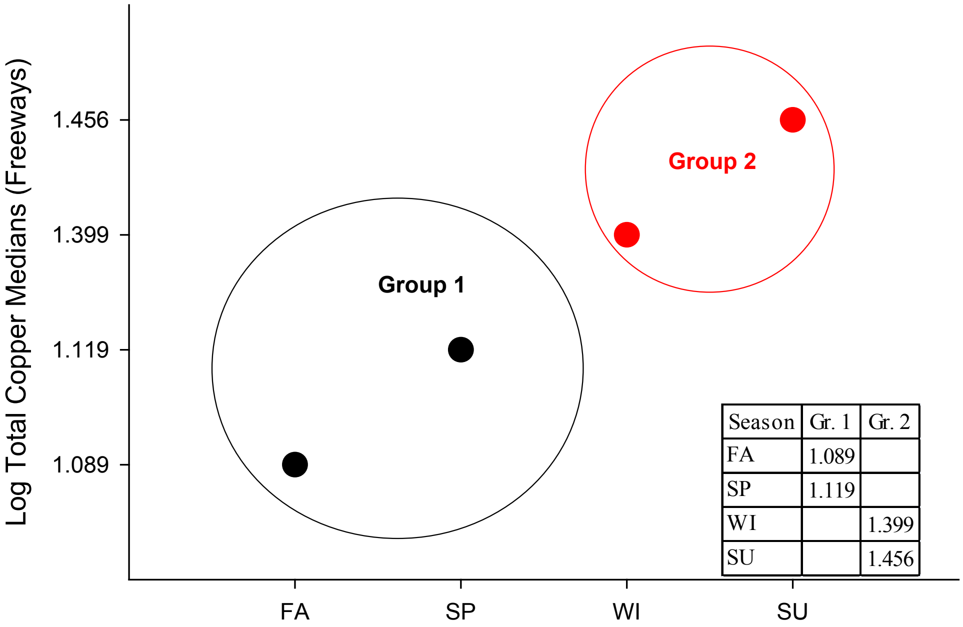


Fig. C38. All Possible Seasonal Combinations for Total Suspended Solids – Freeways Land Use

Table C26. Power of the Test for Total Copper – Freeways Land Use

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	23	1.05	0.373
SP	27	1.04	0.408
SU	27	1.44	0.402
WI	19	1.37	0.349
Pooled Standard Deviation			0.383
Obtained Effect Size			0.48

α level	**Power (%)**
0.20	99.8
0.15	99.6
0.10	99.3
0.05	***98.2***
0.01	92.9

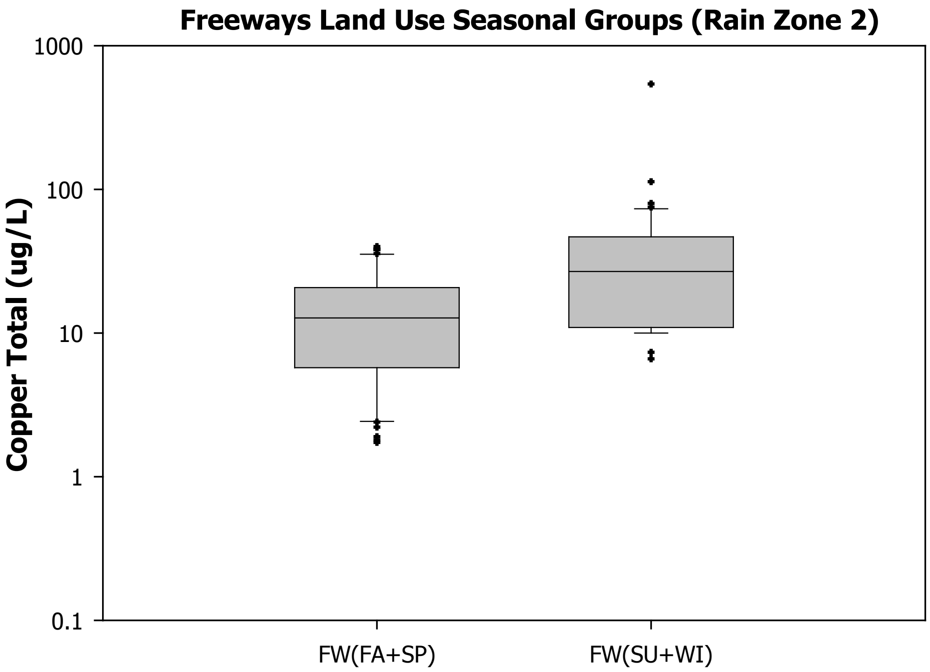


Fig. C39. Total Copper – Freeways Land Use Seasonal Groups

Table C27. Statistical Analyses for Total Copper - Freeways Land Use

Kruskal-Wallis Test
(Freeways: Log Total Copper Groups)

H = 14.38 DF = 1 P = 0.000
H = 14.42 DF = 1 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
FW(FA,SP)	50	1.104	38	-4
FW(SU,WI)	46	1.427	59	4
Overall	96		48.5	

Power of the Test (Freeways: Log Total Copper Groups)

Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FW(FA,SP)	50	1.05	0.389
FW(SU,WI)	46	1.41	0.379

Pooled Standard Deviation 0.384
Obtained Effect Size 0.47

α level	Power (%)
0.20	99.9
0.15	99.9
0.10	99.8
0.05	***99.5***
0□01	97.3

C.3.8 Total Copper Land Use and Season Groups

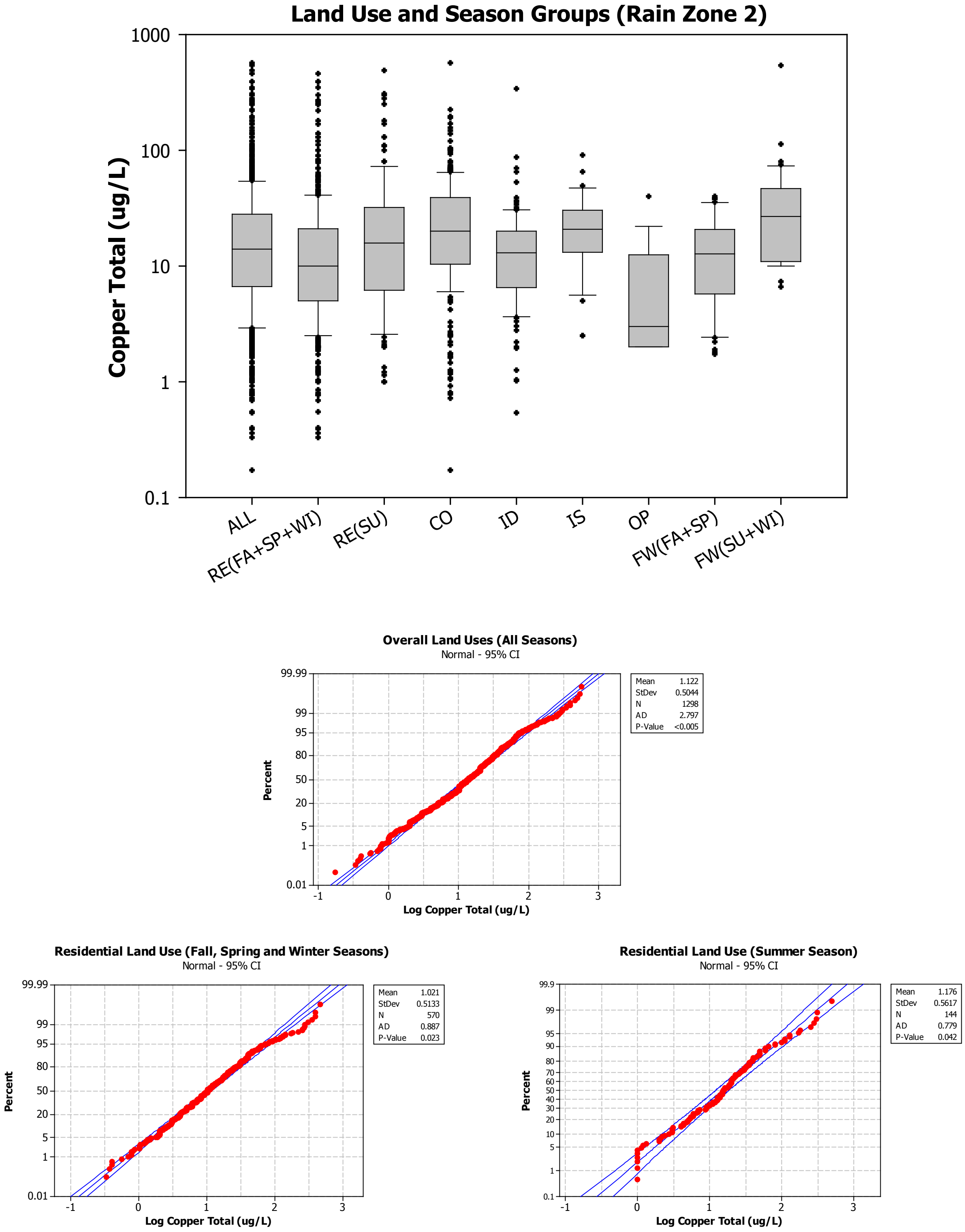


Fig. C40. Total Copper – Land Use and Season Groups

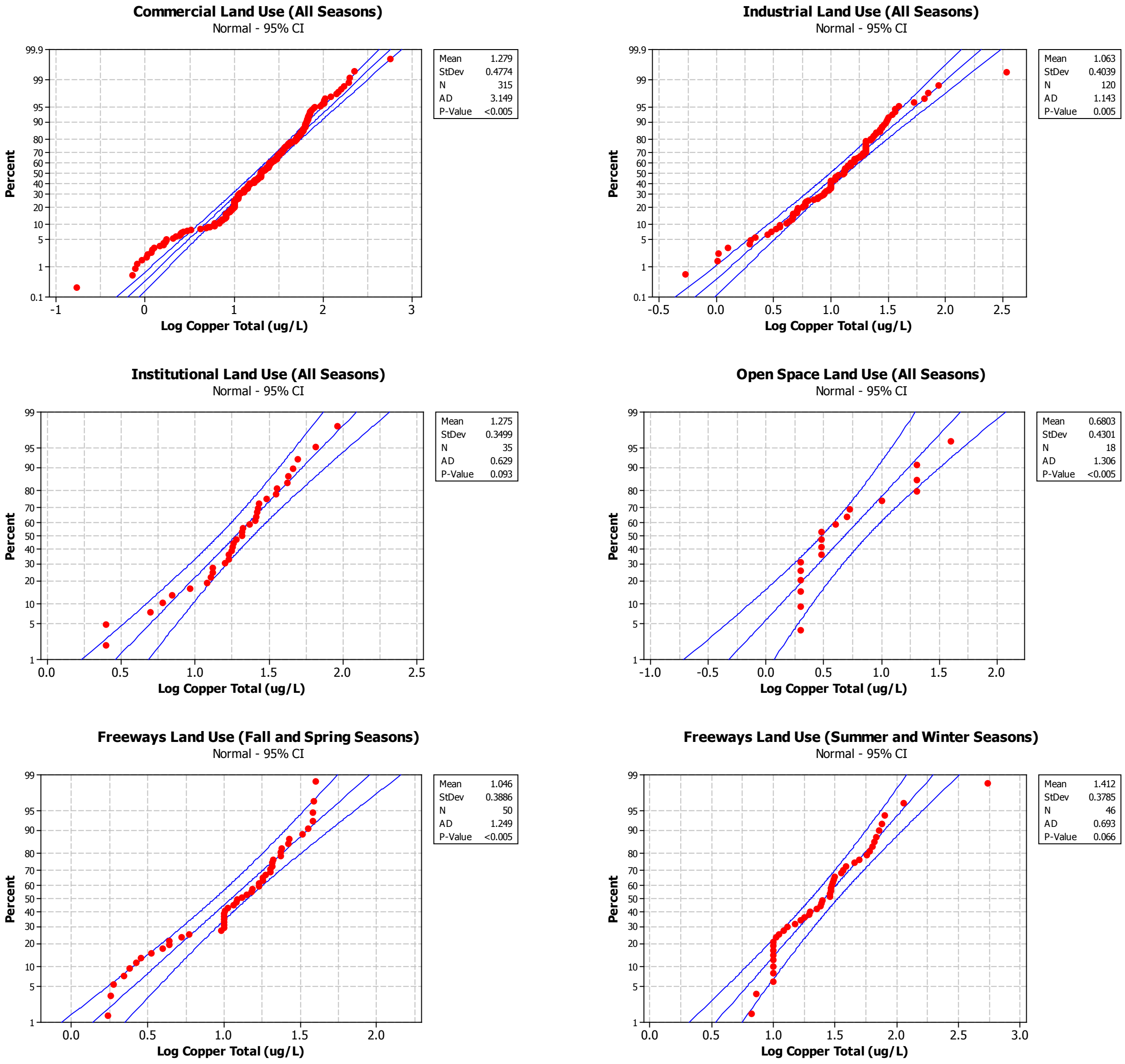


Fig. C40. - *Continued*

Table C28. Statistical Analyses for Total Copper – Land Use and Season Groups

Kruskal-Wallis Test
(Land Use and Season Groups: Log Total Copper)

H = 112.40 DF = 7 P = 0.000
H = 112.43 DF = 7 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE(FA,SP,WI)	570	1.000	563	-7.39
RE(SU)	144	1.199	688	1.31
CO	315	1.301	787	7.46
ID	120	1.114	598	-1.57
IS	35	1.317	792	2.28
OP	18	0.477	324	-3.71
FW(FA,SP)	50	1.104	600	-0.96
FW(SU,WI)	46	1.427	873	4.12
Overall	1298		650	

Land Use and Season Groups
(medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
OP	0.477			
RE(FA,SP,WI)		1.000		
FW(FA,SP)		1.104		
ID		1.114		
RE(SU)			1.199	
IS				1.317
CO				1.301
FW(SU,WI)				1.427

Table C29. Land Use and Season Multiple Comparisons for Total Copper

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
RE(FA,SP,WI)	RE(SU)	0.001*	RE(SU)	CO	0.017*
	CO	0.000*		ID	0.043
	ID	0.165		IS	0.185
	IS	0.000*		OP	0.000*
	OP	0.003*		FW(FA,SP)	0.130
	FW(FA,SP)	0.399		FW(SU,WI)	0.007*
	FW(SU,WI)	0.000*			
			ID	IS	0.001*
CO	ID	0.000*		OP	0.001*
	IS	0.849		FW(FA,SP)	0.871
	OP	0.000*		FW(SU,WI)	0.000*
	FW(FA,SP)	0.001*			
	FW(SU,WI)	0.173	IS	OP	0.000*
				FW(FA,SP)	0.006*
OP	FW(FA,SP)	0.006*		FW(SU,WI)	0.224
	FW(SU,WI)	0.000*	FW(FA,SP)	FW(SU,WI)	0.000*

Table C30. All Possible Land Use and Season Combinations for Total Copper

Groups	Gr. A	Gr. B	Gr. C	Gr. D	Gr. E
OP	0.477				
RE(FA,SP,WI)		1.000			
FW(FA,SP)		1.104	1.104		
ID		1.114	1.114		
RE(SU)			1.199	1.199	
IS				1.317	1.317
CO					1.301
FW(SU,WI)					1.427

Table C31. Power of the Test for Total Copper – Land Use and Season Groups

Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,SP,WI)	570	1.02	0.513
RE(SU)	144	1.18	0.562
CO	315	1.28	0.477
ID	120	1.06	0.404
IS	35	1.27	0.350
OP	18	0.68	0.430
FW(FA,SP)	50	1.05	0.389
FW(SU,WI)	46	1.41	0.379

Pooled Standard Deviation 0.438

Obtained Effect size 0.28

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

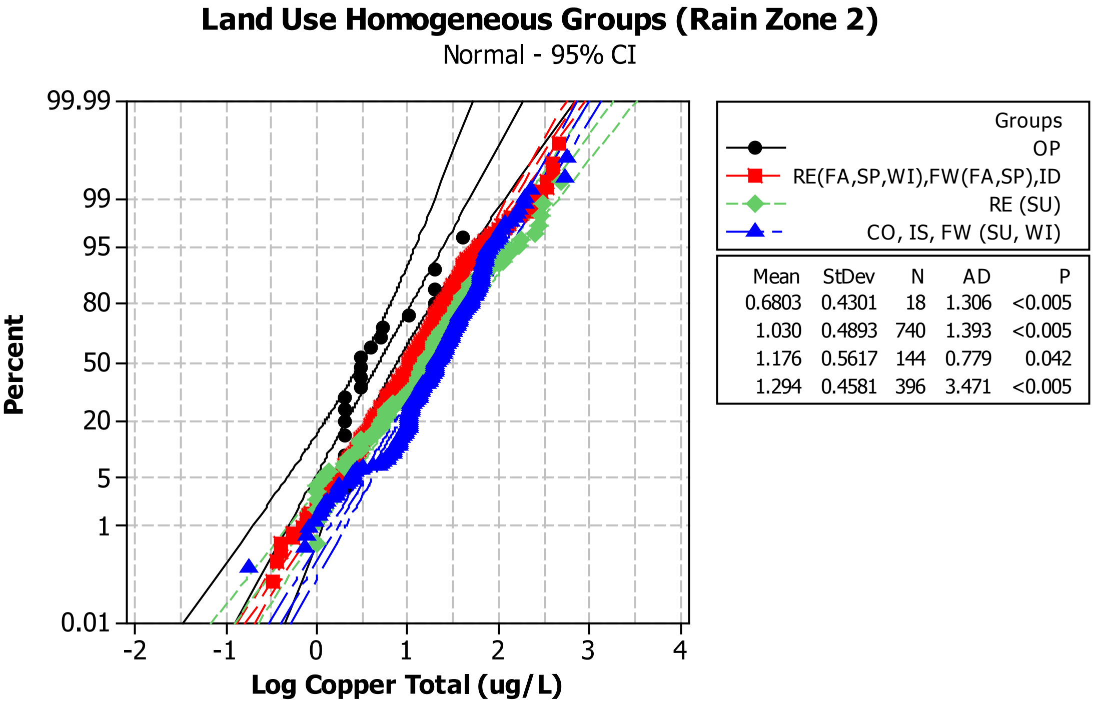
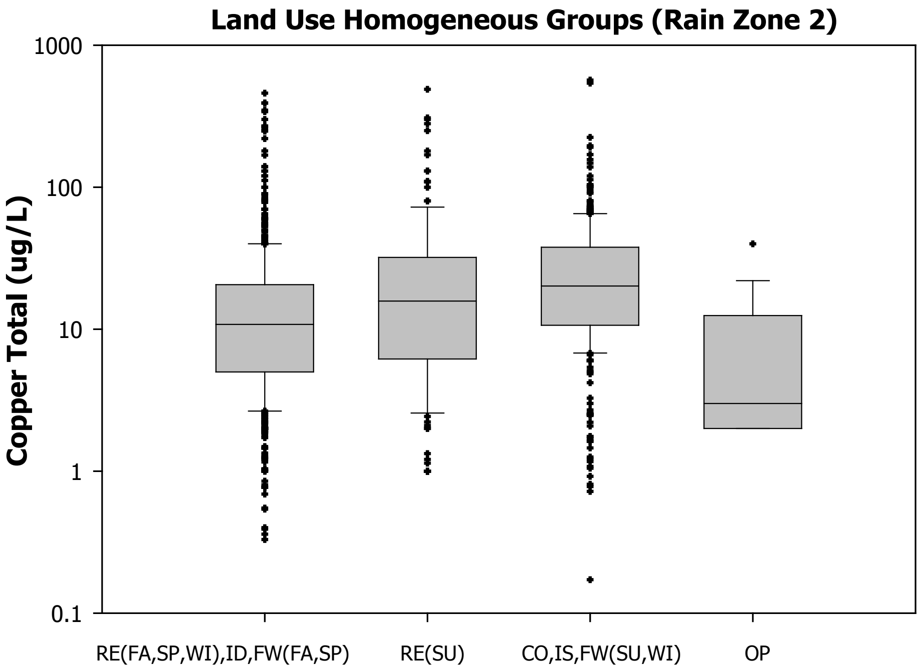


Fig. C41. Total Copper – Land Use Homogeneous Groups (Checks for Normality)



Land Uses	FALL	SPRING	SUMMER	WINTER
Residential	27(2.1)	22(1.8)	35(1.9)	19(2.2)
Commercial	23(0.90)	34(1.0)	35(1.1)	38(1.8)
Industrial	14(0.69)	24(2.3)	15(0.81)	18(1.1)
Institutional	23(0.57)	21(0.49)	25(0.58)	28(0.97)
Open Space	11(1.5)	5.8(1.4)	8.3(1.2)	7.8(0.97)
Freeways	15(0.65)	16(0.75)	51(2.0)	31(0.78)

Fig. C42. Total Copper – Land Use Homogeneous Groups: Mean (CV)

Table C32. Statistical Analyses for Total Copper – Land Use Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: Log Total Copper)

H = 109.04 DF = 3 P = 0.000
H = 109.07 DF = 3 P = 0.000 (adjusted for ties)

Groups		N	Median	Ave Rank	Z
1	RE (FA,SP,WI), FW(FA,SP), ID	740	1.034	571	-9
2	RE(SU)	144	1.199	688	1.3
3	CO, IS, FW (SU,WI)	396	1.304	797	9.4
4	OP	18	0.477	324	-4
	Overall	1298		650	

Multiple Comparisons

(Mann-Whitney U Test)

(I) Group	(J) Group	p-value
1	2	0.001*
	3	0.000*
	4	0.002*
2	3	0.006*
	4	0.000*
3	4	0.000*

Log Total Copper
Homogeneous Groups
(medians)

Group	Gr.A	Gr.B	Gr.C	Gr.D
1	1.034			
2		1.199		
3			1.304	
4				0.477

Table C33. Power of the Test for Total Copper – Land Use Homogeneous Groups

Homogeneous Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,SP,WI), FW(FA,SP), ID	740	1.03	0.489
RE(SU)	144	1.18	0.562
CO, IS, FW(SU,WI)	396	1.29	0.458
OP	18	0.68	0.430
Pooled Standard Deviation			0.485
Obtained Effect Size			0.26

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Table C34. Basic Statistics for Total Copper Homogeneous Groups (Real Space Data)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	RE(FA,SP,WI), FW(FA,SP), ID	740	22	43	2.0	0.33	11	460
B	RE(SU)	144	35	65	1.9	1.00	16	490
C	CO, IS, FW(SU,WI)	396	33	48	1.5	0.17	20	569
D	OP	18	8.2	10	1.3	2.00	3.0	40

C.3. Total Lead

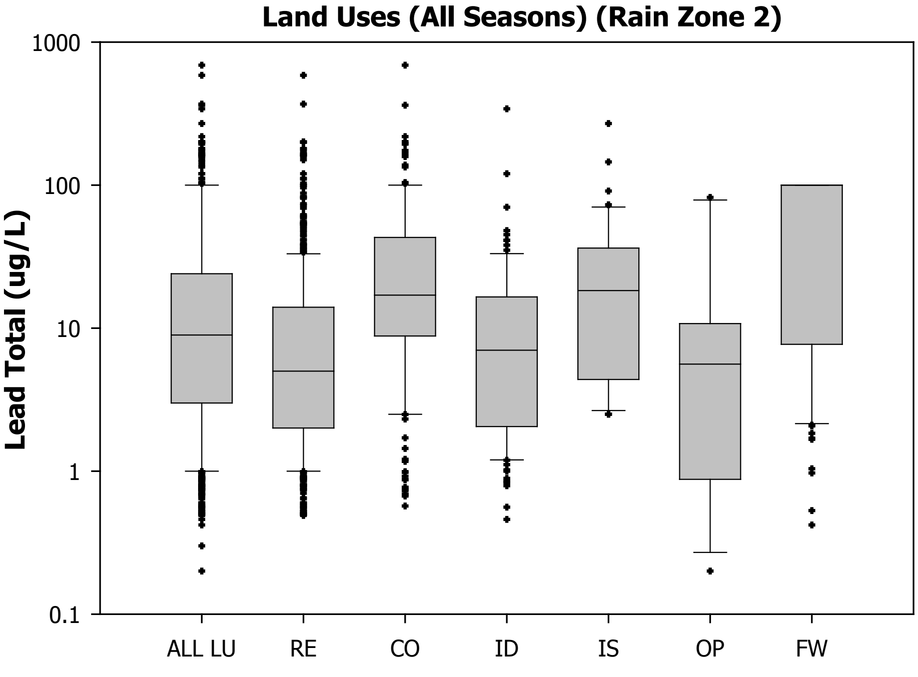
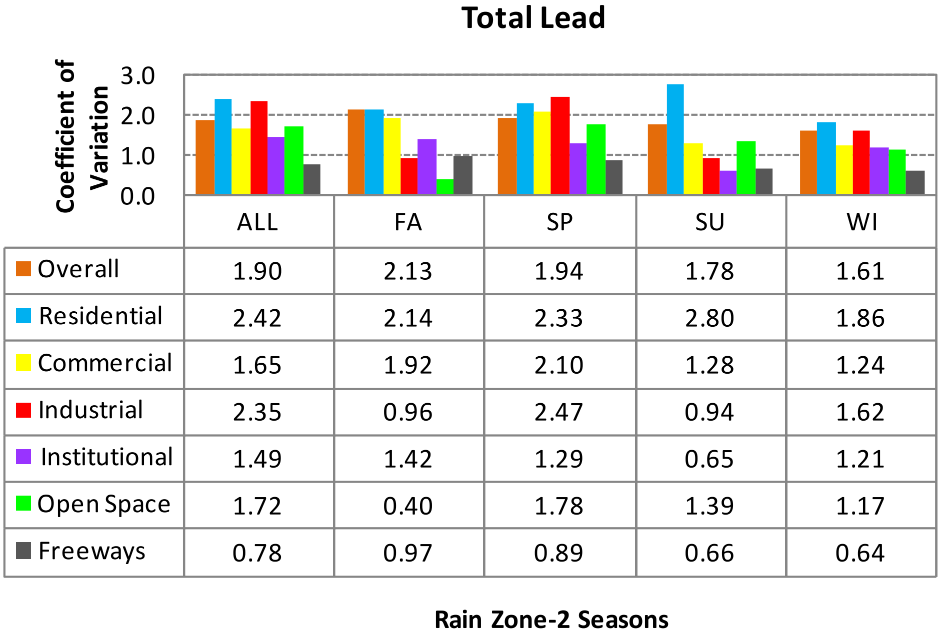


Fig. C43. Total Lead - Single Land Uses in EPA Rain Zone 2



	ALL	FA	SP	SU	WI
🟧 Overall	1.90	2.13	1.94	1.78	1.61
🟦 Residential	2.42	2.14	2.33	2.80	1.86
🟨 Commercial	1.65	1.92	2.10	1.28	1.24
🟥 Industrial	2.35	0.96	2.47	0.94	1.62
🟪 Institutional	1.49	1.42	1.29	0.65	1.21
🟩 Open Space	1.72	0.40	1.78	1.39	1.17
⬛ Freeways	0.78	0.97	0.89	0.66	0.64

Fig. C44. Total Lead - EPA Rain Zone 2 Seasonal Coefficients of Variation

C.3.1 Total Lead - All Single Land Uses

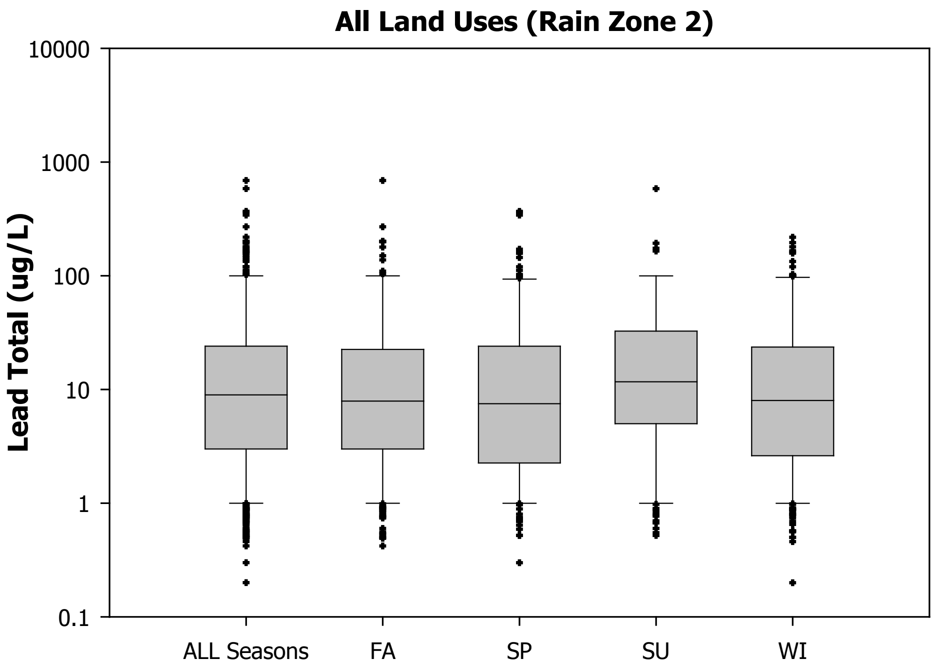


Fig. C45. Total Lead – All Single Land Uses by Season

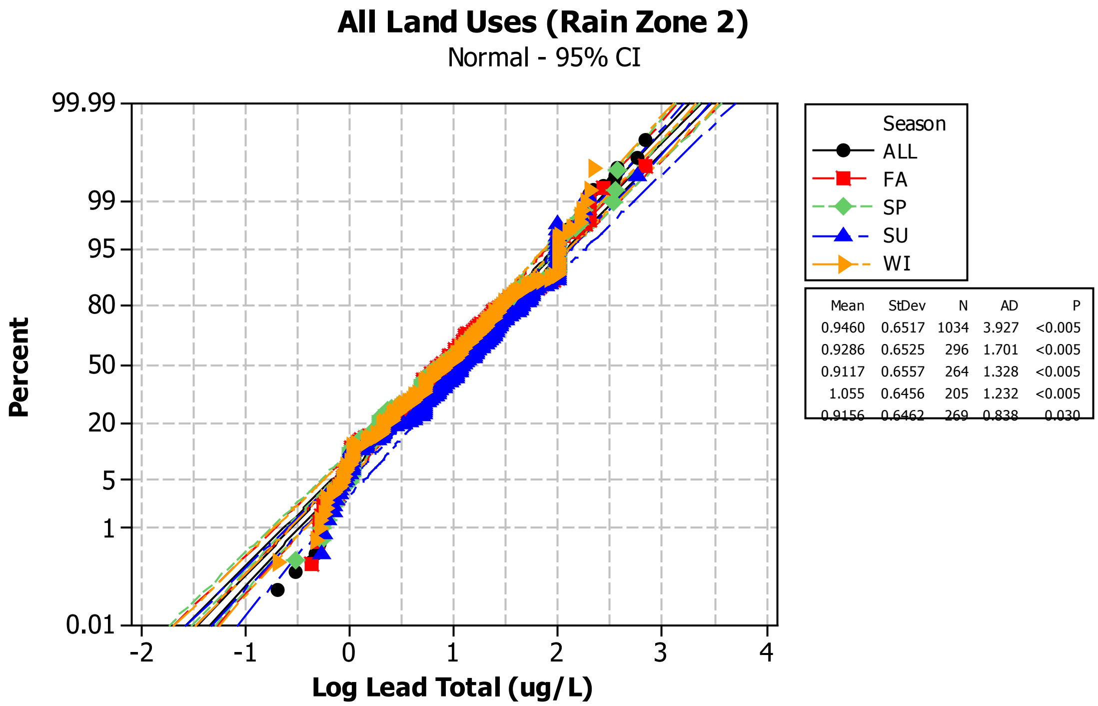


Fig. C46. Total Lead – All Single Land Uses (Checks for Normality)

Table C35. Statistical Analyses for Total Lead - All Single Land Uses

Kruskal-Wallis Test
(All Land Uses: Log Total Lead)

H = 8.48 DF = 3 P = 0.037
H = 8.49 DF = 3 P = 0.037 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	296	0.897	506	-0.8
SP	264	0.882	502	-1.0
SU	205	1.068	572	2.9
WI	269	0.903	505	-0.8
Overall	1034		517.5	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.860
	SU	0.014*
	WI	0.952
SP	SU	0.013*
	WI	0.897
SU	WI	0.015*

All Land Uses
Log Total Lead
Groups (medians)

Season	Gr. 1
FA	0.897
SP	0.882
WI	0.903
SU	1.068

Table C36. Power of the Test for Total Lead - All Single Land Uses

Season	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
FA	296	0.93	0.653
SP	264	0.91	0.656
SU	205	1.06	0.646
WI	269	0.92	0.646
Pooled Standard Deviation			0.650
Obtained Effect Size			0.09

α level	Power (%)
0.20	85.1
0.15	80.9
0.10	74.6
0.05	***63.5***
0.01	39.5

C.3.2 Total Lead - Residential Land Use

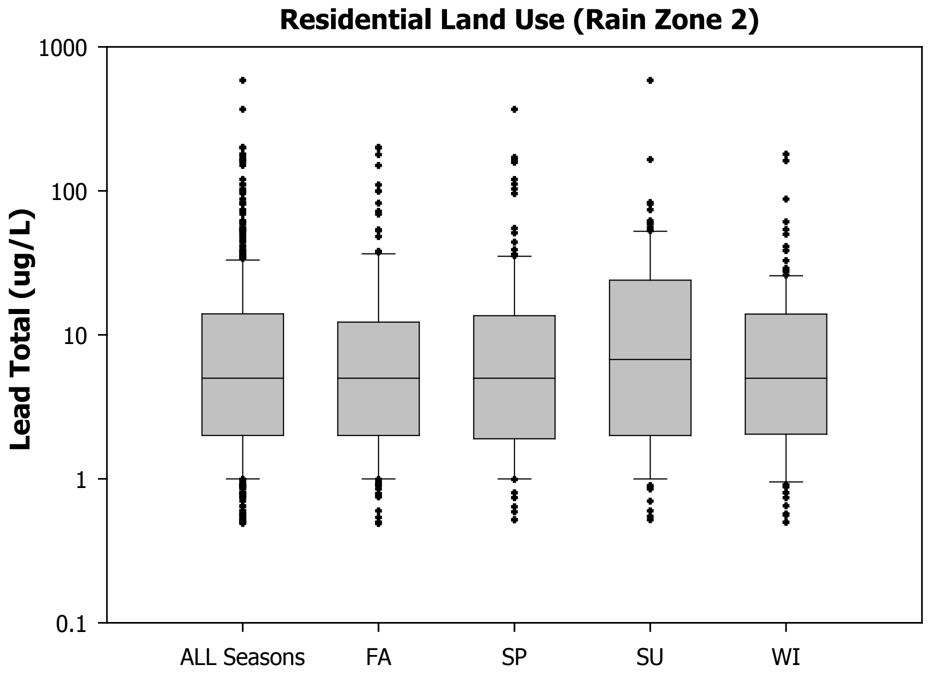
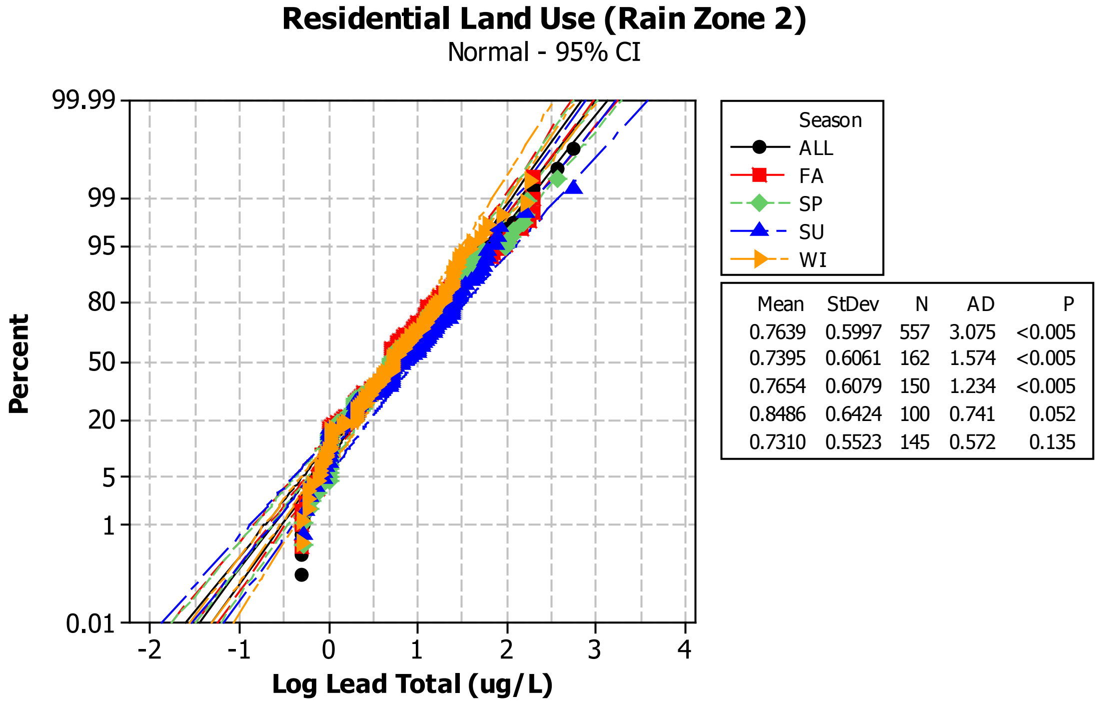


Fig. C47. Total Lead – Residential Land Use by Season



Mean	StDev	N	AD	P
0.7639	0.5997	557	3.075	<0.005
0.7395	0.6061	162	1.574	<0.005
0.7654	0.6079	150	1.234	<0.005
0.8486	0.6424	100	0.741	0.052
0.7310	0.5523	145	0.572	0.135

Fig. C48. Total Lead – Residential Land Use (Checks for Normality)

Table C37. Statistical Analyses for Total Lead – Residential Land Use

Kruskal-Wallis Test
(Residential: Log Total Lead)

H = 2.68 DF = 3 P = 0.444
H = 2.68 DF = 3 P = 0.443 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	162	0.699	27	-0.84
SP	150	0.699	27	0.04
SU	100	0.829	302	1.55
WI	145	0.699	273	-0.53
Overall	557		279	

Power of the Test (Residential: Log Total Lead)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	162	0.74	0.606
SP	150	0.77	0.608
SU	100	0.85	0.642
WI	145	0.73	0.552

Pooled Standard Deviation 0.602

Obtained Effect Size 0.07

α level	Power (%)
0.20	52.4
0.15	45.5
0.10	36.9
0.05	***25.7***
0.01	9.9

C.3.3 Total Lead - Commercial Land Use

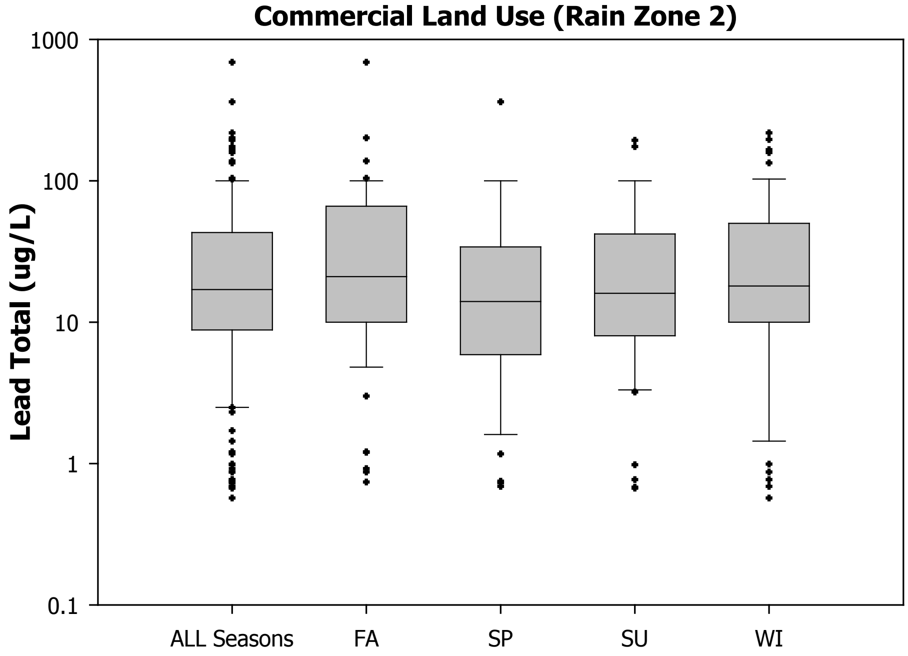
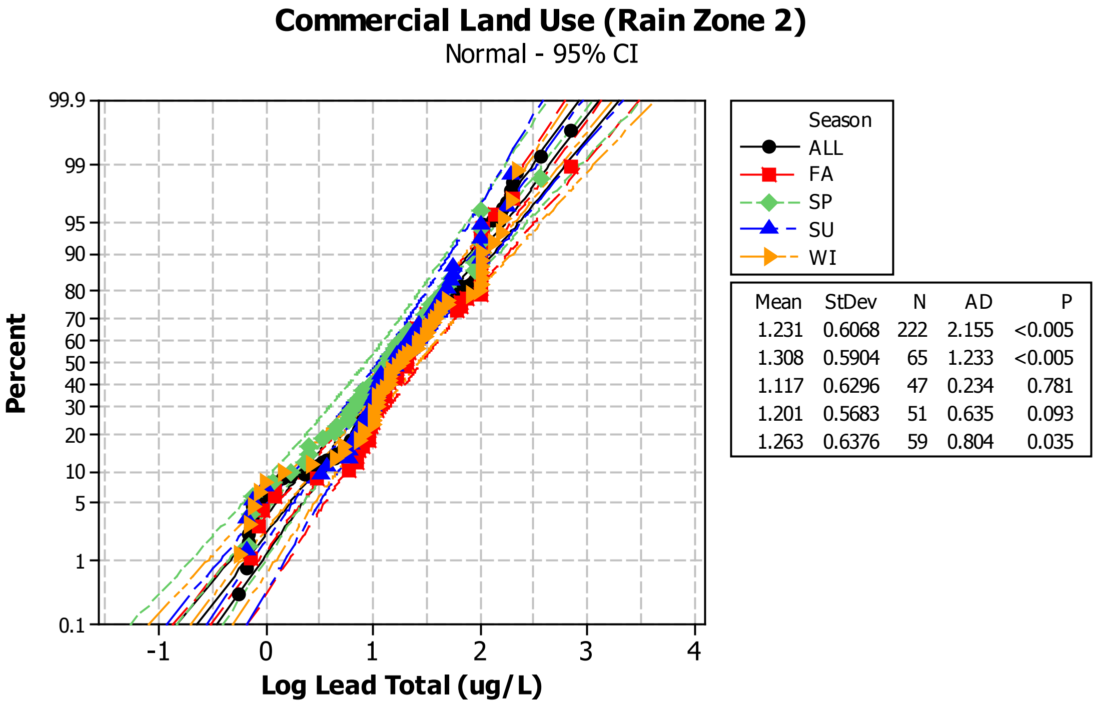


Fig. C49. Total Lead – Commercial Land Use by Season



Mean	StDev	N	AD	P
1.231	0.6068	222	2.155	<0.005
1.308	0.5904	65	1.233	<0.005
1.117	0.6296	47	0.234	0.781
1.201	0.5683	51	0.635	0.093
1.263	0.6376	59	0.804	0.035

Fig. C50. Total Lead – Commercial Land Use (Checks for Normality)

Table C38. Statistical Analyses for Total Lead – Commercial Land Use

Kruskal-Wallis Test
(Commercial: Log Total Lead)

H = 3.37 DF = 3 P = 0.339
H = 3.37 DF = 3 P = 0.338 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	65	1.322	119	1.13
SP	47	1.146	98.6	-1.55
SU	51	1.204	107.7	-0.49
WI	59	1.255	116.8	0.74
Overall	222		111.5	

Power of the Test (Commercial: Log Total Lead)

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	65	1.31	0.590
SP	47	1.12	0.630
SU	51	1.20	0.568
WI	59	1.26	0.638

Pooled Standard Deviation 0.606
Obtained Effect Size 0.12

α level	**Power (%)**
0.20	53.9
0.15	47.0
0.10	38.4
0.05	***26.6***
0.01	10.5

C.3.4 Total Lead - Industrial Land Use

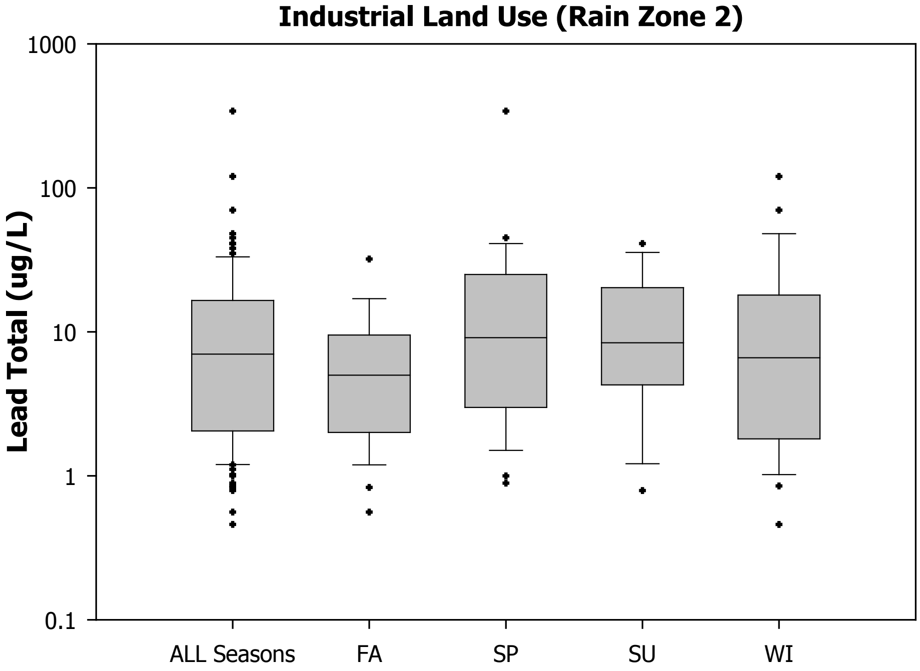
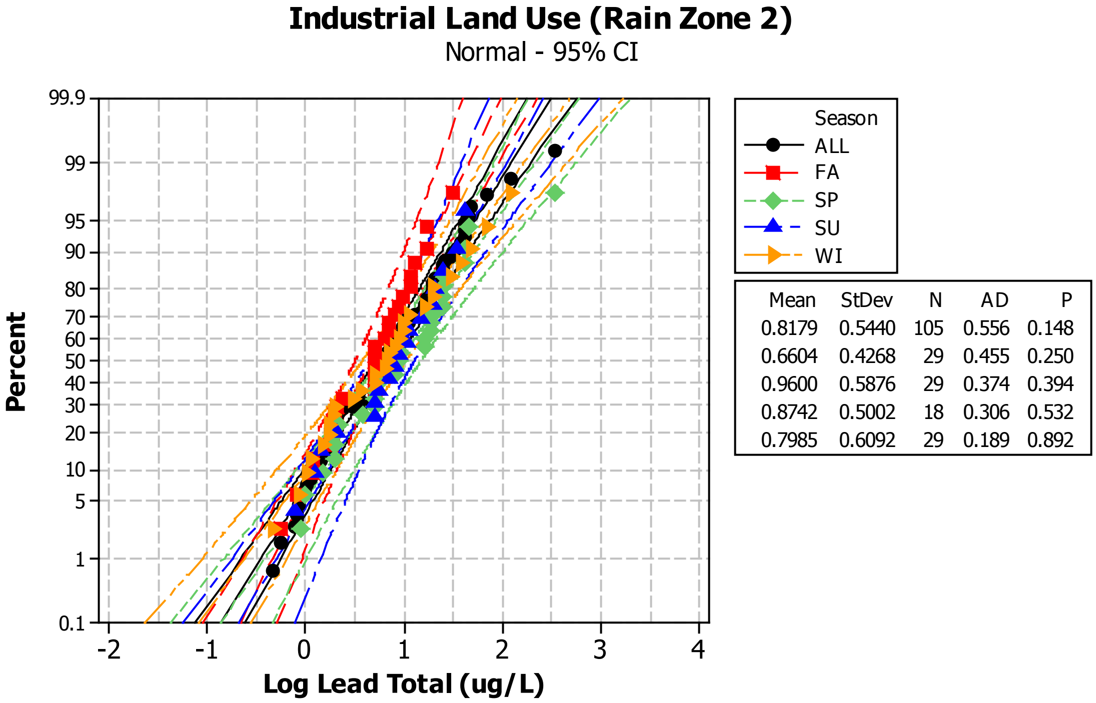


Fig. C51. Total Lead – Industrial Land Use by Season



Mean	StDev	N	AD	P
0.8179	0.5440	105	0.556	0.148
0.6604	0.4268	29	0.455	0.250
0.9600	0.5876	29	0.374	0.394
0.8742	0.5002	18	0.306	0.532
0.7985	0.6092	29	0.189	0.892

Fig. C52. Total Lead – Industrial Land Use (Checks for Normality)

Table C39. Statistical Analyses for Total Lead – Industrial Land Use

Kruskal-Wallis Test (Industrial: Log Total Lead)

H = 4.97 DF = 3 P = 0.174
H = 4.98 DF = 3 P = 0.173 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	29	0.699	43.9	-1.89
SP	29	0.959	60.8	1.63
SU	18	0.924	57.5	0.69
WI	29	0.820	51.4	-0.32
Overall	105		53	

Power of the Test (Industrial: Log Total Lead)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	29	0.66	0.427
SP	29	0.96	0.588
SU	18	0.87	0.500
WI	29	0.80	0.609
Pooled Standard Deviation			0.531
Obtained Effect Size			0.21

α level	Power (%)
0.20	69.2
0.15	62.9
0.10	54.4
0.05	***41.3***
0.01	19.8

C.3.5 Total Lead - Institutional Land Use

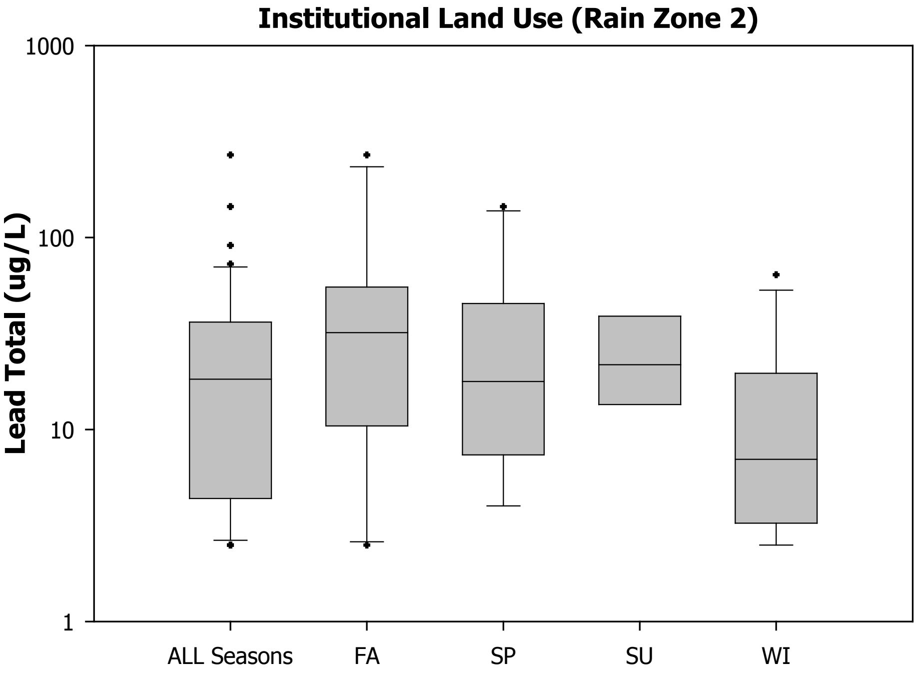


Fig. C53. Total Lead – Institutional Land Use by Season

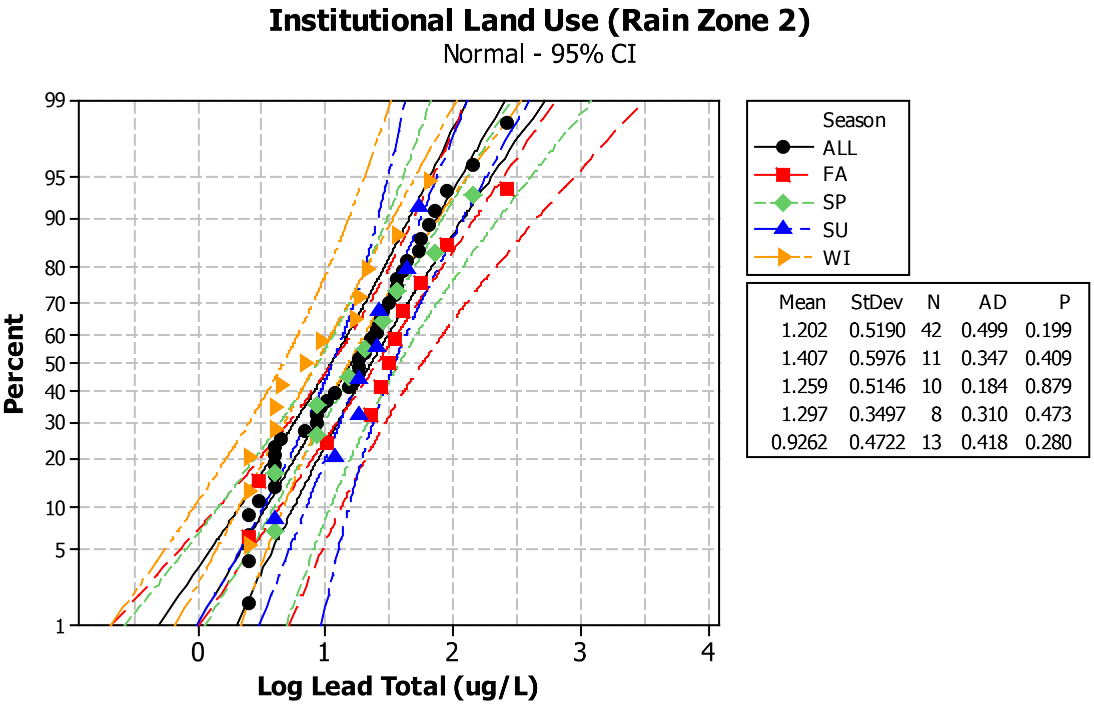


Fig. C54. Total Lead – Institutional Land Use (Checks for Normality)

Table C40. Statistical Analyses for Total Lead – Institutional Land Use

Kruskal-Wallis Test
(Institutional: Log Total Lead)

H = 5.65 DF = 3 P = 0.130
H = 5.66 DF = 3 P = 0.129 (adjusted for ties)

Season	**N**	**Median**	**Ave Rank**	**Z**
FA	11	1.505	26.4	1.54
SP	10	1.246	22.5	0.3
SU	8	1.333	23.9	0.61
WI	13	0.845	15.1	-2.26
Overall	42		21.5	

Power of the Test (Institutional: Log Total Lead)

Season	**n**	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
FA	11	1.41	0.598
SP	10	1.26	0.515
SU	8	1.30	0.350
□I	13	0.9	0.472

Pooled Standard Deviation 0.484
Obtained Effect Size 0.40

α level	**Power (%)**
0.20	78.4
0.15	72.8
0.10	64.9
0.05	***51.5***
0.01	26.7

C.3.6 Total Lead – Open Space Land Use

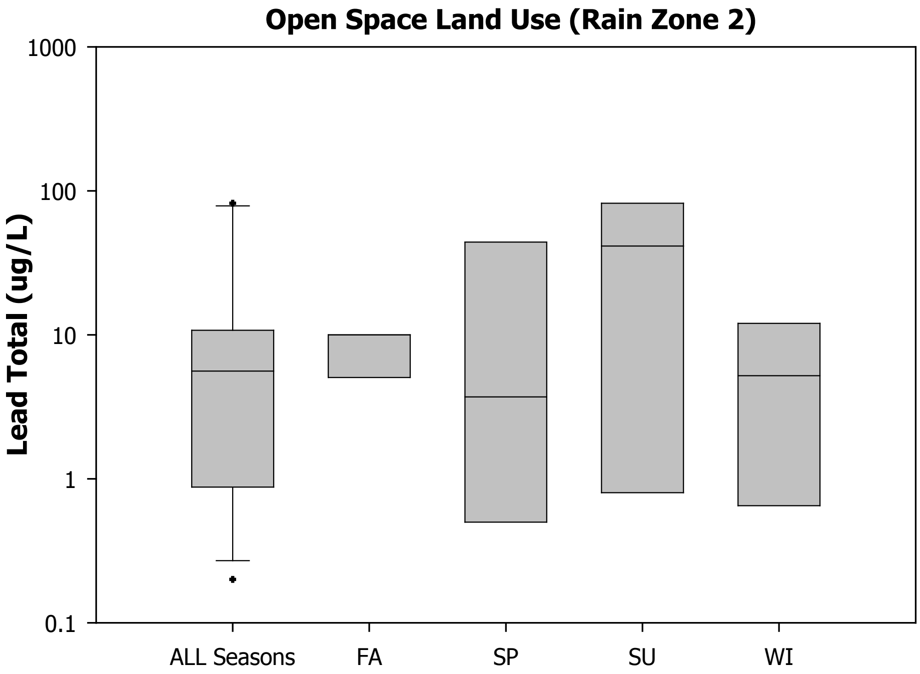
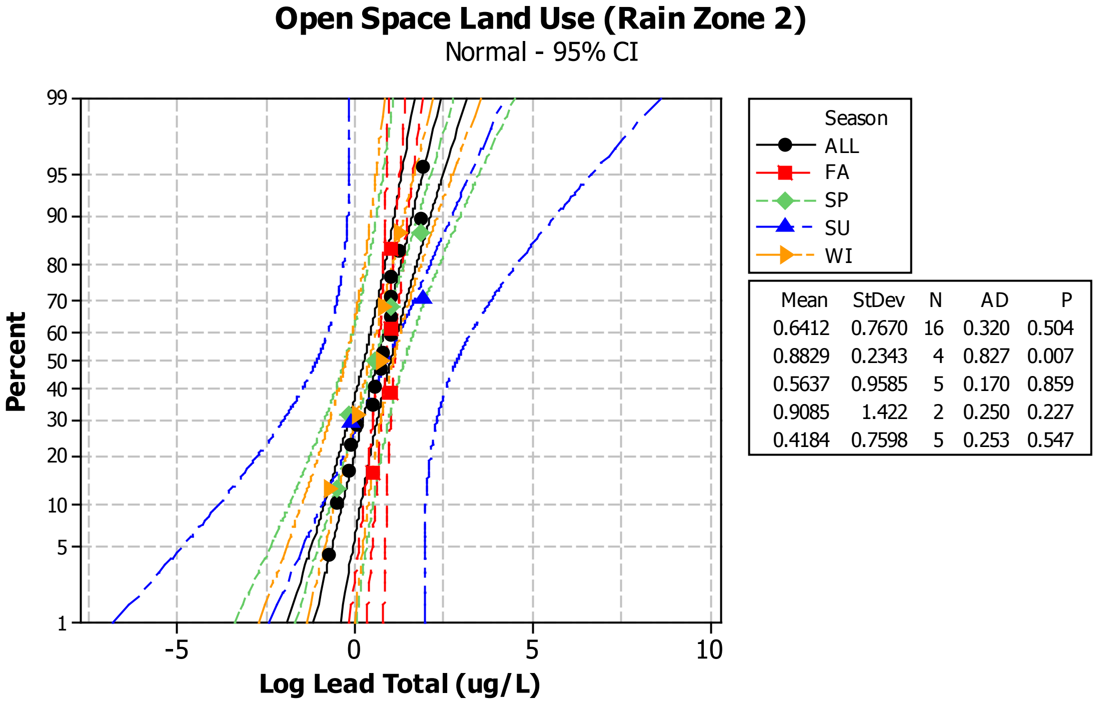


Fig. C55. Total Lead – Open Space Land Use by Season



Mean	StDev	N	AD	P
0.6412	0.7670	16	0.320	0.504
0.8829	0.2343	4	0.827	0.007
0.5637	0.9585	5	0.170	0.859
0.9085	1.422	2	0.250	0.227
0.4184	0.7598	5	0.253	0.547

Fig. C56. Total Lead – Open Space Land Use (Checks for Normality)

Table C41. Statistical Analyses for Total Lead – Open Space Land Use

Kruskal-Wallis Test
(Open Space: Log Total Lead)

H = 0.80 DF = 3 P = 0.850
H = 0.80 DF = 3 P = 0.849 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	4	1.00	9.8	0.61
SP	5	0.568	8	-0.28
SU	2	0.909	10	0.48
WI	5	0.716	7.4	-0.62
Overall	16		8.5	

Power of the Test (Open Space: Log Total Lead)

Season	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
FA	4	0.□8	0.234
SP	5	0.56	0.959
SU	2	0.91	1.420
WI	5	0.42	0.760

Pooled Standard Deviation 0.843
Obtained Effect Size 0.24

α level	Power (%)
0.20	29.8
0.15	23.5
0.10	16.8
0.05	***9.3***
0.01	2.2

C.3.7 Total Lead - Freeways Land Use

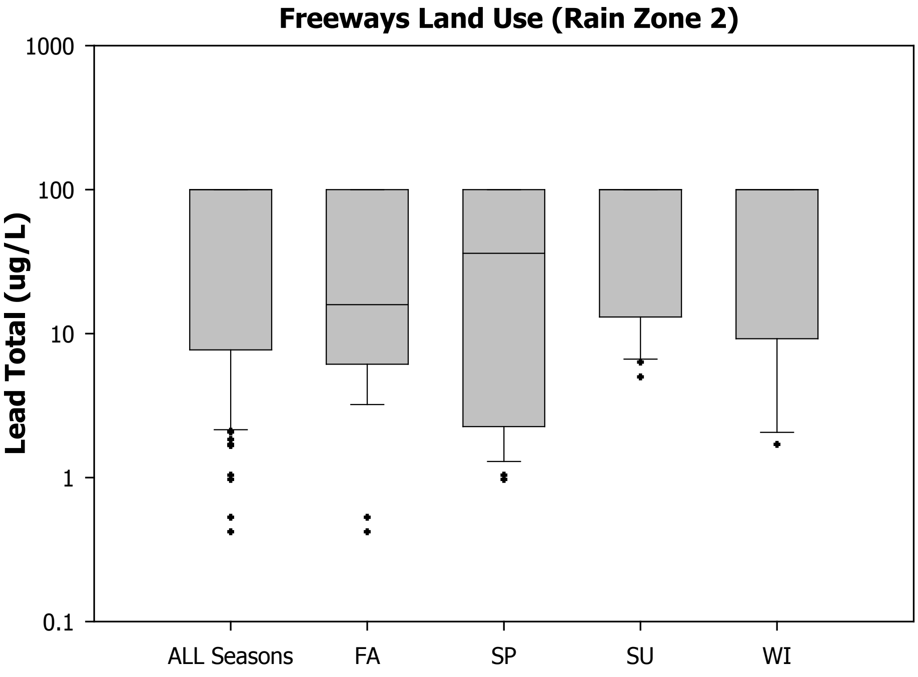
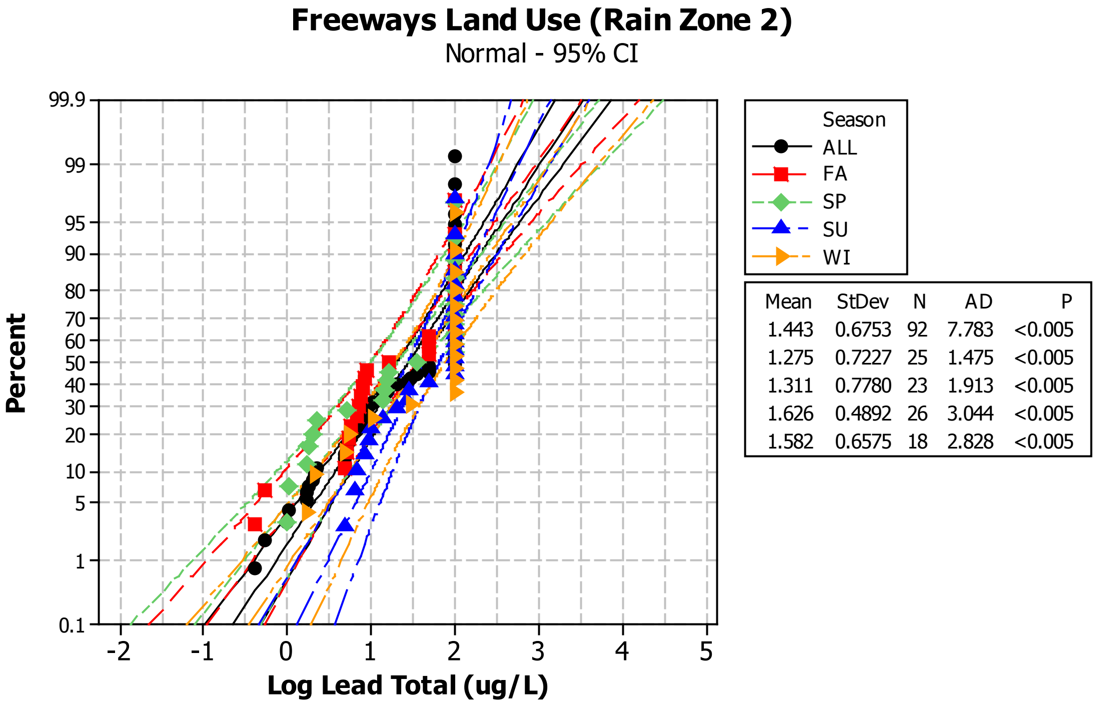


Fig. C57. Total Lead – Freeways Land Use by Season



Mean	StDev	N	AD	P
1.443	0.6753	92	7.783	<0.005
1.275	0.7227	25	1.475	<0.005
1.311	0.7780	23	1.913	<0.005
1.626	0.4892	26	3.044	<0.005
1.582	0.6575	18	2.828	<0.005

Fig. C58. Total Lead – Freeways Land Use (Checks for Normality)

Table C42. Statistical Analyses for Total Lead – Freeways Land Use

Kruskal-Wallis Test
(Freeways: Log Total Lead)

H = 4.03 DF = 3 P = 0.258
H = 4.65 DF = 3 P = 0.199 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	25	1.201	39.7	-1.48
SP	23	1.557	42.9	-0.74
SU	26	2.00	52.2	1.28
WI	18	2.00	52.3	1.02
Overall	92		46.5	

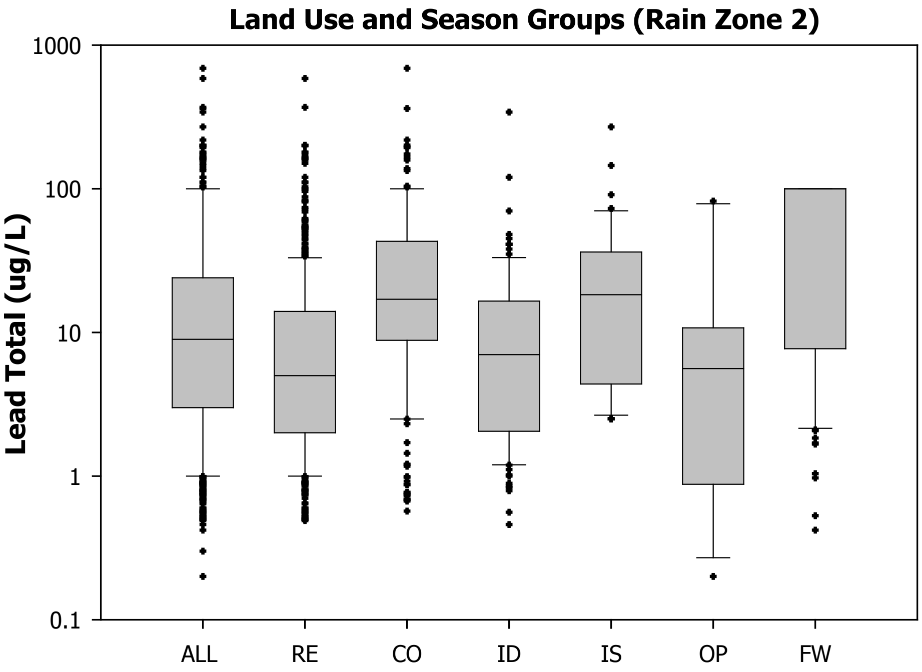
Power of the Test (Freeways: Log Total Lead)

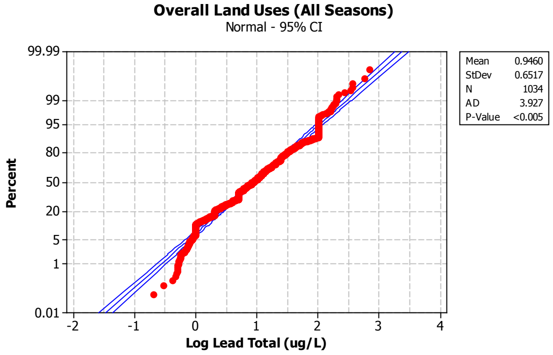
Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	25	1.28	0.723
SP	23	1.31	0.778
SU	26	1.63	0.489
WI	18	1.58	0.658

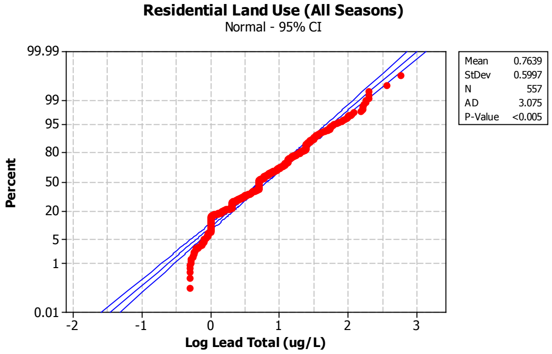
Pooled Standard Deviation □ 0.662
Obtained Effect Size 0.24

α level	**Power (%)**
0.20	72.0
0.15	66.0
0.10	57.6
0.05	***44.5***
0.01	22.0

C.4.8 Total Lead Land Use and Season Groups







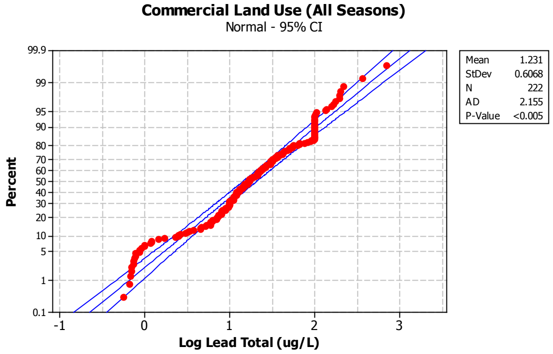


Fig. C59. Total Lead – Land Use and Season Groups

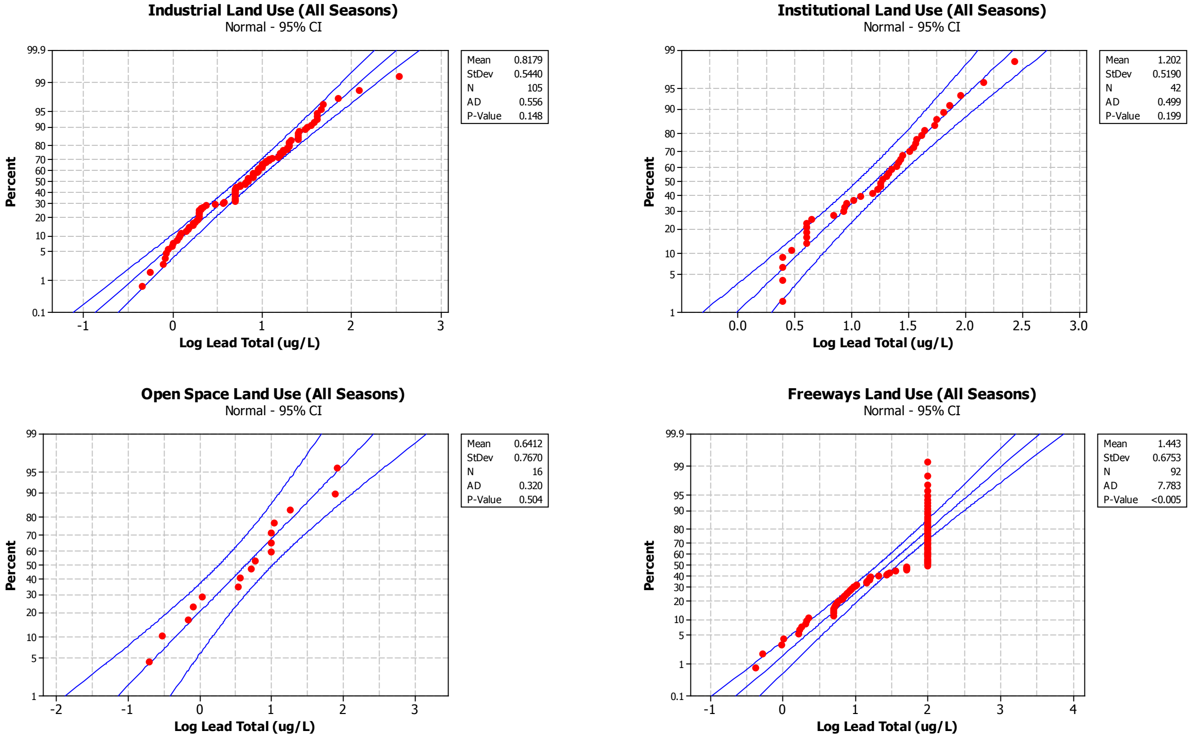


Fig. C59. – *Continued*

Table C43. Statistical Analyses for Total Lead – Land Use and Season Groups

Kruskal-Wallis Test
(Land Use and Season Groups: Log Total Lead)

H = 154.24 DF = 5 P = 0.000
H = 154.37 DF = 5 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE	557	0.699	432	-10
CO	222	1.230	655	7.8
ID	105	0.845	461	-2.0
IS	42	1.262	638	2.7
OP	16	0.747	399	-1.6
FW	92	2.000	733	7.3
Overall	1034		518	

Land Use and Season Groups
(medians)

Groups	Gr. A	Gr. B	Gr. C
RE	0.699		
ID	0.845		
OP	0.747		
IS		1.262	
CO		1.230	
FW			2.000

Table C44. Land Use and Season Multiple Comparisons for Total Lead

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
RE	CO	0.000*	CO	ID	0.000*	ID	IS	0.000*
	ID	0.224		IS	0.667		OP	0.411
	IS	0.000*		OP	0.001*		FW	0.000*
	OP	0.606		FW	0.004*			
	FW	0.000*				IS	OP	0.012*
			OP	FW	0.000*		FW	0.006*

Table C45. All Possible Land Use and Season Combinations for Total Copper

Groups	**Gr. A**	**Gr. B**	**Gr. C**
RE	0.699		
ID	0.845		
OP	0.747		
IS		1.262	
CO		1.230	
FW			2.000

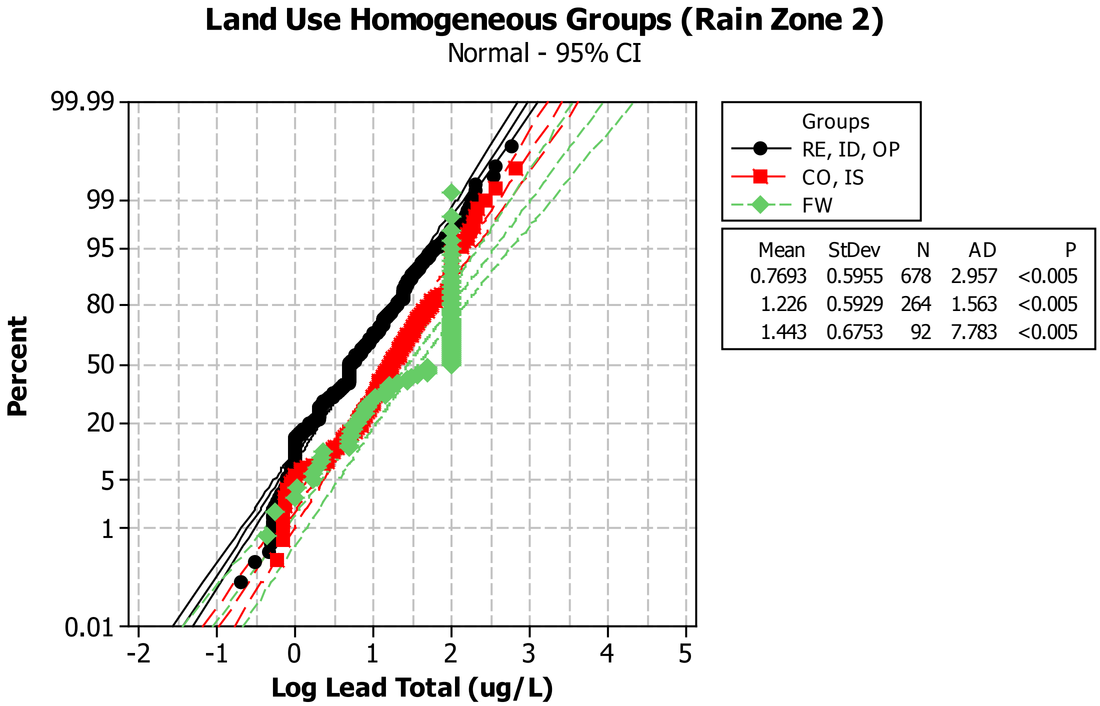
Table C46. Power of the Test for Total Lead - Land Use and Season Groups

Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE	557	0.76	0.600
CO	222	1.23	0.607
ID	105	0.82	0.544
IS	42	1.20	0.519
OP	16	0.64	0.767
FW	92	1.44	0.675

Pooled Standard Deviation 0.619

Obtained Effect size 0.41

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

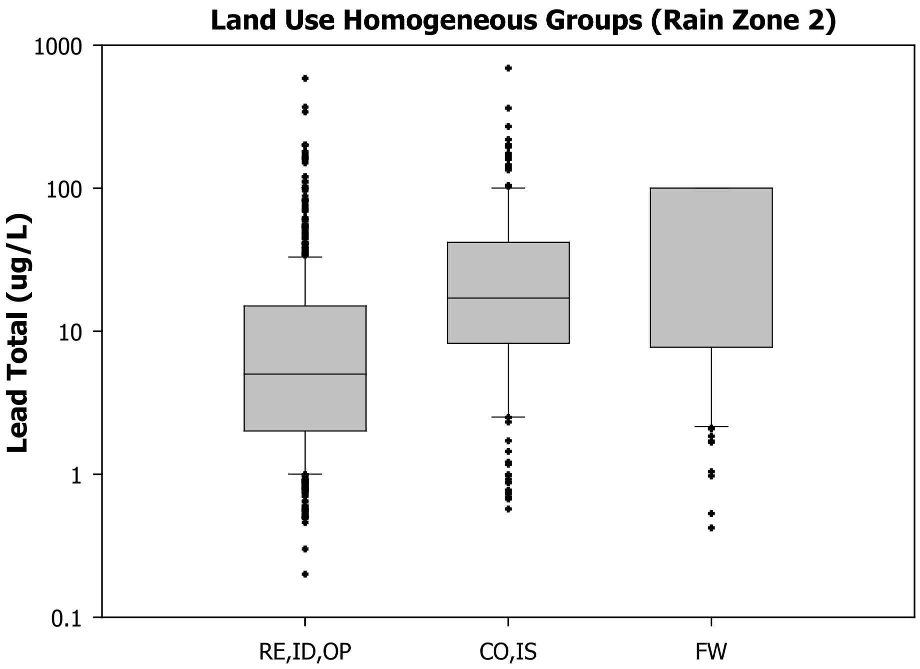


Land Use Homogeneous Groups (Rain Zone 2)

Normal - 95% CI

Mean	StDev	N	AD	P
0.7693	0.5955	678	2.957	<0.005
1.226	0.5929	264	1.563	<0.005
1.443	0.6753	92	7.783	<0.005

Fig. C60. Total Lead – Land Use Homogeneous Groups (Checks for Normality)



Land Uses	FALL	SPRING	SUMMER	WINTER
Residential	17(2.1)	17(2.3)	22(2.8)	12(1.9)
Commercial	48(1.9)	33(1.7)	32(1.3)	41(1.2)
Industrial	7.0(0.96)	25(2.5)	12(0.94)	16(1.6)
Institutional	54(1.4)	34(1.3)	25(0.65)	15(1.2)
Open Space	8.4(0.40)	19(1.8)	41(1.4)	6.1(1.2)
Freeways	45(0.97)	53(0.89)	65(0.66)	70(0.63)

Fig. C61. Total Lead – Land Use Homogeneous Groups: Mean (CV)

Table C47. Statistical Analyses for Total Lead – Land Use Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: Log Total Lead)

H = 153.04 DF = 2 P = 0.000
H = 153.16 DF = 2 P = 0.000
(adjusted for ties)

Groups		N	Median	Ave Rank	Z
1	RE, ID, OP	678	0.699	436	-12
2	CO, IS	264	1.230	653	9
3	FW	92	2.000	733	7
Overall		1034		518	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Group	(J) Group	p-value
1	2	0.000*
	3	0.000*
2	3	0.002*

Log Total Lead
Homogeneous Groups
(medians)

Group	Gr.A	Gr.B	Gr.C
1	0.699		
2		1.230	
3			2.000

Table C48. Power of the Test for Total Lead - Land Use Homogeneous Groups

Homogeneous Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
RE, ID, OP	678	0.77	0.596	0.20	100
CO, IS	264	1.23	0.593	0.15	100
FW	92	1.44	0.675	0.10	100
Pooled Standard Deviation			0.621	***0.05***	***100***
Obtained Effect Size			0.40	0.01	100

Table C49. Basic Statistics for Total Lead Homogeneous Groups (Real Space Data)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	RE, ID, OP	678	16	39	2.4	0.20	5.0	585
B	CO, IS	264	38	62	1.6	0.57	17	689
C	FW	92	57	45	0.78	0.42	100	100

C.4. Total Phosphorous

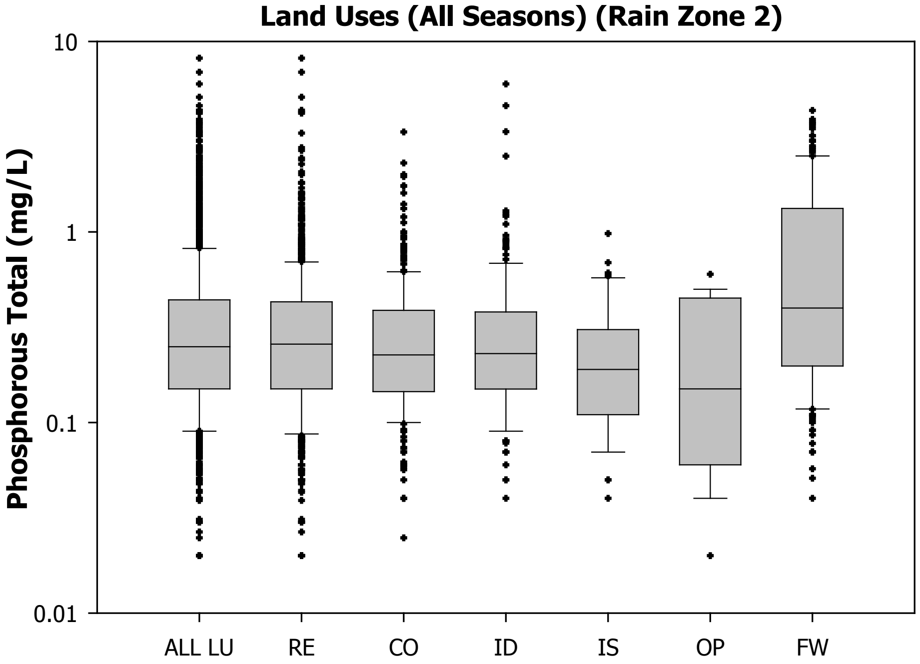
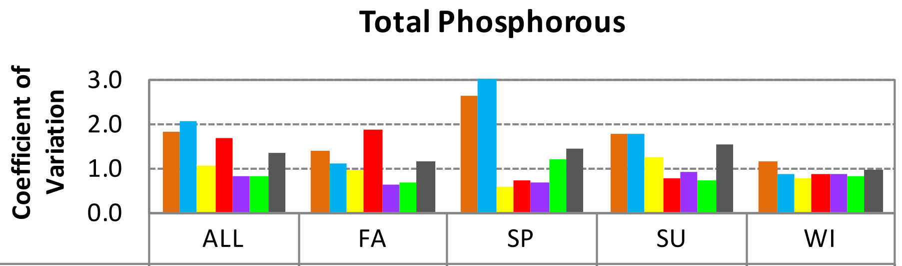


Fig. C62. Total Phosphorous - Single Land Uses in EPA Rain Zone 2



	ALL	FA	SP	SU	WI
🟧 Overall	1.83	1.41	2.62	1.76	1.13
🟦 Residential	2.04	1.10	3.12	1.78	0.86
🟨 Commercial	1.03	0.96	0.57	1.24	0.79
🟥 Industrial	1.67	1.85	0.74	0.75	0.87
🟪 Institutional	0.80	0.61	0.67	0.90	0.89
🟩 Open Space	0.81	0.69	1.18	0.70	0.82
⬛ Freeways	1.33	1.16	1.42	1.52	0.97

Rain Zone-2 Seasons

Fig. C63. Total Phosphorous - EPA Rain Zone 2 Seasonal Coefficients of Variation

C.4.1 Total Phosphorous - All Single Land Uses

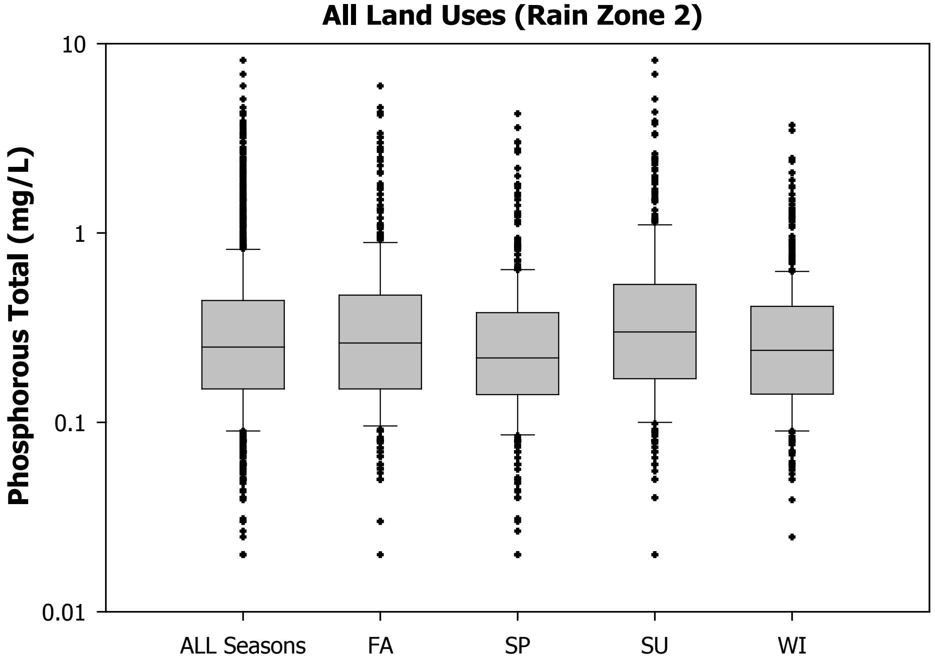


Fig. C64. Total Phosphorous – All Single Land Uses by Season

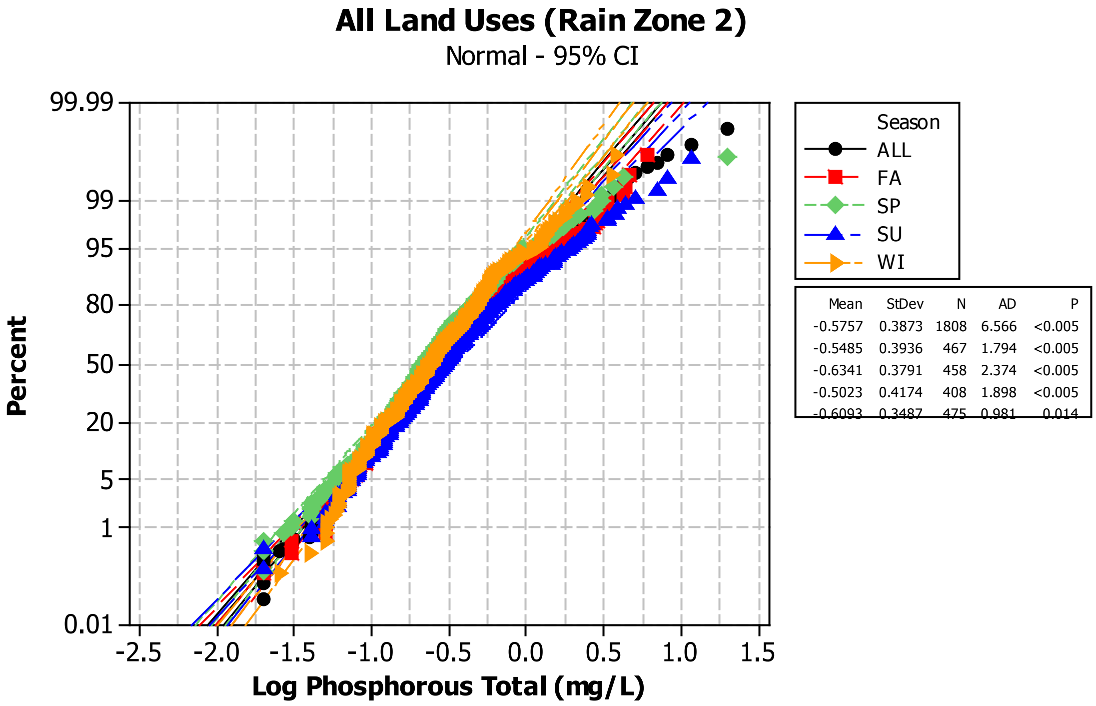


Fig. C65. Total Phosphorous – All Single Land Uses (Checks for Normality)

Table C50. Statistical Analyses for Total Phosphorous - All Single Land Uses

Kruskal-Wallis Test
(All Land Uses: Log Total Phosphorous)

H = 28.25 DF = 3 P = 0.000
H = 28.25 DF = 3 P = 0.000
(adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	467	-0.581	94	1.7
SP	458	-0.659	826	-4
SU	408	-0.523	998	4.1
WI	475	-0.620	865	-2
Overall	1808		904	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.001*
	SU	0.105
	WI	0.028*
SP	SU	0.000*
	WI	0.234
SU	WI	0.000*

All Land Uses
Log Total Phosphorous
Groups (medians)

Season	Gr. 1	Gr. 2
FA	-0.581	
SU	-0.523	
SP		-0.659
WI		-0.620

Table C51. All Possible Seasonal Combinations for Total Phosphorous - All Single Land Uses

Season	Gr. A	Gr. B
SP	-0.659	
WI	-0.620	
FA		-0.581
SU		-0.523

Table C52. Power of the Test for Total Phosphorous - All Single Land Uses

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	467	-0.55	0.394
SP	458	-0.63	0.379
SU	408	-0.50	0.417
WI	475	-0.61	0.349
Pooled Standard Deviation			0.385
Obtained Effect Size			0.13

α level	Power (%)
0.20	99.9
0.15	99.9
0.10	99.9
0.05	***99.8***
0.01	99.2

C.4.2 Total Phosphorous - Residential Land Use

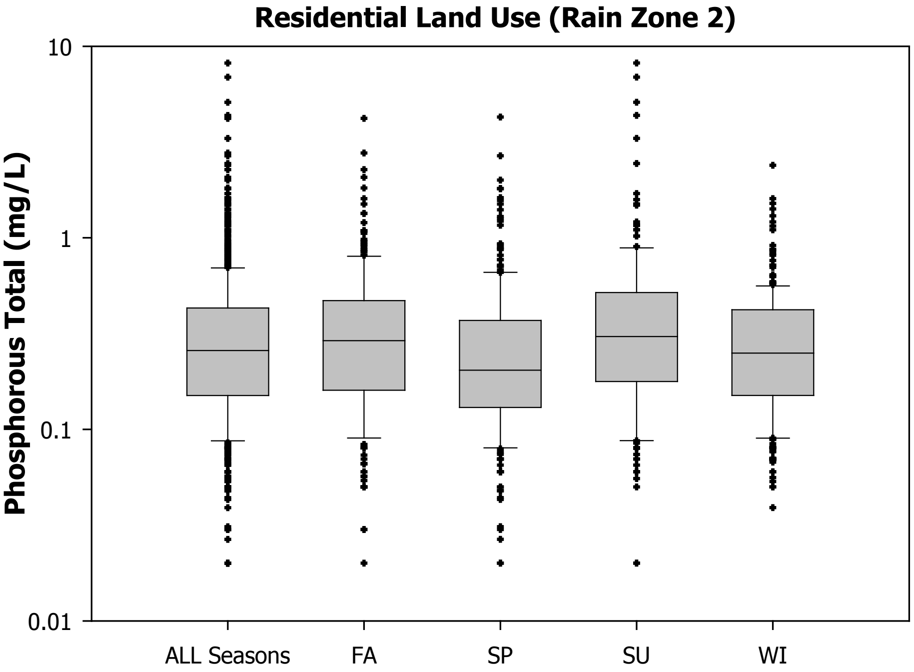


Fig. C66. Total Phosphorous – Residential Land Use by Season

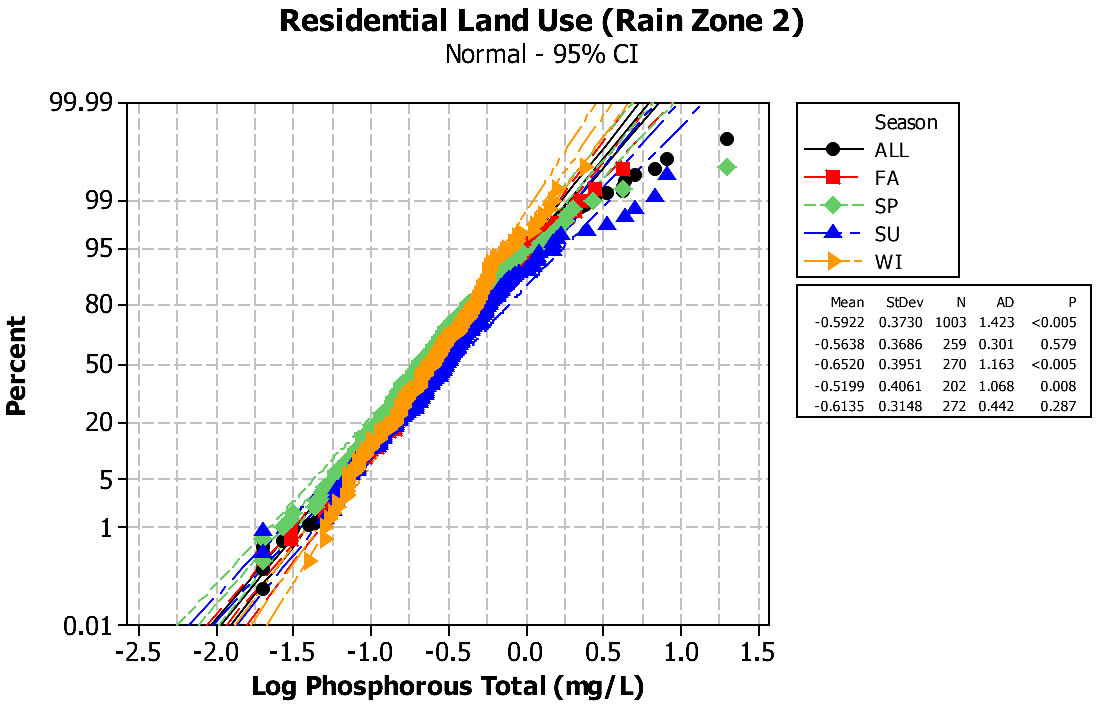


Fig. C67. Total Phosphorous – Residential Land Use (Checks for Normality)

Table C53. Statistical Analyses for Total Phosphorous – Residential Land Use

Kruskal-Wallis Test
(Residential: Log Total Phosphorous)

H = 19.94 DF = 3 P = 0.000
H = 19.95 DF = 3 P = 0.000
(adjusted for ties)

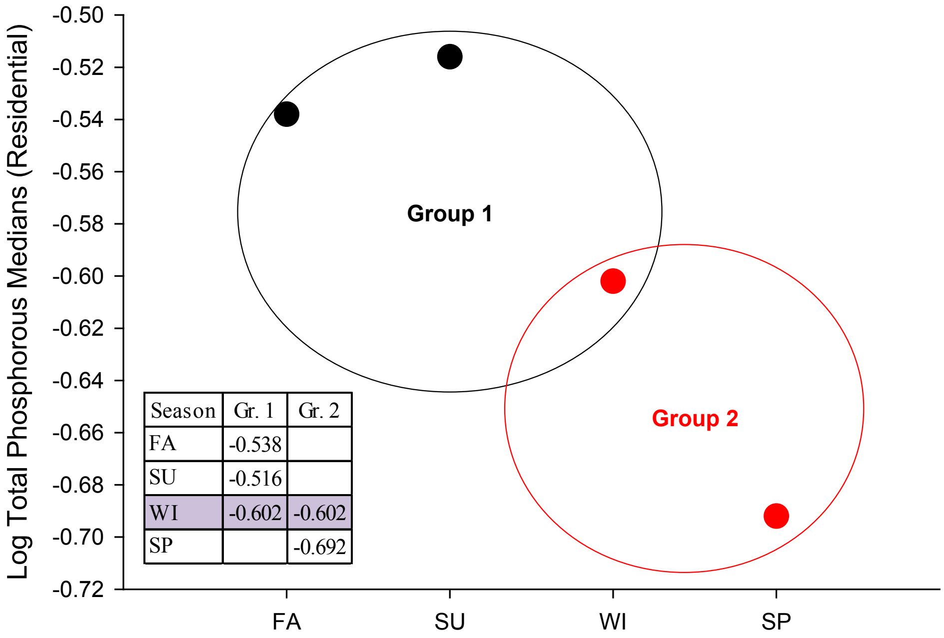
Season	N	Median	Ave Rank	Z
FA	259	-0.538	531	1.84
SP	270	-0.692	44	-3.6
SU	202	-0.516	557	3.0
WI	272	-0.602	489	-0.9
Overall	1003		502	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.001*
	SU	0.329
	WI	0.083
SP	SU	0.000*
	WI	0.068
SU	WI	0.008*

Residential
Log Total Phosphorous
Groups (medians)

Season	Gr. 1	Gr. 2
FA	-0.538	
SU	-0.516	
SP		-0.692
WI		-0.602



Season	Gr. 1	Gr. 2
FA	-0.538	
SU	-0.516	
WI	-0.602	-0.602
SP		-0.692

Fig. C68. All Possible Seasonal Combinations for Total Phosphorous – Residential Land Use

Table C54. Power of the Test for Total Phosphorous – Residential Land Use

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	259	-0.56	0.369
SP	270	-0.65	0.395
SU	202	-0.52	0.406
WI	272	-0.61	0.315
Pooled Standard Deviation			0.371
Obtained Effect Size			0.13

α level	**Power (%)**
0.20	98.8
0.15	98.2
0.10	97.1
0.05	***94.4***
0.01	83.7

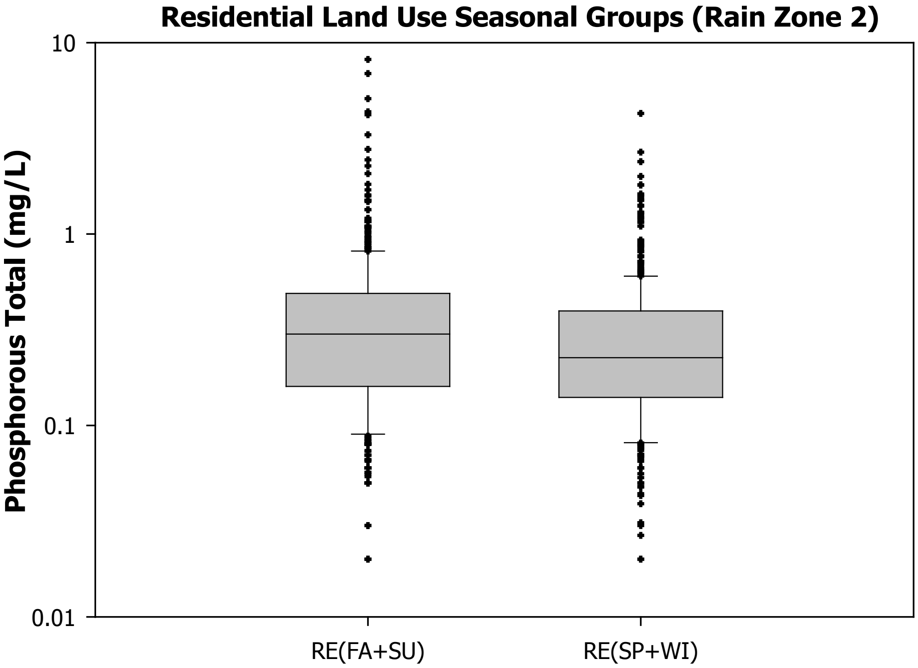


Fig. C69. Total Phosphorous – Residential Land Use Seasonal Groups

Table C55. Statistical Analyses for Total Phosphorous –
Residential Land Use Seasonal Groups

Kruskal-Wallis Test
(Residential: Log Total Phosphorous Groups)

H = 16.24 DF = 1 P = 0.000
H = 16.24 DF = 1 P = 0.000
(adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE (FA,SU)	461	-0.523	542	4
RE (SP,WI)	542	-0.646	468	-4
Overall	1003		502	

Power of the Test (Residential:
Log Total Phosphorous Groups)

Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,SU)	461	-0.54	0.386
RE(SP,WI)	542	-0.63	0.357

Pooled Standard Deviation 0.372
Obtained Effect Size 0.12

α level	Power (%)
0.20	99□4
0.1	99.1
0.10	93.8
0.05	***89.0***
0.01	72.7

C.4.3 Total Phosphorous - Commercial Land Use

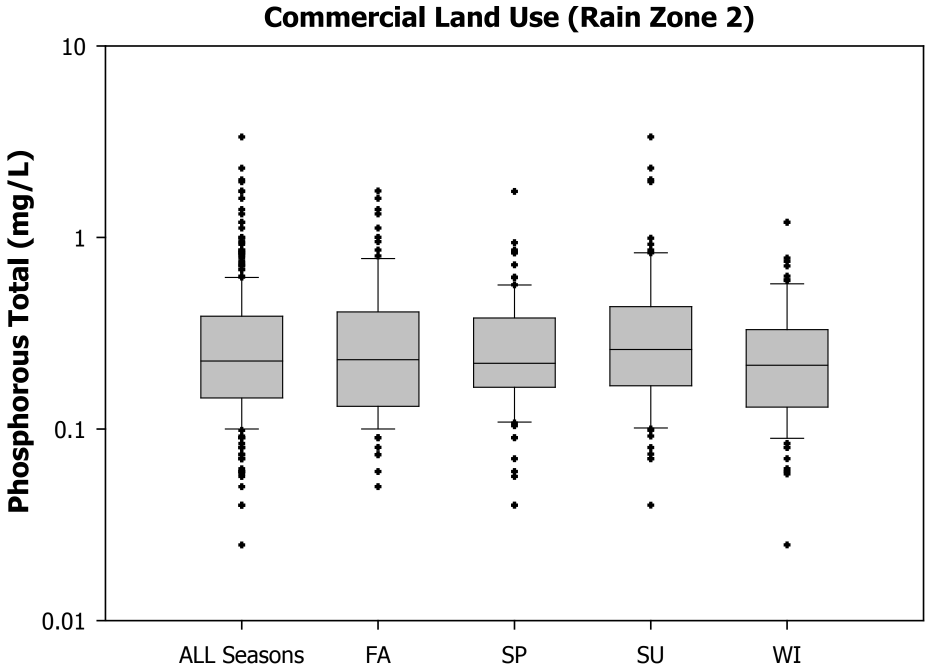
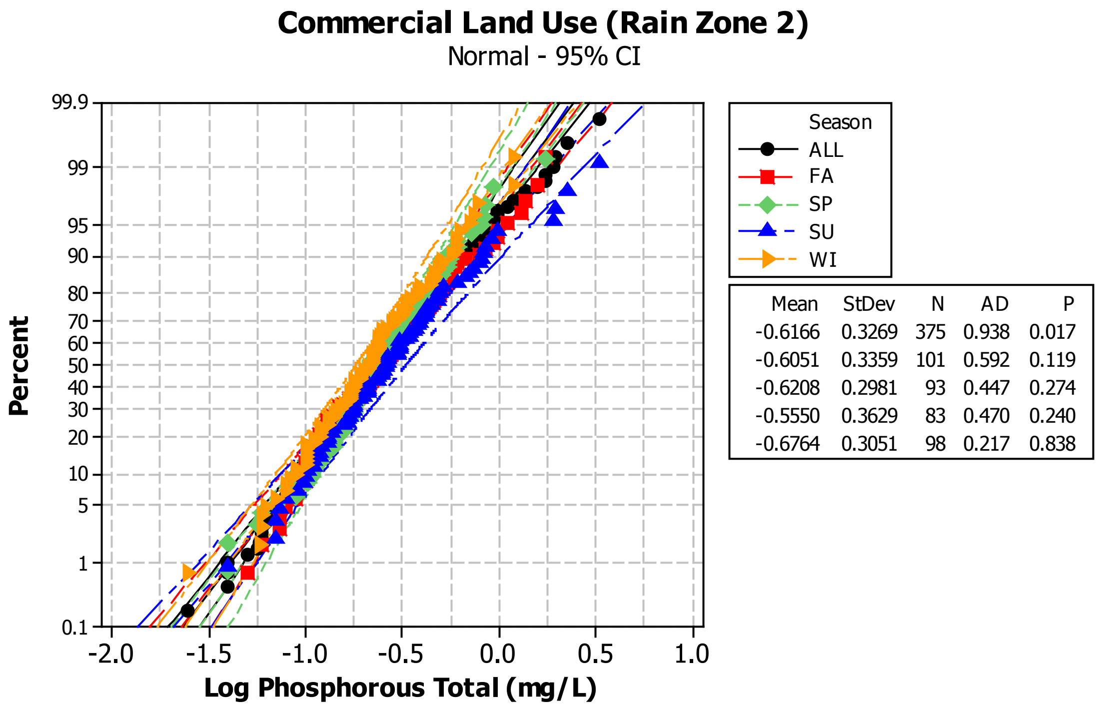


Fig. C70. Total Phosphorous – Commercial Land Use by Season



Mean	StDev	N	AD	P
-0.6166	0.3269	375	0.938	0.017
-0.6051	0.3359	101	0.592	0.119
-0.6208	0.2981	93	0.447	0.274
-0.5550	0.3629	83	0.470	0.240
-0.6764	0.3051	98	0.217	0.838

Fig. C71. Total Phosphorous – Commercial Land Use (Checks for Normality)
Table C56. Statistical Analyses for Total Phosphorous – Commercial Land Use

Kruskal-Wallis Test
(Commercial: Log Total Phosphorous)

H = 4.77 DF = 3 P = 0.190
H = 4.77 DF = 3 P = 0.190 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	101	-0.638	189	0.17
SP	93	-0.658	190	0.21
SU	83	-0.585	205	1.61
WI	98	-0.668	170	-1.9
Overall	375		188	

Power of the Test (Commercial:
Log Total Phosphorous)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	101	-0.61	0.336
SP	93	-0.62	0.298
SU	83	-0.56	0.363
WI	98	-0.68	0.305

Pooled Standard Deviation 0.326
Obtained Effect Size 0.13

α level	Power (%)
0.20	78.2
0.15	72.9
0.10	65.4
0.05	***53.0***
0.01	29.4

C.4.4 Total Phosphorous - Industrial Land Use

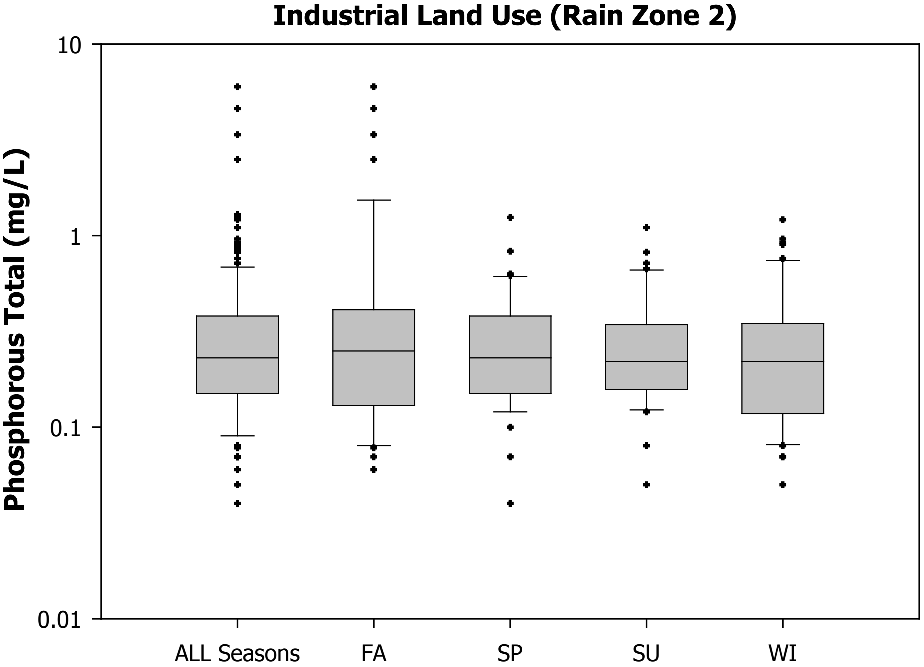


Fig. C72. Total Phosphorous – Industrial Land Use by Season

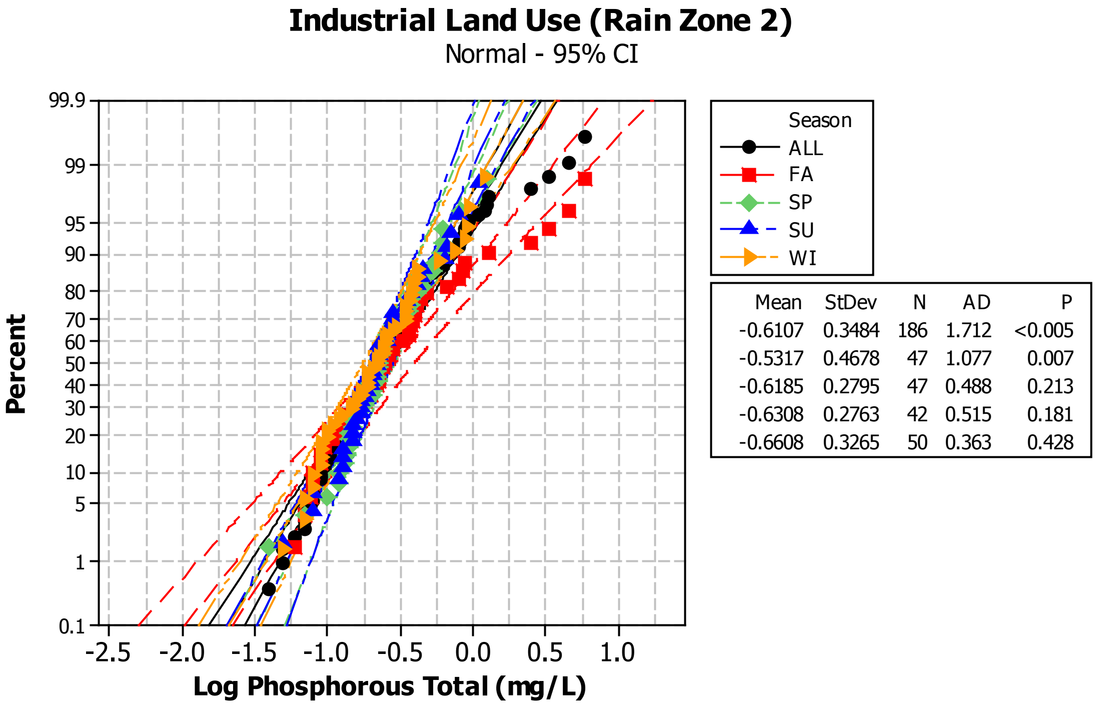


Fig. C73. Total Phosphorous – Industrial Land Use (Checks for Normality)

Table C57. Statistical Analyses for Total Phosphorous – Industrial Land Use

Kruskal-Wallis Test
(Industrial: Log Total Phosphorous)

H = 1.43 DF = 3 P = 0.699
H = 1.43 DF = 3 P = 0.699(adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	47	-0.602	99.9	0.94
SP	47	-0.638	95.2	0.25
SU	42	-0.658	92	-0.2
WI	50	-0.658	87.2	-0.9
Overall	186		93.5	

Power of the Test (Industrial:
Log Total Phosphorous)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	47	-0.53	0.468
SP	47	-0.62	0.280
SU	42	-0□63	0.276
WI	50	-0.66	0.327

Pooled Standard Deviation 0.338
Obtained Effect Size 0.15

α level	Power (%)
0.20	62.5
0.15	55□8
0.10	47.1
0.05	***34.5***
0.01	15.3

C.4.5 Total Phosphorous - Institutional Land Use

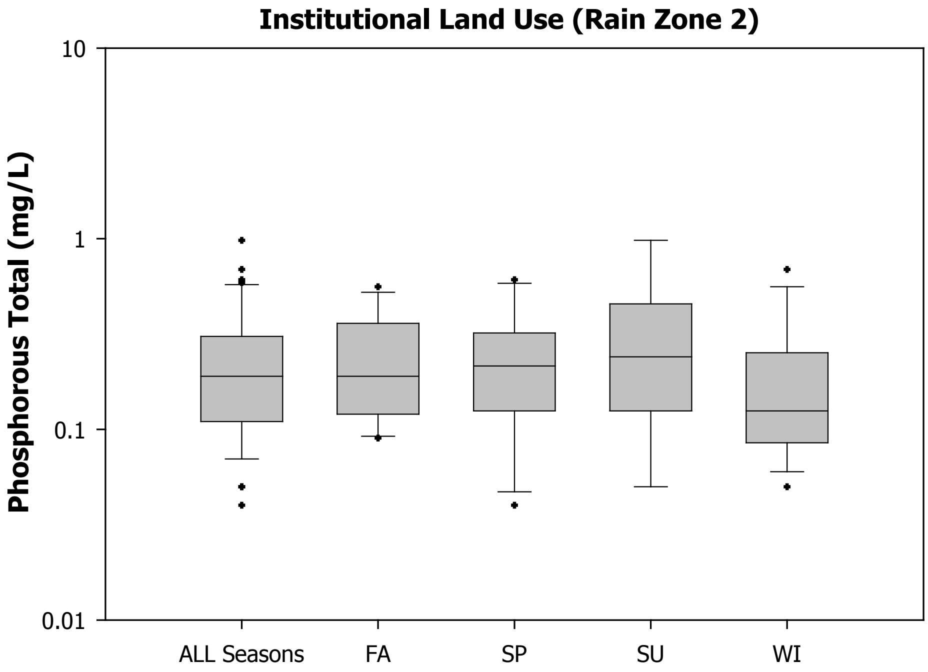
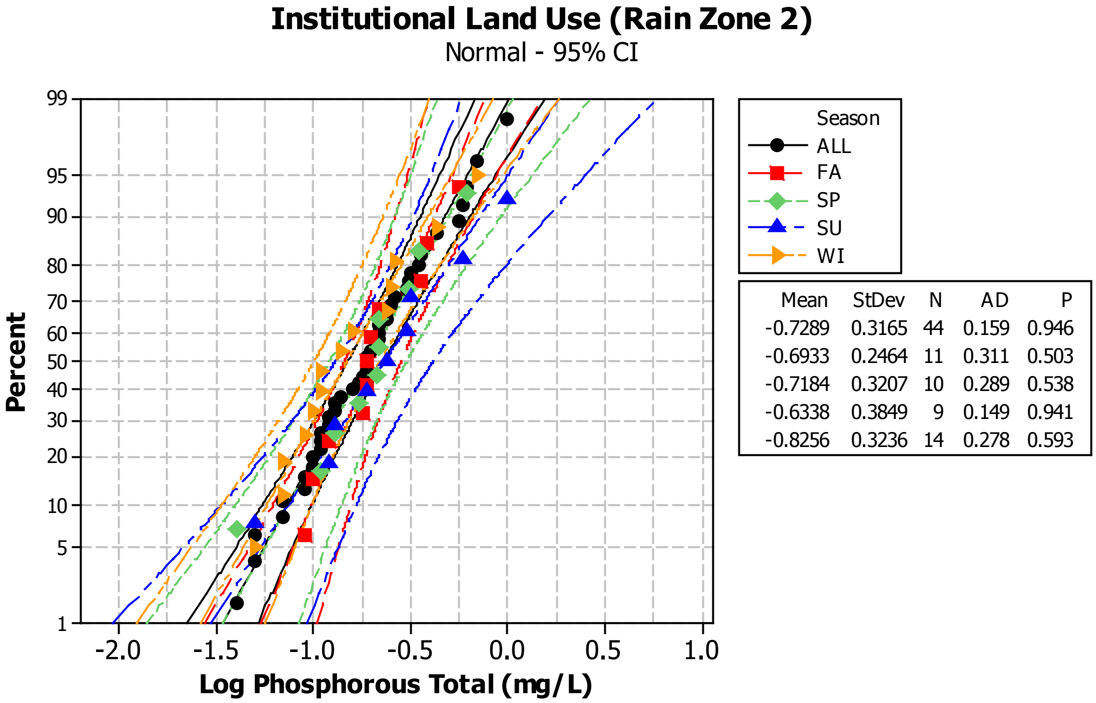


Fig. C74. Total Phosphorous – Institutional Land Use by Season



Mean	StDev	N	AD	P
-0.7289	0.3165	44	0.159	0.946
-0.6933	0.2464	11	0.311	0.503
-0.7184	0.3207	10	0.289	0.538
-0.6338	0.3849	9	0.149	0.941
-0.8256	0.3236	14	0.278	0.593

Fig. C75. Total Phosphorous – Institutional Land Use (Checks for Normality)

Table C58. Statistical Analyses for Total Phosphorous – Institutional Land Use

Kruskal-Wallis Test
(Institutional: Log Total Phosphorous)

H = 2.32 DF = 3 P = 0.508
H = 2.33 DF = 3 P = 0.507 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	11	-0.721	23.5	0.3
SP	10	-0.668	23.8	0.35
SU	9	-0.620	26.2	0.97
WI	14	-0.906	18.4	-1.44
Overall	44		22.5	

Power of the Test (Institutional:
Log Total Phosphorous)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	11	-0.69	0.246
SP	10	-0.72	0.321
SU	9	-0.63	0.385
WI	14	-0.83	0.324

Pooled Standard Deviation 0.319

Obtained Effect Size 0.24

α level	Power (%)
0.20	47.7
0.15	40.6
0.10	32.1
0.05	***21.0***
0.01	7.2

C.4.6 Total Phosphorous – Open Space Land Use

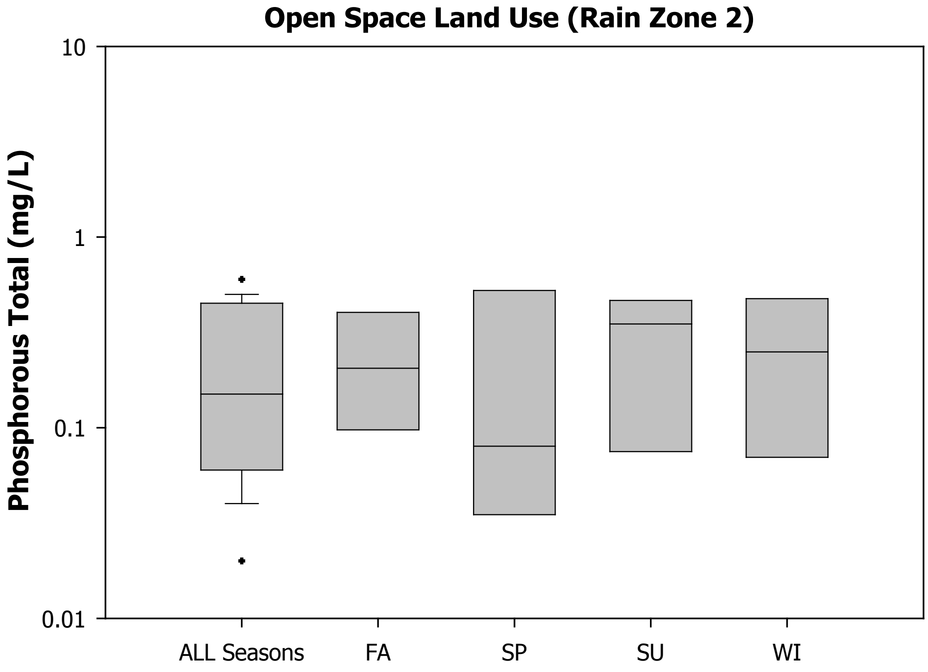
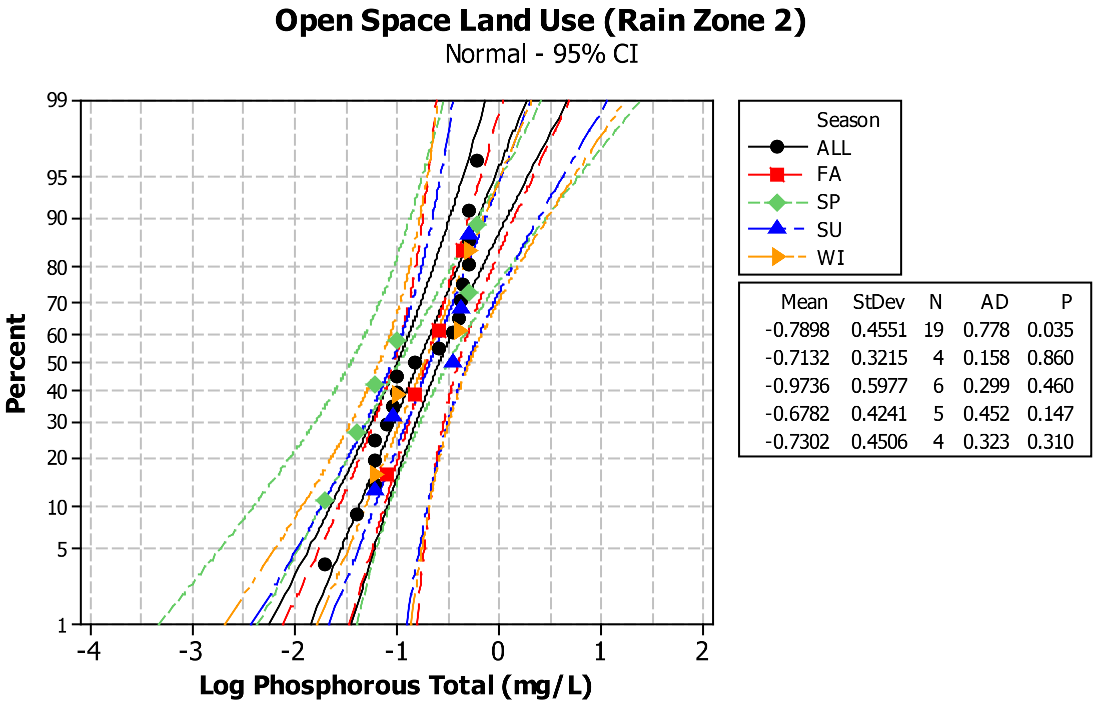


Fig. C76. Total Phosphorous – Open Space Land Use by Season



Mean	StDev	N	AD	P
-0.7898	0.4551	19	0.778	0.035
-0.7132	0.3215	4	0.158	0.860
-0.9736	0.5977	6	0.299	0.460
-0.6782	0.4241	5	0.452	0.147
-0.7302	0.4506	4	0.323	0.310

Fig. C77. Total Phosphorous – Open Space Land Use by Season

Table C59. Statistical Analyses for Total Phosphorous – Open Space Land Use

Kruskal-Wallis Test
(Open Space: Log Total Phosphorous)

H = 0.56 DF = 3 P = 0.905
H = 0.57 DF = 3 P = 0.904 (adjusted for ties)

Season	**N**	**Median**	**Ave Rank**	**Z**
FA	4	-0.705	10.5	0.2
SP	6	-1.12	8.6	-0.75
SU	5	-0.456	10.8	0.37
WI	4	-0.699	10.6	0.25
Overall	19		10	

Power of the Test (Open Space: Log Total Phosphorous)

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	4	-0.71	0.322
SP	6	-0.97	0.598
SU	5	-0.68	0.424
WI	4	-0.73	0.451
Pooled Standard Deviation			0.449
Obtained Effect Size			0.28

α level	**Power (%)**
0.20	35.9
0.15	29.1
□.10	21.5
0.05	***12.6***
0.01	3.4

C.4.7 Total Phosphorous - Freeways Land Use

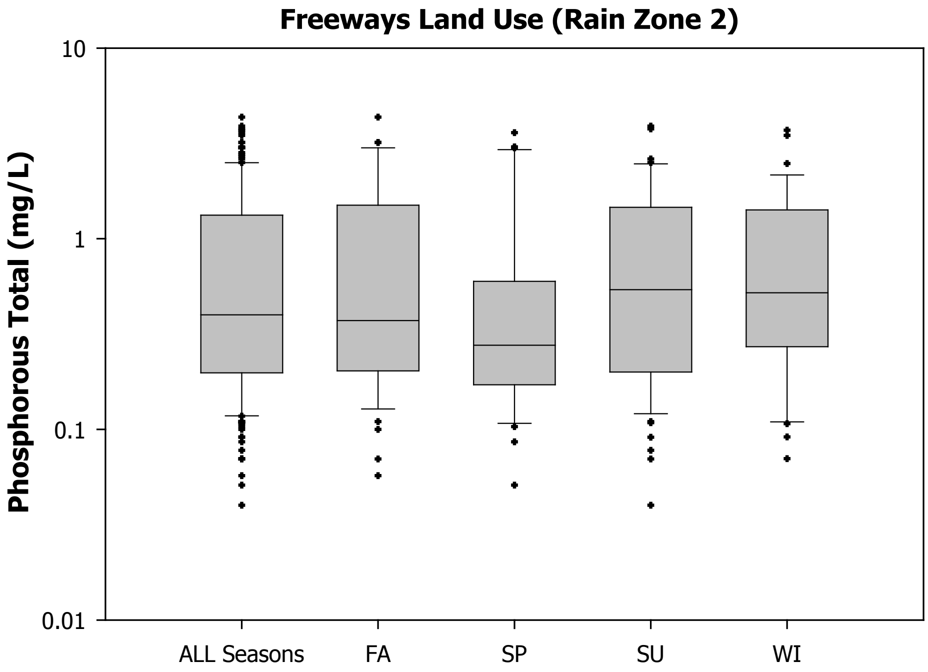
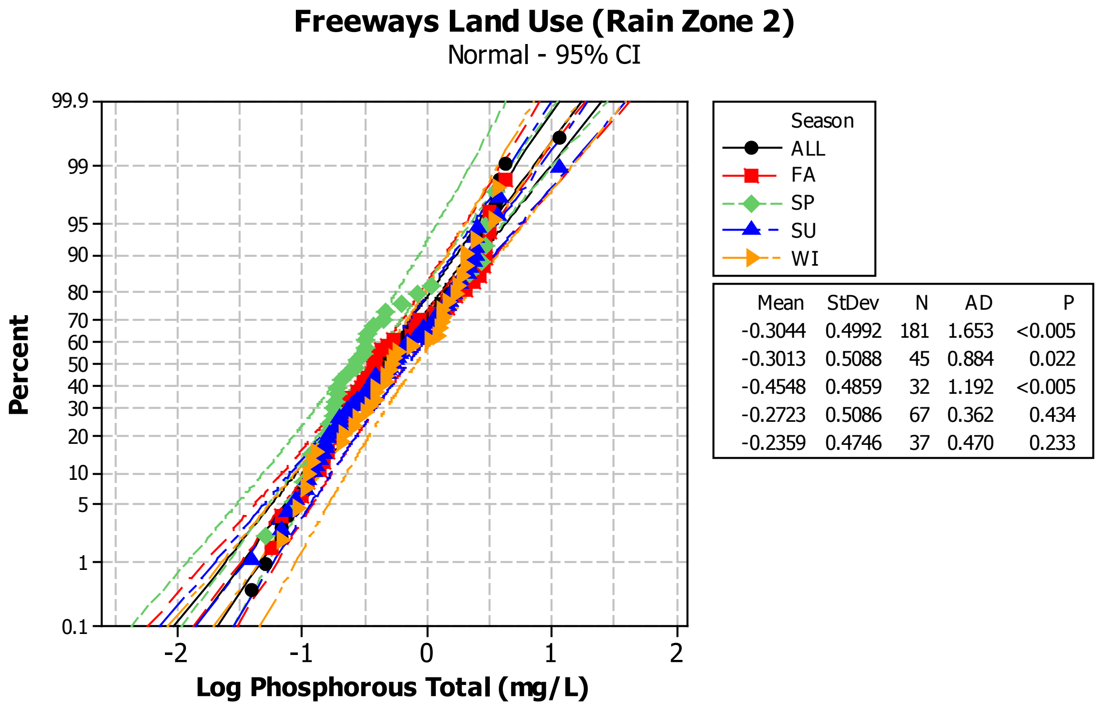


Fig. C78. Total Phosphorous – Freeways Land Use by Season



Mean	StDev	N	AD	P
-0.3044	0.4992	181	1.653	<0.005
-0.3013	0.5088	45	0.884	0.022
-0.4548	0.4859	32	1.192	<0.005
-0.2723	0.5086	67	0.362	0.434
-0.2359	0.4746	37	0.470	0.233

Fig. C79. Total Phosphorous – Freeways Land Use (Checks for Normality)

Table C60. Statistical Analyses for Total Phosphorous – Freeways Land Use

Kruskal-Wallis Test
(Freeways: Log Total Phosphorous)

H = 4.58 DF = 3 P = 0.205
H = 4.58 DF = 3 P = 0.205 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	45	-0.429	91.3	0.05
SP	32	-0.559	74.0	-2.0
SU	67	-0.268	94.3	0.6
WI	37	-0.284	99.3	1.1
Overall	181		91.0	

Power of the Test (Freeways: Log Total Phosphorous)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	45	-0.30	0.509
S	32	-0.45	0.486
SU	67	-0.27	0.509
WI	37	-0.24	0.475

Pooled Standard Deviation 0.494

Obtained Effect Size 0.16

α level	Power (%)
0.20	61.0
0.15	54.2
0.10	45.5
0.05	***38.7***
0.01	14.3

C.5.8 Total Phosphorous Land Use and Season Groups

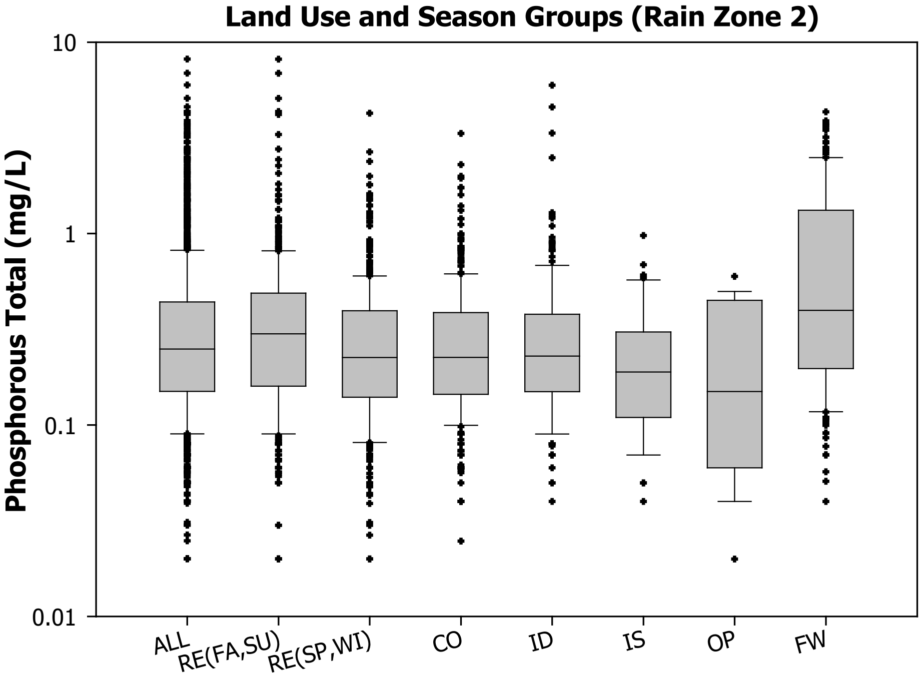


Fig. C80. Total Phosphorous – Land Use and Season Groups

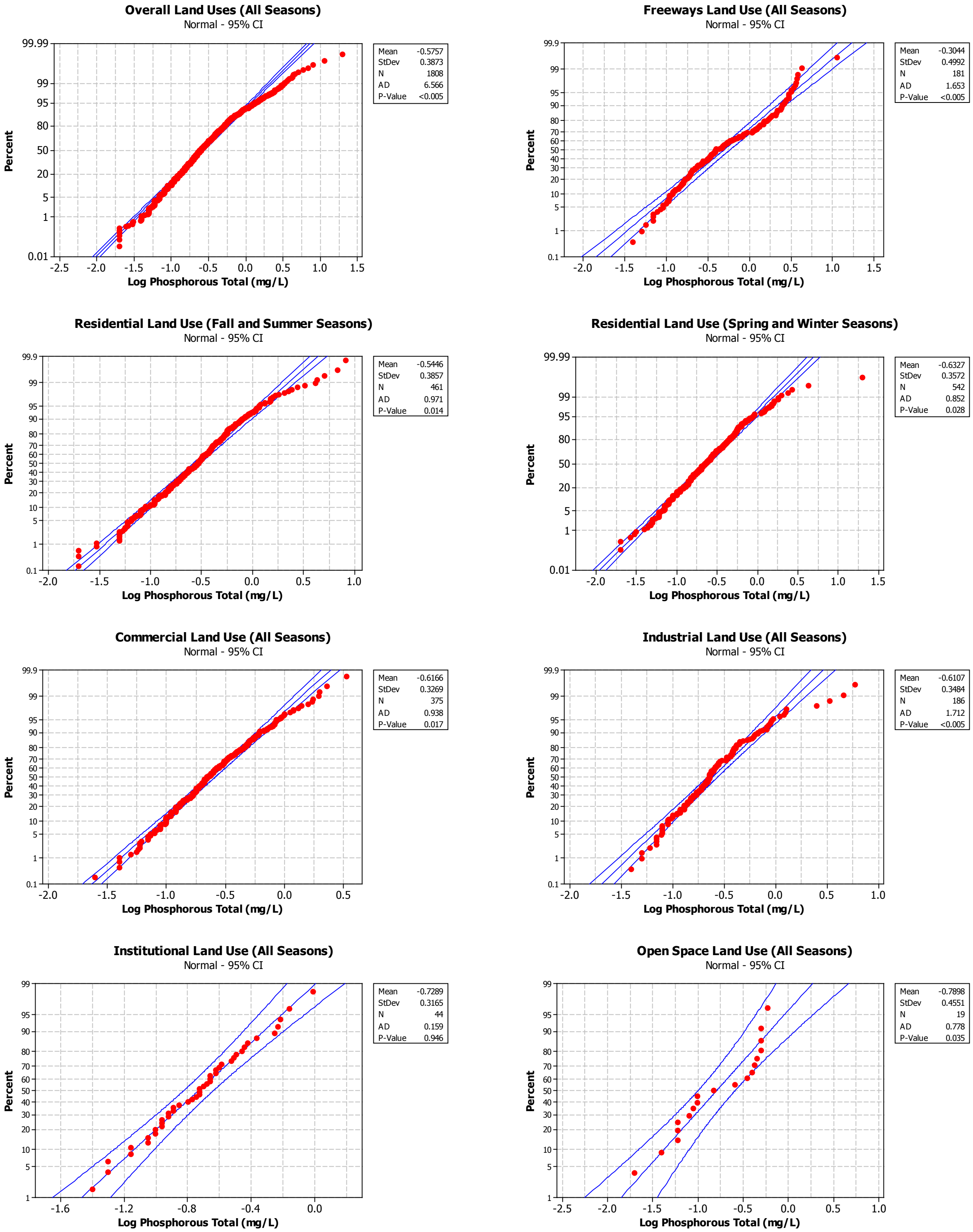


Fig. C80. – *Continued*

Table C61. Statistical Analyses for Total Phosphorous – Land Use and Season Groups

Kruskal-Wallis Test
(Land Use and Season Groups: Log Total Phosphorous)

H = 83.09 DF = 6 P = 0.000
H = 83.10 DF = 6 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE(FA,SU)	461	-0.523	967	3.0
RE(SP,WI)	542	-0.646	836	-3.7
CO	375	-0.645	854	-2.1
ID	186	-0.638	849	-1.5
IS	44	-0.721	698	-2.7
OP	19	-0.824	704	-1.7
FW	181	-0.399	1184	7.6
Overall	1808		905	

Land Use and Season Groups
(medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE(FA,SU)	-0.523			
ID		-0.638		
RE(SP,WI)		-0.646		
CO		-0.645		
IS			-0.721	
OP			-0.824	
FW				-0.399

Table C62. Land Use and Season Multiple Comparisons for Total Phosphorous

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
RE(FA,SU)	RE(SP,WI)	0.000*	RE(SP,WI)	CO	0.540	CO	ID	0.914
	CO	0.001*		ID	0.744		IS	0.046*
	ID	0.006*		IS	0.088		OP	0.170
	IS	0.001*		OP	0.217		FW	0.000*
	OP	0.053		FW	0.000*			
	FW	0.000*				ID	IS	0.056
			IS	OP	0.725		OP	0.241
OP	FW	0.001*		FW	0.000*		FW	0.000*

Table C63. All Possible Land Use and Season Combinations for Total Phosphorous

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE(FA,SU)	-0.523			
OP	-0.824	-0.824	-0.824	
RE(SP,WI)		-0.646	0.646	
ID		-0.638	-0.638	
CO		-0.645		
IS			-0.721	
FW				-0.399

Table C64. Power of the Test for Total Phosphorous – Land Use and Season Groups

Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,SU)	461	-0.54	0.386
RE(SP,WI)	542	-0.63	0.357
CO	375	-0.62	0.327
ID	186	-0.61	0.348
IS	44	-0.73	0.317
OP	19	-0.79	0.455
FW	181	-0.30	0.499

Pooled Standard Deviation	0.384
Obtained Effect size	0.27

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

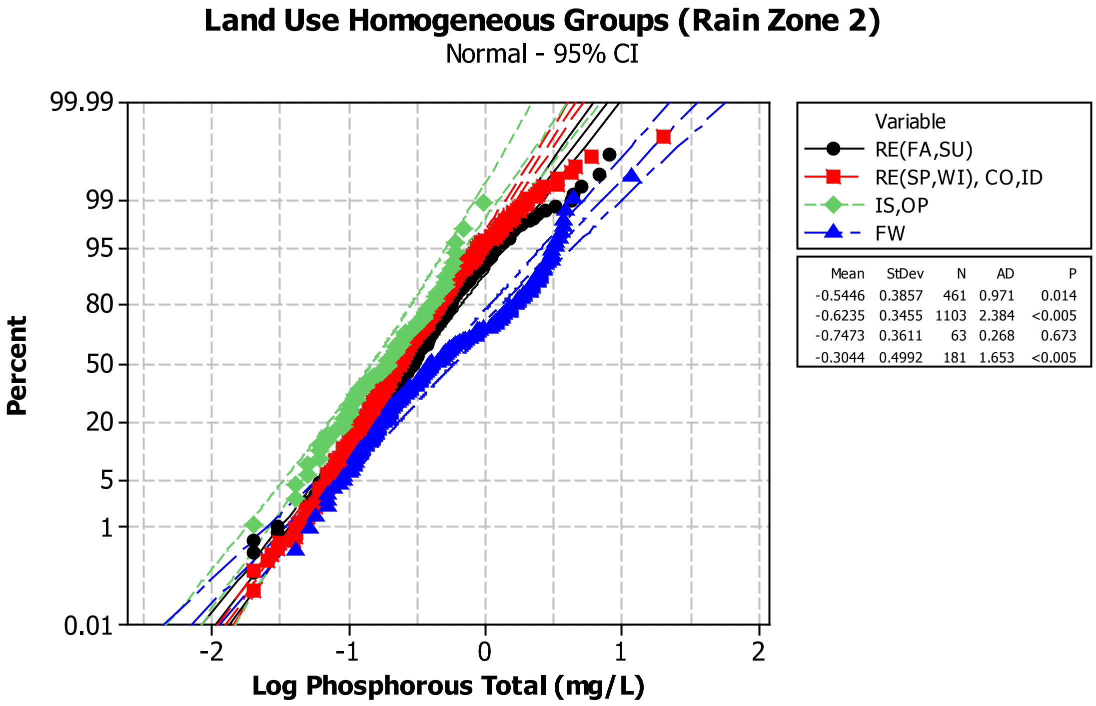
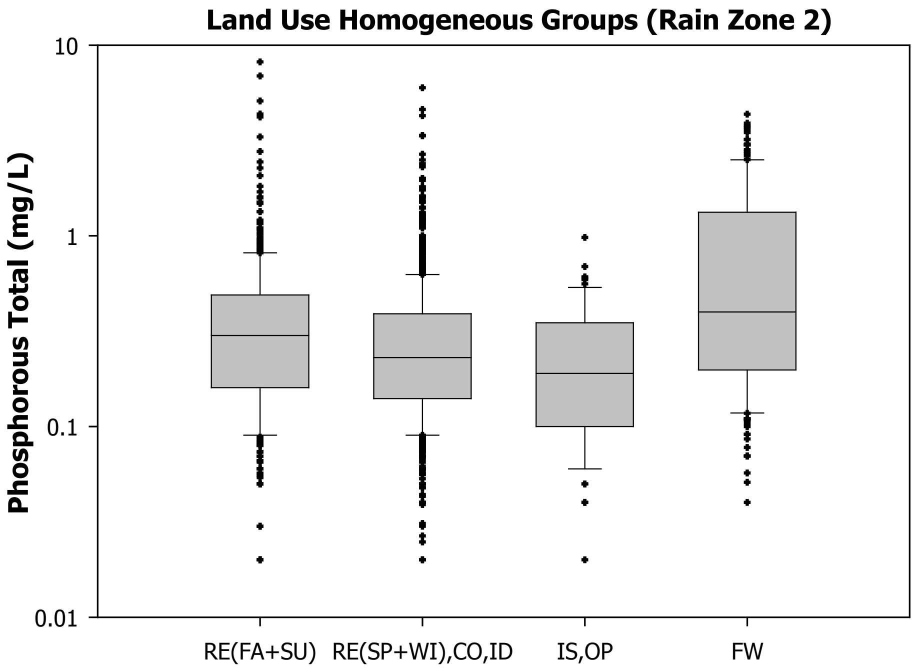


Fig. C81. Total Phosphorous – Land Use Homogeneous Groups (Checks for Normality)



Land Uses	FALL	SPRING	SUMMER	WINTER
Residential	0.39(1.1)	0.40(3.1)	0.51(1.8)	0.32(0.86)
Commercial	0.34(0.96)	0.30(0.80)	0.42(1.2)	0.27(0.79)
Industrial	0.63(1.9)	0.30(0.74)	0.29(0.75)	0.29(0.87)
Institutional	0.24(0.61)	0.24(0.67)	0.32(0.90)	0.20(0.89)
Open Space	0.24(0.69)	0.22(1.2)	0.29(0.70)	0.27(0.82)
Freeways	0.96(1.2)	0.71(1.4)	1.0(1.5)	0.96(0.97)

Fig. C82. Total Phosphorous – Land Use Homogeneous Groups: Mean (CV)

Table C65. Statistical Analyses for Total Phosphorous – Land Use Homogeneous Groups

Kruskal-Wallis Test (Homogeneous Groups: Log Total Phosphorous)

H = 82.78 DF = 3 P = 0.000
H = 82.79 DF = 3 P = 0.000 (adjusted for ties)

Groups		N	Median	Ave Rank	Z
1	RE (FA,SU)	461	-0.52	967	3
2	RE (SP,WI) CO,ID	1103	-0.64	844	-6
3	IS,OP	63	-0.72	700	-3
4	FW	181	-0.40	1184	8
Overall			1808		905

Multiple Comparisons
(Mann-Whitney U Test)

(I) Group	(J) Group	p-value
1	2	0.000*
	3	0.002*
	4	0.000*
2	3	0.023*
	4	0.000*
3	4	0.000*

Log Total Phosphorous Homogeneous Groups (medians)

Group	Gr.A	Gr.B	Gr.C	Gr.D
1	-0.52			
2		-0.64		
3			-0.72	
4				-0.40

Table C66. Power of the Test for Total Phosphorous – Land Use Homogeneous Groups

Homogeneous Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,SU)	461	-0.545	0.386
RE(SP,WI), CO,ID	1103	-0.624	0.346
IS,OP	63	-0.747	0.361
FW	181	-0.304	0.499
Pooled Standard Deviation			0.374
Obtained Effect Size			0.27

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.005	***100***
0.01	100

Table C67. Basic Statistics for Total Phosphorous Homogeneous Groups (Real Space Data)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	RE(FA,SU)	461	0.45	0.69	1.5	0.02	0.30	8.2
B	RE(SP,WI), CO,ID	1103	0.35	0.72	2.0	0.02	0.23	20
C	IS,OP	63	0.24	0.19	0.79	0.02	0.19	0.98
D	FW	181	0.95	1.3	1.3	0.04	0.40	12

C.5. Dissolved Phosphorous

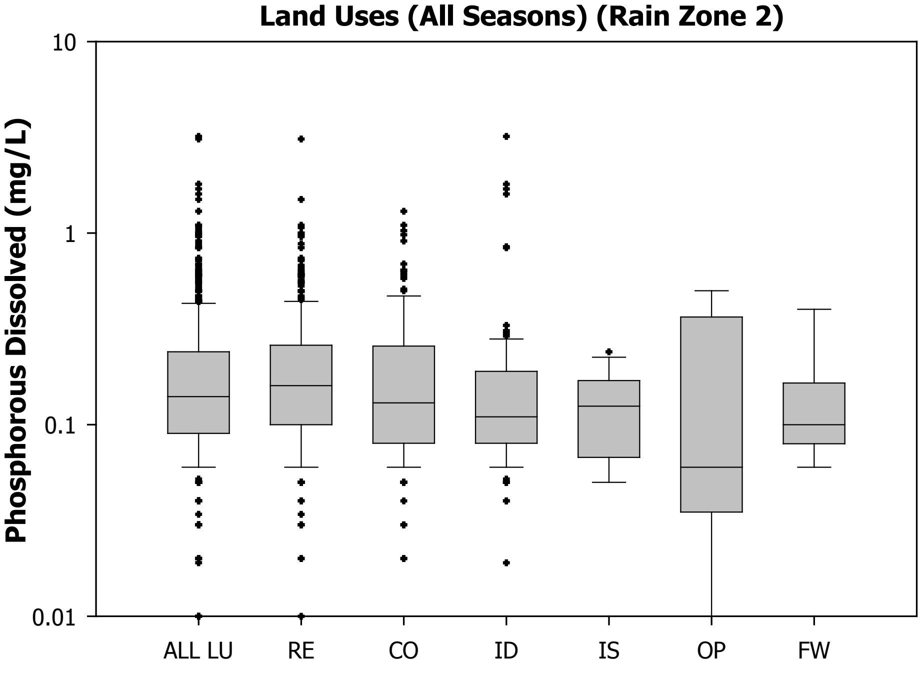
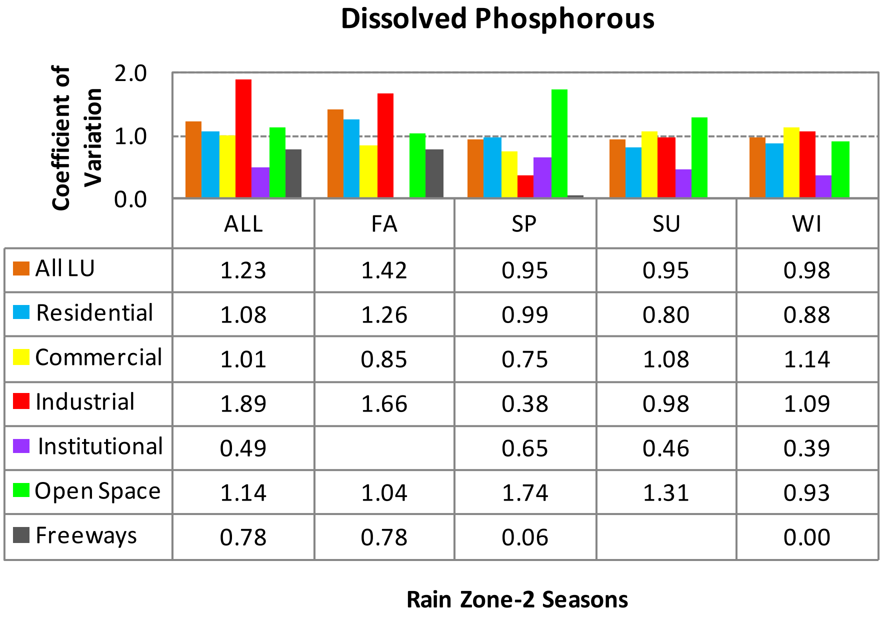


Fig. C83. Dissolved Phosphorous - Single Land Uses in EPA Rain Zone 2



	ALL	FA	SP	SU	WI
🟧 All LU	1.23	1.42	0.95	0.95	0.98
🟦 Residential	1.08	1.26	0.99	0.80	0.88
🟨 Commercial	1.01	0.85	0.75	1.08	1.14
🟥 Industrial	1.89	1.66	0.38	0.98	1.09
🟪 Institutional	0.49		0.65	0.46	0.39
🟩 Open Space	1.14	1.04	1.74	1.31	0.93
⬛ Freeways	0.78	0.78	0.06		0.00

Fig. C84. Dissolved Phosphorous – EPA Rain Zone 2 Seasonal Coefficients of Variation

C.5.1 Dissolved Phosphorous - All Single Land Uses

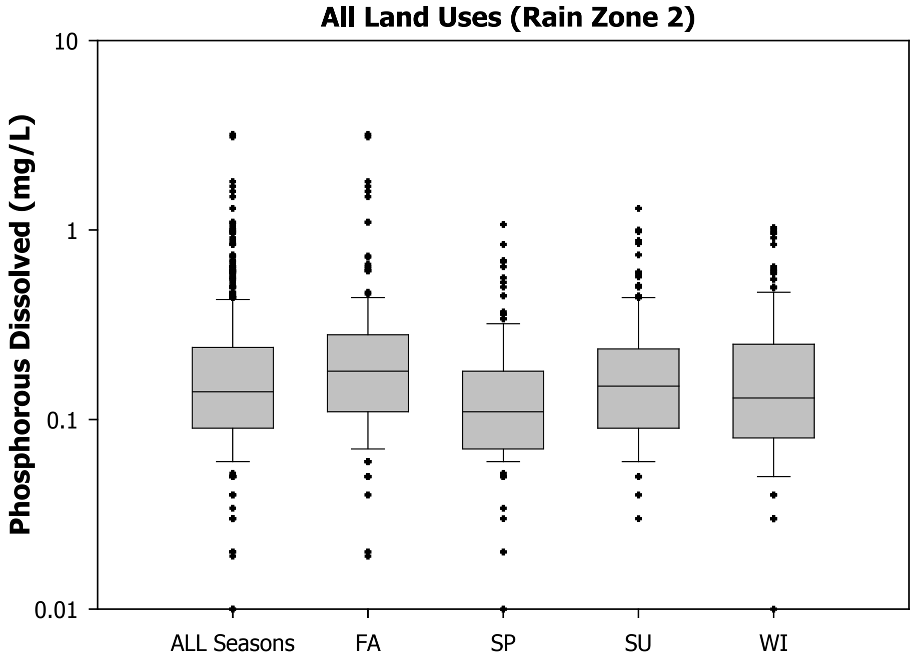


Fig. C85. Dissolved Phosphorous – All Single Land Uses by Season

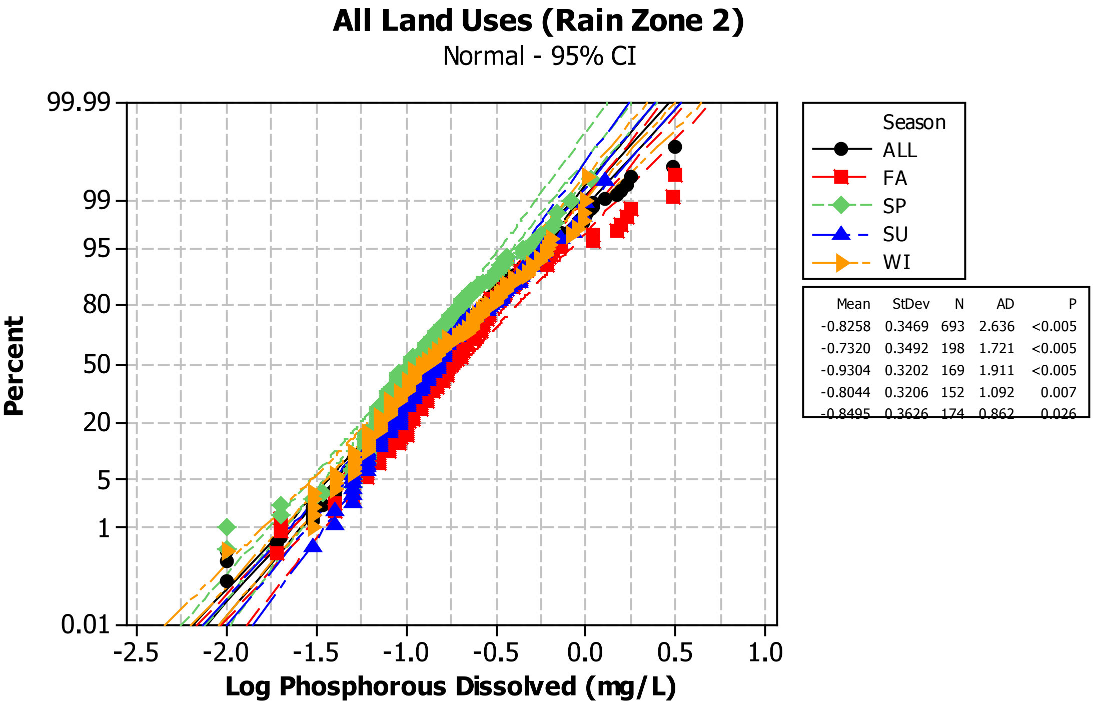


Fig. C86. Dissolved Phosphorous – All Single Land Uses (Checks for Normality)

Table C68. Statistical Analyses for Dissolved Phosphorous - All Single Land Uses

Kruskal-Wallis Test
(All Land Uses: Log Dissolved Phosphorous)

H = 35.26 DF = 3 P = 0.000
H = 35.31 DF = 3 P = 0.00(adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	198	-0.745	406	4.89
SP	169	-0.959	284	-4.7
SU	152	-0.824	358	0.76
WI	174	-0.886	332	-1.2
Overall	693		347	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.000*
	SU	0.019*
	WI	0.001*
SP	SU	0.001*
	WI	0.046*
SU	WI	0.223

All Land Uses
Log Dissolved Phosphorous
Groups (medians)

Season	Gr.1	Gr.2	Gr.3
FA	-0.75		
SU		-0.82	
WI		-0.89	
SP			-0.96

Fig. C69. All Possible Seasonal Combinations for Dissolved Phosphorous – All Single Land Uses

Season	Gr. 1	Gr. 2	Gr. 3
FA	-0.745		
SU		-0.824	
WI		-0.886	
SP			-0.959

Table C70. Power of the Test for Dissolved Phosphorous - All Single Land Uses

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	198	-0.73	0.349
SP	169	-0.93	0.320
SU	152	-0.80	0.321
WI	174	-0.85	0.363
Pooled Standard Deviation			0.338
Obtained Effect Size			0.22

α level	Power (%)
0.20	99.9
0.15	99.9
0.10	99.9
0.05	***99.9***
0.01	99.6

C.5.2 Dissolved Phosphorous - Residential Land Use

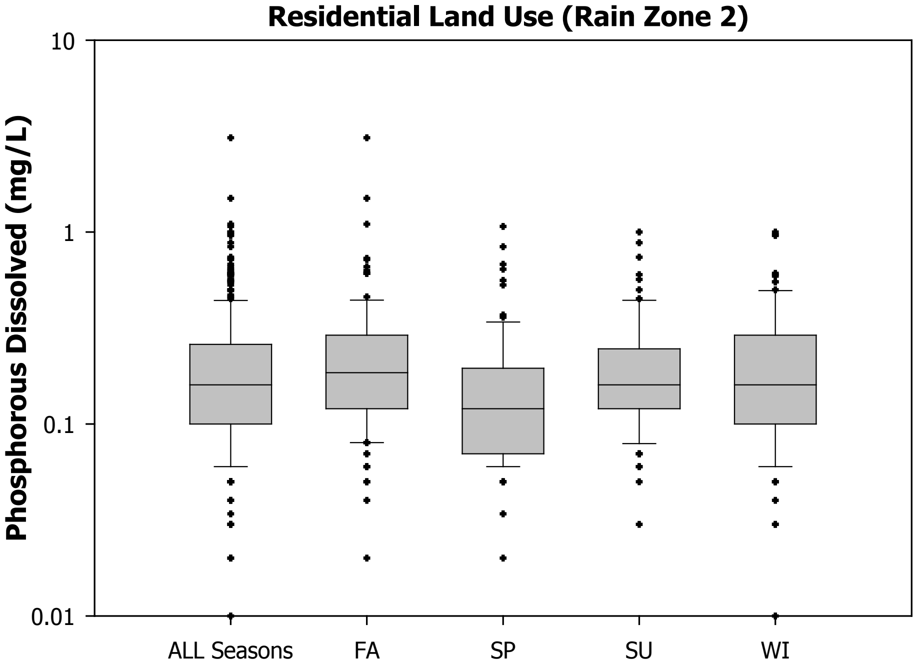


Fig. C87. Dissolved Phosphorous – Residential Land Use by Season

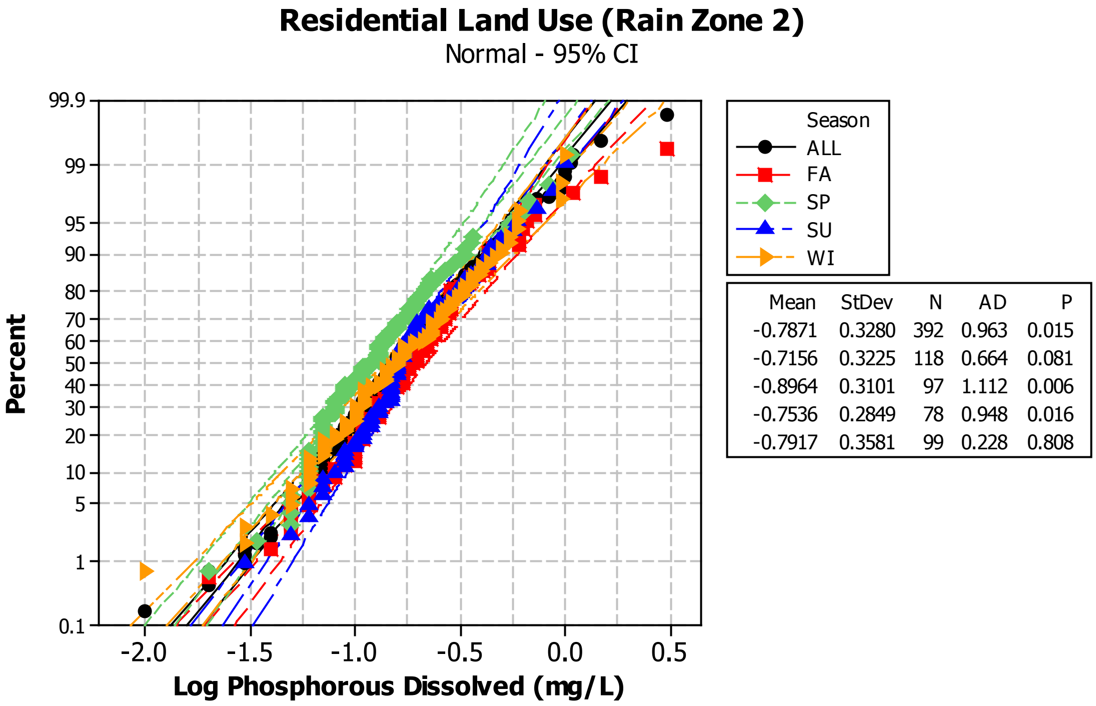


Fig. C88. Dissolved Phosphorous – Residential Land Use (Checks for Normality)

Table C71. Statistical Analyses for Dissolved Phosphorous – Residential Land Use

Kruskal-Wallis Test
(Residential: Log Dissolved Phosphorous)

H = 20.88 DF = 3 P = 0.000
H = 20.90 DF = 3 P = 0.000(adjusted for ties)

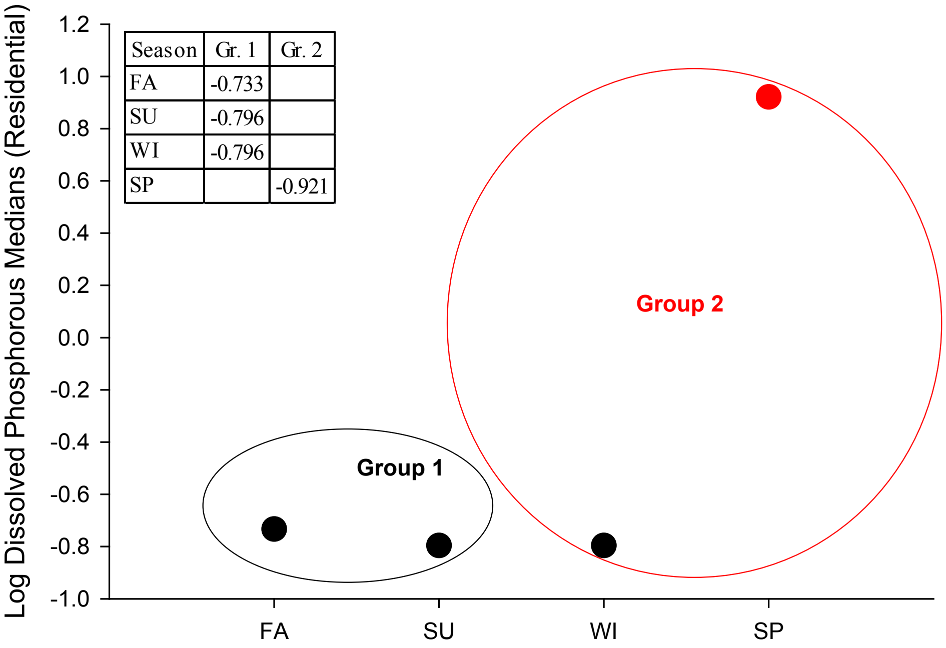
Season	N	Median	Ave Rank	Z
FA	118	-0.733	223	3.02
SP	97	-0.921	154	-4.3
SU	78	-0.796	209	1.1
WI	99	-0.796	197	0.04
Overall	392		196.5	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.000*
	SU	0.308
	WI	0.121
SP	SU	0.001*
	WI	0.014*
SU	WI	0.502

Residential Log
Dissolved Phosphorous
Groups (medians)

Season	Gr. 1	Gr. 2
FA	-0.733	
SU	-0.796	
WI	-0.796	
SP		-0.921



Season	Gr. 1	Gr. 2
FA	-0.733	
SU	-0.796	
WI	-0.796	
SP		-0.921

Fig. C89. All Possible Seasonal Combinations for Dissolved Phosphorous – Residential Land Use

Table C72. Power of the Test for Dissolved Phosphorous – Residential Land Use

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	118	-0.72	0.323
SP	97	-0.90	0.310
SU	78	-0.75	0.285
WI	99	-0.79	0.358
Pooled Standard Deviation			0.319
Obtained Effect Size			0.22

α level	**Power (%)**
0.20	99.3
0.15	98.9
0.10	98.1
0.05	***96.1***
0.01	87.7

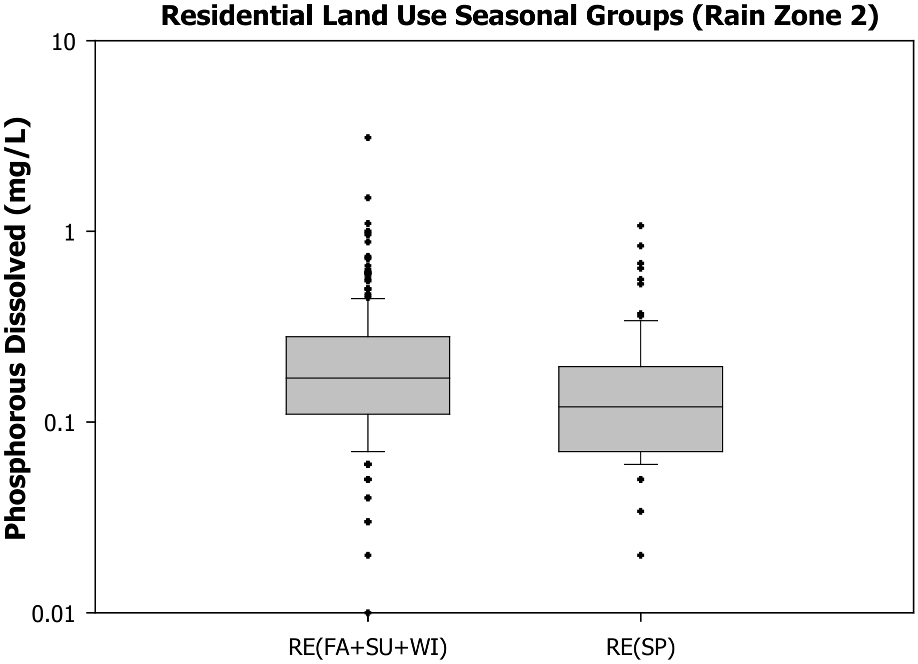


Fig. C90. Dissolved Phosphorous – Residential Land Use Seasonal Groups

Table C73. Statistical Analyses for Dissolved Phosphorous – Residential Land Use Seasonal Groups

Kruskal-Wallis Test (Residential: Log Dissolved Phosphorous Groups)

H = 18.03 DF = 1 P = 0.000
H = 18.05 DF = 1 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE(FA,SU,WI)	295	-0.770	210	4.3
RE(SP)	97	-0.921	154	-4.3
Overall	392		197	

Table C74. Power of the Test for Dissolved Phosphorous – Residential Land Use Seasonal Groups

Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,SU,WI)	295	-0.75	0.326
RE(SP)	97	-0.90	0.310
Pooled Standard Deviation			0.318
Obtained Effect Size			0.20

α level	Power (%)
0.20	99.7
0.15	99.5
0.10	99.1
0.05	***98.0***
0.01	92.5

C.5.3 Dissolved Phosphorous - Commercial Land Use

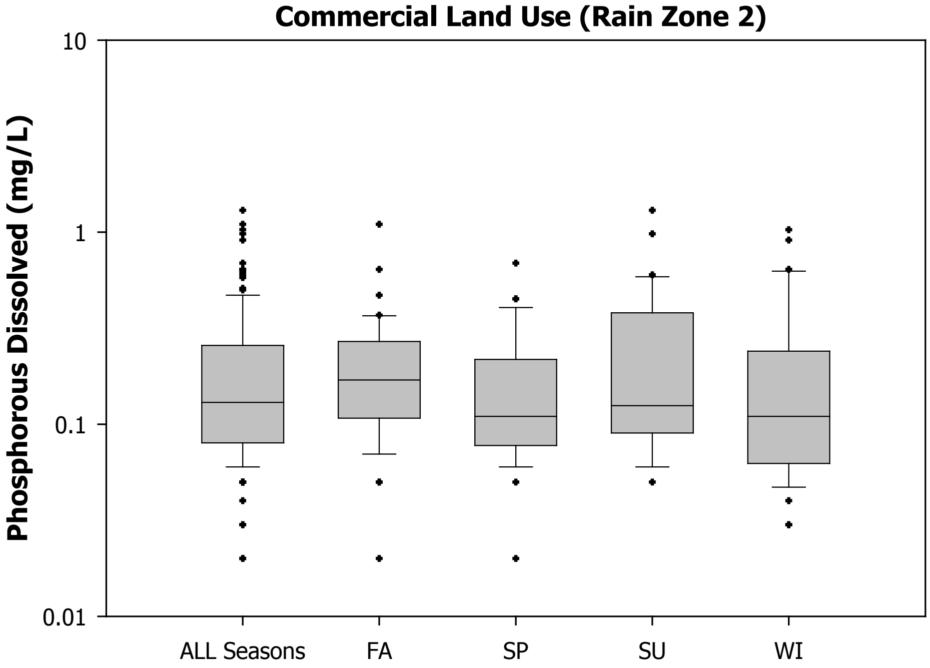
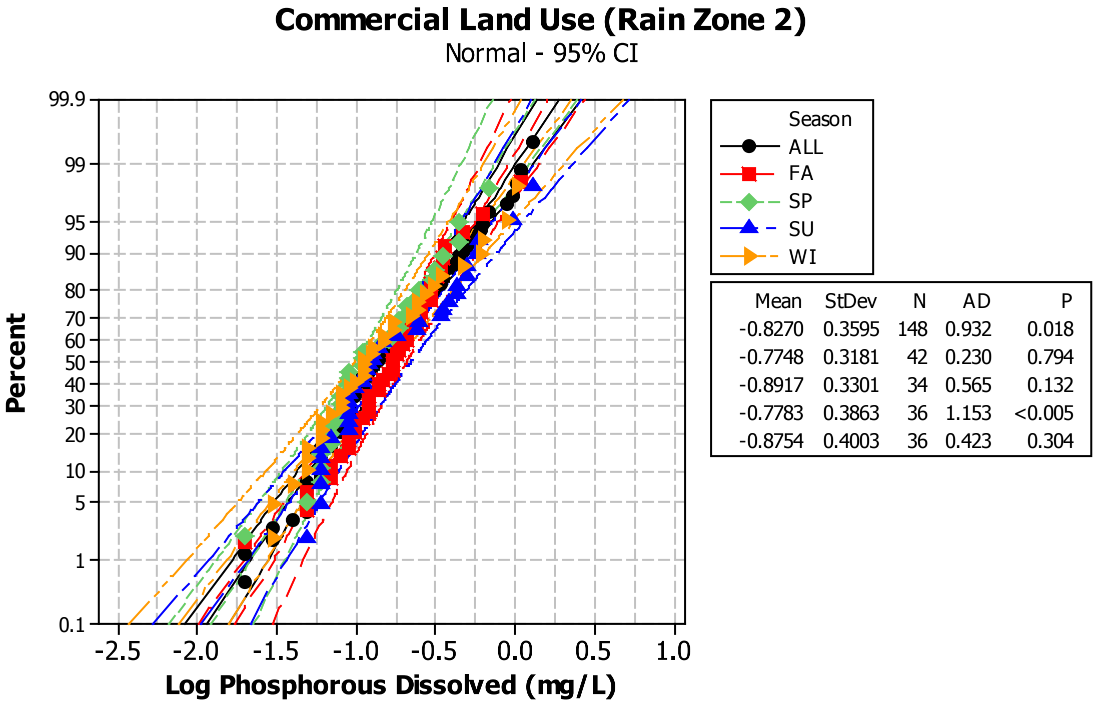


Fig. C91. Dissolved Phosphorous – Commercial Land Use by Season



Mean	StDev	N	AD	P
-0.8270	0.3595	148	0.932	0.018
-0.7748	0.3181	42	0.230	0.794
-0.8917	0.3301	34	0.565	0.132
-0.7783	0.3863	36	1.153	<0.005
-0.8754	0.4003	36	0.423	0.304

Fig. C92. Dissolved Phosphorous – Commercial Land Use (Checks for Normality)

Table C75. Statistical Analyses for Dissolved Phosphorous – Commercial Land Use

Kruskal-Wallis Test (Commercial: Log Dissolved Phosphorous)

H = 4.29 DF = 3 P = 0.232
H = 4.29 DF = 3 P = 0.231
(adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	42	-0.769	83.9	1.7
SP	34	-0.959	66.9	-1.2
SU	36	-0.903	77.8	0.54
WI	36	-0.959	67.4	-1.1
Overall	148		74.5	

Power of the Test (Commercial: Log Dissolved Phosphorous)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	42	-0.77	0.318
SP	34	-0.89	0.330
SU	36	-0.78	0.386
WI	36	-0.88	0.400
Pooled Standard Deviation			0.359
Obtained Effect Size			0.15

α level	Power (%)
0.20	58.9
0.15	52.1
0.10	43.3
0.05	***30.9***
0.01	13.0

C.5.4 Dissolved Phosphorous - Industrial Land Use

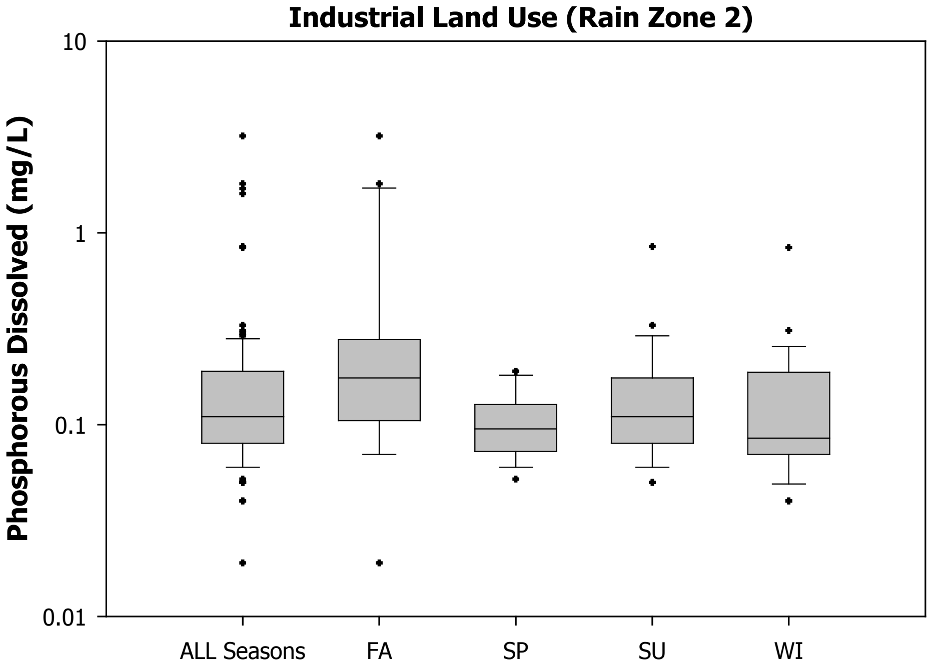


Fig. C93. Dissolved Phosphorous – Industrial Land Use by Season

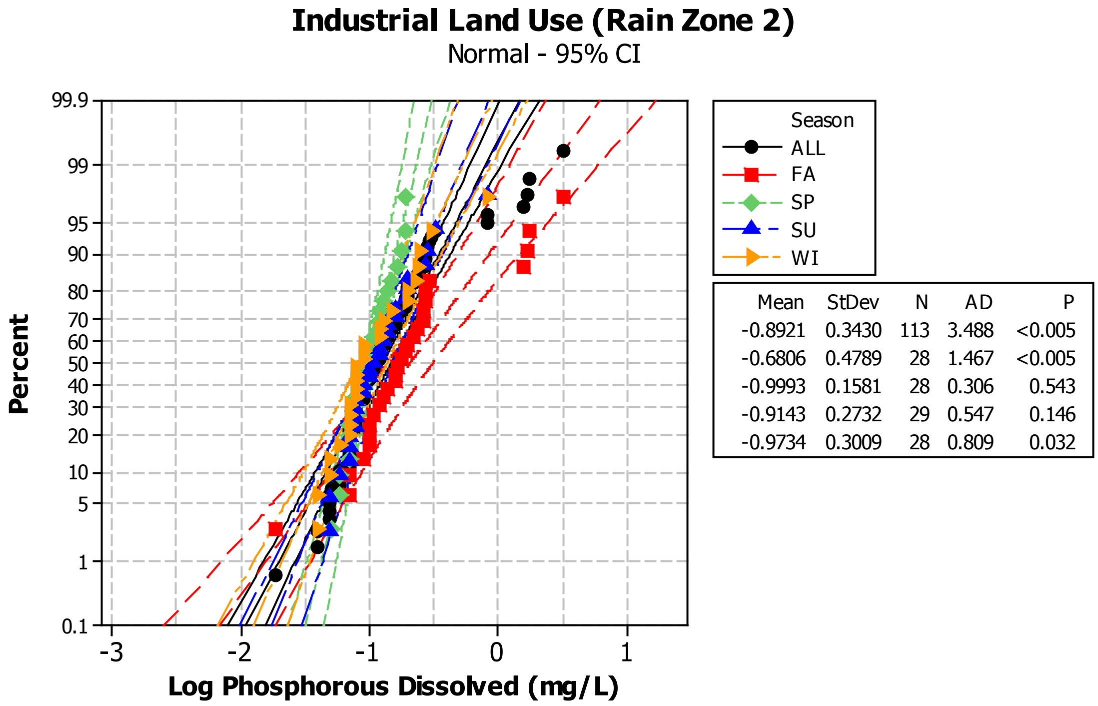


Fig. C94. Dissolved Phosphorous – Industrial Land Use (Checks for Normality)

Table C76. Statistical Analyses for Dissolved Phosphorous – Industrial Land Use

Kruskal-Wallis Test
(Industrial: Log Dissolved Phosphorous)

H = 14.30 DF = 3 P = 0.003
H = 14.36 DF = 3 P = 0.002(adjusted for ties)

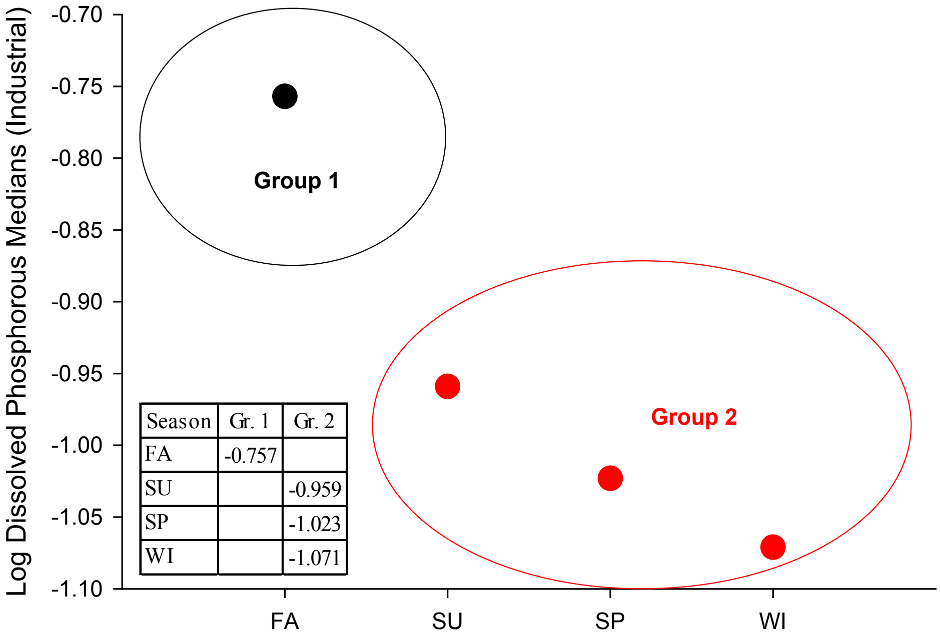
Season	N	Median	Ave Rank	Z
FA	28	-0.757	76.4	4
SP	28	-1.023	47.5	-2
SU	29	-0.959	56.3	0
WI	28	-1.071	47.9	-2
Overall	113		57	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.000*
	SU	0.019*
	WI	0.003*
SP	SU	0.318
	WI	0.857
SU	WI	0.318

Industrial Log Dissolved Phosphorous Groups (medians)

Season	Gr. 1	Gr. 2
FA	-0.757	
SU		-0.959
SP		-1.023
WI		-1.071



Season	Gr. 1	Gr. 2
FA	-0.757	
SU		-0.959
SP		-1.023
WI		-1.071

Fig. C95. All Possible Seasonal Combinations for Dissolved Phosphorous – Industrial Land Use

Table C77. Power of the Test for Dissolved Phosphorous – Industrial Land Use

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	28	-0.68	0.479
SP	28	-1.00	0.158
SU	29	-0.91	0.273
WI	28	-0.97	0.301
Pooled Standard Deviation			0.303
Obtained Effect Size			0.41

α level	**Power (%)**
0.20	99.4
0.15	99.0
0.10	98.3
0.05	***96.4***
0.01	87.9

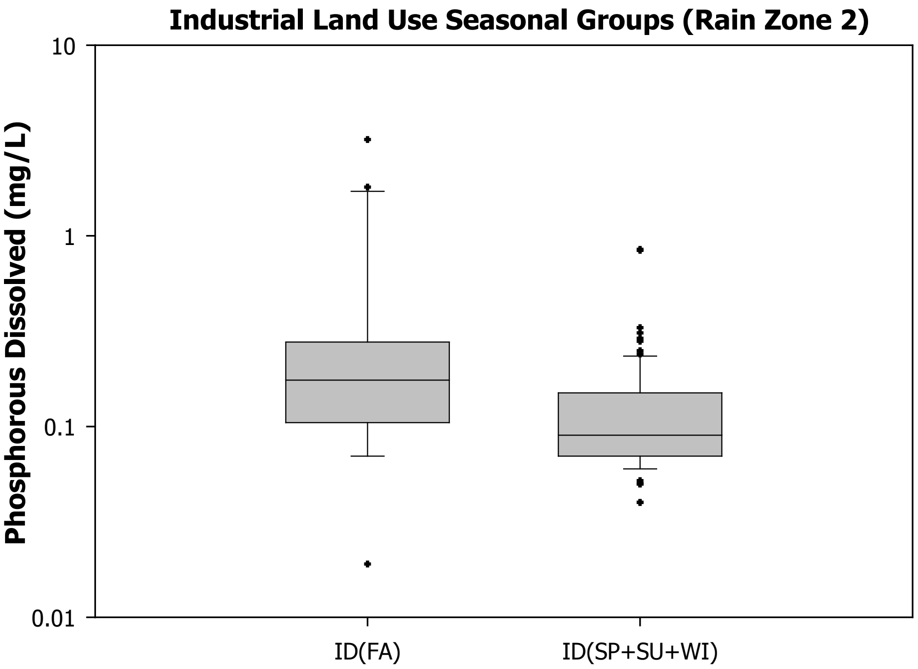


Fig. C96. Dissolved Phosphorous – Industrial Land Use Seasonal Groups

Table C78. Statistical Analyses for Dissolved Phosphorous – Industrial Land Use Seasonal Groups

Kruskal-Wallis Test (Industrial: Log Dissolved Phosphorous Groups)

H = 12.99 DF = 1 P = 0.000
H = 13.05 DF = 1 P = 0.000 (adjusted for ties)

Groups	**N**	**Median**	**Ave Rank**	**Z**
ID(FA)	28	-0.757	76.4	3.6
ID(SP,SU,WI)	85	-1.046	50.6	-3.6
Overall	113		57	

Table C79. Power of the Test for Dissolved Phosphorous – Industrial Land Use Seasonal Groups

Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ID(FA)	28	-0.68	0.479
ID(SP,SU,WI)	85	-0.96	0.252

Pooled Standard Deviation 0.365
Obtained Effect Size 0.33

α level	**Power (%)**
0.20	98.7
0.15	98.1
0.10	96.8
0.05	***93.7***
0.01	81.4

C.5.5 Dissolved Phosphorous - Institutional Land Use

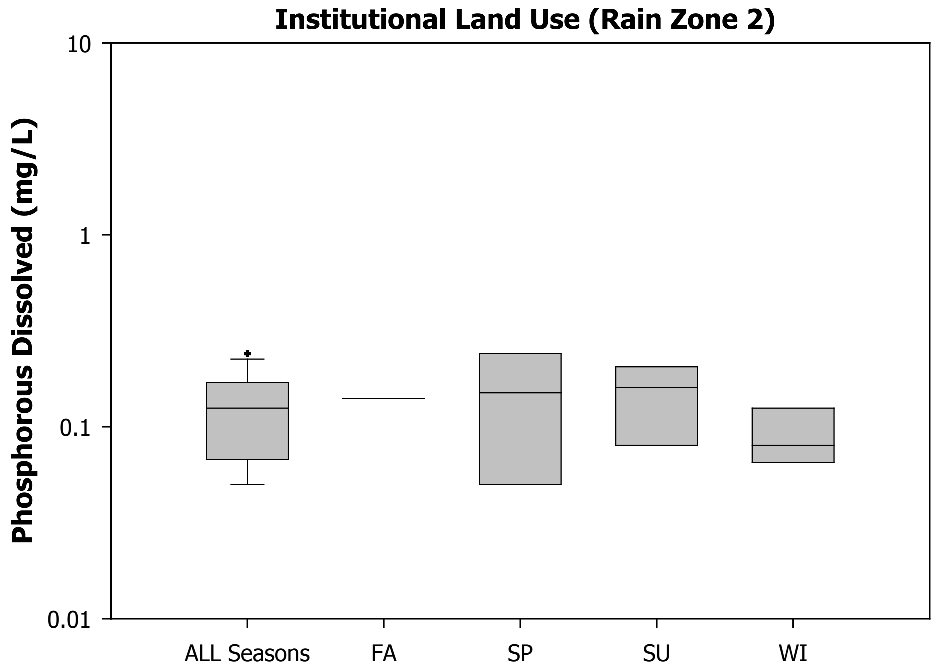
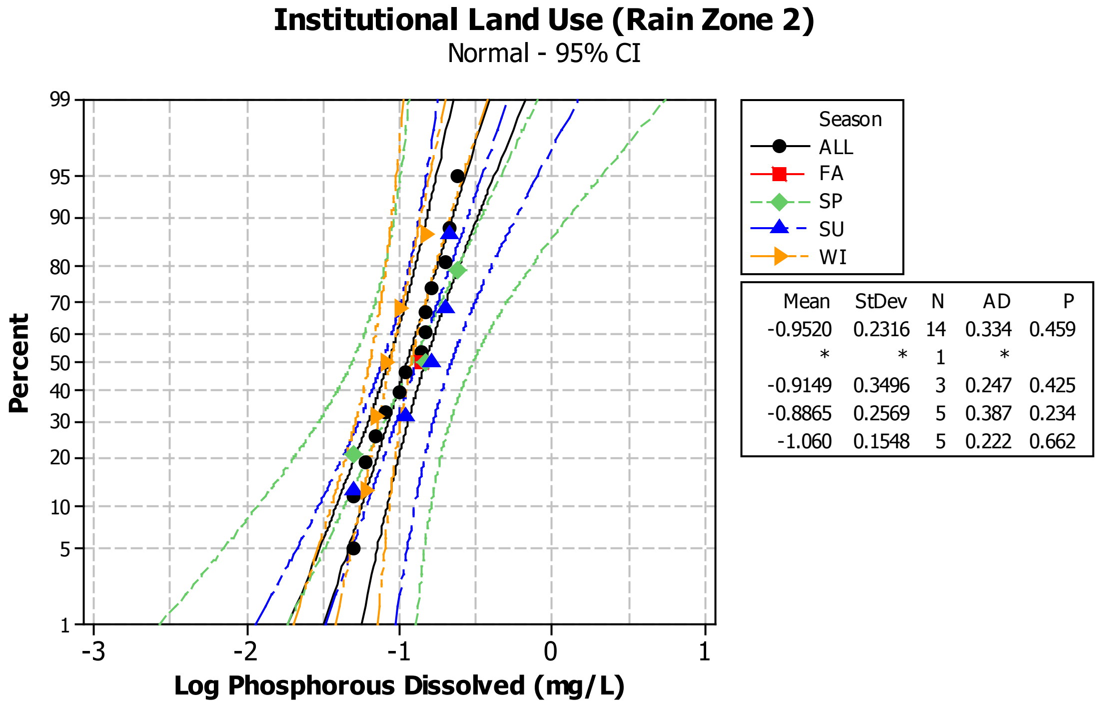


Fig. C97. Dissolved Phosphorous – Institutional Land Use by Season



Mean	StDev	N	AD	P
-0.9520	0.2316	14	0.334	0.459
*	*	1	*	
-0.9149	0.3496	3	0.247	0.425
-0.8865	0.2569	5	0.387	0.234
-1.060	0.1548	5	0.222	0.662

Fig. C98. Dissolved Phosphorous – Institutional Land Use (Checks for Normality)

Table C80. Statistical Analyses for Dissolved Phosphorous – Institutional Land Use

Kruskal-Wallis Test (Institutional: Log Dissolved Phosphorous)

H = 1.84 DF = 3 P = 0.607
H = 1.84 DF = 3 P = 0.605
(adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	1	-0.854	8.0	0.12
SP	3	-0.824	8.3	0.39
SU	5	-0.796	8.9	0.93
WI	5	-1.097	5.5	-1.3
Overall	14		7.5	

Power of the Test (Institutional: Log Dissolved Phosphorous)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	1	-0.85	ND
SP	3	-0.92	0.350
SU	5	-0.89	0.257
WI	5	-1.06	0.1□5

Pooled Standard Deviation 0.254
Obtained Effect Size 0.32

α level	Power (%)
0.20	35.9
0.15	29.2
0.10	21.5
0.05	***12.5***
0.01	3.3

C.5.6 Dissolved Phosphorous – Open Space Land Use

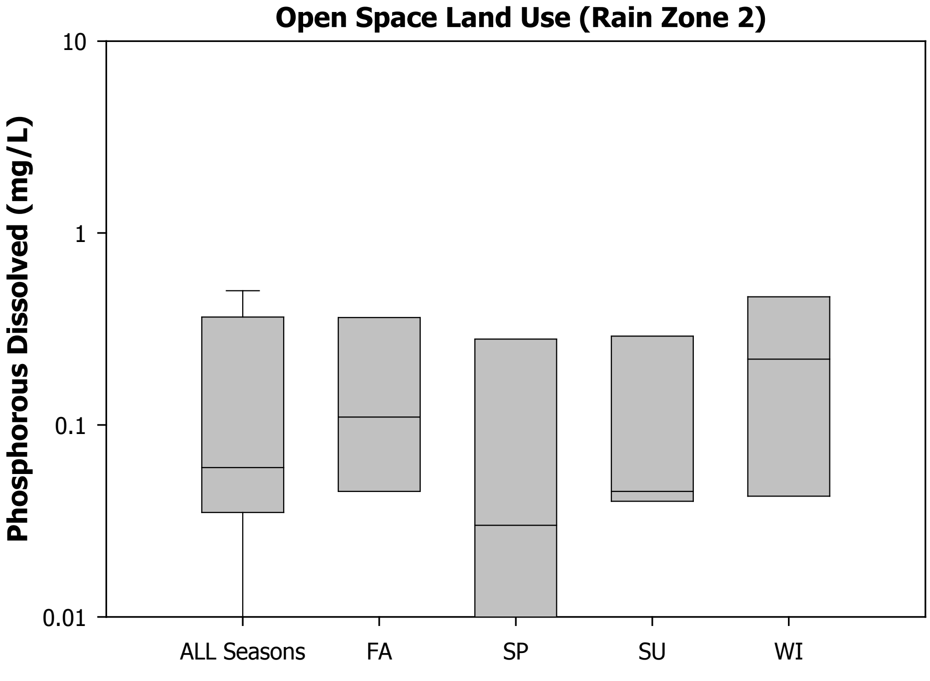


Fig. C99. Dissolved Phosphorous – Open Space Land Use by Season

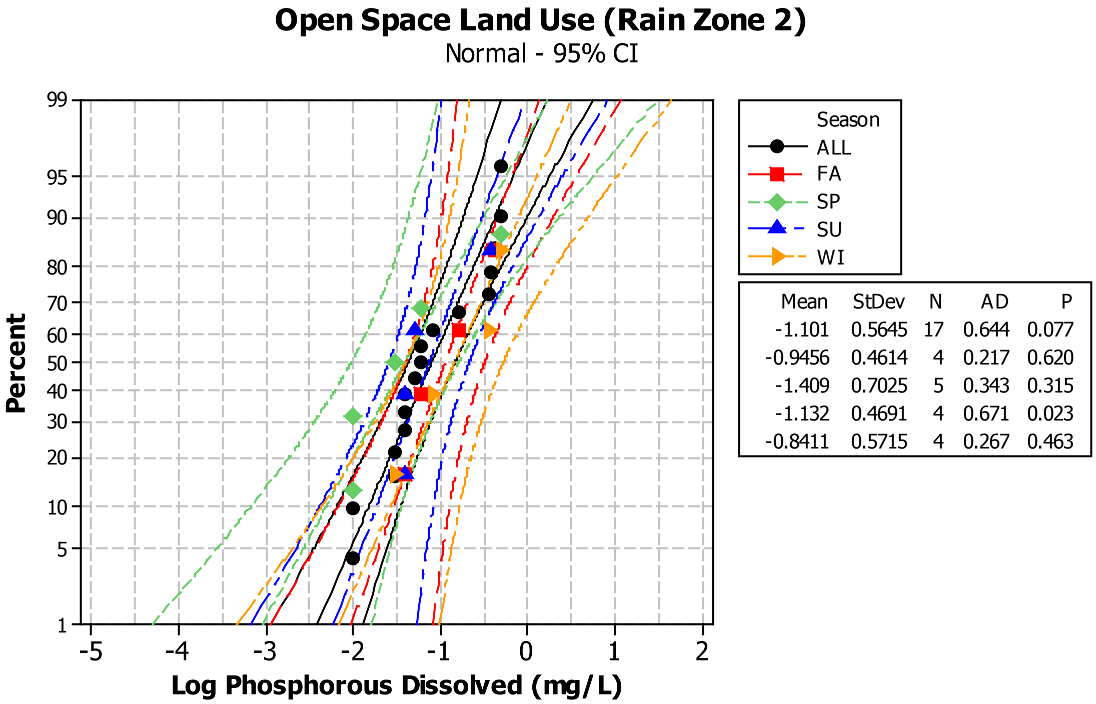


Fig. C100. Dissolved Phosphorous – Open Space Land Use (Checks for Normality)

Table C81. Statistical Analyses for Dissolved Phosphorous – Open Space Land Use

Kruskal-Wallis Test
(Open Space: Log Dissolved Phosphorous)

H = 2.31 DF = 3 P = 0.511
H = 2.33 DF = 3 P = 0.507
(adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	4	-1.009	10.6	0.74
SP	5	-1.523	6.5	-1.3
SU	4	-1.349	8.5	-0.2
WI	4	-0.770	11.0	0.9
Overall	17		9	

Power of the Test (Open Space:
Log Dissolved Phosphorous)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	4	-0□95	0.461
SP	5	-1.41	0.703
SU	4	-1.13	0.469
WI	4	-0.84	0.572

Pooled Standard Deviation 0.551
Obtained Effect Size 0.40

α level	Power (%)
0.20	48.1
0.15	40.6
0.10	31.6
0.05	***19.9***
0.01	6.1

C.5.7 Dissolved Phosphorous - Freeways Land Use

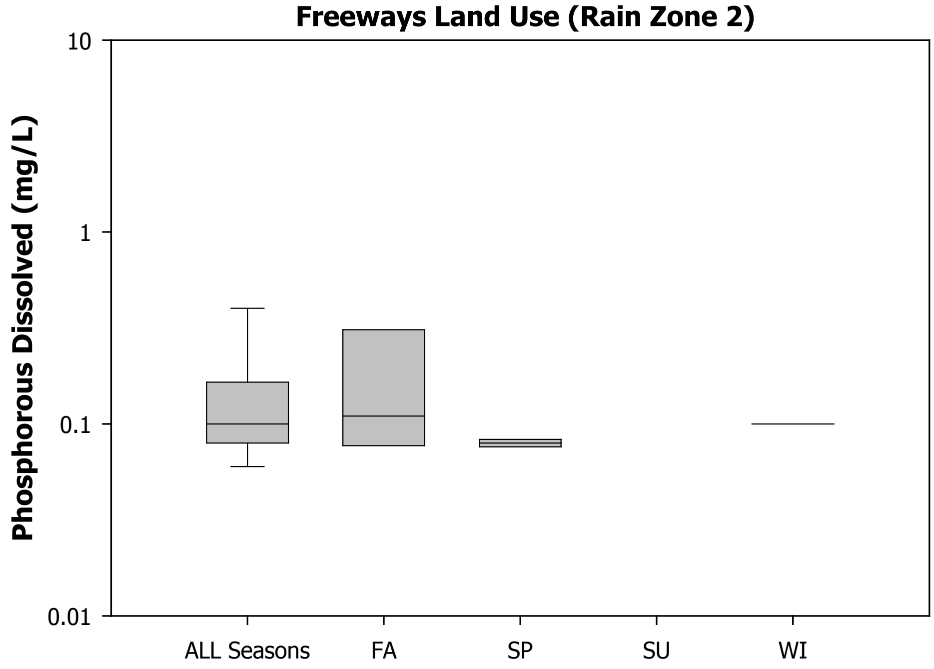


Fig. C101. Dissolved Phosphorous – Freeways Land Use by Season

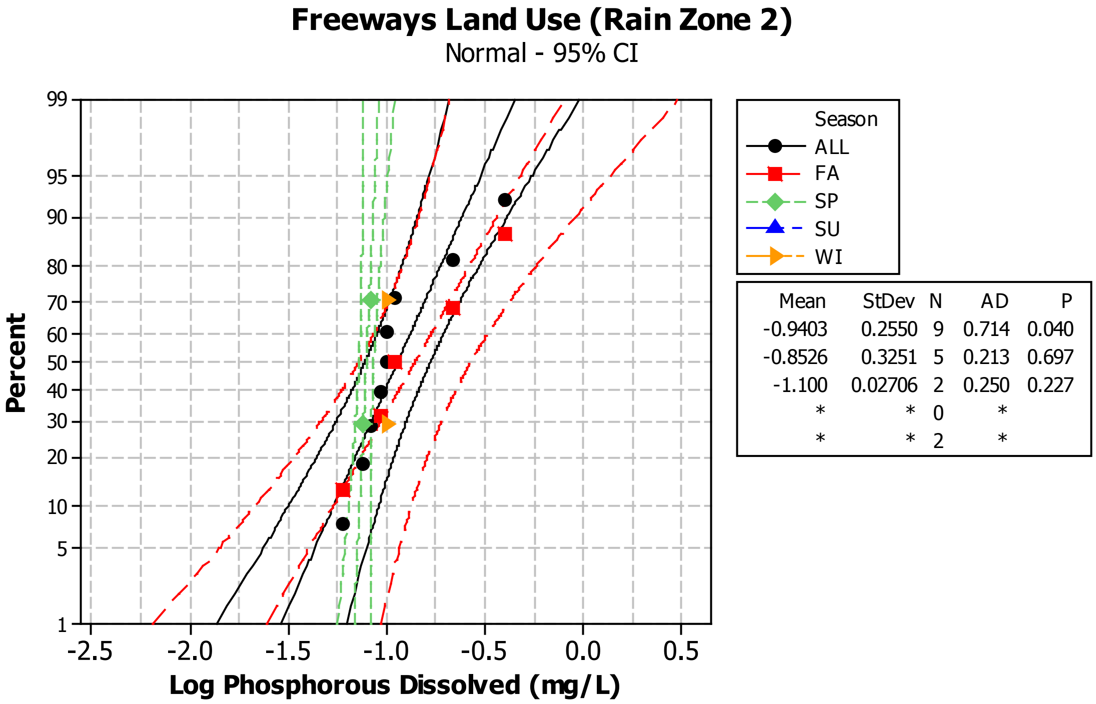


Fig. C102. Dissolved Phosphorous – Freeways Land Use (Checks for Normality)

Table C82. Statistical Analyses for Dissolved Phosphorous – Freeways Land Use

Kruskal-Wallis Test
(Freeways: Log Dissolved Phosphorous)

H = 2.16 DF = 2 P = 0.340
H = 2.18 DF = 2 P = 0.337 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	5	-0.959	5.8	0.98
SP	2	-1.100	2.5	-1.5
WI	2	-1.00	5.5	0.29
Overall	9		5	

Power of the Test (Freeways: Log Dissolved Phosphorous)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	5	-0.85	0.325
SP	2	-1.10	0.027
WI	2	-1.00	0.000

Pooled Standard Deviation 0.117
Obtained Effect Size 0.90

α level	Power (%)
0.20	78.8
0.15	72.0
0.10	61.8
0.05	***44.6***
0.01	16.3

C.6.8 Dissolved Phosphorous Land Use and Season Groups

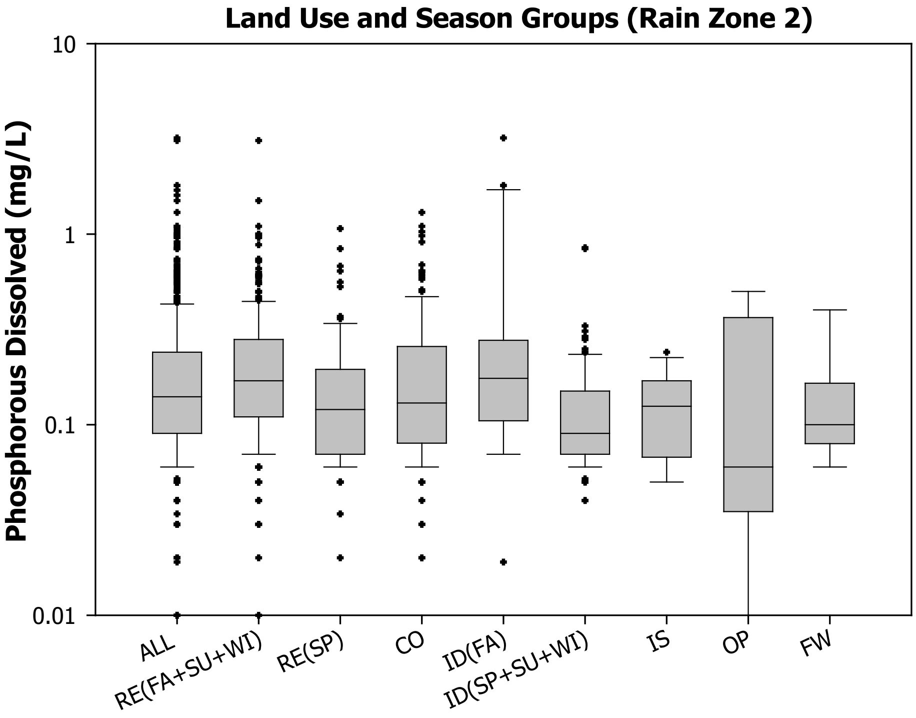
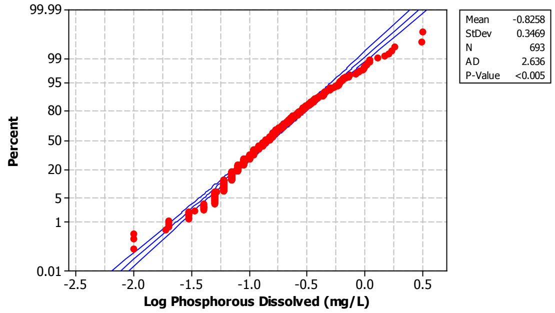
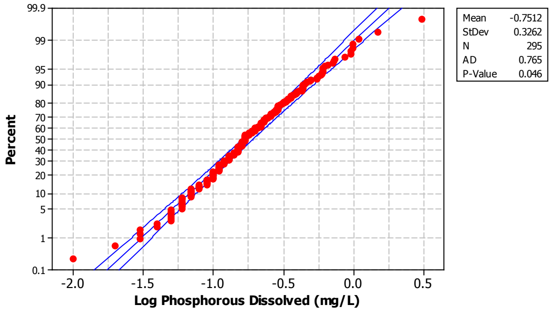


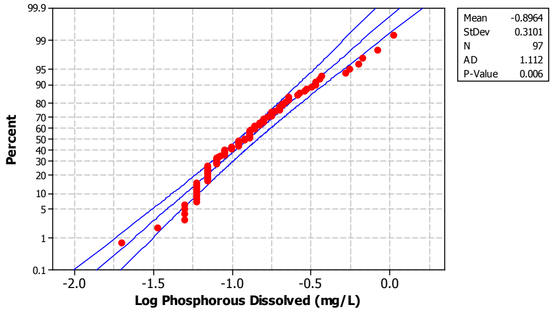
Fig. C103. Dissolved Phosphorous – Land Use and Season Groups


Overall Land Uses (All Seasons)

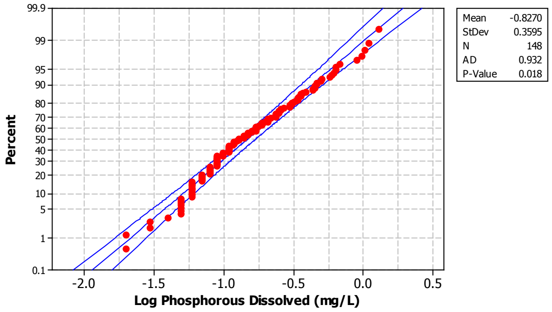
Normal - 95% CI


Residential Land Use (Fall, Summer and Winter Seasons)

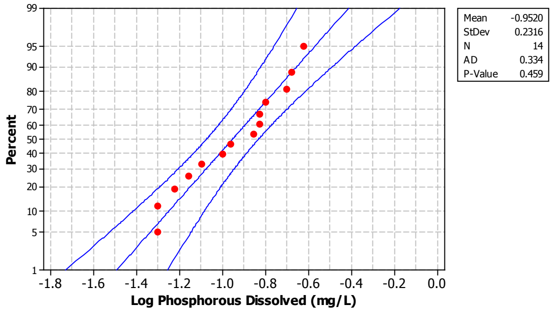
Normal - 95% CI


Residential Land Use (Spring Season)

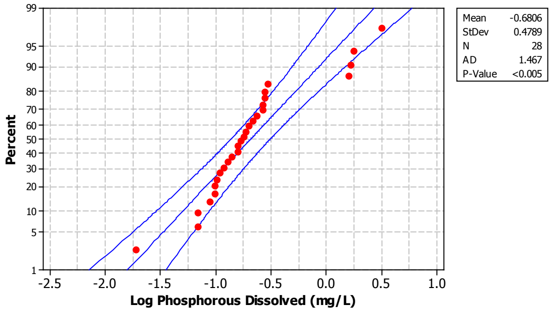
Normal - 95% CI


Commercial Land Use (All Seasons)

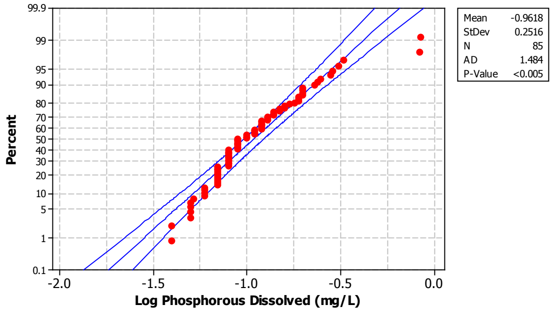
Normal - 95% CI


Institutional Land Use (All Seasons)

Normal - 95% CI


Industrial Land Use (Fall Season)

Normal - 95% CI


Industrial Land Use (Spring, Summer and Winter Seasons)

Normal - 95% CI

Figure C103. - *Continued*

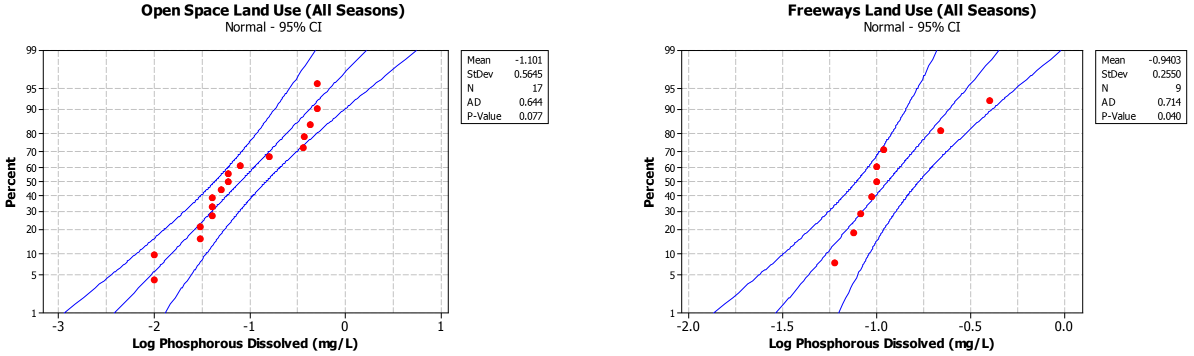


Figure C103. - *Continued*

Table C83. Statistical Analyses for Dissolved Phosphorous – Land Use and Season Groups

Kruskal-Wallis Test
(Land Use and Season Groups: Log Dissolved Phosphorous)

H = 53.88 DF = 7 P = 0.000
H = 53.95 DF = 7 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE(FA,SU,WI)	295	-0.770	398	5.8
RE(SP)	97	-0.921	300	-2.5
CO	148	-0.886	343	-0.3
ID(FA)	28	-0.757	407	1.6
ID(SP,SU,WI)	85	-1.046	255	-4.5
IS	14	-0.906	272	-1.4
OP	17	-1.222	232	-2.4
FW	9	-1.000	266	-1.2
Overall	693		347	

Land Use and Season Groups
(medians)

Groups	Gr. A	Gr. B	Gr. C
RE (FA,SU,WI)	-0.770		
ID (FA)	-0.757		
CO		-0.886	
RE (SP)		-0.921	
IS		-0.906	
FW			-1.000
ID (SP,SU,WI)			-1.046
OP			-1.222

Table C84. Land Use and Season Multiple Comparisons for Dissolved Phosphorous

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
RE (FA,SU,WI)	RE (SP)	0.000*	RE (SP)	CO	0.128
	CO	0.010*		ID (FA)	0.011*
	ID (FA)	0.819		ID (SP,SU,WI)	0.161
	ID (SP,SU,WI)	0.000*		IS	0.696
	IS	0.016*		OP	0.052
	OP	0.008*		FW	0.708
	FW	0.033*			
			ID (FA)	ID (SP,SU,WI)	0.000*
CO	ID (FA)	0.130		IS	0.036*
	ID (SP,SU,WI)	0.003*		OP	0.027*
	IS	0.226		FW	0.050*
	OP	0.023*			
	FW	0.321	IS	OP	0.275
				FW	0.925
ID (SP,SU,WI)	IS	0.677			
	OP	0.091	OP	FW	0.215
	FW	0.787			

Table C85. All Possible Land Use and Season Combinations for Dissolved Phosphorous

Groups	Gr. A	Gr. B	Gr. C	
RE (FA,SU,WI)	-0.770			
ID (FA)	-0.757	-0.757		
CO		-0.886	-0.886	
FW			-1.000	-1.000
RE (SP)			-0.921	-0.921
IS			-0.906	-0.906
ID (SP,SU,WI)				-1.046
OP				-1.222

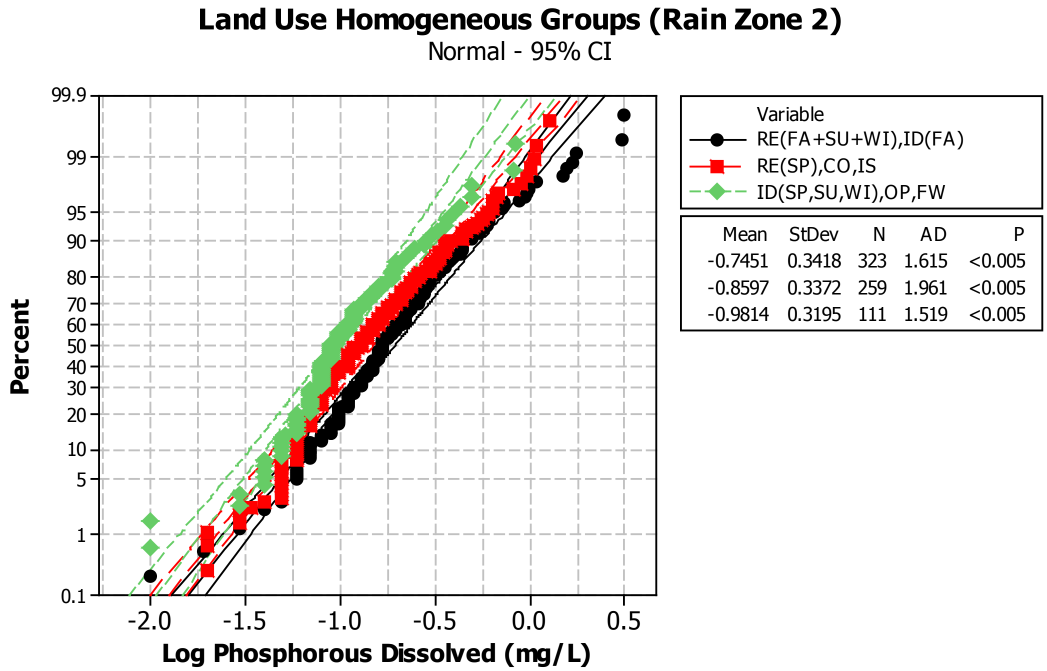
Table C86. Power of the Test for Dissolved Phosphorous – Land Use and Season Groups

Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE (FA,SU,WI)	295	-0.75	0.326
RE (SP)	97	-0.90	0.310
CO	148	-0.83	0.360
ID (FA)	28	-0.68	0.479
ID (SP,SU,WI)	85	-0.96	0.252
IS	14	-0.95	0.232
OP	17	-1.10	0.564
FW	9	-0.94	0.255

Pooled Standard Deviation 0.347

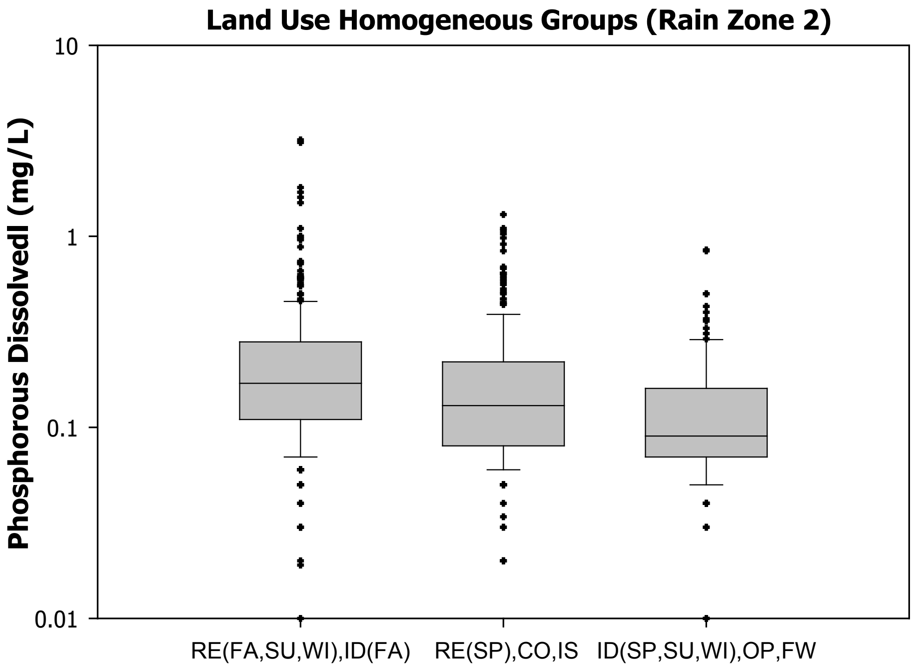
Obtained Effect Size 0.27

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	99.9



Mean	StDev	N	AD	P
-0.7451	0.3418	323	1.615	<0.005
-0.8597	0.3372	259	1.961	<0.005
-0.9814	0.3195	111	1.519	<0.005

Fig. C104. Dissolved Phosphorous – Land Use Homogeneous Groups (Checks for Normality)



Land Uses	FALL	SPRING	SUMMER	WINTER
Residential	0.27(1.3)	0.17(0.99)	0.22(0.80)	0.22(0.88)
Commercial	0.22(0.85)	0.17(0.85)	0.25(1.1)	0.21(1.1)
Industrial	0.44(1.7)	0.11(0.38)	0.15(0.98)	0.14(1.1)
Institutional	ND	0.15(0.65)	0.15(0.46)	0.09(0.39)
Open Space	0.17(1.0)	0.12(1.7)	0.13(1.3)	0.24(0.93)
Freeways	0.18(0.78)	0.08(0.06)	ND	0.10(0.0)

Fig. C105. Dissolved Phosphorous – Land Use Homogeneous Groups: Mean (CV)

Table C87. Statistical Analyses for Dissolved Phosphorous – Land Use Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: Log Dissolved Phosphorous)

H = 49.91 DF = 2 P = 0.000
H = 49.98 DF = 2 P = 0.000 (adjusted for ties)

Groups		N	Median	Ave Rank	Z
1	RE(FA,SU,WI), ID(FA)	323	-0.77	399	6
2	RE(SP),CO,IS	259	-0.89	323	-2
3	ID(SP,SU,WI), OP, FW	111	-1.05	252	-5
	Overall	693		347	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Group	(J) Group	p-value
1	2	0.00*
	3	0.00*
2	3	0.002

Log Dissolved Phosphorous
Homogeneous Groups
(medians)

Group	Gr.A	Gr.B	Gr.C
1	-0.77		
2		-0.89	
3			-1.05

Table C88. Power of the Test for Dissolved Phosphorous – Land Use Homogeneous Groups

Homogeneous Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
RE(FA,SU,WI),ID(FA)	323	-0.745	0.342	0.20	99.9
RE(SP),CO,IS	259	-0.860	0.337	0.15	99.9
ID(SP,SU,WI),OP,FW	111	-0.981	0.320	0.10	99.9
Pooled Standard Deviation			0.337	***0.05***	***99.9***
Obtained Effect Size			0.25	0.01	99.9

Table C89. Basic Statistics for Dissolved Phosphorous Homogeneous Groups (Real Space Data)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	RE(FA,SU,WI),ID(FA)	323	0.26	0.33	1.3	0.01	0.17	3.2
B	RE(SP),CO,IS	259	0.19	0.20	1.0	0.02	0.13	1.3
C	ID(SP,SU,WI),OP,FW	111	0.14	0.14	0.97	0.01	0.09	0.9

C.6. Total Nitrogen

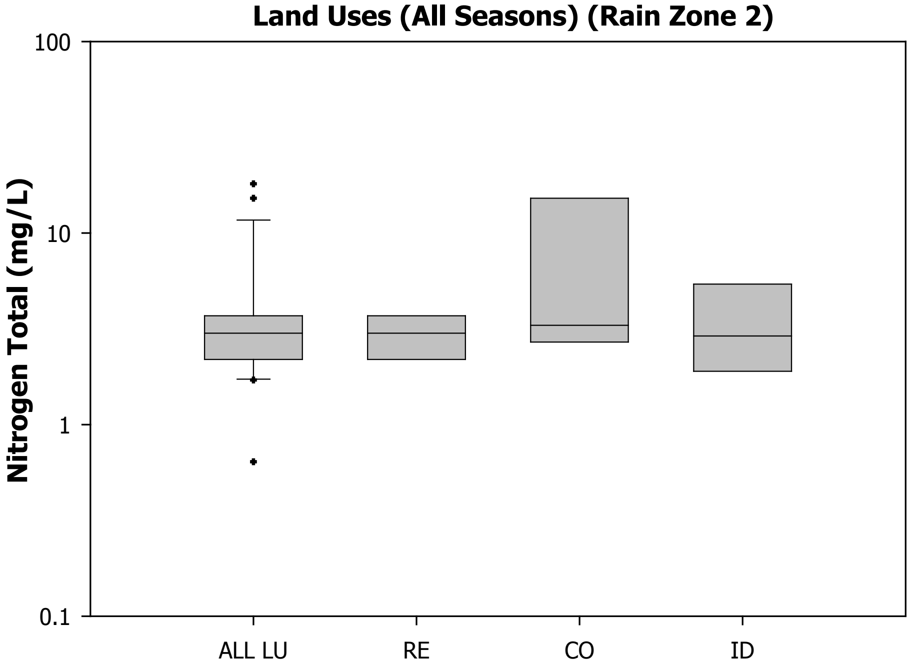
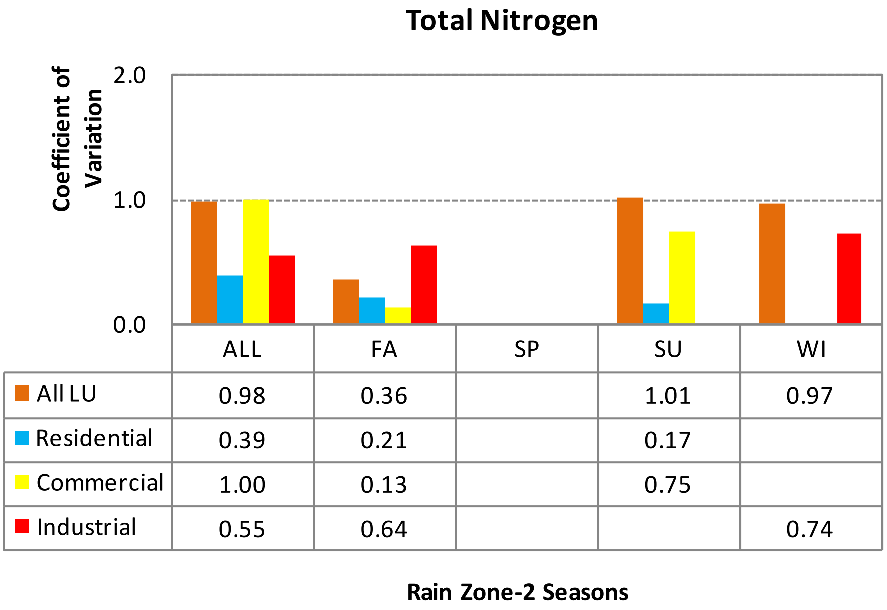


Fig. C106. Total Nitrogen - Single Land Uses in EPA Rain Zone 2



	ALL	FA	SP	SU	WI
🟧 All LU	0.98	0.36		1.01	0.97
🟦 Residential	0.39	0.21		0.17	
🟨 Commercial	1.00	0.13		0.75	
🟥 Industrial	0.55	0.64			0.74

Fig. C107. Total Nitrogen - EPA Rain Zone 2 Seasonal Coefficients of Variation

C.6.1 Total Nitrogen - All Single Land Uses

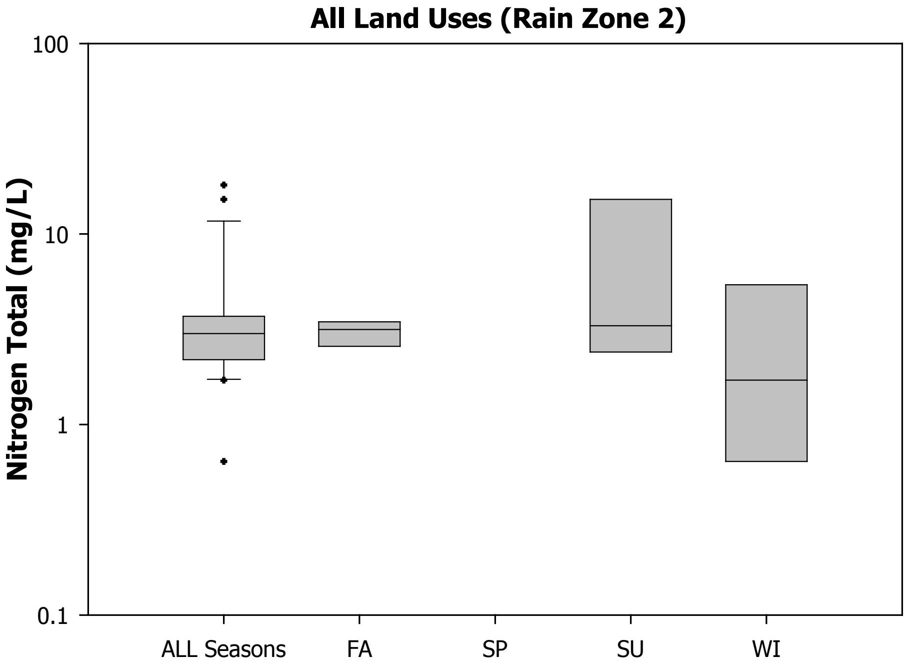


Fig. C108. Total Nitrogen – All Single Land Uses by Season

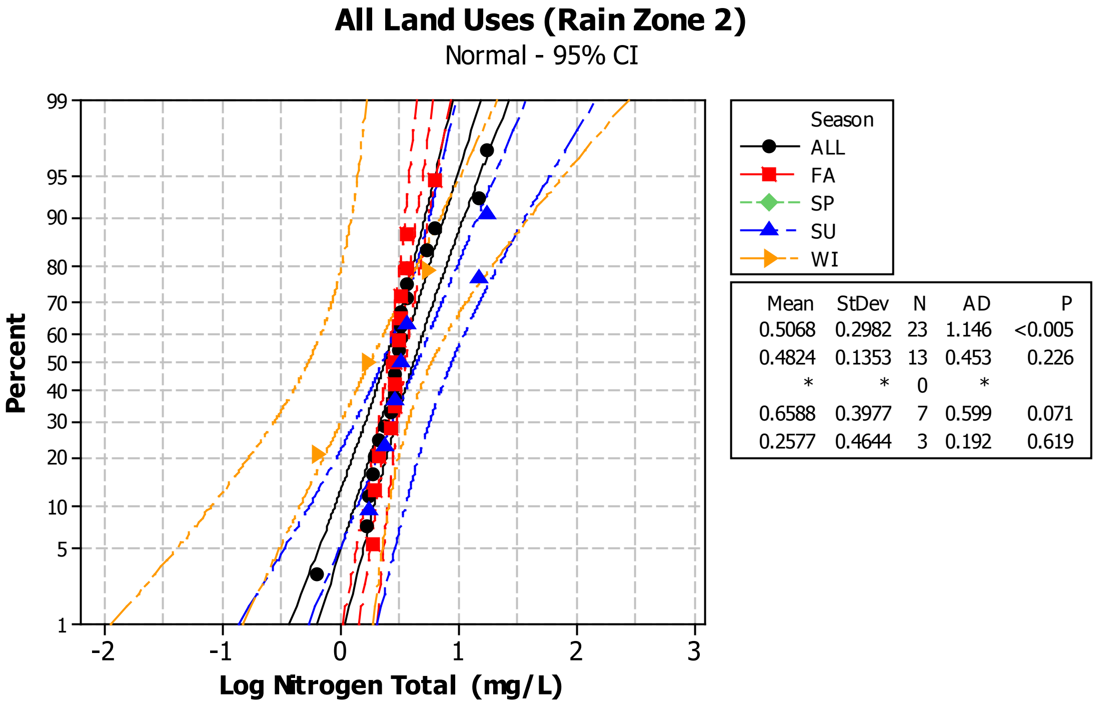


Fig. C109. Total Nitrogen – All Single Land Uses (Checks for Normality)

Table C90. Statistical Analyses for Total Nitrogen - All Single Land Uses

Kruskal-Wallis Test
(All Land Uses: Log Total Nitrogen)

H = 1.75 DF = 2 P = 0.417
H = 1.76 DF = 2 P = 0.416 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	13	0.477	12	0
SU	7	0.518	13.9	0.87
WI	3	0.233	7.7	-1.19
Overall	23		12	

Power of the Test
(All Land Uses: Log Total Nitrogen)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	13	0.48	0.135
SU	7	0.6	0.398
WI	3	0.26	0.464
Pooled Standard Deviation			0.332
Obtained Effect Size			0.37

α level	Power (%)
0.20	59.3
0.15	52.3
0.10	43.1
0.05	***30.1***
0.01	11.5

C.6.2 Total Nitrogen - Residential Land Use

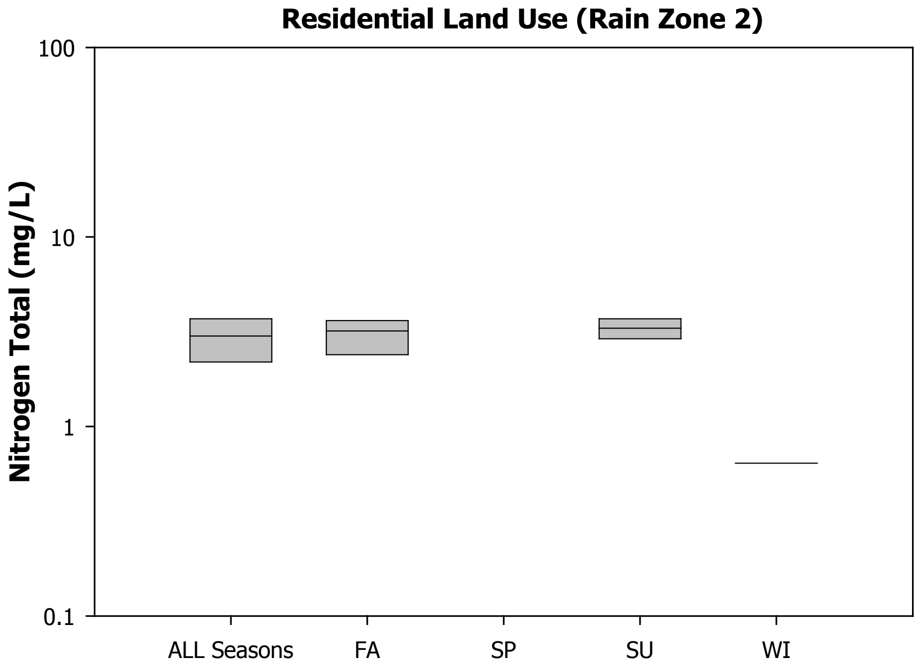
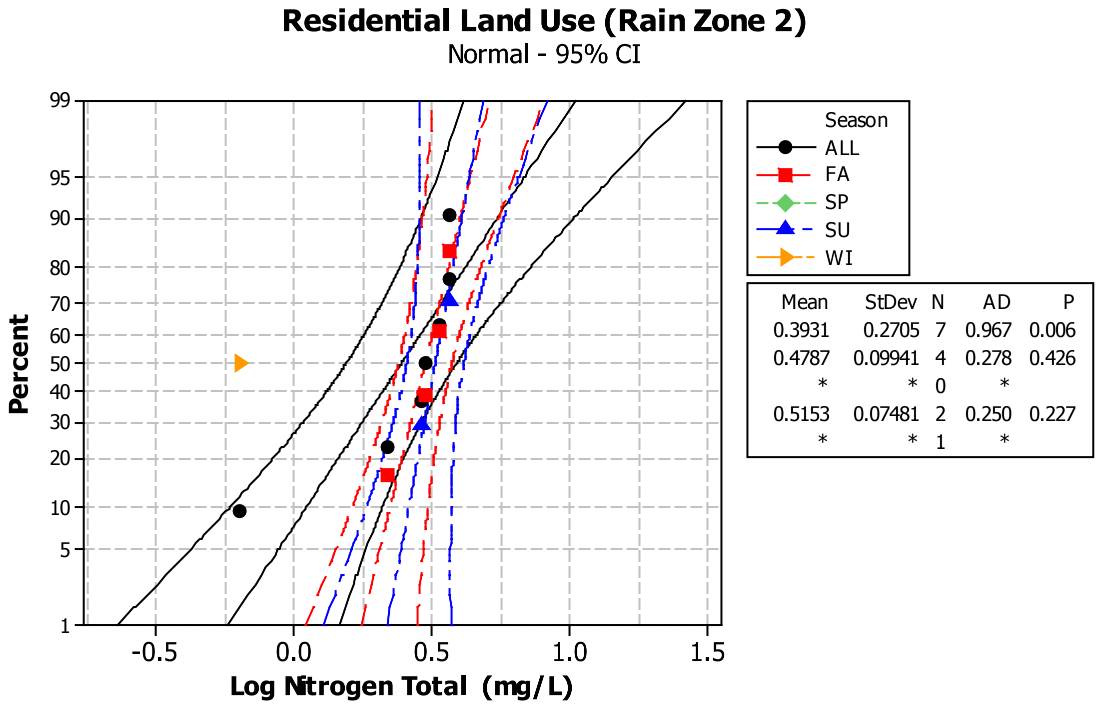


Fig. C110. Total Nitrogen – Residential Land Use by Season



Mean	StDev	N	AD	P
0.3931	0.2705	7	0.967	0.006
0.4787	0.09941	4	0.278	0.426
*	*	0	*	
0.5153	0.07481	2	0.250	0.227
*	*	1	*	

Fig. C111. Total Nitrogen – Residential Land Use (Checks for Normality)

Table C91. Statistical Analyses for Total Nitrogen – Residential Land Use

Kruskal-Wallis Test
(Residential: Log Total Nitrogen)

H = 2.29 DF = 2 P = 0.318
H = 2.33 DF = 2 P = 0.312 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	4	0.503	4.4	0.53
SU	2	0.515	4.8	0.58
WI	1	-0.194	1.0	-1.5
Overall	7		4.0	

Power of the Test
(Residential: Log Total Nitrogen)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	4	0.48	0.099
SU	2	0.52	0.075
WI	1	-0.19	ND

Pooled Standard Deviation 0.087

Obtained Effect Size 0.22

α level	Power (%)
0.20	25.0
0.15	19.3
0.10	13.5
0.05	***7.0***
0.01	1.5

C.6.3 Total Nitrogen - Commercial Land Use

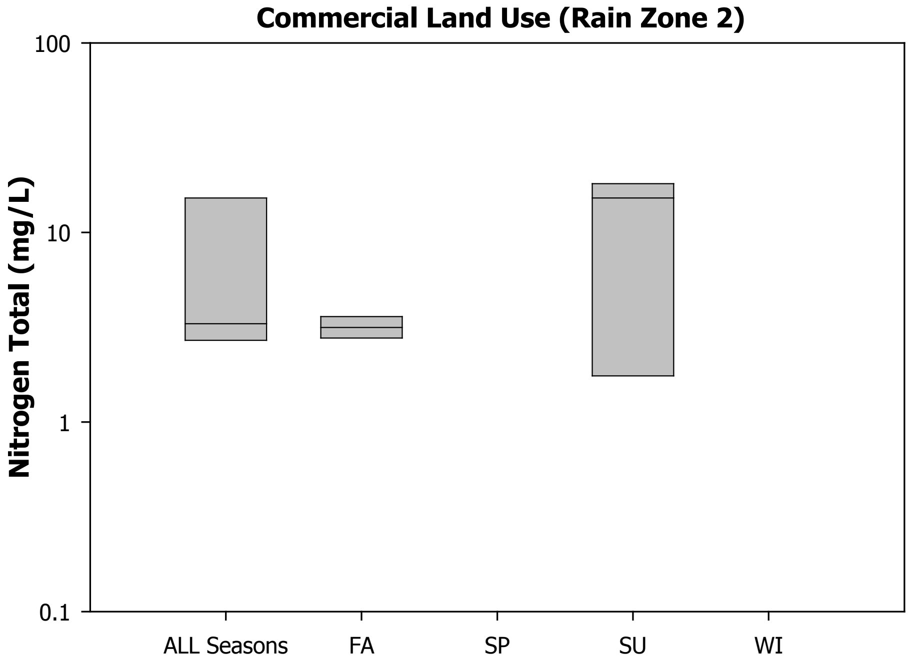
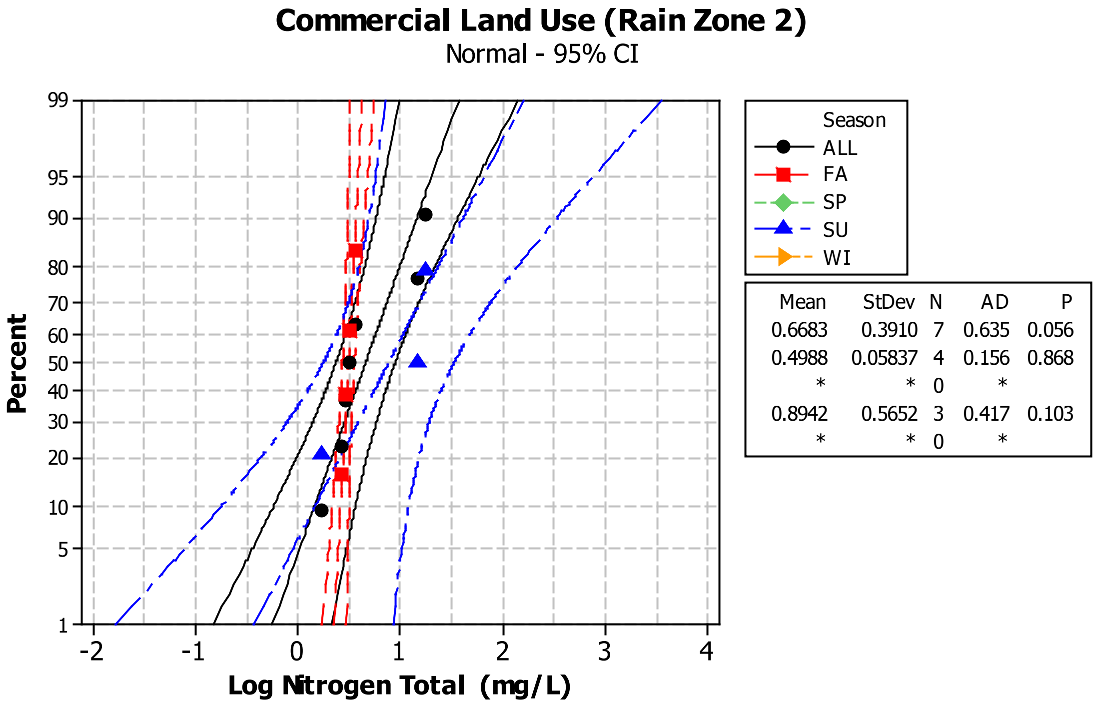


Fig. C112. Total Nitrogen – Commercial Land Use by Season



Mean	StDev	N	AD	P
0.6683	0.3910	7	0.635	0.056
0.4988	0.05837	4	0.156	0.868
*	*	0	*	
0.8942	0.5652	3	0.417	0.103
*	*	0	*	

Fig. C113. Total Nitrogen – Commercial Land Use (Checks for Normality)

Table C92. Statistical Analyses for Total Nitrogen – Commercial Land Use

Kruskal-Wallis Test
(Commercial: Log Total Nitrogen)

H = 0.50 DF = 1 P = 0.480

Season	N	Median	Ave Rank	Z
FA	4	0.498	3.5	-0.71
SU	3	1.182	4.7	0.71
Overall	7		4.0	

Power of the Test
(Commercial: Log Total Nitrogen)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	4	0.50	0.058
SU	3	0.89	0.565
Pooled Standard Deviation			0.312
Obtained Effect Size			0.62

α level	Power (%)
0.20	58.8
0.15	51.1
0.10	41.0
0.05	***26.6***
0.01	7.9

C.6.4 Total Nitrogen - Industrial Land Use

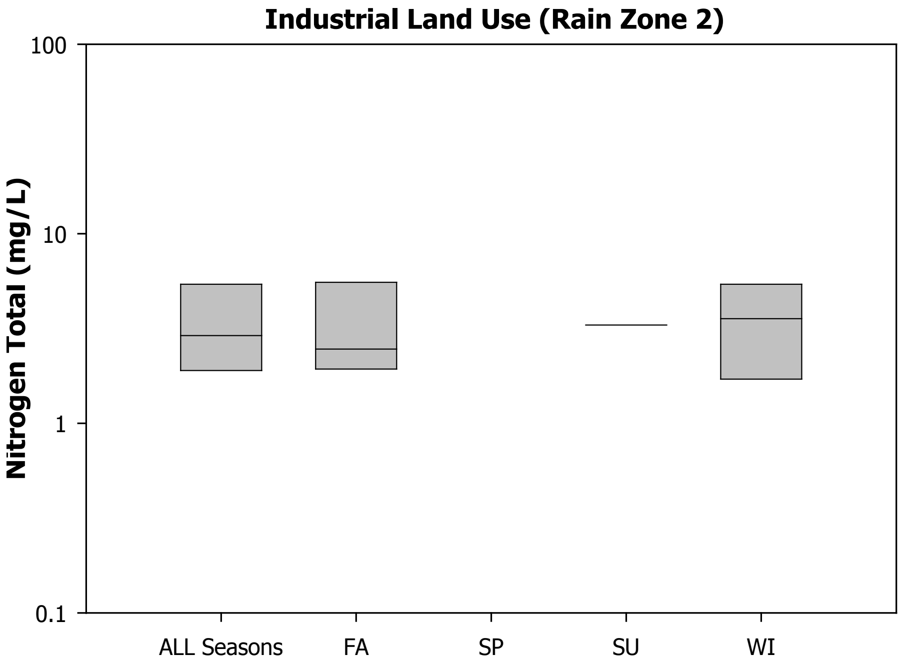


Fig. C114. Total Nitrogen – Industrial Land Use by Season

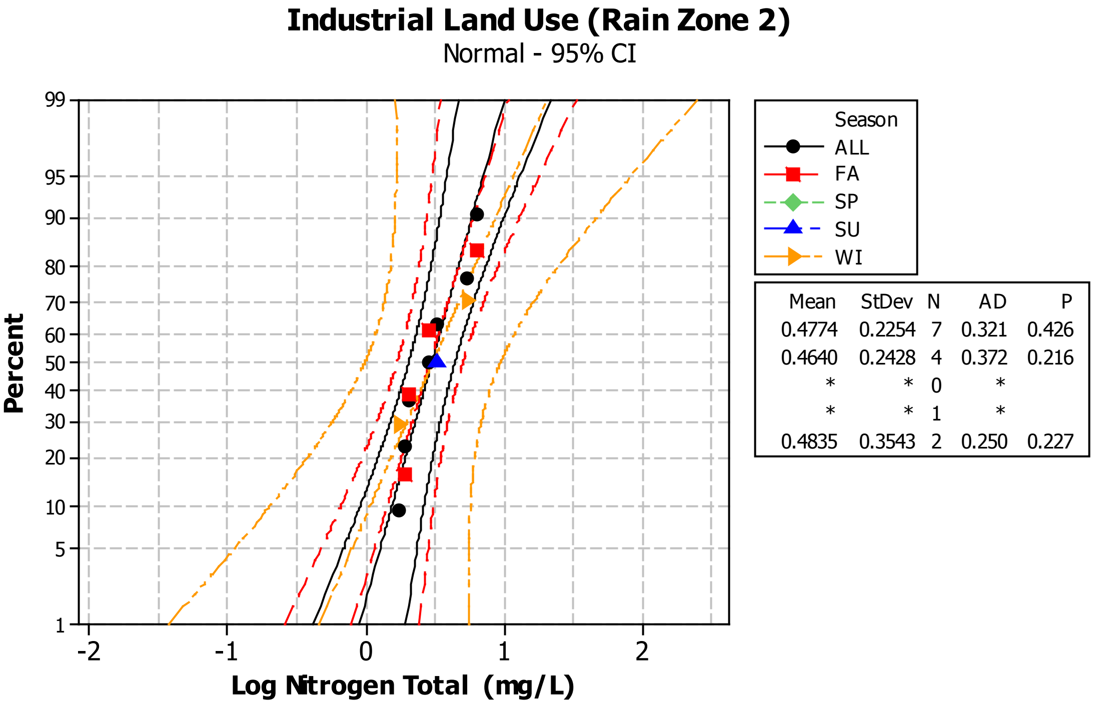


Fig. C115. Total Nitrogen – Industrial Land Use (Checks for Normality)

Table C93. Statistical Analyses for Total Nitrogen – Industrial Land Use

Kruskal-Wallis Test
(Industrial: Log Total Nitrogen)

H = 0.32 DF = 2 P = 0.852

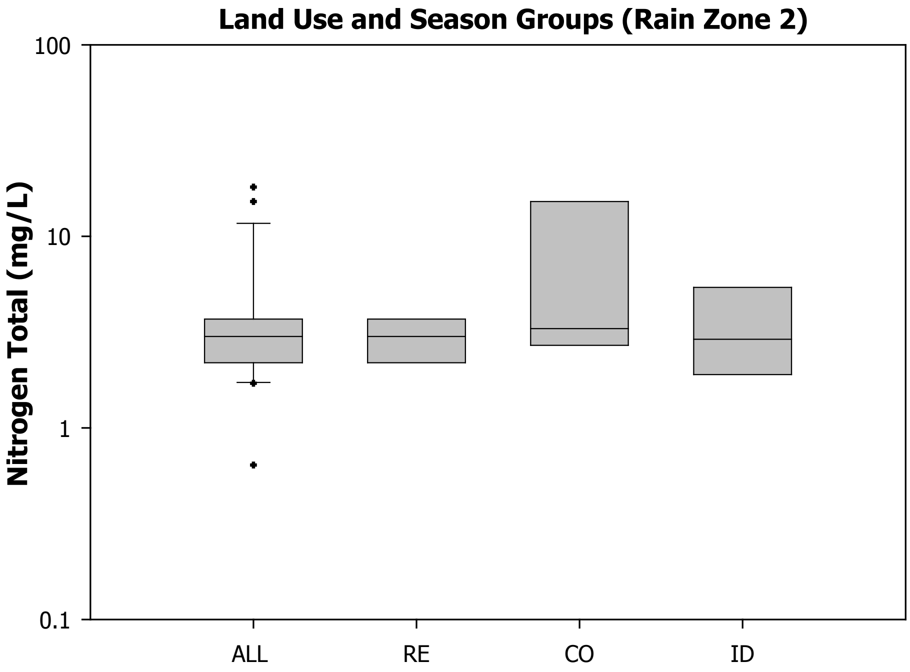
Season	N	Median	Ave Rank	Z
FA	4	0.385	4.0	0
SU	1	0.519	5.0	0.5
WI	2	0.484	3.5	-0.39
Overall	7		4.0	

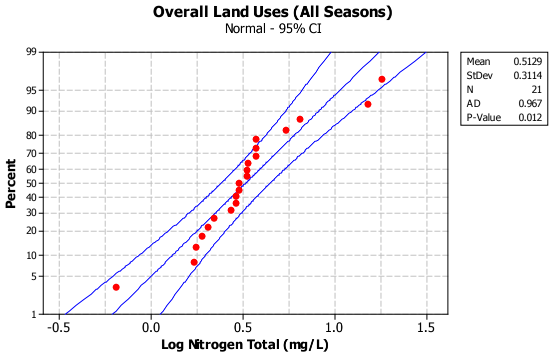
Power of the Test
(Industrial: Log Total Nitrogen)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	4	0.46	0.243
SU	1	0.52	ND
WI	2	0.48	0.354
Pooled Standard Deviation			0.299
Obtained Effect Size			0.03

α level	Power (%)
0.2	20.1
0.15	15.1
0.1	10.1
0.05	***5.0***
0.01	1.0

C.7.5 Total Nitrogen Land Use and Season Groups





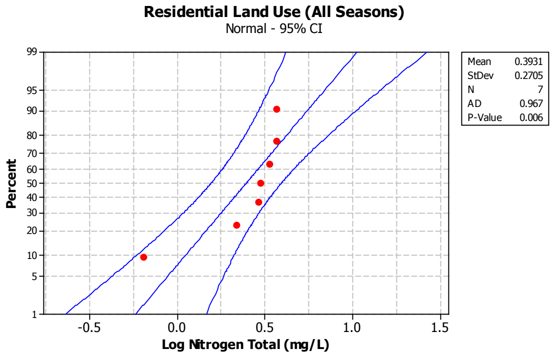


Fig. C116. Total Nitrogen – Land Use and Season Groups

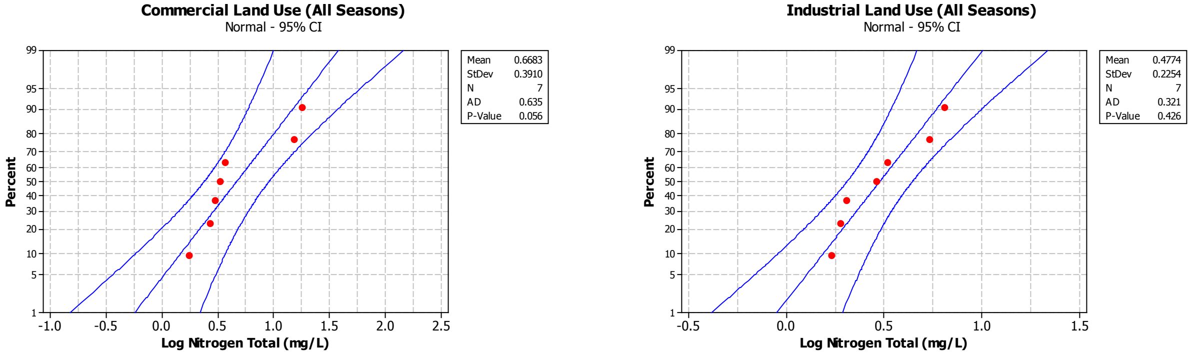


Fig. C116. - *Continued*

Table C94. Statistical Analyses for Total Nitrogen – Land Use and Season Groups

Kruskal-Wallis Test
(Land Use and Season Groups: Log Total Nitrogen)

Land Use and Season Groups
(medians)

H = 0.96 DF = 2 P = 0.620
H = 0.96 DF = 2 P = 0.618 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE	7	0.519	12.9	0.97
CO	7	0.462	9.9	-0.6
ID	7	0.477	10.3	-0.37
Overall	21		11	

Groups	Gr. A
RE	0.519
CO	0.462
ID	0.477

Table C95. Power of the Test for Total Nitrogen – Land Use and Season Groups

Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE	7	0.39	0.270
CO	7	0.67	0.391
ID	7	0.48	0.225
Pooled Standard Deviation			0.295
Obtained Effect Size			0.40

α level	Power (%)
0.20	59.6
0.15	52.5
0.10	43.2
0.05	***30.1***
0.01	11.4

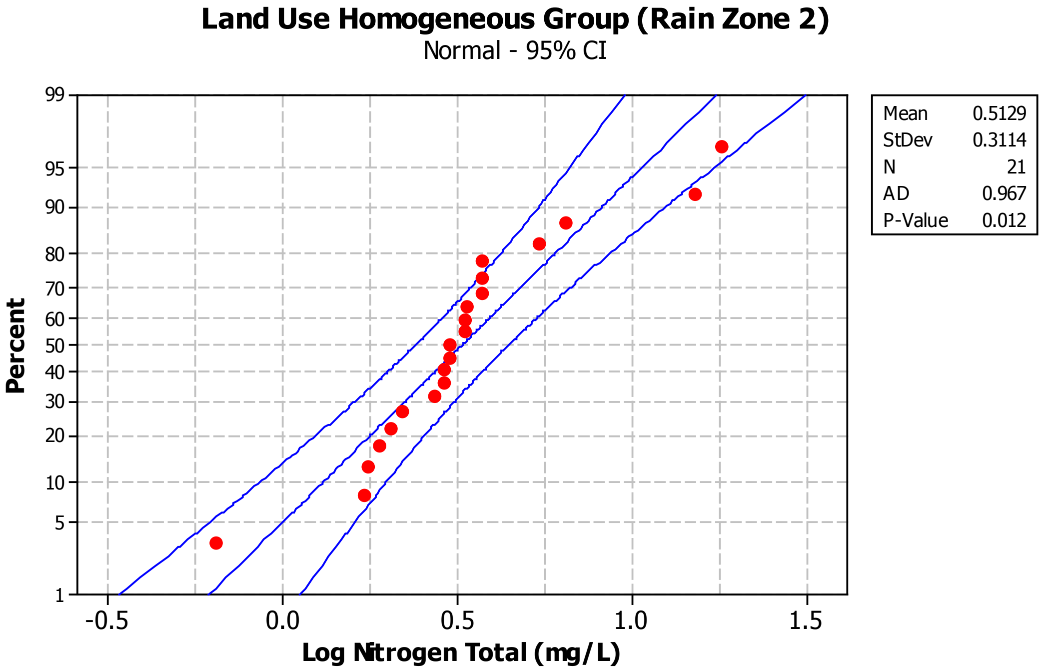
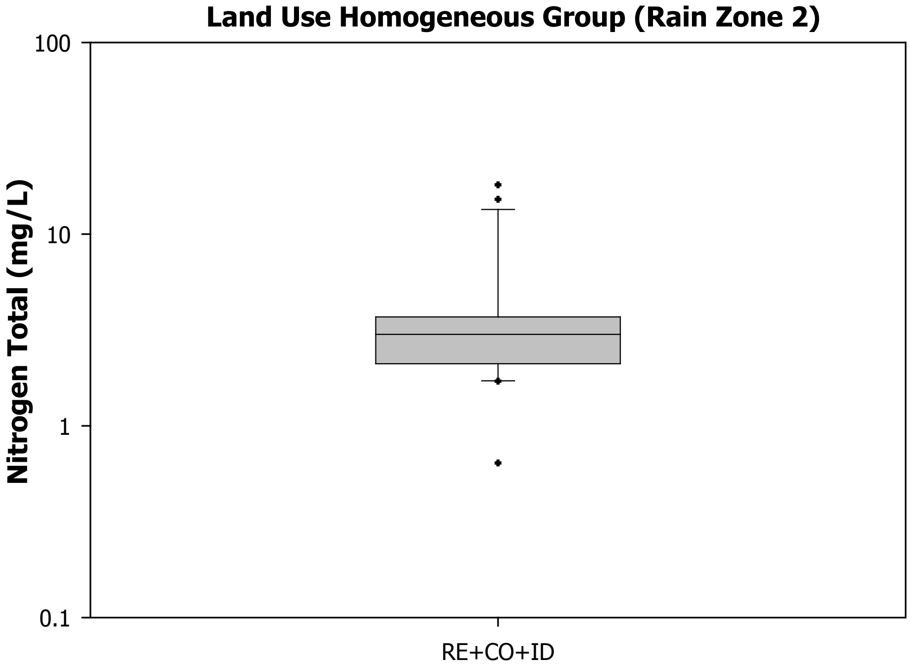


Fig. C117. Total Nitrogen – Land Use Homogeneous Groups (Checks for Normality)



Land Uses	FALL	SPRING	SUMMER	WINTER
Residential	3.1(0.21)	ND	3.3(0.17)	ND
Commercial	3.2(0.13)	ND	12(0.75)	ND
Industrial	3.3(0.64)	ND	ND	3.56(0.74)

Fig. C118. Total Nitrogen – Land Use Homogeneous Groups: Mean (CV)

Table C96. Basic Statistics for Total Nitrogen Homogeneous Groups (Real Space Data)

Groups	**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
RE, CO, ID	21	4.33	4.31	0.99	0.64	3.00	18.1

C.7. Total Kjeldahl Nitrogen

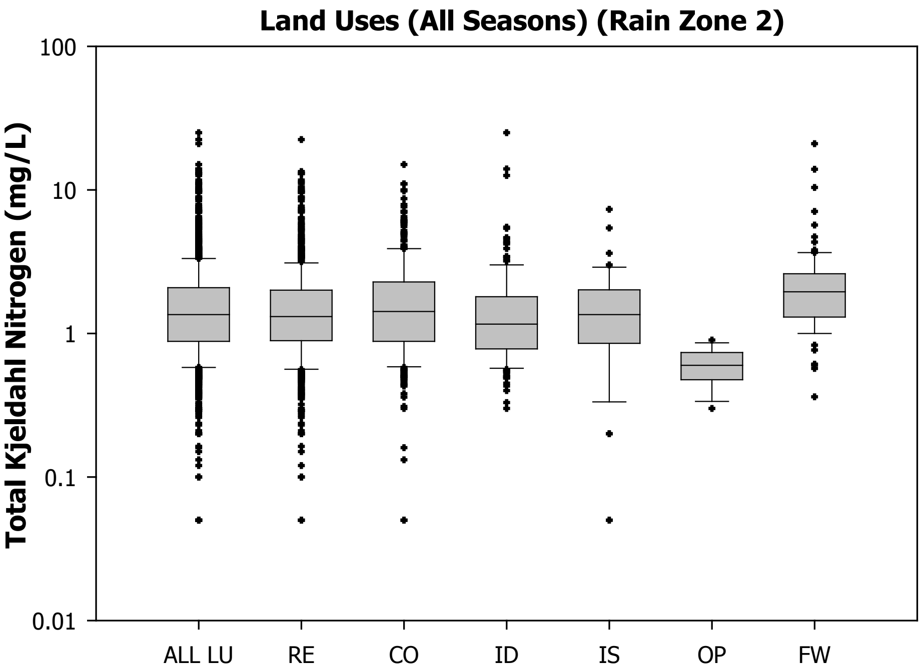
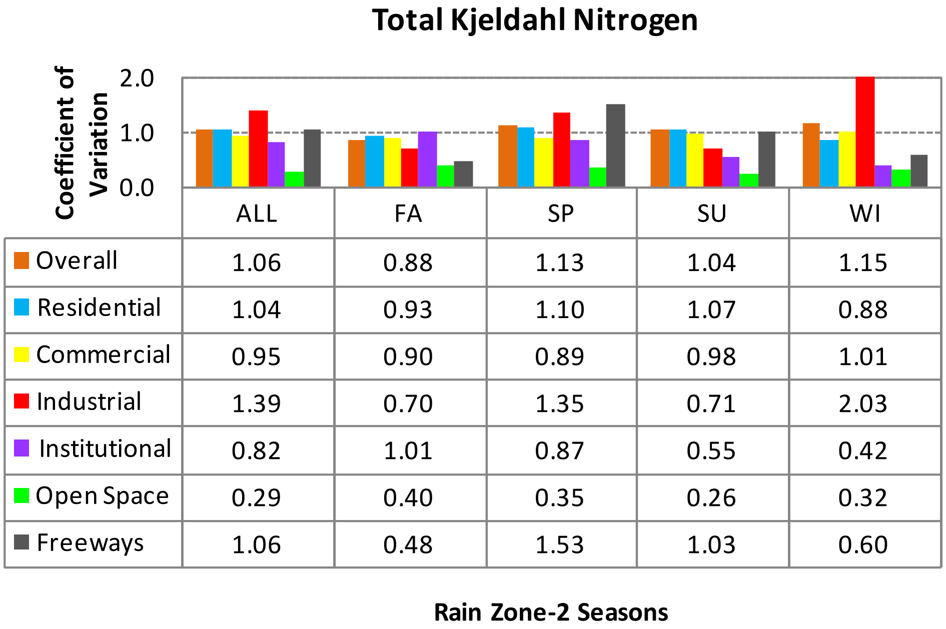


Fig. C119. Total Kjeldahl Nitrogen- Single Land Uses in EPA Rain Zone 2



	ALL	FA	SP	SU	WI
🟧 Overall	1.06	0.88	1.13	1.04	1.15
🟦 Residential	1.04	0.93	1.10	1.07	0.88
🟨 Commercial	0.95	0.90	0.89	0.98	1.01
🟥 Industrial	1.39	0.70	1.35	0.71	2.03
🟪 Institutional	0.82	1.01	0.87	0.55	0.42
🟩 Open Space	0.29	0.40	0.35	0.26	0.32
⬛ Freeways	1.06	0.48	1.53	1.03	0.60

Fig. C120. Total Kjeldahl Nitrogen - EPA Rain Zone 2 Seasonal Coefficients of Variation

C.7.1 Total Kjeldahl Nitrogen - All Land Uses

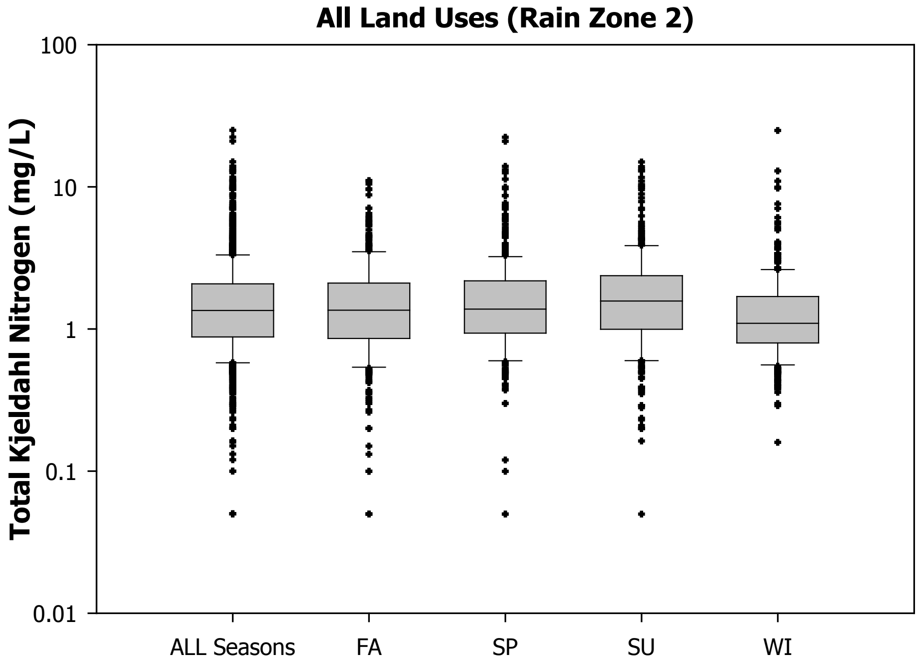


Fig. C121. Total Kjeldahl Nitrogen – All Single Land Uses by Season

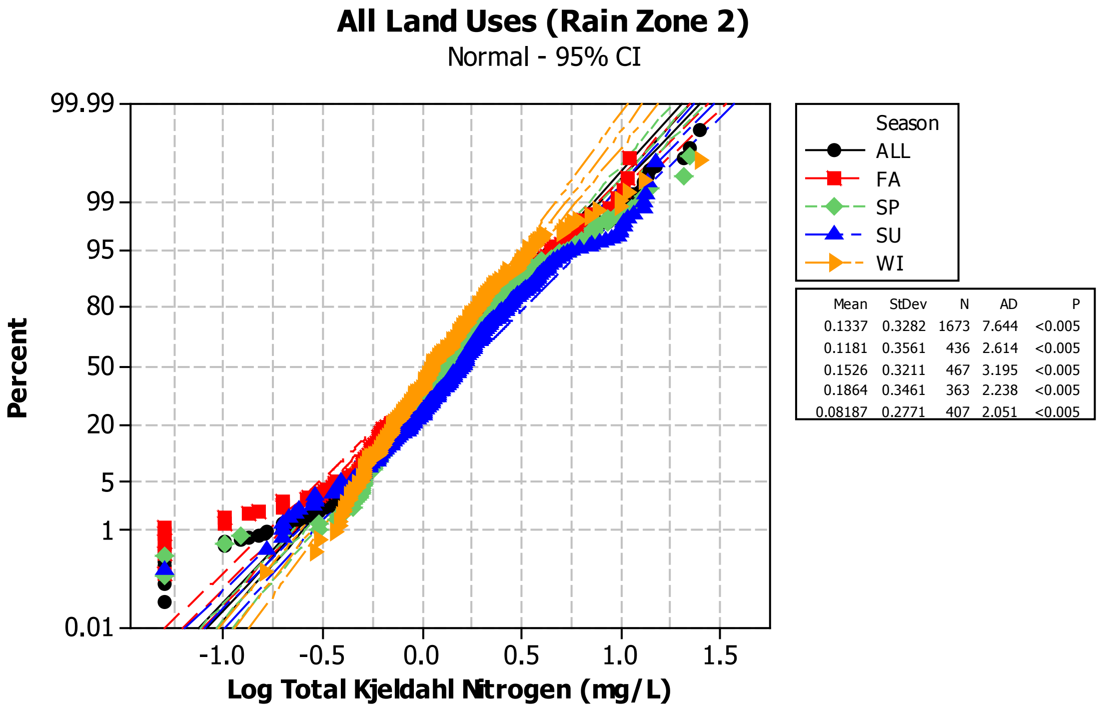


Fig. C122. Total Kjeldahl Nitrogen – All Single Land Uses

Table C97. Statistical Analyses for Total Kjeldahl Nitrogen - All Single Land Uses

Kruskal-Wallis Test
(All Land Uses: Log TKN)

H = 31.70 DF = 3 P = 0.000
H = 31.70 DF = 3 P = 0.000 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	436	0.134	835	-0.1
SP	467	0.139	859	1.19
SU	363	0.199	925	3.94
WI	407	0.041	734	-4.9
Overall	1673		837	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.473
	SU	0.012*
	WI	0.004*
SP	SU	0.043*
	WI	0.000*
SU	WI	0.000*

All Land Uses
Log TKN
Groups (medians)

Season	Gr. 1	Gr. 2	Gr. 2
FA	0.134		
SP	0.139		
SU		0.199	
WI			0.041

Table C98. Power of the Test for Total Kjeldahl Nitrogen – All Single Land Uses

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	436	0.12	0.356
SP	467	0.15	0.321
SU	363	0.19	0.346
WI	407	0.08	0.277
Pooled Standard Deviation			0.325
Obtained Effect Size			0.12

α level	Power (%)
0.20	99.9
0.15	99.8
0.10	99.6
0.05	***99.1***
0.01	96.1

C.7.2 Total Kjeldahl Nitrogen - Residential Land Use

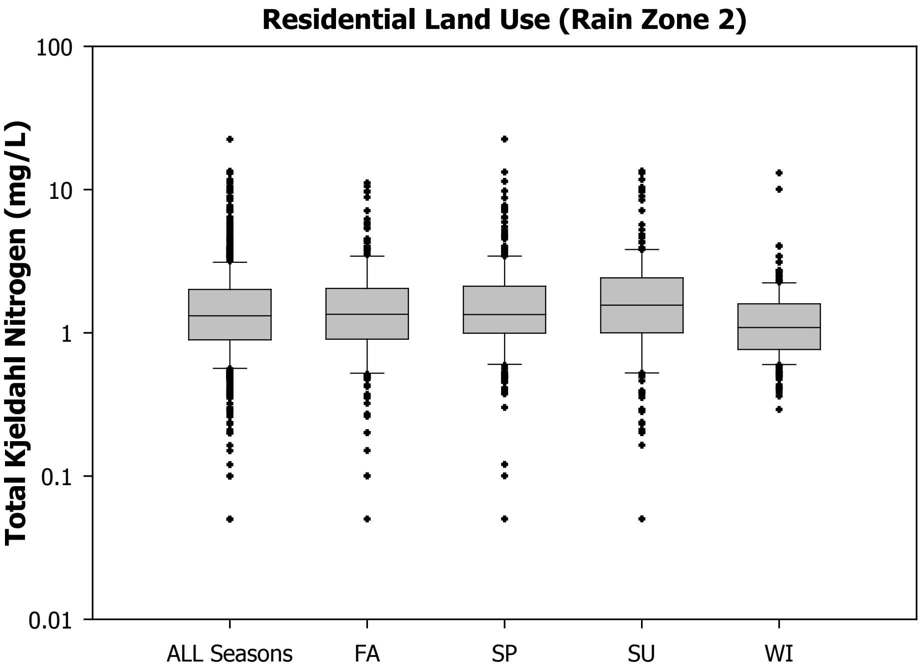
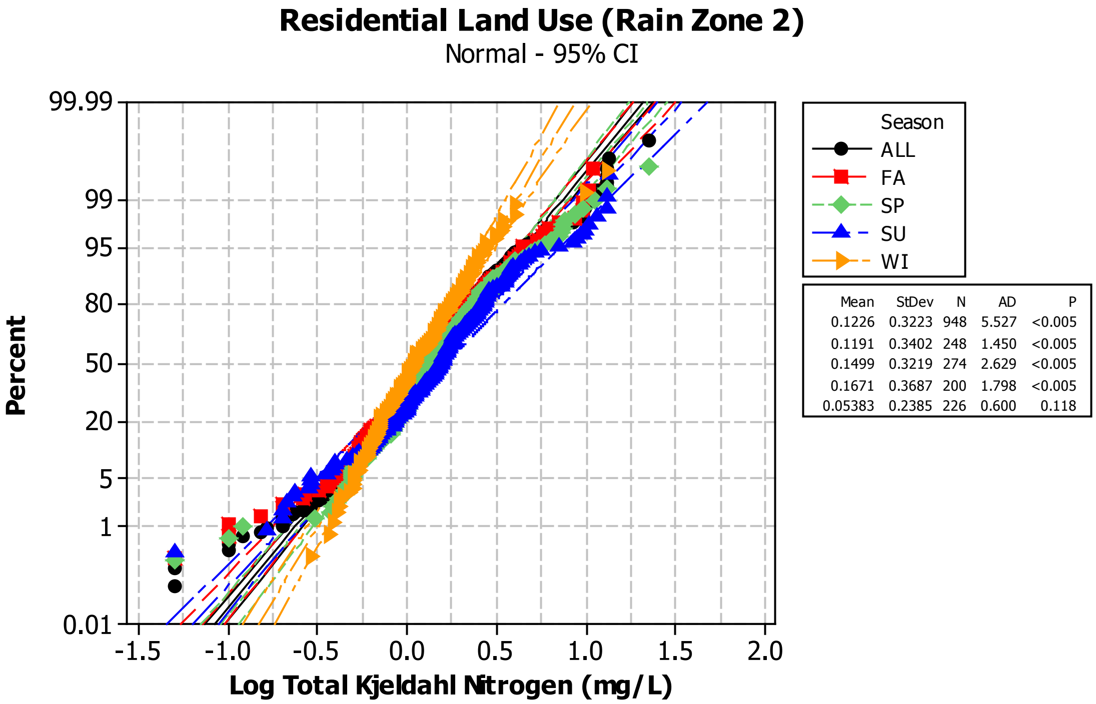


Fig. C123. Total Kjeldahl Nitrogen – Residential Land Use by Season



Mean	StDev	N	AD	P
0.1226	0.3223	948	5.527	<0.005
0.1191	0.3402	248	1.450	<0.005
0.1499	0.3219	274	2.629	<0.005
0.1671	0.3687	200	1.798	<0.005
0.05383	0.2385	226	0.600	0.118

Fig. C124. Total Kjeldahl Nitrogen – Residential Land Use (Checks for Normality)

Table C99. Statistical Analyses for Total Kjeldahl Nitrogen – Residential Land Use

Kruskal-Wallis Test
(Residential: Log TKN)

H = 25.36 DF = 3 P = 0.000
H = 25.37 DF = 3 P = 0.000 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	248	0.127	479	0.31
SP	274	0.126	496	1.55
SU	200	0.190	524	2.88
WI	226	0.033	399	-4.7
Overall	948		474.5	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.503
	SU	0.095
	WI	0.002*
SP	SU	0.229
	WI	0.000*
SU	WI	0.000*

Residential
Log TKN
Groups (medians)

Season	Gr. 1	Gr. 2
FA	0.127	
SP	0.126	
SU	0.190	
WI		0.033

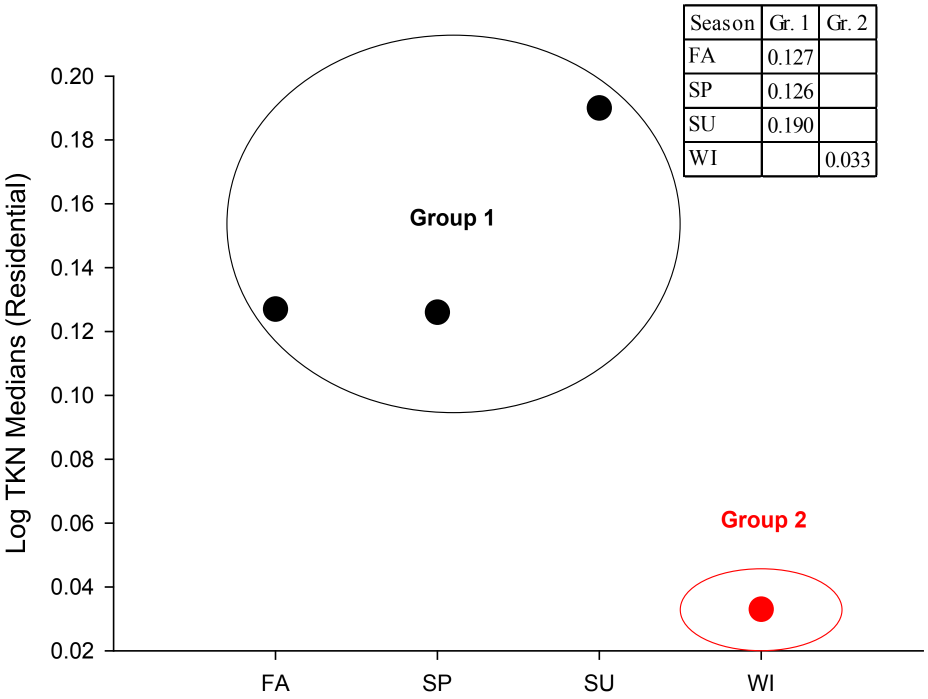


Fig. C125. All Possible Seasonal Combinations for Total Kjeldahl Nitrogen – Residential Land Use

Table C100. Power of the Test for Total Kjeldahl Nitrogen – Residential Land Use

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	248	0.12	0.340
SP	274	0.15	0.322
SU	200	0.17	0.369
WI	226	0.05	0.239

Pooled Standard Deviation 0.317
Obtained Effect Size 0.14

α level	Power (%)
0.20	99.3
0.15	98.9
0.10	98.2
0.05	***96.2***
0.01	88.0

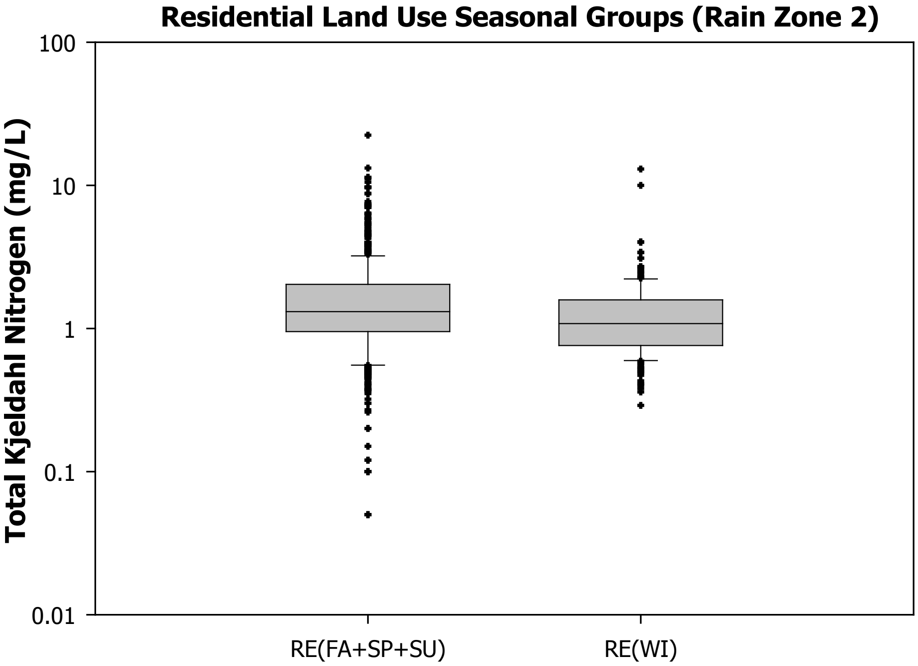


Fig. C126. Total Kjeldahl Nitrogen – Residential Land Use Seasonal Groups

Table C101. Statistical Analyses for Total Kjeldahl Nitrogen – Residential Land Use Seasonal Groups

Kruskal-Wallis Test
(Residential: Log TKN Groups)

H = 22.37 DF = 1 P = 0.000
H = 22.37 DF = 1 P = 0.000 (adjusted for ties)

Groups	**N**	**Median**	**Ave Rank**	**Z**
RE(FA,SP,SU)	722	0.15	498	5
RE(WI)	226	0.03	399	-5
Overall	948		475	

Power of the Test (Residential: Log TKN Groups)

Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,SP,SU)	722	0.14	0.342
RE(WI)	226	0.05	0.239
Pooled Standard Deviation			0.290
Obtained Effect Size			0.13

α level	**Power (%)**
0.20	99.7
0.15	99.6
0.10	99.2
0.05	***98.2***
0.01	93.2

C.7.3 Total Kjeldahl Nitrogen - Commercial Land Use

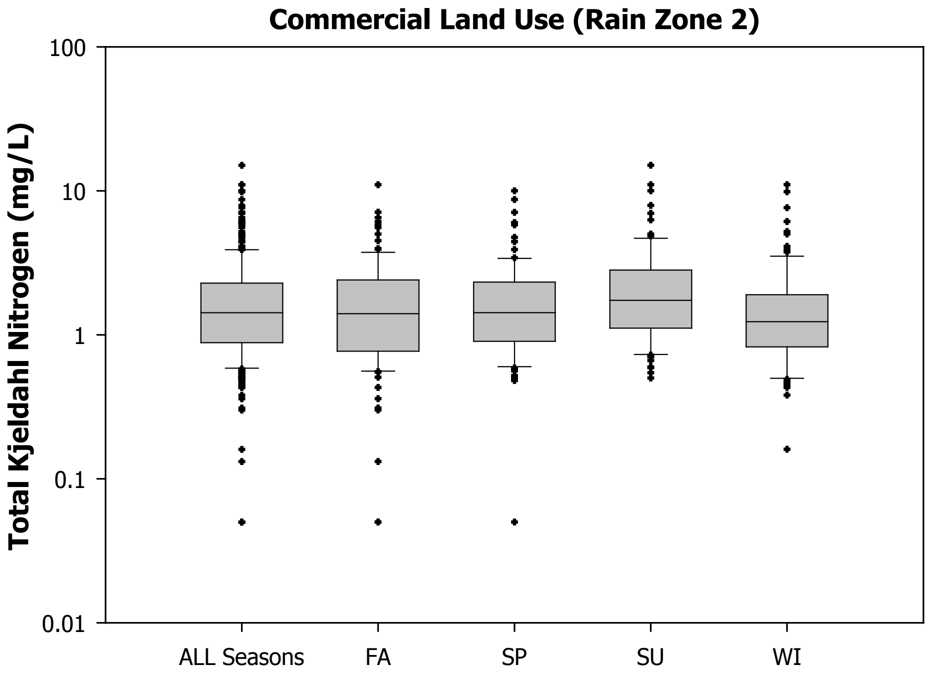
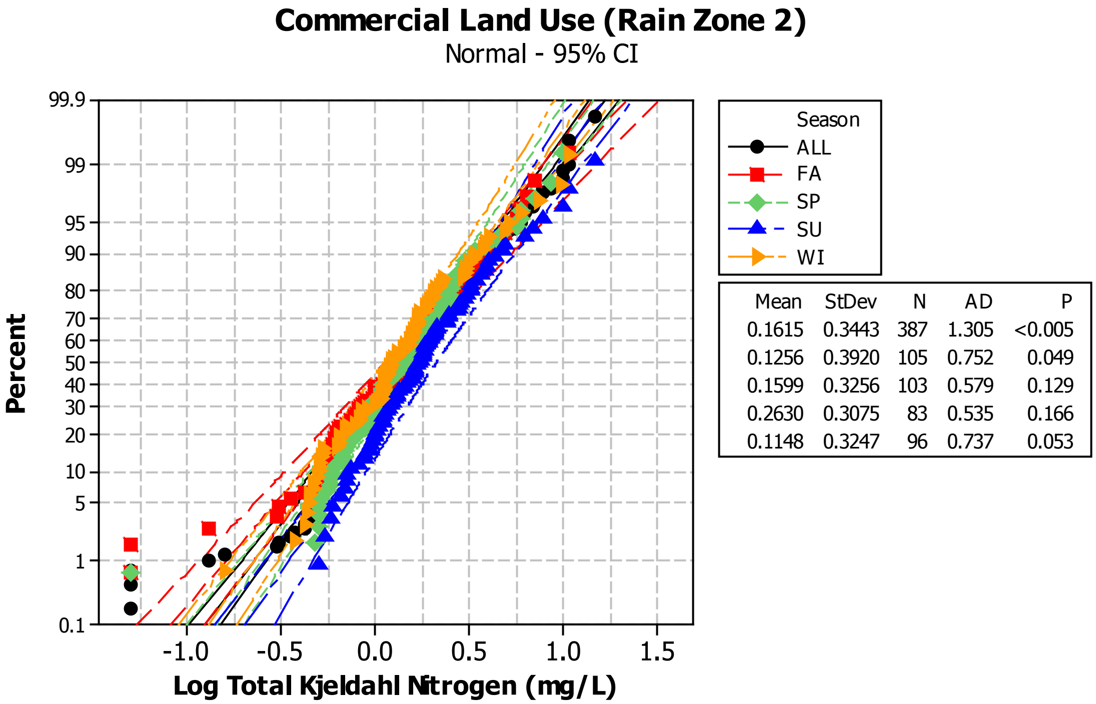


Fig. C127. Total Kjeldahl Nitrogen – Commercial Land Use by Season



Mean	StDev	N	AD	P
0.1615	0.3443	387	1.305	<0.005
0.1256	0.3920	105	0.752	0.049
0.1599	0.3256	103	0.579	0.129
0.2630	0.3075	83	0.535	0.166
0.1148	0.3247	96	0.737	0.053

Fig. C128. Total Kjeldahl Nitrogen – Commercial Land Use (Checks for Normality)

Table C102. Statistical Analyses for Total Kjeldahl Nitrogen – Commercial Land Use

Kruskal-Wallis Test
(Commercial: Log TKN

H = 9.81 DF = 3 P = 0.020
H = 9.81 DF = 3 P = 0.020 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	105	0.146	188.1	-0.6
SP	103	0.153	193.1	-0.1
SU	83	0.238	225.4	2.90
WI	96	0.089	174.3	-20
Overall	387		194	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.727
	SU	0.032*
	WI	0.424
SP	SU	0.044*
	WI	0.222
SU	WI	0.002*

Commercial
Log TKN
Groups (medians)

Season	Gr. 1	Gr. 2
FA	0.146	
SP	0.153	
WI	0.089	
SU		0.238

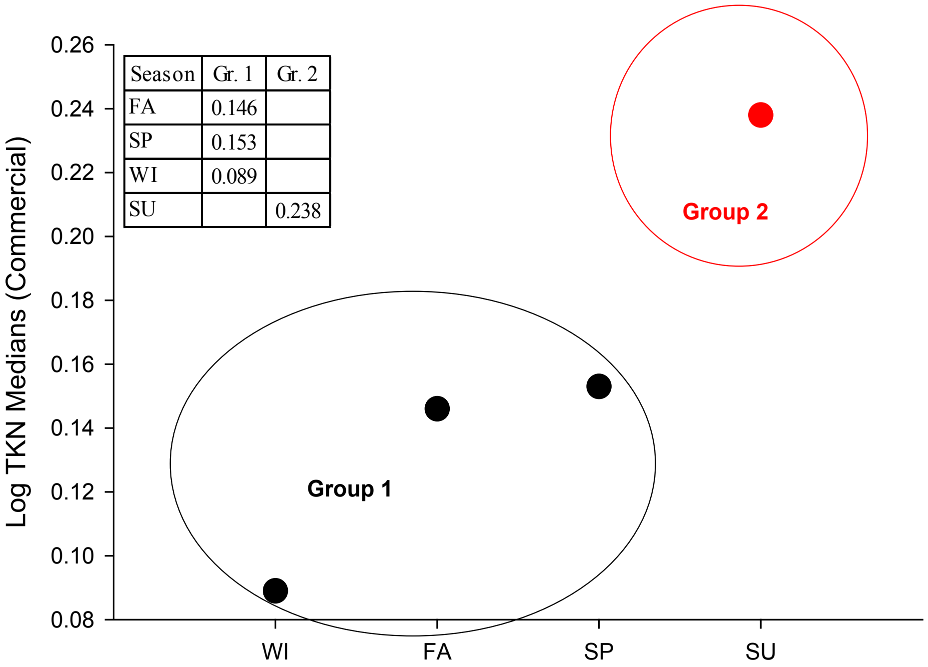


Fig. C129. All Possible Seasonal Combinations for Total Kjeldahl Nitrogen – Commercial Land Use

Table C103. Power of the Test for Total Kjeldahl Nitrogen – Commercial Land Use

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	105	0.13	0.392
SP	103	0.16	0.326
SU	83	0.26	0.308
WI	96	0.11	0.325
Pooled Standard Deviation			0.337
Obtained Effect Size			0.16

α level	Power (%)
0.20	92.3
0.15	89.6
0.10	85.3
0.05	***76.8***
0.01	54.8

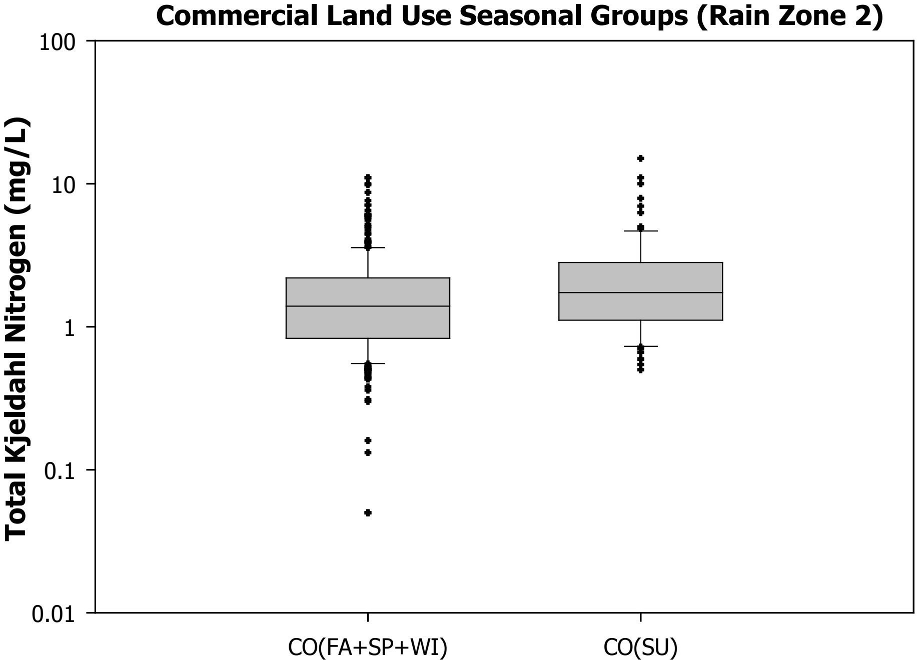


Fig. C130. Total Kjeldahl Nitrogen – Commercial Land Use Seasonal Groups

Table C104. Statistical Analyses for Total Kjeldahl Nitrogen –
Commercial Land Use Seasonal Groups

Kruskal-Wallis Test
(Commercial: Log TKN Groups)

H = 8.30 DF = 1 P = 0.004
H = 8.30 DF = 1 P = 0.004 (adjusted for ties)

Groups	**N**	**Median**	**Ave Rank**	**Z**
CO(FA,SP,WI)	304	0.1430	185	-3
CO(SU)	83	0.2380	225	3
Overall	387		194	

Power of the Test (Commercial: Log TKN Groups)

Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
CO(FA,SP,WI)	304	0.13	0.349
CO(SU)	83	0.26	0.308
Pooled Standard Deviation			0.328
Obtained Effect Size			0.16

α level	**Power (%)**
0.20	97.2
0.15	96.0
0.10	93.9
0.05	***89.1***
0.01	72.9

C.7.4 Total Kjeldahl Nitrogen - Industrial Land Use

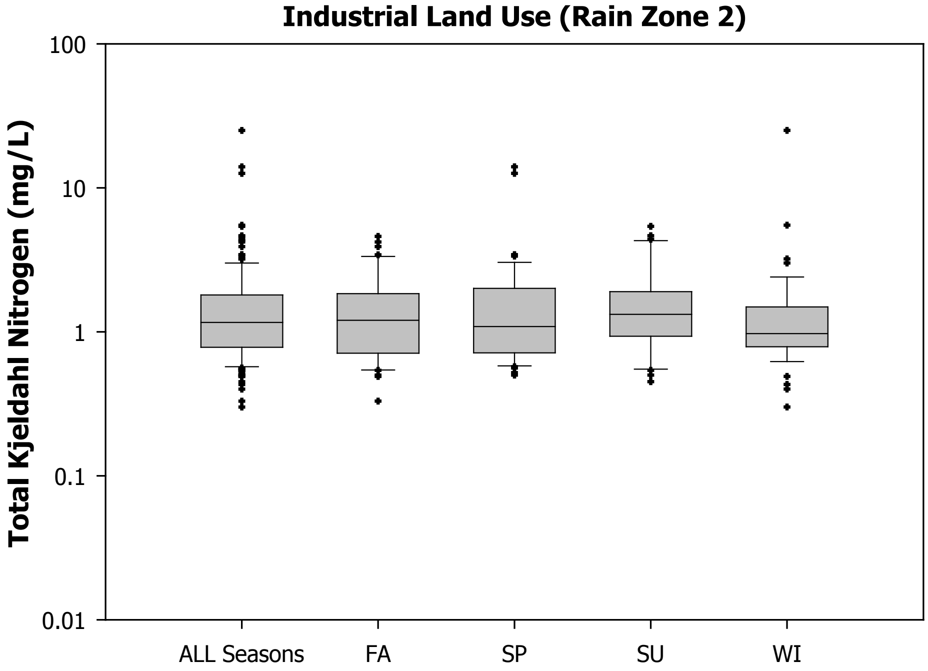
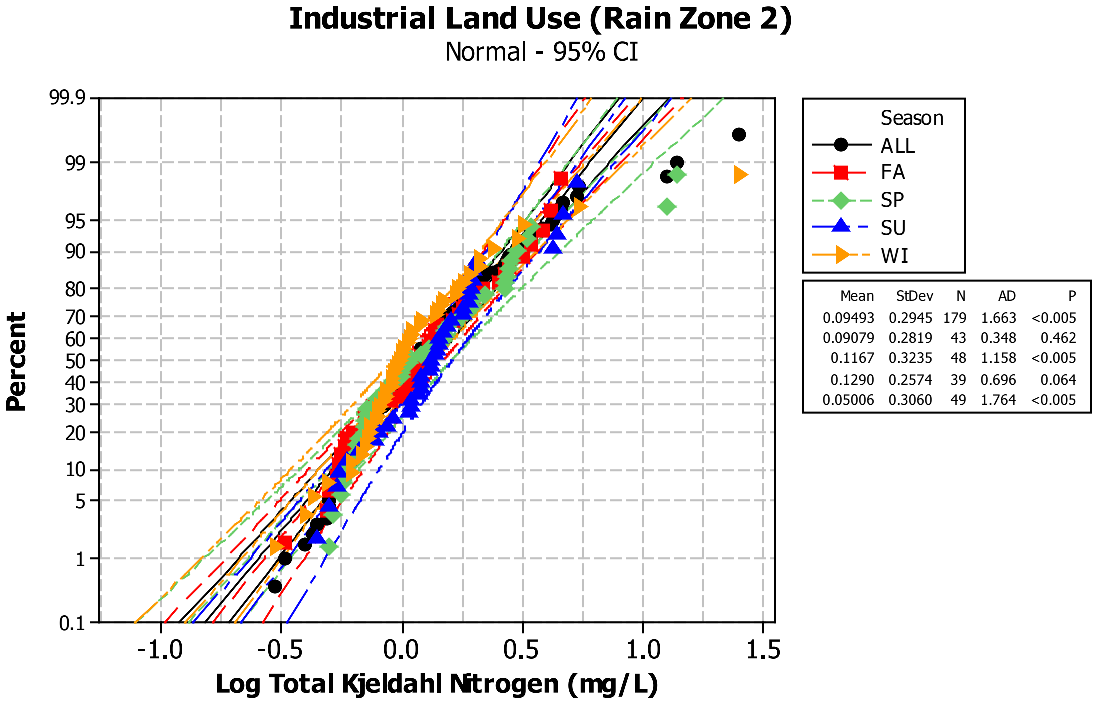


Fig. C131. Total Kjeldahl Nitrogen – Industrial Land Use by Season



Mean	StDev	N	AD	P
0.09493	0.2945	179	1.663	<0.005
0.09079	0.2819	43	0.348	0.462
0.1167	0.3235	48	1.158	<0.005
0.1290	0.2574	39	0.696	0.064
0.05006	0.3060	49	1.764	<0.005

Fig. C132. Total Kjeldahl Nitrogen – Industrial Land Use (Checks for Normality)

Table C105. Statistical Analyses for Total Kjeldahl Nitrogen – Industrial Land Use

Kruskal-Wallis Test
(Industrial: Log TKN)

H = 3.39 DF = 3 P = 0.335
H = 3.39 DF = 3 P = 0.335 (adjusted for ties)

Season	N	Media	Ave Rank	Z
FA	43	0.079	90.9	0.13
SP	48	0.035	91.0	0.16
SU	39	0.121	100	1.40
WI	49	-0.013	80.0	-1.58
Overall	179		90.0	

Power of the Test (Industrial: Log TKN)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	43	0.09	0.282
SP	48	0.12	0.324
SU	39	0.13	0.257
WI	49	0.05	0.306

Pooled Standard Deviation 0.292
Obtained Effect Size 0.11

α level	Power (%)
0.20	45.0
0.15	38.2
0.10	30.0
0.05	***19.6***
0.01	6.8

C.7.5 Total Kjeldahl Nitrogen - Institutional Land Use

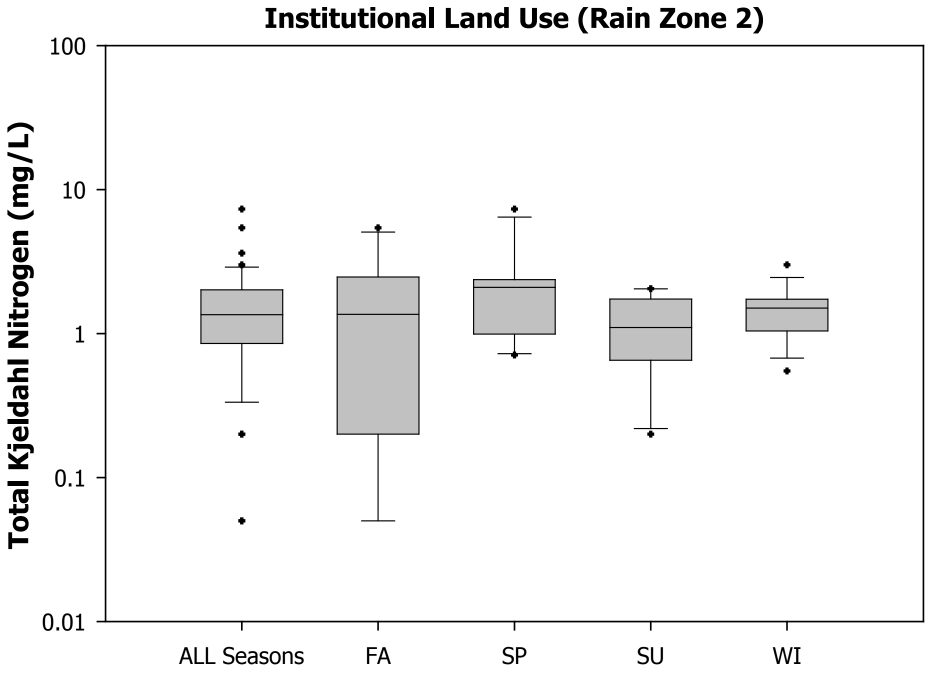


Fig. C133. Total Kjeldahl Nitrogen – Institutional Land Use by Season

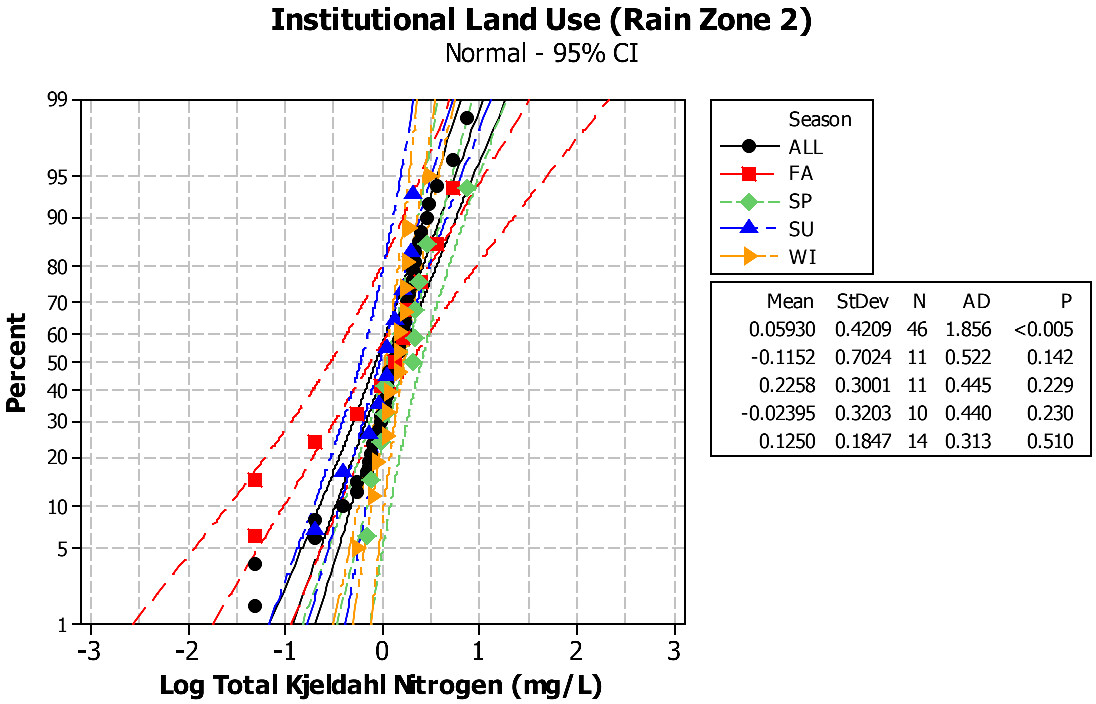


Fig. C134. Total Kjeldahl Nitrogen – Institutional Land Use (Checks for Normality)

Table C106. Statistical Analyses for Total Kjeldahl Nitrogen – Institutional Land Use

Kruskal-Wallis Test
(Institutional: Log TKN)

H = 2.35 DF = 3 P = 0.504
H = 2.35 DF = 3 P = 0.503 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	11	0.134	22.1	-0.4
SP	11	0.320	27.9	1.25
SU	10	0.041	19.3	-1.13
WI	14	0.176	24.2	0.23
Overall	46		23.5	

Power of the Test (Institutional: Log TKN)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	11	-0.12	0.702
SP	11	0.23	0.300
SU	10	-0.02	0.320
WI	14	0.13	0.185
Pooled Standard Deviation			0.377
Obtained Effect Size			0.35

α level	Power (%)
0.20	73.5
0.15	67.4
0.10	58.9
0.05	***45.5***
0.01	22.1

C.7.6 Total Kjeldahl Nitrogen – Open Space Land Use

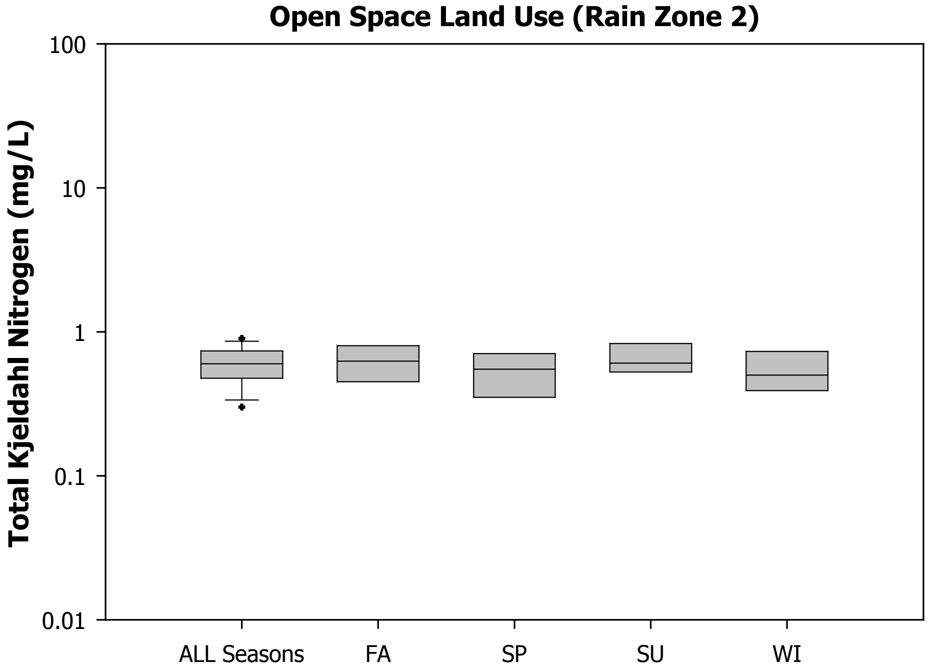
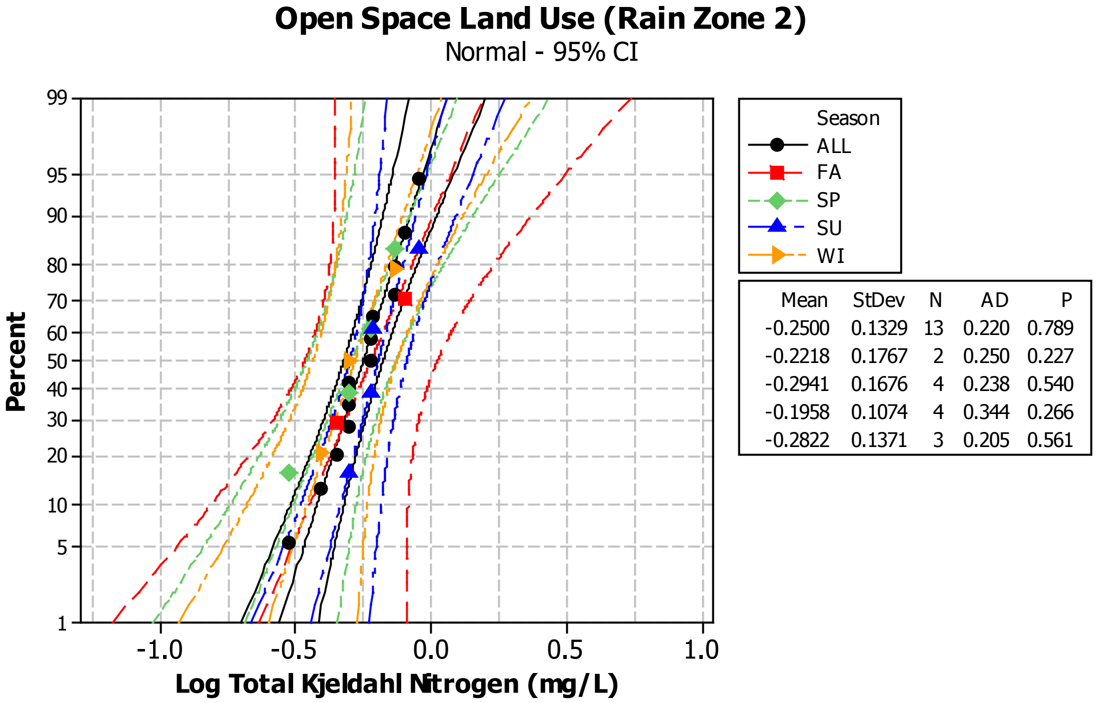


Fig. C135. Total Kjeldahl Nitrogen – Open Space Land Use by Season



Mean	StDev	N	AD	P
-0.2500	0.1329	13	0.220	0.789
-0.2218	0.1767	2	0.250	0.227
-0.2941	0.1676	4	0.238	0.540
-0.1958	0.1074	4	0.344	0.266
-0.2822	0.1371	3	0.205	0.561

Fig. C136. Total Kjeldahl Nitrogen – Open Space Land Use (Checks for Normality)

Table C107. Statistical Analyses for Total Kjeldahl Nitrogen – Open Space Land Use

Kruskal-Wallis Test
(Open Space: Log TKN)

H = 1.28 DF = 3 P = 0.733
H = 1.30 DF = 3 P = 0.729 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	2	-0.222	7.5	0.2
SP	4	-0.261	6.1	-0.54
SU	4	-0.218	8.6	1.0
WI	3	-0.301	5.7	-0.68
Overall	13		7.0	

Power of the Test (Open Space: Log TKN)

Season	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
FA	2	-0.22	0.177
SP	4	-0.29	0.168
SU	4	-0.20	0.107
WI	3	-0.□8	0.137

Pooled Standard Deviation 0.147

Obtained Effect Size 0.27

α level	Power (%)
0.20	29.7
0.15	23.4
0.10	16.6
0.05	***9.1***
0.01	2.1

C.7.7 Total Kjeldahl Nitrogen - Freeways Land Use

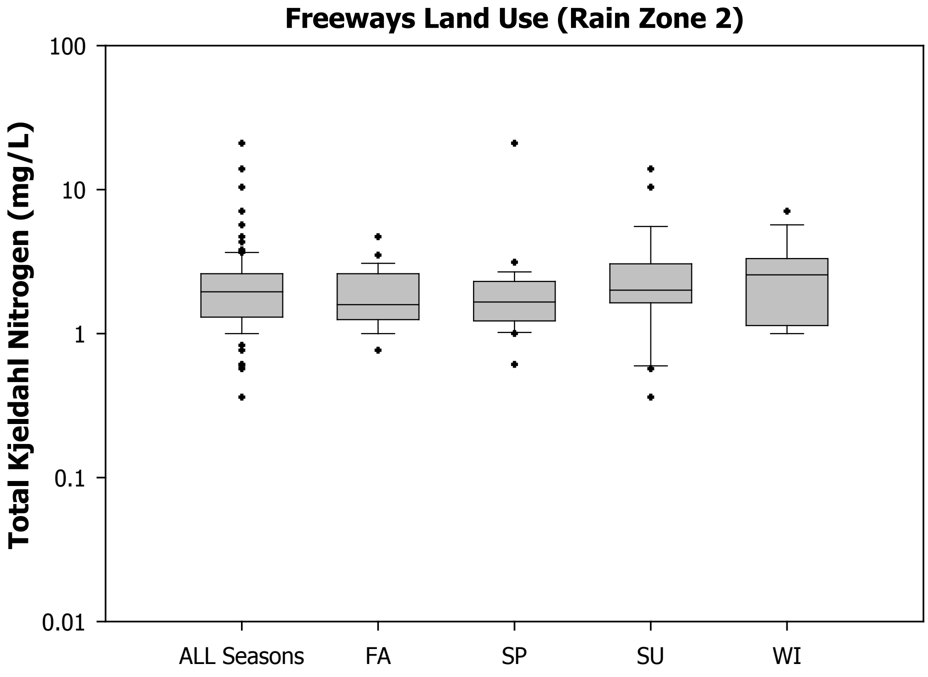
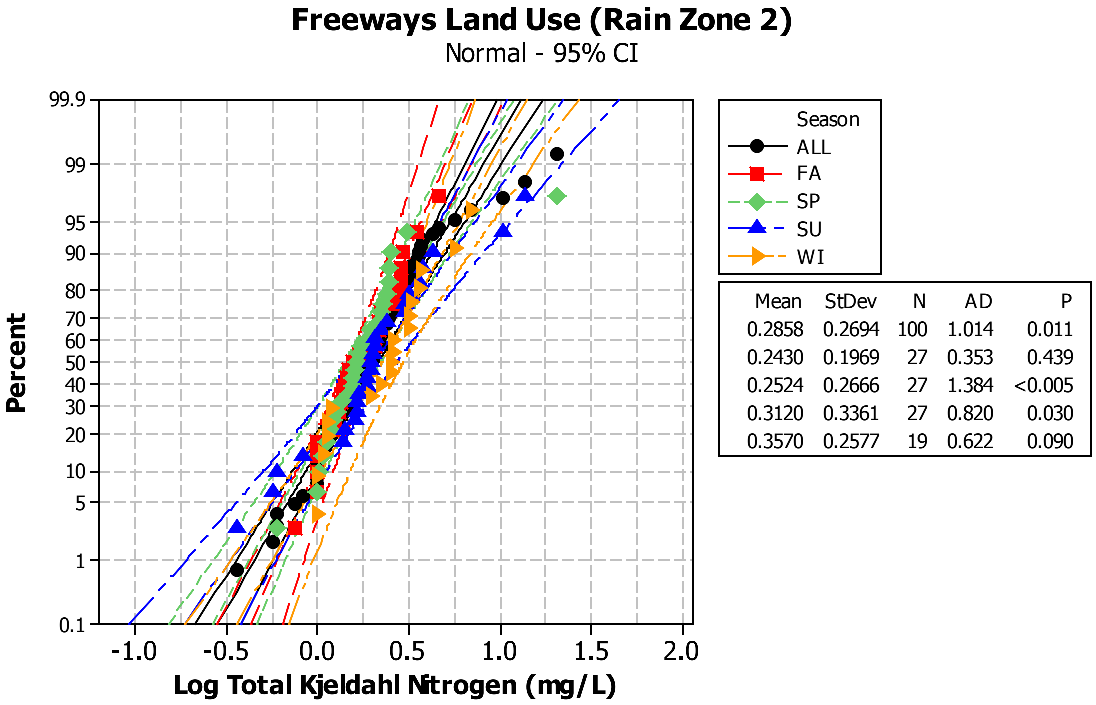


Fig. C137. Total Kjeldahl Nitrogen – Freeways Land Use by Season



Mean	StDev	N	AD	P
0.2858	0.2694	100	1.014	0.011
0.2430	0.1969	27	0.353	0.439
0.2524	0.2666	27	1.384	<0.005
0.3120	0.3361	27	0.820	0.030
0.3570	0.2577	19	0.622	0.090

Fig. C138. Total Kjeldahl Nitrogen – Freeways Land Use (Checks for Normality)

Table C108. Statistical Analyses for Total Kjeldahl Nitrogen – Freeways Land Use

Kruskal-Wallis Test
(Freeways: Log TKN)

H = 4.28 DF = 3 P = 0.233
H = 4.28 DF = 3 P = 0.233 (adjusted for ties)

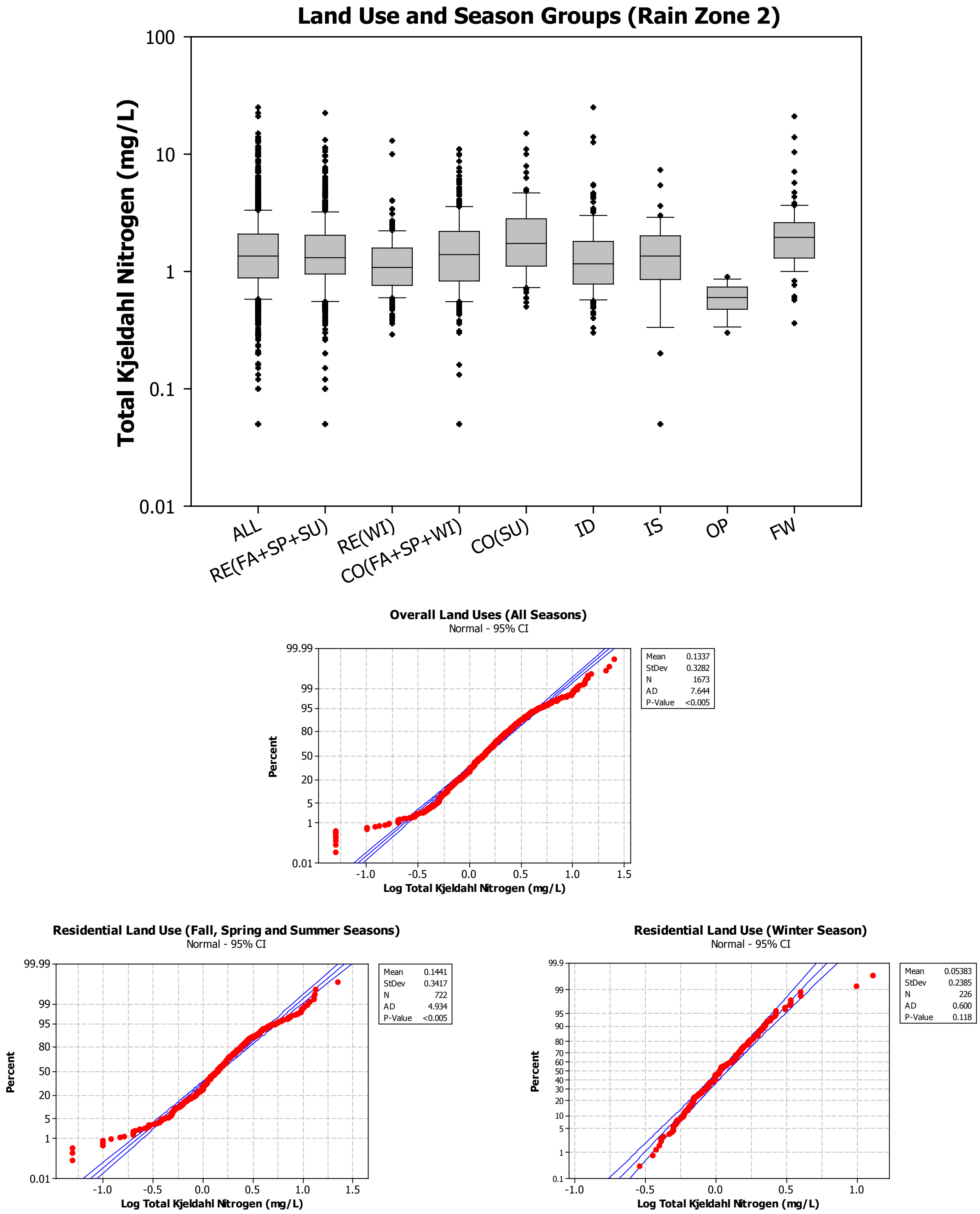
Season	**N**	**Median**	**Ave Rank**	**Z**
FA	27	0.260	45.9	-0.97
SP	27	0.219	44.6	-1.23
SU	27	0.301	54.4	0.81
WI	19	0.407	59.9	1.57
Overall	100		50.5	

Power of the Test (Freeways: Log TKN)

Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	27	0.24	0.197
SP	27	0.25	0.267
S	27	0.31	0.336
WI	19	0.36	0.258
Pooled Standard Deviation			0.264
Obtained Effect Size			0.17

α level	**Power (%)**
0.20	54.3
0.15	47.4
0.10	38.7
0.05	***26.7***
0.01	10.5

C.8.8 Total Kjeldahl Nitrogen Land Use and Season Groups


Land Use and Season Groups (Rain Zone 2)

Overall Land Uses (All Seasons)

Normal - 95% CI

Residential Land Use (Fall, Spring and Summer Seasons)

Normal - 95% CI

Residential Land Use (Winter Season)

Normal - 95% CI

Fig. C139. Total Kjeldahl Nitrogen – Land Use and Season Groups

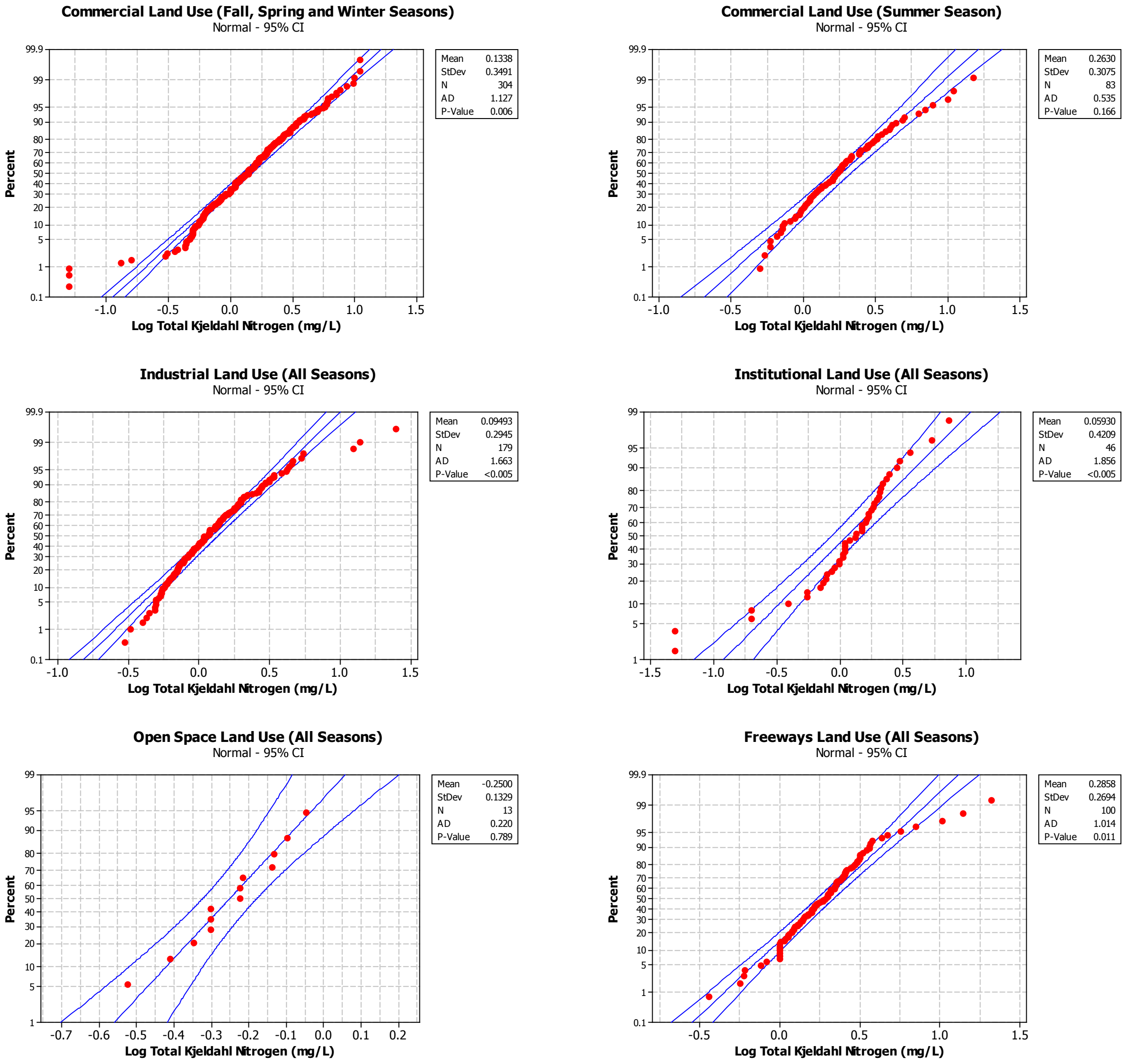


Fig. C139. – *Continued*

Table C109. Statistical Analyses for Total Kjeldahl Nitrogen – Land Use and Season Groups

Kruskal-Wallis Test
(Land Use and Season Groups: Log TKN)

H = 93.13 DF = 7 P = 0.000
H = 93.14 DF = 7 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE(FA,SP,SU)	722	0.146	861	1.7
RE(WI)	226	0.033	689	-5
CO(FA,SP,WI)	304	0.143	843	0.2
CO(SU)	83	0.238	1022	3.6
ID	179	0.065	745	-3
IS	46	0.130	807	0
OP	13	-0.222	191	-5
FW	100	0.290	1093	5.5
Overall	1673		837	

Land Use and Season Groups
(medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
FW	0.290			
CO(SU)	0.238			
RE(FA,SP,SU)		0.146		
CO(FA,SP,WI)		0.143		
IS		0.130		
ID			0.065	
RE(WI)			0.033	
OP				-0.222

Table C110. Land Use and Season Multiple Comparisons for Total Kjeldahl Nitrogen

(I) Group	(J) Group	p-value	(I) Group	(J) Group	p-value
RE(FA,SP,SU)	RE (WI)	0.000*	RE (WI)	CO(FA,SP,WI)	0.001*
	CO(FA,SP,WI)	0.633		CO (SU)	0.000*
	CO (SU)	0.004*		ID	0.326
	ID	0.004*		IS	0.109
	IS	0.455		OP	0.000*
	OP	0.000*		FW	0.000*
	FW	0.000*			
			CO(FA,SP,WI)	CO (SU)	0.004*
CO (SU)	ID	0.000*		ID	0.046*
	IS	0.016*		IS	0.612
	OP	0.000*		OP	0.000*
	FW	0.382		FW	0.000*
ID	IS	0.404	IS	OP	0.000*
	OP	0.000*		FW	0.001*
	FW	0.000*	OP	FW	0.000*

Table C111. All Possible Land Use and Season Combinations for Total Kjeldahl Nitrogen

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE(FA,SP,SU)	0.1461			
CO(FA,SP,WI)	0.1430			
IS	0.1303	0.1303		
RE (WI)		0.0334		
ID		0.0645		
CO (SU)			0.2381	
FW			0.2895	
OP				-0.2219

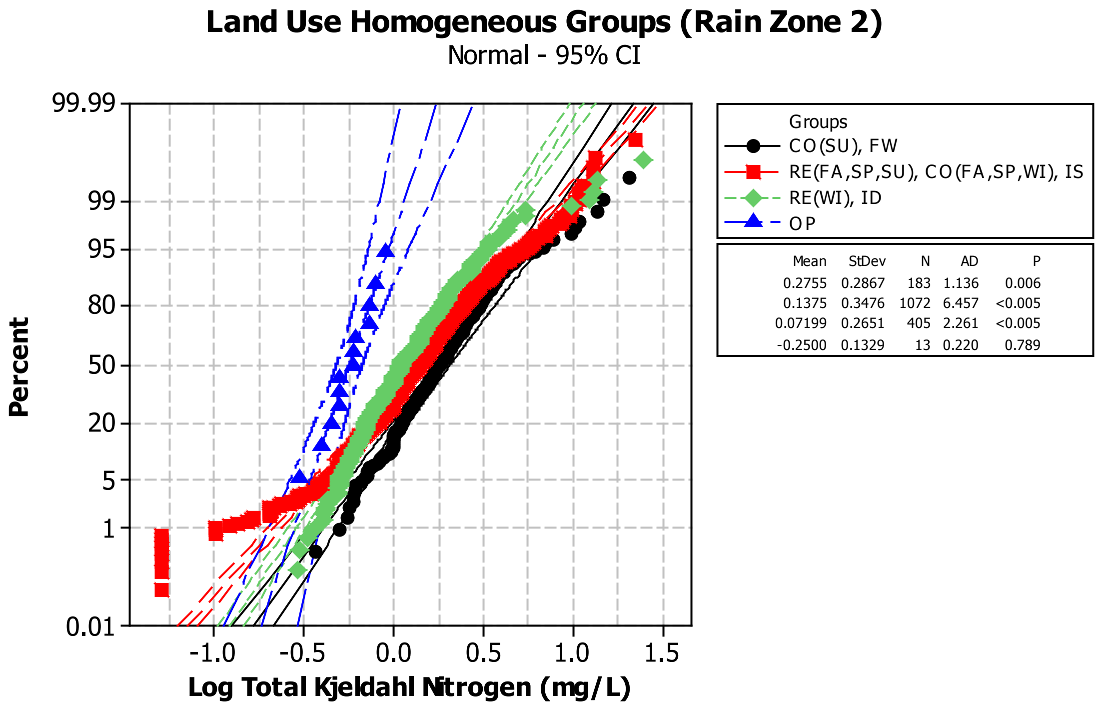
Table C112. Power of the Test for Total Kjeldahl Nitrogen – Land Use and Season Groups

Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA,SP,SU)	722	0.14	0.342
RE(WI)	226	0.05	0.239
CO(FA,SP,WI)	304	0.13	0.349
CO(SU)	83	0.26	0.308
ID	179	0.09	0.295
IS	46	0.06	0.421
OP	13	-0.25	0.133
FW	100	0.29	0.269

Pooled Standard Deviation 0.294

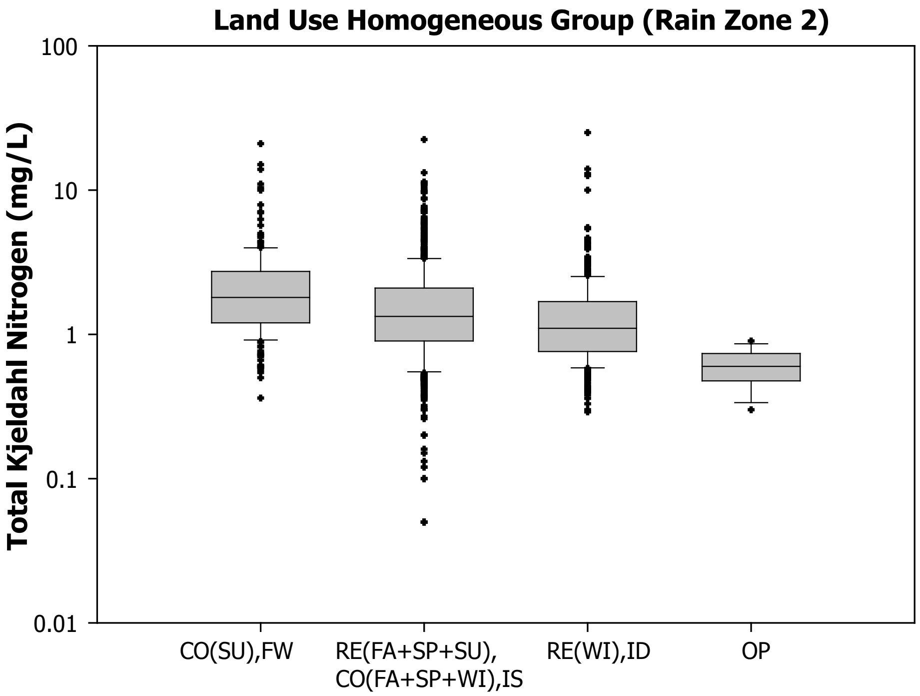
Obtained Effect Size 0.23

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100



Mean	StDev	N	AD	P
0.2755	0.2867	183	1.136	0.006
0.1375	0.3476	1072	6.457	<0.005
0.07199	0.2651	405	2.261	<0.005
-0.2500	0.1329	13	0.220	0.789

Fig. C140. Total Kjeldahl Nitrogen – Land Use Homogeneous Groups (Checks for Normality)



Land Uses	FALL	SPRING	SUMMER	WINTER
Residential	1.8(0.93)	1.9(1.1)	2.1(1.1)	1.4(0.88)
Commercial	1.9(0.90)	1.9(0.87)	2.4(0.98)	1.8(1.0)
Industrial	1.5(0.70)	1.9(1.3)	1.6(0.71)	1.7(2.0)
Institutional	1.7(1.0)	2.1(0.87)	1.1(0.55)	1.4(0.42)
Open Space	0.63(0.40)	0.54(0.35)	0.65(0.26)	0.54(0.32)
Freeways	1.9(0.48)	2.4(1.5)	2.8(1.0)	2.7(0.60)

Fig. C141. Total Kjeldahl Nitrogen – Land Use Homogeneous Groups: Mean (CV)

Table C113. Statistical Analyses for Total Kjeldahl Nitrogen – Land Use Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: Log TKN)

H = 90.09 DF = 3 P = 0.000
H = 90.09 DF = 3 P = 0.000 (adjusted for ties)

	Groups	N	Median	Ave Rank	Z
1	CO(SU), FW	183	0.255	1061	7
2	RE(FA,SP,SU), CO(FA,SP,WI), IS	1072	0.146	853	2
3	RE(WI), ID	405	0.041	714	-6
4	OP	13	-0.222	191	-5
Overall		1673		837	

Log TKN
Homogeneous Groups
(medians)

Group	Gr. A	Gr. B	Gr. C	Gr. D
1	0.255			
2		0.146		
3			0.041	
4				-0.222

Table C113. - *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) Group	(J) Group	p-value
1	2	0.00*
	3	0.00*
	4	0.00*
2	3	0.00*
	4	0.00*
3	4	0.00*

Table C114. Power of the Test for Total Kjeldahl Nitrogen – Land Use Homogeneous Groups

Homogeneous Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
CO(SU), FW	183	0.28	0.287
RE(FA,SP,SU), CO(FA,SP,WI), IS	1072	0.14	0.348
RE(WI), ID	405	0.07	0.265
OP	13	-0.25	0.133
Pooled Standard Deviation			0.258
Obtained Effect Size			0.26

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Table C115. Basic Statistics for Total Kjeldahl Nitrogen
Homogeneous Groups (Real Space Data)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	CO(SU), FW	183	2.4	2.5	1.0	0.36	1.8	21
B	RE(FA,SP,SU), CO(FA,SP,WI), IS	1072	1.9	1.9	1.0	0.05	1.4	22
C	RE(WI), ID	405	1.5	1.8	1.2	0.29	1.1	25
D	OP	13	0.59	0.17	0.29	0.30	0.60	0.90

C.8. Fecal Colifom Bacteria

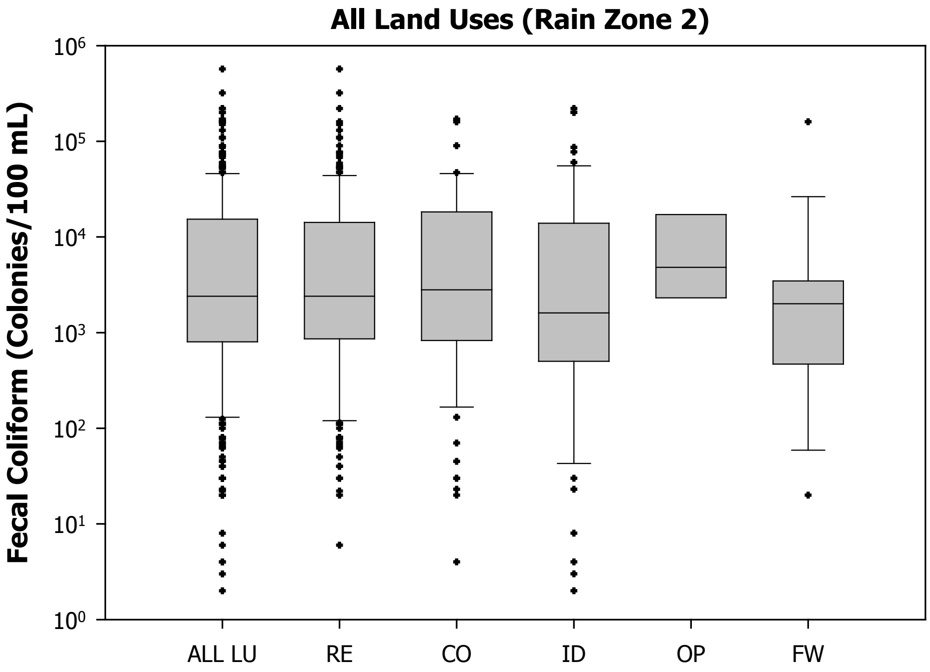
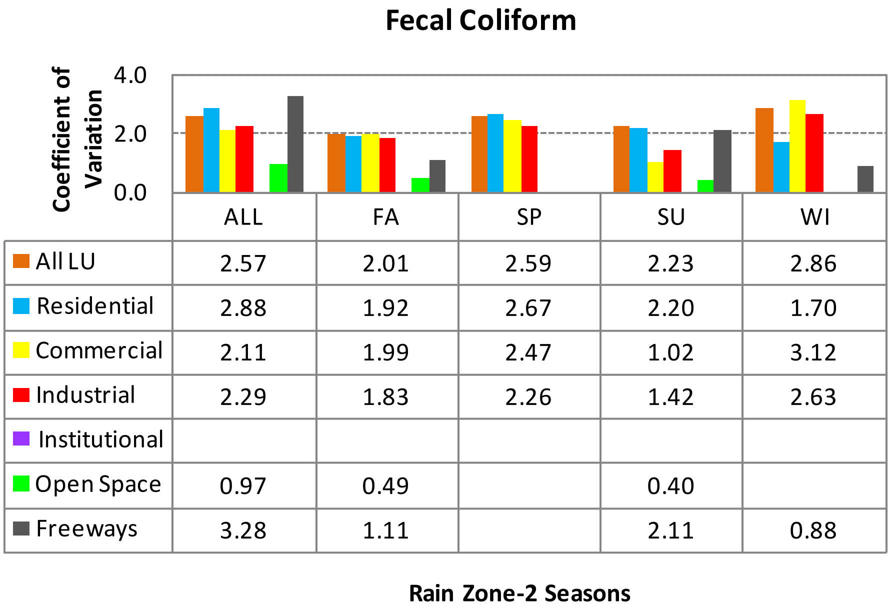


Fig. C142. Fecal Coliform Bacteria - Single Land Uses in EPA Rain Zone 2



	ALL	FA	SP	SU	WI
🟧 All LU	2.57	2.01	2.59	2.23	2.86
🟦 Residential	2.88	1.92	2.67	2.20	1.70
🟨 Commercial	2.11	1.99	2.47	1.02	3.12
🟥 Industrial	2.29	1.83	2.26	1.42	2.63
🟪 Institutional					
🟩 Open Space	0.97	0.49		0.40	
⬛ Freeways	3.28	1.11		2.11	0.88

Fig. C143. Fecal Coliform Bacteria - EPA Rain Zone 2 Seasonal Coefficients of Variation

C.8.1 Fecal Coliform Bacteria – All Single Land Uses

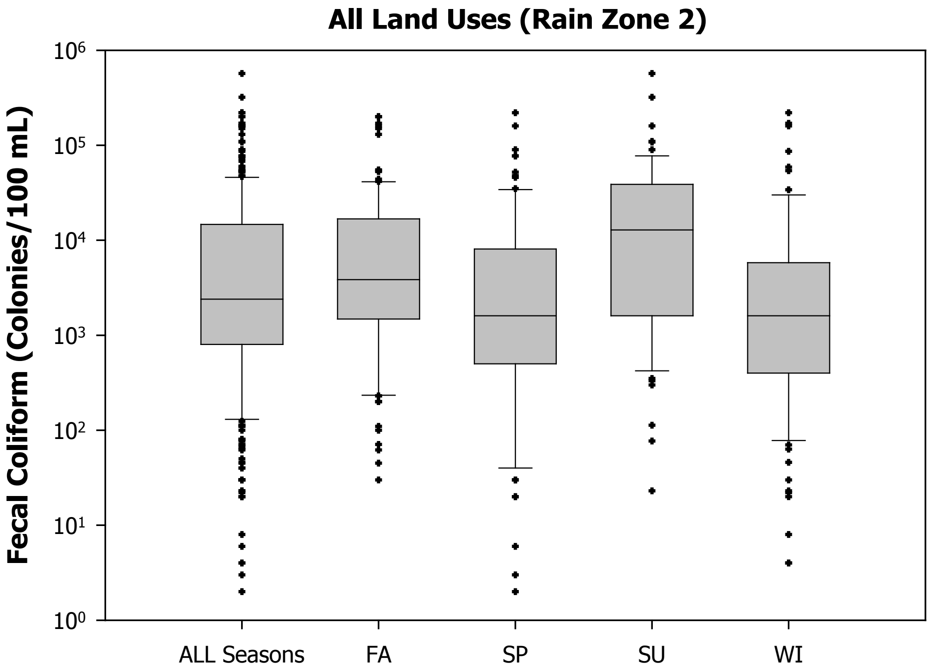
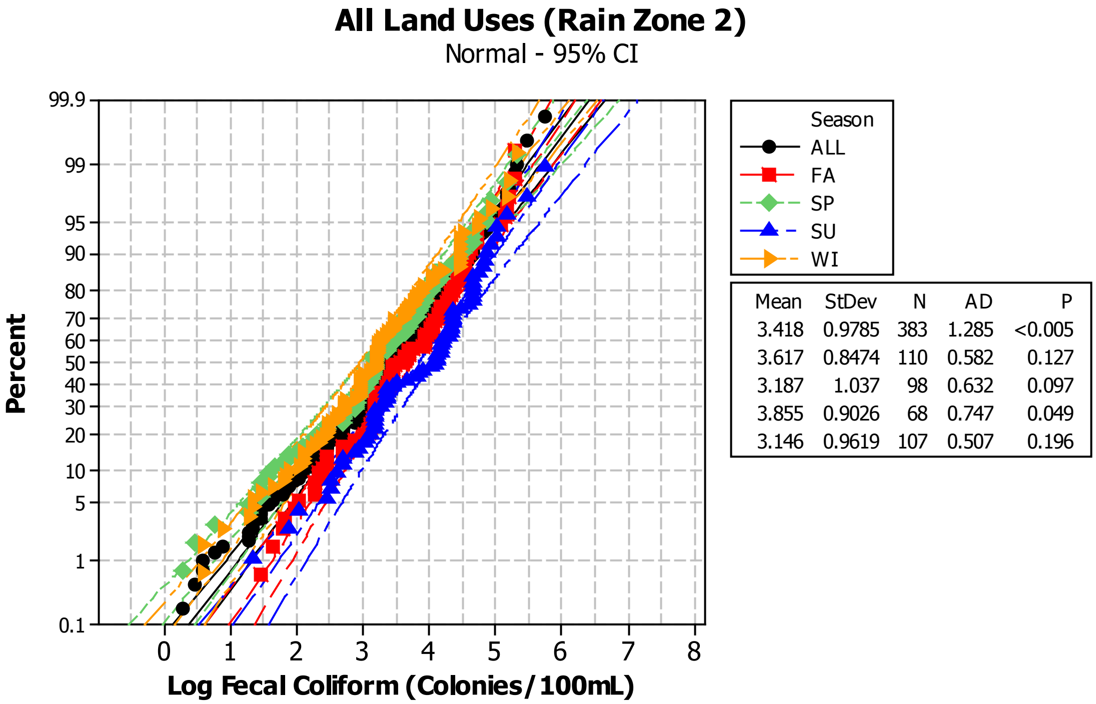


Fig. C144. Fecal Coliform Bacteria – All Single Land Use by Season



Mean	StDev	N	AD	P
3.418	0.9785	383	1.285	<0.005
3.617	0.8474	110	0.582	0.127
3.187	1.037	98	0.632	0.097
3.855	0.9026	68	0.747	0.049
3.146	0.9619	107	0.507	0.196

Fig. C145. Fecal Coliform Bacteria – All Single Land Use (Checks for Normality)

Table C116. Statistical Analyses for Fecal Coliform Bacteria - All Single Land Uses

Kruskal-Wallis Test
(All Land Uses: Log Fecal Coliform)

H = 33.89 DF = 3 P = 0.000
H = 33.91 DF = 3 P = 0.000 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	110	3.6	214	3
SP	98	3.2	167	-3
SU	68	4.1	241	4
WI	107	3.2	160	-4
Overall	383		192	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.002*
	SU	0.066
	WI	0.000*
SP	SU	0.000*
	WI	0.617
SU	WI	0.000*

All Land Uses
Log Fecal Coliform
Groups (medians)

Season	Gr. 1	Gr. 2
FA	3.6	
SU	4.1	
SP		3.2
WI		3.2

Table C117. Power of the Test for Fecal Coliform Bacteria - All Single Land Uses

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	110	3.6	0.85
SP	98	3.2	1.04
SU	68	3.9	0.90
WI	107	3.1	0.96

Pooled Standard Deviation 0.94
Obtained Effect Size 0.32

α level	Power (%)
0.20	99.9
0.15	99.9
0.10	99.9
0.05	***99.9***
0.01	99.9

C.8.2 Fecal Coliform Bacteria – Residential Land Use

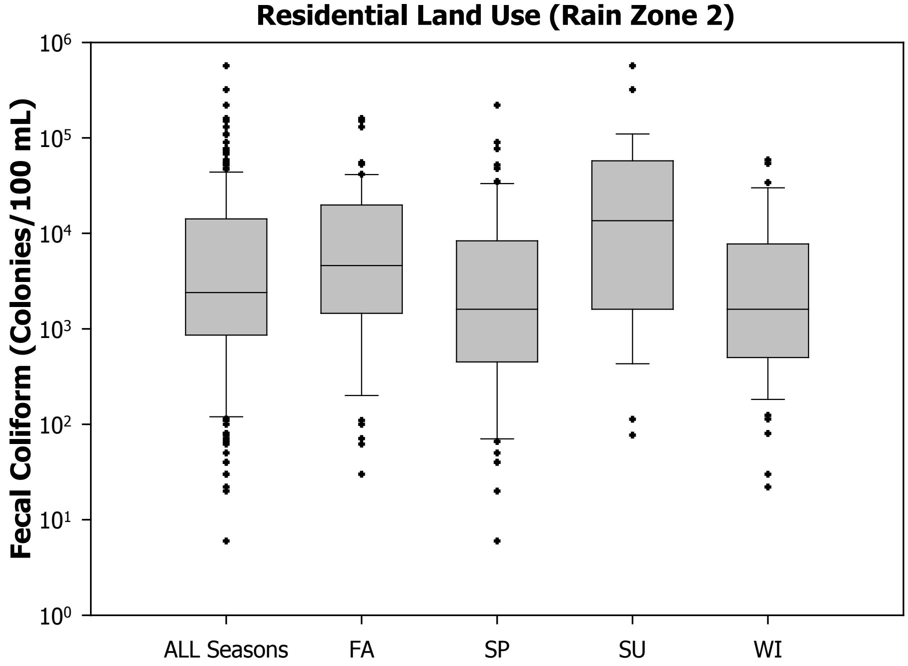
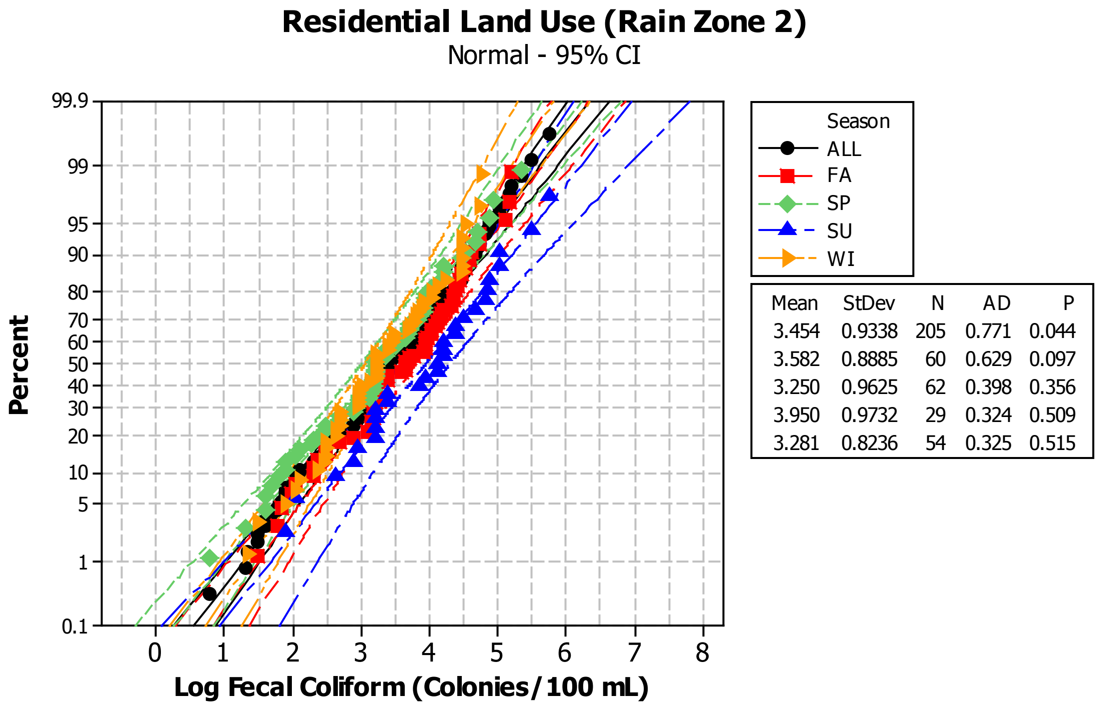


Fig. C146. Fecal Coliform Bacteria – Residential Land Use by Season



Mean	StDev	N	AD	P
3.454	0.9338	205	0.771	0.044
3.582	0.8885	60	0.629	0.097
3.250	0.9625	62	0.398	0.356
3.950	0.9732	29	0.324	0.509
3.281	0.8236	54	0.325	0.515

Fig. C147. Fecal Coliform Bacteria – Residential Land Use (Checks for Normality)

Table C118. Statistical Analyses for Fecal Coliform Bacteria - Residential Land Use

Kruskal-Wallis Test
(Residential: Log Fecal Coliform)

H = 13.40 DF = 3 P = 0.004
H = 13.42 DF = 3 P = 0.004 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	60	3.7	112	1
SP	62	3.2	91	-2
SU	29	4.1	133	3
WI	54	3.2	92	-2
Overall	205		103	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.043*
	SU	0.080
	WI	0.075
SP	SU	0.002*
	WI	0.956
SU	WI	0.003*

Residential
Log Fecal Coliform
Groups (medians)

Season	Gr. 1	Gr. 2
FA	3.7	
SU	4.1	
SP		3.2
WI		3.2

Table C119. Power of the Test for Fecal Coliform Bacteria - Residential Land Use

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	60	3.6	0.89
SP	62	3.2	0.96
SU	29	4.0	0.97
WI	54	3.3	0.82
Pooled Standard Deviation			0.91
Obtained Effect Size			0.30

α level	Power (%)
0.20	99.3
0.15	98.8
0.10	98.0
0.05	***95.9***
0.01	86.9

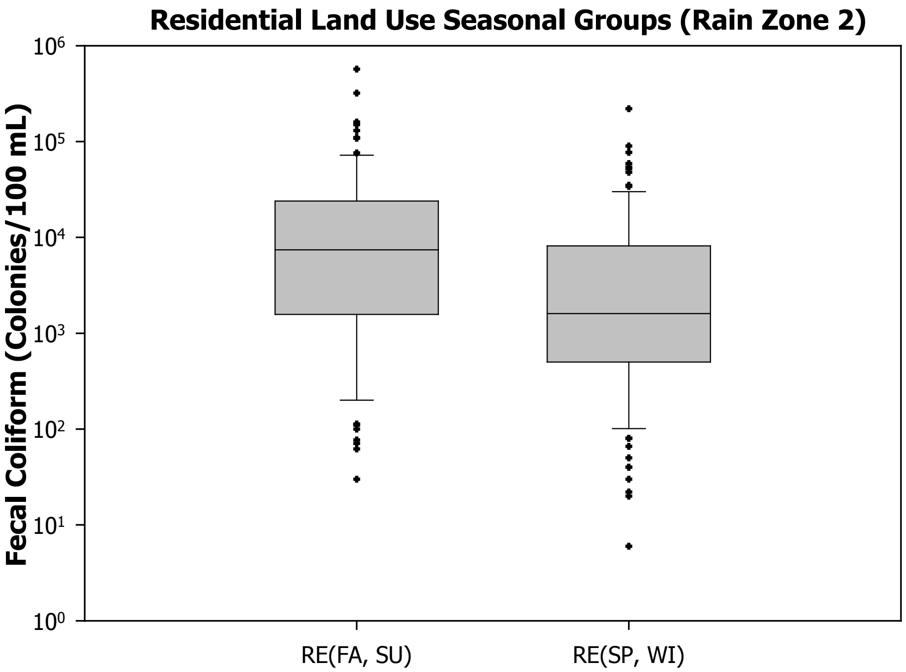


Fig. C148. Fecal Coliform Bacteria – Residential Land Use Seasonal Groups

Table C120. Statistical Analyses for Fecal Coliform Bacteria – Residential Land Use Seasonal Groups

Kruskal-Wallis Test (Residential: Log Fecal Coliform Groups)

H = 10.80 DF = 1 P = 0.001
H = 10.81 DF = 1 P = 0.001 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE(FA, SU)	89	3.9	118	3
RE(SP, WI)	116	3.2	91	-3
Overall	205		103	

Power of the Test (Residential: Log Fecal Coliform Groups)

Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA, SU)	89	3.7	0.93
RE(SP, WI)	116	3.3	0.90

Pooled Standard Deviation	0.91
Obtained Effect Size	0.22

α level	Power (%)
0.20	96.6
0.15	95.3
0.10	92.8
0.05	***87.4***
0.01	69.8

C.8.3 Fecal Coliform Bacteria – Commercial Land Use

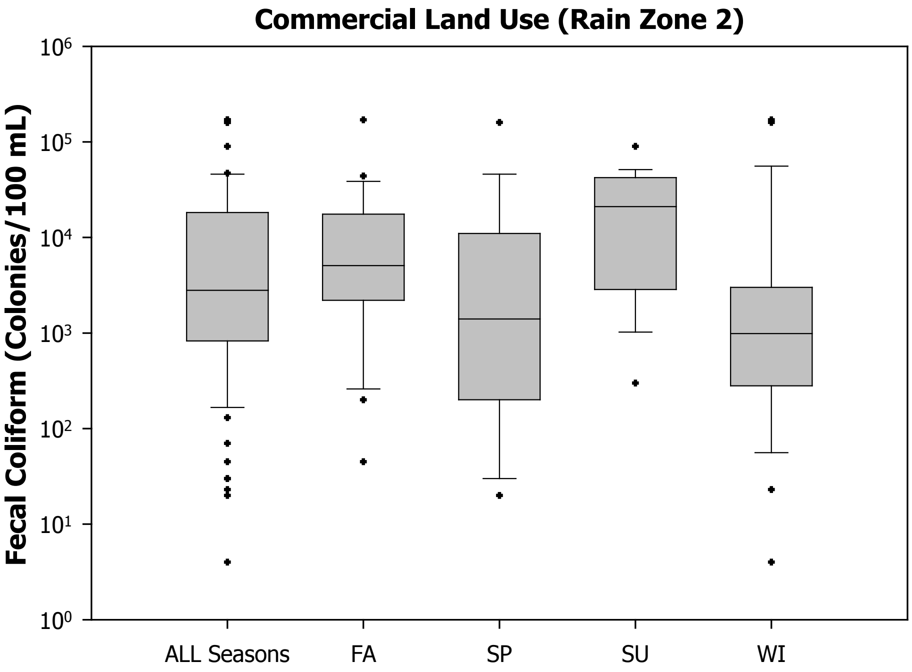
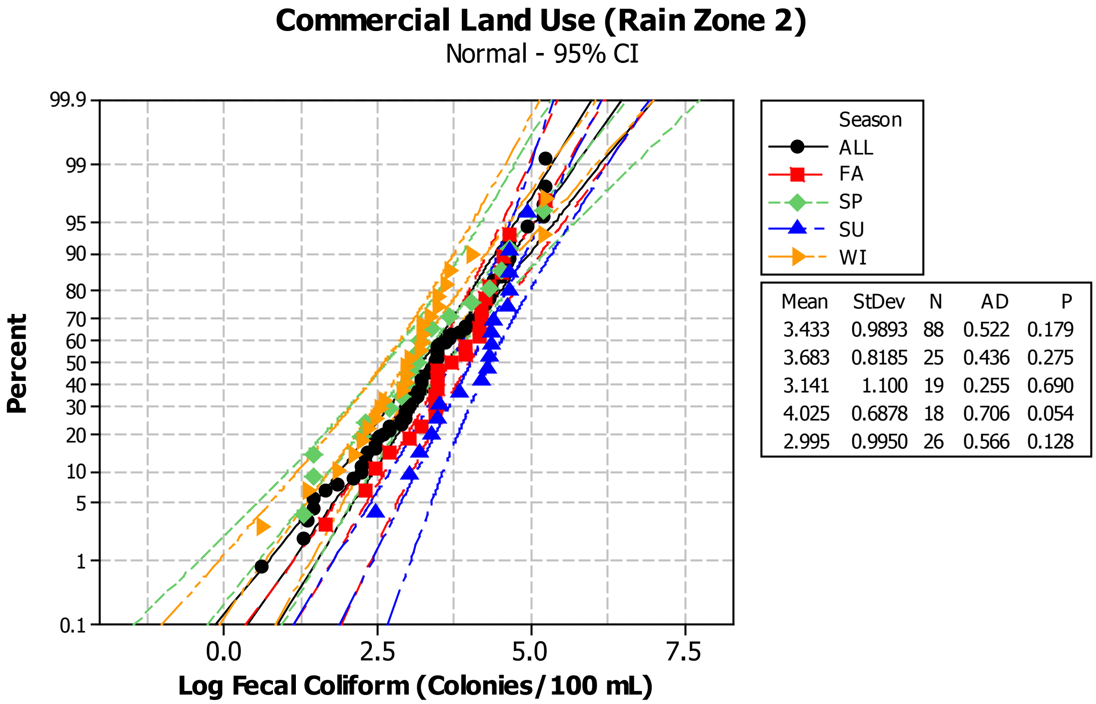


Fig. C149. Fecal Coliform Bacteria – Commercial Land Use by Season



Mean	StDev	N	AD	P
3.433	0.9893	88	0.522	0.179
3.683	0.8185	25	0.436	0.275
3.141	1.100	19	0.255	0.690
4.025	0.6878	18	0.706	0.054
2.995	0.9950	26	0.566	0.128

Fig. C150. Fecal Coliform Bacteria – Commercial Land Use (Checks for Normality)

Table C121. Statistical Analyses for Fecal Coliform Bacteria- Commercial Land Use

Kruskal-Wallis Test
(Commercial: Log Fecal Coliform)

H = 17.47 DF = 3 P = 0.001
H = 17.49 DF = 3 P = 0.001 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	25	3.7	51	2
SP	19	3.1	36	-2
SU	18	4.3	62	3
WI	26	3.0	32	-3
Overall	88		45	

Multiple Comparisons
(Mann-Whitney U Test)

(I) Season	(J) Season	p-value
FA	SP	0.058
	SU	0.089
	WI	0.004*
SP	SU	0.008*
	WI	0.739
SU	WI	0.000*

Commercial
Log Fecal Coliform
Groups (medians)

Season	Gr. 1	Gr. 2
FA	3.7	
SU	4.3	
SP		3.1
WI		3.0

Table C122. Power of the Test for Fecal Coliform Bacteria - Commercial Land Use

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	25	3.7	0.81
SP	19	3.1	1.1
SU	18	4.0	0.69
WI	26	3.0	0.99
Pooled Standard Deviation			0.92
Obtained Effect Size			0.44

α level	Power (%)
0.20	98.8
0.15	98.2
0.10	97.0
0.05	***94.0***
0.01	82.0

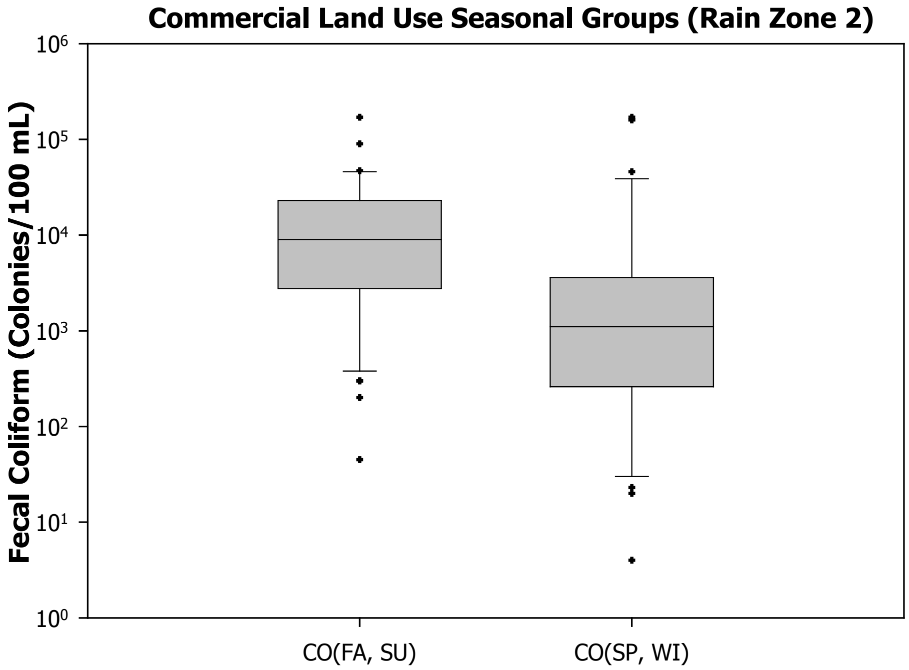


Fig. C151. Fecal Coliform Bacteria – Commercial Land Use Seasonal Groups

Table C123. Statistical Analyses for Fecal Coliform Bacteria – Commercial Land Use Seasonal Groups

Kruskal-Wallis Test
(Commercial: Log Fecal Coliform Groups)

H = 15.46 DF = 1 P = 0.000
H = 15.47 DF = 1 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
CO(FA, SU)	43	4.0	56	4
CO(SP, WI)	45	3.0	34	4
Overall	88		45	

Power of the Test (Commercial: Log Fecal Coliform Groups)

Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
CO(FA, SU)	43	3.8	0.78
CO(SP, WI)	45	3.1	1.0

Pooled Standard Deviation	0.92
Obtained Effect Size	0.38

α level	Power (%)
0.20	98.8
0.15	98.2
0.10	97.1
0.05	***94.2***
0.01	82.2

C.8.4 Fecal Coliform Bacteria – Industrial Land Use

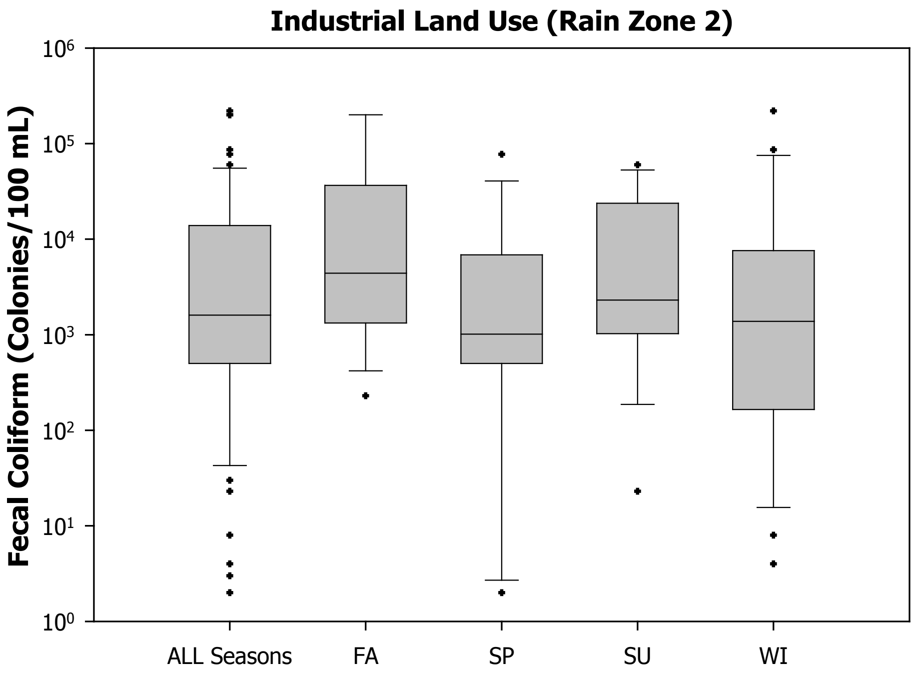


Fig. C152. Fecal Coliform Bacteria – Industrial Land Use by Season

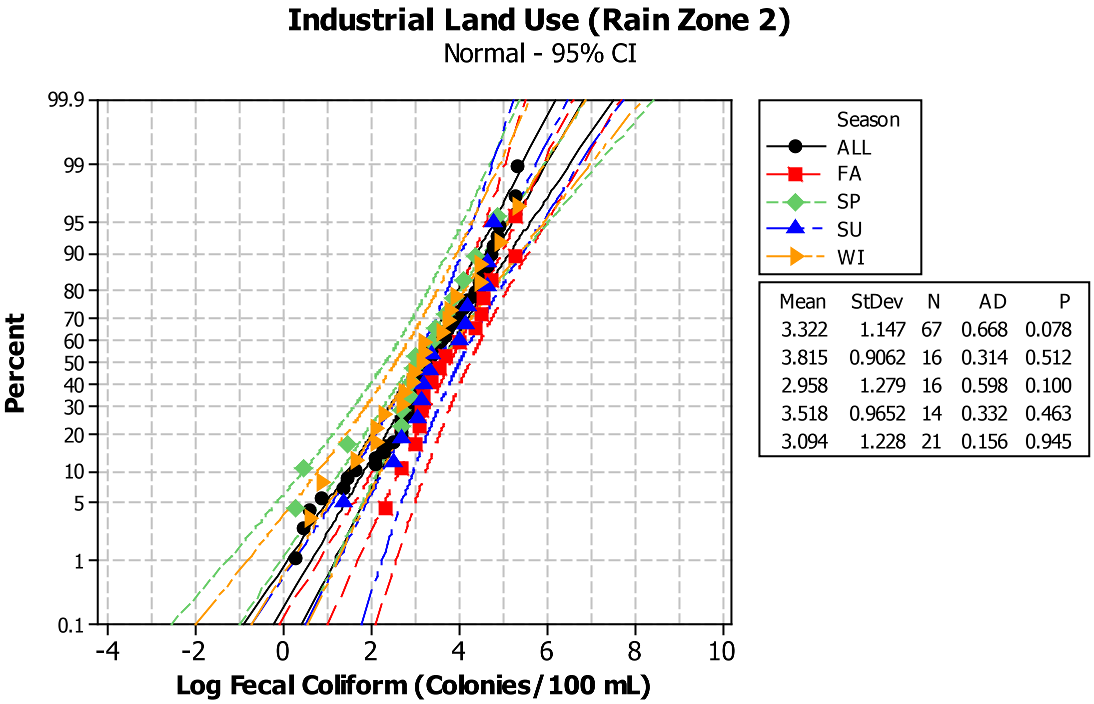


Fig. C153. Fecal Coliform Bacteria – Industrial Land Use (Checks for Normality)

Table C124. Statistical Analyses for Fecal Coliform Bacteria – Industrial Land Use

Kruskal-Wallis Test
(Industrial: Log Fecal Coliform)

H = 5.05 DF = 3 P = 0.168
H = 5.06 DF = 3 P = 0.168 (adjusted for ties)

Season	N	Median	Ave Rank	Z
FA	16	3.6	42	2
SP	16	3.0	29	-1
SU	14	3.4	37	1
WI	21	3.1	30	-1
Overall	67		34	

Power of the Test (Industrial: Log Fecal Coliform)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	16	3.8	0.91
SP	16	3.0	1.28
SU	14	3.5	0.97
WI	21	3.1	1.23

Pooled Standard Deviation 1.1
Obtained Effect Size 0.29

α level	Power (%)
0.20	73.7
0.15	67.8
0.10	59.5
0.05	***46.3***
0.01	23.1

C.8.5 Fecal Coliform Bacteria – Open Space Land Use

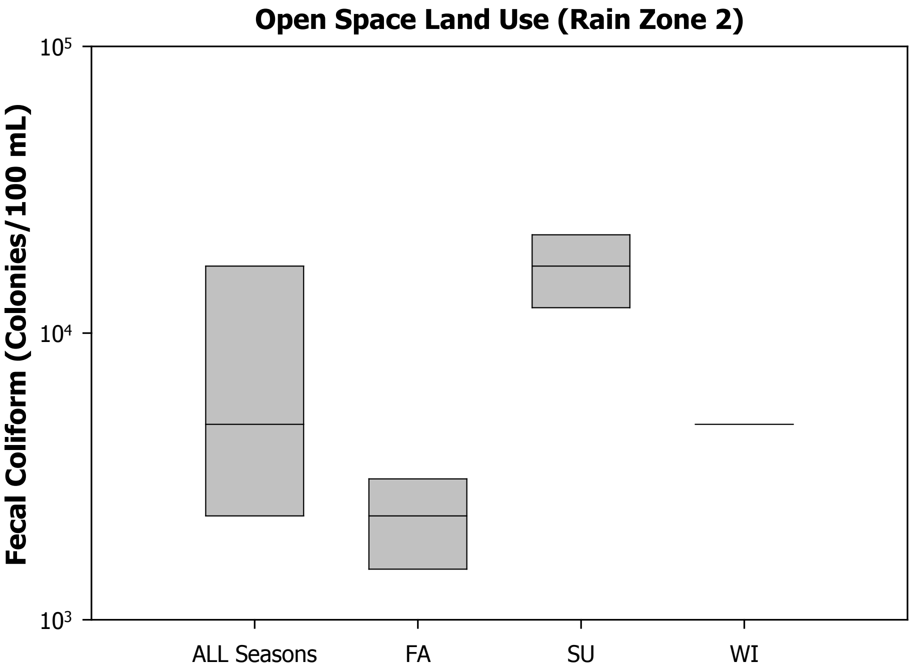


Fig. C154. Fecal Coliform Bacteria – Open Space Land Use by Season

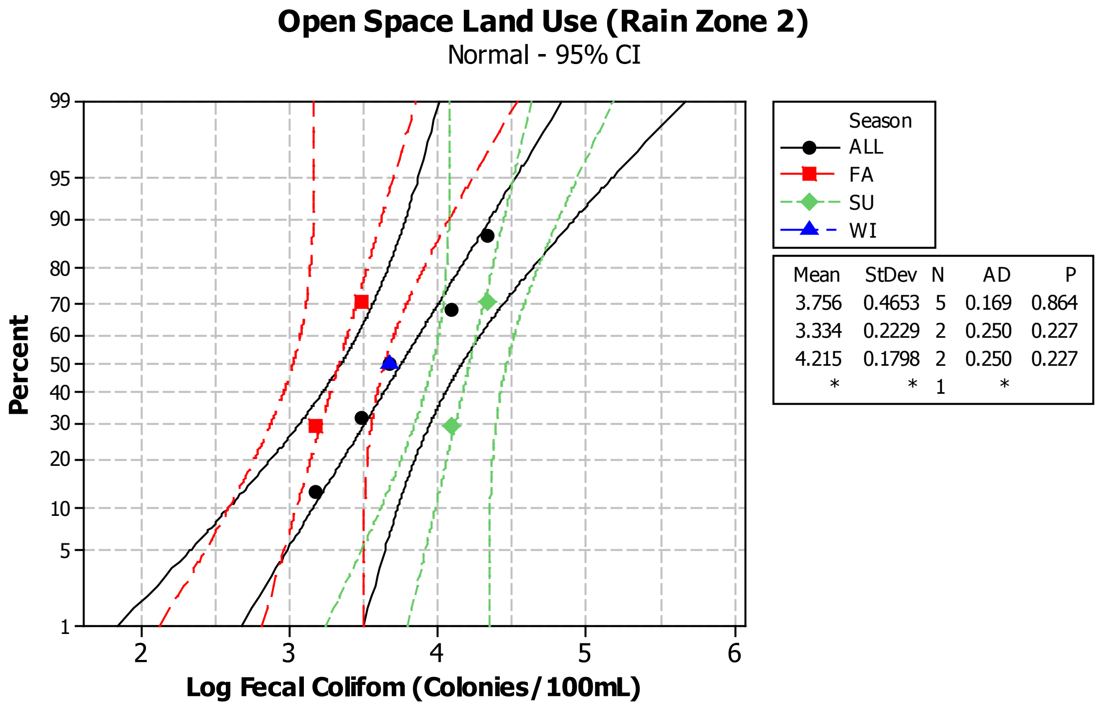


Fig. C155. Fecal Coliform Bacteria – Open Space Land Use (Checks for Normality)

Table C125. Statistical Analyses for Fecal Coliform Bacteria – Open Space Land Use

Kruskal-Wallis Test
(Open Space: Log Fecal Coliform)

H = 3.6 DF = 2 P = 0.165

Season	N	Median	Ave Rank	Z
FA	2	3.3	1.5	-2
SU	2	4.2	4.5	2
WI	1	3.7	3.0	0
Overall	5		3.0	

Power of the Test (Open Space: Log Fecal Coliform)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	2	3.3	0.22
SP	*	*	*
SU	2	4.2	0.18
WI	1	3.7	*
Pooled Standard Deviation			0.20
Obtained Effect Size			2.0

α level	Power (%)
0.20	89.5
0.15	81.5
0.10	67.4
0.05	***42.8***
0.01	10.6

C.8.6 Fecal Coliform Bacteria – Freeways Land Use

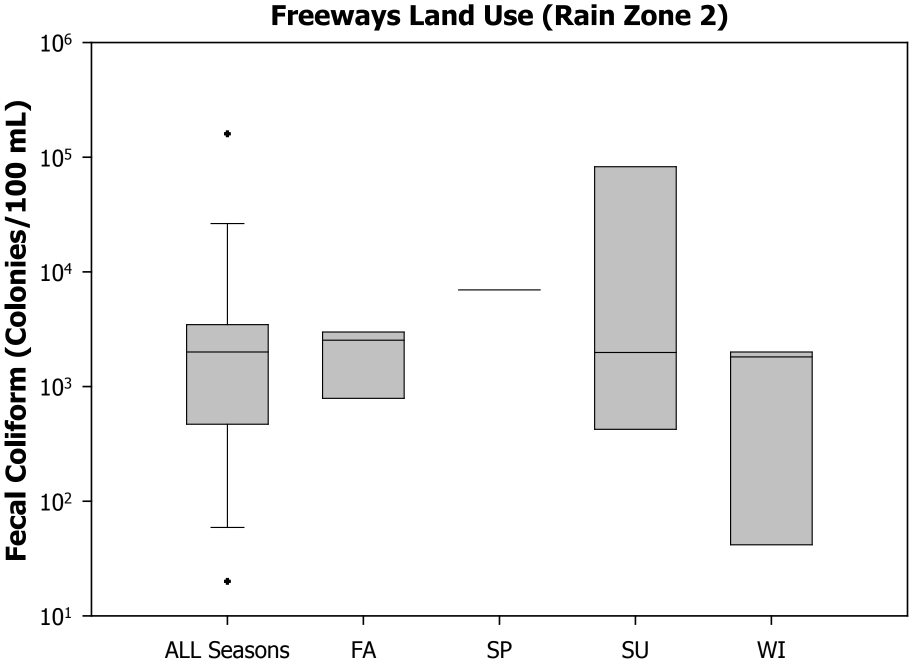


Fig. C156. Fecal Coliform Bacteria – Freeways Land Use by Season

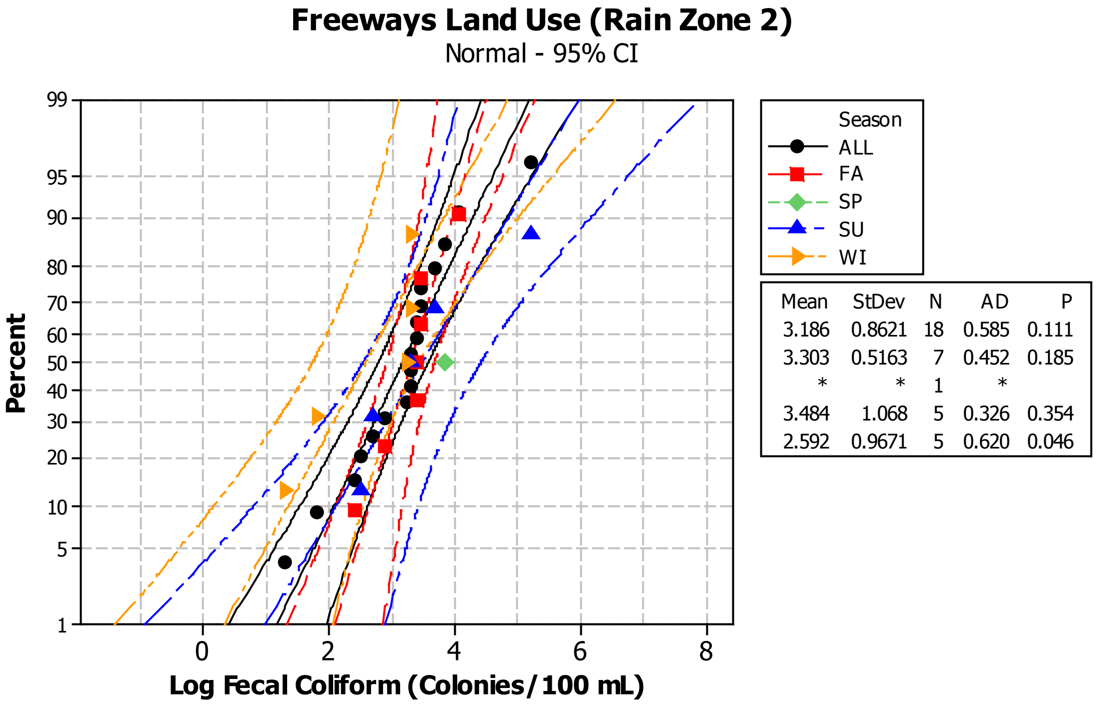


Fig. C157. Fecal Coliform Bacteria – Freeways Land Use (Checks for Normality)

Table C126. Statistical Analyses for Fecal Coliform Bacteria – Freeways Land Use

Kruskal-Wallis Test
(Freeways: Log Fecal Coliform)

H = 4.38 DF = 3 P = 0.223
H = 4.38 DF = 3 P = 0.223 (adjusted for ties)

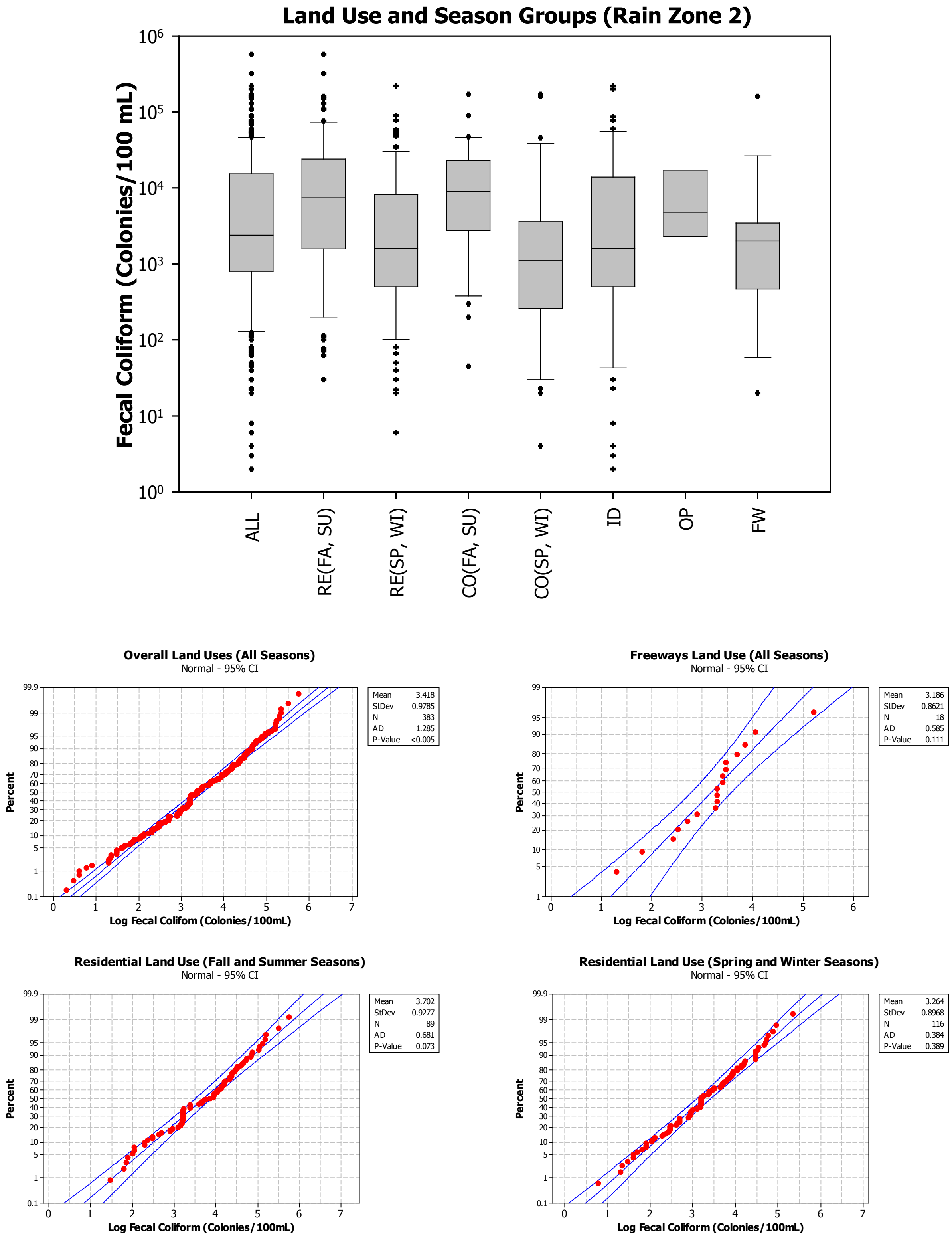
Season	N	Median	Ave Rank	Z
FA	7	3.4	11	1
SP	1	3.8	16	1
SU	5	3.3	10	0
WI	5	3.3	6	-2
Overall	18		10	

Power of the Test (Freeways: Log Fecal Coliform)

Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
FA	7	3.3	0.52
SP	1	3.8	*
SU	5	3.5	1.07
WI	5	2.6	0.97
Pooled Standard Deviation			0.84
Obtained Effect Size			0.46

α level	Power (%)
0.20	56.9
0.15	49.3
0.10	39.8
0.05	***26.6***
0.01	9.2

C.8.7 Fecal Coliform Bacteria Land Use and Season Groups


Land Use and Season Groups (Rain Zone 2)

Overall Land Uses (All Seasons)

Normal - 95% CI

Freeways Land Use (All Seasons)

Normal - 95% CI

Residential Land Use (Fall and Summer Seasons)

Normal - 95% CI

Residential Land Use (Spring and Winter Seasons)

Normal - 95% CI

Fig. C158. Fecal Coliform Bacteria – Land Use and Season Groups

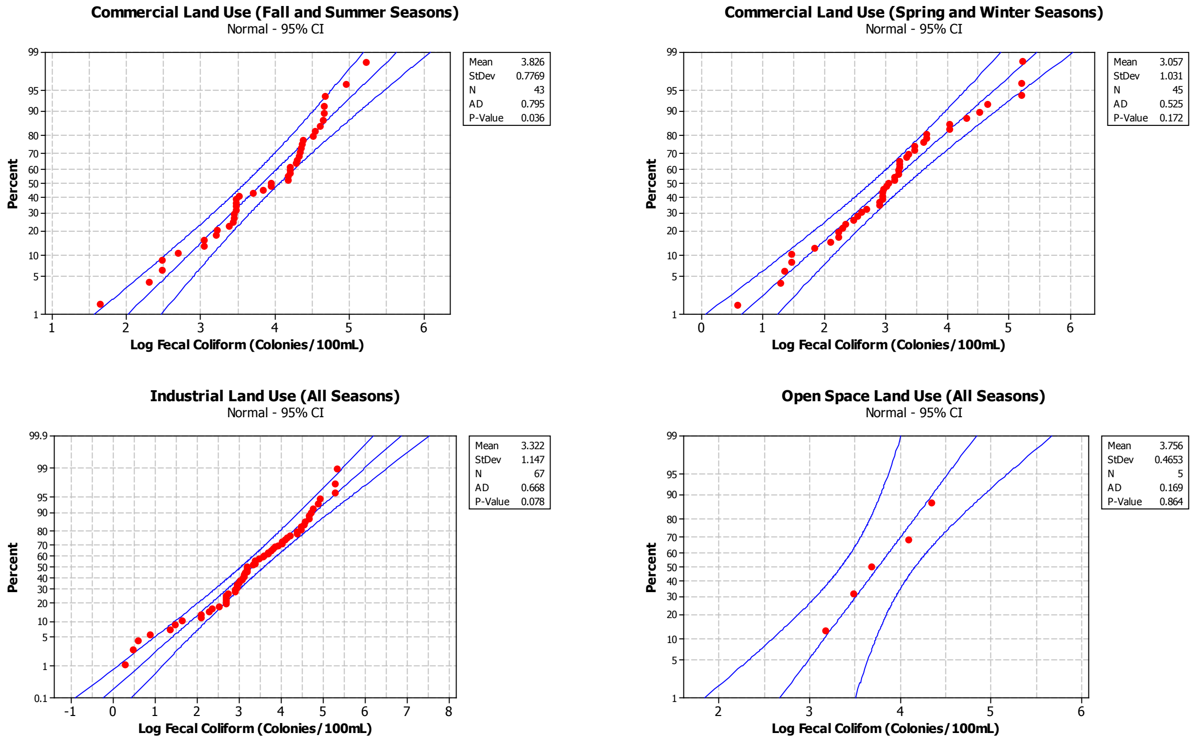


Fig. C158. - *Continued*

Table C127. Statistical Analyses for Fecal Coliform Bacteria – Land Use and Season Groups

Kruskal-Wallis Test
(Land Use and Season Groups: Log Fecal Coliform)

H = 29.13 DF = 6 P = 0.000
H = 29.14 DF = 6 P = 0.000 (adjusted for ties)

Groups	N	Median	Ave Rank	Z
RE(FA, SU)	89	3.9	222	3
RE(SP, WI)	116	3.2	172	-2
CO(FA, SU)	43	4.0	243	3
CO(SP, WI)	45	3.0	147	-3
ID	67	3.2	184	-1
OP	5	3.7	234	0.9
FW	18	3.3	165	-1
Overall	384		193	

Land Use and Season Groups
(medians)

Groups	Gr. A	Gr. B
RE(FA, SU)	3.9	
CO(FA, SU)	4.0	
OP	3.7	
RE(SP, WI)		3.2
CO(SP, WI)		3.0
ID		3.2
FW		3.3

Table C128. Land Use and Season Multiple Comparisons for Fecal Coliform Bacteria

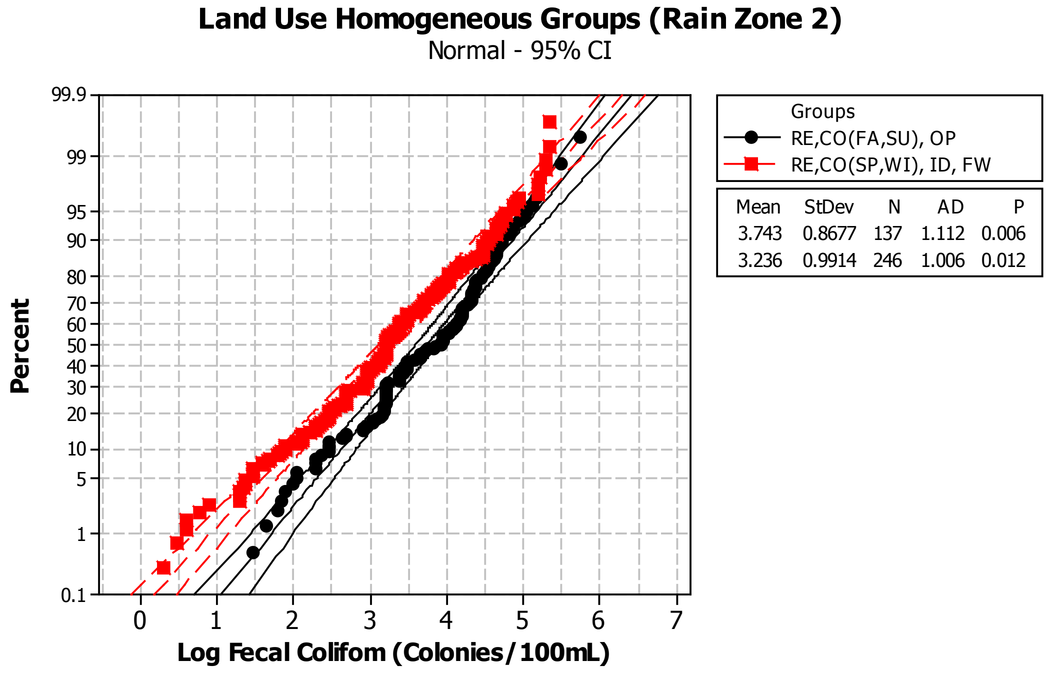
(I) Group	(J) Group	p-value
RE(FA, SU)	RE(SP, WI)	0.001*
	CO(FA, SU)	0.345
	CO(SP, WI)	0.000*
	ID	0.038*
	OP	0.959
	FW	0.050*
RE(SP, WI)	CO(FA, SU)	0.000*
	CO(SP, WI)	0.150
	ID	0.554
	OP	0.195
	FW	0.839

(I) Group	(J) Group	p-value
CO(FA, SU)	CO(SP, WI)	0.001*
	ID	0.013*
	OP	0.673
	FW	0.003*
CO(SP, WI)	ID	0.117
	OP	0.045*
	FW	0.378
ID	OP	0.347
	FW	0.609
OP	FW	0.094

Table C129. Power of the Test for Fecal Coliform Bacteria – Land Use and Season Groups

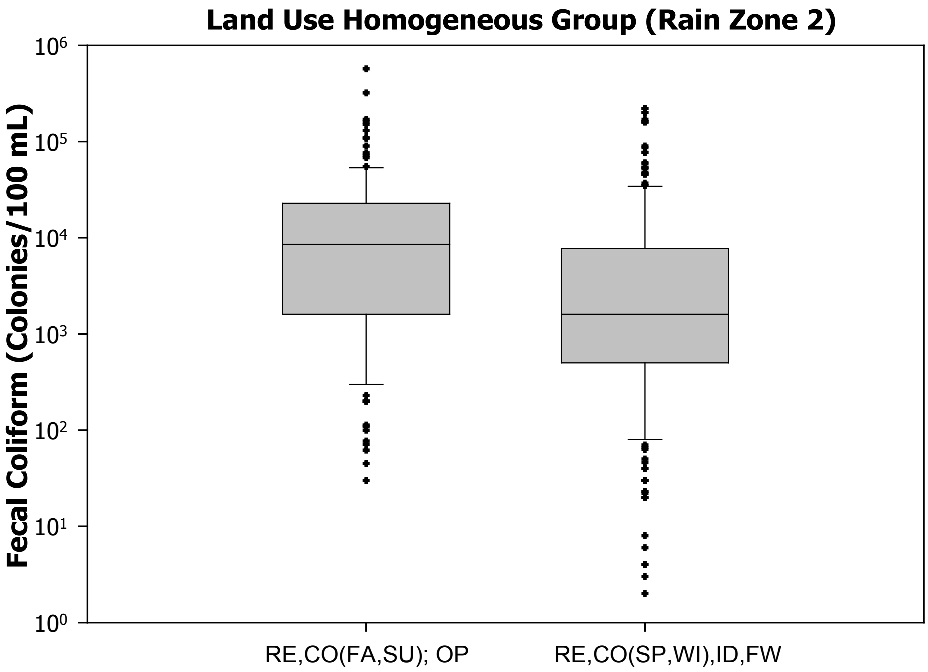
Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(FA, SU)	89	3.7	0.93
RE(SP, WI)	116	3.3	0.90
CO(FA, SU)	43	3.8	0.78
CO(SP, WI)	45	3.1	1.0
ID	67	3.3	1.1
OP	5	3.6	0.47
FW	18	3.2	0.86
Pooled Standard Deviation			0.95
Obtained Effect size			0.28

α level	Power (%)
0.20	99.9
0.15	99.8
0.10	99.7
0.05	***99.3***
0.01	96.7



Mean	StDev	N	AD	P
3.743	0.8677	137	1.112	0.006
3.236	0.9914	246	1.006	0.012

Fig. C159. Fecal Coliform Bacteria – Land Use Homogeneous Groups (Checks for Normality)



Land Uses	FALL	SPRING	SUMMER	WINTER
Residential	17130 (1.9)	11987 (2.7)	53659 (2.2)	7971 (1.7)
Commercial	17131 (2.0)	15113 (2.5)	23132 (1.0)	14267 (3.1)
Industrial	36132 (1.8)	8622 (2.3)	14492 (1.4)	19023 (2.6)
Institutional	ND	ND	ND	ND
Open Space	2300 (0.49)	ND	17125 (0.40)	ND
Freeways	3359 (1.1)	ND	33544 (2.1)	1179 (0.88)

Fig. C160. Fecal Coliform Bacteria – Land Use Homogeneous Groups: Mean (CV)

Table C130. Statistical Analyses for Fecal Coliform Bacteria – Land Use Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: Log Fecal Coliform)

H = 25.06 DF = 2 P = 0.000
H = 25.08 DF = 2 P = 0.000 (adjusted for ties)

Groups		N	Median	Ave Rank	Z
1	RE,CO(FA,SU) OP	137	3.9	230	5
2	RE,CO(SP,WI) ID, FW	246	3.2	171	-5
	Overall	383		192	

Log Fecal Coliform
Homogeneous Groups
(medians)

Group	Gr.A	Gr.B
1	3.9	
2		3.2

Table C131. Power of the Test for Fecal Coliform Bacteria – Land Use Homogeneous Groups

Homogeneous Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE,CO(FA,SU), OP	137	3.7	0.87
RE,CO(SP,WI), ID,FW	246	3.2	0.99

Pooled Standard Deviation	0.95
Obtained Effect Size	0.25

α level	**Power (%)**
0.20	99.9
0.15	99.9
0.10	99.9
0.05	***99.8***
0.01	99.0

Table C132. Basic Statistics for Fecal Coliform Bacteria
Homogeneous Groups (Real Space Data)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	RE,CO(FA,SU), OP	137	25344	61865	2.4	30	8550	570000
B	RE,CO(SP,WI), ID,FW	246	13635	35457	2.6	2	1600	220000

Appendix D
Alabama Jefferson County Watersheds – Detailed Analyses of Selected Pollutants

Table D1. ALJC001 Watershed – Stormwater Pollutant Concentrations Used for Analyses

Season	Rain Depth (in)	Runoff Vol (cu.ft)	TSS (mg/L)	Total Zinc (ug/L)	Total Copper (ug/L)	Total Lead (ug/L)	Total Phosphorous (mg/L)	Dissolved Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Fecal Coliform (Col/100mL)
W	0.17	33,539	36	170	50	22	0.49	0.44	2.3	1.3	360
W	0.30	64,091	23	50	10	13	0.22	0.17	1.0	0.70	325
W	0.40	88,709	57	80	10	19	0.19	0.19	2.3	1.4	800
W	0.40	88,709	102	120	30	25	0.45	0.20	2.2	1.5	ND
W	0.40	88,709	57	120	10	14	0.68	0.57	7.2	6.5	250
W	0.50	113,001	65	ND	ND	32	0.21	0.19	1.6	0.77	1280
W	0.60	138,047	268	270	60	58	0.35	0.11	3.6	2.7	1000
W	1.30	320,124	58	110	10	33	0.31	0.21	1.3	0.89	30
W	1.30	320,124	88	90	30	17	0.09	0.06	1.1	0.65	ND
W	1.35	333,860	74	60	10	23	0.49	0.46	1.1	0.79	ND
D	0.20	41,048	60	230	50	31	0.21	0.13	0.68	0.25	275
D	0.30	64,091	130	210	40	19	0.59	0.51	3.4	2.2	2000
D	0.32	68,901	173	300	20	42	0.80	0.45	8.0	6.8	ND
D	0.38	64,091	74	130	10	14	0.37	0.34	1.6	0.90	ND
D	0.40	88,709	28	60	30	9	0.40	0.16	0.82	0.57	200
D	0.45	100,749	124	250	40	41	1.5	1.3	2.4	1.9	ND
D	0.50	113,001	57	170	30	31	0.39	0.13	1.8	1.3	ND
D	0.75	177,064	83	180	30	22	0.41	0.29	1.7	1.2	9095
D	1.60	402,542	158	250	10	60	0.27	0.08	0.60	0.42	260
D	1.90	488,565	54	100	20	12	0.43	0.30	2.6	1.9	ND

Source: Storm Water Management Inc. NPDES Monitoring Data

Table D2. ALJC002 Watershed – Stormwater Pollutant Concentrations Used for Analyses

Season	Rain Depth (in)	Runoff Vol (cu.ft)	TSS (mg/L)	Total Zinc (ug/L)	Total Copper (ug/L)	Total Lead (ug/L)	Total Phosphorous (mg/L)	Dissolved Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Fecal Coliform (Col/100mL)
W	0.20	22,678	42	460	20	33	0.19	0.14	2.9	2.2	2900
W	0.21	23,965	17	310	50	18	0.32	0.09	2.0	1.7	30
W	0.22	25,266	31	ND	40	34	0.15	0.09	3.8	3.1	760
W	0.35	43,513	43	550	50	17	0.21	0.11	1.5	1.4	3740
W	0.50	65,982	85	430	50	18	0.2	0.14	2.0	1.5	30
W	0.62	84,608	390	240	70	26	0.27	0.2	2.2	1.4	ND
W	0.65	89,169	96	330	60	18	0.33	0.18	1.0	0.56	6300
W	1.10	161,772	79	560	120	45	0.21	0.07	2.8	2.2	ND
D	0.15	15,077	55	270	110	20	0.18	0.08	2.9	2.2	ND
D	0.23	26,583	22	700	80	31	0.10	0.11	3.2	2.5	ND
D	0.28	33,382	42	160	20	13	0.25	0.10	1.6	0.91	208
D	0.30	36,203	53	290	10	12	0.84	0.14	3.2	1.9	550
D	0.32	39,083	18	120	40	5	0.41	0.27	2.1	1.7	10
D	0.39	49,622	108	630	110	38	0.36	0.23	3.2	2.8	ND
D	0.40	51,108	26	320	40	13	0.14	0.13	2.1	1.4	1440
D	0.80	112,543	76	270	80	19	0.30	0.25	2.5	1.7	40

Table D3. ALJC009 Watershed – Stormwater Pollutant Concentrations Used for Analyses

Season	Rain Depth (in)	Runoff Vol (cu.ft)	TSS (mg/L)	Total Lead (ug/L)	Total Phosphorous (mg/L)	Dissolved Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Fecal Coliform (Col/100mL)
W	0.12	7,827	23	6.0	0.14	0.14	1.8	0.87	2000
W	0.20	17,277	23	8.0	0.25	0.17	2.7	1.7	ND
W	0.36	35,374	34	1.5	0.24	0.16	0.24	0.77	50
W	0.42	42,825	22	1.5	0.21	0.06	1.8	1.2	27
W	0.65	72,379	25	12	0.34	0.27	3.1	2.7	2900
W	1.60	213,528	28	5.0	0.14	0.08	1.2	0.91	ND
W	2.10	303,048	6.0	6.0	ND	ND	1.4	0.95	3750
D	0.15	11,009	17	1.5	0.52	0.25	0.52	0.98	4650
D	0.19	16,015	17	1.5	0.34	0.29	1.8	1.3	760
D	0.20	17,277	15	5.0	0.29	0.11	3.2	2.4	ND
D	0.23	20,381	44	7.0	0.21	0.15	2.2	1.6	16800
D	0.23	20,381	8.0	13	0.34	0.18	0.34	1.7	1000
D	0.30	28,142	18	18	0.17	0.17	1.0	1.0	880
D	0.30	28,142	18	3.0	0.14	0.07	1.3	0.63	ND
D	0.30	28,142	16	3.0	0.45	0.32	1.5	1.3	1080
D	0.35	34,131	4.0	1.5	0.13	0.08	1.6	1.1	ND
D	0.50	52,810	18	4.0	0.29	0.25	1.1	0.98	390
D	0.50	52,810	26	6.0	0.22	0.21	3.0	1.2	ND
D	0.60	66,008	42	1.5	0.18	0.07	1.7	0.97	190
D	0.95	111,497	61	11	0.48	0.32	3.3	2.6	400

Table D4. ALJC010 Watershed – Stormwater Pollutant Concentrations Used for Analyses

Season	Rain Depth (in)	Runoff Vol (cu.ft)	TSS (mg/L)	Total Phosphorous (mg/L)	Dissolved Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Fecal Coliform (Col/100mL)
W	0.15	8,613	20	0.05	0.05	1.4	0.25	1150
W	0.30	22,841	11	0.17	0.11	0.99	0.88	100
W	0.42	35,204	85	0.15	0.07	1.7	1.0	21400
W	0.45	38,302	89	0.88	0.11	4.2	2.9	ND
W	1.00	101,601	145	0.17	0.04	1.9	1.3	ND
W	1.55	174,519	123	0.19	0.10	1.6	0.69	600
D	0.10	4,689	54	ND	0.15	2.4	1.1	150
D	0.22	15,521	15	0.18	0.16	0.75	0.25	1000
D	0.28	20,927	46	0.18	0.07	1.4	0.90	1200
D	0.31	23,819	65	0.34	0.15	2.7	2.0	ND
D	0.34	26,836	22	0.15	0.14	1.2	0.84	900
D	0.50	43,638	20	0.28	0.17	1.6	0.82	ND
D	0.50	43,638	26	0.1	0.05	1.6	0.53	45
D	0.85	83,030	35	0.43	0.14	1.1	0.81	100

Table D5. ALJC012 Watershed – Stormwater Pollutant Concentrations Used for Analyses

Season	Rain Depth (in)	Runoff Vol (cu.ft)	TSS (mg/L)	Total Zinc (ug/L)	Total Lead (ug/L)	Total Phosphorous (mg/L)	Dissolved Phosphorous (mg/L)	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Fecal Coliform (Col/100mL)
W	0.15	27,361	30	70	1.5	0.37	0.2	1.44	0.96	8000
W	0.15	27,361	7	70	1.5	0.21	0.18	1.84	1.2	200
W	0.40	84,430	18	70	4	0.08	0.06	0.96	0.64	60
W	0.50	107,523	50	120	3	0.21	0.18	1.34	0.95	800
W	1.2	278,380	100	80	6	0.22	0.13	1.38	1.38	ND
W	1.8	433,626	82	80	3	0.13	0.07	0.35	0.25	400
D	0.30	61,081	23	100	6	0.19	0.16	1.28	0.82	320
D	0.32	65,646	45	50	7	0.12	0.06	0.46	0.32	200
D	0.55	119,367	27	15	1.5	0.19	0.15	0.35	0.25	5250
D	1.25	290,828	59	160	5	0.25	0.22	2.1	1.4	ND

D.1. Total Zinc

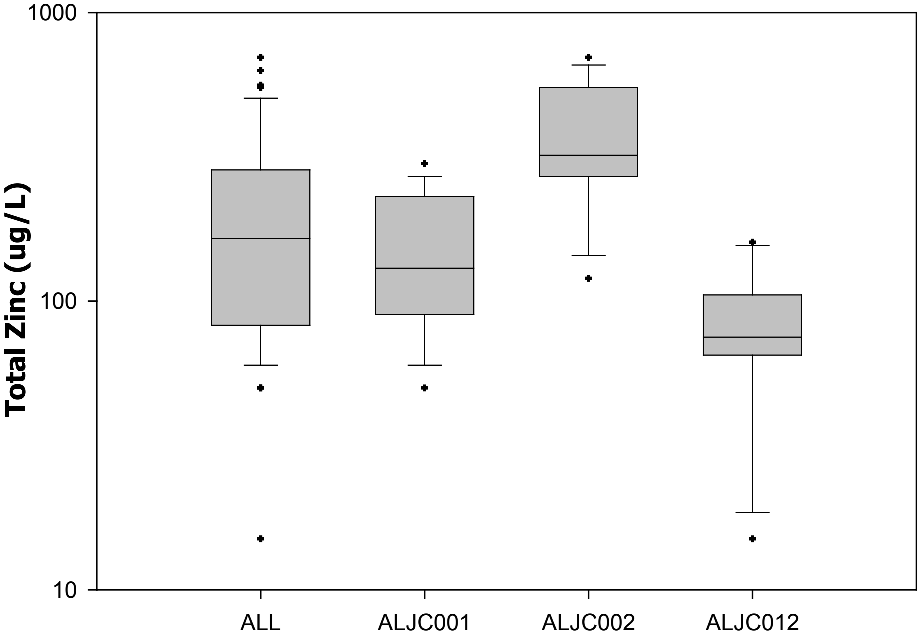
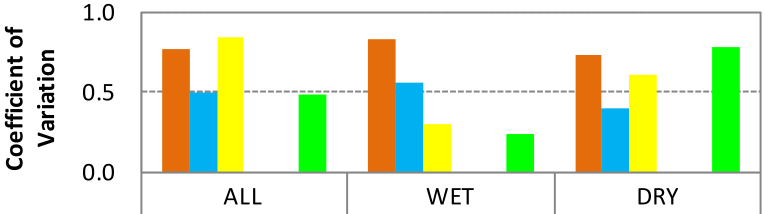


Fig. D1. Total Zinc - Jefferson County Watersheds



	ALL	WET	DRY
🟧 ALL Watersheds	0.77	0.83	0.74
🟦 ALJC001 [Mixed Industrial]	0.50	0.56	0.40
🟨 ALJC002 [Mixed Industrial]	0.85	0.30	0.61
🟥 ALJC009 [Mixed Residential]	0.00	0.00	0.00
🟪 ALJC010 [Mixed Residential]	0.00	0.00	0.00
🟩 ALJC012 [Mixed Commercial]	0.48	0.24	0.78

Fig. D2. Total Zinc - Jefferson County Watersheds
Seasonal Coefficients of Variation

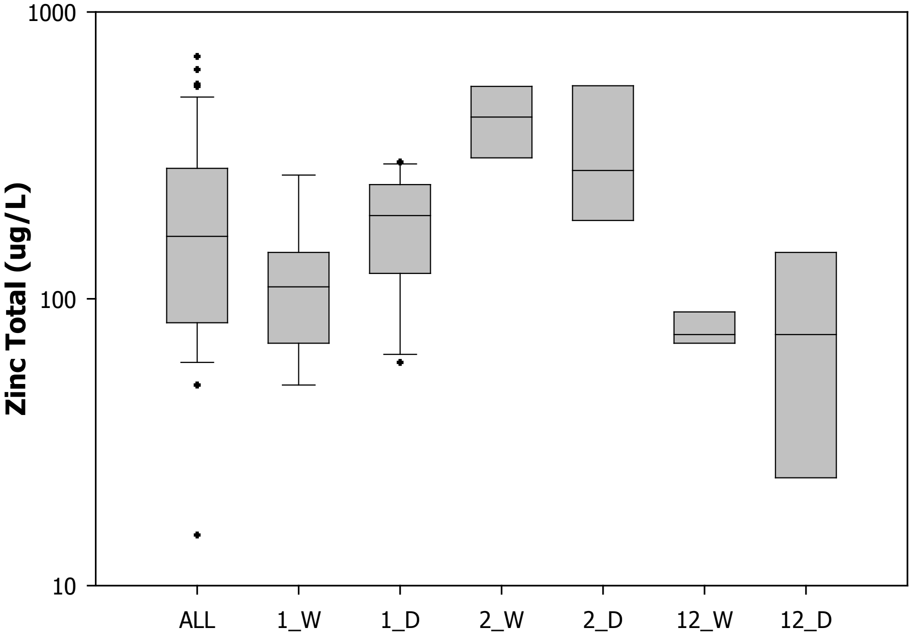


Fig. D3. Total Zinc – Seasons for Jefferson County Watersheds

One-Way ANOVA

ALJC001 Log Zn	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.212	1	0.212	4.429	0.051
Within Seasons	0.815	17	0.048		
Total	1.027	18			

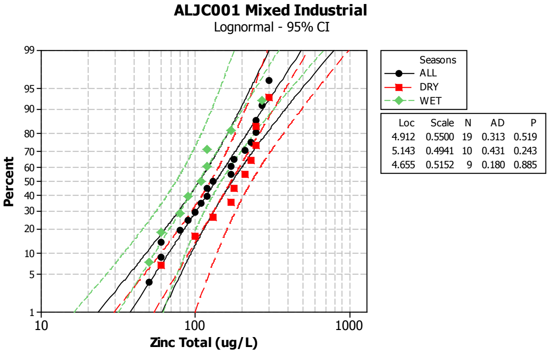
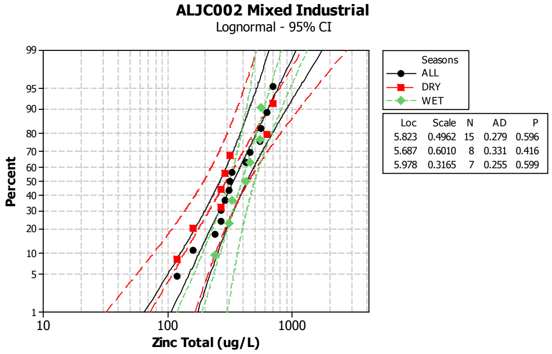


Fig. D4. Total Zinc – Jefferson County Watersheds
Checks for Normality and Seasonal Differences

One-Way ANOVA

ALJC002 Log Zn	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.157	1	0.157	0.338	0.570
Within Seasons	6.489	14	0.463		
Total	6.646	15			



One-Way ANOVA

ALJC012 Log Zn	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.043	1	0.043	0.536	0.485
Within Seasons	0.640	8	0.080		
Total	0.683	9			

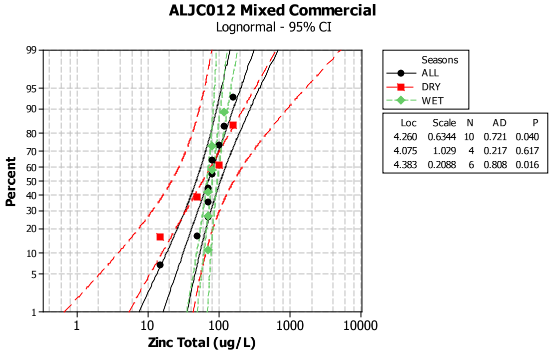


Fig. D4. - *Continued*

Table D6. Power of the Test for Total Zinc – Jefferson County Watersheds Separated by Seasons

ALJC001 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	10	2.23	0.21
WET	9	2.02	0.22

Pooled Standard Deviation 0.22

Obtained Effect Size 0.48

α level	Power (%)
0.20	77.2
0.15	71.7
0.10	63.6
0.05	***50.0***
0.01	24.3

ALJC002 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	8	2.47	0.26
WET	7	2.60	0.14

Pooled Standard Deviation 0.20

Obtained Effect Size 0.32

α level	Power (%)
0.20	48.0
0.15	41.2
0.10	32.7
0.05	***21.4***
0.01	7.1

ALJC012 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	4	1.77	0.45
WET	6	1.90	0.09

Pooled Standard Deviation 0.27

Obtained Effect Size 0.24

α level	Power (%)
0.20	30.6
0.15	24.5
0.10	17.8
0.05	***10.1***
0.01	2.5

Table D7. Summary Statistics for Total Zinc –
Jefferson County Watersheds Separated by Seasons

Watershed	Seasons	N	Mean	p-value	Power (%)	Significant (?)	Results
ALJC001	DRY WET	10 9	2.23 2.02	0.051	50.0	No	No seasonal influence
ALJC002	DRY WET	8 7	2.47 2.60	0.570	21.4	No	No seasonal influence
ALJC012	DRY WET	4 6	0.45 0.09	0.485	10.1	No	No seasonal influence

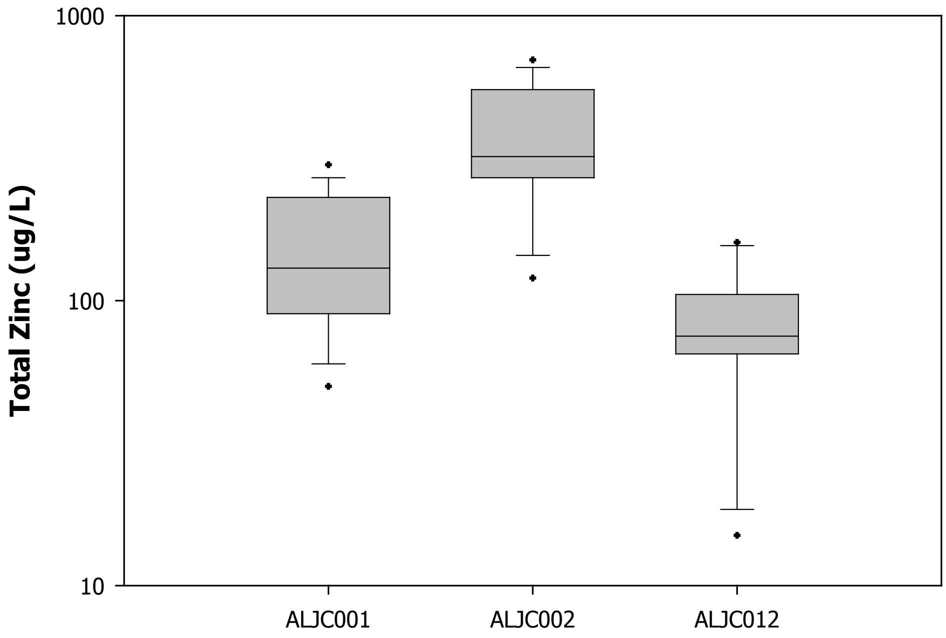


Fig. D5. Total Zinc – Jefferson County Watershed Homogeneous Groups

Table D8. Statistical Analyses for Total Zinc –
Jefferson County Watershed Homogeneous Groups

ANOVA (Watersheds: Log Total Zinc)

P = 0.00

Log Zn	Sum of Squares	DF	Mean Square	F
Between Watersheds	2.93	2	1.466	26
Within Watersheds	2.36	41	0.058	
Total	5.29	43		

Multiple Comparisons
(Scheffe Test,
Equal Variances Assumed)

(I) ALJC	(J) ALJC	p-value
1	2	0.000*
	12	0.016*
2	12	0.000*

Watershed
Log Total Zinc
Homogeneous Groups

Groups	Gr. A	Gr. B	Gr. C
AL01	2.133		
AL02		2.529	
AL12			1.850

Table D9. Power of the Test for Total Zinc – Jefferson County Watershed Homogeneous Groups

Watersheds	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
ALJC001	19	2.13	0.24	0.20	100
ALJC002	15	2.53	0.22	0.15	100
ALJC012	10	1.85	0.28	0.10	100
Pooled Standard Deviation			0.24	***0.05***	***100***
Obtained Effect Size			1.1	0.01	100

Table D10. Basic Statistics for Jefferson County Watersheds - Total Zinc Homogeneous Groups (Real Space Data) (µg/L)

Groups		**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
A	ALJC001	19	155	78	0.50	50	130	300
B	ALJC002	15	376	172	0.46	120	320	700
C	ALJC012	10	82	39	0.48	15	75	160

D.2. Total Copper

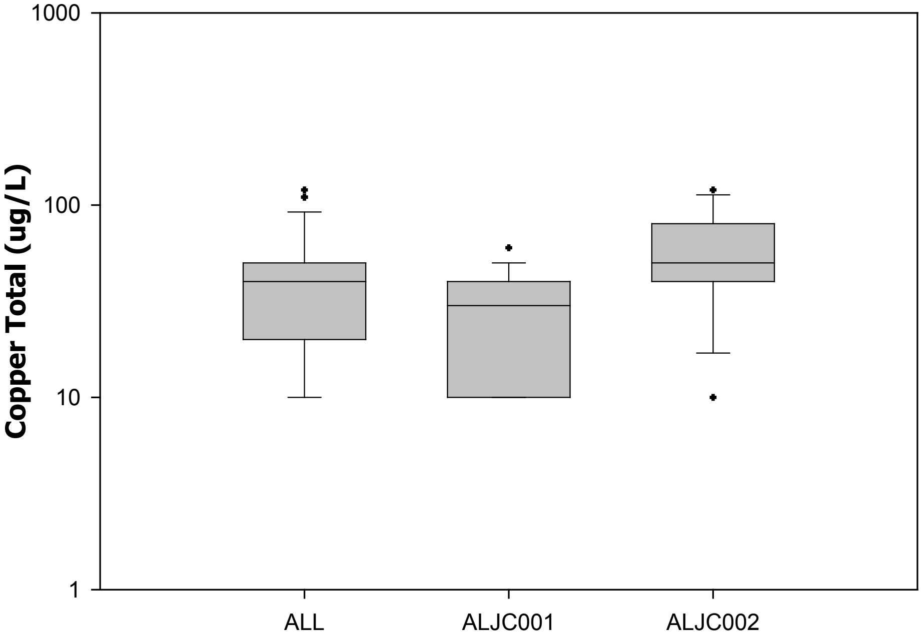
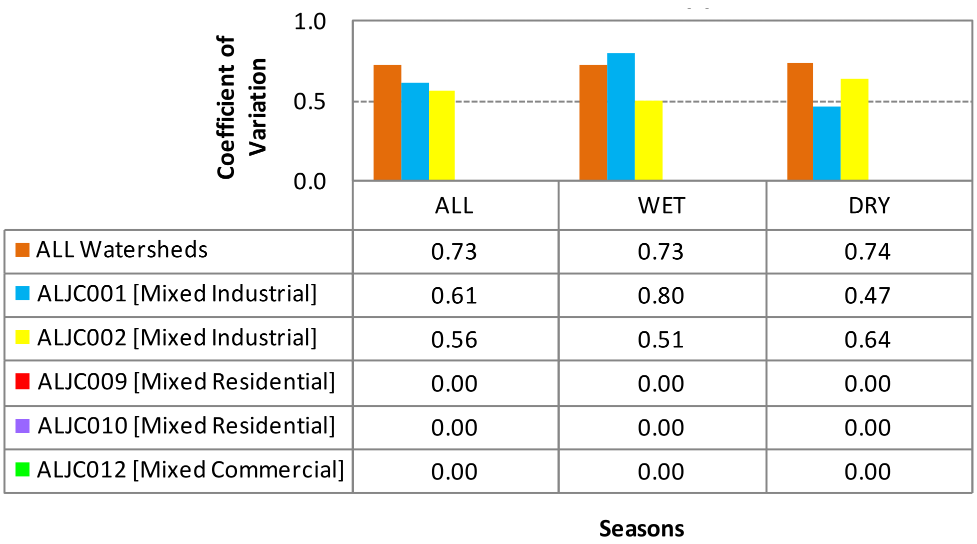


Fig. D6. Total Copper - Jefferson County Watersheds



	ALL	WET	DRY
🟧 ALL Watersheds	0.73	0.73	0.74
🟦 ALJC001 [Mixed Industrial]	0.61	0.80	0.47
🟨 ALJC002 [Mixed Industrial]	0.56	0.51	0.64
🟥 ALJC009 [Mixed Residential]	0.00	0.00	0.00
🟪 ALJC010 [Mixed Residential]	0.00	0.00	0.00
🟩 ALJC012 [Mixed Commercial]	0.00	0.00	0.00

Fig. D7. Total Copper - Jefferson County Watersheds
Seasonal Coefficients of Variation

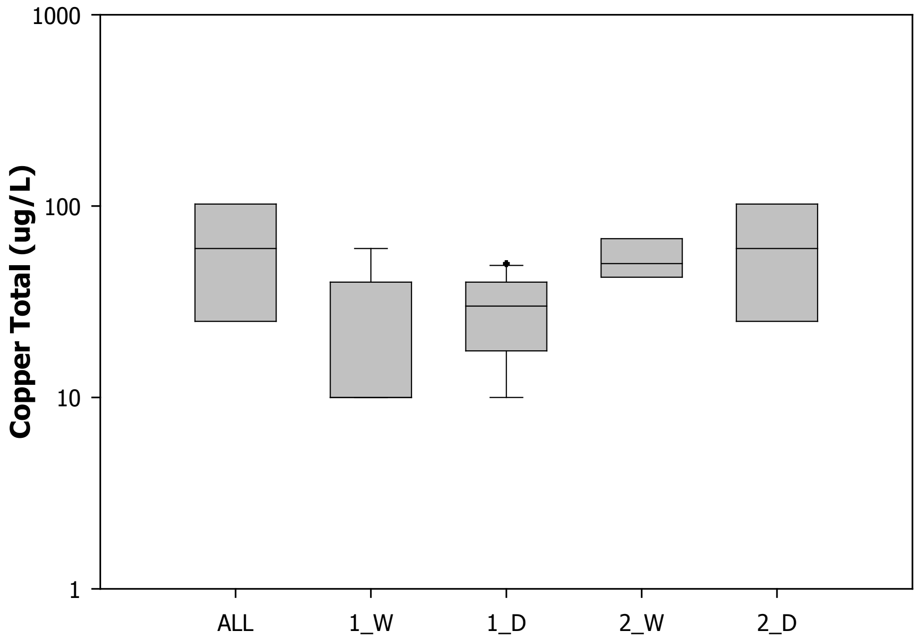
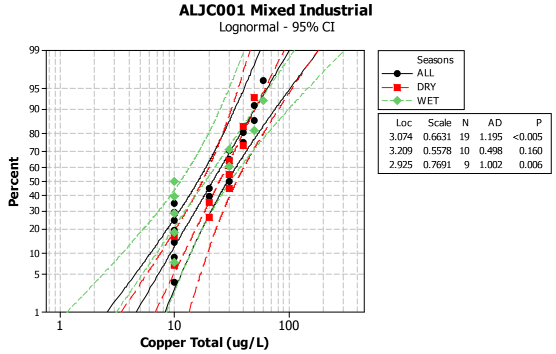


Fig. D8. Total Copper – Seasons for Jefferson County Watersheds

One-Way ANOVA

ALJC001 Log Cu	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.072	1	0.072	0.865	0.365
Within Seasons	1.421	17	0.084		
Total	1.493	18			



One-Way ANOVA

ALJC002 Log Cu	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.006	1	0.006	0.063	0.805
Within Seasons	1.317	14	0.094		
Total	1.323	15			

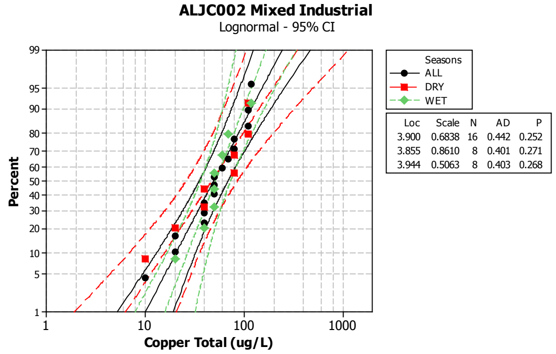


Fig. D9. Total Copper – Jefferson County Watersheds
Checks for Normality and Seasonal Differences

Table D11. Power of the Test for Total Copper –
Jefferson County Watersheds Separated by Seasons

ALJC001 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	10	1.39	0.24
WET	9	1.27	0.33
Pooled Standard Deviation			0.29
Obtained Effect Size			0.21

α level	Power (%)
0.20	35.9
0.15	29.6
0.10	22.4
0.05	***13.6***
0.01	3.96

ALJC002 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	8	1.67	0.37
WET	8	1.71	0.22
Pooled Standard Deviation			0.30
Obtained Effect Size			0.07

α level	Power (%)
0.20	21.5
0.15	16.3
0.10	11.1
0.05	***5.71***
0.01	1.21

Table D12. Summary Statistics for Total Copper –
Jefferson County Watersheds Separated by Seasons

Watershed	Seasons	N	Mean	p-value	Power (%)	Significant (?)	Results
ALJC001	DRY WET	10 9	1.39 1.27	0.365	13.6	No	No seasonal influence
ALJC002	DRY WET	8 8	1.67 1.71	0.805	5.71	No	No seasonal influence

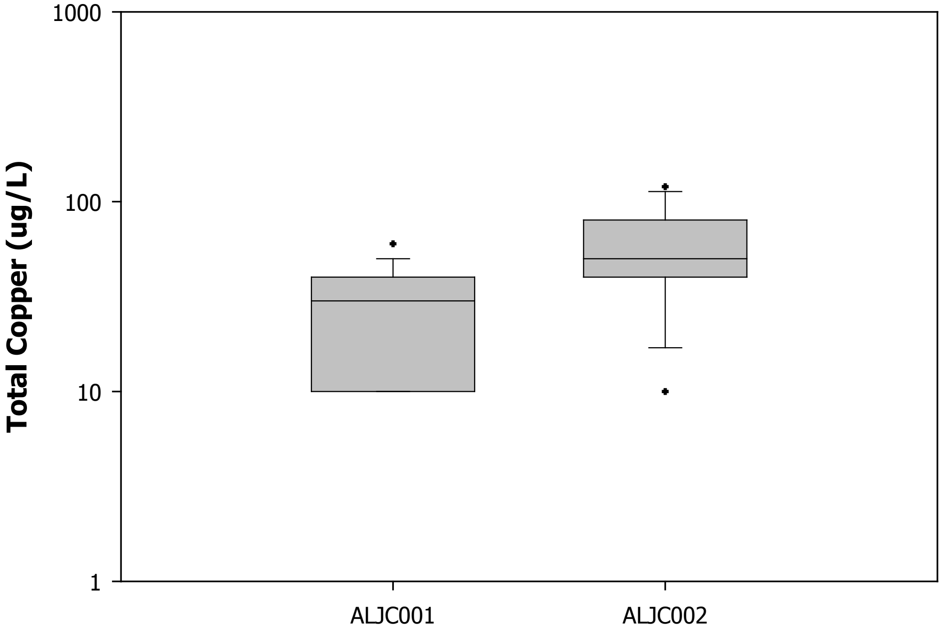


Fig. D10. Total Copper – Jefferson County Watershed Homogeneous Groups

Table D13. Statistical Analyses for Total Copper –
Jefferson County Watershed Homogeneous Groups

ANOVA (Watersheds: Log Total Copper)

P = 0.001

Log Cu	**Sum of Squares**	**DF**	**Mean Square**	**F**
Between Watersheds	1.12	1	1.12	13
Within Watersheds	2.82	33	0.085	
Total	3.93	34		

Watershed
Log Total Copper
Homogeneous Groups

Groups	**Gr. A**	**Gr. B**
AL01	1.335	
AL02		1.694

Table D14. Power of the Test for Total Copper –
Jefferson County Watershed Homogeneous Groups

Watersheds	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	19	1.34	0.29
ALJC002	16	1.69	0.30

Pooled Standard Deviation	0.29
Obtained Effect Size	0.60

α level	**Power (%)**
0.20	98.7
0.15	98.0
0.10	96.7
0.05	***93.2***
0.01	78.8

Table D15. Basic Statistics for Jefferson County Watersheds - Total Copper Homogeneous Groups (Real Space Data) (µg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001	19	26	16	0.61	10	30	60
B	ALJC002	16	59	33	0.56	10	50	120

D.3. Total Lead

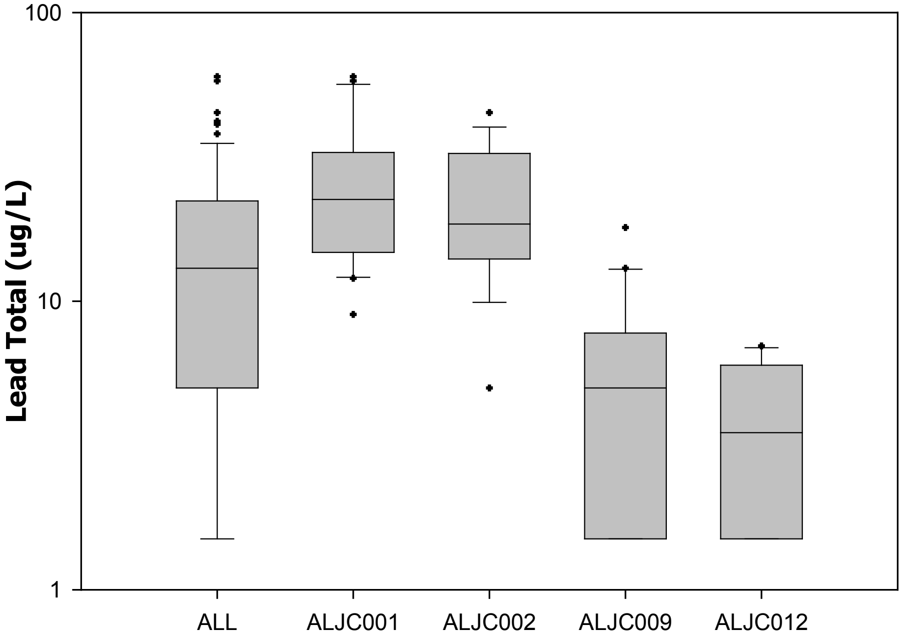
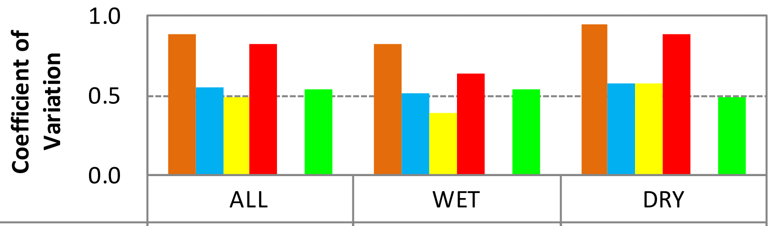


Fig. D11. Total Lead - Jefferson County Watersheds



	ALL	WET	DRY
🟧 ALL Watersheds	0.88	0.83	0.94
🟦 ALJC001 [Mixed Industrial]	0.55	0.52	0.57
🟨 ALJC002 [Mixed Industrial]	0.48	0.40	0.57
🟥 ALJC009 [Mixed Residential]	0.82	0.64	0.89
🟪 ALJC010 [Mixed Residential]	0.00	0.00	0.00
🟩 ALJC012 [Mixed Commercial]	0.54	0.53	0.49

Seasons

Fig. D12. Total Lead - Jefferson County Watersheds
Seasonal Coefficients of Variation

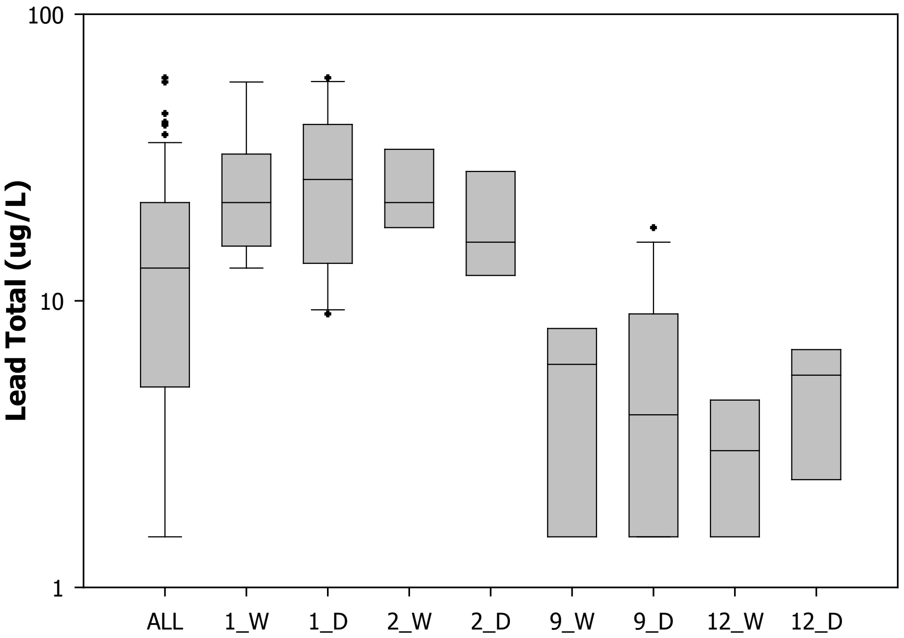
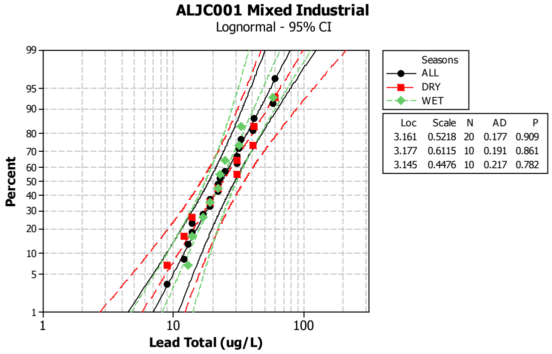


Fig. D13. Total Lead – Seasons for Jefferson County Watersheds

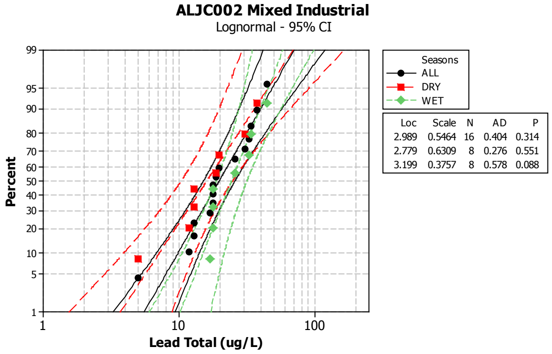
One-Way ANOVA

ALJC001 Log Pb	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.001	1	0.001	0.018	0.895
Within Seasons	0.975	18	0.054		
Total	0.976	19			



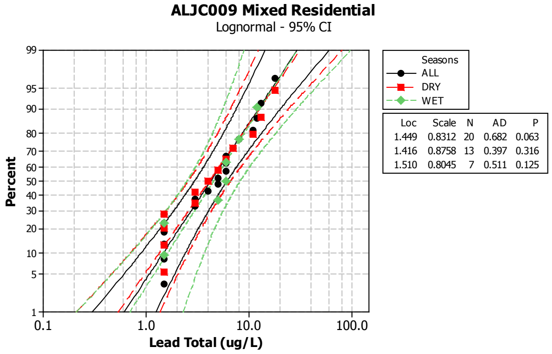
One-Way ANOVA

ALJC002 Log Pb	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.133	1	0.133	2.611	0.128
Within Seasons	0.712	14	0.051		
Total	0.845	15			



One-Way ANOVA

ALJC009 Log Pb	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.008	1	0.008	0.055	0.817
Within Seasons	2.469	18	0.137		
Total	2.476	19			



One-Way ANOVA

ALJC012 Log Pb	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.075	1	0.075	1.070	0.331
Within Seasons	0.561	8	0.070		
Total	0.636	9			

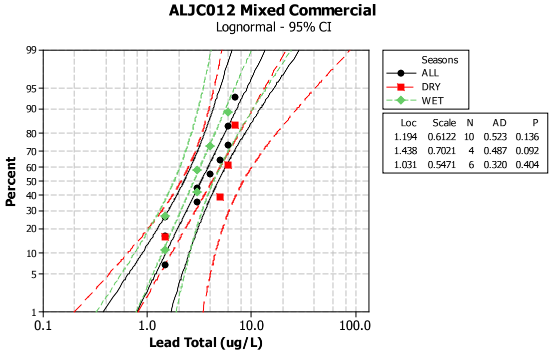


Fig. D14. Total Lead – Jefferson County Watersheds
Checks for Normality and Seasonal Differences

Table D16. Power of the Test for Total Lead – Jefferson County Watersheds Separated by Seasons

ALJC001 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
DRY	10	1.38	0.27	0.20	20.2
WET	10	1.37	0.19	0.15	15.2
Pooled Standard Deviation			0.23	0.10	10.1
Obtained Effect Size			0.02	***0.05***	***5.1***
				0.01	1.0

ALJC002 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
DRY	8	1.21	0.27	0.20	62.2
WET	8	1.39	0.16	0.15	55.5
Pooled Standard Deviation			0.22	0.10	46.6
Obtained Effect Size			0.41	***0.05***	***33.2***
				0.01	13.0

ALJC009 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
DRY	13	0.62	0.38	0.20	21.2
WET	7	0.66	0.35	0.15	16.1
Pooled Standard Deviation			0.36	0.10	10.9
Obtained Effect Size			0.05	***0.05***	***5.6***
				0.01	1.2

ALJC012 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
DRY	4	0.63	0.31	0.20	39.3
WET	6	0.45	0.24	0.15	32.6
Pooled Standard Deviation			0.27	0.10	24.7
Obtained Effect Size			0.32	***0.05***	***15.0***
				0.01	4.2

Table D17. Summary Statistics for Total Lead – Jefferson County Watersheds Separated by Seasons

Watershed	**Seasons**	**N**	**Mean**	**p-value**	**Power (%)**	**Significant (?)**	**Results**
ALJC001	DRY WET	10 10	1.38 1.37	0.895	5.1	No	No seasonal influence
ALJC002	DRY WET	8 8	1.21 1.39	0.128	33	No	No seasonal influence
ALJC009	DRY WET	13 7	0.62 0.66	0.817	5.6	No	No seasonal influence
ALJC012	DRY WET	4 6	0.63 0.45	0.331	15	No	No seasonal influence

Table D18. Statistical Analyses for Total Lead – Jefferson County Watershed Groups

ANOVA (Watersheds: Log Total Lead)

P = 0.00

Log Pb	**Sum of Squares**	**DF**	**Mean Square**	**F**
Between Watersheds	9.271	3	3.090	39
Within Watersheds	4.933	62	0.080	
Total	14.204	65		

Multiple Comparisons
(Scheffe Test,
Equal Variances Assumed)

(I) ALJC	**(J) ALJC**	**p-value**
1	2	0.891
	9	0.000*
	12	0.000*
2	9	0.000*
	12	0.000*
9	12	0.795

Watershed Log Total Lead Groups

ALJC	**Gr. A**	**Gr. B**
12	0.518	
9	0.629	
2		1.298
1		1.373

Table D19. Power of the Test for Total Lead –
Jefferson County Watershed Groups

Watersheds	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	20	1.37	0.23
ALJC002	16	1.30	0.24
ALJC009	20	0.63	0.36
ALJC012	10	0.52	0.27

Pooled Standard Deviation 0.28

Obtained Effect Size 1.33

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

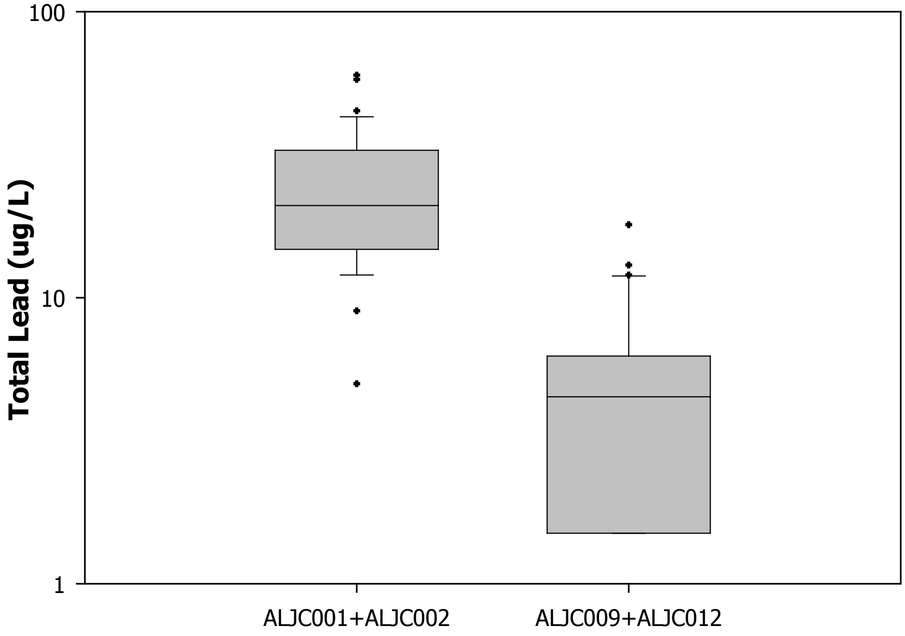


Fig. D15. Total Lead – Jefferson County Watershed Homogeneous Groups

Table D20. Statistical Analyses for Total Lead –
Jefferson County Watershed Homogeneous Groups

ANOVA (Watershed Groups: Log Total Lead)

P = 0.00

Log Pb	**Sum of Squares**	**DF**	**Mean Square**	**F**
Between Groups	9.140	1	9.1404	116
Within Groups	5.064	64	0.079	
Total	14.204	65		

Watershed
Log Total Lead
Homogeneous Groups

Groups	**Gr. A**	**Gr. B**
AL01+AL02	1.340	
AL09+AL12		0.592

Table D21. Power of the Test for Total Lead –
Jefferson County Watershed Homogeneous Groups

Homogeneous Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001 + ALJC002	36	1.34	0.23
ALJC009 + ALJC012	30	0.59	0.33

Pooled Standard Deviation	0.28
Obtained Effect Size	1.33

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Table D22. Basic Statistics for Jefferson County Watersheds –
Total Lead Homogeneous Groups (Real Space Data) (µg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001 + ALJC002	36	25	13	0.52	5.0	21	60
B	ALJC009 + ALJC012	30	5.2	4.0	0.78	1.5	4.5	18

D.4. Total Phosphorous

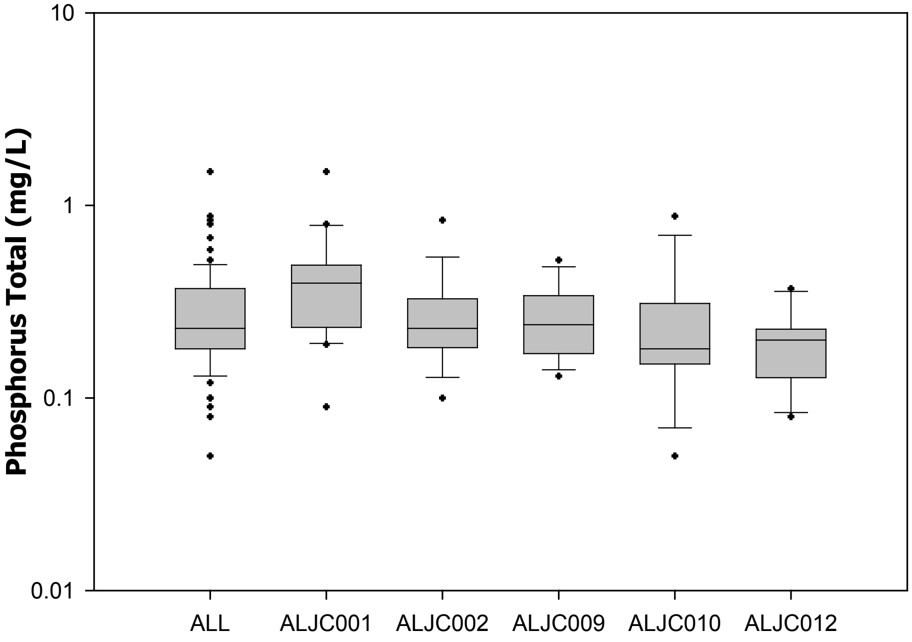
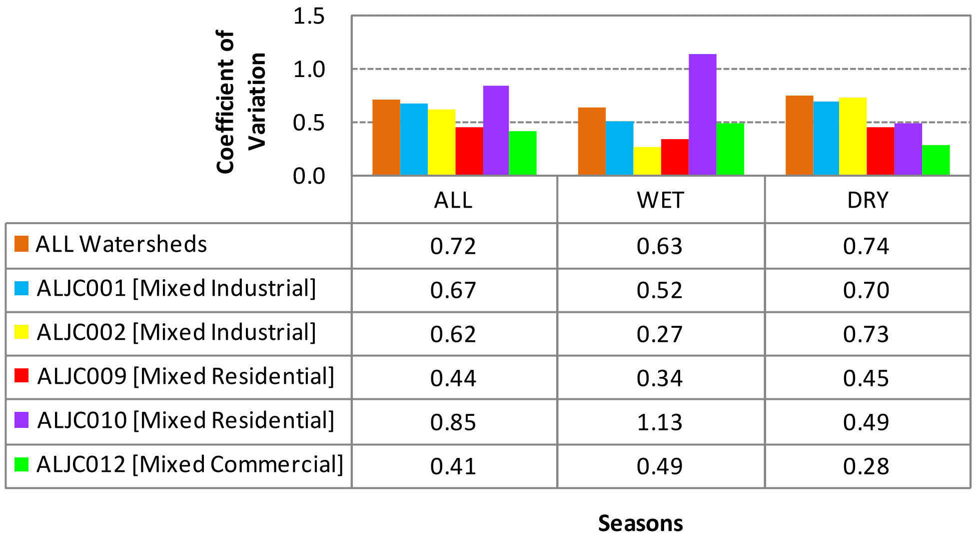


Fig. D16. Total Phosphorous - Jefferson County Watersheds



	ALL	WET	DRY
🟧 ALL Watersheds	0.72	0.63	0.74
🟦 ALJC001 [Mixed Industrial]	0.67	0.52	0.70
🟨 ALJC002 [Mixed Industrial]	0.62	0.27	0.73
🟥 ALJC009 [Mixed Residential]	0.44	0.34	0.45
🟪 ALJC010 [Mixed Residential]	0.85	1.13	0.49
🟩 ALJC012 [Mixed Commercial]	0.41	0.49	0.28

Fig. D17. Total Phosphorous - Jefferson County Watersheds
Seasonal Coefficients of Variation

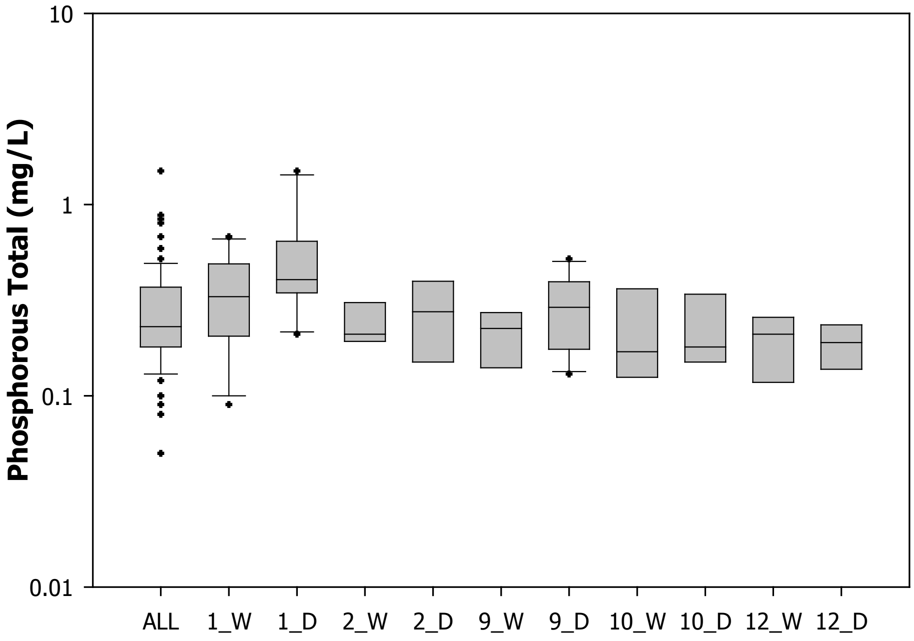
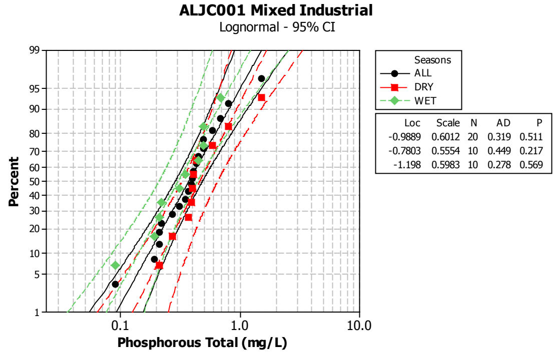


Fig. D18. Total Phosphorous – Seasons for Jefferson County Watersheds

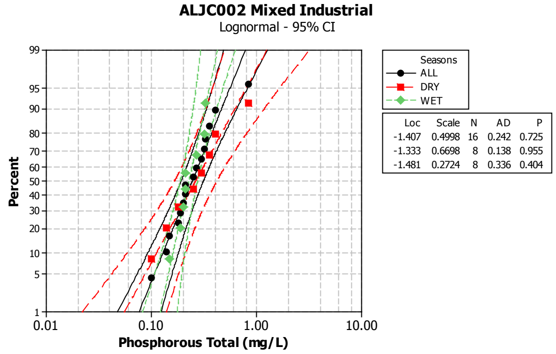
One-Way ANOVA

ALJC001 Log TP	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.164	1	0.164	2.612	0.123
Within Seasons	1.131	18	0.063		
Total	1.295	19			



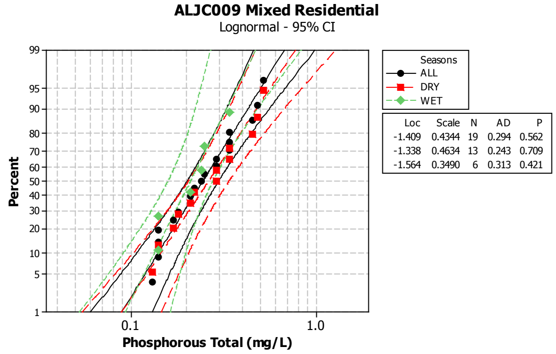
One-Way ANOVA

ALJC002 Log TP	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.017	1	0.017	0.336	0.572
Within Seasons	0.690	14	0.049		
Total	0.707	15			



One-Way ANOVA

ALJC009 Log TP	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.040	1	0.040	1.126	0.304
Within Seasons	0.601	17	0.035		
Total	0.641	18			



One-Way ANOVA

ALJC010 Log TP	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.015	1	0.015	0.154	0.702
Within Seasons	1.083	11	0.098		
Total	1.098	12			

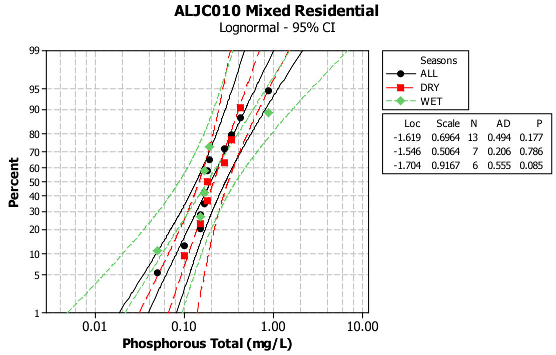


Fig. D19. Total Phosphorous – Jefferson County Watersheds
Checks for Normality and Seasonal Differences

One-Way ANOVA

ALJC012 Log TP	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.000	1	0.000	0.001	0.980
Within Seasons	0.311	8	0.039		
Total	0.311	9			

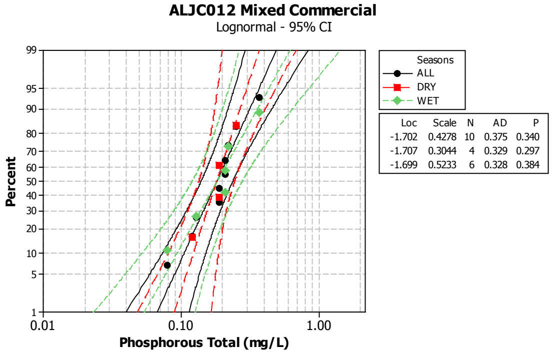


Fig. D19. - *Continued*

Table D23. Power of the Test for Total Phosphorous – Jefferson County Watersheds Separated by Seasons

ALJC001 Season	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
DRY	10	-0.34	0.24
WET	10	-0.52	0.26
Pooled Standard Deviation			0.25
Obtained Effect Size			0.36

α level	Power (%)
0.20	61.7
0.15	55.1
0.10	46.3
0.05	***33.2***
0.01	13.4

ALJC002 Season	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
DRY	8	-0.58	0.29
WET	8	-0.64	0.12
Pooled Standard Deviation			0.20
Obtained Effect Size			0.15

α level	Power (%)
0.20	27.3
0.15	21.6
0.10	15.5
0.05	***8.7***
0.01	2.1

ALJC009 Season	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
DRY	13	-0.58	0.20
WET	6	-0.68	0.15
Pooled Standard Deviation			0.18
Obtained Effect Size			0.26

α level	Power (%)
0.20	43.6
0.15	36.9
0.10	28.9
0.05	***18.6***
0.01	6.0

ALJC010 Season	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
DRY	7	-0.67	0.22
WET	6	-0.74	0.40
Pooled Standard Deviation			0.31
Obtained Effect Size			0.11

α level	Power (%)
0.20	23.4
0.15	18.0
0.10	12.5
0.05	***6.6***
0.01	1.5

ALJC012 Season	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
DRY	4	-0.74	0.13
WET	6	-0.74	0.23
Pooled Standard Deviation			0.18
Obtained Effect Size			0

α level	Power (%)
0.20	20.0
0.15	15.0
0.10	10.0
0.05	***5.0***
0.01	1.0

Table D24. Summary Statistics for Total Phosphorous –
Jefferson County Watersheds Separated by Seasons

Watershed	Seasons	N	Mean	p-value	Power (%)	Significant (?)	Results
ALJC001	DRY WET	10 10	-0.34 -0.52	0.123	33.2	No	No seasonal influence
ALJC002	DRY WET	8 8	-0.58 -0.64	0.572	8.7	No	No seasonal influence
ALJC009	DRY WET	13 6	-0.58 -0.68	0.304	18.6	No	No seasonal influence
ALJC010	DRY WET	7 6	-0.67 -0.74	0.702	6.6	No	No seasonal influence
ALJC012	DRY WET	4 6	-0.74 -0.74	0.980	5.0	No	No seasonal influence

Table D25. Statistical Analyses for Total Phosphorous – Jefferson County Watershed Groups

ANOVA (Watersheds:
Log Total Phosphorous)

P = 0.004

Log TP	Sum of Squares	DF	Mean Square	F
Between Watersheds	0.918	4	0.229	4.1
Within Watersheds	4.051	73	0.055	
Total	4.969	77		

Multiple Comparisons
(Scheffe Test,
Equal Variances Assumed)

(I) ALJC	(J) ALJC	p-value
1	2	0.271
	9	0.223
	10	0.039*
	12	0.028*
2	9	1.000
	10	0.893
	12	0.767
9	10	0.884
	12	0.751
10	12	0.998

Watershed
Log Total Phosphorous
Groups

ALJC	Gr. A	Gr. B
1	-0.43	
2		-0.61
9		-0.61
10		-0.70
12		-0.74

Table D26. Power of the Test for Total Phosphorous –
Jefferson County Watershed Groups

Watersheds	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	20	-0.43	0.26
ALJC002	16	-0.61	0.22
ALJC009	19	-0.61	0.19
ALJC010	13	-0.70	0.30
ALJC012	10	-0.74	0.19
Pooled Standard Deviation			0.24
Obtained Effect Size			0.45

α level	Power (%)
0.20	97.3
0.15	96.1
0.10	93.8
0.05	***88.5***
0.01	71.0

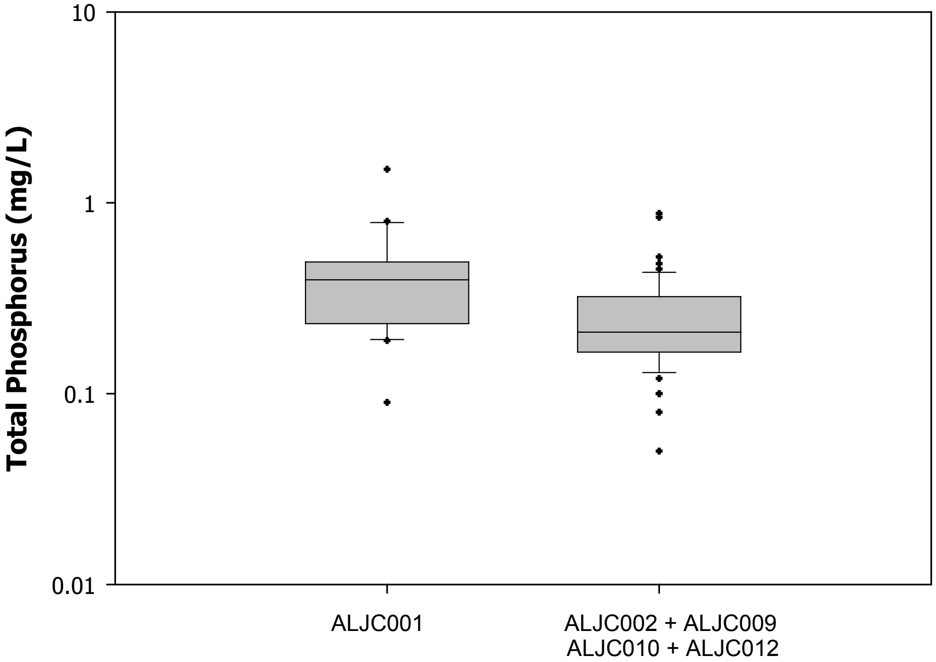


Fig. D20. Total Phosphorous – Jefferson County Watershed Homogeneous Groups

Table D27. Statistical Analyses for Total Phosphorous –
Jefferson County Watershed Homogeneous Groups

ANOVA (Watershed Groups: Log Total Phosphorous)

P = 0.00

Log TP	Sum of Squares	DF	Mean Square	F
Between Groups	0.750	1	0.750	14
Within Groups	4.219	76	0.056	
Total	4.969	77		

Watershed
Log Total Phosphorous
Homogeneous Groups

Groups	Gr. A	Gr. B
AL01	-0.429	
AL02+AL09 AL10 AL12		-0.654

Table D28. Power of the Test for Total Phosphorous –
Jefferson County Watershed Homogeneous Groups

Homogeneous Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	20	-0.43	0.26
ALJC002+ ALJC009+ ALJC010+ ALJC012	58	-0.65	0.23

Pooled Standard Deviation	0.24
Obtained Effect Size	0.40

α level	Power (%)
0.20	98.7
0.15	98.1
0.10	96.8
0.05	***93.7***
0.01	81.1

Table D29. Basic Statistics for Jefferson County Watersheds –
Total Phosphorous Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001	20	0.44	0.30	0.68	0.09	0.40	1.5
B	ALJC002+ ALJC009+ ALJC010+ ALJC012	58	0.25	0.15	0.60	0.05	0.21	0.88

D.5. Dissolved Phosphorous

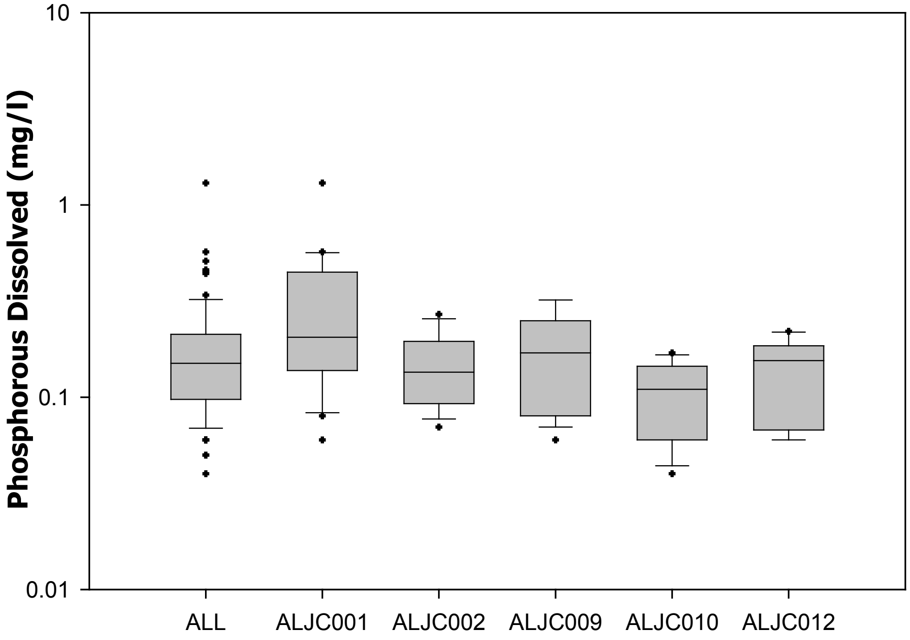
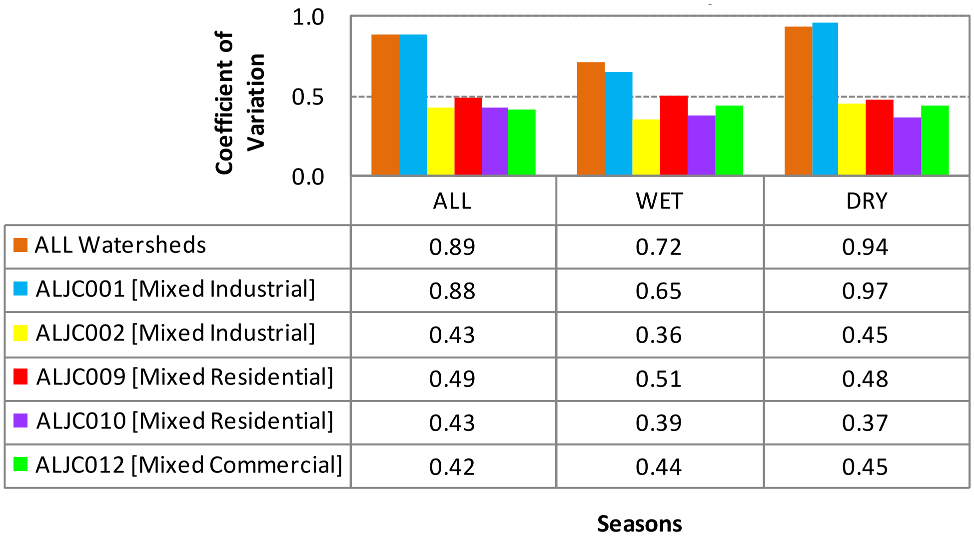


Fig. D21. Dissolved Phosphorous - Jefferson County Watersheds



	ALL	WET	DRY
🟧 ALL Watersheds	0.89	0.72	0.94
🟦 ALJC001 [Mixed Industrial]	0.88	0.65	0.97
🟨 ALJC002 [Mixed Industrial]	0.43	0.36	0.45
🟥 ALJC009 [Mixed Residential]	0.49	0.51	0.48
🟪 ALJC010 [Mixed Residential]	0.43	0.39	0.37
🟩 ALJC012 [Mixed Commercial]	0.42	0.44	0.45

Fig. D22. Dissolved Phosphorous - Jefferson County Watersheds
Seasonal Coefficients of Variation

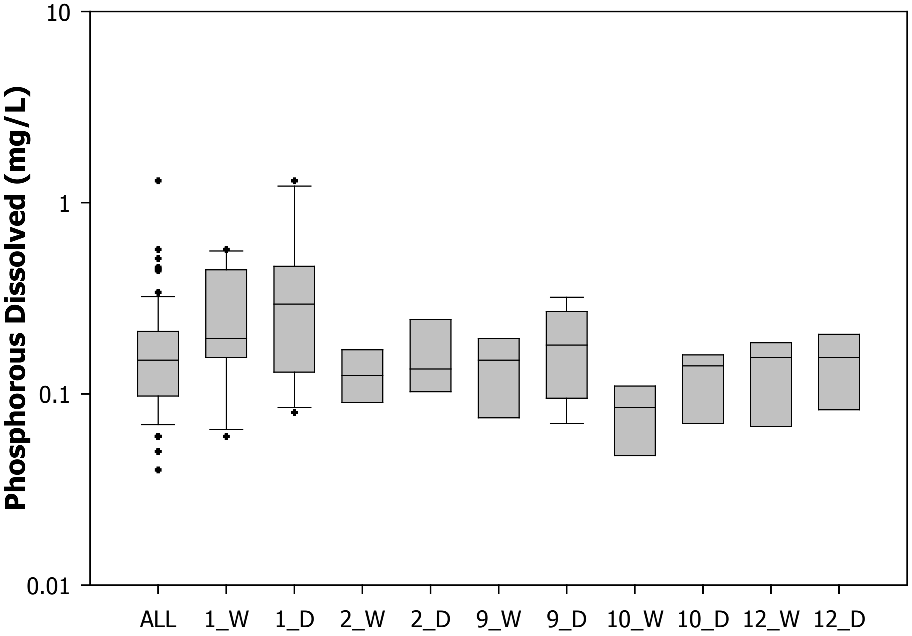
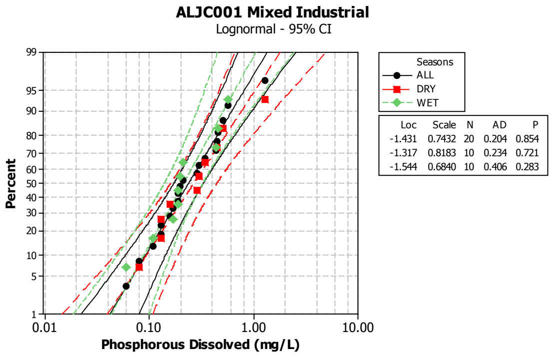


Fig. D23. Dissolved Phosphorous – Seasons for Jefferson County Watersheds

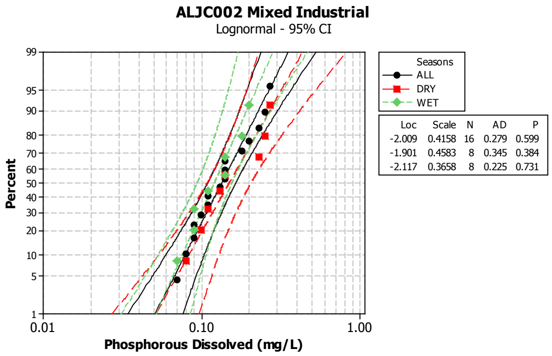
One-Way ANOVA

ALJC001 Log DP	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.049	1	0.049	0.455	0.509
Within Seasons	1.931	18	0.107		
Total	1.980	19			



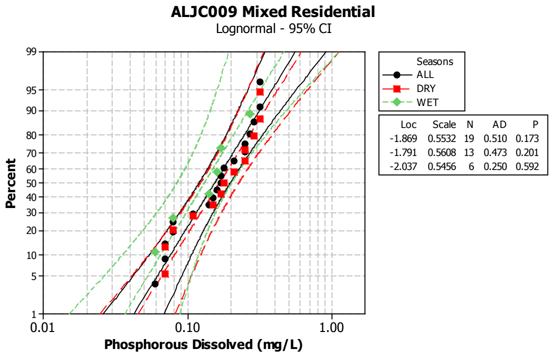
One-Way ANOVA

ALJC002 Log DP	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.035	1	0.035	1.090	0.314
Within Seasons	0.454	14	0.032		
Total	0.489	15			



One-Way ANOVA

ALJC009 Log DP	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.047	1	0.047	0.798	0.384
Within Seasons	0.993	17	0.058		
Total	1.039	18			



One-Way ANOVA

ALJC010 Log DP	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.120	1	0.120	3.045	0.109
Within Seasons	0.432	11	0.039		
Total	0.551	12			

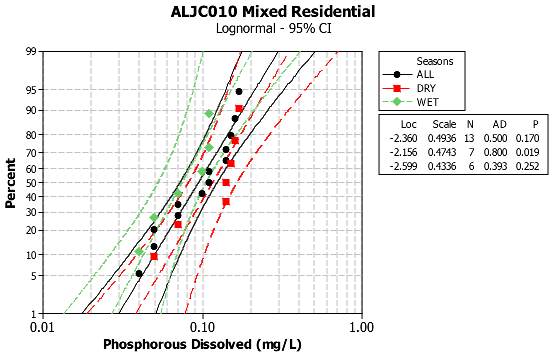


Fig. D24. Dissolved Phosphorous – Jefferson County Watersheds
Checks for Normality and Seasonal Differences

One-Way ANOVA

ALJC012 Log DP	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
Between Seasons	0.003	1	0.003	0.050	0.828
Within Seasons	0.433	8	0.054		
Total	0.436	9			

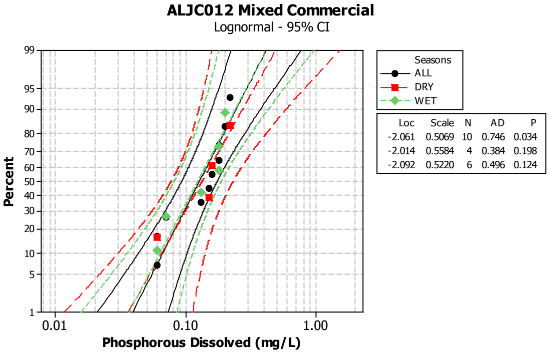


Fig. D24. - *Continued*

Table D30. Power of the Test for Dissolved Phosphorous – Jefferson County Watersheds Separated by Seasons

ALJC001 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	10	-0.57	0.36
WET	10	-0.67	0.30
Pooled Standard Deviation			0.33
Obtained Effect Size			0.15

α level	**Power (%)**
0.20	29.4
0.15	23.5
0.10	17.1
0.05	***9.8***
0.01	2.6

ALJC002 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	8	-0.83	0.20
WET	8	-0.92	0.16
Pooled Standard Deviation			0.18
Obtained Effect Size			0.25

α level	**Power (%)**
0.20	39.0
0.15	32.5
0.10	24.9
0.05	***15.4***
0.01	4.6

ALJC009 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	13	-0.78	0.24
WET	6	-0.88	0.24
Pooled Standard Deviation			0.24
Obtained Effect Size			0.19

α level	**Power (%)**
0.20	34.1
0.15	27.9
0.10	20.9
0.05	***12.5***
0.01	3.6

ALJC010 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	7	-0.94	0.21
WET	6	-1.13	0.19
Pooled Standard Deviation			0.20
Obtained Effect Size			0.47

α level	**Power (%)**
0.20	64.3
0.15	57.5
0.10	48.3
0.05	***34.5***
0.01	13.3

ALJC012 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	4	-0.88	0.24
WET	6	-0.91	0.23
Pooled Standard Deviation			0.23
Obtained Effect Size			0.06

α level	**Power (%)**
0.20	20.8
0.15	15.7
0.10	10.6
0.05	***5.4***
0.01	1.1

Table D31. Summary Statistics for Dissolved Phosphorous – Jefferson County Watersheds Separated by Seasons

Watershed	Seasons	N	Mean	p-value	Power (%)	Significant (?)	Results
ALJC001	DRY WET	10 10	-0.57 -0.67	0.509	9.8	No	No seasonal influence
ALJC002	DRY WET	8 8	-0.83 -0.92	0.314	15.4	No	No seasonal influence
ALJC009	DRY WET	13 6	-0.78 -0.88	0.384	12.5	No	No seasonal influence
ALJC010	DRY WET	7 6	-0.94 -1.13	0.109	34.5	No	No seasonal influence
ALJC012	DRY WET	4 6	-0.88 -0.91	0.828	5.4	No	No seasonal influence

Table D32. Statistical Analyses for Dissolved Phosphorous – Jefferson County Watershed Groups

ANOVA (Watersheds: Log Dissolved Phosphorous)

P = 0.00

Log DP	Sum of Squares	DF	Mean Square	F
Between Watersheds	1.437	4	0.359	5.8
Within Watersheds	4.496	73	0.062	
Total	5.933	77		

Multiple Comparisons
(Scheffe Test,
Equal Variances Assumed)

(I) ALJC	(J) ALJC	p-value
1	2	0.069
	9	0.232
	10	0.001*
	12	0.099
2	9	0.970
	10	0.611
	12	1.000
9	10	0.234
	12	0.945
10	12	0.817

Watershed Log Dissolved Phosphorous Groups

ALJC	Gr. A	Gr. B
1	-0.62	
2		-0.87
9		-0.81
10		-1.02
12		-0.90

Table D33. Power of the Test for Dissolved Phosphorous – Jefferson County Watershed Groups

Watersheds	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	20	-0.62	0.32
ALJC002	16	-0.87	0.18
ALJC009	19	-0.81	0.24
ALJC010	13	-1.02	0.21
ALJC012	10	-0.90	0.22
Pooled Standard Deviation			0.25
Obtained Effect Size			0.54

α level	Power (%)
0.20	99.6
0.15	99.4
0.10	98.9
0.05	***97.4***
0.01	90.1

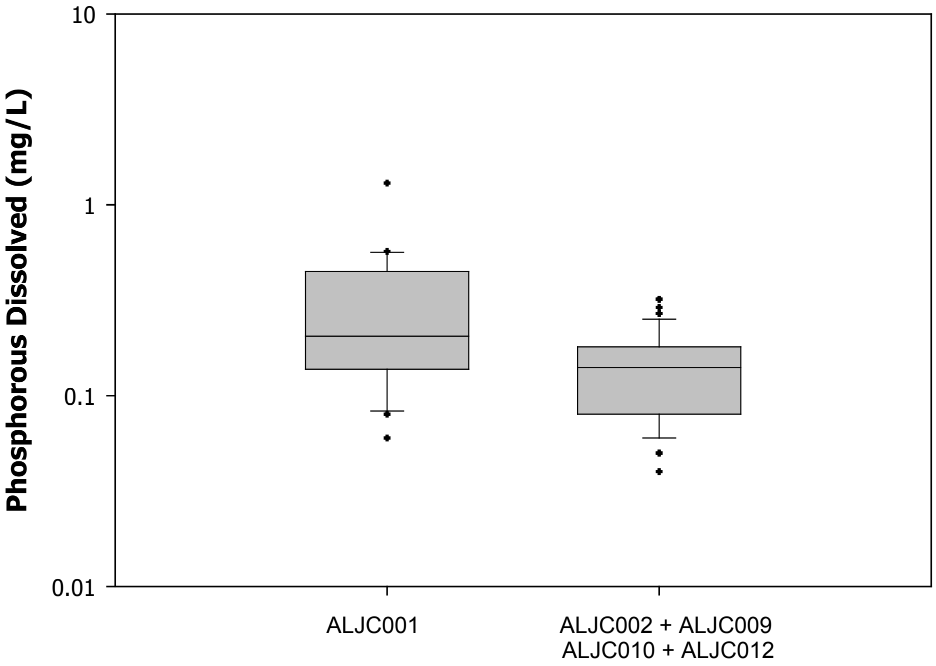


Fig. D25. Dissolved Phosphorous – Jefferson County Watershed Homogeneous Groups

Table D34. Statistical Analyses for Dissolved Phosphorous –
Jefferson County Watershed Homogeneous Groups

ANOVA (Watershed Groups: Log Dissolved Phosphorous)

P = 0.00

Log DP	**Sum of Squares**	**DF**	**Mean Square**	**F**
Between Groups	1.078	1	1.078	17
Within Groups	4.854	76	0.064	
Total	5.933	77		

Watershed
Log Dissolved Phosphorous
Homogeneous Groups

Groups	**Gr. A**	**Gr. B**
AL01	-0.621	
AL02+AL09 AL10+AL12		-0.891

Table D35. Power of the Test for Dissolved Phosphorous –
Jefferson County Watershed Homogeneous Groups

Homogeneous Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC01	20	-0.62	0.32
ALJC002 + ALJC009 + ALJC010 + ALJC012	58	-0.89	0.22

Pooled Standard Deviation	0.25
Obtained Effect Size	0.47

α level	**Power (%)**
0.20	99.8
0.15	99.6
0.10	99.3
0.05	***98.4***
0.01	93.3

Table D36. Basic Statistics for Jefferson County Watersheds –
Total Dissolved Phosphorous Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC01	20	0.31	0.28	0.88	0.06	0.21	1.3
B	ALJC002 + ALJC009 + ALJC010 + ALJC012	58	0.15	0.07	0.49	0.04	0.14	0.32

D.6. Total Nitrogen

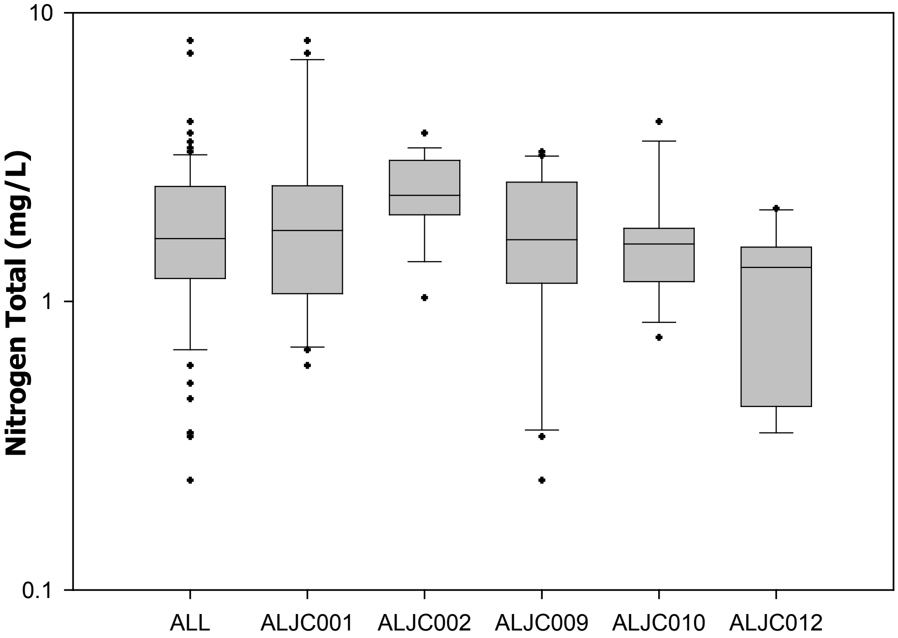
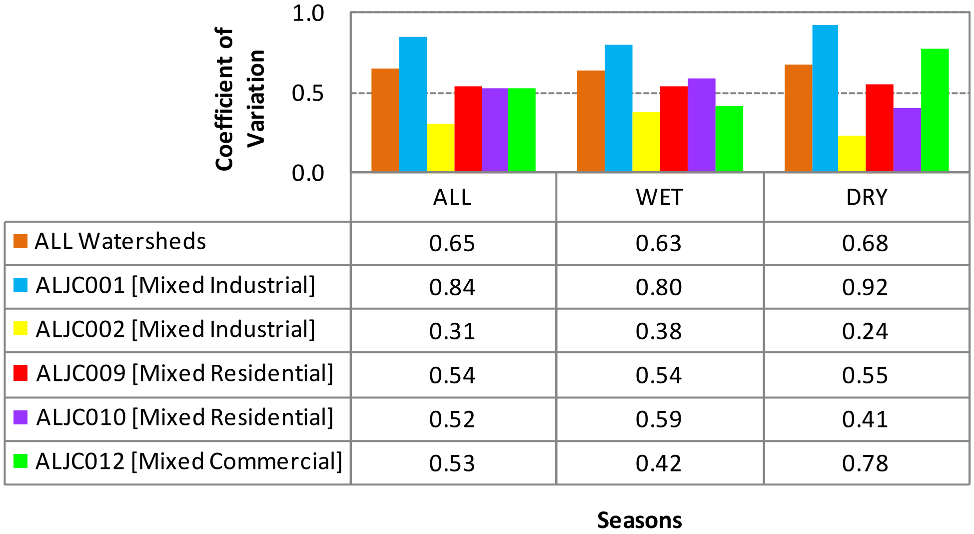


Fig. D26. Total Nitrogen - Jefferson County Watersheds



	ALL	WET	DRY
🟧 ALL Watersheds	0.65	0.63	0.68
🟦 ALJC001 [Mixed Industrial]	0.84	0.80	0.92
🟨 ALJC002 [Mixed Industrial]	0.31	0.38	0.24
🟥 ALJC009 [Mixed Residential]	0.54	0.54	0.55
🟪 ALJC010 [Mixed Residential]	0.52	0.59	0.41
🟩 ALJC012 [Mixed Commercial]	0.53	0.42	0.78

Fig. D27. Total Nitrogen - Jefferson County Watersheds
Seasonal Coefficients of Variation

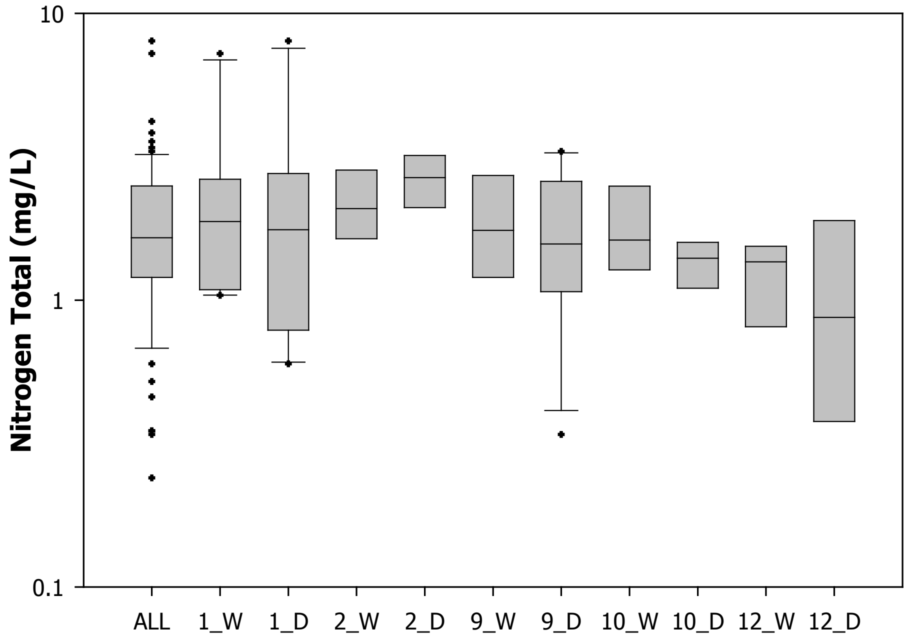
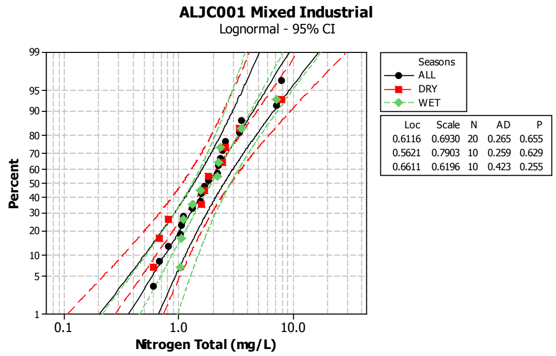


Fig. D28. Total Nitrogen – Seasons for Jefferson County Watersheds

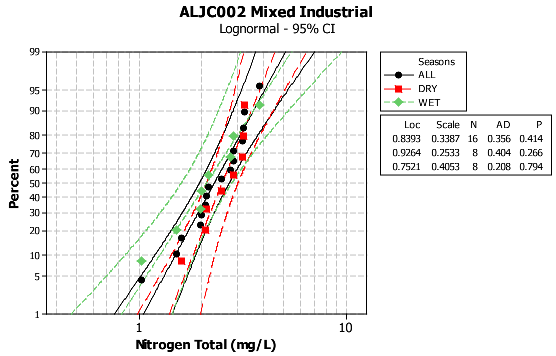
One-Way ANOVA

ALJC001 Log N	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
Between Seasons	0.009	1	0.009	0.097	0.759
Within Seasons	1.712	18	0.095		
Total	1.721	19			



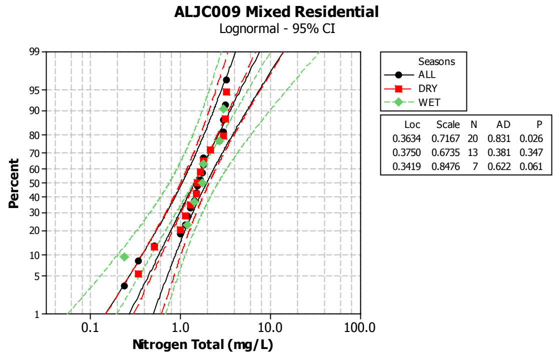
One-Way ANOVA

ALJC002 Log N	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
Between Seasons	0.023	1	0.023	1.064	0.320
Within Seasons	0.302	14	0.022		
Total	0.325	15			



One-Way ANOVA

ALJC009 Log N	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
Between Seasons	0.001	1	0.001	0.009	0.925
Within Seasons	1.840	18	0.102		
Total	1.841	19			



One-Way ANOVA

ALJC010 Log N	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
Between Seasons	0.034	1	0.034	0.953	0.350
Within Seasons	0.394	11	0.036		
Total	0.428	12			

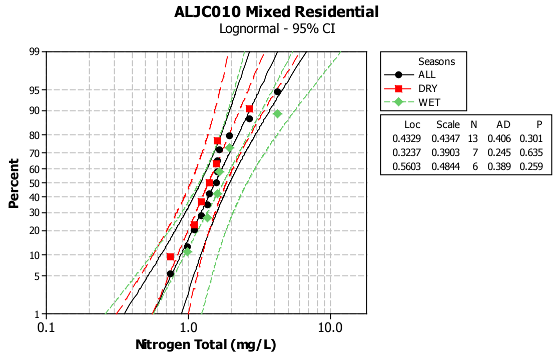


Fig. D29. Total Nitrogen – Jefferson County Watersheds
Checks for Normality and Seasonal Differences

One-Way ANOVA

ALJC012 Log N	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.039	1	0.039	0.421	0.534
Within Seasons	0.735	8	0.092		
Total	0.774	9			

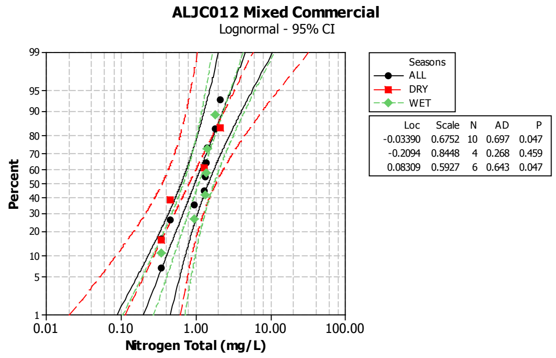


Fig. D29. - *Continued*

Table D37. Power of the Test for Total Nitrogen –
Jefferson County Watersheds Separated by Seasons

ALJC001 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	10	0.24	0.34
WET	10	0.29	0.27
Pooled Standard Deviation			0.31
Obtained Effect Size			0.08

α level	Power (%)
0.20	22.8
0.15	17.5
0.10	12.0
0.05	***6.3***
0.01	1.4

ALJC002 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	8	0.40	0.11
WET	8	0.33	0.18
Pooled Standard Deviation			0.14
Obtained Effect Size			0.25

α level	Power (%)
0.20	39.0
0.15	32.5
0.10	24.9
0.05	***15.4***
0.01	4.6

ALJC009 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	13	0.16	0.29
WET	7	0.15	0.37
Pooled Standard Deviation			0.33
Obtained Effect Size			0.01

α level	Power (%)
0.20	20.1
0.15	15.1
0.10	10.0
0.05	***5.0***
0.01	1.0

ALJC010 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	7	0.14	0.17
WET	6	0.24	0.21
Pooled Standard Deviation			0.19
Obtained Effect Size			0.26

α level	Power (%)
0.20	36.9
0.15	30.5
0.10	23.0
0.05	***13.9***
0.01	3.9

ALJC012 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
DRY	4	-0.09	0.37
WET	6	0.04	0.26
Pooled Standard Deviation			0.31
Obtained Effect Size			0.21

α level	Power (%)
0.20	28.2
0.15	22.3
0.10	16.0
0.05	***8.9***
0.01	2.1

Table D38. Summary Statistics for Total Nitrogen – Jefferson County Watersheds Separated by Seasons

Watershed	Seasons	N	Mean	p-value	Power (%)	Significant (?)	Results
ALJC001	DRY WET	10 10	0.24 0.29	0.759	6.3	No	No seasonal influence
ALJC002	DRY WET	8 8	0.40 0.33	0.320	15.4	No	No seasonal influence
ALJC009	DRY WET	13 7	0.16 0.15	0.925	5.0	No	No seasonal influence
ALJC010	DRY WET	7 6	0.14 0.24	0.350	13.9	No	No seasonal influence
ALJC012	DRY WET	4 6	-0.09 0.04	0.534	8.9	No	No seasonal influence

Table D39. Statistical Analyses for Total Nitrogen – Jefferson County Watershed Groups

ANOVA (Watersheds: Log Total Nitrogen)

P = 0.009

Log N	Sum of Squares	DF	Mean Square	F
Between Watersheds	1.009	4	0.252	3.7
Within Watersheds	5.088	74	0.069	
Total	6.097	78		

Multiple Comparisons
(Scheffe Test,
Equal Variances Assumed)

(I) ALJC	(J) ALJC	p-value
1	2	0.866
	9	0.792
	10	0.952
	12	0.119
2	9	0.249
	10	0.521
	12	0.017*
9	10	0.999
	12	0.580
10	12	0.501

**Watershed
Log Total Nitrogen
Groups**

ALJC	Gr. A	Gr. B
12	-0.015	
1		0.266
2		0.364
9		0.158
10		0.188

Table D40. Power of the Test for Total Nitrogen – Jefferson County Watershed Groups

Watersheds	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	20	0.27	0.30
ALJC002	16	0.36	0.15
ALJC009	20	0.16	0.31
ALJC010	13	0.19	0.19
ALJC012	10	-0.01	0.29
Pooled Standard Deviation			0.26
Obtained Effect Size			0.43

α level	Power (%)
0.20	96.2
0.15	94.5
0.10	91.6
0.05	***85.1***
0.01	65.5

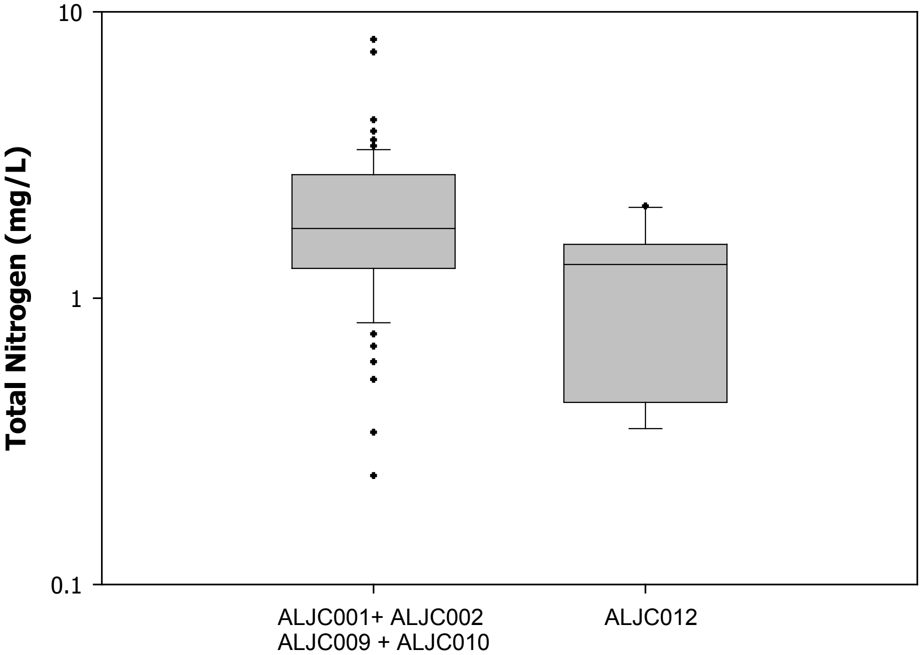


Fig. D30. Total Nitrogen – Jefferson County Watershed Homogeneous Groups

Table D41. Statistical Analyses for Total Nitrogen –
Jefferson County Watershed Homogeneous Groups

ANOVA (Watershed Groups: Log Total Nitrogen)

P = 0.006

Log N	Sum of Squares	DF	Mean Square	F
Between Groups	0.579	1	0.579	8.1
Within Groups	5.519	77	0.072	
Total	6.097	78		

Watershed Log Total Nitrogen Homogeneous Groups

Groups	Gr. A	Gr. B
AL01+ AL02 AL09 AL10	0.243	
AL12		-0.015

Table D42. Power of the Test for Total Nitrogen –
Jefferson County Watershed Homogeneous Groups

Homogeneous Groups	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
ALJC001 + ALJC002+ ALJC009 + ALJC010	69	0.243	0.26
ALJC012	10	-0.015	0.29

Pooled Standard Deviation	0.268
Obtained Effect Size	0.32

α level	Power (%)
0.20	93.9
0.15	91.7
0.10	88.0
0.05	***80.2***
0.01	58.2

Table D43. Basic Statistics for Jefferson County Watersheds –
Total Nitrogen Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001 + ALJC002+ ALJC009 + ALJC010	69	2.1	1.3	0.63	0.24	1.8	8.0
B	ALJC012	10	1.2	0.61	0.53	0.35	1.3	2.1

D.7. Total Kjeldahl Nitrogen

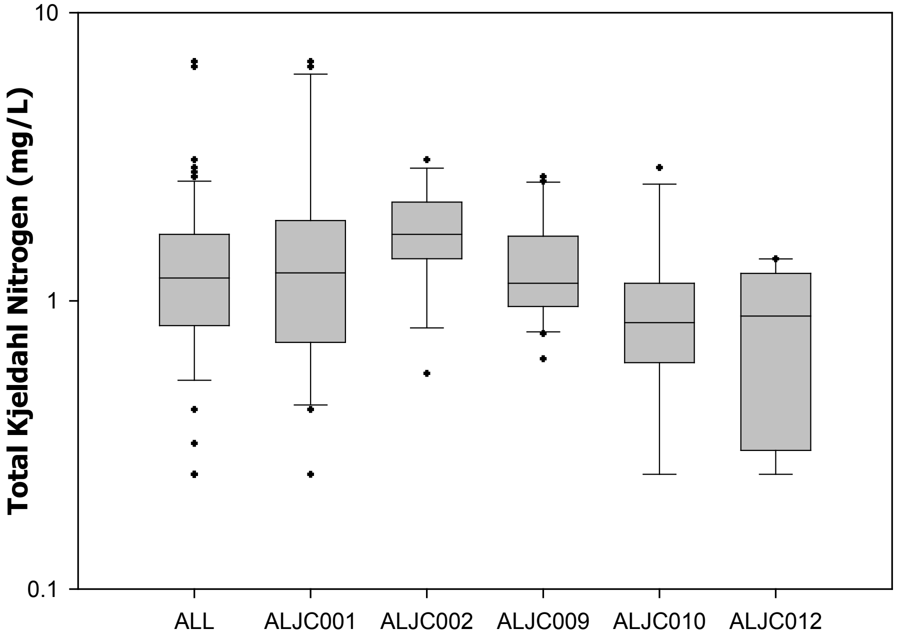
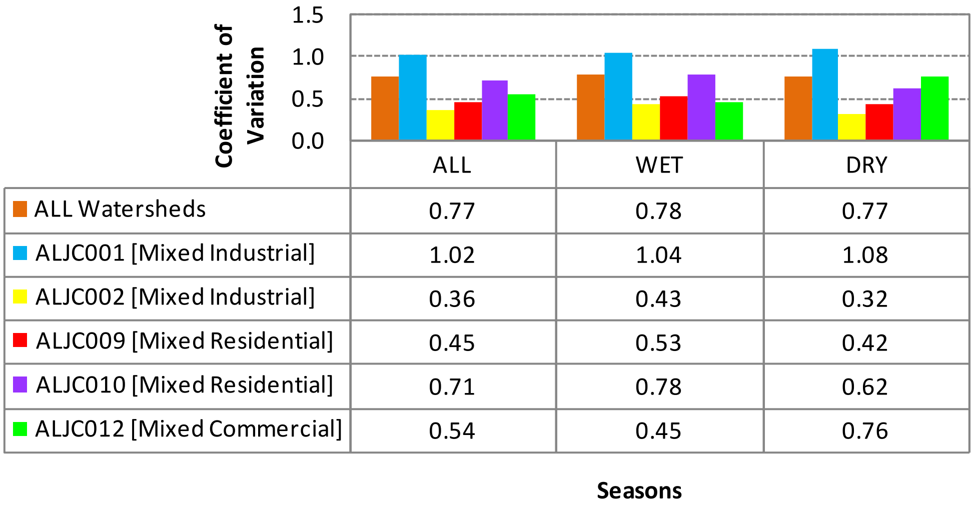


Fig. D31. Total Kjeldahl Nitrogen - Jefferson County Watersheds



	ALL	WET	DRY
🟧 ALL Watersheds	0.77	0.78	0.77
🟦 ALJC001 [Mixed Industrial]	1.02	1.04	1.08
🟨 ALJC002 [Mixed Industrial]	0.36	0.43	0.32
🟥 ALJC009 [Mixed Residential]	0.45	0.53	0.42
🟪 ALJC010 [Mixed Residential]	0.71	0.78	0.62
🟩 ALJC012 [Mixed Commercial]	0.54	0.45	0.76

Fig. D32. Total Kjeldahl Nitrogen - Jefferson County Watersheds
Seasonal Coefficients of Variation

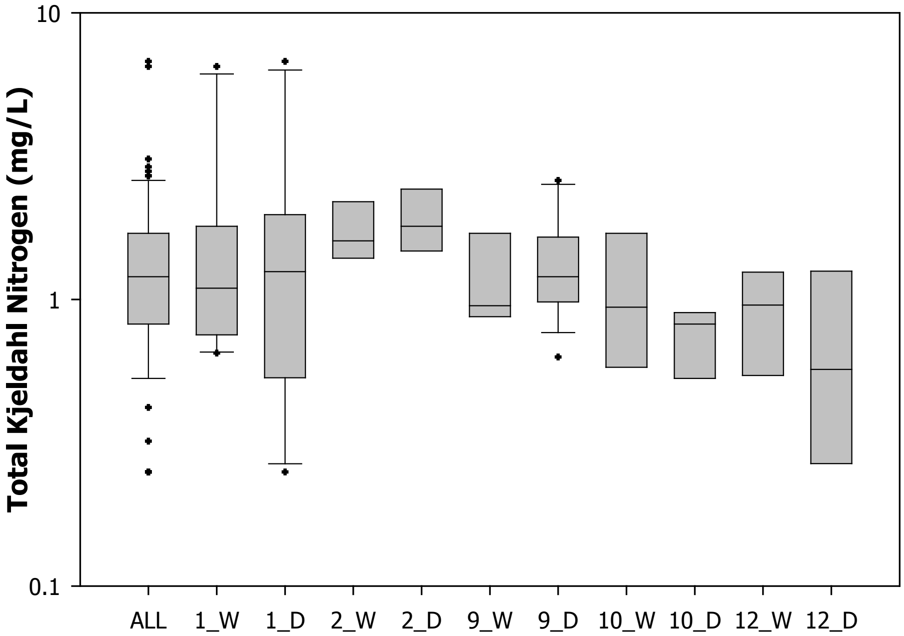
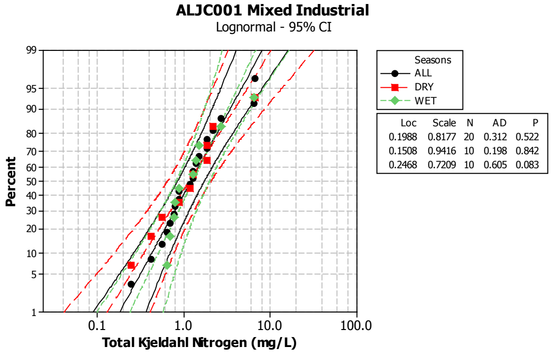


Fig. D33. Total Kjeldahl Nitrogen – Seasons for Jefferson County Watersheds

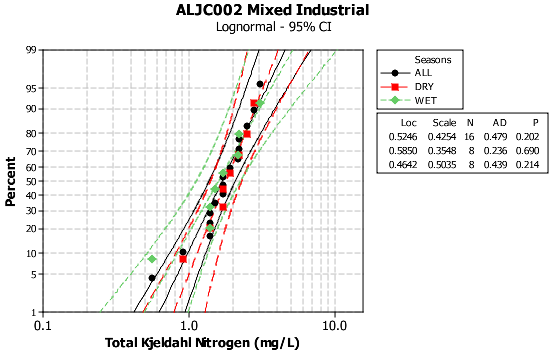
One-Way ANOVA

ALJC001 Log TKN	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.009	1	0.009	0.066	0.801
Within Seasons	2.387	18	0.133		
Total	2.396	19			



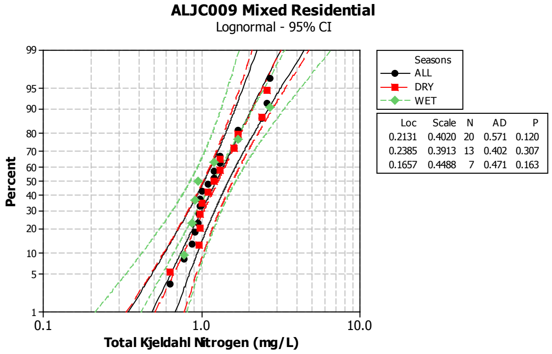
One-Way ANOVA

ALJC002 Log TKN	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.011	1	0.011	0.308	0.588
Within Seasons	0.501	14	0.036		
Total	0.512	15			



One-Way ANOVA

ALJC009 Log TKN	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.005	1	0.005	0.143	0.710
Within Seasons	0.574	18	0.032		
Total	0.579	19			



One-Way ANOVA

ALJC010 Log TKN	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.023	1	0.023	0.243	0.632
Within Seasons	1.052	11	0.096		
Total	1.075	12			

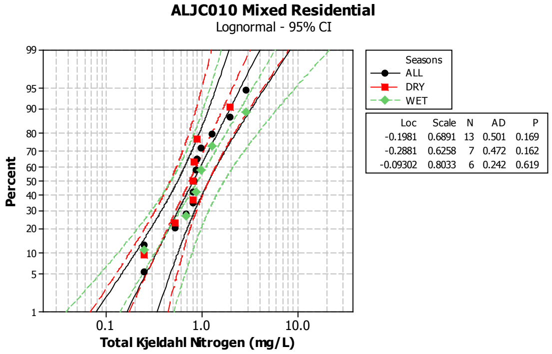


Fig. D34. Total Kjeldahl Nitrogen – Jefferson County Watersheds
Checks for Normality and Seasonal Differences

One-Way ANOVA

ALJC012 Log TKN	**Sum of Squares**	**DF**	**Mean Square**	**F**	**p-value**
Between Seasons	0.059	1	0.059	0.643	0.446
Within Seasons	0.731	8	0.091		
Total	0.789	9			

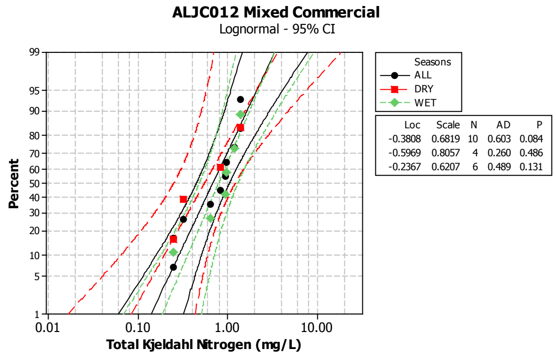


Fig. D34. - *Continued*

Table D44. Power of the Test for Total Kjeldahl Nitrogen – Jefferson County Watersheds Separated by Seasons

ALJC001 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
DRY	10	0.07	0.41	0.20	21.3
WET	10	0.11	0.31	0.15	16.2
Pooled Standard Deviation			0.36	0.10	11.0
Obtained Effect Size			0.06	***0.05***	***5.6***
				0.01	1.2

ALJC002 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
DRY	8	0.25	0.15	0.20	25.7
WET	8	0.20	0.22	0.15	20.1
Pooled Standard Deviation			0.19	0.10	14.2
Obtained Effect Size			0.13	***0.05***	***7.8***
				0.01	1.9

ALJC009 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
DRY	13	0.10	0.17	0.20	22.7
WET	7	0.07	0.19	0.15	17.4
Pooled Standard Deviation			0.18	0.10	12.0
Obtained Effect Size			0.08	***0.05***	***6.3***
				0.01	1.4

ALJC010 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
DRY	7	-0.13	0.27	0.20	25.5
WET	6	-0.04	0.35	0.15	20.0
Pooled Standard Deviation			0.31	0.10	14.0
Obtained Effect Size			0.14	***0.05***	***7.7***
				0.01	1.8

ALJC012 Season	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	**α level**	**Power (%)**
DRY	4	-0.26	0.35	0.20	32.1
WET	6	-0.10	0.27	0.15	25.9
Pooled Standard Deviation			0.31	0.10	19.0
Obtained Effect Size			0.25	***0.05***	***10.9***
				0.01	2.8

Table D45. Summary Statistics for Total Kjeldahl Nitrogen – Jefferson County Watersheds Separated by Seasons

Watershed	**Seasons**	**N**	**Mean**	**p-value**	**Power (%)**	**Significant (?)**	**Results**
ALJC001	DRY WET	10 10	0.07 0.11	0.801	5.6	No	No seasonal influence
ALJC002	DRY WET	8 8	0.25 0.20	0.588	7.8	No	No seasonal influence
ALJC009	DRY WET	13 7	0.10 0.07	0.710	6.3	No	No seasonal influence
ALJC010	DRY WET	7 6	-0.13 -0.04	0.632	7.7	No	No seasonal influence
ALJC012	DRY WET	4 6	-0.26 -0.10	0.446	10.9	No	No seasonal influence

Table D46. Statistical Analyses for Total Kjeldahl Nitrogen – Jefferson County Watershed Groups

ANOVA (Watersheds: Log Total Kjeldahl Nitrogen)

P = 0.003

Log TKN	**Sum of Squares**	**DF**	**Mean Square**	**F**
Between Watersheds	1.270	4	0.317	4.4
Within Watersheds	5.351	74	0.072	
Total	6.621	78		

Multiple Comparisons
(Scheffe Test,
Equal Variances
Assumed)

(I) ALJC	**(J) ALJC**	**p-value**
1	2	0.653
	9	1.000
	10	0.523
	12	0.223
2	9	0.691
	10	0.054*
	12	0.015*
9	10	0.487
	12	0.201
10	12	0.974

Watershed Log Total Kjeldahl Nitrogen Groups

ALJC	**Gr. A**	**Gr. B**
1	0.086	
2	0.228	
9	0.092	
10		-0.165
12		-0.086

Table D47. Power of the Test for Total Kjeldahl Nitrogen – Jefferson County Watershed Groups

Watersheds	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	20	0.09	0.36
ALJC002	16	0.23	0.18
ALJC009	20	0.09	0.17
ALJC010	13	-0.09	0.30
ALJC012	10	-0.17	0.30

Pooled Standard Deviation	0.27
Obtained Effect Size	0.48

α level	**Power (%)**
0.20	98.6
0.15	97.8
0.10	96.4
0.05	***92.8***
0.01	79.3

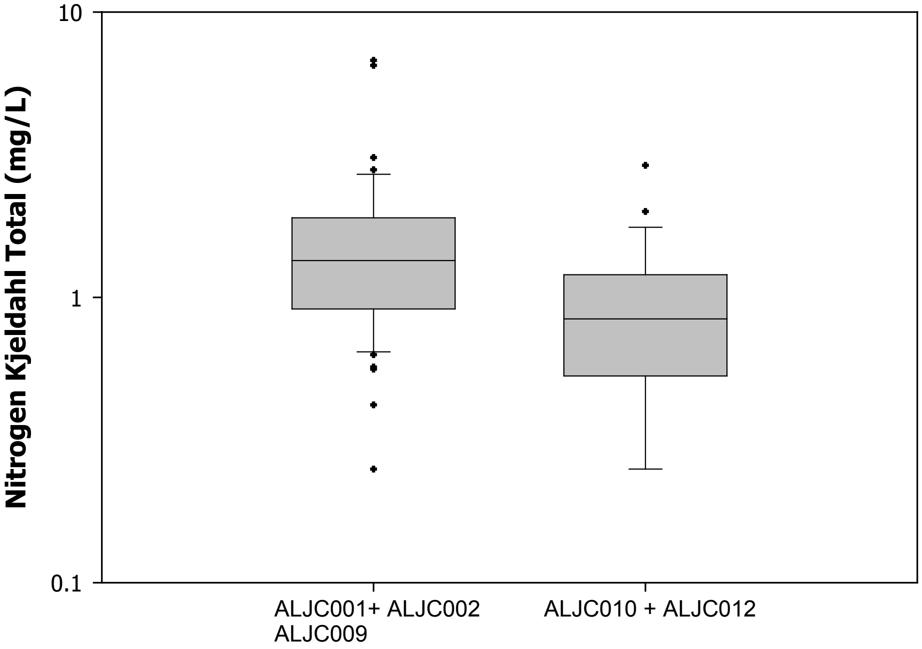


Fig. D35. Total Kjeldahl Nitrogen – Jefferson County Watershed Homogeneous Groups

Table D48. Statistical Analyses for Total Kjeldahl Nitrogen –
Jefferson County Watershed Homogeneous Groups

ANOVA (Watershed Groups:
Log Total Kjeldahl Nitrogen)

P = 0.000

Log TKN	**Sum of Squares**	**DF**	**Mean Square**	**F**
Between Groups	1.015	1	1.015	14
Within Groups	5.606	77	0.073	
Total	6.621	78		

Watershed
Log Total Kjeldahl Nitrogen
Homogeneous Groups

Groups	**Gr. A**	**Gr. B**
AL01+AL02 AL09	0.129	
AL10+AL12		-0.121

Table D49. Power of the Test for Total Kjeldahl Nitrogen –
Jefferson County Watershed Homogeneous Groups

Homogeneous Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001+ALJC002+ALJC009	56	0.129	0.26
ALJC010+ALJC012	23	-0.121	0.29

Pooled Standard Deviation	0.270
Obtained Effect Size	

α level	**Power (%)**
0.20	
0.15	
0.10	
0.05	
0.01	

Table D50. Basic Statistics for Jefferson County Watersheds –
Total Kjeldahl Nitrogen Homogeneous Groups (Real Space Data) (mg/L)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001, ALJC002 ALJC009	56	1.6	1.2	0.73	0.25	1.3	6.8
B	ALJC010, ALJC012	23	0.93	0.61	0.66	0.25	0.84	2.9

D.8 Fecal Coliform Bacteria

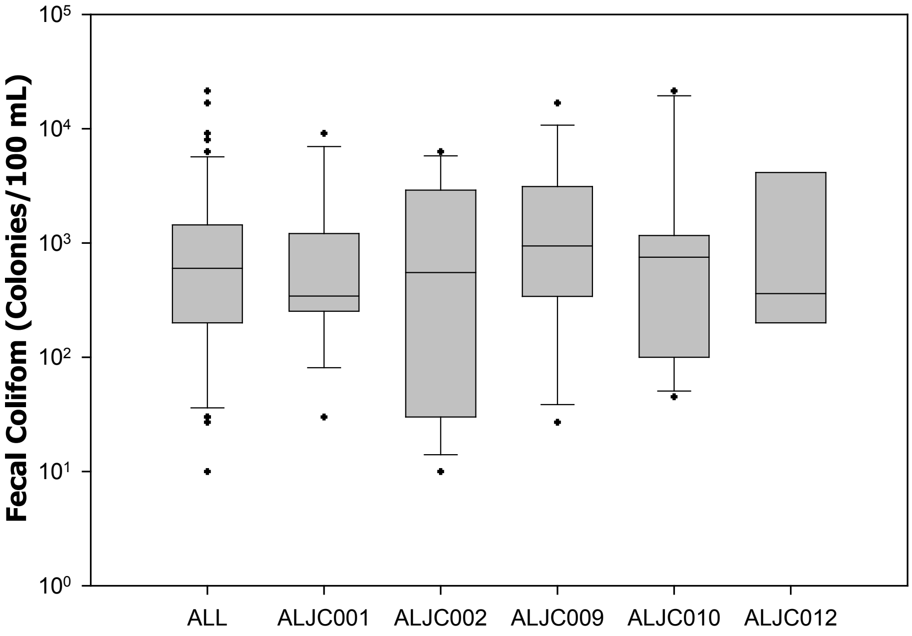
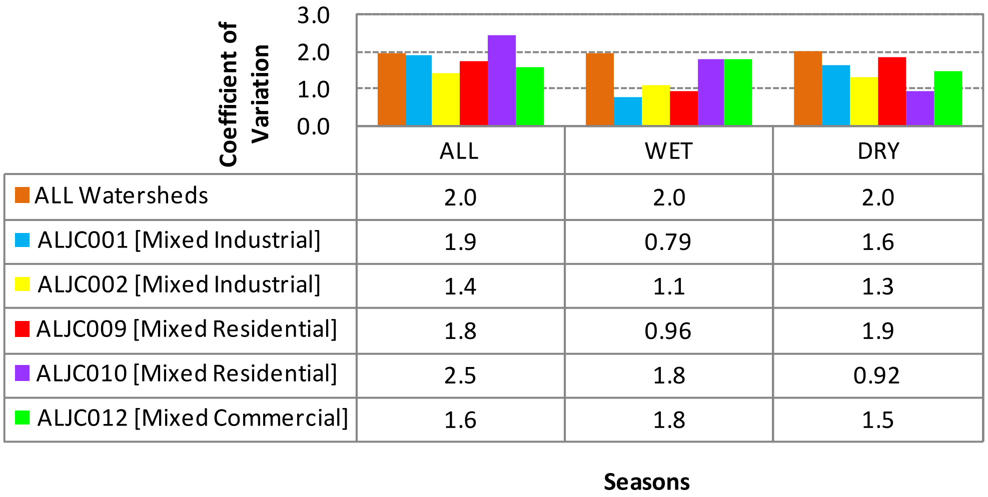


Fig. D36. Fecal Coliform Bacteria - Jefferson County Watersheds



	ALL	WET	DRY
🟧 ALL Watersheds	2.0	2.0	2.0
🟦 ALJC001 [Mixed Industrial]	1.9	0.79	1.6
🟨 ALJC002 [Mixed Industrial]	1.4	1.1	1.3
🟥 ALJC009 [Mixed Residential]	1.8	0.96	1.9
🟪 ALJC010 [Mixed Residential]	2.5	1.8	0.92
🟩 ALJC012 [Mixed Commercial]	1.6	1.8	1.5

Fig. D37. Fecal Coliform Bacteria - Jefferson County Watersheds
Seasonal Coefficients of Variation

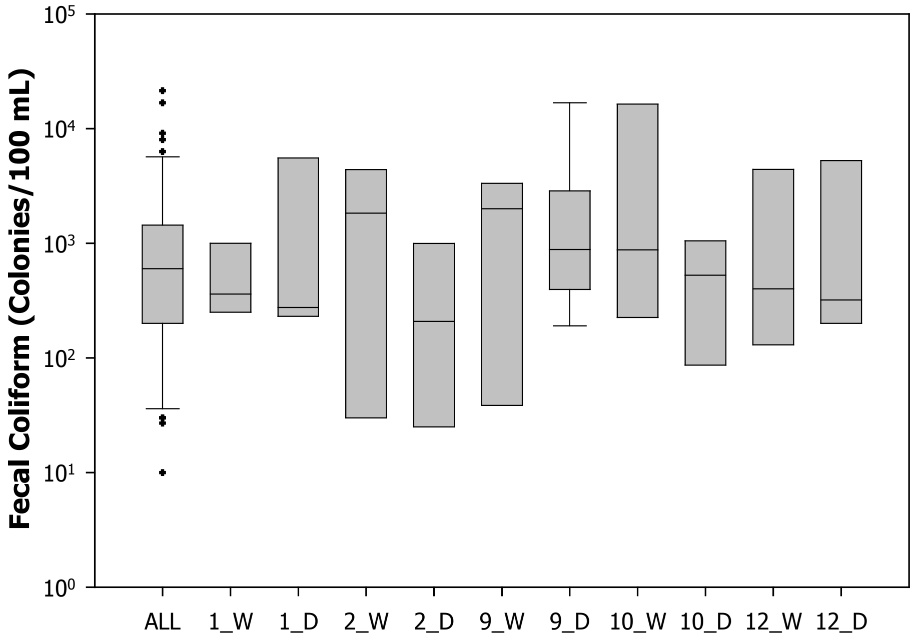
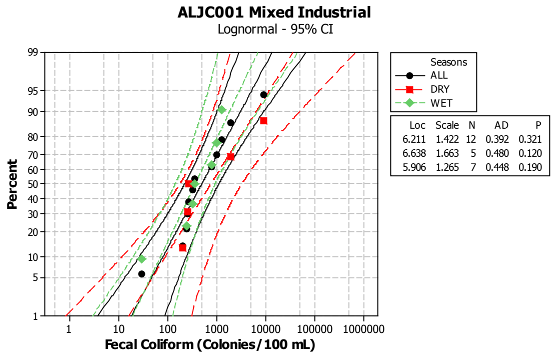


Fig. D38. Fecal Coliform Bacteria – Seasons for Jefferson County Watersheds

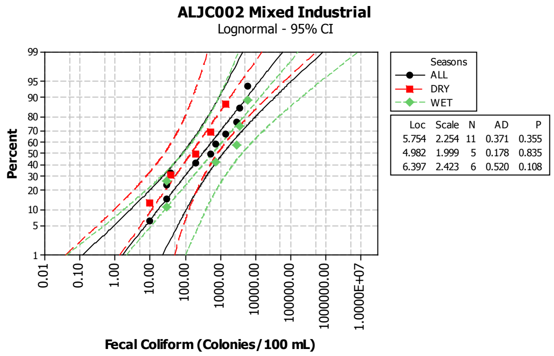
One-Way ANOVA

ALJC001 Log FC	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.295	1	0.295	0.758	0.404
Within Seasons	3.90	10	0.390		
Total	4.19	11			



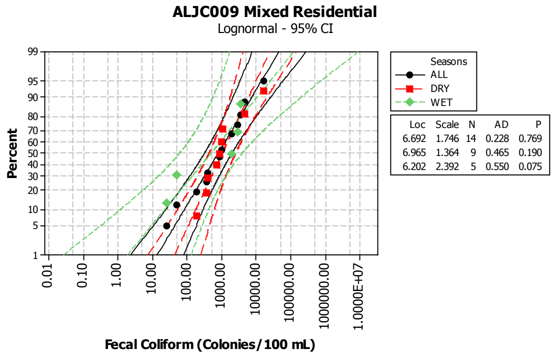
One-Way ANOVA

ALJC002 Log FC	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	1.03	1	1.03	1.08	0.325
Within Seasons	8.55	9	0.950		
Total	9.58	10			



One-Way ANOVA

ALJC009 Log FC	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.353	1	0.353	0.594	0.456
Within Seasons	7.12	12	0.594		
Total	7.48	13			



One-Way ANOVA

ALJC010 Log FC	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.767	1	0.767	1.31	0.285
Within Seasons	4.68	8	0.585		
Total	5.44	9			

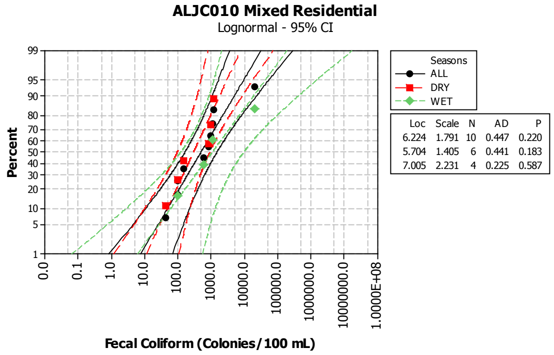


Fig. D39. Fecal Coliform Bacteria – Jefferson County Watersheds
Checks for Normality and Seasonal Differences

One-Way ANOVA

ALJC012 Log FC	Sum of Squares	DF	Mean Square	F	p-value
Between Seasons	0.039	1	0.039	0.064	0.809
Within Seasons	3.68	6	0.614		
Total	3.72	7			

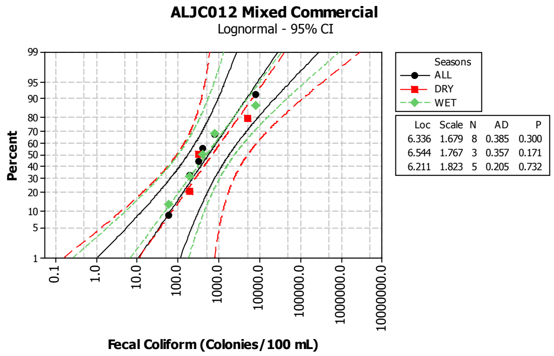


Fig. D39. – *Continued*

Table D51. Power of the Test for Fecal Coliform Bacteria – Jefferson County Watersheds Separated by Seasons

ALJC001 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	α level	Power (%)
DRY	5	2.9	0.72	0.20	33.1
WET	7	2.6	0.55	0.15	26.9
Pooled Standard Deviation			0.62	0.10	19.9
Obtained Effect Size			0.24	***0.05***	***11.6***
				0.01	3.1

ALJC002 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	α level	Power (%)
DRY	5	2.2	0.87	0.20	39.1
WET	6	2.8	1.1	0.15	32.5
Pooled Standard Deviation			0.97	0.10	24.7
Obtained Effect Size			0.31	***0.05***	***15.0***
				0.01	4.2

ALJC009 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	α level	Power (%)
DRY	9	3.0	0.59	0.20	29.7
WET	5	2.7	1.0	0.15	23.8
Pooled Standard Deviation			0.77	0.10	17.3
Obtained Effect Size			0.19	***0.05***	***9.9***
				0.01	2.5

ALJC010 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	α level	Power (%)
DRY	6	2.5	0.61	0.20	38.9
WET	4	3.0	0.97	0.15	32.2
Pooled Standard Deviation			0.76	0.10	24.3
Obtained Effect Size			0.32	***0.05***	***14.7***
				0.01	4.1

ALJC012 Season	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$	α level	Power (%)
DRY	3	2.8	0.77	0.20	20.6
WET	5	2.7	0.79	0.15	15.5
Pooled Standard Deviation			0.78	0.10	10.4
Obtained Effect Size			0.06	***0.05***	***5.3***
				0.01	1.1

Table D52. Summary Statistics for Fecal Coliform Bacteria – Jefferson County Watersheds Separated by Seasons

Watershed	**Seasons**	**N**	**Mean**	**p-value**	**Power (%)**	**Significant (?)**	**Results**
ALJC001	DRY WET	5 7	2.9 2.6	0.404	11.6	No	No seasonal influence
ALJC002	DRY WET	5 6	2.2 2.8	0.325	15.0	No	No seasonal influence
ALJC009	DRY WET	9 5	3.0 2.7	0.456	9.9	No	No seasonal influence
ALJC010	DRY WET	6 4	2.5 3.0	0.285	14.7	No	No seasonal influence
ALJC012	DRY WET	3 5	2.8 2.7	0.809	5.3	No	No seasonal influence

Table D53. Statistical Analyses for Fecal Coliform Bacteria – Jefferson County Watershed Groups

ANOVA (Watersheds: Log Fecal Coliform)

P = 0.788

Log FC	**Sum of Squares**	**DF**	**Mean Square**	**F**
Between Watersheds	1.04	4	0.260	0.43
Within Watersheds	30.4	50	0.608	
Total	31.5	54		

Watershed Log Fecal Coliform Groups

ALJC	**Gr. A**
1	2.7
2	2.5
9	2.9
10	2.7
12	2.8

Table D54. Power of the Test for Fecal Coliform Bacteria – Jefferson County Watershed Groups

Watersheds	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	12	2.7	0.62
ALJC002	11	2.5	0.98
ALJC009	14	2.9	0.76
ALJC010	10	2.7	0.78
ALJC012	8	2.8	0.73
Pooled Standard Deviation			0.78
Obtained Effect Size			0.18

α level	**Power (%)**
0.20	37.7
0.15	31.0
0.10	23.4
0.05	***14.2***
0.01	4.2

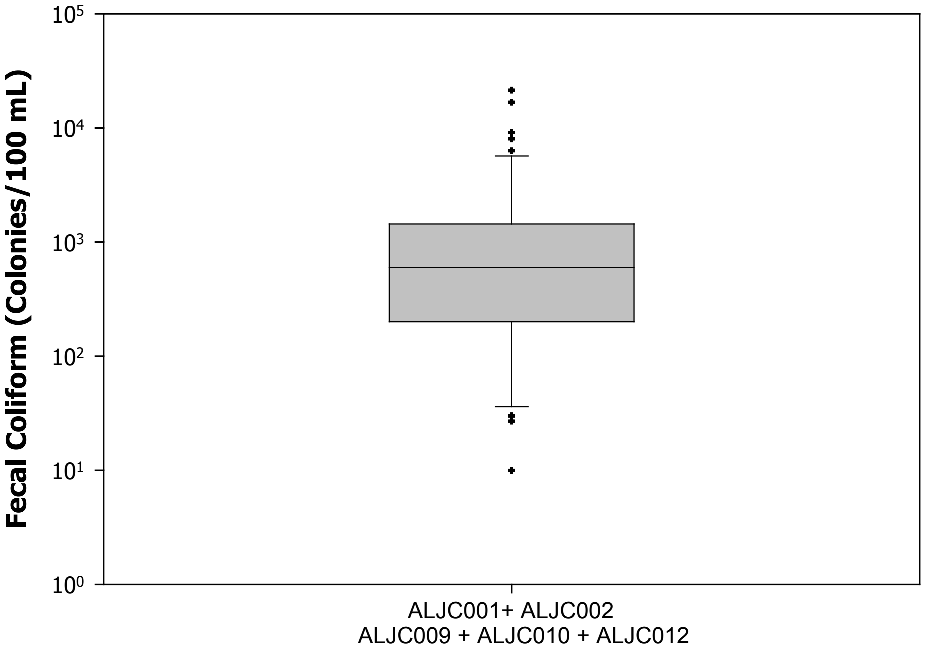


Fig. D40. Fecal Coliform Bacteria – Jefferson County Watershed Homogeneous Group

Table D55. Basic Statistics for Jefferson County Watersheds –
Fecal Coliform Bacteria Homogeneous Group (Real Space Data) (Colonies/100mL)

Groups		N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
A	ALJC001, ALJC002 ALJC009, ALJC010 ALJC012	55	1975	3922	2.0	10	600	21400

Appendix E

Alabama Jefferson County Watersheds – Detailed Analyses of Selected Land Development Characteristics

E.1 Land Development Characteristics Used for Analyses

Table E1. ALJC001 Watershed - Land Development Characteristics (Percentages)

ALJC001	**DCIA**	**DSIA**	**Total Pervious**	**Street Area**	**Paved Parking Area**	**Connected Roof Area**	**Disconnected Roof Area**	**Small Landscaped Area**
SHOP 102	75	0	25	27	36	12	0	21
SHOP 105	53	0	47	20	19	14	0	0
SHOP 108	93	0	6.6	29	52	12	0	6.6
SHOP 109	95	0	5.4	24	40	24	0	5.4
SHOP 112	67	0	33	12	39	16	0	0
RLD 103	18	24	58	18	0	0	24	58
RMD 110	24	22	53	24	0	0	22	53
ID 107	100	0	0	34	45	21	0	0
ID 100	76	2.7	22	15	44	17	3	0
CEM 111	21	0	79	21	0	0	0	0
UND 106	7.6	0	92	7.6	0	0	0	0
UND 113	6.7	0	93	6.7	0	0	0	0
FW 101	0	55	45	46	8.3	0	0	0

Table E2. ALJC002 Watershed - Land Development Characteristics (Percentages)

ALJC002	DCIA	DSIA	Total Pervious	Street Area	Paved Parking Area	Connected Roof Area	Disconnected Roof Area	Small Landscaped Area
SHOP 202	100	0	0	30	54	12	0	0
SHOP 203	100	0	0	24	51	26	0	0
SHOP 204	100	0	0	21	66	10	0	0
SHOP 206	92	0	8.3	28	46	18	0	0
SHOP 207	59	0	41	24	17	16	0	0
RHD 213	34	8.1	58	30	1.4	1.7	6.7	14
RHD 216	34	12	54	23	0	8.1	8.1	54
RHD 218	30	12	58	18	0	8.6	8.7	58
RMD 214	31	10	59	27	0	2.0	8.1	59
RMD 215	24	10	65	21	0	2.4	10	46
RMD 217	24	18	58	24	0	0	18	43
ID 205	24	0	76	13	0	11	0	0
ID 208	37	25	39	7.6	14	9.4	7.7	0
ID 209	74	6.8	19	17	15	15	6.8	0
ID 210	100	0	0	16	59	25	0	0
SCH 211	48	0	52	23	16	10	0	8.5
CHU 212	67	0	33	37	21	9.0	0	33
UND 201	18	0	82	18	0	0	0	0

Table E3. ALJC009 Watershed - Land Development Characteristics (Percentages)

ALJC009	DCIA	DSIA	Total Pervious	Street Area	Paved Parking Area	Connected Roof Area	Disconnected Roof Area	Small Landscaped Area
SHOP 902	73	1.4	25	21	28	23	0	0
RHD 904	32	12	56	25	0	7.1	12	56
RHD 901	24	14	62	15	0	6.7	10	62
SCH 905	40	1.8	58	5.1	15	18	0	0
CHU 903	67	11	22	17	20	19	0	22

Table E4. ALJC002 Watershed - Land Development Characteristics (Percentages)

ALJC010	DCIA	DSIA	Total Pervious	Street Area	Paved Parking Area	Connected Roof Area	Disconnected Roof Area	Small Landscaped Area
RLD 1001	34	10	57	23	0	7.8	7.0	57
RLD 1002	15	7.4	77	7.3	0	5.4	4.8	77
RLD 1003	31	10	59	19	0	7.8	6.9	59
RLD 1004	27	10	63	16	0	6.2	5.5	63
RLD 1005	26	9.4	64	16	0	6.9	6.1	64
UND1000	0	0	100	0	0	0	0	0

Table E5. ALJC002 Watershed - Land Development Characteristics (Percentages)

ALJC012	DCIA	DSIA	Total Pervious	Street Area	Paved Parking Area	Connected Roof Area	Disconnected Roof Area	Small Landscaped Area
APT 1201	33	6.8	60	12	15	6.8	6.8	0
APT 1202	23	5.5	71	6.2	12	5.5	5.5	0
APT 1203	34	5.8	61	15	13	5.8	5.8	0
APT 1204	30	6.0	64	11	14	6.0	6.0	0
APT 1205	46	0	54	5.4	18	22	0	0
SHOP 1206	72	0	28	16	36	14	0	0
SHOP 1207	79	0	21	10	38	19	0	0
SHOP 1208	84	0	16	13	37	20	0	0

E.2. Disconnected Impervious Area

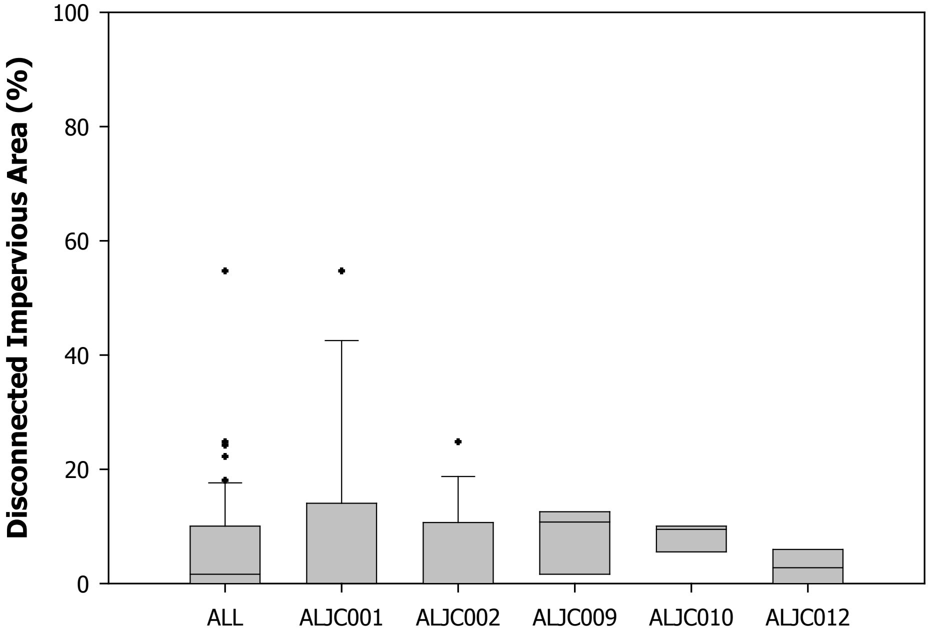


Fig. E1. Disconnected Impervious Area –
Jefferson County Watersheds

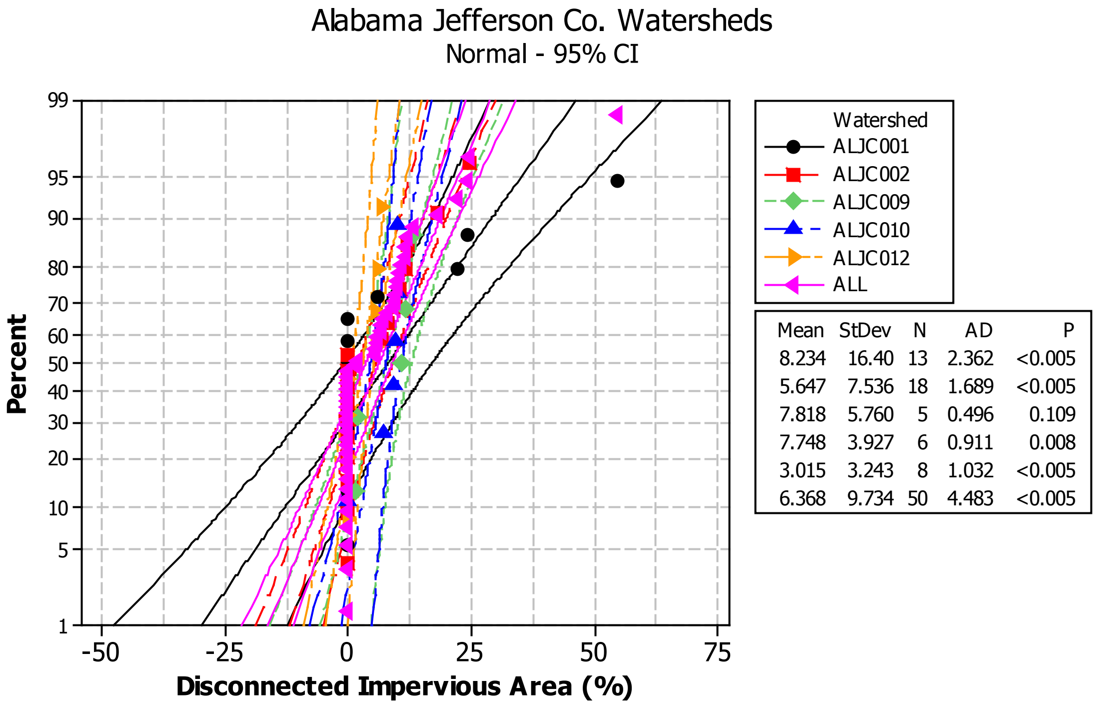


Fig. E2. Disconnected Impervious Area –
Jefferson County Watersheds (Checks for Normality)

Table E6. Statistical Analyses for Disconnected Impervious Area –
Jefferson County Watersheds

Kruskal-Wallis Test (Watersheds: %DSIA)

H = 5.45 DF = 4 P = 0.244
H = 6.13 DF = 4 P = 0.190 (adjusted for ties)

Watershed	N	Median	Ave Rank	Z
ALJC001	13	0	22.0	-1.0
ALJC002	18	0	24.9	-0.2
ALJC009	5	11	36.0	1.7
ALJC010	6	9.5	32.3	1.2
ALJC012	8	2.8	20.9	-1.0
Overall	50		25.5	

Power of the Test (Watersheds: %DSIA)

Watershed	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	13	8.2	16.4
ALJC002	18	5.7	7.5
ALJC009	5	7.8	5.8
ALJC010	6	7.8	3.9
ALJC012	8	3.0	3.2

α level	Power (%)
0.20	37.1
0.15	30.4
0.10	22.8
0.05	***13.7***
0.01	4.0

Pooled Standard Deviation	9.97
Obtained Effect Size	0.18

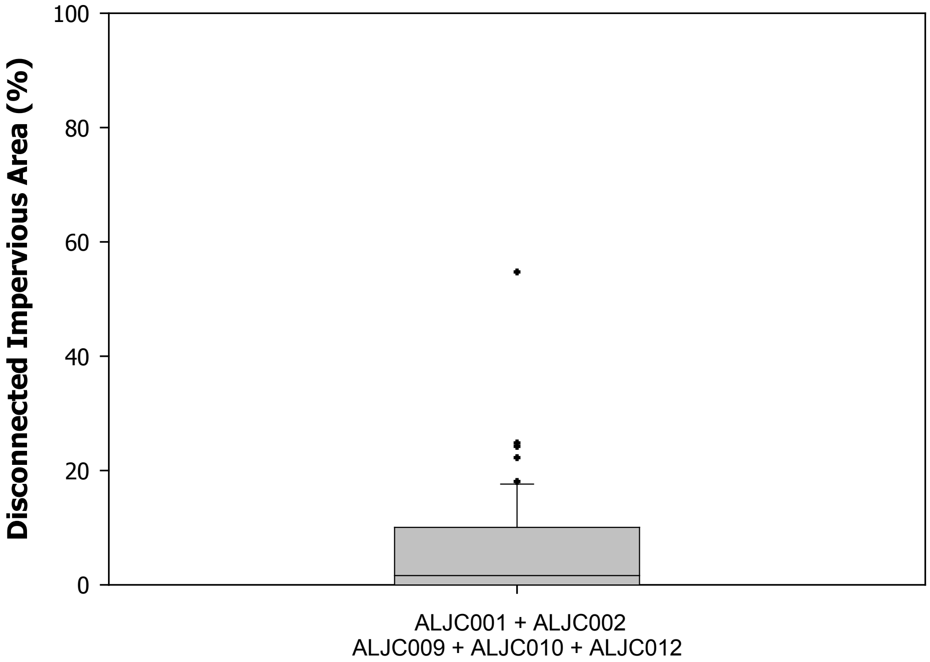


Fig. E3. Disconnected Impervious Area –
Jefferson County Watersheds Homogeneous Groups

Table E7. Basic Statistics for Jefferson County Watersheds –
Disconnected Impervious Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001+ALJC002+ALJC009 ALJC010+ALJC012	50	6.4	10	1.5	0	1.6	55

E.3. Total Pervious Area

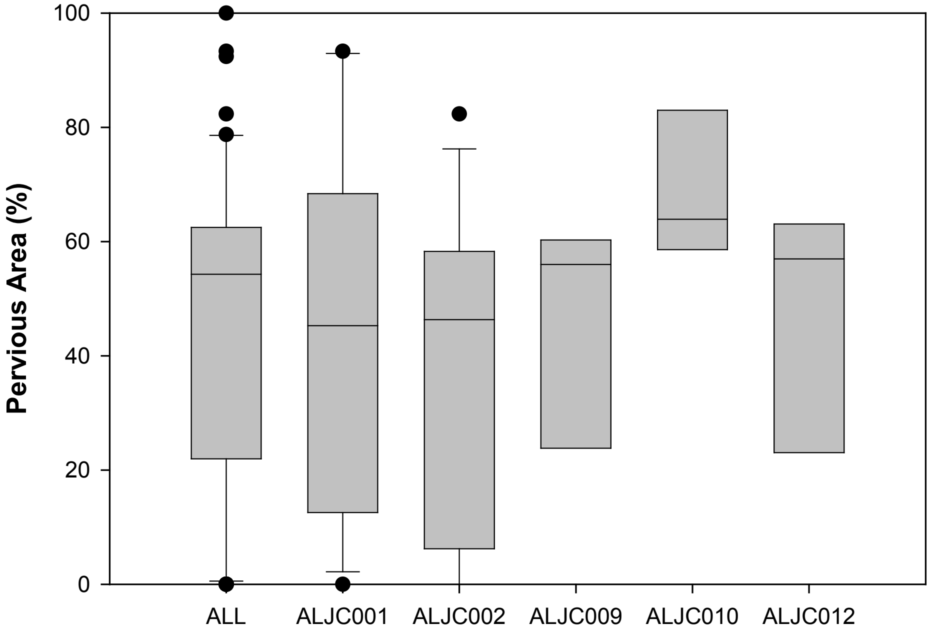
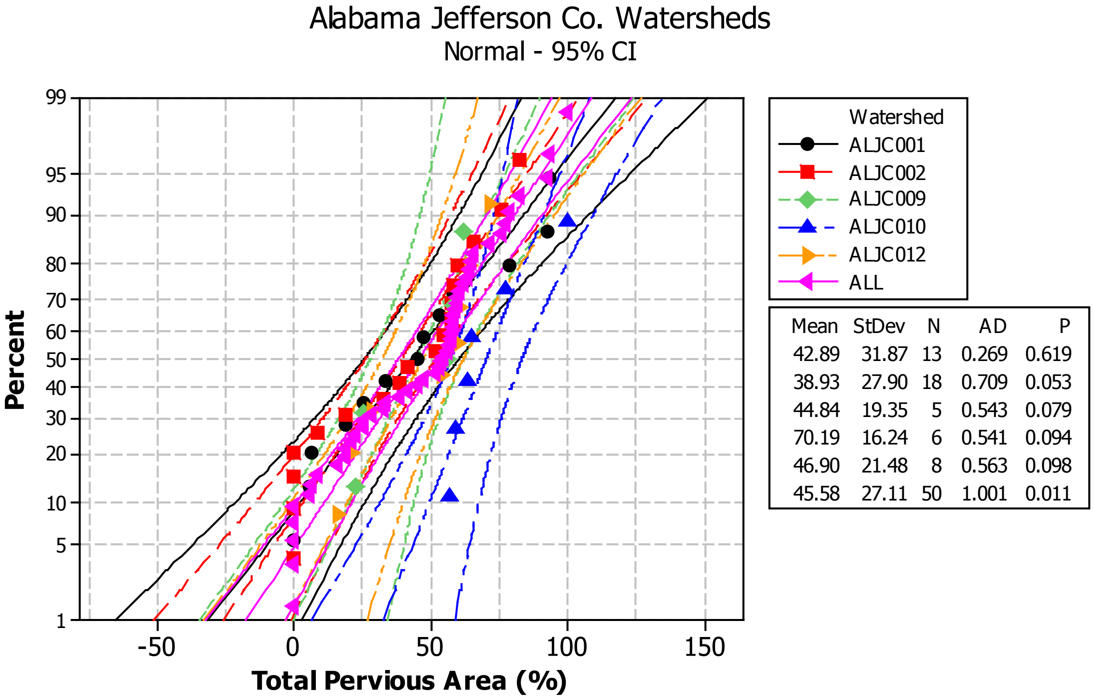


Fig. E4. Total Pervious Area – Jefferson County Watersheds



Mean	StDev	N	AD	P
42.89	31.87	13	0.269	0.619
38.93	27.90	18	0.709	0.053
44.84	19.35	5	0.543	0.079
70.19	16.24	6	0.541	0.094
46.90	21.48	8	0.563	0.098
45.58	27.11	50	1.001	0.011

Fig. E5. Total Pervious Area – Jefferson County Watersheds (Checks for Normality)

Table E8. Statistical Analyses for Total Pervious Area – Jefferson County Watersheds

Kruskal-Wallis Test
(Watersheds: %Total Pervious Area)

H = 7.12 DF = 4 P = 0.130
H = 7.12 DF = 4 P = 0.130 (adjusted for ties)

Watershed	N	Median	Ave Rank	Z
ALJC001	13	45.3	23.1	-0.7
ALJC002	18	46.3	21.9	-1.3
ALJC009	5	56.0	25.2	-0.1
ALJC010	6	63.9	39.5	2.5
ALJC012	8	57.0	27.3	0.4
Overall	50		25.5	

Power of the Test (Watersheds: %Total Pervious Area)

Watershed	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	13	42.9	31.9
ALJC002	18	38.9	27.9
ALJC009	5	44.8	19.4
ALJC010	6	70.2	16.2
ALJC012	8	46.9	21.5

Pooled Standard Deviation 26.4
Obtained Effect Size 0.36

α level	Power (%)
0.20	74.3
0.15	68.2
0.10	59.7
0.05	***46.2***
0.01	22.6

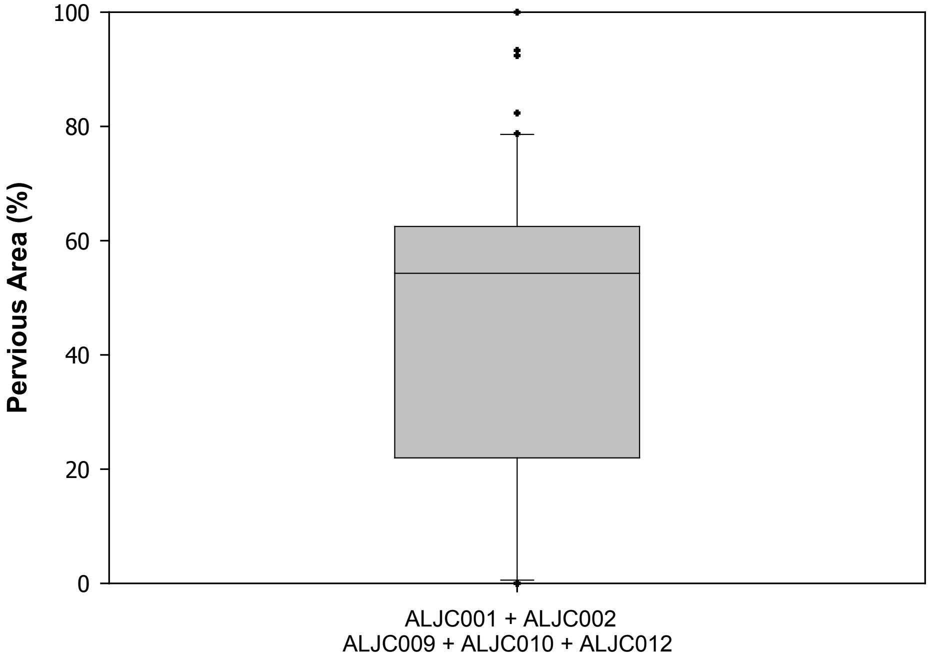


Fig. E6. Total Pervious Area – Jefferson County Watersheds Homogeneous Groups

Table E9. Basic Statistics for Jefferson County Watersheds – Total Pervious Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001+ALJC002+ALJC009 ALJC010+ALJC012	50	46	27	0.59	0	54	100

E.4. Paved Street Area

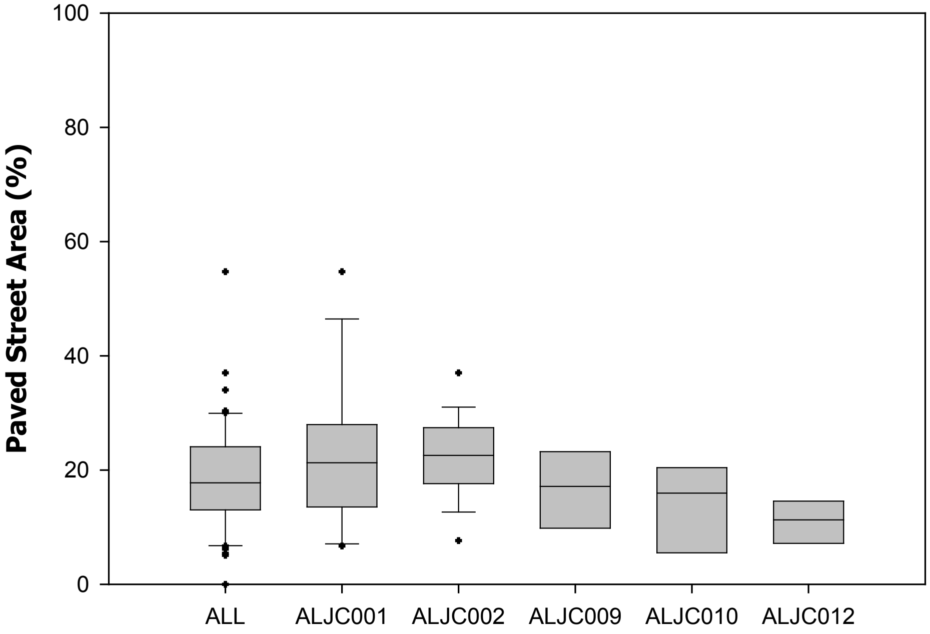


Fig. E7. Paved Street Area – Jefferson County Watersheds

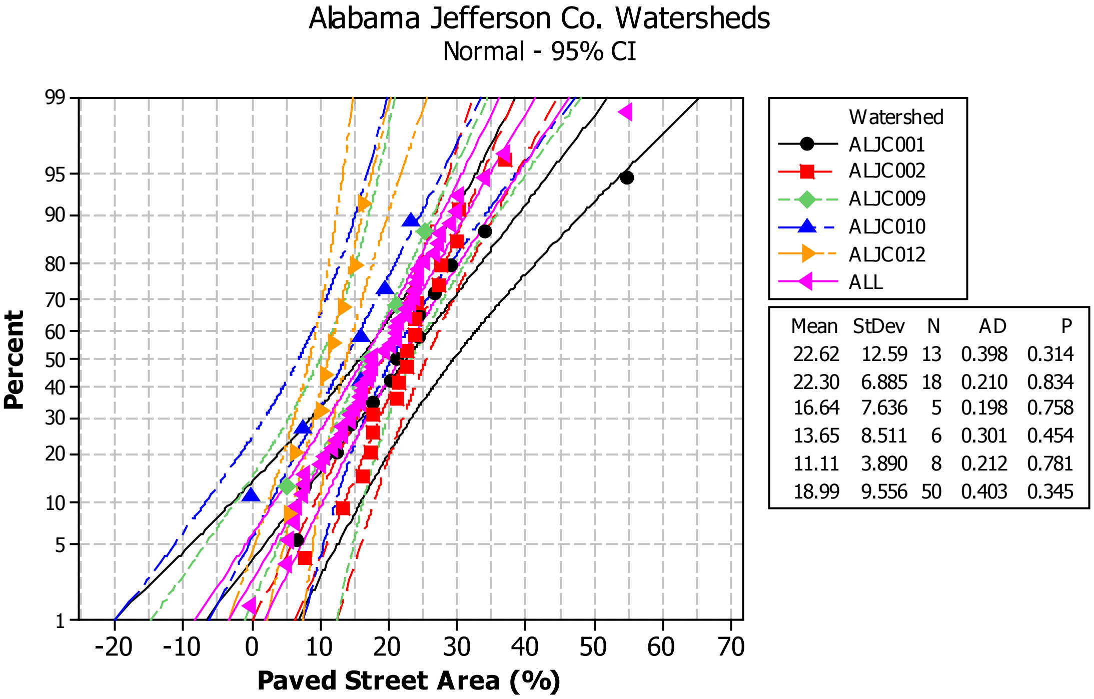


Fig. E8. Paved Street Area – Jefferson County Watersheds (Checks for Normality)

Table E10. Statistical Analyses for Paved Street Area – Jefferson County Watersheds

Kruskal-Wallis Test
(Watersheds: %Paved Street Area)

H = 15.03 DF = 4 P = 0.005

Watershed	N	Median	Ave Rank	Z
ALJC001	13	21.3	29.8	1.2
ALJC002	18	22.6	32.4	2.5
ALJC009	5	17.1	21.8	-0.6
ALJC010	6	16.0	17.7	-1.4
ALJC012	8	11.3	11.1	-3.0
Overall	50		25.5	

Multiple Comparisons
(Mann-Whitney U Test)

(I) ALJC	(J) ALJC	p-value
1	2	0.764
	9	0.324
	10	0.125
	12	0.013*
2	9	0.127
	10	0.026*
	12	0.001*
9	10	0.648
	12	0.164
10	12	0.333

Watershed
%Paved Street Area
Groups
(medians)

ALJC	Gr. A	Gr. B
1	21.3	
2	22.6	
9		17.1
10		16.0
12		11.3

Table E11. Power of the Test for Paved Street Area – Jefferson County Watersheds

Watershed	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	13	22.6	12.6
ALJC002	18	22.3	6.9
ALJC009	5	16.6	7.6
ALJC010	6	13.7	8.5
ALJC012	8	11.1	3.9
Pooled Standard Deviation			8.7
Obtained Effect Size			0.53

α level	Power (%)
0.20	95.4
0.15	93.4
0.10	90.0
0.05	***82.5***
0.01	60.3

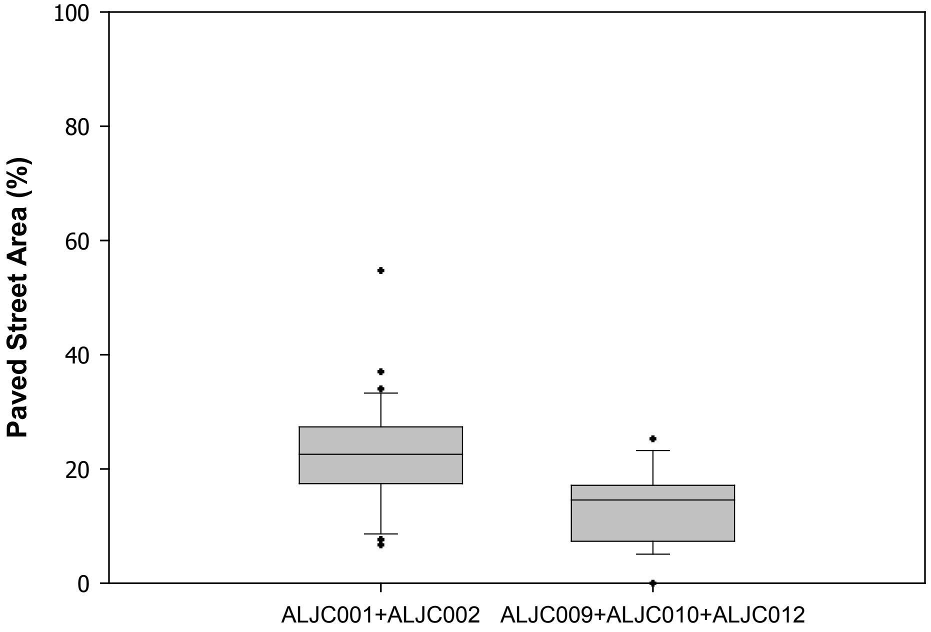


Fig. E9. Paved Street Area - Jefferson County Watersheds Homogeneous Groups

Table E12. Statistical Analyses for Paved Street Area –
Jefferson County Watersheds Homogeneous Groups

Kruskal-Wallis Test
(Watershed Groups: %Paved Street Area)

H = 13.02 DF = 1 P = 0.000

Groups	N	Median	Ave Rank	Z
ALJC001+ALJC002	31	22.6	31.3	4
ALJC009+ALJC010 ALJC012	19	14.6	16.0	-4
Overall	50		25.5	

Power of the Test
(Watershed Groups: %Paved Street Area)

Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001+ ALJC002	31	22	10
ALJC009+ ALJC010 ALJC012	19	13	6.7

Pooled Standard Deviation	8.5
Obtained Effect Size	0.51

α level	Power (%)
0.20	99.0
0.15	98.4
0.10	97.4
0.05	***94.5***
0.01	82.4

Table E13. Basic Statistics for Jefferson County Watersheds –
Paved Street Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001+ALJC002	31	22	10	0.42	6.7	23	55
ALJC009+ALJC010+ALJC012	19	13	6.7	0.50	0	15	25

E.5. Paved Parking Lot Area

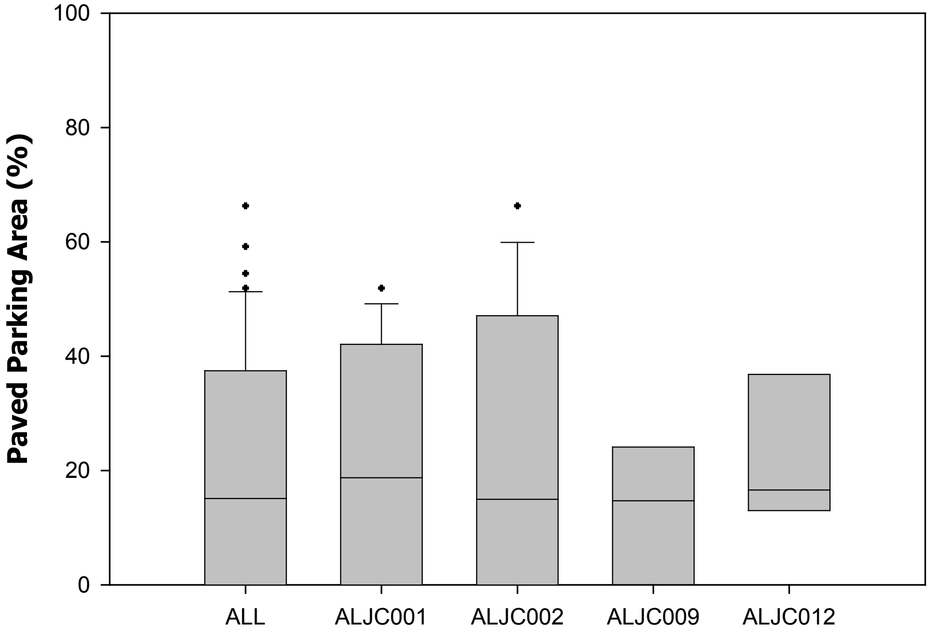


Fig. E10. Paved Parking Lot Area – Jefferson County Watersheds

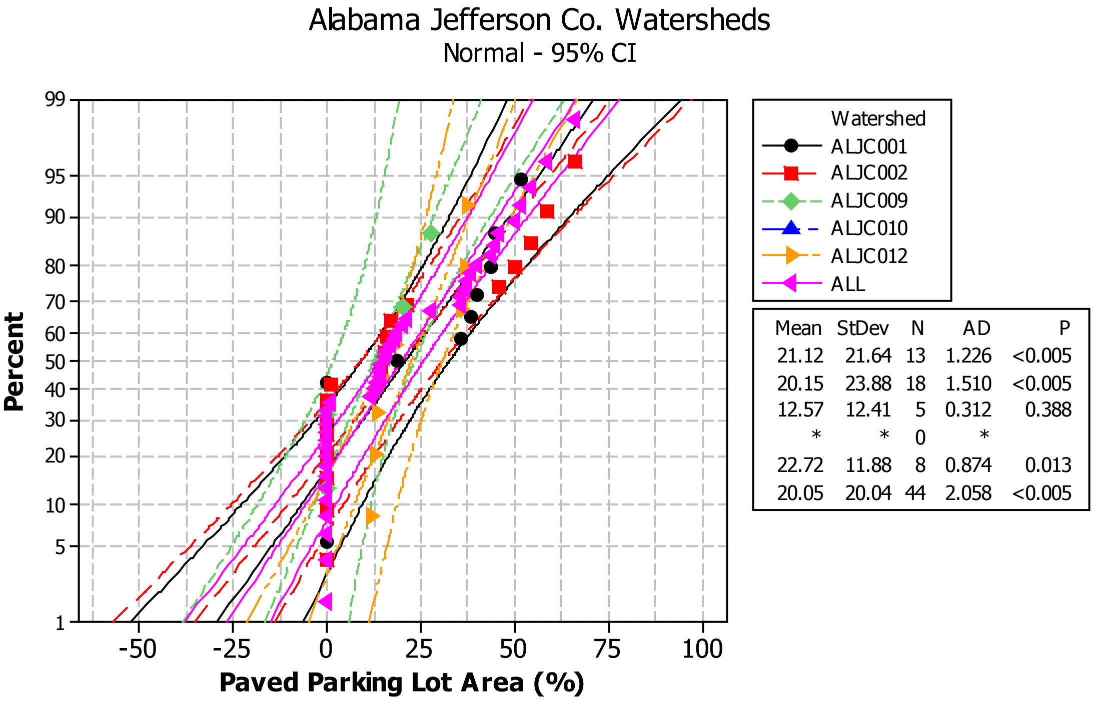


Fig. E11. Paved Parking Lot Area – Jefferson County Watersheds
(Checks for Normality)

Table E14. Statistical Analyses for Paved Parking Lot Area – Jefferson County Watersheds

Kruskal-Wallis Test
(Watersheds: %Paved Parking Lots)

H = 0.68 DF = 3 P = 0.878
H = 0.71 DF = 3 P = 0.871 (adjusted for ties)

Watershed	N	Median	Ave Rank	Z
ALJC001	13	18.7	22.6	0.0
ALJC002	18	15.0	22.3	-0.1
ALJC009	5	14.7	19.0	-0.7
ALJC012	8	16.6	25.0	0.6
Overall	44		22.5	

Power of the Test
(Watersheds: %Paved Parking Lots)

Watershed	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	13	21.1	21.6
ALJC002	18	20.2	23.9
ALJC009	5	12.6	12.4
ALJC012	8	22.7	11.9
Pooled Standard Deviation			20.6
Obtained Effect Size			0.14

α level	Power (%)
0.20	29.9
0.15	23.8
0.10	17.2
0.05	***9.8***
0.01	2.5

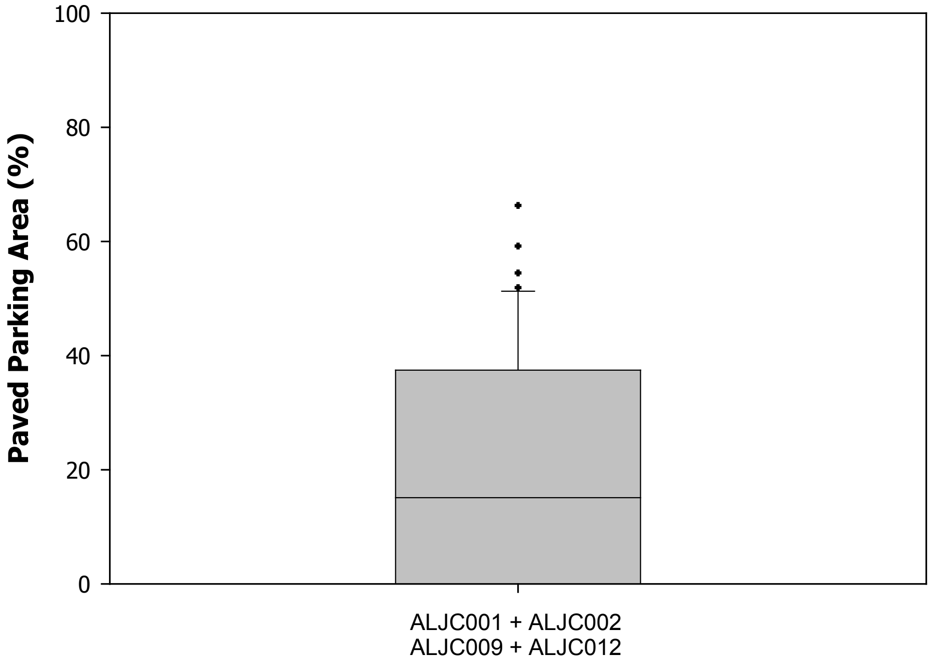


Fig. E12. Paved Parking Lot Area – Jefferson County Watersheds Homogeneous Groups

Table E15. Basic Statistics for Jefferson County Watersheds – Paved Parking Lot Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001+ALJC002 ALJC009+ALJC012	44	20	20	1.0	0	15	66

E.6. Connected Roof Area

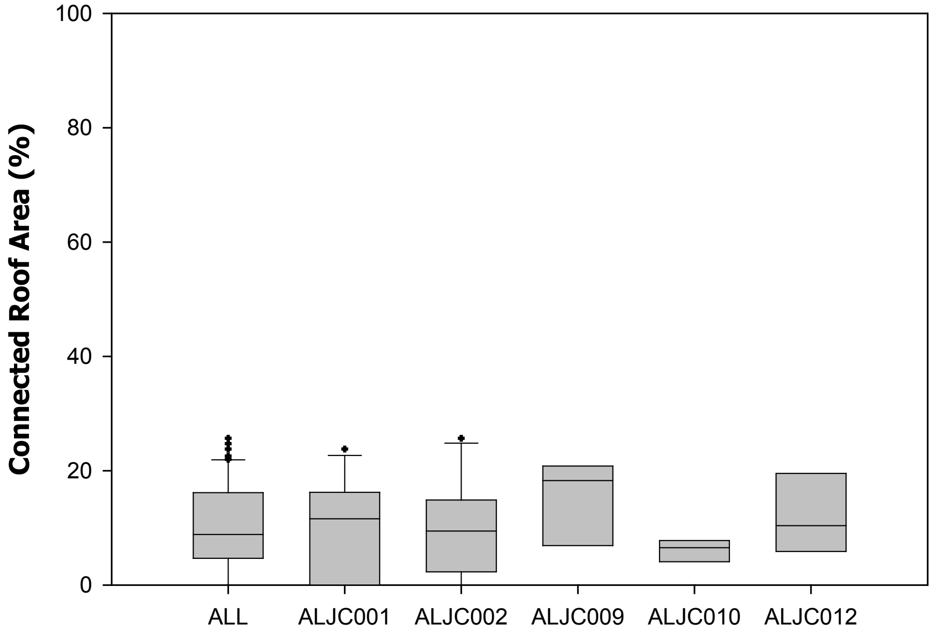


Fig. E13. Connected Roof Area – Jefferson County Watersheds

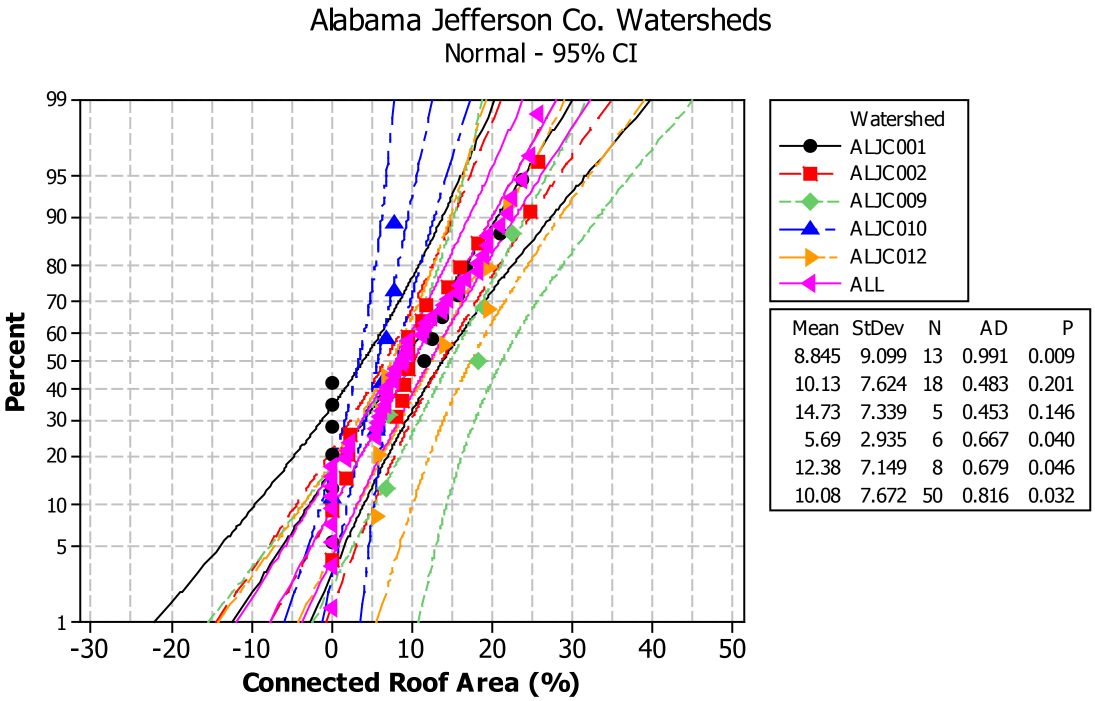


Fig. E14. Connected Roof Area – Jefferson County Watersheds (Checks for Normality)

Table E16. Statistical Analyses for Connected Roof Area - Jefferson County Watersheds

Kruskal-Wallis Test
(Watersheds: %Connected Roof Area)

H = 4.80 DF = 4 P = 0.308
H = 4.83 DF = 4 P = 0.305 (adjusted for ties)

Watershed	N	Median	Ave Rank	Z
ALJC001	13	11.6	22.8	-0.8
ALJC002	18	9.5	26.5	0.4
ALJC009	5	18.3	33.8	1.3
ALJC010	6	6.5	16.7	-1.6
ALJC012	8	10.4	29.0	0.7
Overall	50		26	

Power of the Test
(Watersheds: %Connected Roof Area)

Watershed	n	$\mu_{\overline{x}}$	$\sigma_{\overline{x}}$
ALJC001	13	8.8	9.1
ALJC002	18	10.1	7.6
ALJC009	5	14.7	7.3
ALJC010	6	5.7	2.9
ALJC012	8	12.4	7.2

Pooled Standard Deviation 7.6
Obtained Effect Size 0.31

α level	Power (%)
0.20	64.8
0.15	57.9
0.10	48.9
0.05	***35.6***
0.01	15.3

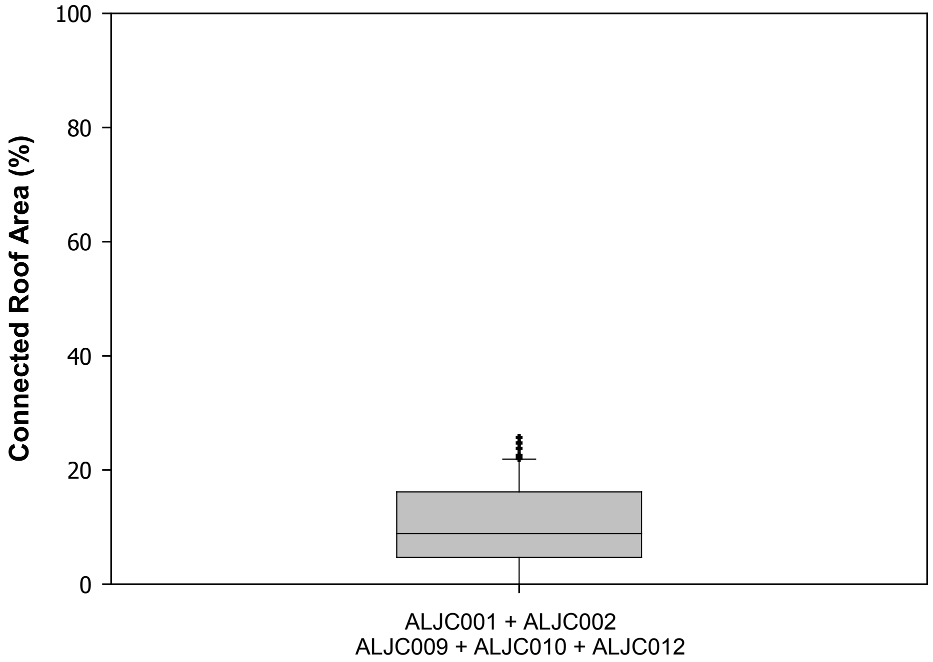


Fig. E15. Connected Roof Area – Jefferson County Watersheds Homogeneous Groups

Table E17. Basic Statistics for Jefferson County Watersheds – Connected Roof Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001+ALJC002+ALJC009 ALJC010+ALJC012	50	10	7.7	0.76	0	8.8	26

E.7. Disconnected Roof Area

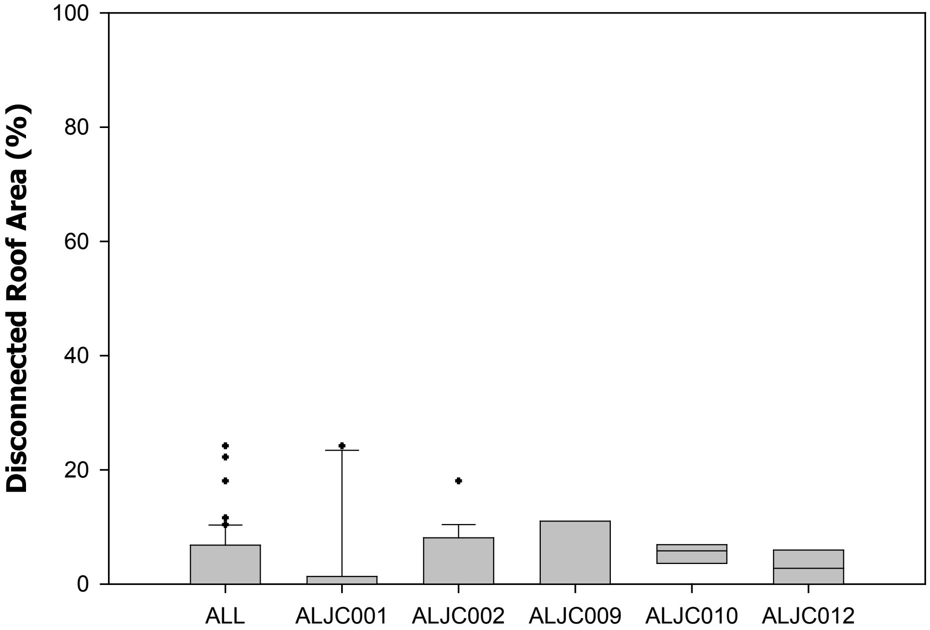
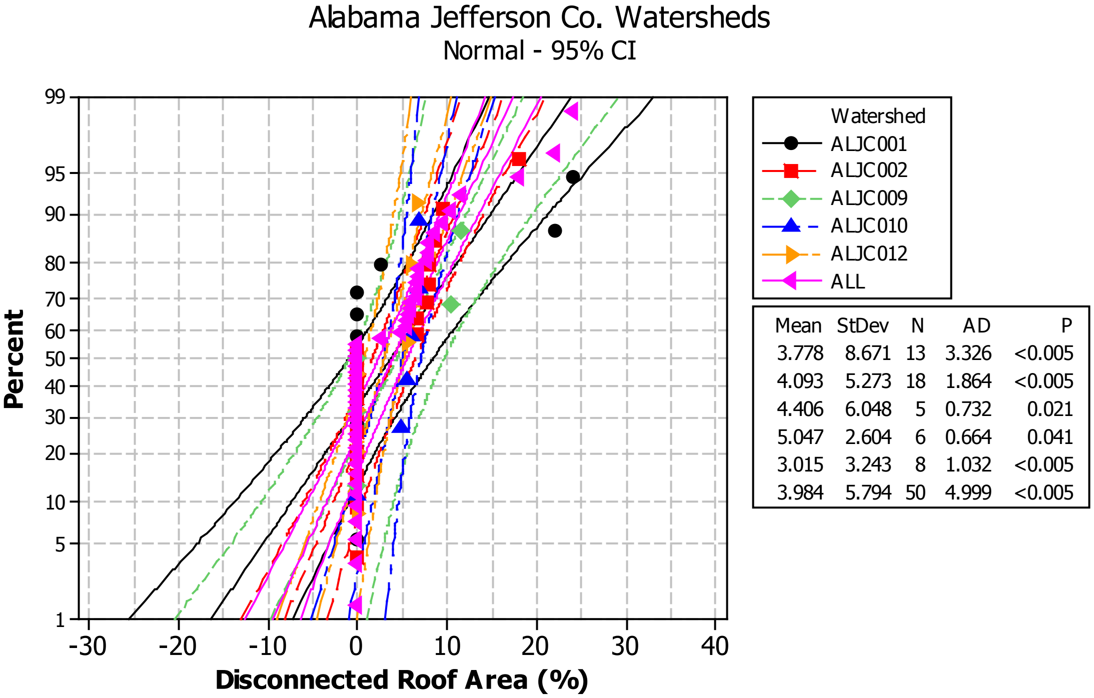


Fig. E16. Disconnected Roof Area – Jefferson County Watersheds



Mean	StDev	N	AD	P
3.778	8.671	13	3.326	<0.005
4.093	5.273	18	1.864	<0.005
4.406	6.048	5	0.732	0.021
5.047	2.604	6	0.664	0.041
3.015	3.243	8	1.032	<0.005
3.984	5.794	50	4.999	<0.005

Fig. E17. Disconnected Roof Area – Jefferson County Watersheds
(Checks for Normality)

Table E18. Statistical Analyses for Disconnected Roof Area – Jefferson County Watersheds

Kruskal-Wallis Test
(Watersheds: %Disconnected Roof Area)

H = 2.60 DF = 4 P = 0.626
H = 3.16 DF = 4 P = 0.532 (adjusted for ties)

Watershed	N	Median	Ave Rank	Z
ALJC001	13	0	21.0	-1.3
ALJC002	18	0	26.7	0.4
ALJC009	5	0	27.3	0.3
ALJC010	6	5.8	31.8	1.1
ALJC012	8	2.8	24.3	-0.3
Overall	50		25.5	

Power of the Test
(Watersheds: %Disconnected Roof Area)

Watershed	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	13	3.8	8.7
ALJC002	18	4.1	5.3
ALJC009	5	4.4	6.1
ALJC010	6	5.1	2.6
ALJC012	8	3.0	3.2

Pooled Standard Deviation 6.0
Obtained Effect Size 0.10

α level	Power (%)
0.20	24.9
0.15	19.3
0.10	13.4
0.05	***7.2***
0.01	1.6

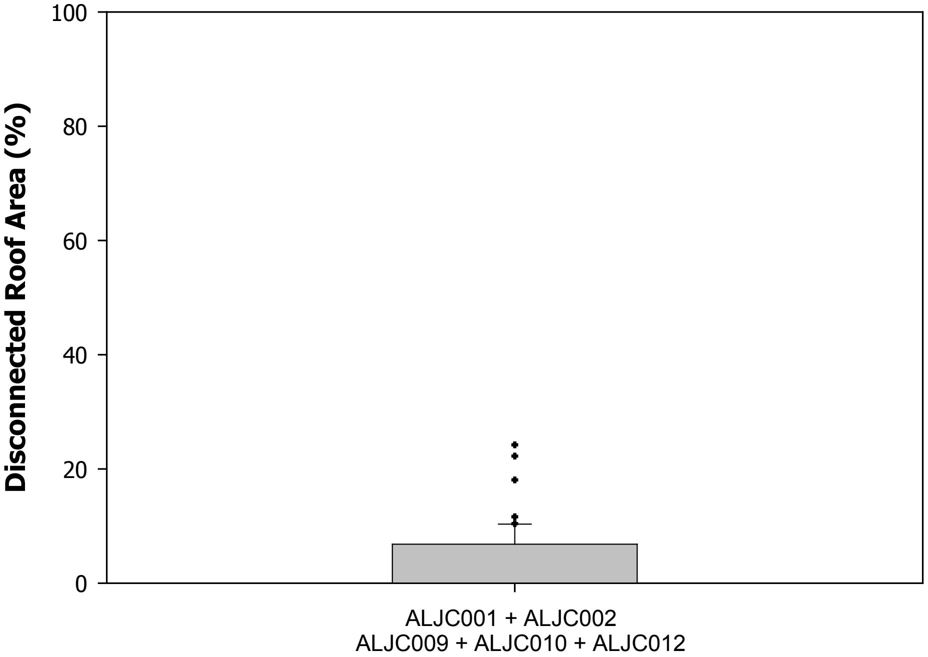


Fig. E18. Disconnected Roof Area – Homogeneous Groups

Table E19. Basic Statistics for Jefferson County Watersheds – Disconnected Roof Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
ALJC001+ALJC002+ALJC009 ALJC010+ALJC012	50	4.0	5.8	1.5	0	0	24

E.8. Small Landscaped Area

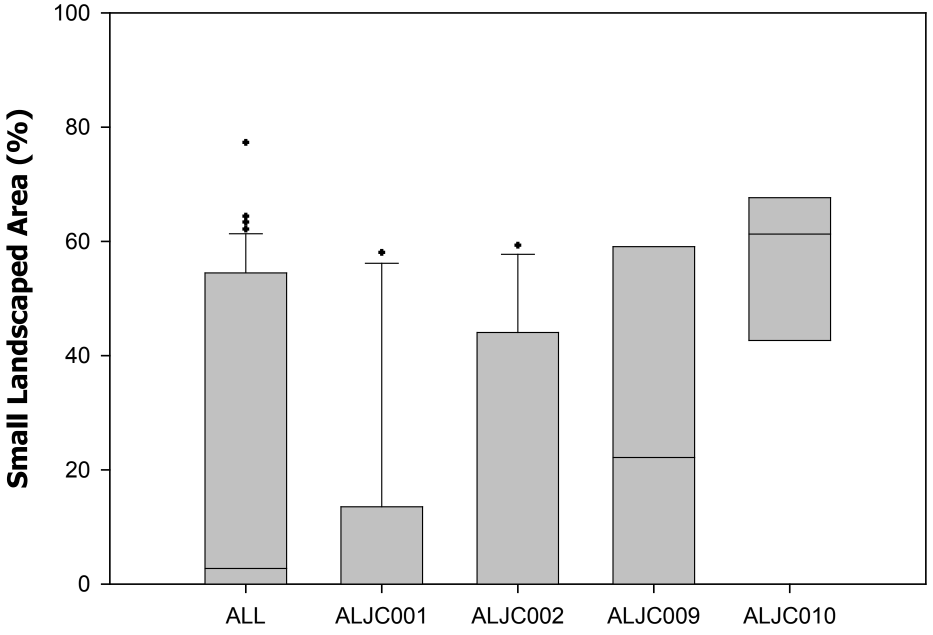


Fig. E19. Small Landscaped Area – Jefferson County Watersheds

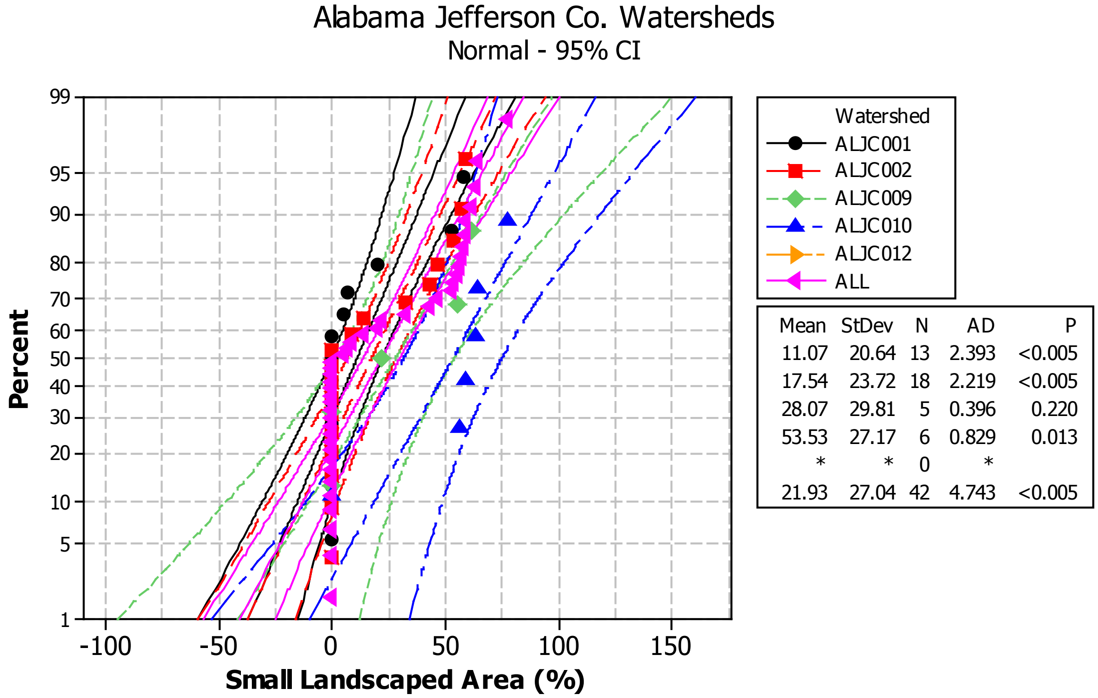


Fig. E20. Small Landscaped Area – Jefferson County Watersheds
(Checks for Normality)

Table E20. Statistical Analyses for Small Landscaped Area – Jefferson County Watersheds

Kruskal-Wallis Test
(Watersheds: %Small Landscaped Area)

H = 8.58 DF = 3 P = 0.035
H = 9.80 DF = 3 P = 0.020 (adjusted for ties)

Watershed	N	Median	Ave Rank	Z
ALJC001	13	0	17.4	-1.5
ALJC002	18	0	19.5	-0.9
ALJC009	5	22	24.2	0.5
ALJC010	6	61	34.2	2.7
Overall	42		21.5	

Multiple Comparisons
(Mann-Whitney U Test)

(I) ALJC	(J) ALJC	p-value
1	2	0.617
	9	0.278
	10	0.012*
2	9	0.434
	10	0.012*
9	10	0.121

Watershed
%Small Landscaped
Area Groups
(medians)

ALJC	Gr. A	Gr. B
1	0	
2	0	
9	22	
10		61

Table E21. Power of the Test for Small Landscaped Area – Jefferson County Watersheds

Watershed	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001	13	11	20.6
ALJC002	18	18	23.7
ALJC009	5	28	29.8
ALJC010	6	54	27.2
Pooled Standard Deviation			24.0
Obtained Effect Size			0.58

α level	Power (%)
0.20	96.7
0.15	95.1
0.10	92.3
0.05	***85.9***
0.01	65.4

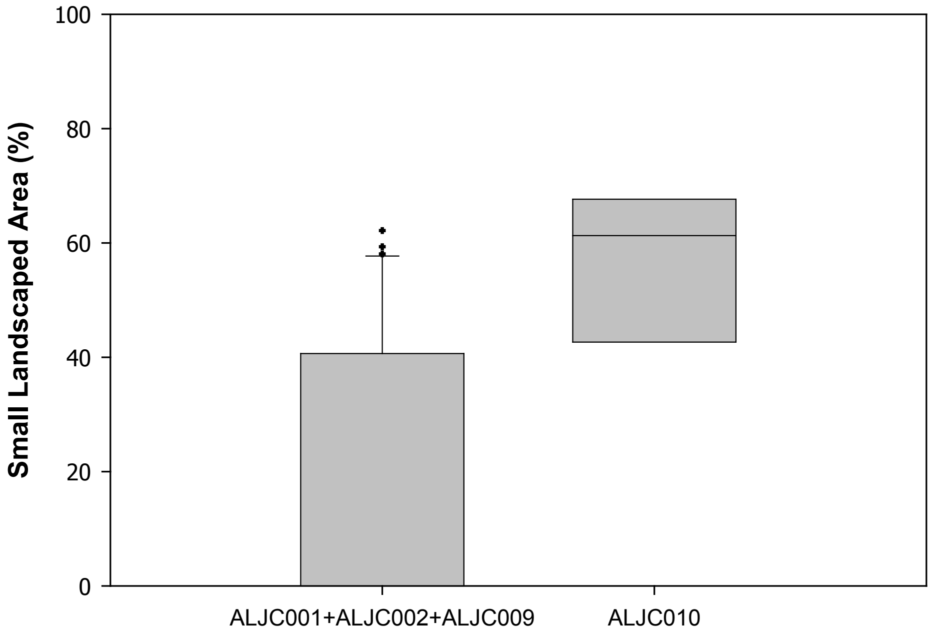


Fig. E21. Small Landscaped Area - Jefferson County Watersheds Homogeneous Groups

Table E22. Statistical Analyses for Small Landscaped Area – Jefferson County Watersheds Homogeneous Groups

Kruskal-Wallis Test
(Watershed Groups: %Small Landscaped Area)

H = 7.46 DF = 1 P = 0.006
H = 8.53 DF = 1 P = 0.004 (adjusted for ties)

Groups	**N**	**Median**	**Ave Rank**	**Z**
ALJC001+ALJC002 ALJC009	36	0	19.4	-3
ALJC010	6	61	34.2	3
Overall	42		21.5	

Power of the Test
(Watershed Groups: %Small Landscaped Area)

Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
ALJC001+ ALJC002 ALJC009	36	17	23
ALJC010	6	54	27

Pooled Standard Deviation 24
Obtained Effect Size 0.54

α level	**Power (%)**
0.20	98.5
0.15	97.8
0.10	96.4
0.05	***92.7***
0.01	78.2

Table E23. Basic Statistics for Jefferson County Watersheds – Small Landscaped Area Homogeneous Groups (%)

Groups	**N**	**Mean**	**Standard Deviation**	**Coefficient of Variation**	**Minimum**	**Median**	**Maximum**
ALJC001+ALJC002 ALJC009	36	17	23	1.4	0	0	62
ALJC010	6	54	27	0.51	0	61	77

Appendix F

Alabama Jefferson County Land Uses – Detailed Analyses of Selected Land Development Characteristics

Table F.1. Land Development Characteristics Used for Analyses

Land Use		**DCIA**	**DSIA**	**Total Pervious**	**Paved Street Area**	**Paved Parking Area**	**Connected Roof Area**	**Disconnected Roof Area**	**Small Landscaped Area**
High Density Residential	HD58	13	8.6	79	9.2	0	2.7	7.8	40
	HD63	22	11	67	12	0	7.7	9.0	67
	HD104	9.3	5.9	85	3.9	0	4.6	5.2	85
	HD105	12	5.4	83	4.9	0	5.0	3.3	83
	HD110	17	17	65	10	0	3.4	14	65
	HD111	16	20	64	5.5	0	8.0	18	64
	HD114	8.2	6.3	86	6.6	0	0.82	5.5	86
	HD116	16	7.2	77	8.4	0	6.0	6.0	77
	HD117	4.4	18	77	5.7	0	4.4	9.3	77
	HD120	17	5.2	78	12	0	3.2	3.0	78
	RH213	34	8.1	58	30	1.4	1.7	6.7	14
	RH216	34	12	54	23	0	8.1	8.1	54
	RH218	30	12	58	18	0	8.6	8.7	58
	RH901	24	14	62	15	0	6.7	10	62
	RH904	32	12	56	25	0	7.1	12	56
Freeways	HY101	0	55	45	46	8.3	0	0	45
	FW88	0	63	37	53	11	0	0	26
	FW96	0	56	44	48	8.6	0	0	35
	FW97	0	55	45	46	9.4	0	0	37
	FW98	0	71	29	52	19	0	0	22
	FW113	0	49	51	35	14	0	0	41

Table F1. - *Continued*

Land Use		DCIA	DSIA	Total Pervious	Paved Street Area	Paved Parking Area	Connected Roof Area	Disconnected Roof Area	Small Landscaped Area
Med. Density Residential	MD52a	0	16	84	5.5	0	0	7.6	84
	MD61a	1.1	13	86	5.3	0	1.1	3.6	86
	MD66a	8.1	7.1	85	5.2	0	1.8	6.1	85
	MD67a	11	4.7	84	4.0	0	5.5	3.4	84
	MD69a	8.9	5.2	86	4.9	0	2.8	4.0	86
	MD80a	9.0	5.4	86	5.8	0	1.5	3.7	86
	MD99a	13	6.7	80	7.3	0	4.0	5.1	80
	MD100a	26	11	63	5.6	0	17	7.7	63
	MD101a	14	3.7	83	6.4	0	6.3	2.8	83
	MD112a	0	19	81	5.8	0	0	11	81
	MD1b	3.9	19	77	4.6	0	3.9	12	77
	MDA1b	1.5	15	83	8.6	0	1.5	4.2	82
	MD19b	7.1	5.6	87	4.6	0	2.0	5.1	87
	MD102b	13	3.1	83	9.1	0	2.7	1.5	83
	MD103b	10	6.0	84	7.4	0	1.4	4.7	84
	MD106b	12	4.6	84	6.8	0	2.5	2.1	84
	MD107b	11	28	61	6.7	0	0	24	61
	MD109b	9.1	3.6	87	5.2	0	2.8	2.5	87
	MD122b	12	4.9	84	7.7	0	2.8	3.9	84
	MD32c	29	6.0	65	11	0	18	5.6	41
	MD84c	12	4.1	84	6.2	0	4.6	3.2	84
	MD85c	17	0.8	82	8.9	0	7.1	0	82
	MD86c	13	4.1	83	8.2	0	4.0	3.7	73
	MD87c	17	2.2	80	10	0	6.8	1.3	80
	MD90c	11	3.8	85	5.8	0	3.7	2.6	85
	MD91c	8.1	4.8	87	3.1	0	3.3	3.1	83
	MD92c	15	8.6	76	8.1	0	5.3	6.5	76
	RM110	24	22	53	24	0	0	22	53
	RM214	31	10	59	27	0	2.0	8.1	59
	RM215	24	10	65	21	0	2.4	9.6	46
	RM217	24	18	58	24	0	0	18	43

Table F1. – *Continued*

Land Use		DCIA	DSIA	Total Pervious	Paved Street Area	Paved Parking Area	Connected Roof Area	Disconnected Roof Area	Small Landscaped Area
Low Density Residential	LD4	0	10	90	6.4	0	0.31	2.3	41
	LD62	0.53	13	87	4.2	0	0.53	5.3	87
	LD70	5.7	1.8	92	4.6	0	0.88	1.6	92
	LD71	8.8	1.9	89	6.6	0	1.7	1.4	89
	LD72	7.0	11	88	6.1	0	0.42	4.8	88
	LD73	7.6	2.7	90	6.1	0	1.2	2.4	80
	LD74	4.5	2.8	93	3.3	0	1.1	2.6	93
	RL103	18	24	58	18	0	0	24	58
	RLD 1001	34	10	57	23	0	7.8	7.0	57
	RLD 1002	15	7.4	77	7.3	0	5.4	4.8	77
	RLD 1003	31	10	59	19	0	7.8	6.9	59
	RLD 1004	27	10	63	16	0	6.2	5.5	63
	RLD 1005	26	9.4	64	16	0	6.9	6.1	64
Apartment and Multifamily Units	AP6	20	41	38	8.1	7.2	13	32	38
	AP38	12	23	65	8.2	7.6	0	16	65
	AP39	0	35	65	8.2	7.3	0	17	65
	AP41	15	12	72	11	2.5	1.6	11	52
	AP42	8.0	11	81	10	2.3	0	5.3	71
	AP60	0	30	70	11	6.1	0	11	70
	AP76	45	18	37	12	33	0	16	37
	AP81	0	47	53	9.3	21	0	14	53
	AP119	37	24	38	11	7.0	18	21	38
	APT 1201	33	6.8	60	12	15	6.8	6.8	0
	APT 1202	23	5.5	71	6.2	12	5.5	5.5	0
	APT 1203	34	5.8	61	15	13	5.8	5.8	0
	APT 1204	30	6.0	64	11	14	6.0	6.0	0
	APT 1205	46	0	54	5.4	18	22	0	0
	MF30	42	4.1	54	4.2	27	11	4.1	54
	MF31	15	10	75	0.9	2.5	11	8.7	75
	MF33	36	1.7	62	13	4.6	17	0	62
	MF34	26	2.6	71	8.0	7.5	10	2.2	53
	MF35	7.9	1.2	91	2.6	1.7	3.3	0.9	26
	MF36	60	1.0	39	7.6	25	27	0	39
	MF37	29	3.3	68	7.0	3.8	17	2.4	68
	MF57	26	18	56	5.2	16	3.1	17	56
	MF75	20	24	56	10	9.5	0	24	56
	MF108	36	2.1	62	10	1.5	24	0	62
	MF115	16	14	70	11	5.2	0	14	70
	MF128	14	6.9	79	8.3	0	5.8	6.8	79

Table F1. – *Continued*

Land Use		DCIA	DSIA	Total Pervious	Paved Street Area	Paved Parking Area	Connected Roof Area	Disconnected Roof Area	Small Landscaped Area
Commercial (Shopping Centers)	SH2	59	0	41	18	32	8.6	0	41
	SH3	47	0	53	21	13	12	0	53
	SH45	81	0	19	8.1	47	26	0	19
	SH47	99	0	1.3	15	19	64	0	1.3
	SH48	64	0	36	19	31	13	0	36
	SH50	38	6.9	55	9.2	24	5.2	6.9	49
	SH51	74	0	26	16	30	0	26	26
	SH53	69	0	31	18	38	13	0	31
	SH55	69	0	31	20	30	18	0	31
	SHP102	75	0	25	27	36	12	0	21
	SHP105	53	0	47	20	19	14	0	0
	SHP108	93	0	6.6	29	52	12	0	6.6
	SHP109	95	0	5.4	24	40	24	0	5.4
	SHP112	67	0	33	12	39	16	0	0
	SHP202	100	0	0	30	54	12	0	0
	SHP203	100	0	0	24	51	26	0	0
	SHP204	100	0	0	21	66	10	0	0
	SHP206	92	0	8.3	28	46	18	0	0
	SHP207	59	0	41	24	17	16	0	0
	SHOP 902	73	1.4	25	21	28	23	0	0
	SHOP 1206	72	0	28	16	36	14	0	0
	SHOP 1207	79	0	21	10	38	19	0	0
	SHOP 1208	84	0	16	13	37	20	0	0
Commercial (Offices)	OF77	97	0	2.5	29	32	35	0	2.5
	OF78	50	0	50	33	10	6.1	0	50
	OF82	34	15	51	10	11	24	0	51
	OF118	70	0	30	4.1	50	15	0	30
	OF125	58	2.0	40	11	43	4.0	2.0	40
	OF126	41	0	59	5.7	14	19	0	59
Institutional (Schools)	SC26	12	5.4	82	4.2	6.1	2.0	5.2	44
	SC27	14	4.8	81	6.8	2.9	4.7	4.7	45
	SC28	5.4	1.2	93	0.6	1.9	2.9	1.1	44
	SC29	18	7.2	75	3.1	7.3	7.5	7.2	50
	SC89	22	1.0	77	6.1	9.1	7.2	0.90	66
	SC93	23	10	67	4.2	7.1	12	9.4	44
	SCH211	48	0	52	23	16	9.5	0	8.5
	SCH 905	40	1.8	58	5.1	15	18	0	0

Table F1. – *Continued*

Land Use		DCIA	DSIA	Total Pervious	Paved Street Area	Paved Parking Area	Connected Roof Area	Disconnected Roof Area	Small Landscaped Area
Institutional (Churches)	CH25	71	3.7	25	21	26	24	3.6	25
	CH43	76	3.2	21	40	30	5.8	2.5	21
	CH49	30	0	70	4.2	19	6.8	0	42
	CH94	56	1.6	42	8.6	42	5.3	0.9	42
	CHU212	67	0	33	37	21	9.0	0	33
	CHU903	67	11	22	17	20	19	0	22
Industrial	ID129	43	0	57	8.6	10	11	0	57
	ID130	70	0	30	5.5	9.2	4.8	0	30
	ID131	42	0	58	5.7	7.6	17	0	58
	ID132	44	0	56	4.9	30	8.2	0	56
	ID133	0	73	27	15	20	0	38	27
	ID134	70	0	30	10	5.1	3.0	0	30
	ID135	0.5	11	88	5.9	0	0	5.4	73
	ID136	18	0	82	8.6	8.9	0	0	17
	IND100	76	3	22	15	44	17	2.7	0
	IND107	100	0	0	34	45	21	0	0
	IND205	24	0	76	13	0	11	0	0
	IND208	37	25	39	7.6	14	9.4	7.7	0
	IND209	74	6.8	19	17	15	15	6.8	0
	IND210	100	0	0	16	59	25	0	0
Open Space	PK56	23	17	60	12	12	0	0	60
	PK79	41	28	31	21	21	0	0	58
	CEM64	0	28	72	10	18	0	0	72
	CEM95	0	5.8	94	3.8	0	0	2.0	94
	GL65	1.9	3.5	95	1.2	0.7	0	2.8	95
	OPN8	0	7.2	93	7.2	0	0	0	93
	OPN68	0	6.6	93	6.6	0	0	0	93
	OPN83	0	0.57	99	0.57	0	0	0	99
	UND44	10	0	90	10	0	0	0	90
	UND46	2.8	0	97	2.8	0	0	0	97
	UND54	17	0	83	17	0	0	0	83
	UND59	1.2	0	99	1.2	0	0	0	99
	UND121	10	0	90	10	0	0	0	90
	UND123	10	0	90	10	0	0	0	90
	UND124	5.6	0	94	5.6	0	0	0	94
	UND127	5.7	0	94	5.7	0	0	0	94
	CEM111	21	0	79	21	0	0	0	79
	UND106	7.6	0	92	7.6	0	0	0	92
	UND113	6.7	0	93	6.7	0	0	0	93
	OPEN 201	18	0	82	18	0	0	0	82
	UND1002	0	0	100	0	0	0	0	100

F.1. Disconnected Impervious Area

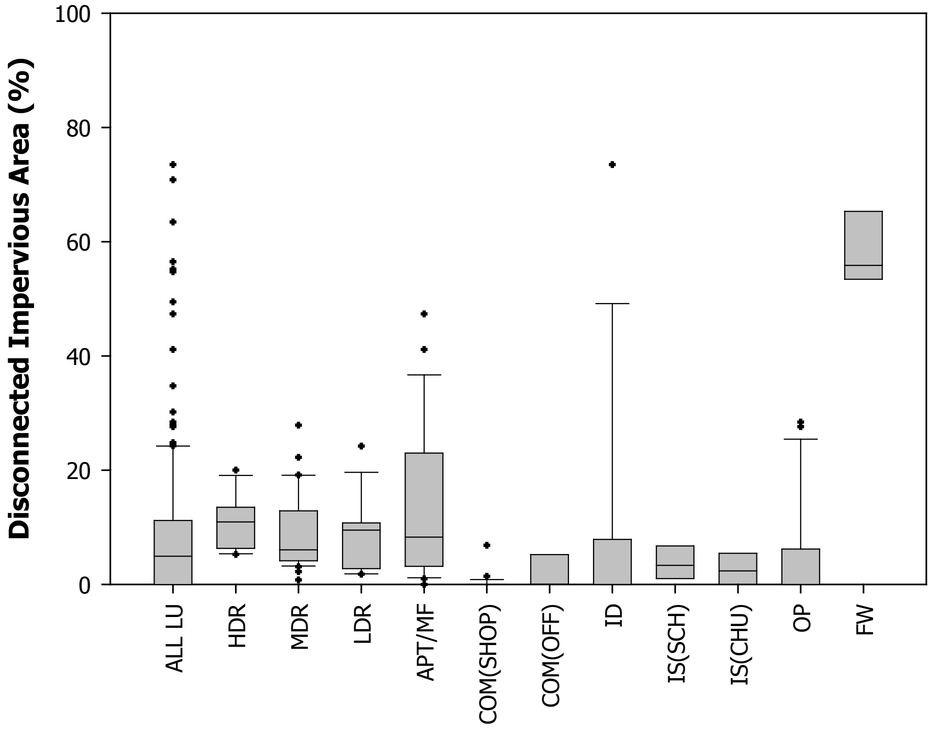
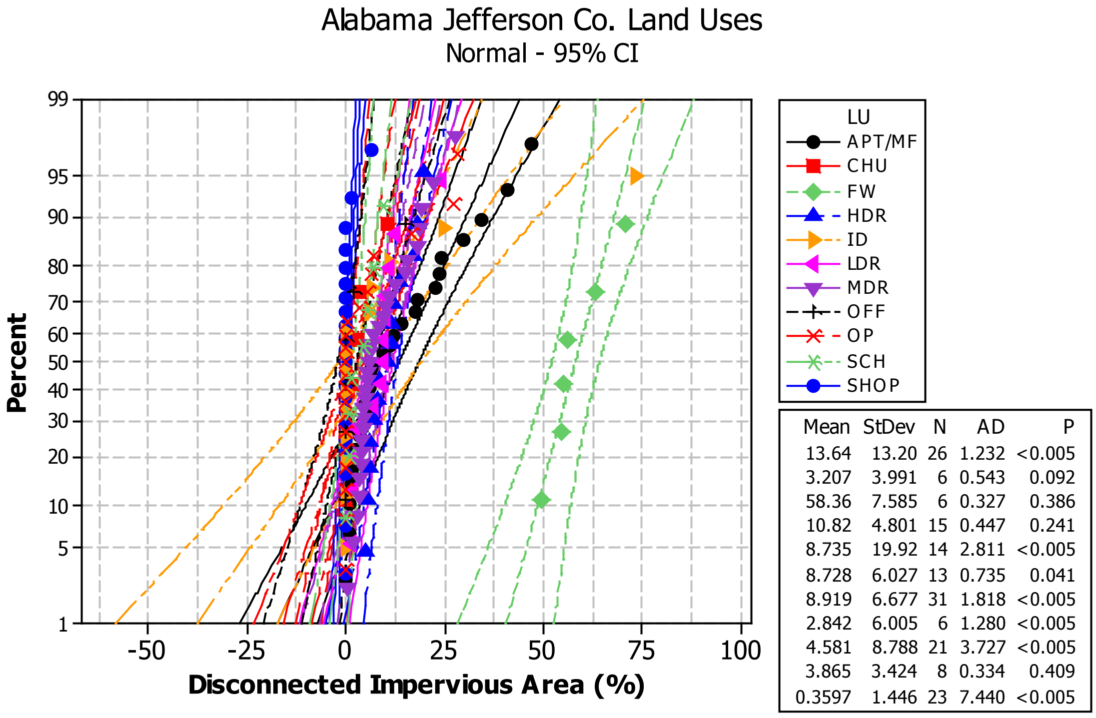


Fig. F1. Disconnected Impervious Area – Jefferson County Land Uses



Mean	StDev	N	AD	P
13.64	13.20	26	1.232	<0.005
3.207	3.991	6	0.543	0.092
58.36	7.585	6	0.327	0.386
10.82	4.801	15	0.447	0.241
8.735	19.92	14	2.811	<0.005
8.728	6.027	13	0.735	0.041
8.919	6.677	31	1.818	<0.005
2.842	6.005	6	1.280	<0.005
4.581	8.788	21	3.727	<0.005
3.865	3.424	8	0.334	0.409
0.3597	1.446	23	7.440	<0.005

Fig. F2. Disconnected Impervious Area – Jefferson County Land Uses
(Checks for Normality)

Table F2. Statistical Analyses for Disconnected Impervious Area – Jefferson County Land Uses

Kruskal-Wallis Test (Land Uses: %DSIA)

H = 80.58 DF = 10 P = 0.00
H = 82.47 DF = 10 P = 0.00 (adjusted for ties)

Land Use	N	Median	Ave Rank	Z
HDR	15	11	120	3
MDR	31	6.0	104	2
LDR	13	9.5	106	2
APT/MF	26	8.3	111	3
CO(SHOP)	23	0	30	-6
CO(OFF)	6	0	54	-2
ID	14	0	64	-2
IS(SCH)	8	3.3	74	-1
IS(CHU)	6	2.4	67	-1
OP	21	0	57	-3
FW	6	56	166	4
Overall	169		85	

Power of the Test (Land Uses: %DSIA)

Land Use	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
HDR	15	11	4.8
MDR	31	8.9	6.7
LDR	13	8.7	6.0
APT/MF	26	14	13
CO(SHOP)	23	0.36	1.4
CO(OFF)	6	2.8	6.0
ID	14	8.7	20
IS(SCH)	8	3.9	3.4
IS(CHU)	6	3.2	4.0
OP	21	4.6	8.8
FW	6	58	7.6

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 9.35
Obtained
Effect Size = 1.1

Table F2. - *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value	(I) LU	(J) LU	p-value	(I) LU	(J) LU	p-value
HDR	MDR	0.064	APT/MF	CO (SHOP)	0.000*	MDR	LDR	0.979
	LDR	0.289		CO (OFF)	0.009*		APT/MF	0.428
	APT/MF	0.776		ID	0.009*		CO(SHOP)	0.000*
	CO (SHOP)	0.000*		IS (SCH)	0.028*		CO(OFF)	0.005*
	CO (OFF)	0.011*		IS (CHU)	0.026*		ID	0.015*
	ID	0.008*		OP	0.000*		IS(SCH)	0.046*
	IS(SCH)	0.002*		FW	0.000*		IS(CHU)	0.010*
	IS(CHU)	0.004*	CO (SHOP)	CO (OFF)	0.132		OP	0.001*
	OP	0.001*		ID	0.077		FW	0.000*
	FW	0.001*		IS (SCH)	0.001*	ID	IS(SCH)	0.322
LDR	APT/MF	0.623		IS (CHU)	0.006*		IS(CHU)	0.483
	CO(SHOP)	0.000*		OP	0.084		OP	0.775
	CO(OFF)	0.032*		FW	0.000*		FW	0.003*
	ID	0.024*	CO (OFF)	ID	1.00	IS(SCH)	IS(CHU)	0.699
	IS(SCH)	0.023*		IS(SCH)	0.245		OP	0.143
	IS(CHU)	0.072*		IS(CHU)	0.337		FW	0.002*
	OP	0.004*		OP	0.954	IS(CHU)	OP	0.322
	FW	0.001*		FW	0.005*		FW	0.005*
			ID	IS(SCH)	0.322	OP	FW	0.000*

Table F3. - Disconnected Impervious Area –
Jefferson County Land Uses Homogeneous Groups

Land Use	Gr. A	Gr. B	Gr. C	Gr. D
HDR	11			
MDR	6			
LDR	9.5			
APT/MF	8.3			
CO(SHOP)		0		
CO(OFF)		0		
ID		0		
OP		0		
IS(SCH)			3.3	
IS(CHU)			2.4	
FW				56

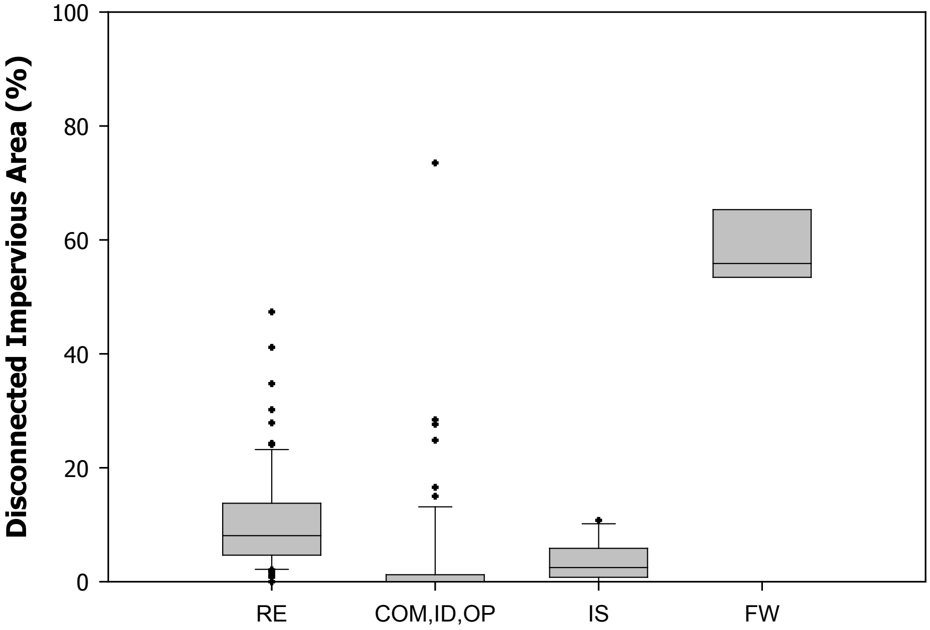


Fig. F3. Disconnected Impervious Area –
Jefferson County Land Uses Homogeneous Groups

Table F4. Statistical Analyses for Disconnected Impervious Area – Jefferson County Land Uses Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: % DSIA)

H = 73.75 DF = 3 P = 0.00
H = 75.48 DF = 3 P = 0.000 (adjusted for ties)

Land Use Groups	N	Median	Ave Rank	Z
RE	85	8.1	109	6
CO, ID,OP	64	0	48	-8
IS	14	2.5	71	-1
FW	6	56	166	4
Overall	169		85	

Power of the Test
(Homogeneous Groups: % DSIA)

Land Use Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE	85	11	9.0
CO, ID,OP	64	3.8	11
IS	14	3.6	3.5
FW	6	58	7.6

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 9.5

Obtained Effect Size = 1.1

Table F4. – *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value
RE	CO, ID,OP IS FW	0.000* 0.000* 0.000*
CO, ID,OP	IS FW	0.006* 0.000*
IS	FW	0.001*

Homogeneous Groups: % DSIA
(medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE	8.1			
CO, ID, OP		0		
IS			2.5	
FW				56

Table F5. Basic Statistics for Jefferson County Land Uses – Disconnected Impervious Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE	85	11	9.0	0.84	0.0	8.1	47
CO, ID,OP	64	3.8	11	2.9	0.0	0.0	74
IS	14	3.6	3.5	0.99	0.0	2.5	11
FW	6	58	7.6	0.13	49	56	71

F.2. Total Pervious Area

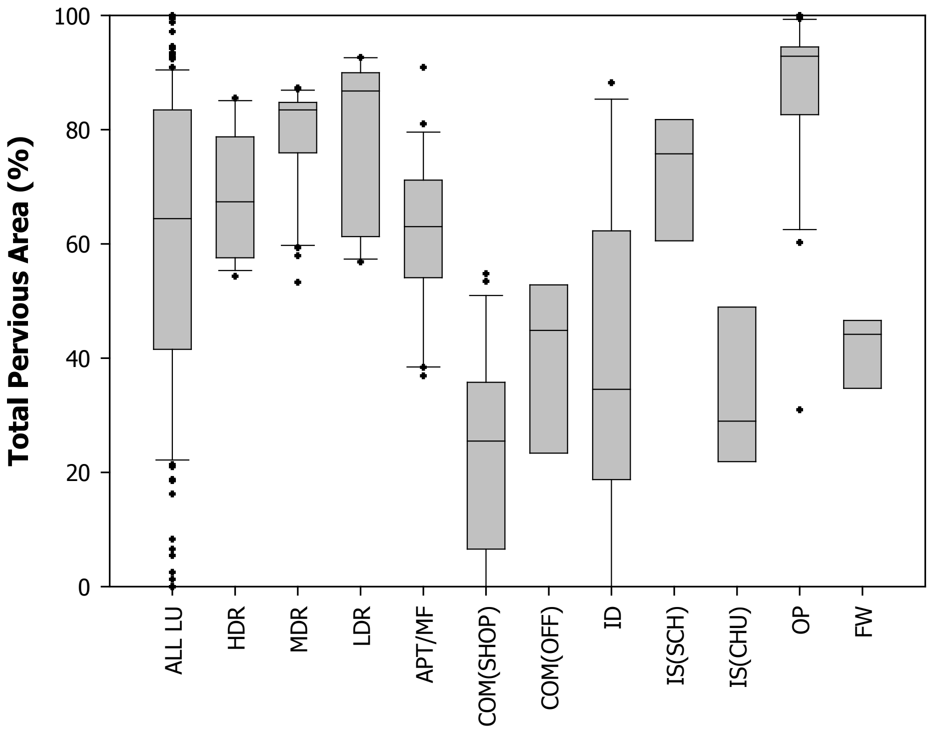
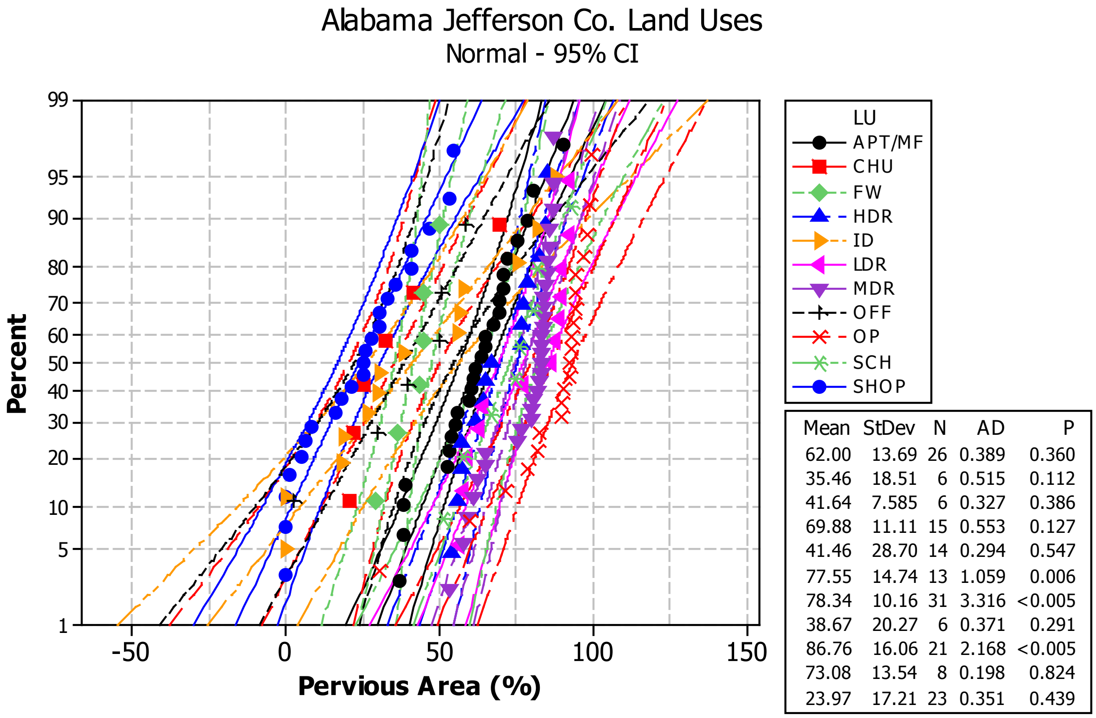


Fig. F4. Total Pervious Area – Jefferson County Land Uses



Mean	StDev	N	AD	P
62.00	13.69	26	0.389	0.360
35.46	18.51	6	0.515	0.112
41.64	7.585	6	0.327	0.386
69.88	11.11	15	0.553	0.127
41.46	28.70	14	0.294	0.547
77.55	14.74	13	1.059	0.006
78.34	10.16	31	3.316	<0.005
38.67	20.27	6	0.371	0.291
86.76	16.06	21	2.168	<0.005
73.08	13.54	8	0.198	0.824
23.97	17.21	23	0.351	0.439

Fig. F5. Total Pervious Area – Jefferson County Land Uses (Checks for Normality)

Table F6. Statistical Analyses for Total Pervious Area – Jefferson County Land Uses

Kruskal-Wallis Test
(Land Uses: %Total Pervious Area)

H = 108.81 DF = 10 P = 0.00
H = 108.81 DF = 10 P = 0.00 (adjusted for ties)

Land Use	N	Median	Ave Rank	Z
HDR	15	67	95	1
MDR	31	83	117	43
LDR	13	87	118	3
APT/MF	26	63	79	-1
CO(SHOP)	23	26	23	-7
CO(OFF)	6	45	40	-2
ID	14	35	51	-3
IS(SCH)	8	76	102	1
IS(CHU)	6	29	36	-3
OP	21	93	142	6
FW	6	44	40	-2
Overall	169		85	

Power of the Test (Land Uses: %Total Pervious Area)

Land Use	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
HDR	15	70	11
MDR	31	78	10
LDR	13	78	15
APT/MF	26	62	14
CO(SHOP)	23	24	17
CO(OFF)	6	39	20
ID	14	41	29
IS(SCH)	8	73	14
IS(CHU)	6	35	19
OP	21	87	16
FW	6	42	7.6

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 15.9
Obtained
Effect Size = 1.3

Table F6. - *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value	(I) LU	(J) LU	p-value	(I) LU	(J) LU	p-value
HDR	MDR	0.010*	APT/MF	CO(SHOP)	0.000*	LDR	APT/MF	0.012*
	LDR	0.080		CO(OFF)	0.006*		CO(SHOP)	0.000*
	APT/MF	0.086		ID	0.024*		CO(OFF)	0.001*
	CO(SHOP)	0.000*		IS(SCH)	0.071		ID	0.001*
	CO(OFF)	0.002*		IS(CHU)	0.006*		IS(SCH)	0.492
	ID	0.007*		OP	0.000*		IS(CHU)	0.003*
	IS(SCH)	0.723		FW	0.003*		OP	0.009*
	IS(CHU)	0.005*	CO(SHOP)	CO(OFF)	0.090		FW	0.001*
	OP	0.000*		ID	0.077	ID	IS(SCH)	0.019*
	FW	0.001*		IS(SCH)	0.000*		IS(CHU)	0.773
MDR	LDR	0.354		IS(CHU)	0.319		OP	0.000*
	APT/MF	0.000*		OP	0.000*		FW	0.902
	CO(SHOP)	0.000*		FW	0.059	IS (SCH)	IS (CHU)	0.008*
	CO(OFF)	0.000*	CO(OFF)	ID	1.00		OP	0.009*
	ID	0.000*		IS(SCH)	0.006*		FW	0.024*
	IS(SCH)	0.114		IS(CHU)	0.575	IS(CHU)	OP	0.001*
	IS(CHU)	0.000*		OP	0.001*		FW	0.174
	OP	0.001*		FW	0.810	OP	FW	0.001*
	FW	0.000*						

Table F7. Total Pervious Area – Jefferson County Land Uses Homogeneous Groups

Land Use	Gr. A	Gr. B	Gr. C	Gr. D
HDR	67			
APT/MF	63			
IS(SCH)	76			
MDR		83		
LDR		87		
CO(SHOP)			26	
CO(OFF)			45	
IS(CHU)			29	
ID			35	
FW			44	
OP				93

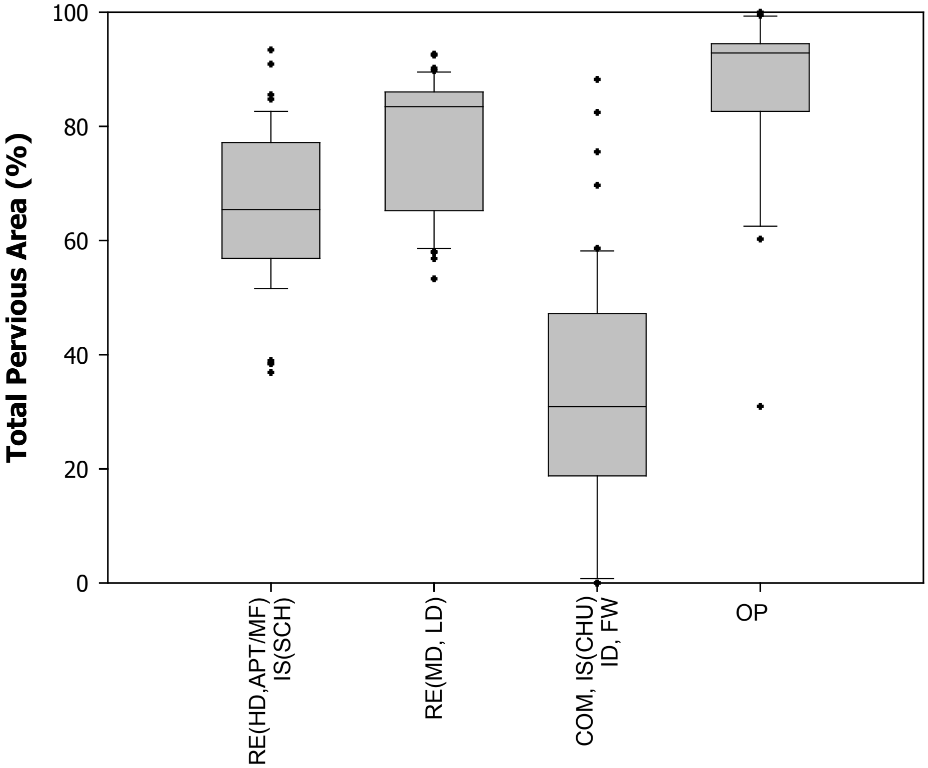


Fig. F6. Total Pervious Area – Jefferson County Land Uses Homogeneous Groups

Table F8. Statistical Analyses for Total Pervious Area – Jefferson County Land Uses Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: % Total Pervious Area)

H = 104.1 DF = 3 P = 0.00
H = 104.1 DF = 3 P = 0.00 (adjusted for ties)

Land Use Groups	N	Median	Ave Rank	Z
RE(HD,APT/MF) IS(SCH)	49	65	88	1
RE(MD, LD)	44	83	117	5
CO, IS(CHU), ID, FW	55	31	35	9
OP	21	93	142	6
Overall	169		85	

Power of the Test
(Homogeneous Groups: % Total Pervious Area)

Land Use Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(HD,APT/MF) IS(SCH)	49	66	13
RE(MD, LD)	44	78	12
CO, IS(CHU) ID, FW	55	33	21
OP	21	87	16

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 16.4

Obtained Effect Size = 1.3

Table F8. – *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value
RE(HD, APT/MF),IS(SCH)	RE(MD, LD)	0.000*
	CO, IS(CHU), ID, FW	0.000*
	OP	0.000*
RE(MD, LD)	CO, IS(CHU), ID, FW	0.000*
	OP	0.000*
CO, IS(CHU), ID, FW	OP	0.000*

Homogeneous Groups: %Total Pervious Area (medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE(HD,APT/MF) IS(SCH)	65			
RE(MD, LD)		83		
CO, IS(CHU), ID, FW			31	
OP				93

Table F9. Basic Statistics for Jefferson County Land Uses – Total Pervious Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE(HD,APT/MF), IS(SCH)	49	66	13	0.20	37	65	93
RE(MD, LD)	44	78	12	0.15	53	83	93
CO, IS(CHU), ID, FW	55	33	21	0.65	0.0	31	88
OP	21	87	16	0.19	31	93	100

F.3. Paved Street Area

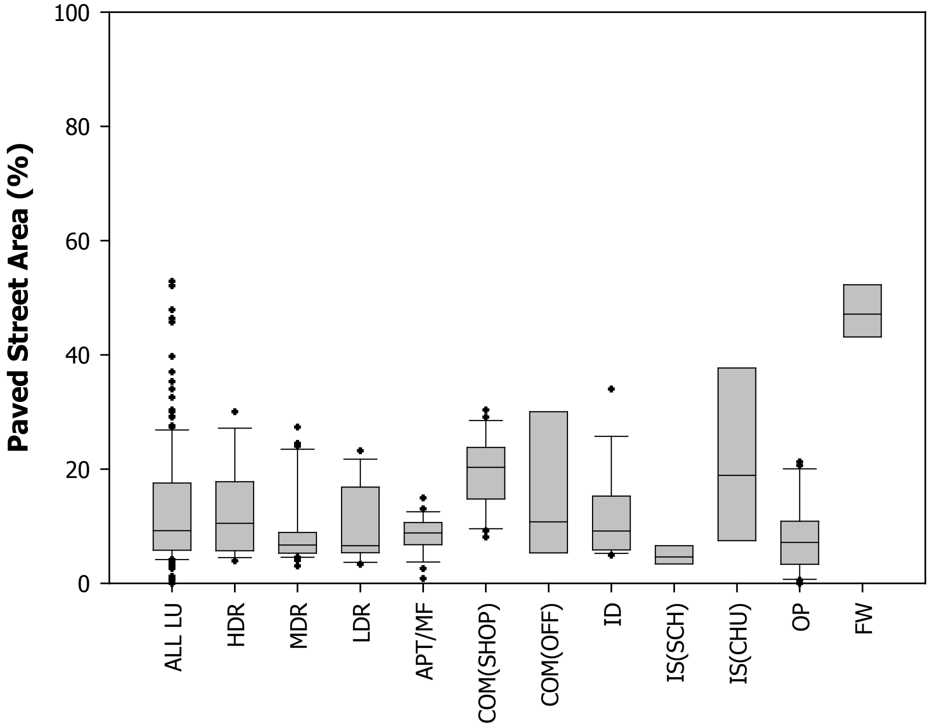
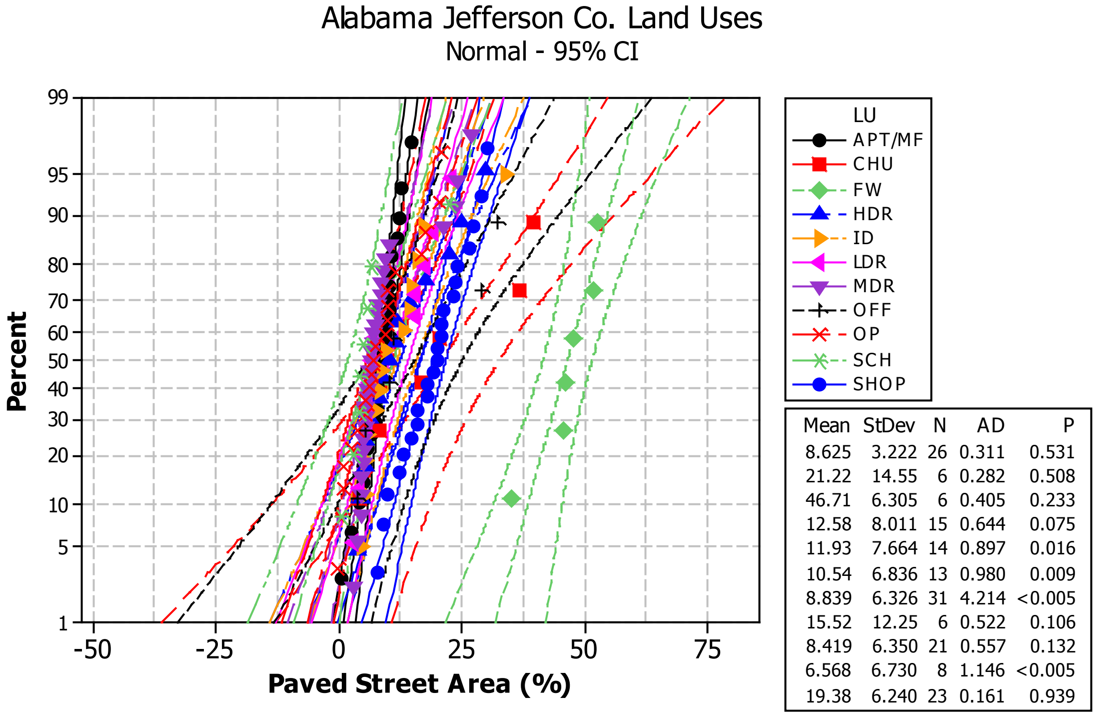


Fig. F7. Paved Street Area – Jefferson County Land Uses



Mean	StDev	N	AD	P
8.625	3.222	26	0.311	0.531
21.22	14.55	6	0.282	0.508
46.71	6.305	6	0.405	0.233
12.58	8.011	15	0.644	0.075
11.93	7.664	14	0.897	0.016
10.54	6.836	13	0.980	0.009
8.839	6.326	31	4.214	<0.005
15.52	12.25	6	0.522	0.106
8.419	6.350	21	0.557	0.132
6.568	6.730	8	1.146	<0.005
19.38	6.240	23	0.161	0.939

Fig. F8. Paved Street Area – Jefferson County Land Uses (Checks for Normality)

Table F10. Statistical Analyses for Paved Street Area – Jefferson County Land Uses

Kruskal-Wallis Test
(Land Uses: %Paved Street Area)

H = 57.07 DF = 10 P = 0.000

Land Use	**N**	**Median**	**Ave Rank**	**Z**
HDR	15	11	89	0
MDR	31	6.7	63	-3
LDR	13	6.6	74	-1
APT/MF	26	8.8	75	-1
CO(SHOP)	23	20	130	5
CO(OFF)	6	11	96	1
ID	14	9.2	87	0
IS(SCH)	8	4.6	40	-3
IS(CHU)	6	19	115	2
OP	21	7.2	64	-2
FW	6	47	166	4
Overall	169		85	

Power of the Test (Land Uses: %Paved Street Area)

Land Use	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
HDR	15	13	8.0
MDR	31	8.8	6.3
LDR	13	11	6.8
APT/MF	26	8.6	3.2
CO(SHOP)	23	19	6.2
CO(OFF)	6	16	12
ID	14	12	7.7
IS(SCH)	8	6.6	6.7
IS(CHU)	6	21	15
OP	21	8.4	6.4
FW	6	47	6.3

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 6.97
Obtained
Effect Size = 1.1

Table F10. - *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	**(J) LU**	**p-value**
HDR	MDR	0.079
	LDR	0.490
	APT/MF	0.250
	CO(SHOP)	0.007*
	CO(OFF)	0.785
	ID	1.00
	IS(SCH)	0.026*
	IS(CHU)	0.259
	OP	0.124
	FW	0.001*
MDR	LDR	0.719
	APT/MF	0.072
	CO(SHOP)	0.000*
	CO(OFF)	0.168
	ID	0.068
	IS(SCH)	0.049*
	IS(CHU)	0.055
	OP	1.00
	FW	0.000*
APT/MF	CO (SHOP)	0.000*
	CO (OFF)	0.347
	ID	0.275
	IS(SCH)	0.020*
	IS(CHU)	0.045*
	OP	0.386
	FW	0.000*
CO (SHOP)	CO (OFF)	0.346
	ID	0.001*
	IS(SCH)	0.001*
	IS(CHU)	0.979
	OP	0.000*
	FW	0.000*
CO (OFF)	ID	0.837
	IS(SCH)	0.107
	IS(CHU)	0.471
	OP	0.153
	FW	0.005*
ID	IS(SCH)	0.022*
	IS(CHU)	0.201
	OP	0.232
	FW	0.001*
LDR	APT/MF	0.941
	CO(SHOP)	0.001*
	CO(OFF)	0.567
	ID	0.645
	IS(SCH)	0.076
	IS(CHU)	0.105
	OP	0.547
	FW	0.001*
IS(SCH)	IS(CHU)	0.033*
	OP	0.341
	FW	0.002*
IS(CHU)	OP	0.044*
	FW	0.013*
OP	FW	0.000*

Table F11. - Paved Street Area - Jefferson County Land Uses Homogeneous Groups

Land Use	Gr. A	Gr. B	Gr. C	Gr. D
HDR	11			
MDR	6.7			
LDR	6.6			
APT/MF	8.8			
ID	9.2			
OP	7.2			
CO(SHOP)		20		
CO(OFF)		11		
IS(CHU)		19		
IS(SCH)			4.6	
FW				47

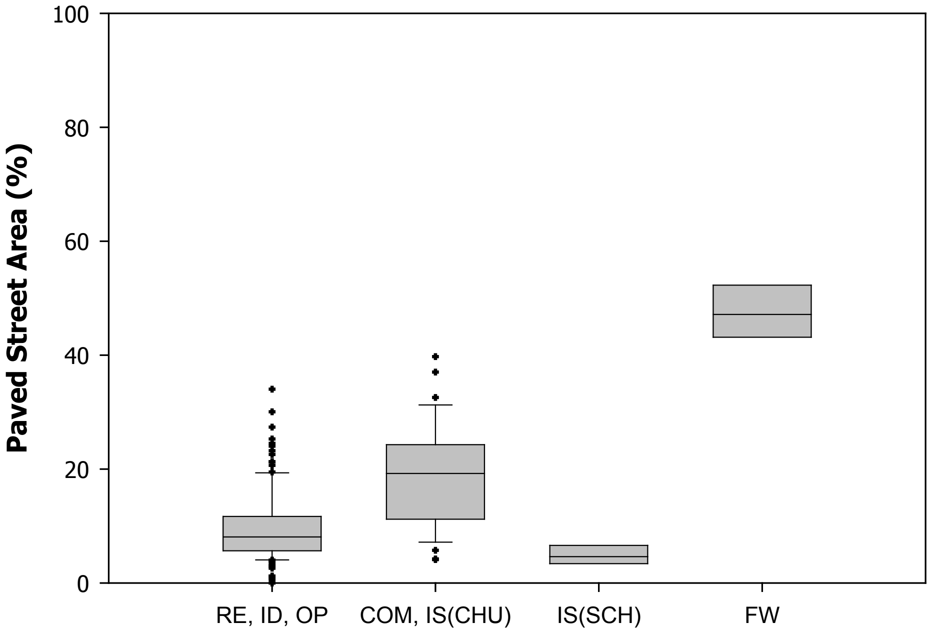


Fig. F9. Paved Street Area - Jefferson County Land Uses Homogeneous Groups

Table F12. Statistical Analyses for Paved Street Area – Jefferson County Land Uses Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: %Paved Street Area)

H = 49.89 DF = 3 P = 0.000

Land Use Groups	N	Median	Ave Rank	Z
RE, ID, OP	120	8.1	73	-5
CO, IS(CHU)	35	19	122	5
IS(SCH)	8	4.6	40	-3
FW	6	47	166	4
Overall	169		85	

Power of the Test
(Homogeneous Groups: %Paved Street Area)

Land Use Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE, ID, OP	120	10	6.3
CO, IS(CHU)	35	19	9.0
IS(SCH)	8	6.6	6.7
FW	6	47	6.3

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 6.99

Obtained Effect Size = 1.1

Table F12. – *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value
RE, ID, OP	CO, IS(CHU)	0.000*
	IS(SCH)	0.025*
	FW	0.000*
CO, IS(CHU)	IS(SCH)	0.001*
	FW	0.000*
IS(SCH)	FW	0.002*

Homogeneous Groups: %Paved Street Area
(medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE, ID, OP	8.1			
CO, IS(CHU)		19		
IS(SCH)			4.6	
FW				47

Table F13. Basic Statistics for Jefferson County Land Uses – Paved Street Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE, ID, OP	120	10	6.3	0.65	0.0	8.1	34
CO, IS(CHU)	35	19	9.0	0.47	4.1	19	40
IS(SCH)	8	6.6	6.7	1.0	0.6	4.6	23
FW	6	47	6.3	0.13	35	47	53

F.4 Paved Parking Lot Area

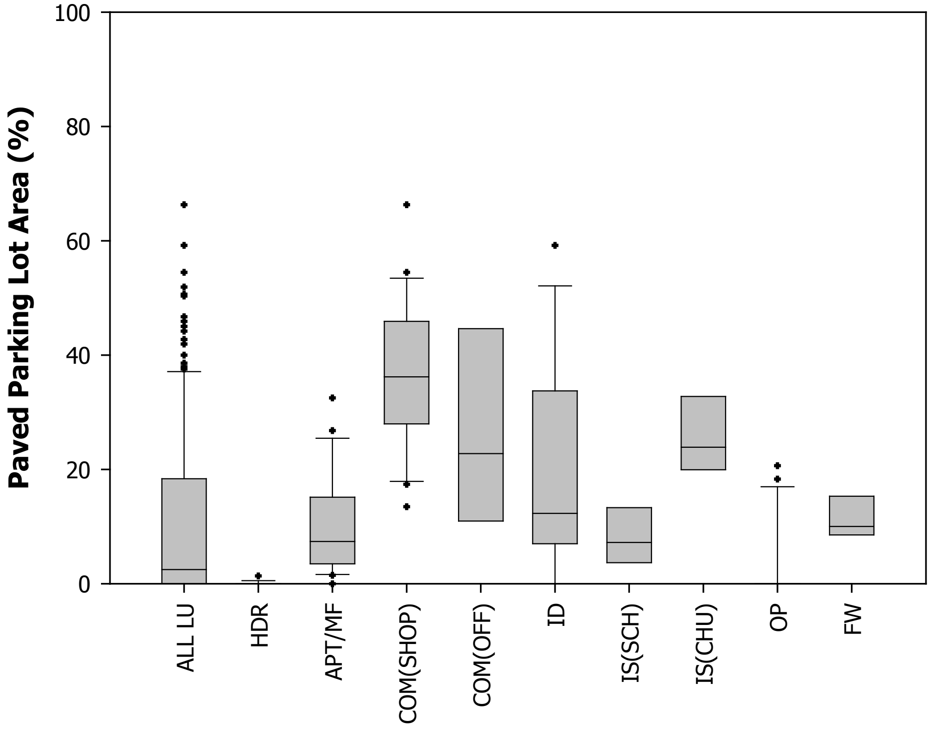
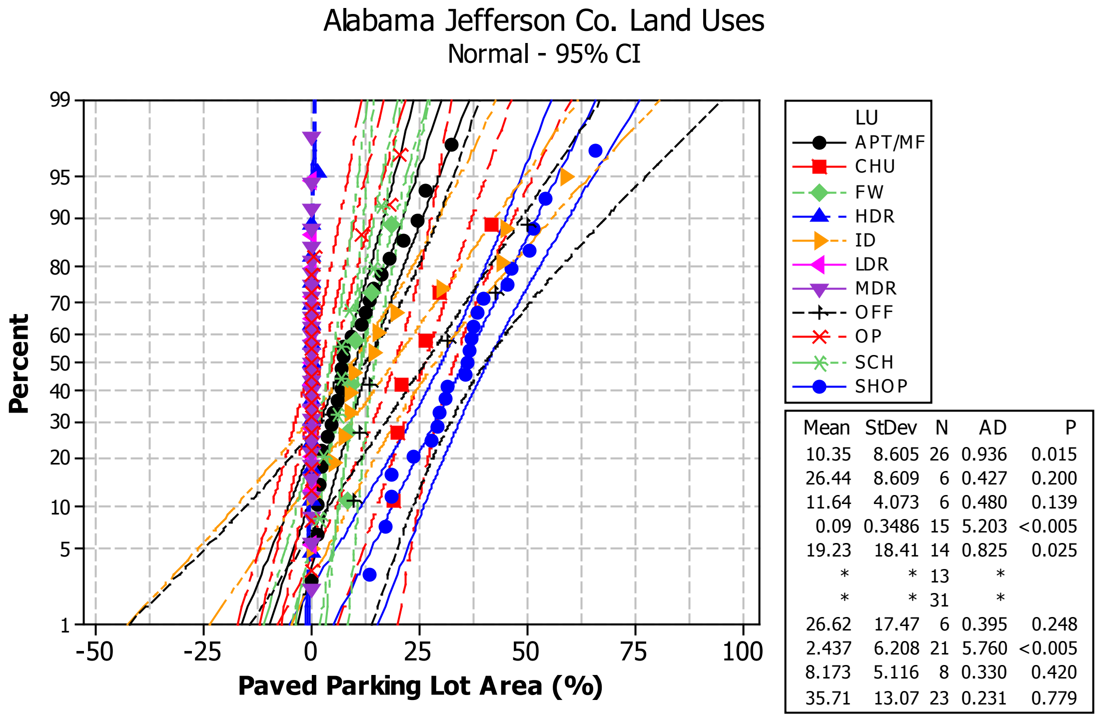


Fig. F10. Paved Parking Lot Area – Jefferson County Land Uses



Mean	StDev	N	AD	P
10.35	8.605	26	0.936	0.015
26.44	8.609	6	0.427	0.200
11.64	4.073	6	0.480	0.139
0.09	0.3486	15	5.203	<0.005
19.23	18.41	14	0.825	0.025
*	*	13	*	
*	*	31	*	
26.62	17.47	6	0.395	0.248
2.437	6.208	21	5.760	<0.005
8.173	5.116	8	0.330	0.420
35.71	13.07	23	0.231	0.779

Fig. F11. Paved Parking Lot Area – Jefferson County Land Uses (Checks for Normality)

Table F14. Statistical Analyses for Paved Parking Lot Area – Jefferson County Land Uses

Kruskal-Wallis Test
(Land Uses: %Paved Parking Lots)

H = 123.54 DF = 10 P = 0.00
H = 137.00 DF = 10 P = 0.00 (adjusted for ties)

Land Use	N	Median	Ave Rank	Z
HDR	15	0	42	-4
MDR	31	0	40	-6
LDR	13	0	40	-3
APT/MF	26	7.4	104	2
CO(SHOP)	23	36	149	7
CO(OFF)	6	23	135	3
ID	14	12	114	2
IS(SCH)	8	7.2	101	1
IS(CHU)	6	24	141	3
OP	21	0	54	-3
FW	6	10	112	1
Overall	169		85	

Power of the Test
(Land Uses: %Paved Parking Lots)

Land Use	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
HDR	15	0.09	0.35
MDR	31	0	0
LDR	13	0	0
APT/MF	26	10	8.6
CO(SHOP)	23	36	13
CO(OFF)	6	27	17
ID	14	19	18
IS(SCH)	8	8.2	5.1
IS(CHU)	6	26	8.6
OP	21	2.4	6.2
FW	6	12	4.1

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 9.1
Obtained
Effect Size = 1.4

Table F14. - *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value	(I) LU	(J) LU	p-value
HDR	APT/MF	0.000*	CO (SHOP)	CO (OFF)	0.247
	CO(SHOP)	0.000*		ID	0.005*
	CO(OFF)	0.001*		IS(SCH)	0.000*
	ID	0.000*		IS(CHU)	0.139
	IS(SCH)	0.000*		OP	0.000*
	IS(CHU)	0.001*		FW	0.001*
	OP	0.521	CO(OFF)	ID	0.303
	FW	0.001*		IS(SCH)	0.024*
APT/MF	CO(SHOP)	0.000*		IS(CHU)	0.936
	CO(OFF)	0.017*		OP	0.002*
	ID	0.144		FW	0.093
	IS(SCH)	0.823	ID	IS(SCH)	0.162
	IS(CHU)	0.003*		IS(CHU)	0.149
	OP	0.000*		OP	0.001*
	FW	0.257		FW	0.711
IS(CHU)	OP	0.000*	IS(SCH)	IS(CHU)	0.002*
	FW	0.005*		OP	0.003*
OP	FW	0.006*		FW	0.138

Land Use
%Paved Parking Lot Area Groups
(medians)

Land Use	Gr.A	Gr.B	Gr.C
HDR	0		
OP	0		
APT/MF		7.4	
IS(SCH)		7.2	
ID		12	
FW		10	
CO(SHOP)			36
CO(OFF)			23
IS(CHU)			24

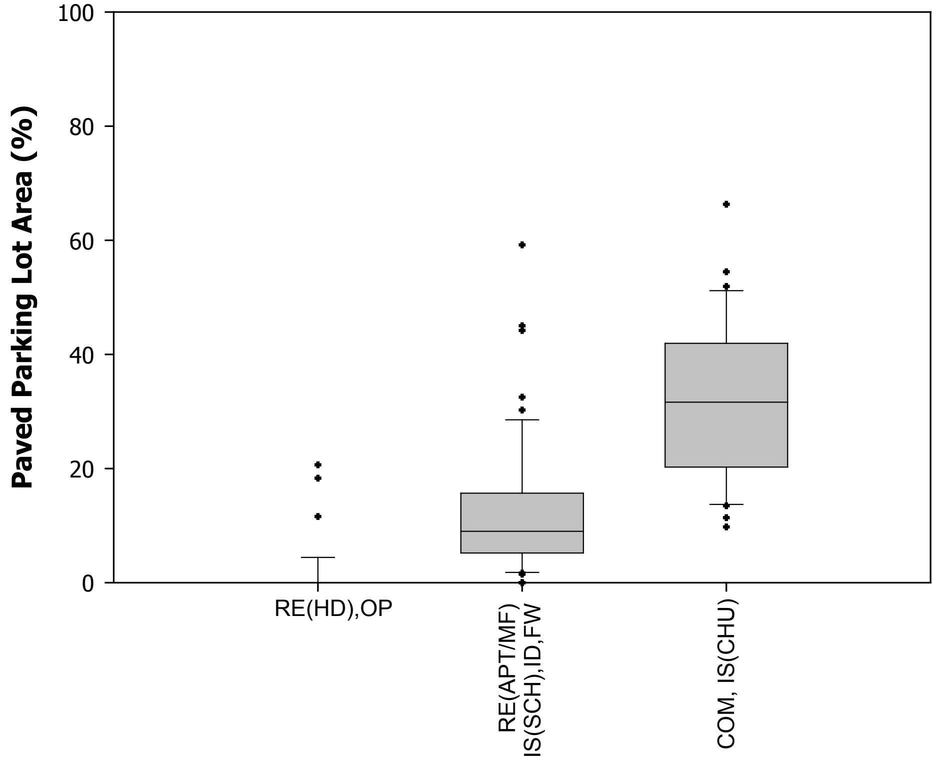


Fig. F12. Paved Parking Lot Area – Jefferson County Land Uses Homogeneous Groups

Table F15. Statistical Analyses for Directly Connected Impervious Area – Jefferson County Land Uses Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: %Paved Parking Lots)

H = 81.55 DF = 2 P = 0.00
H = 83.23 DF = 2 P = 0.00 (adjusted for ties)

Land Use Groups	N	Median	Ave Rank	Z
RE(HD), OP	36	0.0	24	-8
RE(APT/MF) IS(SCH), ID,FW	54	9.0	64	0
CO, IS(CHU)	35	32	101	7
Overall	125		63	

Power of the Test
(Homogeneous Groups: %Paved Parking Lots)

Land Use Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(HD), OP	36	1.5	4.8
RE(APT/MF) IS(SCH), ID, FW	54	12	12
CO, IS(CHU)	35	33	14

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 10.9

Obtained Effect Size = 1.1

Table F15. – *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value
RE(HD), OP	RE(APT/MF) IS(SCH), ID, FW	0.000*
	CO, IS(CHU)	0.000*
RE(APT/MF) IS(SCH), ID, FW	CO, IS(CHU)	0.000*

Homogeneous Groups: %Paved Parking Lots (medians)

Groups	Gr. A	Gr. B	Gr. C
RE(HD), OP	0		
RE(APT/MF) IS(SCH), ID, FW		9.0	
CO, IS(CHU)			32

Table F16. Basic Statistics for Jefferson County Land Uses –
Paved Parking Lot Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE(HD), OP	36	1.5	4.8	3.3	0.0	0.0	21
RE(APT/MF) IS(SCH), ID, FW	54	12	12	0.95	0.0	9.0	59
CO, IS(CHU)	35	33	14	0.42	10	32	66

F.5. Connected Roof Area

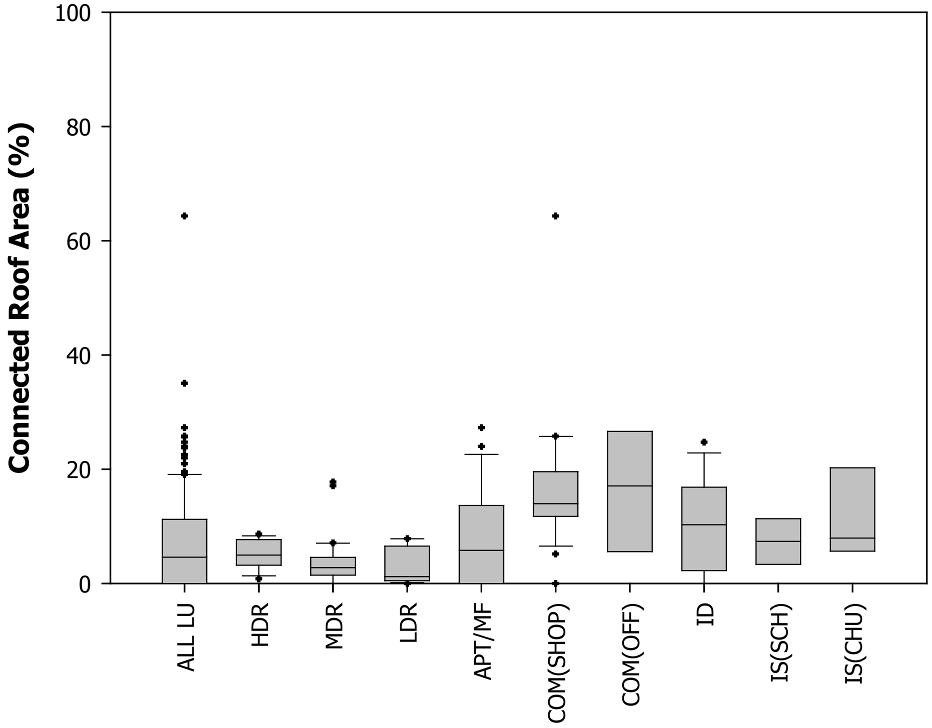


Fig. F13. Connected Roof Area – Jefferson County Land Uses

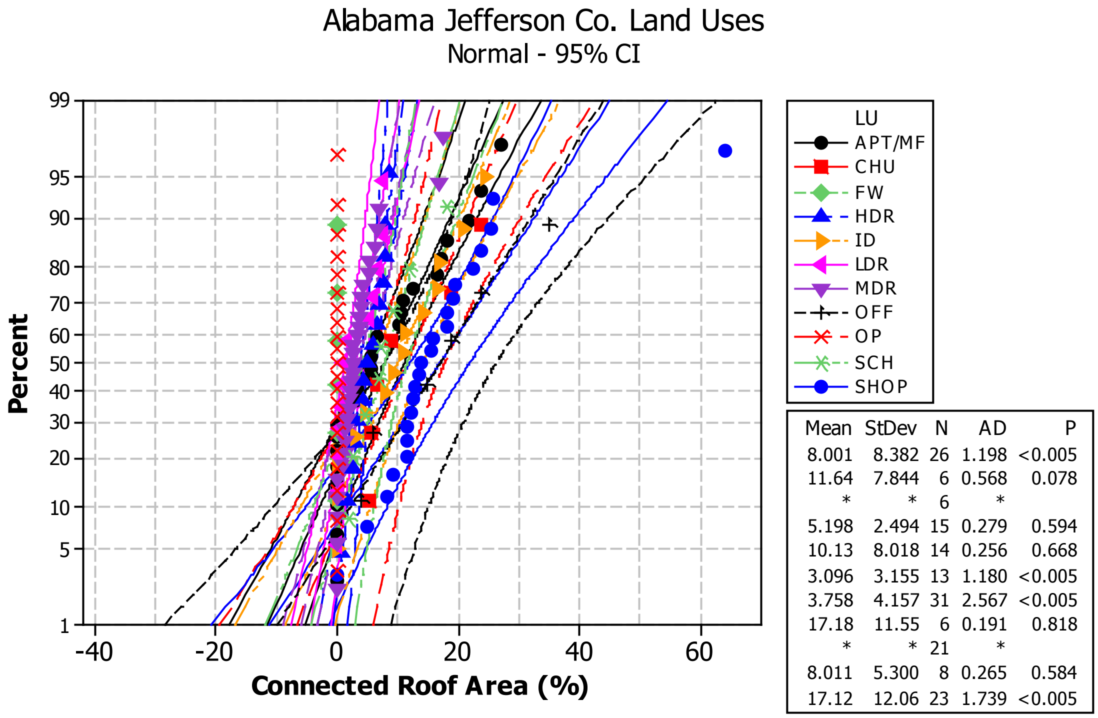


Fig. F14. Connected Roof Area – Jefferson County Land Uses
(Checks for Normality)

Table F17. Statistical Analyses for Connected Roof Area - Jefferson County Land Uses

Kruskal-Wallis Test
(Land Uses: %Connected Roof Area)

H = 86.16 DF = 10 P = 0.00
H = 87.82 DF = 10 P = 0.00 (adjusted for ties)

Land Use	**N**	**Median**	**Ave Rank**	**Z**
HDR	15	5.0	90	0
MDR	31	2.8	71	-2
LDR	13	1.2	70	-1
APT/MF	26	5.8	89	0
CO(SHOP)	23	14	136	5
CO(OFF)	6	17	134	3
ID	14	10	105	2
IS(SCH)	8	7.4	106	1
IS(CHU)	6	7.9	121	2
OP	21	0	23	-6
FW	6	0	23	-3
Overall	169		85	

Power of the Test
(Land Uses: %Connected Roof Area)

Land Use	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
HDR	15	5.2	2.5
MDR	31	3.8	4.2
LDR	13	3.1	3.2
APT/MF	26	8.0	8.4
CO(SHOP)	23	17	12
CO(OFF)	6	17	12
ID	14	10	8.0
IS(SCH)	8	8.0	5.3
IS(CHU)	6	12	7.8
OP	21	0	0
FW	6	0	0

α level	**Power (%)**
0.20	100
0.15	100
0.10	100
0.05	***99.9***
0.01	99.9

Pooled Std. Dev. = 7.0
Obtained
Effect Size = 0.7

Table F17. - *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	**(J) LU**	**p-value**	**(I) LU**	**(J) LU**	**p-value**
HDR	MDR	0.017*	LDR	APT/MF	0.318
	LDR	0.059		CO (SHOP)	0.000*
	APT/MF	0.903		CO (OFF)	0.010*
	CO (SHOP)	0.000*		ID	0.037*
	CO (OFF)	0.027*		IS(SCH)	0.019*
	ID	0.093		IS(CHU)	0.020*
	IS(SCH)	0.232	APT/MF	CO (SHOP)	0.002*
	IS(CHU)	0.047*		CO (OFF)	0.051
MDR	LDR	0.580		ID	0.419
	APT/MF	0.138		IS(SCH)	0.556
	CO (SHOP)	0.000*		IS(CHU)	0.237
	CO (OFF)	0.001*	CO (SHOP)	CO (OFF)	0.893
	ID	0.017*		ID	0.039*
	IS(SCH)	0.008*		IS(SCH)	0.008*
	IS(CHU)	0.002*		IS(CHU)	0.206*
ID	IS(SCH)	0.609	CO (OFF)	ID	0.201
	IS(CHU)	0.773		IS(SCH)	0.138
IS(SCH)	IS(CHU)	0.477		IS(CHU)	0.575

Land Use
% Connected Roof Area Groups (medians)

Land Use	**Gr.A**	**Gr.B**	**Gr.C**	**Gr.D**
HDR	5.0			
APT/MF	5.8			
MDR		2.8		
LDR		1.2		
CO(SHOP)			14	
CO(OFF)			17	
IS(SCH)				7.4
IS(CHU)				7.9
ID				10

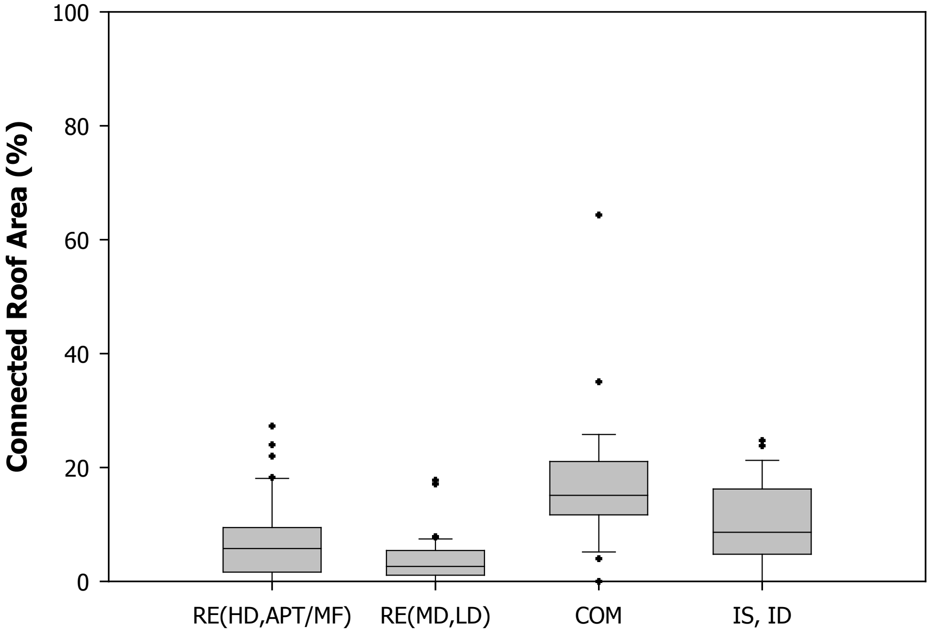


Fig. F15. Connected Roof Area – Jefferson County Land Uses Homogeneous Groups

Table F18. Statistical Analyses for Connected Roof Area –
Jefferson County Land Uses Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: %Connected Roof Area)

H = 45.93 DF = 3 P = 0.00
H = 46.03 DF = 3 P = 0.00 (adjusted for ties)

Land Use Groups	**N**	**Median**	**Ave Rank**	**Z**
RE(HD, APT/MF)	41	5.8	65	-1
RE(MD, LD)	44	2.6	45	-5
CO	29	15	109	6
IS, ID	28	8.6	83	2
Overall	142		72	

Power of the Test
(Homogeneous Groups: %Connected Roof Area)

Land Use Groups	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(HD, APT/MF)	41	7.0	6.9
RE(MD, LD)	44	3.6	3.9
CO	29	17	12
IS, ID	28	10	7.2

α level	**Power (%)**
0.20	100
0.15	100
0.10	99.9
0.05	***99.9***
0.01	99.9

Pooled Std. Dev. = 7.53

Obtained Effect Size = 0.64

Table F18. – *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value
RE(HD, APT/MF)	RE(MD, LD)	0.017*
	CO	0.000*
	IS, ID	0.050*
RE(MD, LD)	CO	0.000*
	IS, ID	0.000*
CO	IS, ID	0.004*

Homogeneous Groups: %Connected Roof Area (medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE(HD, APT/MF)	5.8			
RE(MD, LD)		2.6		
CO			15	
IS, ID				8.6

Table F19. Basic Statistics for Jefferson County Land Uses – Connected Roof Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE(HD, APT/MF)	41	7.0	6.9	0.99	0.0	5.8	27
RE(MD, LD)	44	3.6	3.9	1.1	0.0	2.6	18
CO	29	17	12	0.69	0.0	15	64
IS, ID	28	10	7.2	0.73	0.0	8.6	25

F.6. Disconnected Roof Area

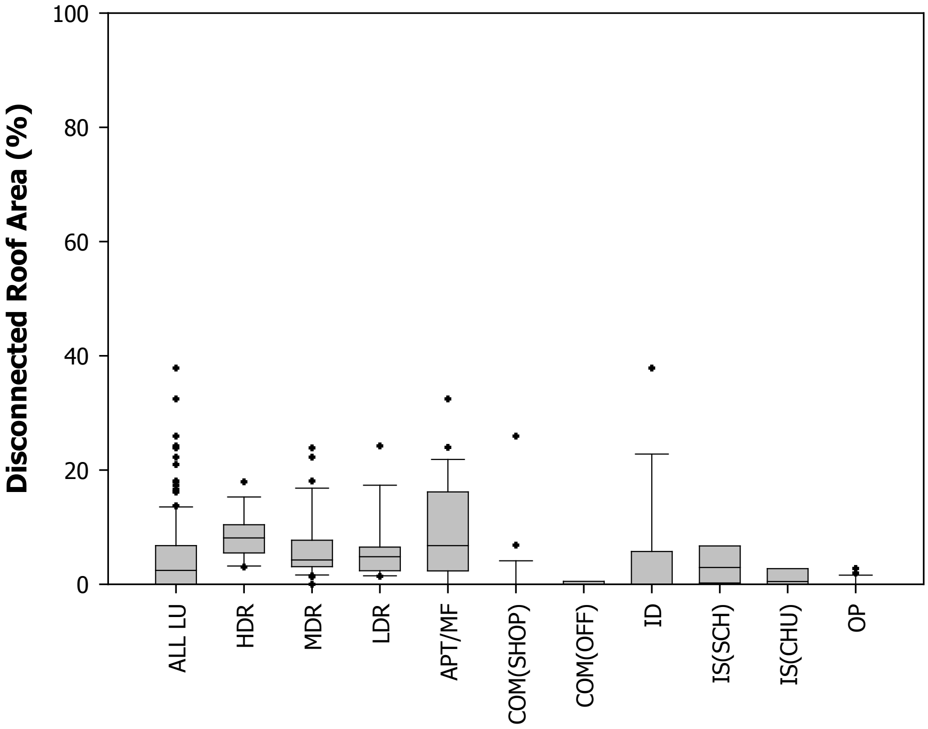
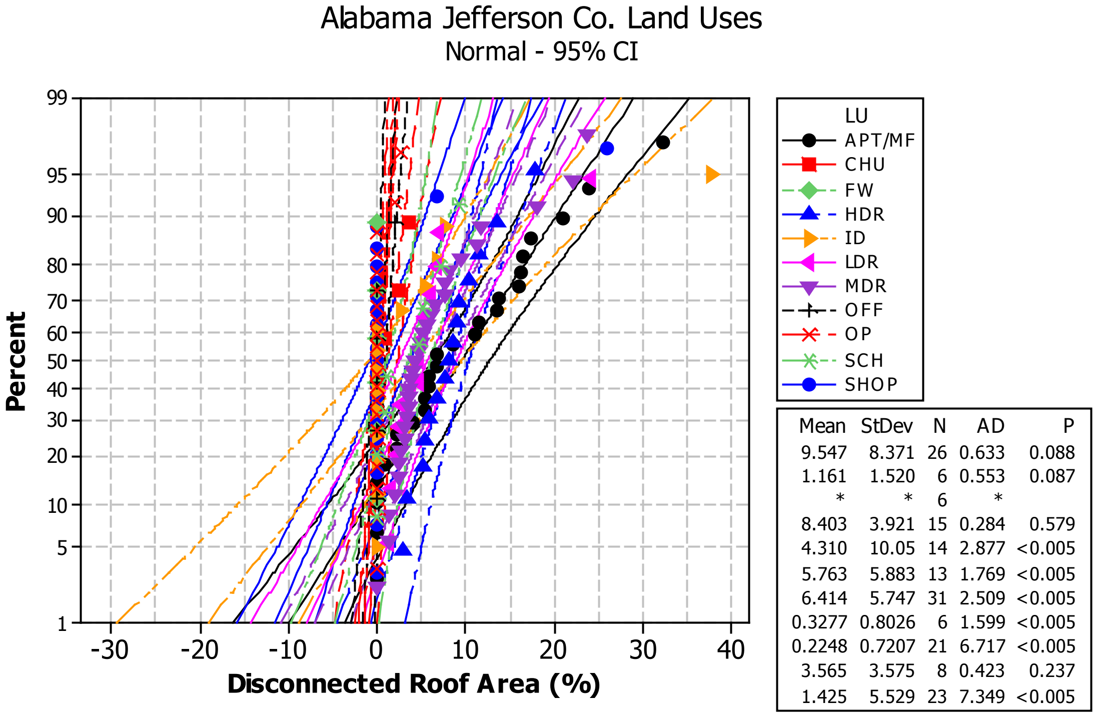


Fig. F16. Disconnected Roof Area – Jefferson County Land Uses



Mean	StDev	N	AD	P
9.547	8.371	26	0.633	0.088
1.161	1.520	6	0.553	0.087
*	*	6	*	
8.403	3.921	15	0.284	0.579
4.310	10.05	14	2.877	<0.005
5.763	5.883	13	1.769	<0.005
6.414	5.747	31	2.509	<0.005
0.3277	0.8026	6	1.599	<0.005
0.2248	0.7207	21	6.717	<0.005
3.565	3.575	8	0.423	0.237
1.425	5.529	23	7.349	<0.005

Fig. F17. Disconnected Roof Area – Jefferson County Land Uses
(Checks for Normality)

Table F20. Statistical Analyses for Disconnected Roof Area – Jefferson County Land Uses

Kruskal-Wallis Test
(Land Uses: %Disconnected Roof Area)

H = 85.54 DF = 10 P = 0.00
H = 92.08 DF = 10 P = 0.00 (adjusted for ties)

Land Use	**N**	**Median**	**Ave Rank**	**Z**
HDR	15	8.1	132	4
MDR	31	4.2	112	3
LDR	13	4.8	109	2
APT/MF	26	6.8	119	4
CO(SHOP)	23	0	45	-4
CO(OFF)	6	0	43	-2
ID	14	0	69	-1
IS(SCH)	8	2.9	90	0
IS(CHU)	6	0.47	61	-1
OP	21	0	40	-4
FW	6	0	36	-3
Overall	169		85	

Power of the Test
(Land Uses: %Disconnected Roof Area)

Land Use	**n**	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
HDR	15	8.4	3.9
MDR	31	6.4	5.7
LDR	13	5.8	5.9
APT/MF	26	9.5	8.4
CO(SHOP)	23	1.4	5.5
CO(OFF)	6	0.33	0.80
ID	14	4.3	10
IS(SCH)	8	3.6	3.6
IS(CHU)	6	1.2	1.5
OP	21	0.23	0.72
FW	6	0	0

α level	**Power (%)**
0.20	99.9
0.15	99.9
0.10	99.9
0.05	***99.9***
0.01	99.8

Pooled Std. Dev. = 5.9
Obtained
Effect Size = 0.56

Table F20. - *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value	(I) LU	(J) LU	p-value	(I) LU	(J) LU	p-value
HDR	MDR	0.025*	APT/MF	CO (SHOP)	0.000*	LDR	APT/MF	0.239
	LDR	0.013*		CO (OFF)	0.003*		CO(SHOP)	0.000*
	APT/MF	0.925		ID	0.007*		CO(OFF)	0.001*
	CO(SHOP)	0.000*		IS(SCH)	0.071		ID	0.039*
	CO(OFF)	0.001*		IS(CHU)	0.011*		IS(SCH)	0.262
	ID	0.001*		OP	0.000*		IS(CHU)	0.010*
	IS(SCH)	0.016*	CO (SHOP)	CO (OFF)	0.830		OP	0.000*
	IS(CHU)	0.001*		ID	0.199	IS(SCH)	IS(CHU)	0.220
	OP	0.000*		IS(SCH)	0.011*		OP	0.006*
MDR	LDR	0.719		IS(CHU)	0.178	IS(CHU)	OP	0.145
	APT/MF	0.192		OP	1.00			
	CO(SHOP)	0.000*	CO (OFF)	ID	0.410			
	CO(OFF)	0.000*		IS(SCH)	0.061			
	ID	0.007*		IS(CHU)	0.337			
	IS(SCH)	0.192		OP	0.816			
	IS(CHU)	0.002*	ID	IS(SCH)	0.290			
	OP	0.000*		IS(CHU)	1.00			
				OP	0.157			

Table F21. - Disconnected Roof Area – Jefferson County
Land Uses Homogeneous Groups

Land Use	Gr. A	Gr. B	Gr. C	Gr. D
HDR	8.1			
APT/MF	6.8			
MDR		4.2		
LDR		4.8		
CO (SHOP)			0	
CO (OFF)			0	
OP			0	
IS(SCH)				2.9
IS(CHU)				0.47
ID				0

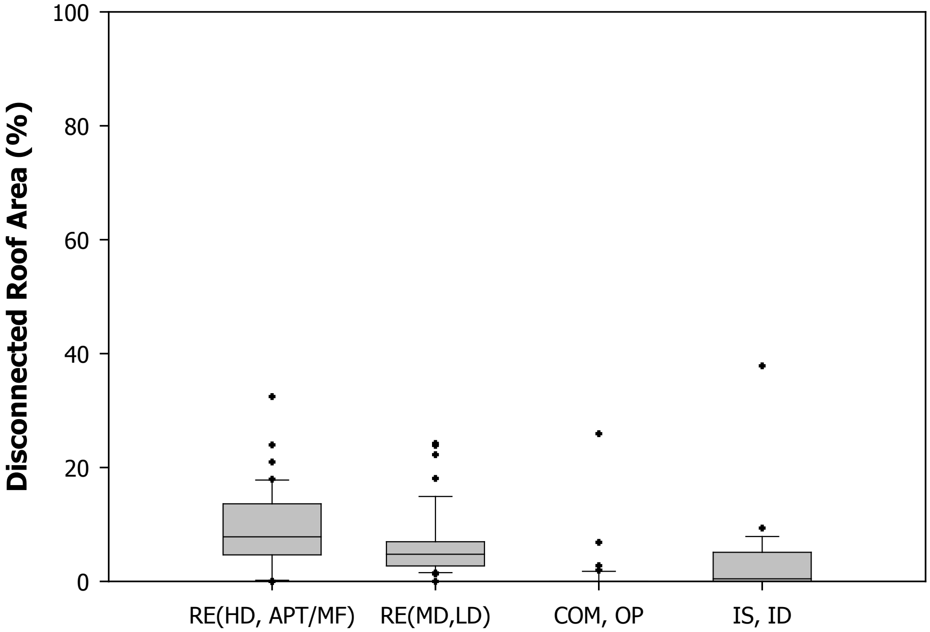


Fig. F18. Disconnected Roof Area – Jefferson County Land Uses Homogeneous Groups

Table F22. Statistical Analyses for Disconnected Roof Area –
Jefferson County Land Uses Homogeneous Groups

Kruskal-Wallis Test
(Homogeneous Groups: %Disconnected Roof Area)

H = 77.34 DF = 3 P = 0.00
H = 82.33 DF = 3 P = 0.00 (adjusted for ties)

Land Use Groups	N	Median	Ave Rank	Z
RE(HD, APT/MF)	41	7.8	118	6
RE(MD, LD)	44	4.7	105	4
CO, OP	50	0.0	40	-8
IS, ID	28	0.45	68	-2
Overall	163		82	

Power of the Test
(Homogeneous Groups: %Disconnected Roof Area)

Land Use Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(HD, APT/MF)	41	9.1	7.0
RE(MD, LD)	44	6.2	5.7
CO, OP	50	0.79	3.8
IS, ID	28	3.4	7.3

α level	Power (%)
0.20	99.9
0.15	99.9
0.10	99.9
0.05	***99.9***
0.01	99.9

Pooled Std. Dev. = 5.91
Obtained Effect Size = 0.55

Table F22. – *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value
RE(HD, APT/MF)	RE (MD, LD)	0.017*
	CO, OP	0.000*
	IS, ID	0.000*
RE(MD, LD)	CO, OP	0.000*
	IS, ID	0.000*
CO, OP	IS, ID	0.004*

Homogeneous Groups: %Disconnected Roof Area (medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE(HD, APT/MF)	7.8			
RE(MD, LD)		4.7		
CO, OP			0.0	
IS, ID				0.45

Table F23. Basic Statistics for Jefferson County Land Uses – Disconnected Roof Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE(HD, APT/MF)	41	9.1	7.0	0.77	0.0	7.8	32
RE(MD, LD)	44	6.2	5.7	0.92	0.0	4.7	24
CO, OP	50	0.8	3.8	4.8	0.0	0.0	26
IS, ID	28	3.4	7.3	2.1	0.0	0.5	38

F.7. Small Landscaped Area

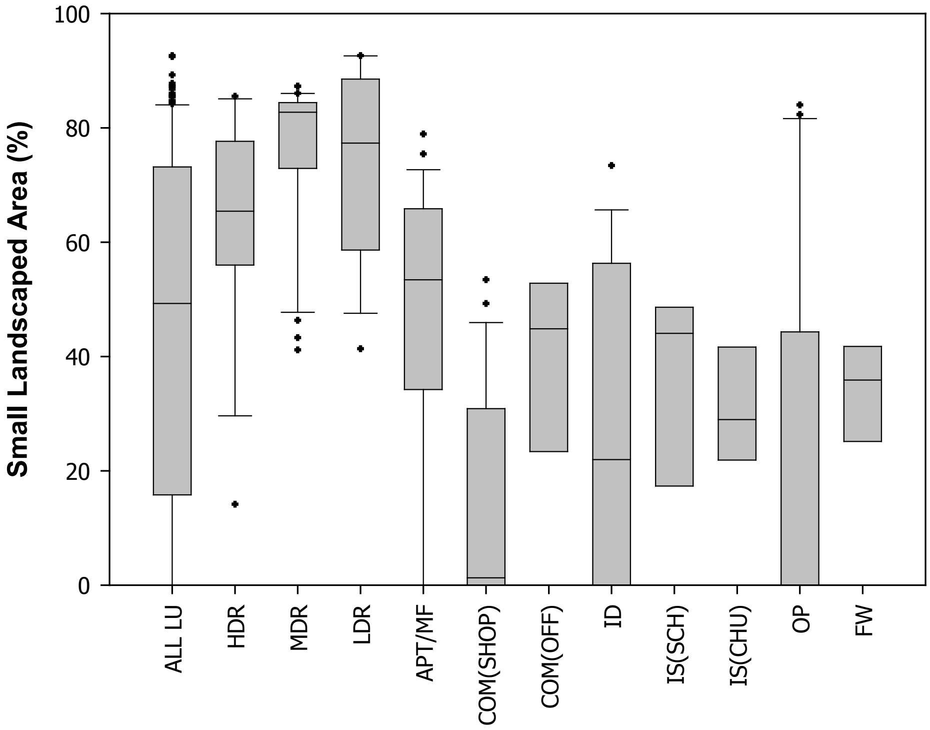


Fig. F19. Small Landscaped Area – Jefferson County Land Uses

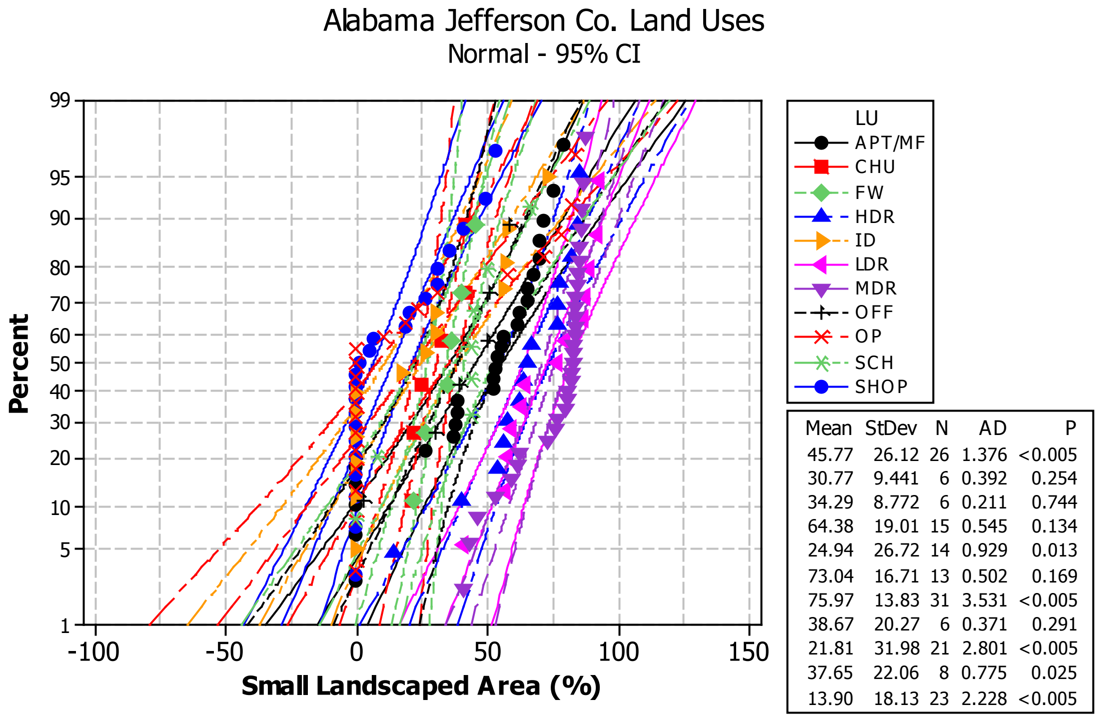


Fig. F20. Small Landscaped Area – Jefferson County Land Uses
(Checks for Normality)

Table F24. Statistical Analyses for Small Landscaped Area –
Jefferson County Land Uses

Kruskal-Wallis Test
(Land Uses: %Small Landscaped Area)

H = 92.34 DF = 10 P = 0.00
H = 93.17 DF = 10 P = 0.00 (adjusted for ties)

Land Use	N	Median	Ave Rank	Z
HDR	15	65	116	3
MDR	31	83	137	7
LDR	13	77	133	4
APT/MF	26	53	84	0
CO(SHOP)	23	1.3	39	-5
CO(OFF)	6	45	74	-1
ID	14	22	54	-3
IS(SCH)	8	44	73	-1
IS(CHU)	6	29	60	-1
OP	21	0	51	-3
FW	6	36	64	-1
Overall	169		85	

Power of the Test
(Land Uses: %Small Landscaped Area)

Land Use	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
HDR	15	64	19
MDR	31	76	14
LDR	13	73	17
APT/MF	26	46	26
CO(SHOP)	23	14	18
CO(OFF)	6	39	20
ID	14	25	27
IS(SCH)	8	38	22
IS(CHU)	6	31	9.4
OP	21	22	32
FW	6	34	8.8

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 21.7
Obtained
Effect Size = 1.0

Table F24. – *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value	(I) LU	(J) LU	p-value	(I) LU	(J) LU	p-value
HDR	MDR	0.019*	APT/MF	CO (SHOP)	0.000*	LDR	APT/MF	0.002*
	LDR	0.182		CO (OFF)	0.322		CO(SHOP)	0.000*
	APT/MF	0.011*		ID	0.040*		CO(OFF)	0.003*
	CO (SHOP)	0.000*		IS(SCH)	0.291		ID	0.000*
	CO(OFF)	0.009*		IS (CHU)	0.078		IS(SCH)	0.003*
	ID	0.001*		OP	0.025*		IS(CHU)	0.001*
	IS(SCH)	0.007*		FW	0.096		OP	0.000*
	IS(CHU)	0.005*	CO (SHOP)	CO (OFF)	0.012*		FW	0.001*
	OP	0.001*		ID	0.372	ID	IS(SCH)	0.290
	FW	0.005*		IS(SCH)	0.012*		IS(CHU)	0.483
MDR	LDR	0.980		IS(CHU)	0.034*		OP	0.649
	APT/MF	0.000*		OP	0.944		FW	0.343
	CO(SHOP)	0.000*		FW	0.022*	IS(SCH)	IS(CHU)	0.138
	CO(OFF)	0.001*	CO (OFF)	ID	0.232		OP	0.138
	ID	0.000*		IS(SCH)	0.847		FW	0.333
	IS(SCH)	0.000*		IS(CHU)	0.298	IS(CHU)	OP	0.109
	IS(CHU)	0.000*		OP	0.097		FW	0.575
	OP	0.000*		FW	0.379	OP	FW	0.085
	FW	0.000*						

Table F25. – Small Landscaped Area - Jefferson County Land Uses Homogeneous Groups

Land Use	Gr. A	Gr. B	Gr. C	Gr. D
HDR	65			
MDR		83		
LDR		77		
APT/MF			53	
CO(OFF)			45	
IS(SCH)			44	
IS(CHU)			29	
FW			36	
CO(SHOP)				1.3
ID				22
OP				0

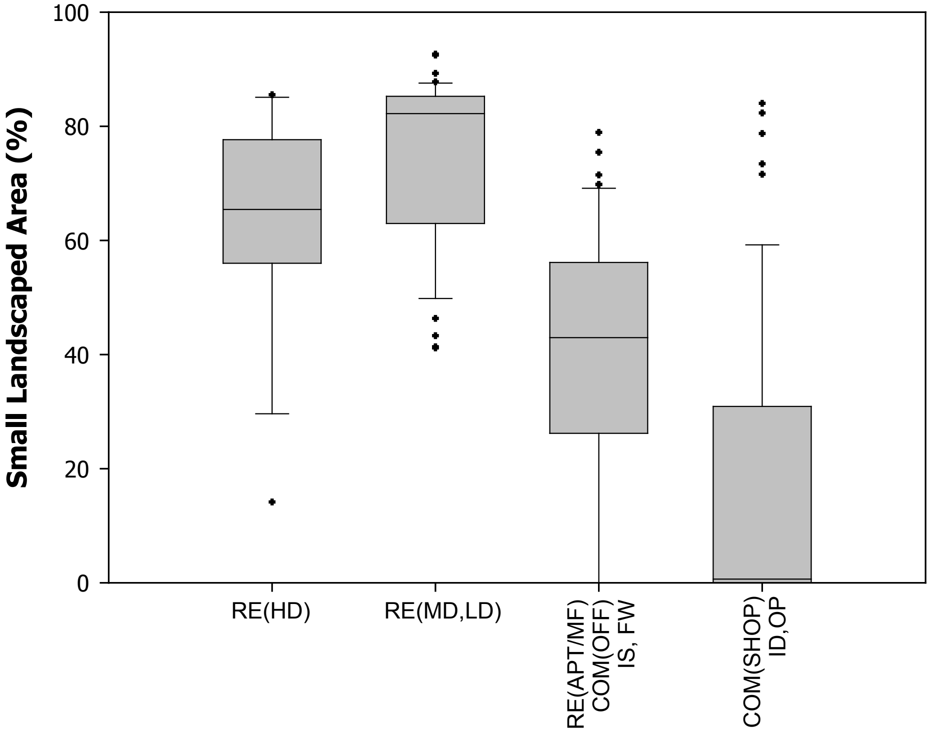


Fig. F21. Small Landscaped Area **-** Jefferson County Land Uses Homogeneous Groups

Table F26. Statistical Analyses for Small Landscaped Area – Jefferson County Land Uses Homogeneous Groups

Kruskal-Wallis Test (Homogeneous Groups: %Small Landscaped Area)

H = 89.47 DF = 3 P = 0.00
H = 90.27 DF = 3 P = 0.00 (adjusted for ties)

Land Use Groups	N	Median	Ave Rank	Z
RE(HD)	15	65	116	3
RE(MD, LD)	44	82	135	8
RE(APT/MF) CO(OFF),IS, FW	52	43	76	-2
CO(SHOP) ID,OP	58	0.64	47	-7
Overall	169		85	

Power of the Test (Homogeneous Groups: %Small Landscaped Area)

Land Use Groups	n	$\mu_{\bar{x}}$	$\sigma_{\bar{x}}$
RE(HD)	15	64	19
RE(MD, LD)	44	75	15
RE(APT/MF) CO(OFF),IS,FW	52	41	22
CO(SHOP) ID,OP	58	19	26

α level	Power (%)
0.20	100
0.15	100
0.10	100
0.05	***100***
0.01	100

Pooled Std. Dev. = 21.7

Obtained Effect Size = 1.0

Table F26. – *Continued*

Multiple Comparisons
(Mann-Whitney U Test)

(I) LU	(J) LU	p-value
RE(HD)	RE(MD, LD)	0.024*
	RE(APT/MF) CO(OFF),IS, FW	0.000*
	CO(SHOP) ID,OP	0.000*
RE(MD, LD)	RE(APT/MF) CO(OFF),IS, FW	0.000*
	CO(SHOP) ID,OP	0.000*
RE(APT/MF) CO(OFF),IS, FW	CO(SHOP) ID,OP	0.000*

Homogeneous Groups: %Small Landscaped Area (medians)

Groups	Gr. A	Gr. B	Gr. C	Gr. D
RE(HD)	65			
RE(MD, LD)		82		
RE(APT/MF) CO(OFF),IS,FW			43	
CO(SHOP) ID,OP				0.64

Table F27. Basic Statistics for Jefferson County Land Uses – Small Landscaped Area Homogeneous Groups (%)

Groups	N	Mean	Standard Deviation	Coefficient of Variation	Minimum	Median	Maximum
RE(HD)	15	64	19	0.30	14	65	86
RE(MD, LD)	44	75	15	0.19	41	82	93
RE(APT/MF) CO(OFF), IS, FW	52	41	22	0.54	0.0	43	79
CO(SHOP), ID, OP	58	19	26	1.3	0.0	0.64	84