Colorado Regulation 85 Nutrient Data Gap Analysis Report

Prepared for

Urban Drainage and Flood Control District
Colorado Stormwater Council

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1 EXECUTIVE SUMMARY

The Colorado Department of Public Health and Environment Water Quality Control Commission (CWQCC) adopted Regulation #85 Nutrients Management Control Regulation (5 CCR 1002-85) on June 11, 2012. For Municipal Separate Storm Sewer Systems (MS4) Colorado Discharge Permit System (CDPS) permittees, Regulation 85 requires public education and outreach on stormwater impacts associated with nutrients, pollution prevention/good housekeeping for municipal operations associated with nutrients, and data collection regarding the approximate nitrogen and phosphorus contribution to state waters due to discharges from MS4s. The purpose of this report is to address the data collection requirement under Regulation 85, which requires MS4s to:

> "Identify information that exists and the need for additional monitoring to be conducted in the future to determine the approximate nitrogen and phosphorus contribution to state waters due to discharges from MS4."

Findings from this effort are required to be provided to the Colorado Water Quality Control Division (CWQCD) by the MS4 permittee (or group of permittees) in a "Discharge Assessment Data Report" by October 31, 2014. This report is required to:

> "Document the availability of existing data, and [provide] a "Gap Analysis" that identifies the need for additional information (e.g., monitoring data or studies), in accordance with the requirements of [the regulation]."

This report was prepared for the Colorado Stormwater Council (CSC) and the Urban Drainage and Flood Control District (UDFCD) to meet the requirements of the Discharge Assessment Data Report (Data Report) required under Regulation 85 for MS4 permittees.

Although both instream and runoff quality data were compiled for purposes of this report, the primary focus of analysis is event mean concentration (EMC) data compiled from these sources:

- Denver Regional Urban Runoff Program (DRURP)
- UDFCD/International Stormwater BMP Database
- City of Fort Collins/Colorado State University
- Phase 1 Stormwater Permit Monitoring for the Denver Metro Area
- Phase 1 Stormwater Permit Monitoring for Colorado Springs
- Colorado Department of Transportation (CDOT)
- Arapahoe County Water and Wastewater Authority
- Bowles Metropolitan District/Grant Ranch

The overall finding from this Data Report is that there is a significant EMC-based urban runoff data set useful and sufficient for characterizing nutrient loads in urban runoff in Colorado. This report provides statistical characterization of total phosphorus and total nitrogen concentrations by land use, including measures of central tendency and variability, which can be used in a variety of load estimation methods, ranging from simple spreadsheet tools to more advanced models. Based on the findings contained in this Data Report, we conclude that additional monitoring for purposes of general characterization of nutrient concentrations and loads in urban runoff in Colorado is not necessary to meet the requirements of Regulation 85. Additional general monitoring may only confirm results previously obtained and not contribute to further understanding of nutrient concentrations and loads in urban runoff in Colorado. However, there may be circumstances in the future where site-specific monitoring is warranted to identify watershed-specific sources of nutrient loading and/or to help prioritize selection and placement of source controls and treatment BMPs. The primary findings supporting the overall conclusions include:

1. Colorado has reasonably well-developed total phosphorus (n = 602) and total nitrogen (n = 398) water quality EMC data sets representing most urban land uses that can be used to estimate urban stormwater runoff nutrient loads to state waters. Data sets for residential and commercial land uses are particularly strong (in terms of numbers of samples and relatively long periods of record) and represent the most common urban land uses. The Denver metropolitan area, Larimer County and El Paso County are the primary areas where runoff data have been collected, with some limited total phosphorus monitoring in Durango. Additionally, published reports characterizing instream water quality during runoff conditions are available, such as those completed by the USGS, local governments and watershed groups. (These reports and associated electronic data sets were not the focus of this Data Report, but may be helpful for future nutrient-related analyses.)

2. Median concentrations of total phosphorus by land use in Colorado range from 0.22 to 0.45 mg/L, with statistically significant differences in total phosphorus concentrations among some land uses. Total phosphorus concentrations in residential runoff are statistically higher than for commercial, industrial and highway-related land uses. Total phosphorus in runoff from natural open space areas was not significantly different statistically relative to urban land uses and is within the range of concentrations documented for urban land uses.

3. Median concentrations of total nitrogen by land use in Colorado range from 2.79 to 4.19 mg/L, with statistically significant differences in total nitrogen concentrations among some land uses. Total nitrogen concentrations in residential runoff are statistically higher than commercial and industrial land uses, based on the available data. No other statistically significant differences among land uses were identified. The highway-related runoff data set is relatively small; however, results are comparable to industrial runoff sites and within the range of conditions observed at other land uses. Additionally, on-going monitoring by CDOT will be useful for supplementing this data set in the future. Total nitrogen in runoff from natural open space areas was not significantly different statistically relative to urban land uses and is within the range of concentrations documented for urban land uses.

4. Colorado total phosphorus data are within ranges observed in other parts of the country, based on comparisons of the Colorado data set to the National Stormwater Quality Database (NSQD) data set categorized by U.S. Environmental Protection Agency (EPA) Rain Zones. Colorado's total nitrogen concentrations are statistically higher than those observed in other EPA Rain Zones for commercial, residential and industrial land uses, as

well as open space areas in some Rain Zones. (Note: Rain Zone 9, which includes the Colorado Front Range, was excluded from the comparative analysis due to overlapping data sets.)

5. Statistical characterizations of the nutrient concentration data described in this report can be combined with land use information, precipitation records, and runoff calculations to estimate nutrient loads from MS4s in Colorado. A simple approach using a Colorado-based spreadsheet tool based on WQ-COSM is provided in this report; however, a variety of simple to complex approaches are available and could be used for this purpose.

6. When developing load estimates for nutrients in urban runoff, it is important to recognize that runoff volume data and methods are critically important in developing such estimates. Nutrient concentrations in urban runoff are highly variable (even within common land uses); however, runoff volume is very distinctive and different for land use and development characteristics. Therefore, loads for different areas are usually strongly associated with differences in runoff volumes. To improve accuracy in load estimation using advanced models, data collection efforts focused on land use characterization in the context of calculated runoff volumes is likely more beneficial than additional general nutrient monitoring data. Advanced models such as WinSLAMM were developed to calculate runoff volumes for different land uses, development characteristics, and water quality controls. The accuracy of such models is typically improved when watershed-specific land use characterization data are available.

2 PURPOSE

The Colorado Department of Public Health and Environment Water Quality Control Commission (CWQCC) adopted Regulation #85 Nutrients Management Control Regulation (5 CCR 1002-85) on June 11, 2012. For Municipal Separate Storm Sewer Systems (MS4) Colorado Discharge Permit System (CDPS) permittees, Regulation 85 requires public education and outreach on stormwater impacts associated with nutrients, pollution prevention/good housekeeping for municipal operations associated with nutrients, and data collection regarding the approximate nitrogen and phosphorus contribution to state waters due to discharges from MS4s. The purpose of this report is to address the data collection requirement under Regulation 85, which requires MS4s to:

> "Identify information that exists and the need for additional monitoring to be conducted in the future to determine the approximate nitrogen and phosphorus contribution to state waters due to discharges from MS4."

Findings from this effort are required to be provided to the Colorado Water Quality Control Division (CWQCD) by the MS4 permittee (or group of permittees) in a "Discharge Assessment Data Report" by October 31, 2014. This report is required to:

> "Document the availability of existing data, and [provide] a "Gap Analysis" that identifies the need for additional information (e.g., monitoring data or studies), in accordance with the requirements of [the regulation]."

This report was prepared for the Colorado Stormwater Council (CSC) and the Urban Drainage and Flood Control District (UDFCD) to meet the requirements of the Discharge Assessment Data Report (Data Report) required under Regulation 85 for MS4 permittees.

The scope of this Data Report is limited to assessing whether adequate information exists to allow for determinations of representative estimates that 1) quantify MS4 discharge flows and associated concentrations and 2) quantify loads of total nitrogen and total phosphorus from MS4s. For this reason, the report discusses both nutrient concentration data for runoff and the hydrologic aspects of load calculations. For rainfall-runoff, precipitation data are available for most MS4s in the state, and there are well-established methods/tools for calculating rainfall-runoff relationships that can easily be applied to rain gages with a suitable period of record with hourly or finer-resolution data. The primary focus of this Data Report is characterizing nutrient concentration data for runoff in urban areas and describing how these data can be used in the future to estimate loads.

3 REGULATORY CONTEXT

The regulatory context for nutrients in Colorado includes two key regulations: Regulation 85, which regulates nutrient concentrations in discharges to state waters, and Regulation 31, which establishes interim instream nutrient standards (also based on concentrations). The data gap analysis in this Data Report is limited to runoff characterization under Regulation 85 and does not address instream issues related to Regulation 31.

Regulation 85 applies to point sources and nonpoint sources of nutrients in Colorado. The regulation establishes requirements that must be implemented in CDPS permits. Under Regulation 85, MS4 nutrient source reductions are required through implementation of 1) public education and outreach on stormwater impacts associated with nutrients and 2) pollution prevention/good housekeeping for municipal operations associated with nutrients. Monitoring for MS4s is dependent on the findings and conclusions reached based on a nutrient data gap analysis (which is being completed for most MS4s through this Data Report).

Along with adoption of Regulation 85, the CWQCC also adopted interim nutrient "values" for streams and lakes as part of Regulation 31, the Basic Standards and Methodologies for Surface Water (5 CCR 1002-31). Section 31.7 establishes interim numeric values for total phosphorus, total nitrogen and chlorophyll-a and also sets forth provisions regarding the use of these numeric values for the adoption of water quality standards. Although these values may be adopted under limited circumstances for specific waterbodies now for total phosphorus and beginning after May 31, 2017 for total nitrogen, the values are considered "interim" until May 31, 2022.

4 COLORADO DATA SOURCES

Regulation 85 allows MS4s to consider a variety of sources of information for purposes of estimating nutrient loads. These sources include:

- Monitoring data from the MS4 discharge or downstream waters
- Monitoring data from other entities
- Land-use based models
- Land-use based data from literature

Although each of these sources can help to estimate nutrient loads, using actual runoff concentration data collected in the state of Colorado (supplemented by comparable data nationally where appropriate) provides the most straightforward approach for approximating nutrient concentrations in stormwater runoff in Colorado. Estimates of nutrient concentrations can then be used in conjunction with well-documented hydrologic methods to estimate loads for various land uses.

As an initial step in developing this Data Report, the CSC and the Project Team completed a significant data compilation effort. These data sets were compiled into a Microsoft Access database to support the data gap analysis. Because a relatively robust event mean concentration (EMC)-based runoff data set was determined to be available, a decision was made to focus primarily on EMC-based runoff data, rather than instream data, models or other literature. Nonetheless, a brief overview of each of the data sources considered for purposes of this Data

Report follows, in the event that some of this information is useful in the future (e.g., model calibrations).

4.1 Instream Data

The CSC issued a call for data in the summer of 2012 to begin compilation of data potentially useful for the Data Report. The majority of data sources resulting from this call for data were instream monitoring studies. A list of data providers and number of samples by nutrient from the instream data sets is provided in Table 1. Although a significant amount of instream water quality data was provided, the level of effort required to estimate nutrient loads from runoff by land use would require more intricate modeling which was deemed to be much more complicated than focusing on direct runoff-based data. The instream data set may, however, be helpful in future efforts to link runoff data with receiving water impacts and to validate or calibrate receiving water modeling efforts. To use this data set for such purposes, additional meta data related to sampling conditions and other factors would be needed. As shown in Table 1, the total phosphorus data set is substantial, with over 20,000 records. For nitrogen, the nitrate and nitrate/nitrite data sets are comparable to the total phosphorus data set; however, total Kjeldahl nitrogen (TKN) has been monitored less consistently, resulting in a smaller data set for instream total nitrogen. In addition to the data sets compiled by the CSC, it is likely that additional instream data from the U.S. Geological Survey (USGS), data from historic reports (Appendix A) and the CWQCD’s nutrient database used to develop Colorado’s nutrient criteria could expand this instream data set for other future uses.

Table 1. Summary of Instream Nutrient Data Compiled by the CSC in 2012

	Number of Observations for Monitored Nutrients										
Organization	**Total P**	**Dissolved P**	**Ortho-P**	**TN**	**TIN**	**TKN**	**NO3/ NO2**	**NO2**	**NO3**	**Organic N**	**Ammonia**
Big Dry Creek Watershed Association	1,022		1,019				1,023	1,016			1,015
Big Thompson Watershed Forum	290	145					258		26		167
Cherry Creek Basin Water Quality Authority	3,091			1,783			2,077				
City and County of Denver	14[1]					3,564		3,682	3,658		17
Chatfield Watershed Association	296			223		60	60				60
City of Fort Collins	1,195		153			590		1,510	1,507		1,163
City of Golden	73			65			61		4		
City of Longmont	261						260				261
City of Pueblo	81	293		81			296				296
Colorado 319 Program	4	2					2		182		1
Colorado Riverwatch Program	10,946	5,473		94			5,564		1,034		5,573
City of Greeley			76		83				321		
Town of Lafayette	24					20	16	20	20		20
North Fork Improvement Association (Gunnison)	2	1						2			1
Selenium Task Force (Gunnison)	2	1						2			1
UDFCD	268		269	269		269	269				269
USGS	4,084	2,042	4,264	1,280		574	4,908	1,932	1,932	1,260	10,092
Total	21,653	7,957	5,781	3,795	83	5,077	14,794	8,164	8,684	1,260	18,936

[1]Additional instream total phosphorus data are available from the City and County of Denver, but were inadvertently omitted by city staff from the database query. If instream data are used in future analyses, these data sets may be obtained from the City and County of Denver.

4.2 Literature Sources Focused on Colorado Streams

Published literature sources regarding instream nutrient concentrations in Colorado are also available. These include studies by the USGS, local governments, watershed associations and others. Because of the emphasis on runoff characterization, these studies were not thoroughly inventoried for purposes of this Data Report; however, several examples of studies completed by the USGS are highlighted below. These examples illustrate the types of information that could be further researched on an as-needed basis in the future, particularly if needed to supplement data in mountain areas or western Colorado, to revise estimates of naturally occurring phosphorus and nitrogen in Colorado streams, or to refine understanding of stressor-response relationships in streams. A few examples include:

- *Assessment of Total Nitrogen and Total Phosphorus in Selected Surface Waters of the National Park Service Northern Colorado Plateau Network, Colorado, Utah, and Wyoming, from 1972 through 2007, USGS Scientific Investigations Report: 2012-5043* (Brown and Thoma 2012). Selected highlights include:

    - The USGS, in cooperation with the National Park Service, assessed total nitrogen and total phosphorus concentration data for 93 sites in or near 14 National Park units in Northern Colorado Plateau Network streams for the time period 1972 through 2007.
    - Detailed analysis results are presented in this report, often showing elevated nitrogen and phosphorus relative to EPA's recommended criteria.
    - Some of the key recommendations of this report that may be relevant to factors that may affect nutrient loads in Colorado include:
        - Quantification of trends in streamflow and (or) loads and precipitation, as well as collection and evaluation of ancillary data, such as dissolved oxygen, macroinvertebrates, and algal community composition and structure for these sites, could provide additional insight into nutrient status in these streams.
        - It also may be helpful to consider and quantify these results within the context of the basin of each water-quality sampling site, including the dominant geology, land cover, and land uses.
        - The overall sampling period of record, the seasonal sampling frequency, and the simultaneous measurement of streamflow and analysis of related constituents are all key considerations when designing and implementing water-quality sampling programs.

- *Effects of Urban Development on Stream Ecosystems along the Front Range of the Rocky Mountains, Colorado and Wyoming* (Sprague et al. 2006). Representative findings include:
    - The USGS conducted a study from 2002 through 2003 through its National Water-Quality Assessment (NAWQA) Program to determine the effects of urbanization on the physical, chemical, and biological characteristics of stream ecosystems along the Front Range of the Rocky Mountains. The objectives of the study were to (1) examine physical, chemical, and biological responses at sites ranging from minimally to highly developed; (2) determine the major physical,

chemical, and landscape variables affecting aquatic communities at these sites; and (3) evaluate the relevance of the results to the management of water resources in the South Platte River Basin.

- In this study, the link between urban development and stream ecosystems was not found to be as strong in transition-zone streams along the Front Range of Colorado and Wyoming. Under natural conditions, aquatic communities in streams in the plains typically are more tolerant than those in less extreme habitats (Matthews, 1986), but historical records indicate that aquatic communities in these streams were more diverse before the advent of irrigated agriculture, localized pollution events, and water management (Jordan, 1891; Ellis, 1914).
- Although there were very few strong relations between chemistry variables and urban development, nutrient, pesticide, and major ion concentrations in baseflow were strongly related to biological community response.
- The movement and storage of water may lead to a disconnect between the land surface and streams, resulting in instream physical, chemical, and biological characteristics that are to some degree independent of land-cover characteristics.
- The lack of a strong link between urban development and stream ecosystem response in transition-zone streams along the Front Range does not mean that urban development has no effect on stream ecosystems in this region. Rather, it is likely that these ecosystems are affected by multiple interacting stressors, including but not limited to urban development, agriculture, and water management.

- *Analysis of Urban Storm-Runoff Data and the Effects on the South Platte River, Denver Metropolitan Area, Colorado, USGS Water-Resources Investigations Report 84-4159* (Ellis et al. 1984). This USGS-Denver Regional Council of Governments (DRCOG) program collected the first urban runoff data on the South Platte River. Additionally, it included baseflow for comparison of stormwater to ambient (non-storm) conditions, reports from wastewater treatment plants for comparison to point-source loading, and bottom-sediment data. The relative contributions of nutrients from point and stormwater loadings are provided in this report.

Examples of other recent reports that may be useful in supplementing understanding of instream nutrients in specific watershed contexts include:

- *Assessment of Surface-Water Quantity and Quality, Eagle River Watershed, Colorado, 1947–2007, USGS Scientific Investigation Report 2011-5075* (Williams et al. 2011).
- *Assessment of Historical Surface Water Quality Data in Southwestern Colorado, 1990-2005, USGS Scientific Investigations Report: 2012-5255* (Miller et al. 2013).

Appendix A also provides a summary of historic studies completed in the 1970s through1990 that were compiled in support of the Phase 1 MS4 permit application.

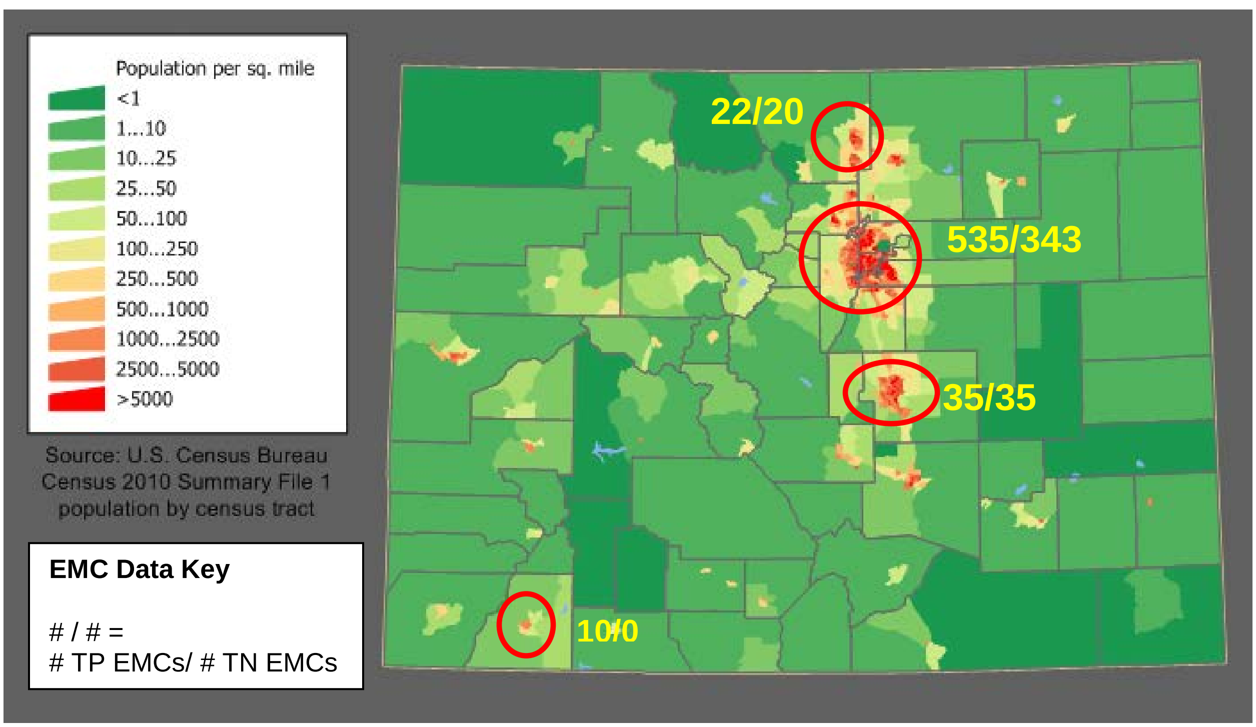
4.3 EMC-based Studies

To support this Data Report, nutrient data collected in Colorado have been compiled into a water quality database and used in the statistical analysis in the remainder of this Data Report. Areas where these EMC-based data sets have been collected generally correspond to urbanized parts of the state, as identified on Figure 1. Data sources with EMC-based data used in this analysis include:

- Denver Regional Urban Runoff Program (DRURP)
- UDFCD/International Stormwater BMP Database
- City of Fort Collins/Colorado State University
- Phase 1 Stormwater Permit Monitoring for the Denver Metro Area
- Phase 1 Stormwater Permit Monitoring for Colorado Springs
- Colorado Department of Transportation
- Arapahoe County Water and Wastewater Authority
- Bowles Metropolitan District/Grant Ranch

As part of the database, information related to analytical methods, precipitation, and flow was also compiled. General descriptions of the monitoring locations and monitoring approach for each of these efforts is described below, along with references to underlying reports which provide more detailed information on sampling procedures, QA/QC, and general site information. The level of detail provided below depends on the extent of readily-available information supplied by the data provider.

Figure 1. General Distribution of Nutrient Monitoring EMCs in Colorado Relative to Population



4.3.1 Denver Regional Urban Runoff Program (DRURP)

Under DRURP, the Denver Regional Council of Governments (DRCOG) and the USGS studied the nature of urban runoff, its influence on receiving waters, and possibilities for control in the Denver region. DRCOG was awarded a grant in 1979 to study the effects of urban runoff on the South Platte River and its tributaries. The program lasted for three years and sampling took place from March 1980 to September 1981. Its national counterpart is known as the Nationwide Urban Runoff Program (NURP).

In an effort to quantify urban runoff pollution in the DRURP study area, the USGS and DRCOG monitored rainfall, runoff, and water quality from urban basins representative of various land uses. Nine small urban runoff basins were selected for storm-event monitoring to assess the contribution of urban runoff pollutants by land use. The basins ranged from 33 to 405 acres, and seven of the nine had homogeneous land uses. Two of the basins represented sites below flood detention ponds and are not included for purposes of urban runoff characterization in this report. Table 2 identifies the monitoring sites, dominant land uses, drainage areas, and the abbreviated site name used in figures later in this Data Report.

Automatic tipping bucket rain gages, water quality samplers, and discharge recorders were installed at the basins. Measurements were recorded at five-minute intervals at all sites except Rooney Ranch; Rooney Ranch information was collected every fifteen minutes. The USGS, through a cooperative agreement with DRCOG, was responsible for equipment installation and maintenance, sample procurement and analysis, rainfall and runoff measurement, and storm load calculations. All water quality sampling and analyses were handled under stringent quality control standards and were analyzed by the USGS Central Laboratory in Denver for constituents including various nutrients, metals, and oxygen demanding substances and solids. The monitoring program is described in more detail in *Hydrologic Data for Urban Storm Runoff from Nine Sites in the Denver Metropolitan Area, Colorado, USGS Open File Report 81-682 (Gibbs 1981) and Hydrologic Data for Urban Storm Runoff in the Denver Metropolitan Area, Colorado, USGS Open File Report 82-872* (Gibbs and Doerfer 1982).

To assist with runoff sampling and pollutant load calculation methodologies, both discrete and composite samples were taken from each basin for the first several storms monitored. Discrete samples were collected at intervals throughout the storm's duration, with each individual sample analyzed and then used to calculate a storm load. Composite samples also included runoff samples from intervals throughout the entire storm, but were combined to create a single composite sample for analysis based upon each sample's proportion of maximum storm flow (i.e., a flow-weighted EMC). No statistically significant differences between calculated loads were found between these two sampling schemes. Because composite sampling only involves one laboratory analysis, this methodology was chosen for later storms for cost-effectiveness. (Composite sampling is now standard practice.)

Urban runoff was monitored from three types of storms: thunderstorms, upslope rainstorms, and snowstorms. Data from thunderstorms and upslope rainstorms were combined for analysis. Due to the difficulty in quantifying precipitation amounts from snowstorms, few of these were sampled and are not included in the data analyses in the DRURP report. Equipment malfunction was a major cause for the difference in number of storms sampled between basins. Monitoring at Asbury Park basin was abandoned after one sampled snowstorm due to excessive equipment problems caused by vandalism. Also, limited data were available from the Rooney Ranch natural grassland site because runoff was only formed in this pervious basin during larger rainstorm events in the spring when either soils were saturated or the ground was frozen.

Table 2. DRURP Monitoring Locations

Station		Monitoring Site[1]	Land Use	Drainage Area (acres)	Plot Abbreviation
1	Southglenn	Big Dry Creek Tributary at Easter St. near Littleton	Multi-Family Residential	33	DRP_Southglenn
2	Rooney Ranch	Rooney Gulch at Rooney Ranch near Morrison	Natural Grassland	405	DRP_Rooney
3	Asbury Park[2]	Asbury Park Storm Drain at Tejon St., Denver	Single Family Residential	121	DRP_Asbury
4	Asbury Park Retention[3]	Asbury Park Storm Drain at Asbury Ave., Denver	Single Family Residential	127	DRP_AsburyRet
5	North Avenue	Upper N. Ave. Storm Drain at Denver Fed. Center, Lakewood	Commercial, Single Family, Open Space	69	DRP_NorthAve
6	North Avenue Retention[3]	Lower N. Ave. Storm Drain at Denver Fed. Center, Lakewood	Commercial, Single Family, Open Space	80	DRP_NorthAveRet
7	Cherry Knolls	Cherry Knolls Storm Drain, Denver	Multi-Family Residential	57	DRP_CherryKnolls
8	Northglenn	116th & Claude Ct. Storm Drain, Northglenn	Single Family Residential	167	DRP_NorthGlenn
9	Villa Italia	Villa Italia Shopping Center Storm Drain, Lakewood	Commercial, Shopping Area	74	DRP_VillaItalia

[1]Monitoring timeframe was 1980-1981 with number of monitoring events per site ranging from 5 to 21.
[2]Monitoring abandoned after one sampled snowstorm due to vandalism. Excluded from analysis.
[3]Retention basin sites excluded from runoff characterization analysis, consistent with Ellis et al. 1984.

4.3.2 Urban Drainage and Flood Control District/BMP Database

4.3.2.1 Overview of UDFCD Monitoring Locations

UDFCD has monitored stormwater BMPs in the metro Denver area since the 1980s. On an annual basis, UDFCD submits BMP monitoring data to the International Stormwater BMP Database (www.bmpdatabase.org), making these data sets publically available to researchers in Colorado and throughout the country. The inflow data and reference watershed data at these BMP monitoring sites are useful for runoff characterization. Table 3 summarizes the monitoring locations used as part of the runoff characterization in this Data Report. Additional descriptions of each site are provided separately below with more detailed information accessible from

Urbonas (1994) and Urbonas and Ommert (1996) for Shop Creek, and Piza and Eisel (2011a&b, 2013) for other UDFCD sites.

Table 3. UDFCD BMP Inflow Monitoring Locations

UDFCD BMP Inflow Monitoring Location[1]	Land Use	City	Drainage Area (acres)	Abbreviation Used on Data Plots
Lakewood Shops[2]	Office Commercial	Lakewood	0.2	UDFCD_MBPP
UDFCD Modular Porous Pavement 05 to 06 (Reference Site)[2]				
UDFCD Modular Porous Pavement 94 to 04 (Reference Site)[2]				
Orchard Pond	Low Density Residential	Littleton	18.7	UDFCD_OrchPnd
Shop Creek Wetland-Pond (1990-94)[3]	Low Density Residential	Aurora	550	UDFCD_Shop
Shop Creek Wetland-Pond (1995-97)[3]				
Denver Wastewater Building (Reference Site)	Office Commercial	Denver	0.02	UDFCD_DenWW
21st and Iris Rain Garden	Medium Density Residential	Lakewood	1.9	UDFCD_21Iris

[1]Monitoring timeframes at these sites with total phosphorus and total nitrogen data ranges from 1995 to the present, with runoff monitoring events per site typically ranging from 45 to 85. The 21st and Iris Rain Garden site began being monitored in 2011, so it has fewer samples.
[2]The parking lot reference site for the Lakewood Shops and UDFCD Modular Porous Pavement sites are the same physical location. They are named differently because they were associated with three different BMP studies, related to different pavement types, submitted to the International Stormwater BMP Database.
[3]Similar to Note 2, the Shop Creek site is identified as two separate studies in the BMP Database due to modifications made to the BMPs; however, the inflow to these sites represents the same physical location.

4.3.2.2 Lakewood Shops and Historic UDFCD Modular Porous Pavement Site

The Lakewood Shops monitoring site is located at 850 Parfet Street in Lakewood in a parking lot for city employees. This is also the location of the BMP studies identified as UDFCD Modular Porous Pavement 05 to 06 and UDFCD Modular Porous Pavement 94 to 04 in the International Stormwater BMP Database. Several different pervious pavements have been tested at this site in various locations from 1994 to the present. Monitoring data were collected for these installations, as well as a reference site that was established to determine baseline water quality conditions. The reference site is the employee parking lot, with traditional asphalt pavement.

The employee parking lot used as the reference site is 8,900 square feet and is entirely impervious. Runoff flows into a sump catch basin at the northeast corner of the watershed and exits through an H-flume. Runoff volume is measured using a pressure transducer (ISCO model 720) installed at the H-flume. The pressure transducer measures head behind the flume and the sampler uses these data to calculate flow based on a stage-discharge table for the weir. Rainfall is measured at the site continuously with a tipping rain gauge (ISCO model 674).

Water quality sampling is automated through the use of an ISCO model 6712 sampler. Composite samples are collected typically within 24 hours and are discarded if not retrieved within 48 hours. The samples are put on ice and transported to the lab for analysis. Samples have been analyzed for 40 constituents including metals, nutrients, TSS, and chemical properties.

4.3.2.3 Shop Creek

The Shop Creek site is a wet pond/wetland system in Aurora, Colorado. The treatment system was constructed by City of Aurora and Cherry Creek Basin Water Quality Authority (CCBWQA) in 1989. The watershed draining to the treatment system is 550 acres of primarily single-family low density housing, with 40% impervious cover. Flow and water quality monitoring of inflow and outflow to the system has been conducted by UCFCD in cooperation with the CCBWQA since 1990.

During 1990-1992, water quality sampling occurred from May through September. Flow measurements were recorded every 10 minutes during the months of April through October. Water quality samples were analyzed for 19 constituents, including nutrients, metals, TSS, and COD. In 1994, the pond was retrofitted to provide a vegetated zone within the pond, with sampling resuming during 1995. During this sampling regime, sampling occurred from April through November. Flow data measurements were collected more frequently at 5 minute intervals during this monitoring period. Water quality samples taken during this period were analyzed for nine additional constituents, including additional forms of nutrients, total volatile suspended solids, and additional metals.

4.3.2.4 Denver Wastewater Building

At the City and County of Denver Wastewater Management Building located at 2000 3rd Avenue in Denver, UDFCD conducts monitoring to evaluate permeable pavement performance. Monitoring of runoff occurs at two permeable pavement locations and one reference site, all of which receive runoff from office buildings and parking lots. The reference site is located in the northwestern corner of the building's parking lot and represents untreated runoff characteristics. The contributing drainage area to the reference site is 8,400 square feet and is located in a slightly less trafficked portion of the parking lot than the test sites. The contributing area is entirely impervious, consisting of asphalt.

UDFCD has collected water quality and flow data during storm events at this location since 2008. Stormwater runoff from the reference watershed flows into a grated catch basin, where sampler tubing pulls samples from the bottom of the catch basin, while a pressure transducer measures head behind a Cipoletti weir. Composite samples are collected with an automatic sampler (ISCO Model 6712). Constituents analyzed include metals, nutrients, TSS, chloride, and chemical oxygen demand. Rainfall is measured with a tipping bucket (ISCO Model 674). The sampling equipment is stored in a metal box adjacent to the parking lot.

4.3.2.5 21st and Iris Rain Garden

In 2011, UDFCD began monitoring a rain garden installed on the corner of an intersection in a residential neighborhood in Lakewood, Colorado. Monitoring was conducted both at the inflow and outflow of the rain garden. The contributing watershed is 1.9 acres of medium-density residential development with 47% impervious cover. Monitoring data for 2011 were submitted to the BMP Database, with monitoring continuing into the future.

Concentrated flow from the tributary area enters the BMP by way of a concrete drain pan at the west end of the rain garden. Runoff volume is measured with a pressure transducer (ISCO Model 720) installed in a v-notched weir at the inlet to the rain garden. The pressure transducer measures head behind the weir and flow is calculated from this value based on a stage-discharge table for the weir.

Rainfall is measured at the site continuously with a tipping rain gauge (ISCO model 674) and flow-weighted composite water quality samples are collected using an ISCO model 6712 sampler. Composite samples are typically collected within 24 hours and are discarded if not retrieved in 48 hours. The samples are put on ice and transported to the lab for analysis. During 2011, water quality samples were collected for nine sampled events, and were analyzed for 31 constituents, including metals, nutrients, COD, and TSS.

4.3.2.6 Orchard Pond

The Orchard Pond site is one of three extended detention basins installed at the Grant Ranch residential development in Littleton, Colorado. Water quality and flow monitoring of these ponds began in 1999 and was originally conducted by Wright Water Engineers. In 2001, UDFCD retrofitted Orchard Pond to be consistent with UDFCD's currently applicable design criteria and later assumed monitoring responsibilities. Orchard Pond is discussed further in Section 4.3.8 with the other monitoring locations at Grant Ranch in Bowles Metropolitan District.

4.3.3 City of Fort Collins/Colorado State University

Inflow data from two BMP monitoring studies were obtained from Colorado State University and the City of Fort Collins, as summarized in Table 4. These two sources are described below.

Table 4. Fort Collins BMP Inflow Monitoring Locations

Study	Monitoring Site[1]	Dominant Land Use	Drainage Area (acres)	Plot Abbreviation
1 (CSU/City)	Howes (HOWES IN)	Residential (with some commercial/institutional/ open space)	524	CSU_Howes
	Udall Outfall (UD OUT)	Residential (with some commercial/institutional/ open space)	517	CSU_UD
2 (Knuth)	Udall natural area (Fort Collins Inlet)	Residential (with some commercial/campus mixed uses)	660	CSU_FCIn

[1]Monitoring timeframe was 2003-2011 with number of monitoring events per site ranging from 5 to 10. Drainage basin characteristics provided by Chris Olson, Colorado State University.

4.3.3.1 Howes and Udall (2009-2011)

Colorado State University and the City of Fort Collins conducted BMP performance monitoring between October of 2009 and April of 2011, investigating a variety of BMPs and locations within the City of Fort Collins. The purpose of the study was to evaluate the effectiveness of the BMPs, estimate average annual pollutant loads to receiving waters, and develop relationships between contributing area, BMP design, and runoff quality. Two inflows at these sites are useful for runoff characterization. These sites are referred to as “Howes In” and “UDout” for purposes of this Data Report.

These sites were both manholes near the inlet of a BMP. The contributing area to the “Howes In” site is 524 acres with 52% impervious cover. Land use is mixed, although it is predominantly medium- and low-density residential (30% and 47% of the watershed area, respectively). The remainder of the land use is roughly equal parts commercial, institutional, and open space. The contributing area to the “UD Out” site is 517 acres with 64% impervious cover. This watershed is approximately half medium- and low-density residential (32% and 25% respectively), with a larger commercial area than the “Howes In” site (21%), with the remainder dedicated to institutional and open space uses.

Runoff depth was measured at the inlets to each site using pressure transducers and these values were converted to flow using flow-stage relationships that were developed for each site. Rainfall in the area of both sites is monitored by several entities within the watersheds. Samples were collected using an ISCO automatic sampler programmed to collect flow-weighted composite samples throughout storm events. All samples were kept on ice and acidified, as appropriate. Samples were analyzed for 19 constituents, including total hardness, TSS, nutrients, metals, TOC, BOD, COD, and *E. coli* (grab samples) using standard methods.

4.3.3.2 Udall Natural Area (2003-2004)

In "Design and Initial Operation of the Udall Natural Area Stormwater Quality Best Management Practice," Jeremiah Knuth summarized his master thesis research completed at Colorado State University in 2005. As part of this project, inflow and outflow of the Udall Natural Area was monitored from July 2003 to August 2004. The Udall Natural Area is a series of BMPs and wetlands on the corner of East Lincoln Ave. and Riverside Ave in Fort Collins, Colorado. The site is downstream of a 2,120-acre basin of completely urbanized residential and commercial area, including 400 acres of the CSU campus. Estimated imperviousness of the watershed is 65%, with a contributing drainage area of approximately 660 acres. Runoff enters the site via a 96-inch storm sewer pipe. Monitoring data for this site included baseflow, snowmelt and runoff events, which are analyzed separately in this Data Report.

Precipitation at the site was monitored using four nearby rain gauge locations (CSU, Fire Station #2, Cache la Poudre River and Lincoln Avenue, and City of Fort Collins Utility Service Center), which are all tipping-bucket rain gauges. Snowfall data were recorded manually at various locations by the Community Collaborative Rain and Hail Study (CoCoRAHS).

Flow was measured at the inlet using a double bubbler and a pressure transducer. For storm runoff events, flow-weighted samples were collected using an ISCO 3700 autosampler. Composite samples were collected between April and October.

During dry weather and snowfall runoff events, grab samples were collected. Dry-weather samples were collected approximately monthly when less than 0.1 inch of rainfall during the previous 72 hours was recorded. Snowfall runoff sampling was conducted between November and March when greater than 0.1 inch of precipitation had fallen. Discrete raw water samples were collected manually once per day in the afternoon during peak melting and continued daily until the snow had melted in the unshaded areas in the drainage basin or a maximum of two weeks.

A total of 10 dry-weather base flow, five rainfall-runoff samples, and three snowfall-runoff samples were collected during the study. Nineteen water quality parameters were measured including general water quality parameters (e.g., DO, pH, TSS), metals (except for snowfall runoff samples), nutrients, TOC, and *E. coli* using standard methods. Samples were transported to the lab on ice, and preserved, as appropriate. Snowfall runoff samples were composited and preserved every three days.

4.3.4 Phase 1 Stormwater Permit Monitoring for the Denver Metro Area

As part of the NPDES Part 1 permit application for municipal stormwater permits, a plan for characterization of urban stormwater runoff was required. This program was conducted and funded jointly by the Cities of Denver, Aurora, and Lakewood and UDFCD in 1992. Under the program, precipitation, runoff, and water quality data were collected from eight monitoring sites with various homogeneous land use types.

The eight basins were monitored by USGS over a six-month period from March 22, 1992 to September 23, 1992, as summarized in Table 5. Automatic tipping bucket rain gages, water samplers, and flow recorders were installed at each station. The USGS conducted the sampling under a cooperative agreement with UDFCD. Samples were analyzed by the USGS National Water Quality Laboratory in Denver.

Table 5. Metro Denver Phase 1 Monitoring Locations

Station	Monitoring Site[1]	Land Use	Drainage Area (acres)	Plot Abbreviation
1	Sand Creek Tributary at 34th and Havana at Denver	Industrial	498	P1_CLFX
2	South Platte River Storm Drain at 54th and Steele at Denver	Industrial	636	P1_UNIV
3	South Platte River Storm Drain at 7th Avenue at Denver	Industrial	56	P1_VILL
4	Villa Italia Storm Drain at Lakewood	Commercial	146	P1_7TH
5	Cherry Creek Storm Drain at Colfax Avenue at Denver	Commercial	150	P1_54TH
6	Cherry Creek Storm Drain at University Boulevard at Denver	Commercial	55	P1_SMTH
7	North Sanderson Gulch Tributary at Lakewood	Residential	269	P1_NSAN
8	Shop Creek at Parker Road at Aurora	Residential	495	P1_SHOP

[1]Monitoring was conducted in 1992 with three events monitored per site.

Flow-weighted composite samples were prepared from discrete samples collected at intervals over the course of the storm event. A cone splitter was used to prepare the required aliquot volume, while maintaining representative subsamples. Samples were fixed with preservatives as required and shipped to the lab on ice.

A total of 25 samples were collected in the program. Three samples were collected at each of the seven sites, resulting in nine samples representing industrial runoff, nine samples representing commercial runoff and six samples representing residential areas. One sample of snowmelt runoff was collected at the North Sanderson Gulch (Storm No. 1, Site No. 7). All other stormwater samples were either convective rainstorms or frontal rainfall events. Precipitation was generally below normal during the monitoring period.

4.3.5 Phase 1 Stormwater Permit Monitoring for Colorado Springs

Similar to the Denver-area Phase 1 stormwater permit sampling program, the USGS worked with the City of Colorado Springs to conduct stormwater sampling as part of the city's Phase 1 permit application in 1992 (USGS 1993). Five locations were monitored during May through August of 1992, as summarized in Table 6. The monitoring program included flow data and event mean concentrations for field parameters, bacteria, solids, nutrients, metals, total organic carbon, and organic constituents for 30 storms collected at the five monitoring locations (6 storms per basin). As general background common to these monitoring locations, convective thunderstorms contributed most of the rainfall that occurs during May through September, and soils in the study area tend to be sandy.

Table 6. Colorado Springs Phase 1 Monitoring Locations

Monitoring Location	Land Use	Drainage Area (acres)	Plot Abbreviation
Sixteenth Hole Valley Hi Golf Course	Commercial	80	P1_CS_ValleyHi
Chestnut Street at Douglas Creek	Industrial	106	P1_CS_Chestnut
Beacon Street at Buchanan Street	Industrial	111	P1_CS_Buchanan
Walmart at Eighth Street	Commercial	31	P1_CS_Wal8th
Wahsatch Street at Cross Lane	Residential Mixed Use	209	P1_CS_Wahsatch

[1]Monitoring was conducted in 1992 with seven events monitored per site.

Key aspects of each monitoring location include:

- **Sixteenth Hole Valley Hi Golf Course**: The predominant land use is commercial and includes retail stores and two automobile dealerships. Effective imperviousness is 58%. The sample location is a 60-inch RCP pipe. The location is upstream of Spring Creek.

- **Chestnut Street at Douglas Creek**: The predominant land use is industrial and includes tool and machine forging, computer software, manufacturing and metallurgy companies. Effective imperviousness is 38%. The sample location is a 72-inch RCP pipe. The location is upstream of Douglas Creek.

- **Beacon Street at Buchanan Street**: The predominant land use is industrial and includes auto repair, machining, manufacturing, food processing, welding, computer software, metal fabrication and paper distribution companies. Effective imperviousness is 56%. The sample location is a 48-inch RCP pipe. The location is upstream of Monument Creek.

- **Walmart at Eighth Street**: The predominant land use is commercial, including two automobile dealerships, a gas station and several retail stores. Effective imperviousness is 40%. The sample location is a 42-inch RCP pipe. The location is upstream of Bear Creek.

- **Wahsatch Street at Cross Lane**: The predominant land use is low-density residential, but includes some commercial areas. Effective imperviousness is 34%. The sample location is a 66-inch RCP pipe. The location is upstream of Shooks Run.

4.3.6 Colorado Department of Transportation

The Colorado Department of Transportation (CDOT) is required to develop and implement a wet weather monitoring program under MS4 Permit No. COS-000005, which became effective February 1, 2007. The purpose of this program is to assess wet weather impacts from highways and the performance of BMPs used to control discharges. The monitoring program is described in *Wet Weather Monitoring Program, CDOT MS4 Areas* (CDOT 2007), and site descriptions and monitoring data are described in appendices to various annual reports.

Table 7 summarizes CDOT monitoring locations used in runoff characterization analysis based on data collected from 2009-2012 and provided for inclusion in this Data Report. Additional monitoring data are anticipated to be available in the future at some of these locations and at new locations. For example, future monitoring is planned to expand to West Slope locations including Montrose, Grand Junction, and Steamboat Springs (in addition to monitoring that began being conducted in Durango in 2011). Sites representing treated outflow from permanent water quality facilities (e.g., extended detention ponds) were excluded from the analyses in this Data Report. Monitoring data for these sites includes both snowmelt and runoff events, which are analyzed separately. The locations at the CDOT monitoring sites are associated with a variety of highway-related activities, which include both highway runoff and maintenance facilities.

Because the Division already has a copy of the monitoring plan, detailed location descriptions, and annual reports associated with CDOT's discharge permit, only a brief overview of the sites is provided in this report. Typical monitoring equipment includes Sigma 900 Max portable auto samplers, and area velocity meters used to measure flow rate and to trigger the samplers when sufficient flows are present. Some locations have also used ISCO samplers. Tipping bucket rain gauges are used to measure precipitation. Photo documentation and maps of the monitoring locations for most of the sites are available in CDOT's annual reports.

Brief narrative descriptions for monitoring locations, which are available in varying levels of detail, include:

- **18500 E Colfax Facility:** The Region 1 Colfax facility includes the full range of CDOT maintenance activities and houses administrative offices.

- **20581 Hwy US160 West Facility:** Durango's west maintenance facility is used as a base for highway maintenance operations and vehicle/equipment maintenance. The facility has three different levels constructed along the hillside. This facility utilizes covered buildings for storage and vehicle and equipment wash-bay facilities. Additional storage at this yard includes highway/landscape maintenance materials and painting operations. The surface at this facility is covered with roto-millings and asphalt. The site drains towards the southeast corner via six inlets and a large drainage swale along the eastern edge of the property. Drop inlets at the site are equipped with Dandy bags or other sediment controls around the inlets. All drainage travels under US 160 West and discharges to Lightner Creek, which ultimately is conveyed to the Animas River. The monitoring location includes flows from both the maintenance facility and from Highway 160 West.

- **2300 W. 11th Avenue Denver Facility and 3601 Park Avenue West Facility:** These facilities are located within one-half mile of the South Platte River in Denver and function as a base for patrol activities such as street sweeping, snow removal, and other highway maintenance operations. In addition to these activities, the maintenance yard is used for the storage of solid and liquid deicers and highway/landscape maintenance materials and equipment. Other onsite activities include minor vehicle maintenance and office use. The surface area at these facilities is covered with paved asphalt and roto-milling.

- **26524 US160 East Durango Facility:** This Region 5 facility serves as a base for highway maintenance operations such as snow removal and vehicle/equipment maintenance and utilizes covered buildings or structures for the storage of solid deicer, salt for brine, herbicides, pesticides, and petroleum products such as oil. Examples of other storage at this maintenance facility include highway/landscape maintenance materials and liquid deicer (magnesium chloride) and salt-brine deicer (salt & water dilution). The majority of the surface area at this facility is covered with paved asphalt, with some exposed soil in the northwest corner. The facility has three drop inlets that collect most of the surface flow. All three of these drop inlets are installed with Dandy bags. Some surface flow is also conveyed to a concrete ponding structure. Drainage at this facility is ultimately conveyed to the Animas River.

- **Cherry Creek Facility and Cherry Creek Flood Control Structure Inlet:** Monitoring at these sites represents inflows to a detention basin receiving runoff from the Cherry Creek CDOT Maintenance Facility near Parker Rd. and I-225, as well as highway runoff from the southeastern two-thirds of the Highway 83 Bridge over Vaughn Way, the westbound on-ramp to Highway 83, Vaughn Way, and some minor incidental runoff from adjacent areas. Because the CDOT Maintenance Facility accounts for only 22% of the total impervious surface, the results from the wet weather monitoring at this location are more indicative of runoff originating from highways. The annual average daily traffic (AADT) for this area is 75,000 cars per day.

- **Durango Snow Dump US 160 & US 550 Highway Runoff**: This location was monitored to characterize the type of stormwater runoff generated by a CDOT snow storage area, which is used when excessive amounts of snow are removed from highway US 550 or US 160. This location also receives stormwater runoff from US 550, US 160W and the Durango/Silverton Railroad yard. Because US 550 accounts for 70% of the total impervious surface runoff, the results from the wet weather monitoring at this location are indicative of runoff originating from highways. The AADT is 38,000 cars per day.

- **Hwy 58 & I-70 SW Permanent Water Quality Structure Inlet 1A and Hwy 58 & I-70 SW Permanent Water Quality Structure Inlet Ditch Highway Runoff:** These monitoring locations represent highway runoff that flows into an extended detention basin located at Highway 58 and I-70 in Wheatridge. Stormwater runoff originating from Highway 58 including portions of both on-ramps to I-70 East and West. The AADT for this stretch of highway is 35,000 cars per day. Inlet1A is an 18-inch RCP that receives stormwater runoff from the on-ramp to I-70 eastbound, which is an extension from eastbound Highway 58. The “inlet ditch” location receives stormwater runoff from both lanes of Highway 58. Within the median between the lanes, there are two drop inlets that discharge stormwater runoff along the southern borrow ditch of Highway 58 prior to discharging into the extended detention basin.

- **RTD Ballast I-225:** RTD requested CDOT’s assistance to characterize the stormwater runoff from RTD’s light rail ballast near I-225 and I-25. Wet weather monitoring was conducted at the location where stormwater discharge from the ballast was conveyed to a point source to CDOT’s right-of-way (ROW), allowing for a safe sampling location along I-225. The RTD light rail accounts for 100% of the total impervious surface. However, the light rail ballast receives an overspray originating from traffic on the highway (I-225 & I-25) during snow removal and deicing operations. Thus, the results from wet weather monitoring at this location can be associated with runoff originating from highways. Precipitation infiltrates through the ballast, then a wrapped perforated pipe collects and conveys the stormwater runoff to a drop inlet box. Within the drop inlet box is an 18-inch concrete pipe which runs to a junction box with a shallow sump. Once the sump is full, it discharges to CDOT’s ROW through an 18-inch concrete pipe, where samples are collected. The AADT for this area is 113,000 cars per day.

- **5701 Federal Denver Facility to Clear Creek, Alton and Yosemite Highway Runoff, E470 and I-70 Highway Runoff, and I-70 WB Park N Ride Highway Runoff:** Descriptive site documentation for these sites was not readily available at the time that this Data Report was completed; however, this information could be obtained from CDOT in the future, if needed. Three of these locations represent primarily highway runoff, whereas the site on Federal includes a highway-related facility.

Table 7. CDOT Monitoring Locations Included in Analysis[1]

Monitoring Location[1,2]	Type	Impervious Drainage (acres)[3]	Abbreviation Used on Data Plots
18500 E Colfax Facility	Maintenance Facility	Not Provided	CDOT_Colfax
20581 Hwy US160 West Facility	Maintenance Facility	8.5	CDOT_Hwy160
2300 W. 11th Avenue Denver Facility	Maintenance Facility	3.2	CDOT_11thAveDen
26524 US160 East Durango Facility	Maintenance Facility	3.7	CDOT_Hwy160Dgo
3601 Park Avenue West Facility	Maintenance Facility	3.1	CDOT_ParkAveW
5701 Federal Denver Facility to Clear Creek	Maintenance Facility	Not Provided	CDOT_FedCenter
Alton and Yosemite Highway Runoff	Highway Runoff	Not Provided	CDOT_AltonYos
Cherry Creek Facility	Highway Runoff	15.2 (3.4 is maintenance facility)	CDOT_CherryCrk
Cherry Creek Flood Control Structure Inlet			CDOT_ChryCrkFIn
Durango Snow Dump UD160 &US550 Highway Runoff	Highway Runoff	4.7	CDOT_DgoSnowDmp
E470 and I-70 Highway Runoff	Highway Runoff	Not provided	CDOT_E470-70
Hwy 58&I-70 SW Permanent Water Quality Structure Inlet 1A	Highway Runoff	7.1	CDOT_Hwy58-70In1A
Hwy 58&I-70 SW Permanent Water Quality Structure Inlet Ditch Highway Runoff			CDOT_Hwy58-70InDtch
I-70 WB Park N Ride Highway Runoff	Highway Runoff	Not provided	CDOT_I70ParkNRide
RTD Ballast I-225	Highway Runoff	0.64	CDOT_RTD225

[1]Monitoring was conducted from 2009-2011 with one to five events monitored per site.
[2]In addition to the monitoring locations included in this table, CDOT has also monitored BMP performance (treated outfalls) and at other recently monitored locations (with data not yet publically available at the time of the CSC's data request). Additional locations are expected to be available in the future.
[3]CDOT's drainage area descriptions only report impervious area rather that total drainage area.

4.3.7 Arapahoe County Water and Wastewater Authority

The Arapahoe County Water and Wastewater Authority (ACWWA) conducted stormwater monitoring during 2008 for two ponds as part of a phosphorus trade credit project. Table 8 identifies these sites. Pond L-3 is located near the outfall of the Lone Tree Creek watershed, and Pond W-6/W-7 is located approximately four miles from the Cherry Creek Reservoir near East Briarwood and Jordan Road. Approximately 1.2 square miles of mostly commercial land use (imperviousness of 80%) drains to Pond L-3, while 1.2 square miles of commercial and multi-family residential land use (imperviousness of 39%) drains to Pond W-6/W-7.

Baseflows and stormwater runoff were monitored at both ponds and reported separately. Rainfall was measured using a tipping bucket rain gauge at each site. Flows were measured continuously at 5-minute intervals using automated equipment, except during winter when a Pygmy flow meter was used to manually measure baseflow.

Automatic samplers at the inflow of the ponds collected flow-weighted composite samples between March and October, with manual sampling from October to December. Baseflow samples were collected monthly for May through October and biweekly in November, March, and April.

Monitored parameters included field parameters, TSS, total phosphorus, dissolved phosphorus, total orthophosphate, and dissolved orthophosphate using standard methods. Samples were kept on ice and preserved. Samples for both forms of soluble phosphorus were filtered in the field prior to transport to the lab.

Table 8. ACWWA Monitoring Locations

Monitoring Location[1]	Land Use	Drainage Area (acres)	Plot Abbreviation
Pond L-3 Inflow	Commercial	768	ACWWA_L3
Pond W-6/W-7 Inflow	Commercial/Multi-Family	768	ACWWA_W6W7

[1]Monitoring was conducted in 2008-2009, with 17-19 runoff events per site with nutrient data.

4.3.8 Bowles Metropolitan District—Grant Ranch

Grant Ranch is a 77-acre residential development in Littleton, CO, that drains into Bow Mar Reservoir, which is a recreational amenity for Bow Mar residents. The land use in the development includes approximately 61 acres of single-family detached residential land use, 5 acres of multi-family residential and 11 acres of open space (native grass and trails) (Carroll et al. 2003). Watershed slopes range from 1.5 to 3 percent.

In 1997, a legally-binding agreement between Bow Mar residents and the developer of Grant Ranch (Simeon Residential Communities) was negotiated to establish numeric thresholds for various pollutants to protect the Bow Mar Reservoir. Compliance with these thresholds required the development of an advanced stormwater management program at Grant Ranch, including three extended detention basins and a monitoring program to track their performance. The water quality monitoring program was implemented in 1999, which included monitoring of all three detention basins. Automated monitoring equipment installed in 1999 included automated flow measurement (ISCO 4250 Area Velocity Meter), water quality sampling (ISCO 3700 Sampler), and tipping bucket rain gauges. Monitoring sites for untreated runoff are summarized in Table 9. As discussed in Section 4.3.2.6, UDFCD assumed monitoring responsibilities at Orchard Pond in 2001, with the on-going monitoring program and results summarized by Piza et al. (2013). Additional detail for the long-term Orchard Pond monitoring site is provided below.

Table 9. Grant Ranch Monitoring Locations

Monitoring Location[1]	Land Use	Drainage Area (acres)	Plot Abbreviation
Orchard Pond	Low Density Residential	18.7	UDFCD_OrchPnd
Reflections Inflow	Low Density Residential	55 (estimated)	Grant_Reflect
Heron Pond Inflow	Low Density Residential	3	Grant_Heron

[1]Monitoring was conducted in the 2001-2011 timeframe, with the number of events with total phosphorus and/or total nitrogen data ranging from 23-77.

The watershed draining to the Orchard Pond is in the middle of the northern edge of the Grant Ranch Subdivision. It includes 18.7 acres with 51% impervious cover, although the effective impervious cover is considered lower because of partially detached downspouts and detached sidewalks. The watershed includes single-family residences, open space, and paved roads. Soils within the watershed are classified as NRCS soil group C. Runoff from 11 acres of the watershed reaches the site through a storm sewer system, while runoff from the remaining 7.7 acres reaches the pond via surface flow (Piza et al 2013).

Due to the long-term monitoring at Orchard Pond, monitoring equipment upgrades have been completed over time. Rainfall at the site is measured continuously using a tipping bucket rain gage (ISCO 674). Flows are measured where runoff enters the detention basin through a 24-inch pipe fitted with a Palmer Bowlus flume, with flow measurements collected by an ISCO 730 bubbler. Runoff from rainfall events generating at least 200 cubic feet of flow are sampled with an automatic composite sampler (ISCO Model 6700). Samples are analyzed for 41 different constituents, including bacteria, chemicals, metals, nutrients, and TSS (Piza et al. 2013).

4.4 Grab Sample Studies

As part of the water quality data set compiled by the CSC, the City and County of Denver and the City of Greeley provided grab samples at stormwater outfalls, as described below. These were not comingled with the EMC data (which are the primary focus of this report), but are provided for information purposes.

4.4.1 City and County of Denver

The City and County of Denver collects samples from storm drain outfalls for the following purposes:

- Assess compliance of discharges with the MS4 permit;
- Identify exceedances of industrial, construction, and other discharge permit limits;
- Identify unpermitted discharges, and;
- Assess impacts of discharges from the City’s storm sewers on instream water.

Based on sampling conducted under this program, the City and County of Denver provided data to the CSC for over 130 outfalls monitored from 1998 through 2009. Samples are collected in accordance with *Quality Assurance Project Plan and Sampling and Analysis Plan Water Quality Program* (Denver Department of Environmental Health 2006). Nutrients have been analyzed for samples collected at these outfalls as part of the city's sampling program. Approximately 10 of these outfalls are suspected to be affected by sanitary sewer leakage (Personal Communication with John Novick, Denver Department of Environmental Health) and have been excluded from further analysis for purposes of this Data Report. The majority of these grab samples have been collected under dry weather conditions (n = 650), although some runoff (n = 36) and snowmelt (n = 96) influenced samples are also included in the data set. For most of the outfalls, only one sample in the data set represents runoff conditions. Similarly, when grouped by land use, there are only a few samples per land use with runoff data. Land use characterization is readily available for some sites, but many are not readily characterized due to the complexities of the storm drain system contributing to each outfall. The City and County of Denver data are discussed further in Section 7.4.

4.4.2 City of Greeley

The City of Greeley has collected dry weather grab samples at two outfalls including the Second Avenue outfall and the Seventh Street outfall from 2006 through 2013. Nutrients sampled at these locations included total inorganic nitrogen (n = 10), nitrate (n = 43), orthophosphate (n = 10). Because the forms analyzed do not enable direct analysis of total phosphorus or total nitrogen, these samples are not evaluated or further discussed for purposes of this Data Report. For general information purposes, the average and median nitrate concentrations for the combined outfall samples under dry weather conditions were 8.2 mg/L and 7.1 mg/L, respectively.

5 NATIONAL DATA SUMMARY

5.1 National Stormwater Quality Database (NSQD)

The National Stormwater Quality Database (NSQD) is a national compilation of runoff characteristics from more than 8,000 events from throughout the U.S. The NSQD has been developed over the past 10 years under the direction of Dr. Robert Pitt of the University of Alabama with support from the U.S. Environmental Protection Agency (EPA). The NSQD also includes important meta data related to land use, storm characteristics, and other factors. Analyses of the NSQD data set conducted by Pitt and others have been useful in refining expected ranges of pollutants in runoff in many parts of the country and have been widely disseminated in national reports such as *Urban Stormwater Management in the United States* (National Research Council 2008). The NSQD is currently publically accessible at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml.[1] The primary data sources included in the NSQD are:

- **Phase 1 NPDES Stormwater Permit Monitoring:** Following the Nationwide Urban Runoff Program (NURP), EPA's NPDES stormwater permit program for Phase 1 communities (includes large municipal areas having >250,000 in population) became another key source of runoff characterization data. As a condition for Phase 1 permits,

[1] In the fall of 2013, the NSQD will be transitioning to a new long-term home associated with the International Stormwater BMP Database (www.bmpdatabase.org).

municipalities were required to establish a monitoring program to characterize their local stormwater quality for their most important land uses discharging to the MS4. Although only a few samples from a few locations are required each year from these communities, the 10 plus years of MS4 data included in the NSQD comprise a suitable number of samples from many locations. Version 3 of the NSQD contains the results from about one-fourth of the total number of communities that participated in the Phase I NPDES stormwater permit monitoring activities.

- **EPA's Nationwide Urban Runoff Program (NURP):** NURP was the best known and earliest effort to collect and summarize these data, conducted in the mid-1980s. Most of the older NURP data are included in the NSQD (one obvious exclusion is for older lead data that have been shown to be dramatically higher before the lead ban in fuels).

- **International Stormwater BMP Database:** Inflow data to urban stormwater BMP performance studies contained in the International Stormwater BMP Database as of 2004 were included in Version 3 of the NSQD.

- **USGS Research Projects and Other Sources**: Other sources of runoff characterization data in the NSQD include research projects by the USGS and special studies conducted by researchers and municipalities in various parts of the country.

Multiple land uses are represented in the NSQD, with most data from residential, commercial, and industrial areas, and less data from freeways, institutional and open space areas. Data contained in the NSQD were all obtained at outfall locations and do not include snowmelt or construction erosion sources. Figure 2 is a map showing the EPA Rain Zones in the U.S. (not to be confused with EPA administrative regions), along with the locations of the communities with data in the NSQD Version 3. As shown on this map, the Colorado Front Range and plains are located in Rain Zone 9, with portions of western Colorado in Rain Zones 8 (Rocky Mountains) and 6 (Southwest).

Selected summary statistics from the NSQD are provided in Tables 13-16 for nutrients by EPA Rain Zone (as a representation of geographical area) and six land uses, as prepared by Pitt (2011). For purposes of representing long-term mass discharges, Pitt provided averages, along with the coefficient of variation and number of samples. The statistical comparison tests used all of the discrete data available in the subgroups of data of interest. In almost all cases, analysis results were above detection limits. The method of handling non-detects in these summary statistics was to report the result at the detection limit, rather than using substitution methods.

Figure 2. NSQD v.3 Runoff Characterization Data by U.S. EPA Rain Zone

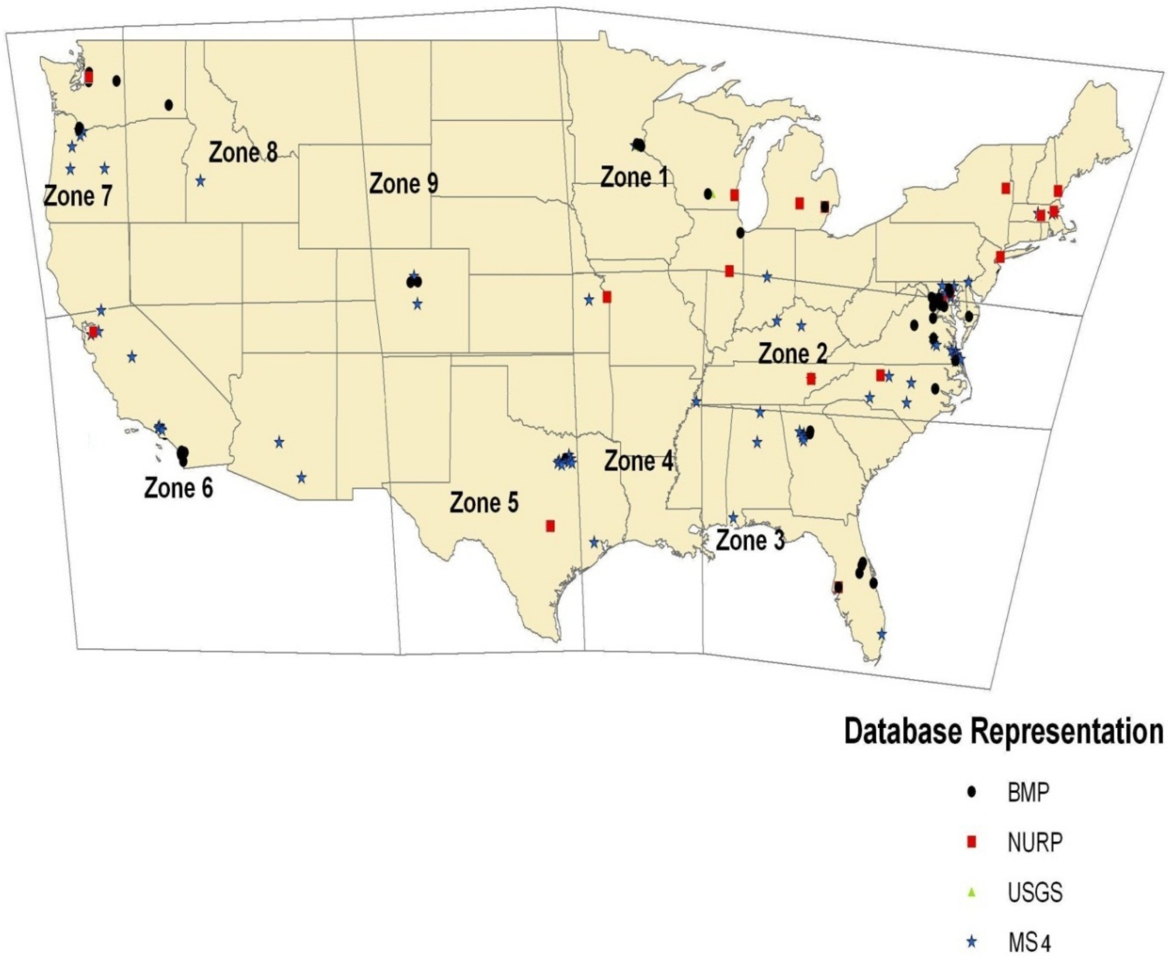


Table 10. Total Phosphorus Concentrations (mg/L) for Land Uses and EPA Rain Zones in the NSQD v. 3

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	**0.25 (2.2) 311**	**0.37 (1.3) 641**	**0.39 (1.1) 141**	**0.38 (1.6) 50**	**0.64 (3.0) 112**	0.57 (0.7) 37	**0.35 (1.3) 84**	0.57 (0.6) 7	0.34 (0.7) 16	**0.37 (2.0) 1399**	96%
Freeways	0.43 (0.5) 3	**0.95 (1.3) 186**	0.16 (0.7) 14	n/a	**0.22 (0.7) 245**	**0.49 (1.6) 135**	0.35 (0.6) 24	n/a	n/a	**0.50 (1.7) 604**	99%
Industrial	**0.33 (0.8) 100**	**0.36 (1.6) 370**	**0.20 (0.9) 108**	**0.36 (1.2) 49**	**0.25 (1.2) 108**	**1.3 (0.9) 63**	**0.33 (0.9) 76**	n/a	0.46 (0.7) 23	**0.39 (1.5) 897**	95%
Institutional	0.21 (0.4) 8	**0.24 (0.8) 45**	0.19 (0.5) 15	n/a	n/a	n/a	n/a	n/a	n/a	**0.23 (0.17) 68**	99%
Open Space	**0.18 (1.7) 139**	**0.33 (1.1) 106**	n/a	0.31 (0.6) 17	0.40 (1.0) 67	0.65 (0.3) 2	n/a	n/a	0.60 (0.5) 7	**0.29 (1.2) 338**	96%
Residential	**0.40 (1.1) 565**	**0.43 (1.7) 1956**	**0.20 (1.4) 410**	**0.70 (1.2) 91**	**0.47 (0.9) 206**	**0.54 (1.1) 70**	**0.30 (1.2) 331**	0.85 (0.7) 15	**0.81 (1.1) 75**	**0.71 (1.5) 3719**	98%
all land uses	**0.32 (0.4) 1203**	**0.42 (1.7) 3572**	**0.24 (1.3) 688**	**0.51 (1.3) 207**	**0.38 (2.2) 738**	**0.68 (1.3) 307**	**0.31 (1.1) 539**	0.74 (0.8) 23	**0.67 (1.1) 121**	**0.40 (1.7) 7295**	97%
% detect	97%	97%	95%	98%	99%	97%	99%	100%	100%		

Note: Reported data show average, coefficient of variation (in parentheses) and number of observations. Cells highlighted in yellow have more than 40 samples.

Table 11. Dissolved Phosphorus Concentrations (mg/L) for Land Uses and EPA Rain Zones in the NSQD v. 3

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	**0.14 (0.5) 81**	**0.24 (1.9) 386**	**0.13 (1.7) 43**	0.25 (1.2) 30	**0.09 (1.0) 103**	0.42 (0.8) 26	0.20 (2.3) 13	n/a	0.17 (0.6) 16	**0.21 (1.8) 698**	77%
Freeways	n/a	0.14 (0.8) 18	0.06 (1.3) 14	n/a	0.04 (0.9) 11	0.78 (2.1) 22	n/a	n/a	n/a	**0.34 (3.1) 65**	85%
Industrial	**0.085 (0.9) 70**	**0.20 (2.1) 275**	**0.10 (1.2) 97**	0.15 (0.7) 33	**0.11 (1.0) 109**	**0.30 (0.9) 52**	0.06 (0.7) 8	n/a	0.24 (0.9) 22	**0.17 (1.8) 666**	82%
Institutional	0.054 (0.6) 5	0.13 (0.5) 17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.11 (0.6) 22	86%
Open Space	n/a	**0.17 (1.1) 100**	n/a	0.20 (0.7) 18	**0.15 (1.2) 67**	0.18 (n/a) 1	n/a	n/a	0.19 (0.5) 6	**0.17 (1.1) 192**	84%
Residential	**0.16 (1.2) 149**	**0.21 (1.1) 797**	**0.13 (1.3) 148**	**0.29 (0.6) 66**	**0.20 (0.7) 164**	0.24 (0.7) 26	0.30 (1.8) 26	n/a	0.26 (0.7) 12	**0.21 (1.1) 1388**	83%
all land uses	**0.14 (1.2) 305**	**0.21 (1.5) 1675**	**0.11 (1.4) 302**	**0.24 (0.8) 147**	**0.14 (0.9) 454**	**0.39 (1.9) 127**	**0.23 (2.0) 47**	n/a	**0.22 (0.8) 56**	**0.20 (1.6) 3113**	81%
% detect	62%	79%	74%	96%	93%	98%	81%	n/a	100%		

Note: Reported data show average, coefficient of variation (in parentheses) and number of observations. Cells highlighted in yellow have more than 40 samples.

Table 12. Total Kjeldahl Nitrogen Concentrations (mg/L) for Land Uses and EPA Rain Zones in the NSQD v. 3

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	**1.5 (1.1) 185**	**2.0 (0.9) 625**	**1.2 (0.7) 41**	**1.8 (0.9) 47**	**1.1 (0.6) 112**	**4.3 (0.7) 39**	**1.6 (1.0) 61**	3.7 (0.7) 5	2.6 (0.6) 16	**1.9 (0.9) 1131**	97%
Freeways	3.6 (0.3) 3	**2.4 (1.1) 100**	n/a	n/a	**2.0 (0.9) 204**	**3.3 (1.4) 122**	1.7 (0.6) 24	n/a	n/a	**2.4 (1.2) 450**	99%
Industrial	**1.9 (0.9) 100**	**1.8 (1.5) 338**	**1.5 (0.8) 99**	**1.6 (0.6) 46**	**1.2 (0.9) 109**	**4.2 (0.8) 76**	1.9 (0.6) 33	n/a	2.5 (0.6) 23	**1.9 (1.2) 824**	96%
Institutional	0.79 (0.6) 7	**1.6 (0.8) 46**	1.4 (0.5) 15	n/a	n/a	n/a	n/a	n/a	n/a	**1.5 (0.8) 68**	97%
Open Space	**0.79 (0.7) 100**	**1.2 (0.8) 77**	n/a	1.9 (0.7) 18	**1.7 (0.9) 67**	1.8 (0.2) 2	n/a	n/a	3.3 (0.6) 7	**1.3 (1.0) 271**	91%
Residential	**1.9 (0.9) 434**	**1.8 (1.1) 1783**	**1.0 (0.9) 335**	**2.3 (1.5) 74**	**2.1 (0.9) 183**	**3.2 (2.7) 74**	**1.1 (0.9) 318**	5.7 (0.8) 15	**3.8 (0.7) 64**	**1.8 (1.1) 3280**	98%
All land uses	**1.6 (0.9) 834**	**1.9 (1.1) 3067**	**1.2 (0.9) 490**	**2.0 (0.7) 185**	**1.7 (0.9) 675**	**3.6 (1.0) 313**	**1.3 (0.9) 460**	5.0 (0.8) 21	**3.3 (0.7) 110**	**1.9 (1.1) 6095**	97%
% detect	100%	97%	93%	97%	96%	99%	98%	100%	100%		

Note: Reported data show average, coefficient of variation (in parentheses) and number of observations. Cells highlighted in yellow have more than 40 samples.

Table 13. Nitrate plus Nitrite Concentrations (mg/L) for Land Uses and EPA Rain Zones in the NSQD v. 3

Land Use	RZ1	RZ2	RZ3	RZ4	RZ5	RZ6	RZ7	RZ8	RZ9	all RZ	% detect
Commercial	**0.81 (0.7) 213**	**0.89 (1.0) 536**	**0.31 (1.5) 109**	0.89 (0.7) 29	**0.54 (0.5) 112**	1.3 (0.7) 33	**0.44 (1.0) 80**	1.0 (n/a) 1	1.2 (0.7) 16	**0.77 (1.0) 1129**	98%
Freeways	0.67 (0.8) 3	**2.2 (2.0) 86**	n/a	n/a	0.72 (0.7) 11	n/a	0.51 (1.2) 25	n/a	n/a	**1.8 (2.2) 122**	99%
Industrial	**0.67 (0.57) 98**	**0.79 (0.8) 335**	**0.71 (1.6) 81**	0.82 (0.6) 31	**0.67 (0.6) 109**	**1.8 (0.5) 62**	0.37 (0.6) 30	0.26 (n/a(1	1.0 (0.4) 23	**0.83 (0.9) 769**	97%
Institutional	1.0 (0.5) 2.0 7	**0.63 (0.7) 46**	0.37 (0.5) 14	n/a	n/a	n/a	n/a	n/a	n/a	**0.61 (0.7) 67**	99%
Open Space	**0.41 (0.8) 138**	**0.81 (0.9) 106**	n/a	0.78 (1.0) 17	**0.84 (0.7) 67**	1.0 (0.6) 2	n/a	n/a	1.2 (0.4) 7	**0.66 (0.9) 337**	96%
Residential	**0.78 (0.6) 434**	**1.1 (2.5) 1583**	**0.35 (1.7) 357**	**0.88 (0.7) 75**	**0.79 (0.9) 202**	**1.1 (0.4) 66**	**0.82 (1.2) 77**	1.5 (1.0) 2	**1.4 (1.0) 54**	**0.94 (2.3) 2850**	99%
All land uses	**0.73 (0.8) 969**	**1.0 (2.2) 2890**	**0.39 (1.8) 561**	**0.86 (0.7) 152**	**0.72 (0.8) 501**	**1.4 (0.6) 163**	**0.59 (1.2) 223**	1.1 (0.9) 4	**1.2 (0.9) 100**	**0.88 (2.0) 5506**	98%
% detect	98%	99%	97%	100%	99%	100%	90%	100%	100%		

Note: Reported data show average, coefficient of variation (in parentheses) and number of observations. Cells highlighted in yellow have more than 40 samples.

Some of Pitt's findings pertinent to runoff characterization for nutrients based on Pitt's 2011 analysis, as well as from previous and related analyses, include:

- The characteristics of stormwater discharges vary considerably. Geographical area and land use are important factors affecting baseflow and stormwater runoff quality. Overall, residential, commercial, industrial, and freeway data are well represented in the NSQD, although Rain Zones 8 and 9 have limited data. Institutional and open space land uses also have limited data.

- Stormwater concentrations usually have a log-normal distribution, resulting in a positive bias, with the average values being larger than the median values. The greater the difference, the greater the positive bias (and the larger the coefficient of variation [COV], which is the ratio of the standard deviation to the average). If the COV is less than about 0.5, there is little difference between the median and the average values. However, most of the stormwater concentration COV values in the NSQD are in the range of 0.5 to 2, with some much larger.

- In most cases, the COV values are smaller for the Rain Zone-Land Use subgroups compared to the overall group values, indicating that the land use and geographical combinations help explain some of the large variability commonly found with stormwater concentrations.

- As part of Ph.D. dissertation research, Bochis (2010) examined all two-way interactions between Rain Zones (representing geographical regions) and the land use categories for selected constituents in the NSQD. She found that the national data could be combined into a reasonable number of statistically 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. Additional analyses examined three-way interactions based on land use, rain zone and seasonality did not result in many additional category distinctions associated with seasonal effects on stormwater concentrations (note: snowmelt data are not included in the NSQD). Findings related to Rain Zone 9 are relevant to urbanized areas in the Colorado Front Range. Given the numbers of samples available, EPA Rain Zones 6 and 9 were not found to have statistically significant differences in land use groups, except for certain metals (total zinc and total copper). This finding suggests that Rain Zone 6 nutrient data may be useful in supplementing the understanding of both the Colorado Front Range (Rain Zone 9) and urbanized areas in western Colorado (Rain Zone 6), at least for total phosphorus and TKN (Table 14).

Table 14. Similar Land Use & Rain Zone Clusters for Selected Constituents in NSQD (v. 3) Related to Rain Zone 9
(Source: Bochis 2012)

Stormwater Constituent	All EPA Rain Zones Land Use[1]	Mean (mg/L) (COV)
Total Phosphorus	6-RES,COM 9-RES,COM,IND	0.52 (0.67)
Total Kjeldahl Nitrogen	6-RES,COM 9-RES,COM,IND	3.6 (0.73)

[1]6 = EPA Rain Zone 6; 9= EPA Rain Zone 9; RES = Residential; COM = Commercial, IND = Industrial.

5.2 Other National Data Compilations

Given the data compilation effort already completed for the NSQD and the availability of Colorado-based nutrient data in urban runoff, evaluation of other national data sources was compiled as background information, but is not discussed further in this report. Representative sources of national stormwater quality data reported by others (excluding the NSQD) include:

- Burton, G.A., and R. E. Pitt, 2002. *Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists and Engineers*. Lewis Publishers. www.crcpress.com.
- National Research Council, 2008. *Urban Stormwater Management in the United States*. National Academies Press. (Note: this report incorporates findings from the NSQD.)
- Pitt, R., Bannerman, R., Clark, S. and D. Williamson, 2004a. Sources of Pollutants in Urban Areas (Part 1): Older Monitoring Projects. In: *Effective Modeling of Urban Water Systems, Monograph 13.* James, Irvine, McBean & Pitt, Eds. ISBN 0-9736716-0-2 ©CHI2004. www.computationalhydraulics.com (Note: this report focuses on source area sheetflow data from very small homogeneous areas.)
- Pitt, R., Bannerman, R., Clark, S. and D. Williamson, 2004b. Sources of Pollutants in Urban Areas (Part 2) – Recent Sheetflow Monitoring. In: *Effective Modeling of Urban Water Systems, Monograph 13.* James, Irvine, McBean & Pitt, Eds. ISBN 0-9736716-0-2 ©CHI2004. www.computationalhydraulics.com (Note: this report focuses on source area sheetflow data from very small homogeneous areas.)
- Shaver, E., Horner, R., Skupien, J., May, C., and G. Ridley. 2007. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues*, 2nd Edition.
- Smullen, J.T., Shallcross, A.L. and Cave, K.A. 1999. Updating the U.S. nationwide urban runoff quality database, *Water Science and Technology*, 39, No. 12, pp. 9-16.

- U.S. Environmental Protection Agency, 1983. *Results of Nationwide Urban Runoff Program, Volume 1, Final Report*. (Note: most of these data are included in the NSQD, but narrative findings published in this report are also relevant.)

- U.S. Environmental Protection Agency, 1999. *Protocol for Developing Nutrient TMDLs.*

6 STATISTICAL APPROACH

In order to determine the approximate contributions of nutrients to state waters, sound statistical characterizations of runoff nutrient data are fundamental. This section provides a basic description of the statistical techniques applied to the Colorado runoff data, as well as to other national data sets used for comparative purposes. These techniques are consistent with and build upon approaches used in other peer-reviewed national stormwater characterization efforts including the International Stormwater BMP Database (www.bmpdatabaseorg) project and the National Stormwater Quality Database (http://rpitt.eng.ua.edu/Research/ms4/Paper/Mainms4paper.html).

The statistical analyses of the Colorado urban runoff data set in this Data Report focus on analyses of event mean concentration (EMC) of total nitrogen and total phosphorus data for various land uses in Colorado. Additionally, some other relationships are also explored considering variables such as precipitation, flow, snowmelt vs. runoff, association with TSS, relative fractions of TKN and nitrate/nitrite, and other factors. Statistical analyses in this Data Report include descriptive statistics using tabular and graphical techniques, correlation analysis, and hypothesis testing. Descriptive statistics provide general characterization of the data set, whereas hypothesis testing can be used to assess whether statistically significant differences exist between subpopulations of the Colorado data set (e.g., land uses, seasons) and between the Colorado data set and other national data sets (e.g., NSQD data by EPA Rain Zone). The statistical analyses are provided in several levels of detail, including for overall land use categories and for individual studies (Appendix B).

A commercially-available statistical package (XLSTAT 2013) was used to conduct the statistical analyses. XLSTAT is an Excel plug-in that enables the user to calculate statistics in a familiar software environment and edit the formatting of graphs and tables using Excel tools. The computations, however, are completely independent of Excel based on algorithms programmed in the C++ programming language. Additional information about this statistical package can be accessed at: http://www.xlstat.com.

6.1 Descriptive Statistics

Descriptive statistics are useful for providing information about the central tendency and variability of the data set, along with basic information such as the number of samples and number of values below laboratory method detection limits. Table 15 provides an overview of the basic descriptive statistics that are provided for EMC data by land use for the runoff data.

Table 15. Summary of Tabular Descriptive Statistics Applied to Nutrient Runoff Data Set

Parameter	Brief Description
Number of observations	The number values analyzed.
Minimum	The minimum sample result of the data set analyzed.
Maximum	The maximum sample result of the data set analyzed.
1st quartile	The first quartile (Q1) is the 25th percentile value for the data set and corresponds to the "floor" of a boxplot.
Median	The median (Q2) is the 50th percentile value for the data set and corresponds to the mid-line of a boxplot. This is a non-parametric estimate of central tendency that does not require the assumption of normally distributed data.
3rd quartile	The third quartile (Q3) is the 75th percentile value of the data set and corresponds to the "roof" of a boxplot.
Mean	The mean of the sample is the arithmetic average. This is a parametric estimate of central tendency that requires the assumption of normally distributed data.
Variance[1]	Provides an estimate of the spread of the data relative to the mean.
Standard deviation[1]	Calculated as the square root of the variance. A small standard deviation (relative to the mean) indicates that most data points are close to the mean; whereas, a large standard deviation indicates that the data points are spread out over a large range of values.
Variation coefficient	The variation coefficient or coefficient of variation (COV) is a normalized measure of dispersion of a probability distribution or frequency distribution. It is calculated as the ratio of the standard deviation to the mean.

[1]Reported in Appendix B only.

6.2 Graphical Summaries

Graphical representations of the data are also provided, including box plots, probability plots, and time series plots. An overview of these graphs includes:

- **Boxplots**: Boxplots provide a graphical representation of the 1st quartile (Q1 or 25th percentile), median (50th percentile), mean and 3rd quartile (Q3 or 75th percentile) displayed together with limits (i.e., the ends of the "whiskers") beyond which values are considered rare. For large data sets, some data fall outside of these whiskers; this should not be taken as poor data that should be removed as "outliers," but as rare or uncommon data that may contribute to a better understanding of the information. The mean is displayed with a red +, and a black line through the box corresponds to the median. For purposes of this Data Report, boxplots are provided to visualize the general distribution of data for various monitoring locations, and the few data points beyond the whiskers are not plotted on the graphs to simplify the plots. The ends of the whiskers represent the following: 1) lower limit: = Q1 – 1.5 (Q3 – Q1) and 2) upper limit: Q3 + 1.5 (Q3 – Q1). Notched boxplots are used in this Data Report, with the "notches" providing the 95 percent confidence interval for the median, as shown in Figure 3. Boxplots were generated to compare land use groups, as well as to plot individual studies comprising a land use group in Appendix B. Side-by-side notched boxplots can be visually compared. If the notches do not overlap, then statistically significant differences at the p = 0.05 significance level are indicated (McGill et al. 1978). This graphical tool is therefore helpful to generally identify which data sets may be different from others, indicating when more rigorous hypothesis testing may be warranted (e.g., ANOVA, Kruskal-Wallis, Mann-Whitney test).

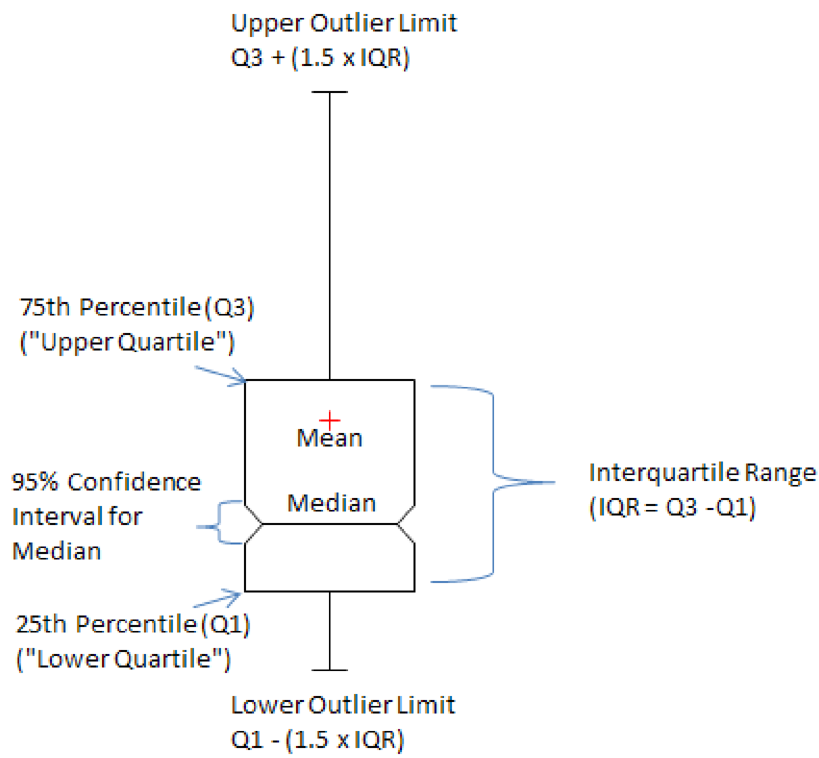
- **Normal Probability Plots:** Normal probability plots are useful for visually assessing whether a data set is normally distributed, as well as comparing the distributions of various data sets. Statistical tests are available to test the probability distribution (such as the Anderson-Darling test). If normally distributed (the data appears as close to a straight line on a normal probability plot and it passes the statistical tests for data normalcy), then many standard statistical tests are possible having high power. If not normally distributed (as expected for stormwater quality data which are usually log-normally distributed) either the data can be transformed as log values (and then retested), or non-parametric statistical tests are needed. (Non-parametric statistics have been used in this Data Report.)

- **Cumulative Frequency Distribution Plots**: Cumulative frequency distributions of data sets were plotted using a "distribution-free" assumption in XLSTAT. Side-by-side plots of land use were provided to illustrate the entire empirical distribution of the data. These plots are useful for estimating the likelihood of nutrient concentrations in a land use exceeding various concentrations of interest, such as stream standards. Additionally, these plots are useful for assessing whether the distributions of data subgroups differ. (If the probability plots overlap for subgroups, then the subgroups are similar; if there is little overlap, then it is likely that the subgroups differ.)

- **Time Series Plots**: Time series plots provide a graphical representation of data over time. The x-axis identifies sample dates and the y-axis provides quantitative values for those sample dates. Time series plots are particularly useful for identifying potential repeating seasonal patterns over time, or identifying whether multiple sample locations behave similarly or differently over time. Time series plots are provided in Appendix B only.

- **Scatter Plot Matrices**: Scatter plot matrices plot values for combinations of variables in a matrix of plots so that general patterns in the data sets and relationships between variables can be visually assessed. Correlation analyses can be conducted to assess whether relationships suggested in scatter plots are statistically significant. For purposes of this report, non-parametric Spearman correlation analysis is used.

Figure 3. Components of a Notched Boxplot



6.3 Correlation Analysis and Hypothesis Testing

In addition to descriptive statistics, exploration of differences in nutrient concentrations among land uses and other subgroups (e.g., runoff types) through hypothesis testing is useful for assessing whether statistically significant differences exist between groups. Although many different hypothesis testing techniques could be considered for analysis of the nutrient runoff data set, non-parametric techniques were selected for this Data Report because assumptions for normality are typically not met for stormwater runoff data. Techniques applied include:

- **Kruskal-Wallis Test, Dunn's Procedure and the Mann-Whitney Test:** The Kruskal-Wallis test is a non-parametric hypothesis test used to evaluate whether two or more sample populations come from the same populations. (It is equivalent to the Mann-Whitney test if only two sample populations are being compared.) This test can be used to evaluate whether there are statistically significant differences between land uses. For purposes of this Data Report, alpha is set at 0.05 as the threshold to reject the null hypothesis that the data are from the same sample population. If the Kruskal-Wallis test indicates that there are statistically significant differences among groups, then multiple pairwise comparisons using Dunn's procedure is applied to identify which sample populations are different (which involves pairwise comparisons using a two-tailed Mann-Whitney test). This technique was applied to evaluate difference between land uses, rain zones, snowmelt versus runoff, and other relationships. When Dunn's Procedure identified statistically significant differences between sample populations, then additional directional hypothesis testing using a one-tailed Mann-Whitney test was applied for selected analyses. Although assessment of statically significant differences among land uses is not required under Regulation 85, these evaluations are expected to be useful in determining appropriate values used in future nutrient load estimates. [2]

- **Spearman Correlation Analysis**: Spearman correlation analysis provides non-parametric correlation coefficients (Spearman's Rho [r_s]) that provide information regarding the correlation between two variables. Coefficients range from 0 to 1 and can be positive or negative (if an inverse relationship is present). In XLSTAT, probabilities (p-values) are also computed for each coefficient to determine whether the relationship is statistically significant. Spearman correlation analysis was used to explore the relationship between runoff and water quality concentration, as well as association between TSS, total nitrogen and total phosphorus.

The data set compiled to support this Data Report is suitable for other types of statistical analyses in addition to the analyses described above.

7 WATER QUALITY STATISTICS

Water quality statistics were generated for three types of data sets, followed by some targeted exploratory data analysis on several topics of interest to UDFCD and the CSC. The primary statistical analyses focused on these data sets:

- Nutrient and TSS EMCs by land use in Colorado—this is the primary data analysis summary developed in support of Regulation 85 requirements.
- Nutrient EMC data for EPA Rain Zones, as extracted from the NSQD V. 3. (Note: the NSQD contains both EMCs and grab samples. For consistency with this Data Report, only EMCs were used.)
- Nutrient grab samples for City and County of Denver outfalls—this is a supplementary data set that is useful for total phosphorus characterization for baseflows in urban areas. It has been analyzed separately because it is based on grab samples and because the land use characterization data are currently less well-defined for the storm drain system.

[2] Two types of errors can occur when conducting hypothesis testing, known as Type 1 and Type 2 errors. Type 1 errors are the most commonly reported with non-academic data analyses; however, both types of errors are important. Alpha is the level of statistical significance in hypothesis testing that represents the probability of rejecting the null hypothesis when it is true and is referred to as a "Type 1 Error." An alpha of 0.05 corresponds to a 95% confidence level in the hypothesis test result. Beta is the probability of accepting the null hypothesis when it is false and is referred to as a "Type 2 Error." (In other words, this type of error means that one concludes that there is no difference between sample populations, when there actually are differences. This is more likely to occur with low sample numbers and/or high coefficients of variation.) Typical values for beta are 0.10 to 0.20. Beta is related to the power of a statistical test, which is the probability of correctly rejecting the null hypothesis when it is false. Power is reported as 1 – beta. Type II errors (beta values) are not included in this Data Report, but can be derived from the summary statistics provided herein using tables accessible in Appendix D of the *Urban Stormwater BMP Monitoring Manual* (http://www.bmpdatabase.org). (These tables can also be obtained from Burton and Pitt [2002]; Pitt and Parmer [1995].).

The supplemental statistical analyses address topics such as: seasonality and snowmelt; water quality-rainfall/runoff relationships; water quality-imperviousness relationships; relationships between total phosphorus, total nitrogen and TSS; and fractions of TKN and nitrate/nitrite in runoff.

7.1 Analysis Data Set Preparation and Assumptions

After compiling available Colorado nutrient data into a master database in Microsoft Access, the following data screening and assumptions were applied prior to statistical analysis:

- For overall characterization of nutrients by land use, the analysis data set was restricted to EMC data for runoff events. Grab samples, snowmelt and baseflow samples were separated from the primary analysis data set (e.g., by using query criteria for Sample Group = Runoff).

- Non-detects were determined to be an insignificant issue for the EMC-based data set, with only 1 percent (10 of 676) of total phosphorus samples being reported below detection limits and only 0.7% (3 of 405) for total nitrogen. Although variation in detection limits over time is present in the data set this is not a substantive issue for purposes of runoff characterization because of the very low percentage of non-detects for the EMC data set. For purposes of analysis, the detection limit was used to represent the analysis values for results below detection limits, consistent with the procedure used for the NSQD.

- Residential land uses were not subcategorized by multi-family or single-family, density, or other characteristics, based on results of Kruskal-Wallis analysis that did not show statistically significant differences between single family and multi-family residential land uses. This “overall” residential land use group is also consistent with the land use categories applied in NSQD analysis.

- Land use types were assigned based on dominant land use in cases where several land uses were present. For the Colorado data set, most sites were clearly dominated by one land use, rather than being equally split among several land uses. Appendix B provides plots and statistical summaries for individual sites so that the variation between sites in each land use can be further reviewed, if desired.

- CDOT’s monitoring locations include both highways and highway-related maintenance facilities. Maintenance facility sites are included in the industrial land use data set. Because of CDOT’s on-going highway monitoring program, the highway data set is expected to continue to grow, with revisions to EMC nutrient estimates potentially occurring in the future.

- One extreme total nitrogen value of 58.01 mg/L at Heron Pond on June 10, 2004 was removed from the Colorado EMC data set prior to analysis. Out of 106 samples in the Grant Ranch sites (where Heron Pond is located), the next highest value was 15 mg/L and the nitrate/nitrite value on that date was 1 mg/L (well within expected ranges), so a data entry error (such as a decimal point shift) is suspected for the total nitrogen result on this date.

- Two extreme values were also removed from the NSQD data set: one for nitrogen at 90.1 mg/L TN in Louisville, KY and one for phosphorus at 80.2 mg/L in Austin, TX. Although these values have little effect on non-parametric statistics, they skew the mean concentrations for smaller data subgroups.

7.2 Nutrient and TSS EMCs by Land Use in Colorado

Water quality statistics were generated according to dominant land use for total nitrogen, total phosphorus and TSS for runoff EMCs reported for the Colorado data set, as described below.

7.2.1 Total Phosphorus

The total phosphorus data set includes 602 sampling events with EMC data collected at commercial, residential, industrial, highway-related, and open space sites. Noteworthy characteristics of the data set include:

- Commercial Land Use: This data set includes 11 monitoring locations with 277 sampling events for total phosphorus. The data set includes a range of time periods: DRURP monitoring in 1980-1981, Phase 1 NPDES monitoring in 1992, and more recent (1995-2011) UDFCD and ACWWA monitoring. Approximately 60 percent of the data set is associated with three recent UDFCD monitoring locations involving small reference parking lot sites at the Denver Wastewater Building and the Lakewood Shops site.

- Residential Land Use: This data set includes 14 monitoring locations with 254 samples collected over a range of time periods: DRURP, Phase 1 and recent UDFCD monitoring. The long-term Orchard Pond monitoring location represents about 30 percent of the data set (77 samples).

- Highway-Related Land Use: This data set includes 9 monitoring locations with 25 sampling events, all conducted recently by CDOT.

- Industrial Land Use: This data set includes 11 monitoring locations with 39 sampling events, which either conducted as part of the Phase 1 sampling program or as part of CDOT's recent sampling at maintenance facilities.

- Open Space: This data set includes seven samples from the Rooney Ranch open space (natural area), which were collected as part of DRURP. As discussed in the DRURP report, natural open space generates runoff less frequently than developed areas; therefore, fewer samples are available for this land use compared to other land uses.

Table 16 provides summary statistics for total phosphorus by land use, and Table 17 provides "p values" resulting from comparison of differences in total phosphorus concentrations among land uses with Dunn's Procedure. Figure 4 provides boxplots of total phosphorus by originally reported land use, and Figure 5 provides boxplots with some land uses combined, based on the results of Dunn's Procedure. Figure 6 provides normal probability plots for total phosphorus by land use, and Figure 7 provides a cumulative frequency distribution comparison of total phosphorus by land use. Assumptions of normality were not met for any land use except highways. Table 18 provides a list of individual sites and numbers of sampling events comprising the analysis data set for total phosphorus. All of the data included in these analyses are individual event EMCs from flow-weighted composite samples. Findings resulting from statistical characterization of the compiled Colorado total phosphorus data include:

- The available EMC-based data set for total phosphorus by land use is considered to be adequate for use in developing estimates for nutrient loads from urban land uses in Colorado.

- Median concentrations of total phosphorus by land use in Colorado range from 0.22 to 0.45 mg/L, with statistically significant differences in total phosphorus concentrations among some land uses (Kruskal Wallis test $p<0.0001$), which were further evaluated using Dunn's Procedure.

- Dunn's Procedure showed that total phosphorus concentrations in runoff from commercial, highway and industrial land uses were similar to each other, but were statistically significantly different from residential land uses, as summarized in Table 17. For this reason, an additional land use subgroup was added to the statistical analysis in Table 16 for commercial-highway-industrial land use. The residential land use group had statistically significant higher phosphorus concentrations than the commercial-highway-industrial subgroup (Man Whitney, 1-tailed test, $p <0.0001$).

- Total phosphorus in runoff from natural open space areas (Rooney Ranch) was not statistically different than the other land uses, based on the available data set. This is likely due to the smaller sample size for open space areas which results in a larger confidence interval for the central tendency of the data set, although the COV for the site is relatively low (COV = 0.4).

- Commercial and residential sites have comparably large data sets, so the COVs for these land uses were compared. The COV for commercial sites is approximately twice that of residential sites, which suggests that site-to-site variability may be a more significant factor for commercial sites than for residential areas.

- Median total phosphorus runoff concentrations for natural open space are within ranges observed for urban areas; available data do not indicate statistically significant differences between natural areas and urban land uses These relatively high concentrations in natural area runoff are hypothesized to be due to runoff samples from natural areas being weighted toward larger infrequently occurring storm events, which may cause erosive flow conditions since runoff occurs less frequently during smaller, frequently occurring storm events for natural areas. (Note: some exceptions to this generalization may occur in steep areas with shallow soils, or in other settings where infiltration in inhibited.) As discussed later in Section 7.2.3, total phosphorus is strongly correlated to TSS in runoff in natural open space areas, which is consistent with erosive flow events.

Table 16. Total Phosphorus (mg/L) Summary Statistics by Land Use

Land Use	#	Min	Max	25th %	Median	75th %	Mean	COV
COM	277	0.01	6.30	0.12	0.22 (0.18-0.26)	0.41	0.36 (0.30-0.42)	1.47
HWY	25	0.07	2.60	0.15	0.28 (0.15-0.41)	0.42	0.39 (0.18-0.60)	1.25
IND	39	0.05	1.30	0.16	0.25 (0.17-0.36)	0.43	0.35 (0.26-0.44)	0.81
OPEN	7	0.21	0.66	0.26	0.41 (0.21-0.53)	0.54	0.41 (0.25-0.58)	0.39
RES	254	0.07	2.71	0.29	0.45 (0.40-0.51)	0.72	0.56 (0.51-0.61)	0.69
Combined Land Use Category								
COM-HWY-IND	341	0.01	6.30	0.12	0.23 (0.19-0.26)	0.42	0.36 (0.31-0.41)	1.39

Table 17. Total Phosphorus Summary of Pairwise Comparisons by Land Use
(p values from Dunn's Procedure; p < 0.05 is statistically significant)[1]

	COM	HWY	IND	OPEN	RES
COM	1	0.540	0.384	0.104	**< 0.0001**
HWY	0.540	1	0.935	0.247	**0.001**
IND	0.384	0.935	1	0.249	**< 0.0001**
OPEN	0.104	0.247	0.249	1	0.586
RES	**< 0.0001**	**0.001**	**< 0.0001**	0.586	1

[1]The p values in bold font indicate statistically significant differences based on Dunn's Procedure.

Figure 4. Boxplots for Total Phosphorus by Land Use in Colorado

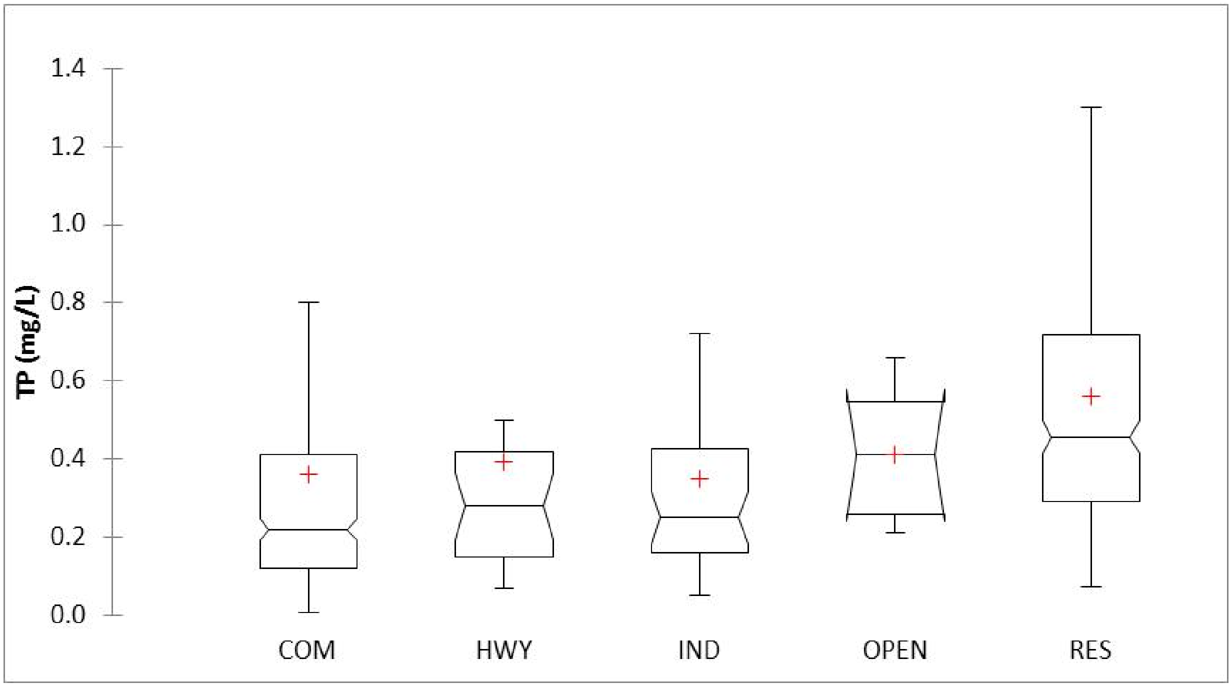


Figure 5. Boxplots for Total Phosphorus by Combined Land Use Groups in Colorado

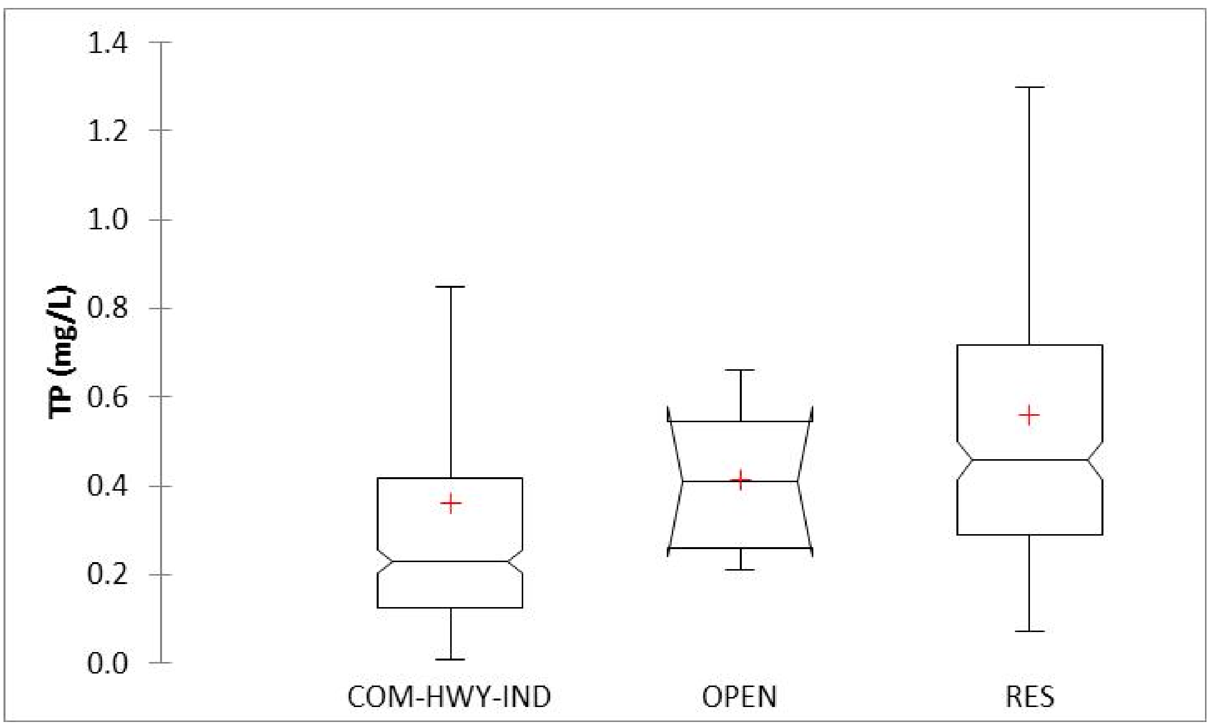


Figure 6. Normal Probability Plot for Total Phosphorus by Land Use

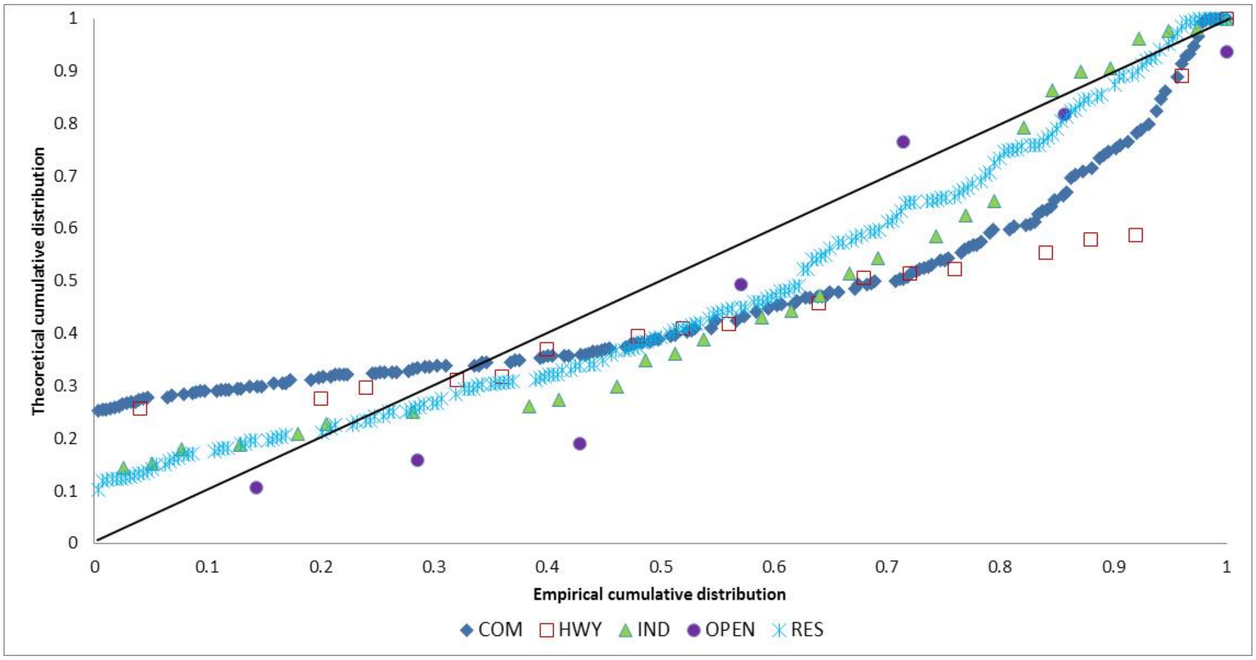


Figure 7. Cumulative Frequency Distribution for Total Phosphorus by Land Use

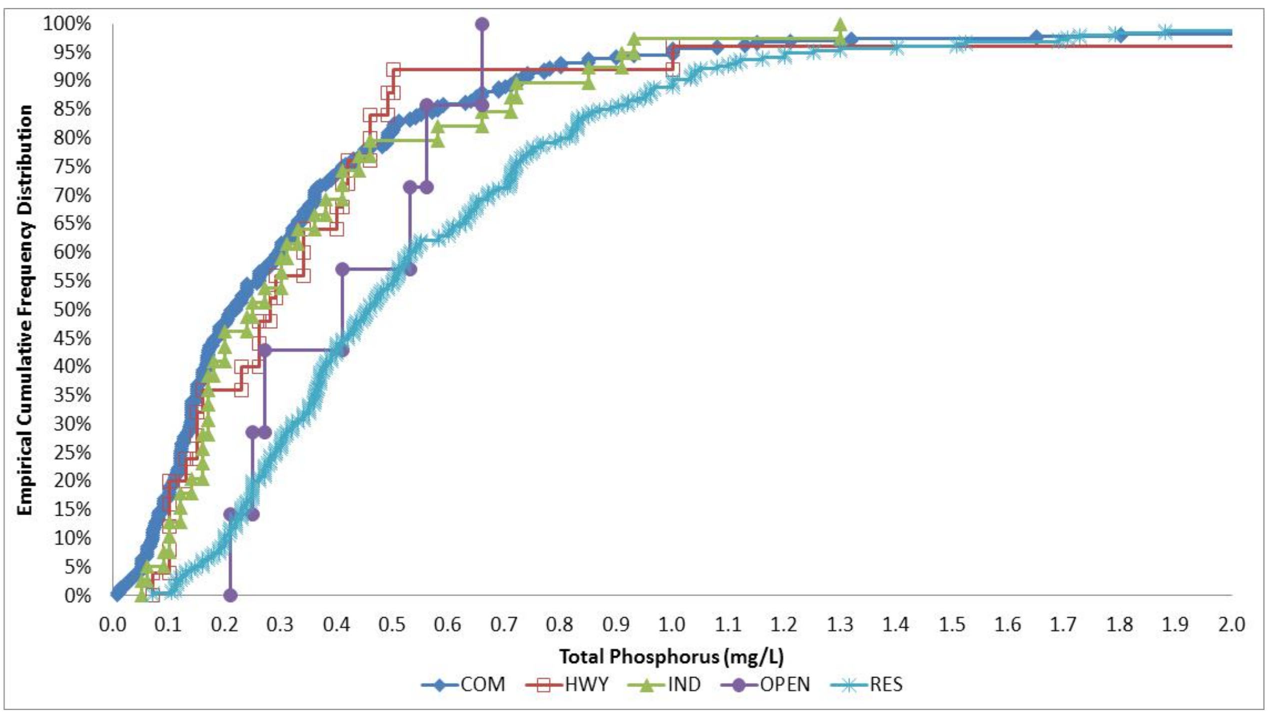


Table 18. Total Phosphorus Monitoring Events by Monitoring Location

Data Source-Site	COM	HWY	IND	OPEN	RES	Total
ACWWA_L3	19					19
ACWWA_W6W7	17					17
CDOT_11thAveDen			3			3
CDOT_AltonYos		5				5
CDOT_CherryCrk		1				1
CDOT_ChryCrkFIn		4				4
CDOT_Colfax			3			3
CDOT_DgoSnowDmp		3				3
CDOT_E470-70		1				1
CDOT_FedCenter			2			2
CDOT_Hwy160			3			3
CDOT_Hwy160Dgo			4			4
CDOT_Hwy58-70In1A		3				3
CDOT_Hwy58-70InDtch		2				2
CDOT_I70ParkNRide		2				2
CDOT_ParkAveW			1			1
CDOT_RTD225		4				4
CSU_FCIn					5	5
CSU_Howes					7	7
CSU_UD					10	10
DRP_CherryKnolls					13	13
DRP_NorthAve	20					20
DRP_NorthGlenn					13	13
DRP_Rooney				7		7
DRP_Southglenn					11	11
DRP_VillaItalia	21					21
Grant_Heron					25	25
Grant_Reflect					23	23
P1_54TH			3			3
P1_7TH			3			3
P1_CLFX	3					3
P1_CS_Buchanan			7			7
P1_CS_Chestnut			7			7
P1_CS_ValleyHi	7					7
P1_CS_Wahsatch					7	7
P1_CS_Wal8th	7					7
P1_NSAN					4	4
P1_SHOP					3	3
P1_SMTH			3			3
P1_UNIV	3					3
P1_VILL	3					3

Table Continued on Next Page

Table 18. Total Phosphorus Monitoring Events by Monitoring Location (continued)

Data Source-Site	COM	HWY	IND	OPEN	RES	Total
UDFCD_21Iris					12	12
UDFCD_DenWW	46					46
UDFCD_MBPP	131					131
UDFCD_OrchPnd					77	77
UDFCD_Shop					44	44
Grand Total	**277**	**25**	**39**	**7**	**254**	**602**

7.2.2 Total Nitrogen

The Colorado total nitrogen data set includes 398 sampling events with EMC data collected at commercial, residential, industrial, highway-related, and open space sites. Noteworthy characteristics of the data set include:

- Commercial Land Use: This data set includes 19 monitoring locations with 168 sampling events for total nitrogen. The data set includes a wide range of time periods—DRURP, Phase 1 NPDES monitoring, and recent UDFCD monitoring. Approximately 75 percent of the data set is associated with two recent UDFCD monitoring locations involving small reference parking lot sites at the Denver Wastewater Building and the Lakewood Shops site.

- Residential Land Use: This data set includes 13 sites with 191 samples, also collected over a wide range of time periods—DRURP, Phase 1 and recent UDFCD monitoring. The long-term Orchard Pond monitoring location represents about 30 percent of the data set (61 samples).

- Highway-related Land Use: This data set includes three monitoring locations with nine sampling events, all conducted recently by CDOT.

- Industrial Land Use: This data set includes five monitoring locations with 23 sampling events, which were all conducted as part of the Phase 1 sampling program.

- Open Space: This data set includes seven samples from the Rooney Ranch open space (natural area), which were collected as part of DRURP.

Table 19 provides summary statistics for total nitrogen by land use, and Table 20 provides p values resulting from comparison of differences in total nitrogen concentrations among land uses with Dunn’s Procedure. Figure 8 provides boxplots of total nitrogen by originally reported land use, and Figure 9 provides boxplots with some land uses combined, based on the results of Dunn’s Procedure. Figure 10 provides normal probability plots for total nitrogen by land use, and Figure 11 provides a cumulative frequency distribution comparison of total nitrogen by land use. Assumptions of normality were not met for any land use except highways. Table 21 provides a list of individual sites and numbers of sampling events comprising the analysis data set for total nitrogen. All of the data included in this analysis are individual event EMCs from flow-weighted composite samples. Findings resulting from statistical characterization of the compiled Colorado total nitrogen data include:

- The available data set for total nitrogen by land use is considered to be adequate for use in estimating nutrient loads from urban land uses in Colorado.

- Median concentrations of total nitrogen by land use in Colorado range from 2.79 to 4.19 mg/L, with statistically significant differences in total nitrogen concentrations among some land uses (Kruskal Wallis test $p<0.0001$), which were further explored using Dunn's Procedure.

- Dunn's Procedure identified statistically significant differences between residential land use and commercial land use ($p<0.0001$), as well as for residential land use and industrial land use ($p = 0.034$). Total nitrogen concentrations in residential runoff were higher than total nitrogen for commercial and industrial land uses. No other statistically significant differences among land uses were identified, based on comparisons using Dunn's procedure. Based on these findings, summary statistics for a combined industrial-commercial land use were completed and provided in Table 19.

- The COVs for total nitrogen for each land use category are relatively low (closer to 0.5), indicating less variability in the results than was present for total phosphorus.

- The highway runoff data set is relatively small; however, results are comparable to industrial runoff sites (both have median total nitrogen concentrations = 3.6 mg/L) and within the range of conditions observed at other land uses. On-going monitoring by CDOT will help to supplement this data set.

Table 19. Total Nitrogen Summary Statistics by Land Use in Colorado

Land Use	#	Min	Max	25th %	Median (Upper & Lower 95% CI)	75th %	Mean (Upper & Lower 95% CI)	COV
COM	168	0.54	16.63	2.01	2.79 (2.52-3.10)	3.88	3.45 (3.08-3.83)	0.71
HWY	9	1.30	6.10	2.30	3.6 (1.30-5.50)	5.50	3.78 (2.39-5.17)	0.45
IND	23	1.20	8.70	2.15	3.60 (2.00-4.37)	4.44	3.56 (2.78-4.34)	0.49
OPEN	7	1.49	6.12	2.08	3.76 (1.49-4.11)	4.14	3.40 (1.90-4.90)	0.44
RES	191	0.51	22.77	2.83	4.19 (3.68-4.82)	6.38	5.06 (4.60-5.53)	0.64
Combined Land Use Category								
COM-IND	191	0.54	16.63	2.01	2.84 (2.55-3.11)	3.93	3.47 (3.12-3.81)	0.69

Table 20. Total Nitrogen Summary of Pairwise Comparisons by Land Use
(p values from Dunn's Procedure; $p < 0.05$ is statistically significant)[1]

Land Use	COM	HWY	IND	OPEN	RES
COM	1	0.359	0.405	0.708	**< 0.0001**
HWY	0.359	1	0.743	0.736	0.320
IND	0.405	0.743	1	0.925	**0.034**
OPEN	0.708	0.736	0.925	1	0.186
RES	**< 0.0001**	0.320	**0.034**	0.186	1

[1]Dunn's procedure was used to test for statistically significant differences among land uses; the p values in bold font indicate statistically significant differences.

Figure 8. Boxplots for Total Nitrogen (mg/L) by Land Use in Colorado

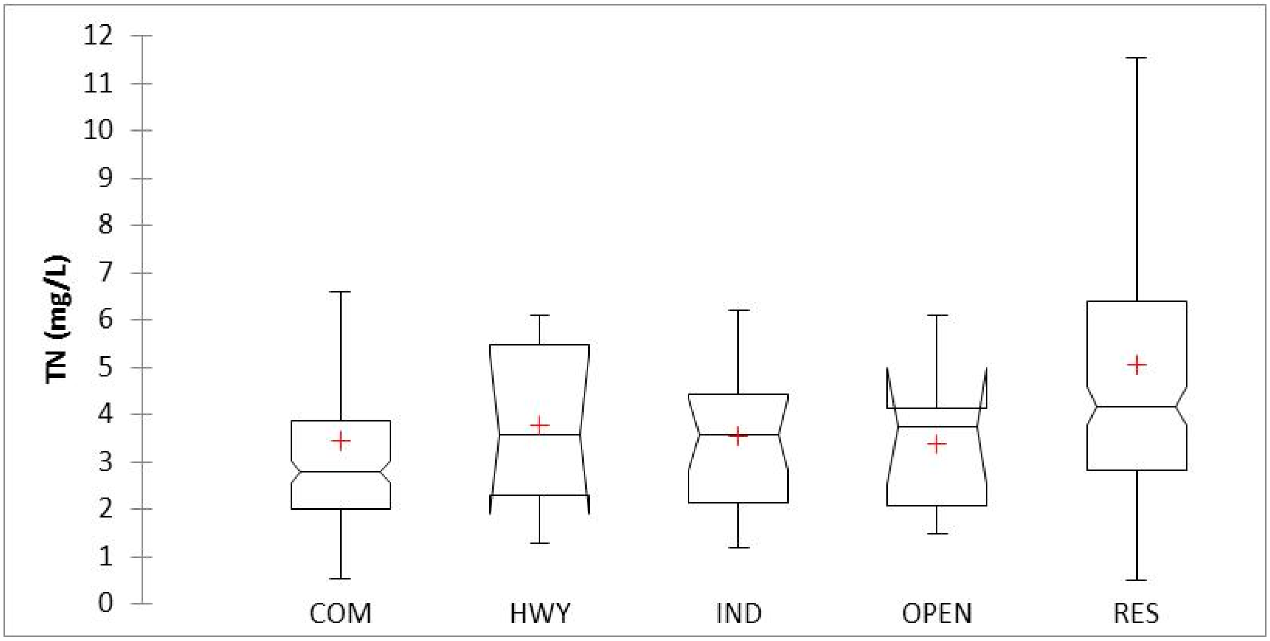


Figure 9. Boxplots for Total Nitrogen (mg/L) by Combined Land Use Groups in Colorado

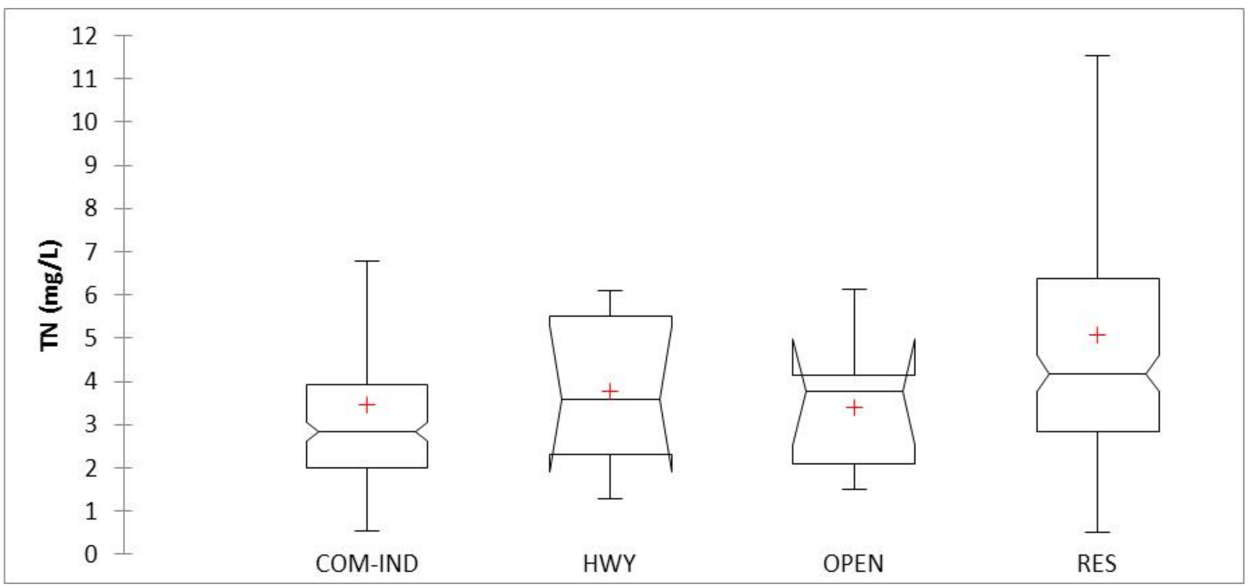


Figure 10. Normal Probability Plot for Total Nitrogen by Land Use in Colorado

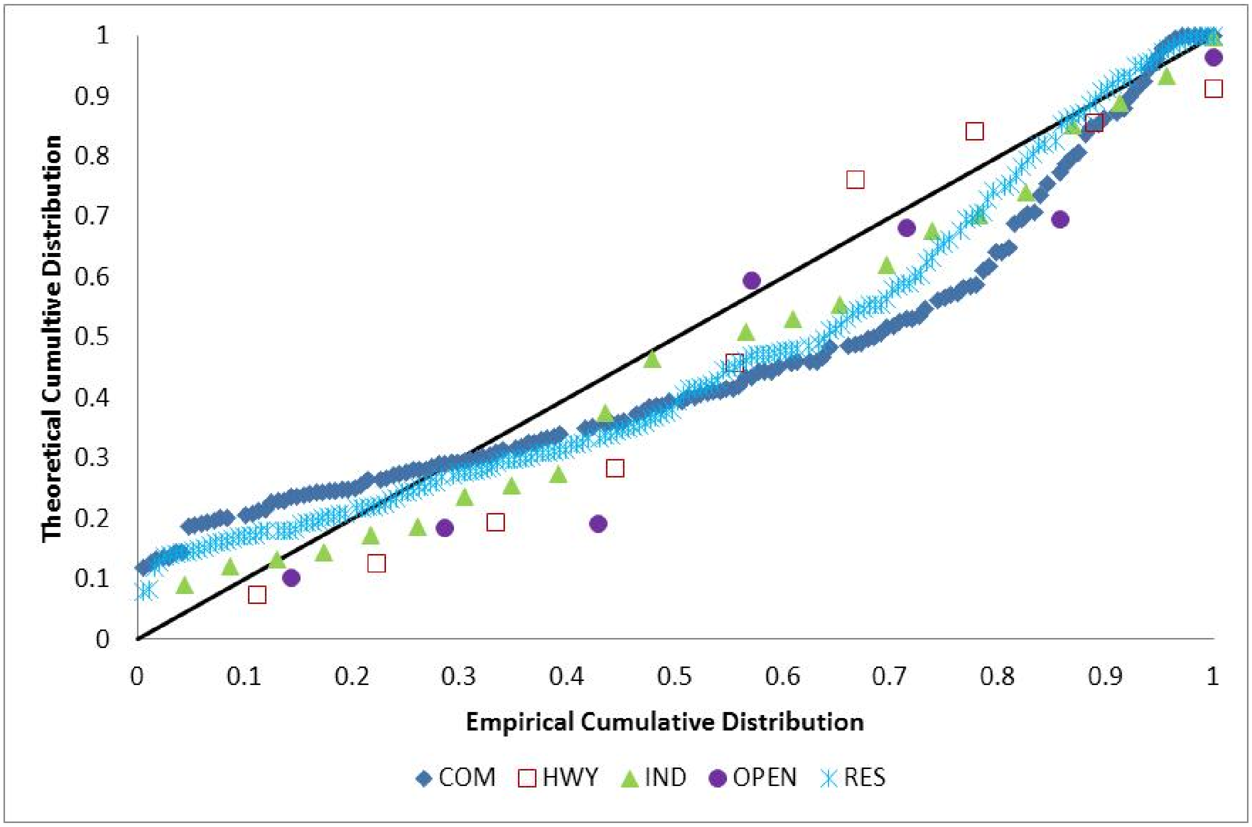


Figure 11. Cumulative Frequency Distribution for Total Nitrogen by Land Use in Colorado

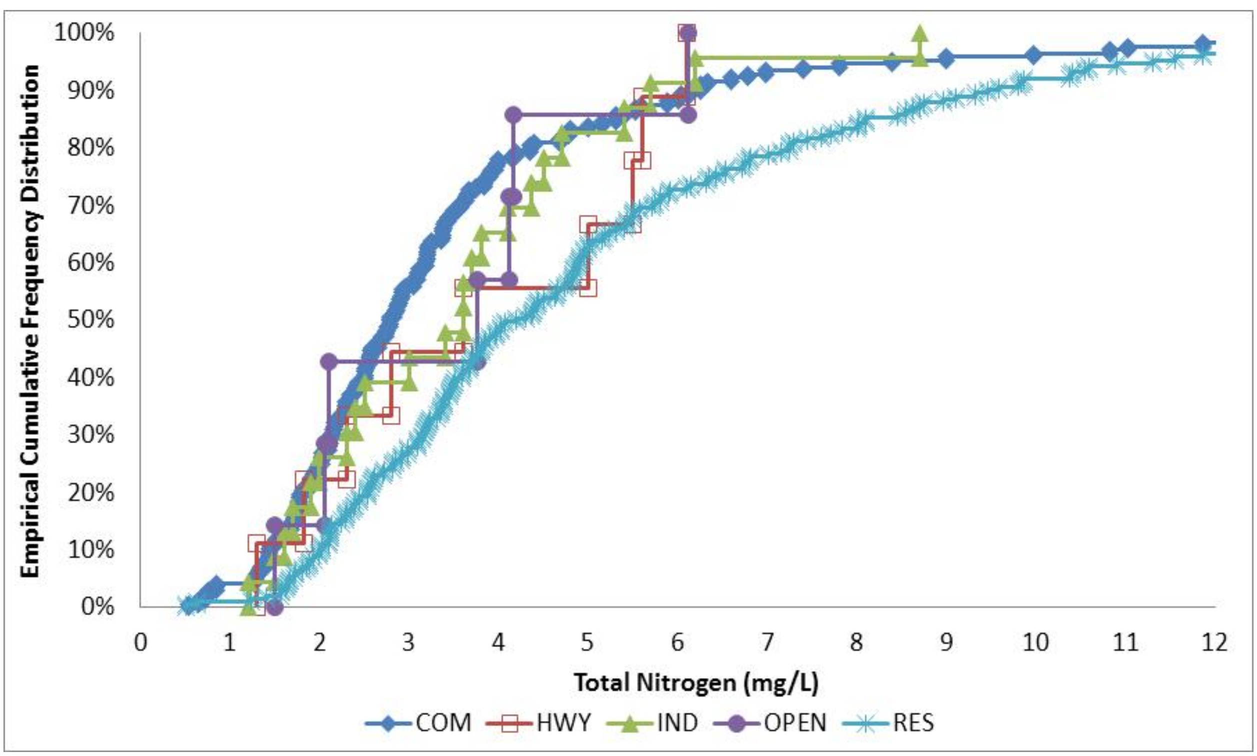


Table 21. Total Nitrogen Runoff Monitoring Events by Land Use

	Land Use					
	COM	HWY	IND	OPEN	RES	Total
Data Source_Monitoring Site						
CDOT_Hwy58-70In1A		3				3
CDOT_Hwy58-70InDtch		2				2
CDOT_RTD225		4				4
CSU_FCIn					5	5
CSU_Howes					7	7
CSU_UD					8	8
DRP_CherryKnolls					11	11
DRP_NorthAve	7					7
DRP_NorthGlenn					9	9
DRP_Rooney				7		7
DRP_Southglenn					7	7
DRP_VillaItalia	10					10
Grant_Heron					23	23
Grant_Reflect					22	22
P1_54TH			3			3
P1_7TH			3			3
P1_CLFX	3					3
P1_CS_Buchanan			7			7
P1_CS_Chestnut			7			7
P1_CS_ValleyHi	7					7
P1_CS_Wahsatch					7	7
P1_CS_Wal8th	7					7
P1_NSAN					4	4
P1_SHOP					3	3
P1_SMTH			3			3
P1_UNIV	3					3
P1_VILL	3					3
UDFCD_DenWW	24					24
UDFCD_MBPP	104					104
UDFCD_OrchPnd					61	61
UDFCD_Shop					24	24
Total	**168**	**9**	**23**	**7**	**191**	**398**

7.2.3 Total Suspended Solids (TSS)

The CSC requested that relationships between TSS, total phosphorus and total nitrogen be explored as part of this data analysis, even though TSS is not a monitoring parameter required under Regulation 85. TSS is frequently monitored as part of runoff characterization and BMP monitoring programs. Table 22 and Figure 12 provide summaries of TSS data in runoff in Colorado for informational purposes. Figure 13 provides a normal probability plot for each land use with TSS data reported, and Figure 14 provides cumulative frequency distributions by land use. Tests for normality showed that TSS is not normally distributed for any land use.

Statistically significant differences in TSS concentrations are present among land uses, based on results from the Kruskal-Wallis test ($p < 0.0001$). Dunn's Procedure identified two statistically significant different groupings of land uses with similar TSS concentrations: 1) residential and commercial and 2) industrial and open space. The residential and commercial land uses had lower TSS concentrations than the industrial and open space sites. (*It is important to note that even though the concentrations of TSS are similar from industrial and open space sites, the runoff rates from these land uses are dramatically different; therefore, loads would be expected to be quite different, particularly for frequently occurring storm events*.)

Correlations between TSS, total phosphorus and total nitrogen were also explored using Spearman Correlation analysis, with results provided in Table 23. Figures 15 through 18 provide scatter plot matrices further illustrating the relationships shown in Table 23. Data for commercial and residential sites are the most robust for purposes of such analysis. Spearman correlation analysis showed the following statistically significant correlations ($p < 0.05$):

- For open space (natural areas), total phosphorus was strongly correlated with TSS ($r_s = 0.93$, $p = 0.007$). No other statistically significant correlations were identified for open space.

- For commercial and residential areas, statistically significant positive correlations were present among TSS, TN and TP, as shown in Table 23. The TSS and TN correlation is not as strong as the TSS and TP correlation or TP and TN correlation for both land uses.

- For industrial areas, TP and TN were strongly correlated with each other ($r_s = 0.77$, $p < 0.0001$); however, neither showed statistically significant correlations with TSS.

- For highway-related areas, TP and TN were not significantly correlated statistically. Relationships with TSS were not analyzed because TSS data were not included in the CDOT data submitted to the CSC.

These findings are consistent with the expectation that particulate phosphorus is associated with sediment loading in land use types with landscaped areas. For industrial areas, smaller areas of natural soil conditions are expected to be present, so the lack of association between nutrients and TSS is not unexpected.

Table 22. TSS (mg/L) Summary Statistics by Land Use in Colorado

Land Use	No.	Min.	Max.	25^{th} %	Median	75^{th}%	Mean	CV
Statistics for Individual Land Uses								
COM	272	1	4380	31	108 (78-134)	298	244 (195-293)	1.7
IND	23	101	1280	227	340 (220-464)	502	445 (301-588)	0.7
OPEN	7	194	866	221	257 (194-464)	509	397 (166-627)	0.6
RES	272	2	2732	54	124 (104-146)	275	221 (186-255)	1.3
Statistics for Similar Groupings								
COM-RES	544	1	4380	40	119 (102-134)	291	233 (203-262)	1.5
IND-OPEN	30	101	1280	224	335 (239-464)	521	433 (317-550)	0.7

Figure 12. Boxplots for TSS by Land Use in Colorado

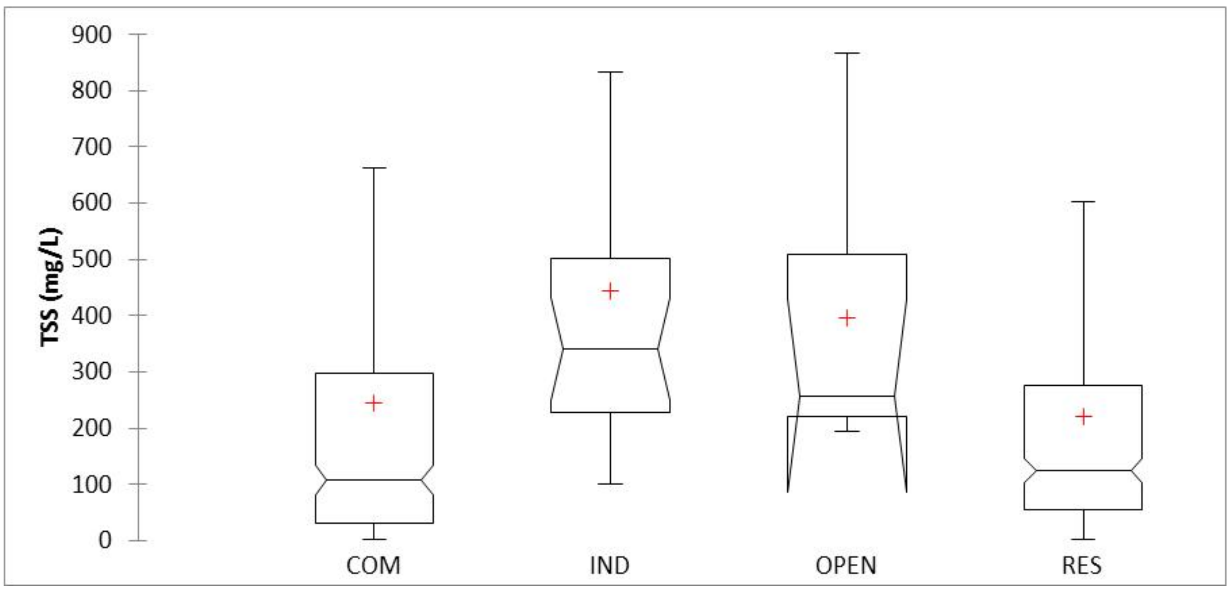


Figure 13. Normal Probability Plot for TSS (mg/L) by Land Use in Colorado

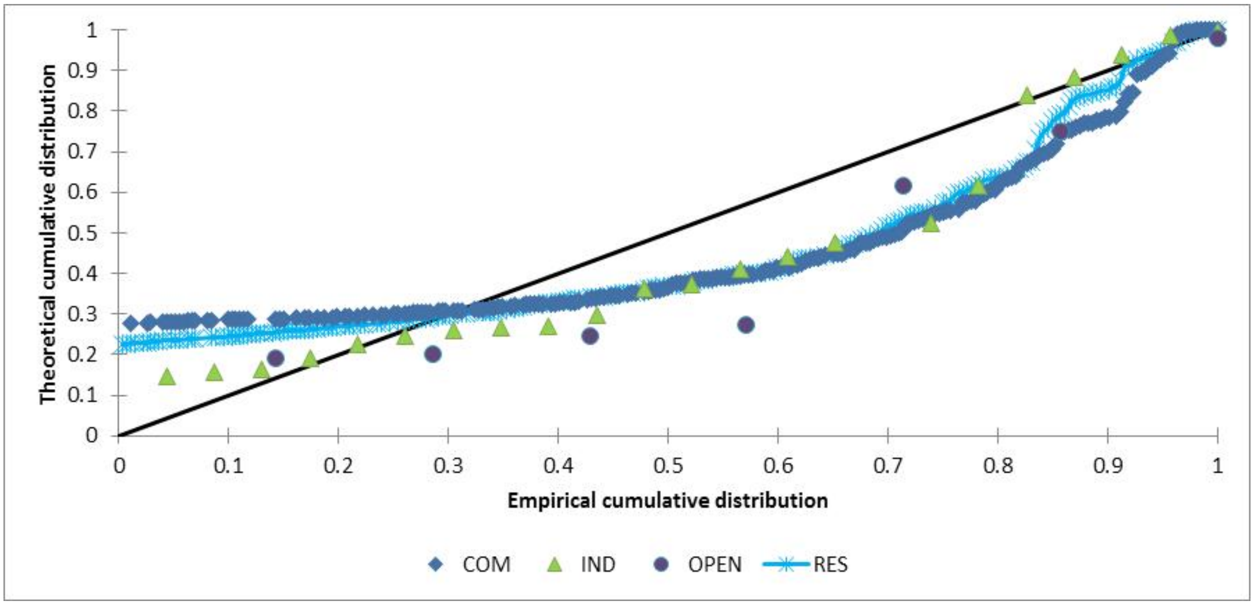


Figure 14. Cumulative Frequency Distribution for TSS (mg/L) by Land Use in Colorado

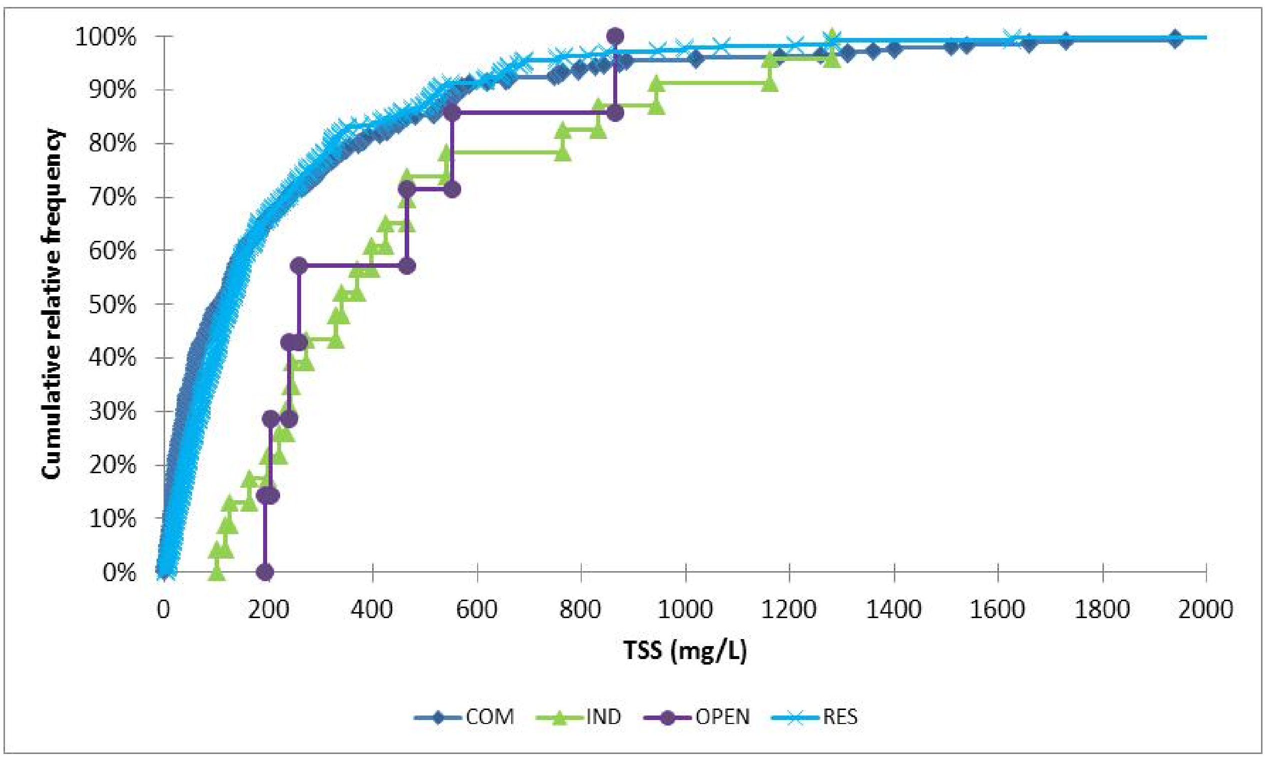


Table 23. Spearman Correlation Matrix for TN, TP and TSS by Land Use[1]

	COM			
COM		TP	TN	TSS
	TP	**1.00**	**0.56**	**0.73**
	TN	**0.56**	**1.00**	**0.38**
	TSS	**0.73**	**0.38**	**1.00**
	HWY			
HWY		TP	TN	TSS
	TP	**1.00**	-0.25	NA
	TN	-0.25	**1.00**	NA
	TSS	NA	NA	NA
	IND			
IND		TP	TN	TSS
	TP	**1.00**	**0.77**	0.20
	TN	**0.77**	**1.00**	0.00
	TSS	0.20	0.00	**1.00**
	OPEN			
OPEN		TP	TN	TSS
	TP	**1.00**	0.68	**0.93**
	TN	0.68	**1.00**	0.46
	TSS	**0.93**	0.46	**1.00**
	RES			
RES		TP	TN	TSS
	TP	**1.00**	**0.59**	**0.57**
	TN	**0.59**	**1.00**	**0.46**
	TSS	**0.57**	**0.46**	**1.00**

[1]Spearman's Rho values in bold have statistically significant correlations, with p values < 0.05.

Figure 15. Scatter Plot Matrix for TSS, TP and TN (mg/L) for Commercial Land Use

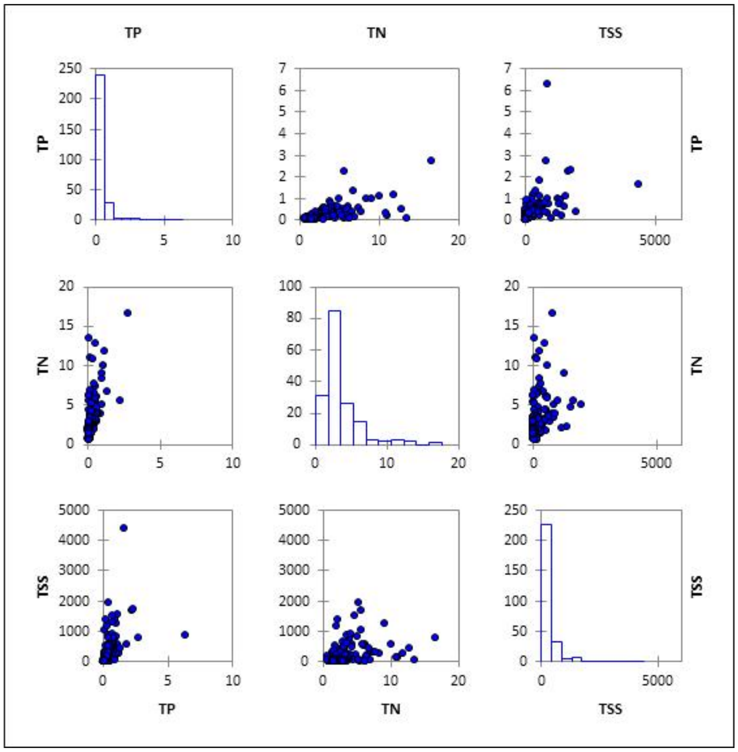


Figure 16. Scatter Plot Matrix for TSS, TP and TN (mg/L) for Industrial Land Use

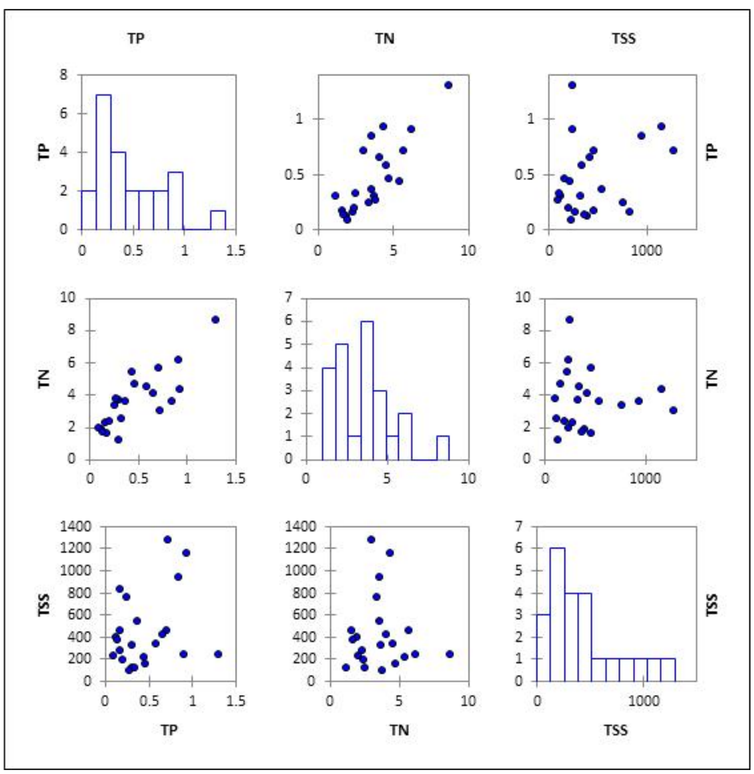


Figure Notes: x and y axis units for scatter plots are mg/L. Y-axis units for histograms are number of sampling events.

Figure 17. Scatter Plot Matrix for TSS, TP and TN (mg/L) for Open Space (Natural Area) Land Use

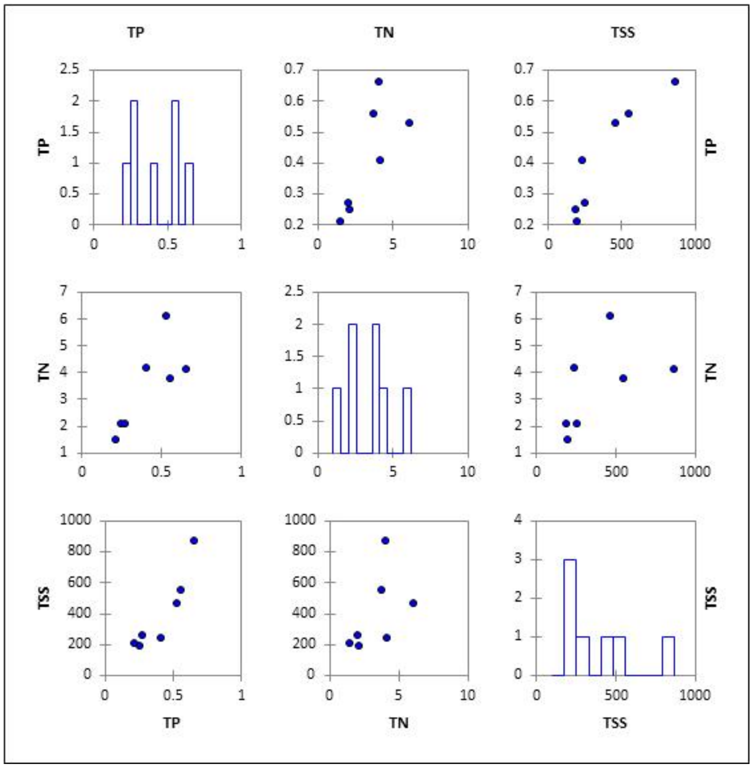


Figure 18. Scatter Plot Matrix for TSS, TP and TN (mg/L) for Residential Land Use

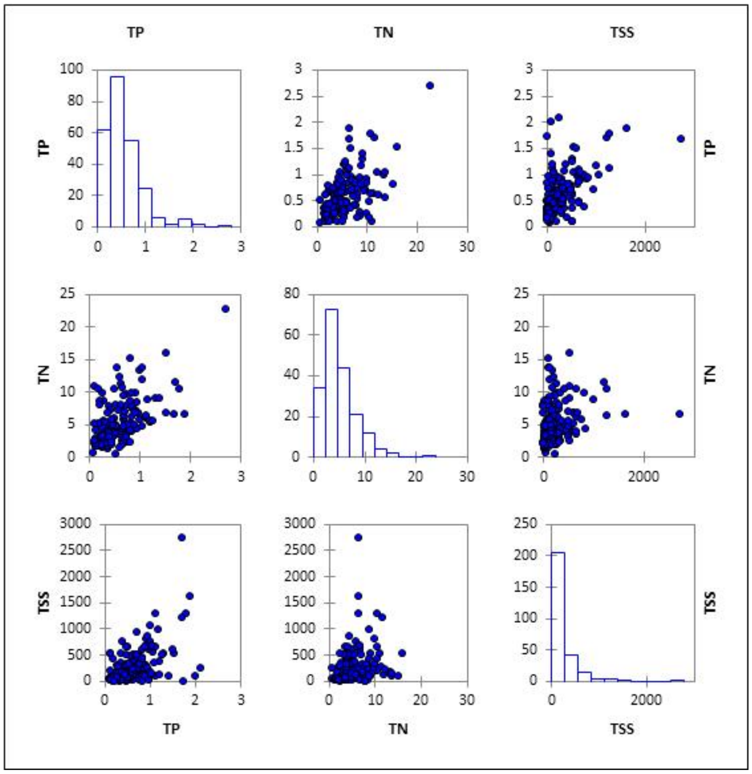


Figure Notes: x and y axis units for scatter plots are mg/L. Y-axis units for histograms are number of sampling events.

7.3 Comparison of Colorado and National Data

7.3.1 Total Phosphorus

Colorado total phosphorus data sets separated by land use categories were compared to the NSQD data sets for corresponding land use categories in EPA's Rain Zones. Table 24 provides a summary of these comparisons based on Kruskal-Wallis hypothesis testing and Dunn's Procedure. More detailed information is provided in Appendix C. Table 25 provides summary statistics for each NSQD Rain Zone by land use compared with Colorado data. Figures 19 through 23 provide boxplots of the data sets by land use for total phosphorus. Because most of the NSQD Rain Zone 9 land use data sets either represent a subset of the Colorado data set or are identical to the Colorado data sets (i.e., industrial and open space land uses), Rain Zone 9 is not shown in the figures or tables to prevent spurious conclusions. Key observations based on these comparisons of the Colorado data set to other EPA Rain Zones in the NSQD include:

- Mean and median total phosphorus concentrations for each Colorado land use are within the range of mean and median total phosphorus concentrations for other Rain Zones. In other words, Colorado total phosphorus concentrations are neither extremely high nor low compared to what was found in other parts of the country.

- Statistically significant differences between Rain Zone-Land Use subgroups and Colorado land use subgroups vary depending on the particular combination of subgroups. The only Rain Zone that is generally similar to Colorado for all land uses is Zone 4, the Lower Mississippi Valley. Most of the Zone 4 data in the NSQD is from the Houston, Texas (60%) or Kansas City (30%) areas, with a smaller subset from Memphis, TN (10%).

Due to differences in total phosphorus between Colorado land uses and most other Rain Zones, use of in-state data is the preferred approach for estimating total phosphorus in urban runoff, at least for the Front Range. In western Colorado, Rain Zone 6 (Southwest) may be useful for supplementing portions of Colorado with lower rainfall, based on findings by Bochis (2010), as discussed in Section 5.1.

Table 24. Summary of Differences in Total Phosphorus in Runoff in Colorado and NSQD Rain Zones by Land Use

Higher/Lower/NSD = indicates whether Colorado's TP results are higher, lower or not significantly different statistically from another other rain zone;
NA = comparison not applicable due to small sample size; -- = no data

Rain Zone		Colorado Land Use				
Rain Zone	**Description**	**COM (277)**	**HWY (25)**	**IND (39)**	**OPEN (7)**	**RES (254)**
1	Great Lakes/ Northeast	**Higher (263)**	NA (3)	NSD (74)	**Higher (139)**	**Higher (498)**
2	Mid-Atlantic	NSD (621)	**Lower (177)**	NSD (360)	NSD (106)	**Higher (1923)**
3	Southeast	NSD (141)	**Higher (14)**	**Higher (108)**	--	**Higher (410)**
4	Lower Miss. Valley	NSD (50)	--	NSD (49)	NSD (18)	NSD (91)
5	Texas	**Higher (112)**	**Higher (246)**	**Higher (108)**	NSD (67)	**Higher (206)**
6	Southwest	**Lower (35)**	NSD (135)	**Lower (61)**	NA (2)	NSD (67)
7	Northwest	NSD (84)	NSD (24)	NSD (76)	--	**Higher (331)**
8	Rocky Mtns.	***Lower (7)***	--	NA (1)	--	NSD (15)

Table Notes:

Red highlighted cells indicate statistically significant differences between the Colorado data set and another Rain Zone, based on Dunn's Procedure, which uses a two-tailed test, with alpha = 0.05.

Red text in a grey highlighted cell indicates that a statistically significant difference was identified, but should be used with caution due to the small sample size.

Rain Zone 9 is not shown because the majority of the Rain Zone 9 data set is from Colorado; therefore, the comparison between Colorado and Rain Zone 9 is not valid.

Table 25. Selected Summary Statistics for Total Phosphorus in Runoff in Colorado and NSQD Rain Zones by Land Use

Land Use and Rain Zone	Runoff Events	Total Phosphorus (mg/L)						
		Min	Max	25^{th} %	Median	75^{th} %	Mean	CV
COM-1	263	0.02	8.60	0.09	0.14	0.27	0.25	2.24
COM-2	621	0.01	6.72	0.14	0.24	0.45	0.37	1.29
COM-3	141	0.01	2.86	0.12	0.27	0.47	0.39	1.10
COM-4	50	0.03	3.55	0.10	0.19	0.36	0.38	1.56
COM-5	112	0.02	15.60	0.09	0.16	0.30	0.63	2.98
COM-6	35	0.16	2.00	0.33	0.48	0.69	0.57	0.71
COM-7	84	0.01	3.30	0.11	0.24	0.37	0.34	1.32
COM-8	7	0.16	1.08	0.35	0.50	0.77	0.57	0.57
COM-CO	277	0.01	6.30	0.12	0.22	0.41	0.36	1.47
HWY-1	3	0.35	0.54	0.38	0.41	0.47	0.43	0.18
HWY-2	177	0.04	11.56	0.21	0.44	1.34	0.96	1.31
HWY-3	14	0.07	0.46	0.11	0.13	0.14	0.16	0.71
HWY-5	246	0.01	0.97	0.12	0.18	0.30	0.22	0.71
HWY-6	135	0.03	7.19	0.18	0.27	0.42	0.48	1.65
HWY-7	24	0.11	0.90	0.22	0.28	0.42	0.35	0.56
HWY-CO	25	0.07	2.60	0.15	0.28	0.42	0.39	1.25
IND-1	74	0.03	1.50	0.14	0.24	0.40	0.33	0.86
IND-2	360	0.02	4.88	0.12	0.23	0.38	0.33	1.42
IND-3	108	0.02	1.00	0.09	0.13	0.25	0.20	0.94
IND-4	49	0.02	2.50	0.15	0.26	0.37	0.35	1.18
IND-5	108	0.02	2.64	0.12	0.19	0.28	0.26	1.18
IND-6	61	0.14	7.90	0.66	1.10	1.60	1.31	0.92
IND-7	76	0.05	1.40	0.10	0.25	0.46	0.33	0.88
IND-8	1	0.31	0.31	0.31	0.31	0.31	0.31	0.94
IND-CO	39	0.05	1.30	0.16	0.25	0.43	0.35	0.81
OPEN-1	139	0.00	2.50	0.03	0.10	0.21	0.18	1.65
OPEN-2	106	0.01	2.50	0.11	0.20	0.45	0.33	1.09
OPEN-4	18	0.10	15.40	0.14	0.32	0.37	1.14	3.04
OPEN-5	67	0.02	2.29	0.16	0.25	0.43	0.37	1.09
OPEN-6	2	0.53	0.76	0.59	0.65	0.70	0.65	0.18
OPEN-CO	7	0.21	0.66	0.26	0.41	0.54	0.41	0.39
RES-1	498	0.02	6.69	0.19	0.30	0.48	0.41	1.08
RES-2	1923	0.01	19.90	0.16	0.28	0.48	0.42	1.74
RES-3	410	0.01	3.40	0.08	0.13	0.21	0.19	1.45
RES-4	91	0.05	5.33	0.26	0.43	0.79	0.69	1.21
RES-5	206	0.08	4.19	0.25	0.36	0.53	0.47	0.89
RES-6	67	0.11	4.96	0.30	0.42	0.59	0.54	1.11
RES-7	331	0.01	3.61	0.13	0.20	0.31	0.30	1.20
RES-8	15	0.22	2.95	0.38	0.70	1.02	0.85	0.81
RES-CO	254	0.07	2.71	0.29	0.45	0.72	0.56	0.69

Note: Rain Zone 9 is not shown because the majority of the Rain Zone 9 data set is from Colorado; therefore, the comparison between Colorado and Rain Zone 9 is not valid.

Figure 19. Boxplots of Total Phosphorus in Runoff for Commercial Land Uses by Rain Zone

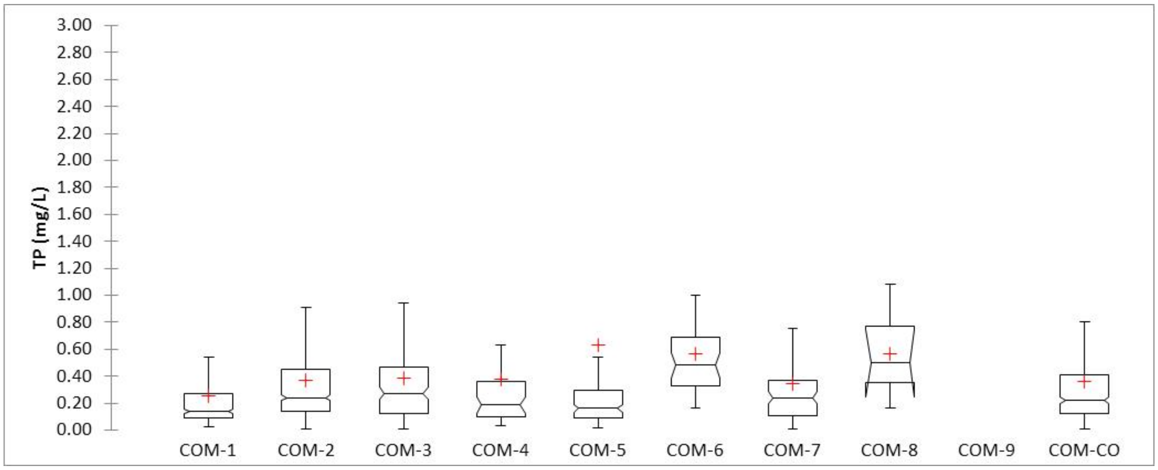


Figure 20. Boxplots of Total Phosphorus in Runoff for Highway Land Uses by Rain Zone

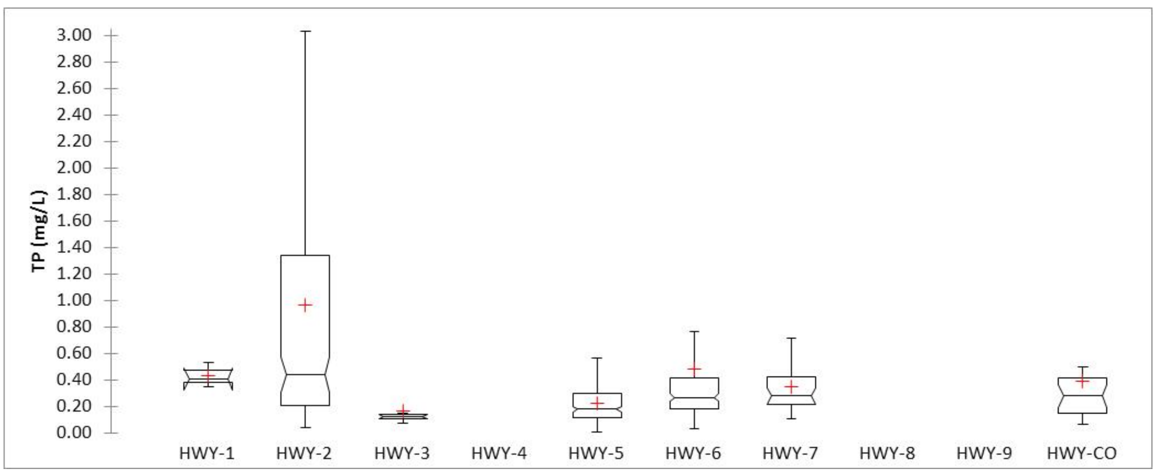


Figure 21. Boxplots of Total Phosphorus in Runoff for Industrial Land Uses by Rain Zone

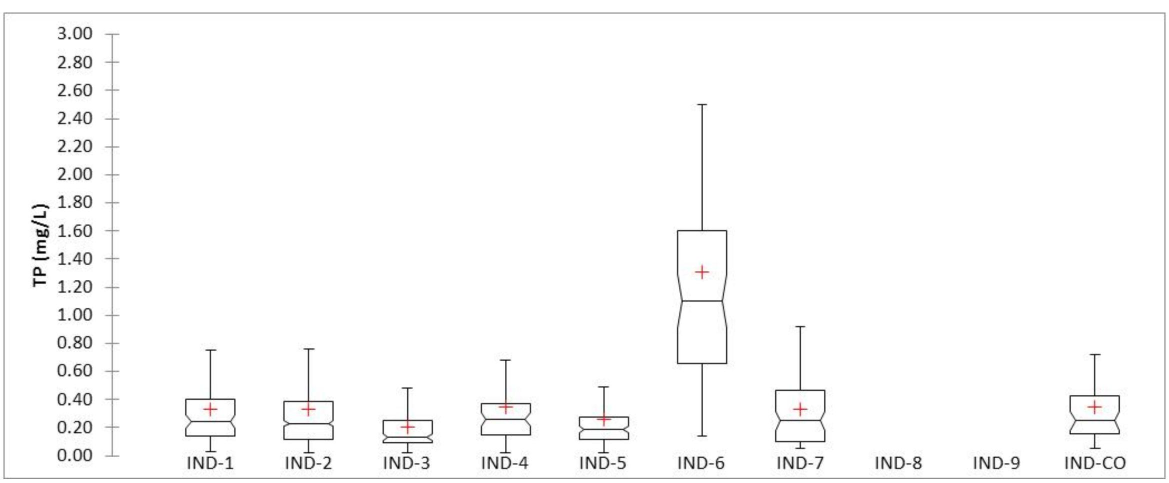


Figure 22. Boxplots of Total Phosphorus in Runoff for Residential Land Uses by Rain Zone

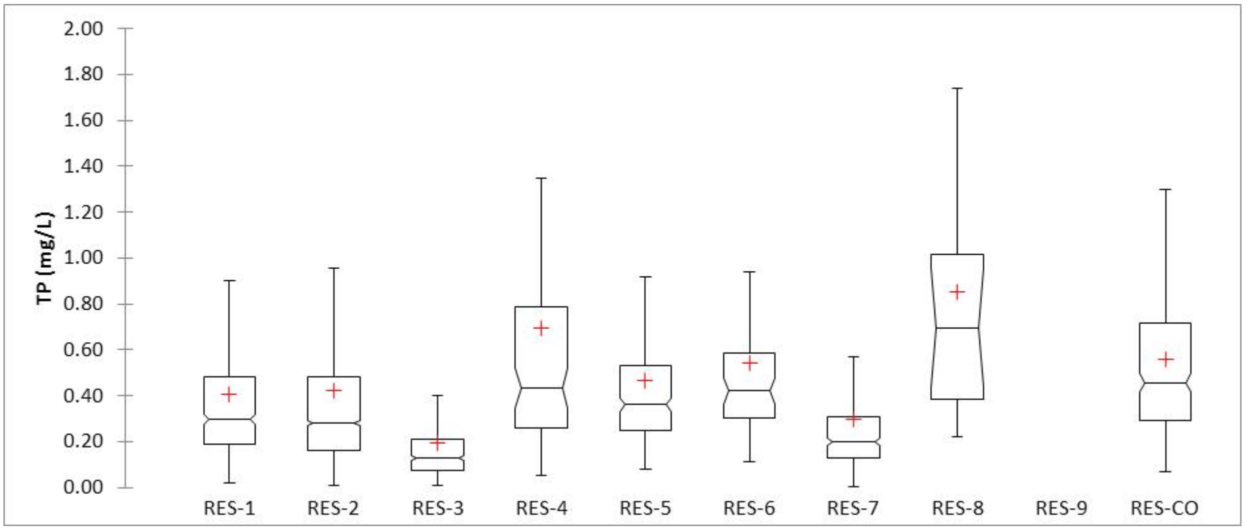
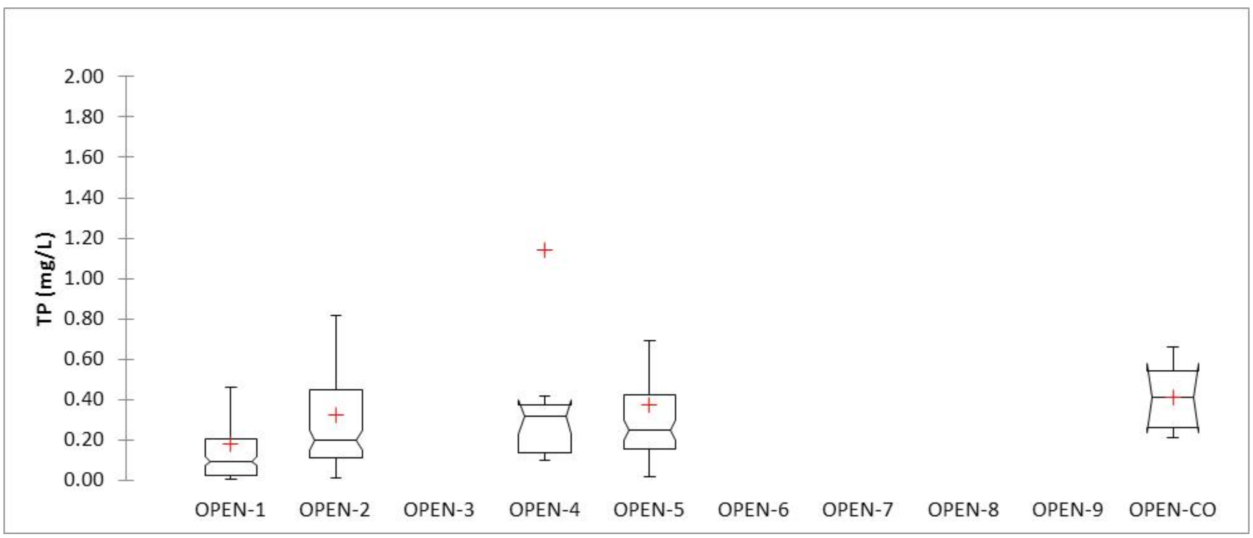


Figure 23. Boxplots of Total Phosphorus in Runoff for Open Space Land Uses by Rain Zone



7.3.2 Total Nitrogen

Colorado total nitrogen data sets by land use category were compared to the NSQD data sets for corresponding land use categories in EPA's Rain Zones. Table 26 provides a summary of these comparisons based on Kruskal-Wallis hypothesis testing and Dunn's Procedure. Appendix C contains more detailed statistical results from this analysis, including p values for multiple pairwise comparisons. Because most of the NSQD Rain Zone 9 land use data sets either represent a subset of the Colorado data set or are identical to the Colorado data sets (i.e., industrial and open space land uses), Rain Zone 9 is not shown in the figures or tables to prevent spurious conclusions.

Table 27 provides summary statistics for each NSQD Rain Zone by land use, with Colorado data also provided for comparison. Figures 24 through 28 provide boxplots of the data sets by land use for total nitrogen. Rain Zones without total nitrogen data are left blank on the boxplots. Findings based on comparison of Colorado total nitrogen data for various land uses to other Rain Zones include:

- The total nitrogen data set is more limited than the total phosphorus data set, so comparisons between each Rain Zone-Land Use subgroup were limited by data availability. For residential and commercial land uses, the Colorado data set was much larger than what was available in other Rain Zones.

- Colorado's mean and median nitrogen concentrations are generally higher than in other Rain Zones (based on simple comparisons rather than hypothesis testing). Identification of the cause of this difference is beyond the scope of this report.

- Due to the relatively small sample sizes in multiple Rain Zones, results of comparisons based on Dunn's Procedure in Table 26 should be used with caution, considering sample size as a factor affecting the reliability of the statistical comparison.[3] With this caveat noted, the following observations are expected to be reasonably reliable:

    - For most Rain Zones with data suitable for comparison, Colorado's residential, commercial and industrial total nitrogen data are significantly higher. Colorado's mean and median concentrations are two or more times the concentrations in many of the Rain Zone-Land Use subgroups.

    - The highway and open space data sets are smaller and are not well suited to comparisons among subgroup combinations; nonetheless, the general trend of Colorado's nitrogen data being higher than other Rain Zones is also present for these land uses.

- Because of the notable differences between Colorado total nitrogen data and other land uses, it is generally not appropriate to supplement Colorado's nitrogen data set with other regions of the country based on available data. West Slope data could potentially be supplemented by Rain Zone 6 data; however, analyses by Bochis (2010) provided conclusions based on TKN, rather than total nitrogen.

[3] Power analyses could be conducted to quantitatively explore the likelihood of a Type II error, but these analyses were beyond the scope of the basic characterizations for purposes of this Data Report.

Table 26. Summary of Differences in Total Nitrogen in Runoff in Colorado and NSQD Rain Zones by Land Use

Higher/Lower/NSD = indicates whether Colorado's TN results are higher, lower or not significantly different statistically from another other rain zone;
NA = comparison not applicable due to small sample size; -- = no data

		Colorado Land Uses (#) = number of samples in data set				
Rain Zone	Description	COM (168)	HWY (9)	IND (23)	OPEN (7)	RES (191)
1	Great Lakes/Northeast	Higher (12)	--	Higher (6)	Higher (5)	Higher (30)
2	Mid-atlantic	Higher (76)	--	Higher (87)	Higher (57)	Higher (110)
3	Southeast	Higher (37)	Higher (14)	Higher (28)		Higher (49)
4	Lower Miss. Valley	NSD (26)	--	NSD (29)	NSD (12)	Higher (56)
5	Texas	--	--	--	--	--
6	Southwest	NA (2)	--	Higher (10)	--	NA (3)
7	Northwest	--	--	--	--	--
8	Rocky Mtns.	--	--	--	--	--

Table Notes:

Red highlighted cells indicate statistically significant differences between the Colorado data set and another Rain Zone, based on Dunn's Procedure, which uses a two-tailed test, with alpha = 0.05.

Red text in a grey highlighted cell indicates that a statistically significant difference was identified, but should be used with caution due to the small sample size.

Rain Zone 9 is not shown because the majority of the Rain Zone 9 data set is from Colorado; therefore, the comparison between Colorado and Rain Zone 9 is not valid.

Table 27. Selected Summary Statistics for Total Nitrogen in Runoff in Colorado and NSQD Rain Zones by Land Use

Land Use and Rain Zone	Runoff Events	Total Nitrogen (mg/L)						
		Min	Max	25th%	**Median**	75th%	Mean	CV
COM-1	12	0.51	4.80	1.23	**1.67**	2.73	2.02	0.60
COM-2	76	0.20	20.20	0.89	**1.60**	2.60	2.59	1.34
COM-3	37	0.22	8.14	0.82	**1.19**	1.50	1.52	0.96
COM-4	26	0.44	7.20	1.46	**2.17**	3.26	2.59	0.66
COM-6	2	0.72	1.20	0.84	**0.96**	1.08	0.96	0.25
COM-CO	168	0.54	16.63	2.01	2.79	3.88	3.45	0.71
HWY-3	14	0.70	3.87	1.16	**1.38**	1.59	1.79	0.62
HWY-CO	9	1.30	6.10	2.30	**3.60**	5.50	3.78	0.45
IND-1	6	0.42	1.90	0.96	**1.50**	1.67	1.31	0.40
IND-2	87	0.20	16.70	0.61	**1.70**	2.75	2.36	1.12
IND-3	28	0.20	3.83	0.43	**0.95**	1.51	1.21	0.82
IND-4	29	0.47	15.20	1.61	**2.21**	2.87	2.76	0.94
IND-6	10	0.30	1.90	0.71	**1.15**	1.48	1.13	0.44
IND-CO	23	1.20	8.70	2.15	**3.60**	4.44	3.56	0.49
OPEN-1	5	0.28	0.98	0.50	**0.57**	0.60	0.59	0.39
OPEN-2	57	0.30	9.40	0.90	**1.60**	2.36	1.87	0.81
OPEN-4	12	0.66	6.33	1.30	**1.91**	3.24	2.44	0.66
OPEN-CO	7	1.49	6.12	2.08	**3.76**	4.14	3.40	0.44
RES-1	30	0.47	4.25	1.36	**1.98**	2.67	2.10	0.48
RES-2	110	0.21	18.30	1.00	**1.55**	2.88	2.19	0.97
RES-3	49	0.20	8.00	0.61	**1.20**	1.61	1.38	0.91
RES-4	56	0.72	6.31	2.07	**2.86**	3.60	2.94	0.43
RES-6	3	0.50	1.40	0.90	**1.30**	1.35	1.07	0.38
RES-CO	191	0.51	22.77	2.83	4.19	6.38	5.06	0.64

Note: Rain Zone 9 is not shown because the majority of the Rain Zone 9 data set is from Colorado; therefore, the comparison between Colorado and Rain Zone 9 is not valid.

Figure 24. Boxplots of Total Nitrogen in Runoff for Commercial Land Uses by Rain Zone

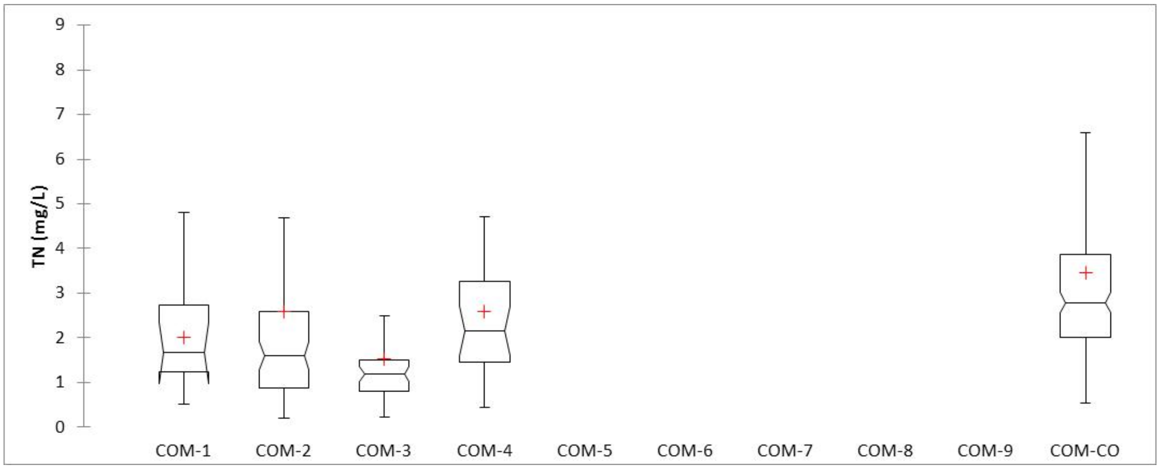


Figure 25. Boxplots of Total Nitrogen in Runoff for Highway Land Uses by Rain Zone

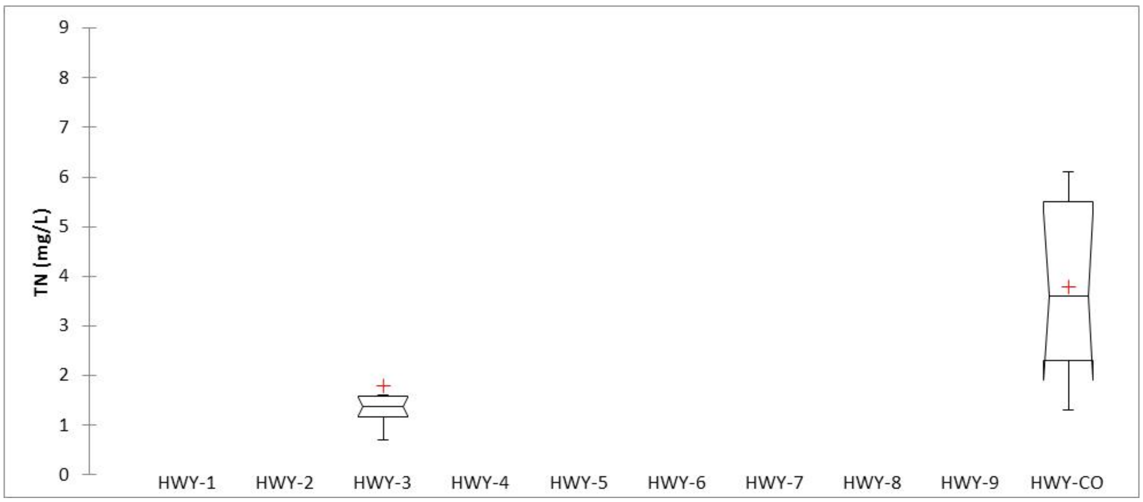


Figure 26. Boxplots of Total Nitrogen in Runoff for Industrial Land Uses by Rain Zone

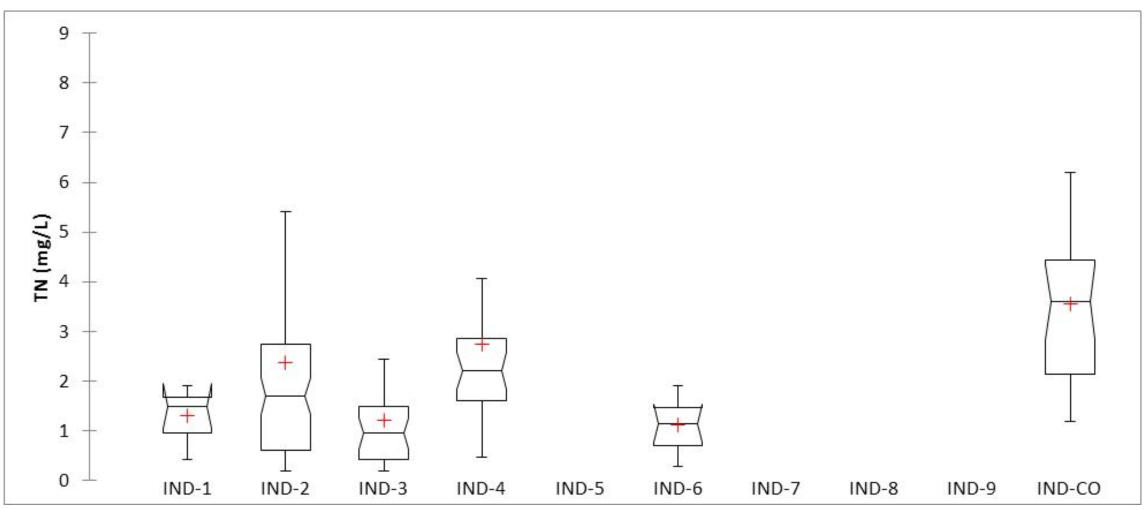


Figure 27. Boxplots of Total Nitrogen in Runoff for Residential Land Uses by Rain Zone

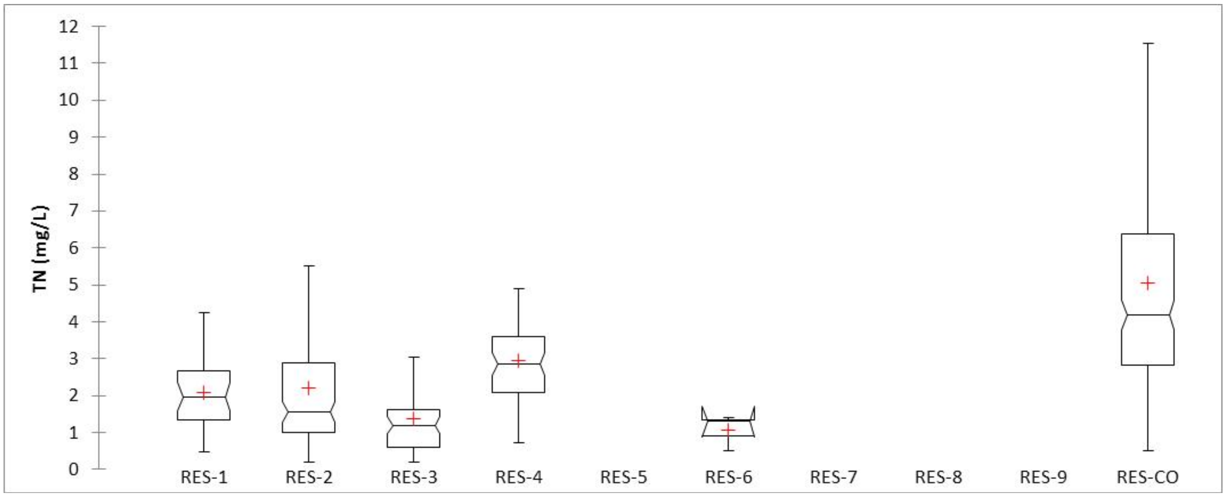
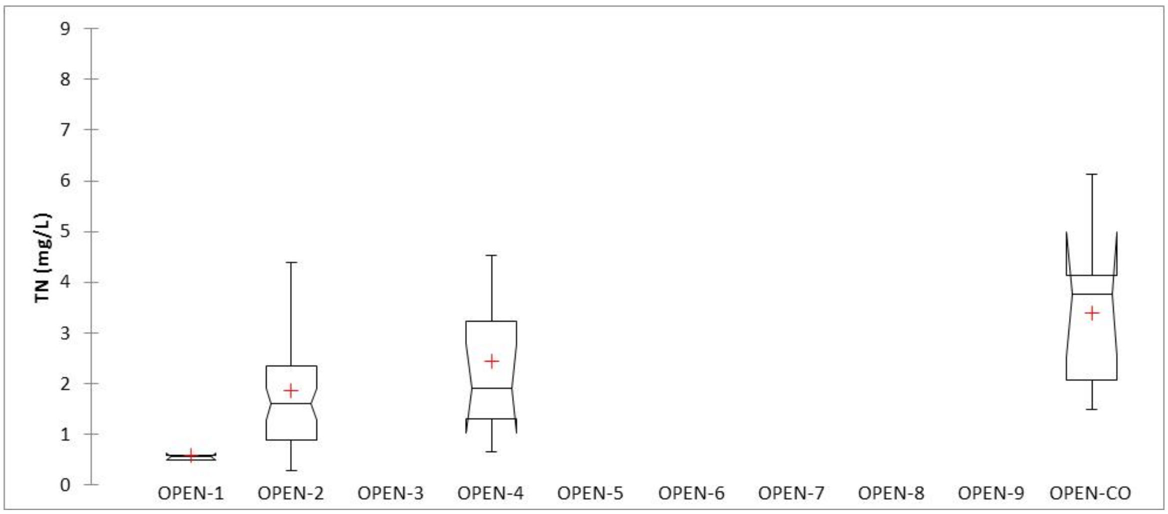


Figure 28. Boxplots of Total Nitrogen in Runoff for Open Space Land Uses by Rain Zone



7.4 City and County of Denver Grab Samples for Baseflow, Runoff and Snowmelt

As discussed in Section 4.4.1, the City and County of Denver collects grab samples at over 130 outfalls in the Denver area. The data set is primarily focused on dry weather sampling, but some runoff and snowmelt influenced samples are included in the data set. (These samples are not flow-weighted EMCs.) Both total phosphorus (n = 787) and total nitrogen (calculated from TKN + NO2 + NO3) (n = 637) data are available; however, only total phosphorus is evaluated further due to detection limit issues for the nitrogen data.

The detection limits for the nitrogen fractions are substantially higher than those required for monitoring by wastewater treatment plants in Regulation 85, and there are large percentages of non-detects for each nitrogen fraction used in the total nitrogen calculation, thereby resulting in potentially misleading runoff characterization for total nitrogen for purposes of this Data

Report.[4] Although advanced substitution techniques for non-detects could potentially be applied (e.g., regression on order statistics [ROS]) to each nitrogen fraction, concerns still remain due to the fact that the substituted values would need to be added together to estimate the total nitrogen value. Information on the detection limits for the nitrogen fractions in the City and County of Denver outfall samples includes:

- 33% non-detects for nitrate with a detection limit of 0.2 mg/L, with 0.02 mg/L nitrate/nitrite required in Regulation 85.
- 31% non-detects for nitrite, detection limit = 0.01 mg/L.
- 48% non-detects for TKN with a detection limit = 1 mg/L, with a 0.1 mg/L TKN detection limit required in Regulation 85.

In contrast, the percent of non-detects for total phosphorus was about 15%, with the majority of these associated with the large dry weather data set, so the total phosphorus data set was considered suitable for further analysis. Table 28 and Figure 29 provide summary statistics and graphical representations of summary statistics for grab samples by flow type. Table 29 and Figures 30 through 32 provide summary statistics and graphical representations of dry weather grab samples only. In these tables and figures, the “URB” land use represents unclassified urban land uses resulting from the complexity of defining land use in urban storm drain systems. The open space land use in this data set includes a combination of natural and manicured areas; this differs from the Open Space category in the Colorado phosphorus EMC data set, which represented only natural open space.

Findings from this analysis include:

- As summarized in Table 28, dry weather total phosphorus grab sample results were highly variable, with a COV of 2.85 and the mean nearly twice the median. This may be due to normal site-to-site variation, or it could be due to possible inclusion of sanitary-influenced outfalls in the analysis, even though efforts were made to remove such outfalls from the data set.
- Because of the wide variation in sample numbers at individual outfalls, site-by-site comparisons are not appropriate for the specific purposes of this Data Report. For example, 40 percent of the sites only have one or two samples, whereas 10 percent have 15 or more samples. For this reason, data are only summarized for the land use subgroups.
- The median concentrations for dry weather and snowmelt for total phosphorus are at or below instream phosphorus criteria for warm water streams, which are based on annual median concentrations.

[4] The purpose of the City and County of Denver sampling is oriented towards dry weather screening for illicit discharges, which focuses on identification of high concentrations, so the detection limit issue is less significant for the City and County of Denver’s study purposes.

- Kruskal-Wallis hypothesis testing did not identify statistically significant differences among types of runoff (e.g., dry weather, snowmelt, runoff), although total phosphorus in runoff was marginally significantly higher statistically than baseflow (p = 0.047) when comparisons using Dunn's Procedure were completed. The validity of this comparison is likely limited by the fact that stormwater influenced grab samples do not capture the range of concentrations experienced during the runoff hydrograph.

- Kruskal-Wallis hypothesis testing indicated that there were statistically significant differences among land uses in dry weather grab sample data collected by the City and County of Denver. Dunn's Procedure results showed that industrial land uses had statistically significant lower concentrations than commercial and residential sites. Commercial land uses had significantly higher concentrations statistically than residential sites; this finding differs from the EMC runoff data results presented in Section 7.2.1. The open space land use data set was smaller, with a larger confidence interval for the median; therefore, statistically significant differences between open space and other land uses were not identified.

- Qualitative comparisons of the runoff grab sample data in Table 29 to the runoff EMCs in Table 16 suggest median concentration results comparable to the Colorado commercial land use EMC data set.

Table 28. Summary Statistics for City and County of Denver Grab Samples by Flow Type for Total Phosphorus (mg/L)

Flow Type	# Events	Min	Max	25th %	Median	75th %	Mean	COV
Dry	650	0.01	17.30	0.08	0.14 (0.12-0.16)	0.28	0.36 (0.28-0.44)	2.85
Runoff	36	0.05	1.17	0.13	0.21 (0.15-0.25)	0.31	0.29 (0.20-0.38)	0.88
Snowmelt	96	0.03	3.23	0.09	0.17 (0.13-0.20)	0.31	0.32 (0.21-0.43)	1.62

Table 29. Summary Statistics for City and County of Denver Dry Weather Grab Samples by Land Use for Total Phosphorus (mg/L)

Land Use	# Events	Min	Max	25th %	Median	75th %	Mean	CV
COM	34	0.06	5.82	0.13	0.32 (0.16-0.45)	0.71	0.58 (0.23-0.93)	1.69
IND	275	0.03	17.30	0.08	0.11 (0.10-0.12)	0.19	0.32 (0.16-0.47)	4.13
OPEN	13	0.03	5.05	0.10	0.28 (0.04-0.34)	0.34	0.66 (-0.16-1.47)	1.97
RES	102	0.01	8.84	0.10	0.14 (0.12-0.23)	0.31	0.44 (0.23-0.65)	2.38
URB	226	0.01	3.23	0.08	0.18 (0.14-0.20)	0.35	0.33 (0.27-0.39)	1.42
ALL	650	0.01	17.30	0.08	0.14 (0.12-0.16)	0.28	0.36 (0.28-0.44)	2.85

Figure 29. Total Phosphorus in Baseflow, Storm Runoff and Snowmelt in City and County of Denver Grab Samples—All Outfalls Combined

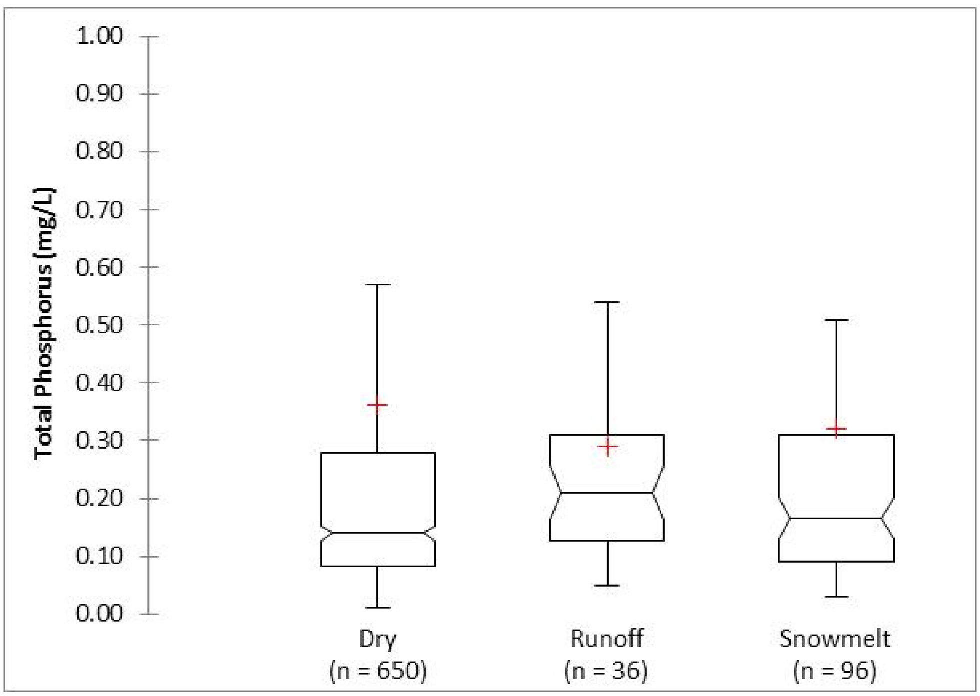


Figure 30. Total Phosphorus in Baseflow in City and County of Denver Grab Samples by Land Use

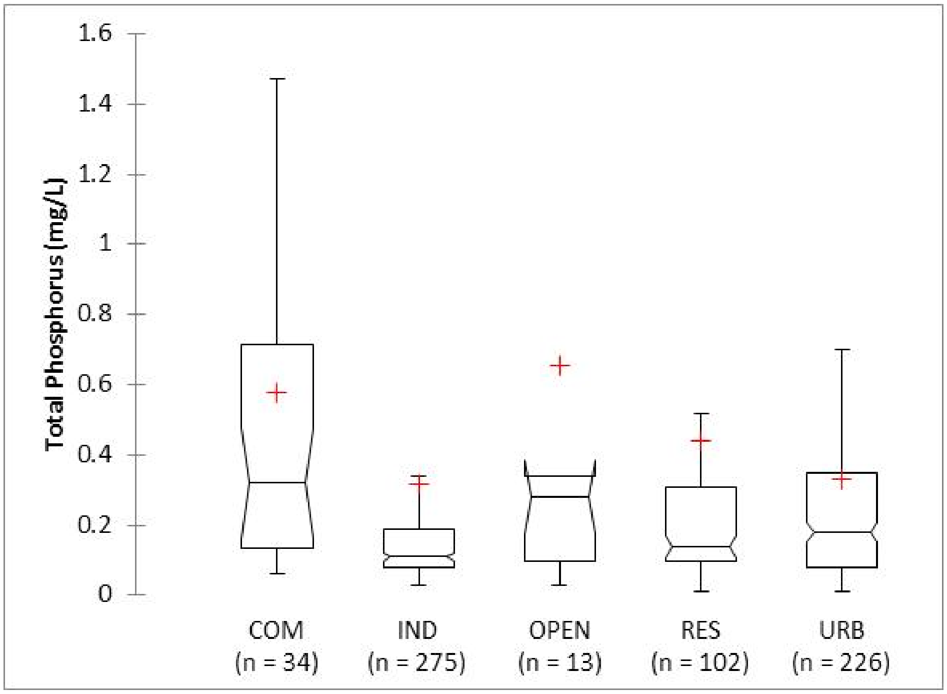


Figure 31. Cumulative Relative Frequency Distribution of Total Phosphorus in Baseflow in City and County of Denver Grab Samples by Land Use

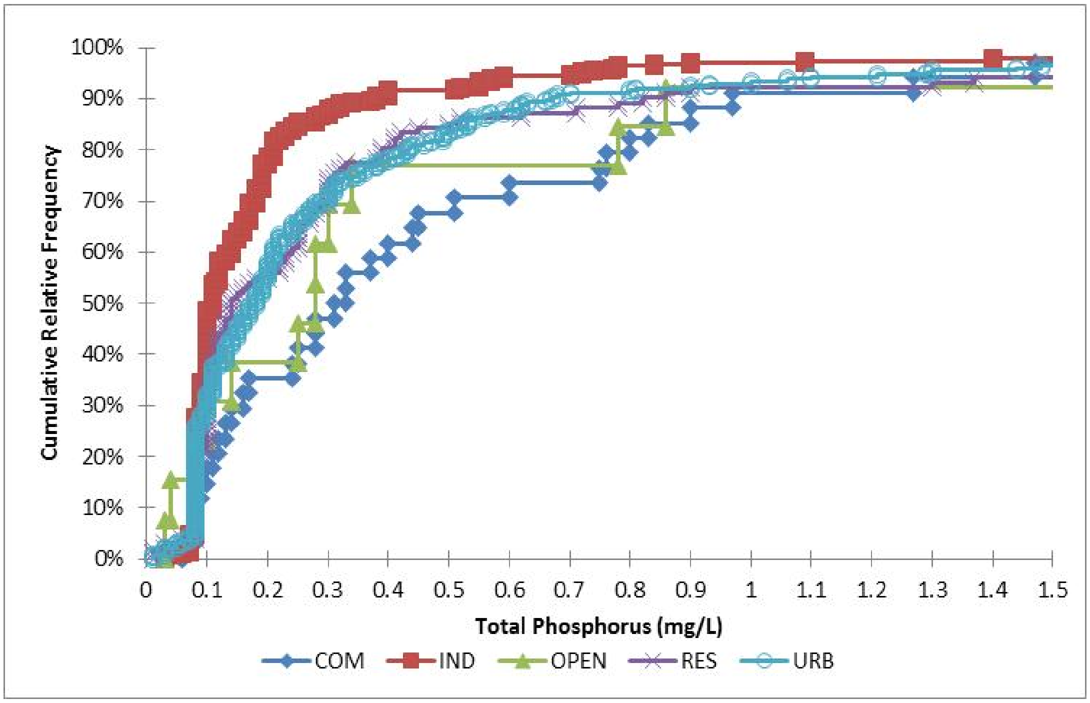
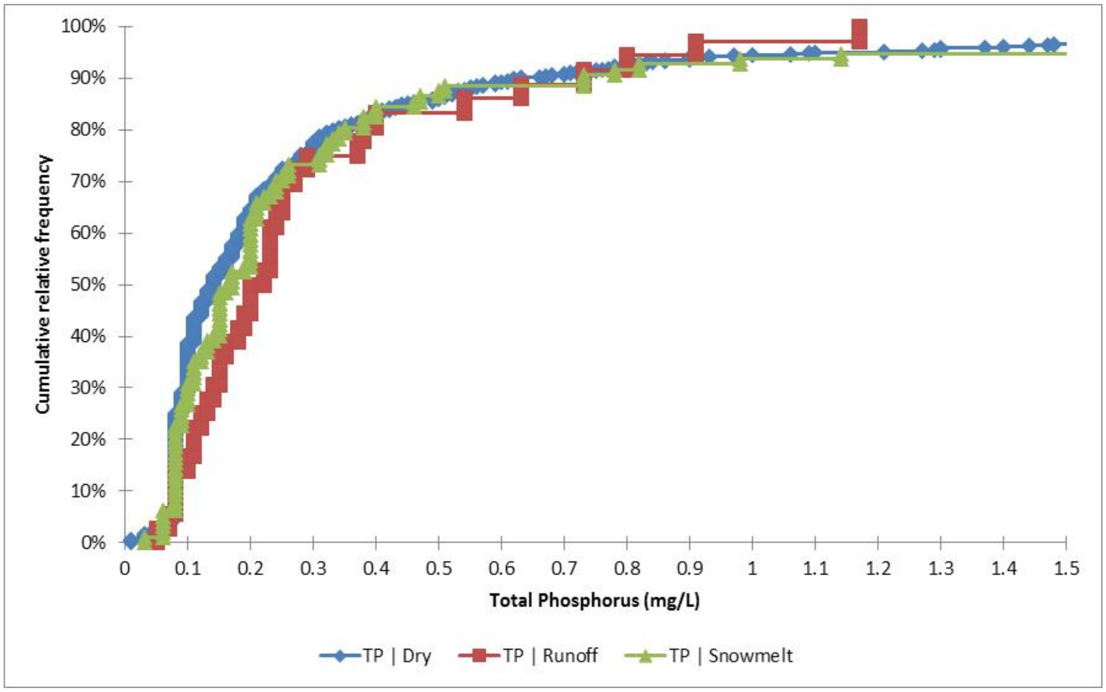


Figure 32. Cumulative Relative Frequency Distribution of Total Phosphorus in City and County of Denver Grab Samples by Flow Type



7.5 Additional Analysis of Colorado Data

Findings of additional, targeted exploratory data analysis for topics of interest to the CSC and UDFCD with relevance to Regulation 85 are provided below.

7.5.1 Relationship of Nutrients to Rainfall Depth and Flow Volume

Approximately two-thirds of the commercial land use data set and one-third of the residential data sets for total phosphorus and total nitrogen had readily available precipitation and flow data. The seven natural open space samples also had runoff and precipitation data. Spearman correlation analysis of total phosphorus and total nitrogen EMC concentrations to rainfall depth and event flow volume (normalized to watershed inches) were conducted for commercial, residential and open space (natural area) land use categories. Other land uses did not have readily available precipitation or runoff data for purposes of this analysis. Primary findings include:

- Commercial, residential and open space total phosphorus concentrations were not significantly correlated with precipitation depth. Total phosphorus for commercial land use showed a weak inverse correlation with runoff volume (r = -0.42).
- Residential and open space total nitrogen concentrations were not correlated with precipitation depth or runoff volume. Total nitrogen concentrations for commercial land use showed a weak inverse correlation with rainfall depth (r = -0.37) and runoff volume (r =-0.26).

These limited findings suggest that rainfall depth and runoff flow volume, although important aspects of stormwater monitoring programs, are not the primary factors driving nutrient concentrations in urban runoff for the Colorado data set. (For clarity, this finding is limited to nutrient concentrations, not nutrient loads [mass], which are clearly related to rainfall-runoff conditions.)

7.5.2 Runoff Nutrient EMCs Relationship to Imperviousness

Previous analyses conducted under DRURP did not show a statistically significant relationship between pollutant concentrations and imperviousness. This relationship was not re-evaluated for purposes of this Data Report; however, it is noteworthy that the more pervious residential land use category has higher nutrient concentrations in runoff than highly impervious land use categories such as commercial and industrial sites.

Other considerations related to the relationship between imperviousness and water quality are that many research studies have found that effective impervious area is a better predictor of ecosystem alteration in urban streams (EPA 2013; Brabec et al. 2002). EPA cites Hatt et al. (2004), who showed that percent connection of imperviousness was more strongly related to water chemistry variables (e.g., conductivity, total phosphorus) than percent total imperviousness, during both baseflows and stormflows. (Note: UDFCD has emphasized the importance of disconnecting directly impervious area for many years in Volume 3.)

7.5.3 Comparison of Baseflow, Snowmelt and Runoff for Selected Sites

Generally, snowmelt is expected to have lower concentrations of nutrients than rainfall runoff; however, there is some variability in findings in the literature. (The cause of these differences was not researched for purposes of this Data Report; however, regional climatic differences and snow management practices may help to explain some of these findings.) Some of these findings include:

- Jensen et al. (2011) reported that runoff caused by rainfall is often associated with soil erosion, and the majority of total phosphorus entering surface water is particulate phosphorus. In contrast, snowmelt runoff is usually less erosive because it has lower kinetic energy than rain drops and flows over soil that is often still frozen. The majority of phosphorus in snowmelt is typically dissolved, rather than particulate.

- Bennett et al. (1981) found that snowmelt contains the same pollutants as other types of runoff, but at lower concentrations. Slow melting of snow allows more infiltration over pervious land areas than with the rain. Additionally, slow melting allows sublimation and evaporation. With snowmelt there was no direct relationship between runoff flow pattern (time of concentration) and the time of precipitation, with snowmelt occurring on the first warm or sunny day following the snowfall. Pollutant loadings are generally lower for snowmelt than for rainfall. Suspended solids and COD loading for snowfall precipitation are approximately one-half of those for rainfall. Total solids loadings for snow are highly variable and related to the amount of deicing chemicals used. Nutrients such as total phosphorus, TKN, and nitrate are much lower for snowfall, in the range of one-fourth or less that for rain.

- Bennett (1978) found that snowmelt pollution is released more slowly than rain runoff to a receiving stream and therefore the maximum concentrations were lower than those for rainfall, with the exception of chlorides. The total mass loadings were slightly lower for snowmelt compared to rain runoff on the same area for the major pollutants, COD, total and suspended solids. The mass loadings were much lower in snowmelt for the nutrients, nitrogen and phosphorus.

- Knuth (2004) summarized findings reported by Oberts (1991, 1994) and WERF (1999) indicating average total phosphorus in snowmelt of 0.12 to 1.08 mg/L, TKN 0.3-4.3 mg/L, and nitrate of 0.9 to 1.19 mg/L. All of the locations included in this summary were from northern latitudes such as New York, Alberta and Minnesota. These are locations where pollutants can accumulate in unmelted snowpack which can later be washed away in spring runoff. (The dynamic on the Denver Front Range is likely different.)

- Oberts (1994) studied snowmelt in the Minneapolis-St. Paul area and found that organic nitrogen (TKN and nitrate) were higher in snowmelt runoff at most sites. Total and dissolved phosphorous were generally similar for both snowmelt and rainfall runoff.

Two Colorado data sets included EMC-based monitoring of both runoff and snowmelt, including the CDOT monitoring locations and the City of Fort Collins inlet location. (City and County of Denver's grab sample data for total phosphorus were previously discussed in Section 7.4 and did not show statistically significant differences between runoff and snowmelt samples.)

CDOT monitoring locations included sites with both runoff and snowmelt for total phosphorus (Figure 33). Due to limited data availability, total nitrogen was not evaluated in this Data Report. Total phosphorus in snowmelt was statistically higher than in runoff ($p = 0.017$), with median snowmelt total phosphorus of 0.44 mg/L ($n = 10$) and 0.23 mg/L ($n = 41$) for runoff. These findings are similar to conclusions drawn by Oberts (1994). CDOT has noted significant difficulty with collecting snowmelt samples. For example, the CDOT 2012 Annual Report describes some of these challenges at the Highway 58 extended detention basin site: "Throughout the winter months the snow events did not melt quickly enough to generate runoff. The snowmelt just saturated the soils of the extended detention basin."

The Fort Collins Inlet site included data for baseflow, runoff and snowmelt for both total phosphorus and total nitrogen, as summarized in Figures 34 and 35. Although the data set is limited for flow type subgroups, the data suggest that runoff events have higher nutrient concentrations than baseflow events, and that snowmelt events have lower concentrations than runoff events. These findings are similar to the published literature on this subject by Bennett (1978, 1981) and Jensen et al. (2011).

Figure 33. Total Phosphorus in Storm Runoff and Snowmelt at CDOT Sites in Colorado

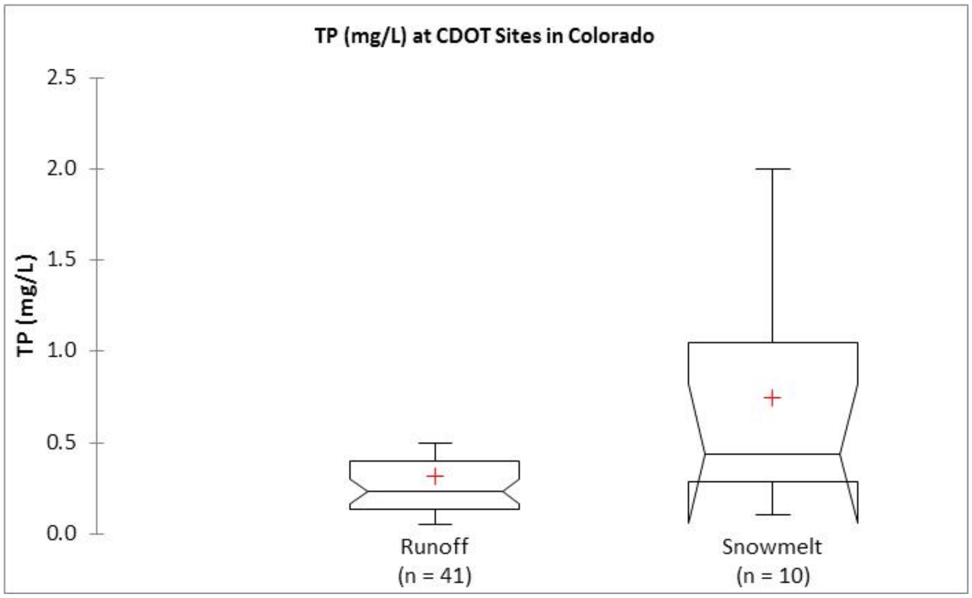


Figure 34. Total Phosphorus in Baseflow, Storm Runoff and Snowmelt at Fort Collins Site

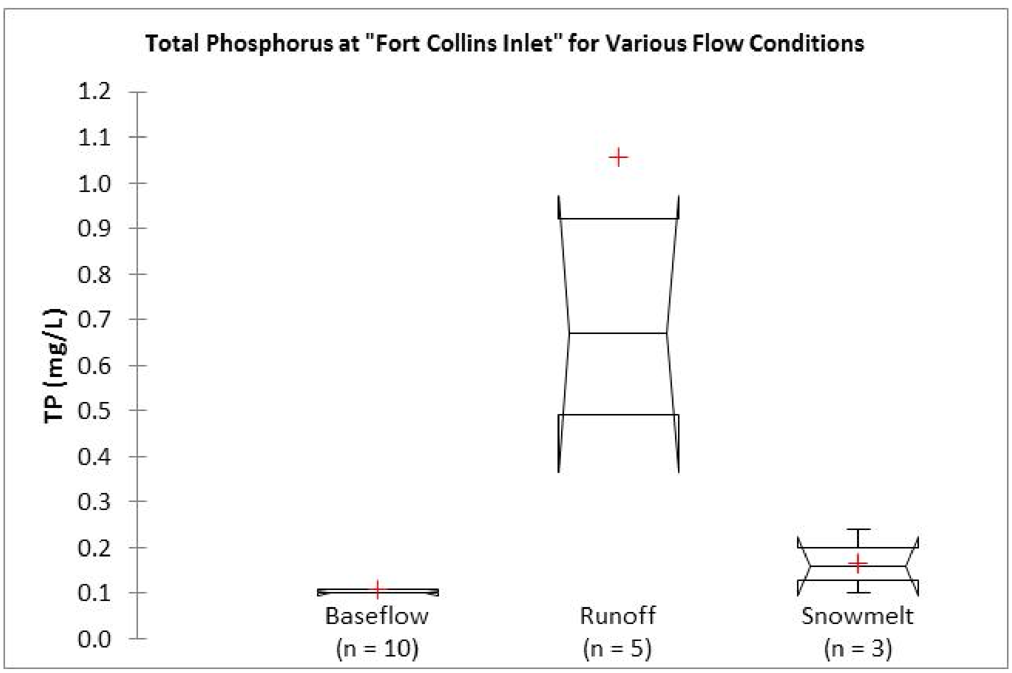
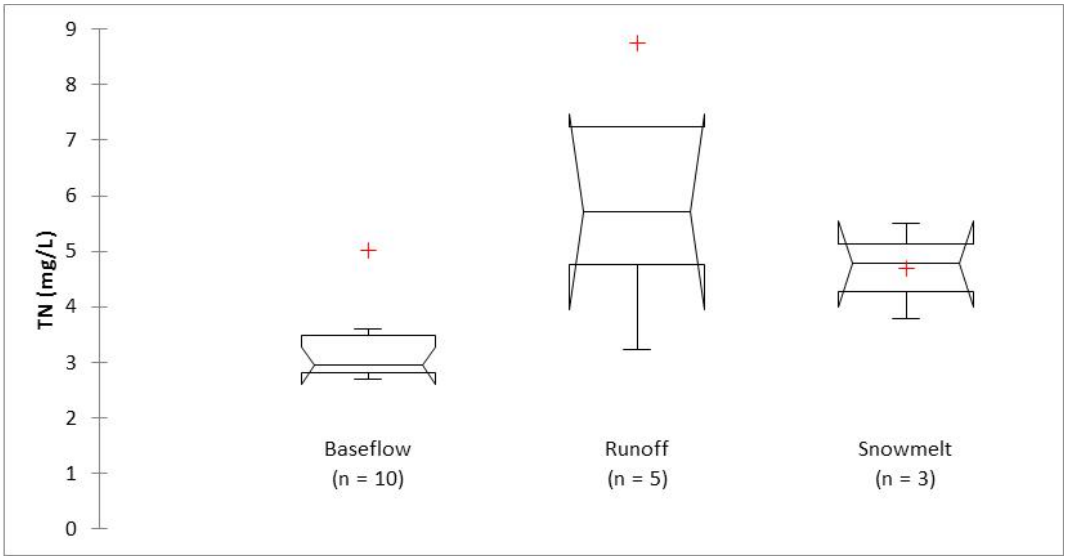


Figure 35. Total Nitrogen in Baseflow, Storm Runoff and Snowmelt at Fort Collins Site



7.5.4 Seasonal Analysis

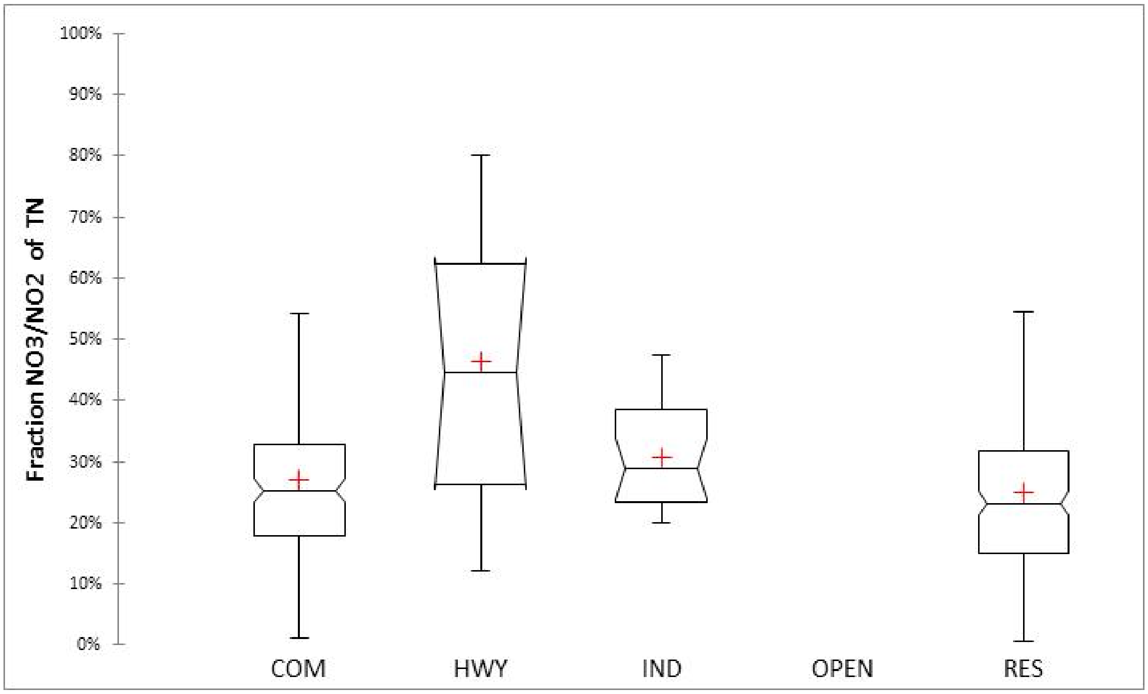
Seasonal analysis of data was considered; however, runoff in Colorado MS4 land areas during winter months is typically in the form of snowmelt, which has different characteristics than storm runoff. Thus, a snowmelt versus runoff analysis is likely the better approach to use to address seasonality in runoff. Additionally, Bochis (2010) did not identify seasonality as a significant predictor of pollutant concentrations in runoff based on analysis of the NSQD, except for bacteria.

Seasonality is expected to be a more significant factor for *instream* nutrient concentrations than it is for runoff quality. As just one example, studies have shown that spring runoff tends to provide dilution of instream nutrient concentrations (Williams et al. 2011).

7.5.5 Ratio of TKN to NO3/NO2 in Colorado Runoff Data

The total nitrogen data set compiled for purposes of this Data Report is smaller than the total phosphorus data set; however, many sites monitor either nitrate/nitrite or TKN. For this reason, the ratios of TKN to nitrate/nitrite were evaluated to assess whether "rules of thumb" may be appropriate for estimating total nitrogen, when one of the two key parameters is missing. Figure 37 provides boxplots of the nitrate/nitrite fractions of total nitrogen. In terms of a potential rule of thumb for estimating total nitrogen when one of the parameters is missing, Kruskal-Wallis test indicates that there some differences among land uses in these relative fractions. Residential (n = 203) and commercial (n = 168) land uses, however, showed similar fractions, with nitrate/nitrite comprising approximately 25% of total nitrogen and TKN comprising 75% of total nitrogen on average for both data sets. (Median values were very similar to the averages). The limited highway-related data set (n = 9) suggests that the portion of nitrate/nitrite may be higher, on the order of 45%; however, variability was also greater in this data set. The average nitrate/nitrite fraction for industrial land uses (n = 23) averaged approximately 30%.

Figure 36. Fraction of NO3/NO2 in TN Results for Runoff for Colorado Land Uses



8 HYDROLOGY AND LOAD ESTIMATION

To estimate nutrient loads from land uses within Colorado MS4s, three types of information are needed: (1) precipitation data, (2) runoff volume calculations, and (3) nutrient EMC data. Given these three factors, nutrient loads can be estimated for a given storm event or a given series of storm events (e.g., annual loads). (Runoff volume calculations require information on drainage area, land use, imperviousness and soil type.) This section discusses each component of the load calculation and then outlines a relatively simple method that can be applied to calculate loads using the Water Quality Capture Optimization and Statistics Model (WQ-COSM) developed in Colorado (UWRI 2011).[5]

Regardless of the load estimation method selected, a fundamental underpinning of nutrient load estimation is proper understanding of hydrology. Differences in hydrology in various parts of the state are likely more critical to load estimation than variations in nutrient concentrations among urban land uses or geographic areas. Additionally, the instream response to nutrient loading from urban runoff is affected by many factors such as geomorphology, flow sources (e.g., snowmelt), seasonality of flows, managed hydrology, and many other factors. (In other words, nutrient fate and transport in streams and lakes is a more complex issue than runoff load estimation, which is the sole focus of this report.)

[5] Urban Watershed Research Institute (UWRI) 2011. *Water Quality Capture Optimization and Statistics Model (WQ-COSM)*. Urban Watershed Research Institute, Denver, Colorado, updated July 2011.

8.1 Precipitation Data

Precipitation data are available from many sources, including the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS). For the purposes of demonstrating the method described below, the Denver Stapleton gage (#52220), with hourly precipitation data, was used for calculation of precipitation statistics in WQ-COSM. This is essentially the same precipitation data set that was used to generate precipitation statistics presented in Volume 3 of the *Urban Storm Drainage Criteria Manual* (UDFCD 2010). The analyses based on this gage are applicable to the MS4s located within the UDFCD jurisdiction. For other locations, WQ-COSM can be applied to a local gage with a sufficient period of record, typically 10 years for analysis of frequent events and longer durations of 20 to 30 years or more for adequate characterization and statistical quantification of larger events. Hourly or 15-minute precipitation data are required to perform this analysis using WQ-COSM.

8.2 Runoff Volume Calculations

There are many different methods that can be used for converting rainfall data into runoff for a given land use. Models that could be used for such purposes include SWMM, WinSLAMM and WQ-COSM, among others. There are also simple methods including using volumetric runoff coefficients, which are runoff coefficients applied to event precipitation depth to determine runoff volume. With proper parameter selection, any of these methods can be used to calculate runoff from precipitation that can be used to then calculate nutrient loads.

Because many of the Colorado MS4s are located along the Front Range and have similar precipitation statistics for frequently occurring events, WQ-COSM, with precipitation input from the Stapleton Gage, is a relatively simple method recommended for runoff calculations. While other methods can be used to produce comparable results for runoff, WQ-COSM with Horton infiltration was chosen for purposes of this Data Report for the following reasons:

- The WQ-COSM software has been developed by UWRI in partnership with UDFCD and is a method that is supported by UDFCD. The methods used in WQ-COSM are the same methods used to generate precipitation statistics in Volume 3, so using WQ-COSM aids in creating consistency between previous methods and the current load estimation effort.

- WQ-COSM is a simple, easy-to-use program that allows for continuous modeling of runoff, given hourly or 15-minute precipitation data. Other models such as SWMM and WinSLAMM have the capabilities to perform the same calculations, using the same methods; however, these programs also have many more advanced features related to hydrology, hydraulics and water quality that go beyond what is required to estimate nutrient loads for purposes of Regulation 85. (Note: these more advanced models should be considered in complex situations, when selecting management strategies for nutrients or when estimating exceedance frequencies.)

- Volumetric runoff coefficients are a viable approach for calculating runoff volumes on an event basis; however, to take advantage of a long-term precipitation record, continuous simulation is preferable. The data generated by WQ-COSM could be used to calculate volumetric runoff coefficients corresponding to various precipitation depths and return periods.

- WQ-COSM can easily be applied to MS4s outside of the Denver metropolitan area to estimate loads given a 10-year +/- period of record for precipitation (longer period of record needed if flood events are also of interest).

8.3 EMC Data

Data for nutrient EMCs for various land uses is the final component needed to calculate estimated nutrient loads. The EMC data are combined with runoff frequency data to calculate a load by multiplying the runoff volume (watershed inches) by the area of interest (acres) and the EMC (mg/L) and adjusting units. An equation with unit conversions is provided in the description of the methodology below.

8.4 Methodology for Nutrient Load Estimate Calculations

This section outlines the procedure for performing load calculations using WQ-COSM and nutrient EMC data for an example Front Range location. The procedure includes these steps:

1. Determine imperviousness for land use of interest from guidance in Runoff Chapter of UDFCD (2010) *Urban Storm Drainage Criteria Manual* (Table RO-3).

2. Run WQ-COSM using Stapleton NWS Rainfall File (hourly data or finer interval [15 minutes] if available):
    a. Use 6-hour storm separation.
    b. Use minimum depth to exclude non-runoff storm events of 0.08 in).
    c. Use 99.5 for extreme runoff (outlier) cutoff percentage.
    d. Specify 0.5 hours for drain time (can use any drain time since we are only interested in runoff calculations and not Water Quality Capture Volume).
    e. Use Horton Option for Storm Runoff Method and select parameters for soil type from Runoff Chapter of USDCM (Table RO-7). Enter imperviousness associated with land use. Enter Horton Drying Time (3 days, typical). Multiple WQ-COSM simulations will be required to cover all combinations of land use (imperviousness) and Hydrologic Soil Group (HSG).
    f. Select Output Report Type 2 (Summary of Storms, Rainfall, and Runoff Used in Analysis).
    g. Run model for each land use for HSG A, HSG B, and HSG C/D. HSG C/D results will generally be most representative of runoff from urban land uses due to urban fill and compaction
3. From model output, copy Storm ID, precipitation depth and runoff depth into an Excel spreadsheet. Sort data by ascending precipitation depth. Calculate percentile precipitation depths and runoff depths and enter into EMC Load Spreadsheet. Create a separate worksheet for each combination of land use and HSG. Total number of worksheets, WQ-COSM runs and associated load calculations will be three times the number of land uses analyzed.

4. Calculate loads for each percentile of the WQ-COSM output by multiplying the runoff depth by the EMC:

$$Load\ \left[\frac{lb}{ac}\right] = 0.226\ \times\ EMC\ \left[\frac{mg}{L}\right] \times\ Runoff\ [in]$$

Where the constant (0.226) is calculated as:

$$0.226\ =\ \frac{1\ ft}{12\ in} \times \frac{28.3\ L}{1\ ft^3} \times \frac{43560\ ft^2}{ac} \times \frac{1\ kg}{10^6\ mg} \times \frac{2.2\ lb}{1\ kg}$$

5. If the area of land use is known, the load for the area can be calculated by multiplying the unit load [lb/ac] by the area in acres.

It is important to note that these load calculations represent the pollutant loads that would be expected to "wash off" a given land use for the various percentiles of storm events. **This is not the same as the load to the receiving water when considering land use at a watershed or sub-watershed scale** because of nutrient fate and transport issues, which could either increase or decrease the load. An example of a fate and transport increase would be surficial erosion during sheet flow and shallow concentrate flow and/or bank erosion of soil containing phosphorus. Examples of fate and transport decreases include deposition of sediment containing phosphorus during transport, removal of phosphorus by BMPs, and vegetative uptake. Chemical processes during transport related to adsorption of phosphorus and speciation between particulate and dissolved forms of phosphorus, which vary with pH and dissolved oxygen, also affect the load to the receiving water.

8.5 Application of Spreadsheet to Estimate Loads

The EMC Load Spreadsheet (see example in Table 30) can be applied in several ways:

- Event Load—For a given storm event with measured precipitation depth, the load for the storm event can be determined by comparing the measured precipitation depth with depths listed for percentiles on the worksheet for the land use and HSG of interest and using the worksheet as a "lookup table." If the measured precipitation depth falls between two of the percentile rainfall depths, use linear interpolation to determine the load for the measured event.

- Annual Load—Rainfall data for a given year can be reviewed and grouped into storms using 6 hours of antecedent dry time to define a "new" storm event. This can be done using WQ-COSM with continuous hourly rainfall data for the year of interest.[6] The

[6] Note: Carefully check record for missing data. Annual loads may be underestimated if there is not a continuous record for the entire year.

procedure outlined for the Event Load calculation can be applied to each storm from the year and the results can be totaled to provide an estimate of the annual load.

This procedure and applications described above can also be applied outside of the metropolitan Denver area, if suitable rainfall data are available. A continuous record with hourly or 15-minute resolution is required, and at least 10 years of data are recommended due to the statistical underpinnings of this method. Rainfall records with significant amounts of missing data or seasonal gages are not appropriate for this analysis.

Table 30. Example Load Estimation Tool for Various Rainfall Depths Using WQ-COSM and Land Use EMCs

(Site Condition Assumptions in Example: Single Family Residential Land Use for10 acres with 40% imperviousness and C/D soils for total phosphorus)

Site Name: CSC Template
Drainage Area: 10.00 acres

From WQ-COSM
From USDCM Storage Chapter for Land Use
Run for A, B and C/D for each Land Use
EMCs from Data Analysis for Land Use

Percentile Distribution of Runoff-Producing Precipitation Events		Landuse Imperviousness	Hydrologic Soil Group	Runoff	Runoff Event Mean Concentration (EMC) for Land Use	Runoff Pollutant Load	Estimated Event Load
Percentile	Precipitation Depth (in)*	Single Family Residential	A, B or C/D	Runoff (in)	Landuse TP (mg/L)	TP (lb/acre)	TP (lb)
1%	0.080	40%	C/D	0.032	0.47	0.003	0.03
5%	0.090	40%	C/D	0.036	0.47	0.004	0.04
10%	0.100	40%	C/D	0.040	0.47	0.004	0.04
15%	0.100	40%	C/D	0.040	0.47	0.004	0.04
20%	0.100	40%	C/D	0.040	0.47	0.004	0.04
25%	0.100	40%	C/D	0.040	0.47	0.004	0.04
30%	0.100	40%	C/D	0.040	0.47	0.004	0.04
35%	0.120	40%	C/D	0.048	0.47	0.005	0.05
40%	0.140	40%	C/D	0.056	0.47	0.006	0.06
45%	0.170	40%	C/D	0.068	0.47	0.007	0.07
50%	0.200	40%	C/D	0.080	0.47	0.008	0.08
55%	0.202	40%	C/D	0.081	0.47	0.009	0.09
60%	0.240	40%	C/D	0.096	0.47	0.010	0.10
65%	0.280	40%	C/D	0.112	0.47	0.012	0.12
70%	0.310	40%	C/D	0.124	0.47	0.013	0.13
75%	0.380	40%	C/D	0.152	0.47	0.016	0.16
80%	0.450	40%	C/D	0.180	0.47	0.019	0.19
85%	0.570	40%	C/D	0.228	0.47	0.024	0.24
90%	0.770	40%	C/D	0.308	0.47	0.033	0.33
95%	1.100	40%	C/D	0.463	0.47	0.049	0.49
99.5%	2.517	40%	C/D	1.184	0.47	0.126	1.26
100%	4.820	40%	C/D	2.975	0.47	0.316	3.16

*Events < 0.08 in excluded to account for impervious depression storage.

9 CONCLUSIONS AND DATA GAP SUMMARY

The purpose of this Data Report is to address the data collection requirement for MS4s under Regulation 85 that requires documentation of existing information and potential additional monitoring needs necessary to determine the "approximate nitrogen and phosphorus contribution to state waters due to discharges from MS4s." The overall finding from this Data Report is that there is a significant EMC-based urban runoff data set useful and sufficient for characterizing nutrient loads in urban runoff in Colorado. This report provides statistical characterization of total phosphorus and total nitrogen concentrations by land use, including measures of central tendency and variability, which can be used in a variety of load estimation methods, ranging from simple spreadsheet tools to more advanced models. Based on the findings contained in this Data Report, we conclude that additional monitoring for purposes of general characterization of nutrient concentrations and loads in urban runoff in Colorado is not necessary to meet the requirements of Regulation 85. Additional general monitoring may only confirm results previously obtained and not contribute to further understanding of nutrient concentrations and loads in urban runoff in Colorado. However, there may be circumstances in the future where site-specific monitoring is warranted to identify watershed-specific sources of nutrient loading and/or to help prioritize selection and placement of source controls and treatment BMPs. Specific findings supporting these overall conclusions include:

1. Colorado has reasonably well-developed total phosphorus (n = 602) and total nitrogen (n = 398) water quality EMC data sets representing most urban land uses that can be used to estimate urban stormwater runoff nutrient loads to state waters. Data sets for residential and commercial land uses are particularly strong (in terms of numbers of samples and relatively long periods of record) and represent the most common urban land uses. The Denver metropolitan area, Larimer County and El Paso County are the primary areas where runoff data have been collected, with some limited total phosphorus monitoring in Durango. Additionally, published reports characterizing instream water quality during runoff conditions are available, such as those completed by the USGS, local governments and watershed groups. (These reports and associated electronic data sets were not the focus of this Data Report, but may be helpful for future nutrient-related analyses.)

2. Median concentrations of total phosphorus by land use in Colorado range from 0.22 to 0.45 mg/L, with statistically significant differences in total phosphorus concentrations among some land uses. Key findings included:

    - Total phosphorus concentrations in residential runoff are statistically higher than for commercial, industrial and highway-related land uses. Total phosphorus in runoff from natural open space areas was not significantly different statistically relative to urban land uses. This lack of statistically significant difference may be due to the smaller sample size for open space; nonetheless, the concentrations observed were within the ranges observed for urban land uses.

    - Total phosphorus is highly correlated to TSS in runoff from natural open space areas. DRURP data (n = 7) showed relatively high total phosphorus concentrations in runoff from natural open space areas.

3. Median concentrations of total nitrogen by land use in Colorado range from 2.79 to 4.19 mg/L, with statistically significant differences in total nitrogen concentrations among some land uses. Key findings included:

   - Total nitrogen concentrations in residential runoff are statistically higher than commercial and industrial land uses, based on the available data. No other statistically significant differences among land uses were identified.

   - For total nitrogen, the highway-related runoff data set is relatively small (n = 9); however, results are comparable to industrial runoff sites and within the range of conditions observed at other land uses. Additionally, on-going monitoring by CDOT will be useful for supplementing this data set in the future.

   - The industrial land use total nitrogen data set (n = 23) is smaller than the commercial (n = 168) and residential (n = 191) data sets, but provides enough data to develop a general estimate of total nitrogen loading from industrial sites.

   - The natural open space total nitrogen data set, which represents natural grasslands, is relatively small (n = 7, from DRURP); however, it is within the range of concentrations documented for urban land uses.

4. Runoff from natural areas and open space generates runoff less frequently than developed areas, which typically results in lower annual loads from natural areas than from urban areas. Less frequent runoff and diffuse flow conditions can pose challenges in collecting samples at natural sites. Because natural open space areas are typically not the primary focus of MS4 control measures, additional sampling from open space areas is likely not warranted, given the availability of the DRURP estimates for total phosphorus and total nitrogen.

5. The industrial land use data set is smaller than the commercial and residential land use data sets; however, many industrial sites are already regulated under industrial stormwater permits. Nutrients are not expected to be a significant stormwater issue at industrial sites unless unusual sources of nutrients are present specific to the industrial process at a particular site. In such a case, site-specific monitoring in response to a local receiving water nutrients issue would be more valuable than general monitoring of additional industrial sites.

6. Colorado total phosphorus data are within ranges observed in EPA Rain Zones, based on comparisons of the Colorado data set to the NSQD data set, excluding comparisons to Rain Zone 9 (which is dominated by Colorado data).

7. Colorado's total nitrogen concentrations are statistically higher than those observed in other EPA Rain Zones (excluding Zone 9) for commercial, residential and industrial land uses, as well as open space areas in some Rain Zones. For this reason, Colorado-based data are expected to better reflect total nitrogen in runoff for Colorado, as opposed to using other national data sets.

8. For urbanized areas in western Colorado, the EMC data set is limited to monitoring conducted by CDOT in the Durango area. Several options exist for the purposes of estimating nutrient loads for urbanized areas subject to Regulation 85 requirements in western Colorado. These include using the statewide estimates developed in this Data Report, using Rain Zone 6 EMCs for the western U.S. based on data in the NSQD, conducting additional literature reviews to identify other data sources not included in this report, or conducting monitoring to develop a western Colorado data set. For purposes of estimating loads, accounting for differences in hydrology between the Front Range and urbanized areas in western Colorado is important because there is significant variability in hydrology, depending on geographic location and elevation. Provided that these differences in hydrology are taken into account, the statewide nutrient concentration estimates can be used to develop general nutrient load estimates for urban runoff in western Colorado.

9. For residential sites in Colorado, snowmelt tends to have lower total phosphorus concentrations than runoff. For highway-related sites, the opposite was observed.

10. For Colorado residential and commercial data sets, the average fractions of TKN and nitrate/nitrite comprising total nitrogen are approximately 75 percent TKN and 25 percent nitrate/nitrite. Industrial sites average approximately 70 percent TKN and 30 percent nitrate/nitrite. Highway data were more variable and with more evenly split nitrogen fractions.

11. Statistical characterizations of the nutrient concentration data described can be combined with land use information, precipitation records, and runoff calculations to estimate nutrient loads from MS4s in Colorado. A simple approach using a Colorado-based spreadsheet tool based on WQ-COSM is provided in this report; however, a variety of simple to complex approaches are available for this purpose.

12. When developing load estimates for nutrients in urban runoff, it is important to recognize that runoff volume data and methods are critically important in developing such estimates. Nutrient concentrations in urban runoff are highly variable (even within common land uses); however, runoff volume is very distinctive and different for land use and development characteristics. Therefore, loads for different areas are usually strongly associated with differences in runoff volumes. To improve accuracy in load estimation using advanced models, data collection efforts focused on land use characterization in the context of calculated runoff volumes is likely more beneficial than additional general nutrient monitoring data. Advanced models such as WinSLAMM were developed to calculate runoff volumes for different land uses, development characteristics, and water quality controls. The accuracy of such models is typically improved when watershed-specific land use characterization data are available.

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Appendix A

Summary of Historic Runoff-Related Studies in Colorado (from Phase 1 MS4 Permit Application)

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Water Quality Report	Outfall(s) Studied	Sampling Procedures Used	Comments
Hydrologic Data for Urban Storm Runoff from Three Localities in the Denver Met-ropolitan Area, Colorado (OF 78-410) Author: Sherman R. Ellis Agency: USGS (DBWC, DRCOG, UDFCD) Date: May 1978	Big Dry Creek Tributary, Littleton North Avenue Storm Drain, Lakewood (Federal Center) 36th Street Storm Sewer, Denver	Automated water quality sampling and rainfall-runoff monitors	Data consists of rainfall runoff data, miscellaneous water quality data, major constituents, nutrient, biochemical, oxygen demand, coliform bacteria, comprehensive trace elements, selected trace elements, and pesticide water quality data.
Quantity and Quality of Urban Runoff From Three Localities in the Denver Metropolitan Area, Colorado (WRI 79-64) Author: Sherman R. Ellis and William M. Alley Agency: USGS (DBWC, DRCOG, UDFCD) Date: May 1979	Big Dry Creek Tributary, Littleton North Avenue Storm Drain and Denver Federal Center, Lakewood 36th Street, Denver	See Ellis (1978)	Interpretative report based on data in Ellis (1978). Discussion of water quality from snowmelt, rainfall and dry-weather flow. Comparison to standards and wastewater treatment plant effluent.
Hydrologic data from Grange Hall Creek Basin, Northglenn, Adams County, Colorado (OF 80-578) Author: D. C. Hall and A. C Duncan Agency: USGS Date: 1980	Grange Hall Creek at Grant Park Grange Hall Creek at Northglenn	Automatic water quality sampling and rainfall-runoff monitors	This site is located north of Denver in the Northglenn area. Major ions, nutrients, metals, trace elements, pesticides, PCBs, fecal coliform bacteria, suspended sediment and sediment-size distribution were monitored.
Characterization of urban runoff from Grange Hall Creek at Northglenn, Adams County, Colorado (OF-81-28) Author: D. C. Hall and A. C. Duncan Agency: USGS Water Resources Date: 1981	Hall and Duncan, 1980	See Report.	Dry weather, snowmelt and rainfall-runoff were monitored. Three storm events were monitored for pesticides.
Hydrologic data for urban storm runoff from nine sites in the Denver metropolitan area, Colorado (OF 81-682) Author: J. W. Gibbs Agency: USGS Water Resources Date: 1981	Big Dry Creek Tributary at Easter Street, Littleton Rooney Gulch at Rooney Ranch, Morrison Asbury Park Storm Drain at Tejon Street, Denver Asbury Park Storm Drain at Asbury Avenue, Denver Upper North Avenue Storm Drain at Denver Federal Center, Lakewood Lower North Avenue Storm Drain at Denver Federal Center, Lakewood Cherry Knolls Storm Drain, Lakewood Villa Italia Shopping Center Storm Drain, Lakewood	See report. See attached "Analytical Data from the USGS Denver Analytical Laboratory and the Metropolitan Denver Sewage Disposal District No. 1 Laboratory".	Same as those under DRCOG, June, 1983. Characteristics of drainage basins, including air photo maps, provided. Data from first year (1989) of two-year program reported.

Water Quality Report	Outfall(s) Studied	Sampling Procedures Used	Comments
Hydrologic data for urban storm runoff in the Denver metropolitan area, Colorado (OF 82-872) Author: J. W. Gibbs and J. T. Doerfer Agency: USGS Water Resources Date: 1982	South Platte, Littleton South Platte, Florida Avenue Cherry Creek, Denver South Platte, 19th Street South Platte, 50th Avenue Southglenn Rooney Ranch Asbury Park Asbury Park Retention North Avenue North Avenue Retention Cherry Knolls Northglenn Villa Italia	See Gibbs (1981) and report. See "Analytical Data from the USGS Denver Analytical Laboratory and the Metropolitan Denver Sewage Disposal District No. 1 Laboratory"	Water quality data consists of nutrients: total phosphorus, dissolved phosphorus, ortho-phosphate, total nitrogen, total kjeldahl nitrogen, ammonia (dissolved), nitrite-nitrate nitrogen; Metals--total lead, total zinc, total copper, total manganese, total iron, total cadmium; Oxygen demanding substances and solids: total suspended solids, total organic carbon, dissolved organic carbon, and chemical oxygen demand. South Platte River sampling at 5 sites for rainfall-runoff, snowmelt, and ambient baseflows. Results of second year (1981) from 9 small sites reported. Data from special studies (rainfall simulation, modeling), wetfall/dryfall and toxics (129 priority pollutants) reported.[a]
Sloan Lake Clean Lake Study Author: DRCOG Agency DRCOG Date: May 1982	Sloan Lake	Inflow and inlake water quality samples, bottom-sediment samples.	Nutrients, chlorophyll, suspended solids, oxygen-demanding substances, metals, bacteria, oil and grease, and detergents monitored. Emphasis on in-lake sampling, no storm events monitored.
Analysis of the August 14, 1980 rainstorm and storm runoff to the South Platte River in the southern Denver metropolitan area, Colorado (OF 83-4138) Author: S. R. Blakely, M. H. Mustard, and J. T. Doerfer Agency: USGS Water Resources Investigations Date: 1983	South Platte at Lincoln Bear Creek Harvard Gulch Sanderson Gulch Weir Gulch Lakewood Gulch Cherry Creek South Platte River at 19th Street South Platte River at 50th Ave.	See Report and Gibbs and Doerfer (1982).	This was a one-time special study to monitor major tributaries as well as the established stations on South Platte River.
Urban Runoff Quality in the Denver Region Author: DRCOG Agency: DRCOG Date: September 1983	South Platte, Littleton South Platte, Florida Avenue Cherry Creek, Denver South Platte, 19th Street South Platte, 50th Avenue Southglenn Rooney Ranch Asbury Park Asbury Park Retention North Avenue North Avenue Retention Cherry Knolls Northglenn Villa Italia	See Gibbs (1981) and Gibbs and Doerfer (1982).	Constituents of urban runoff analyzed in samples: (nutrients): total phosphorus, dissolved phosphorus, orthophosphate, total nitrogen, total kjeldahl nitrogen, ammonia, nitrite-nitrate nitrogen, total lead, total zinc, total copper, total manganese, total suspended solids, total organic carbon, chemical oxygen demand.[a] This is the final report of the Denver NURP and by DRCOG and includes interpretations based on data collected in the program.

Water Quality Report	Outfall(s) Studied	Sampling Procedures Used	Comments
Prediction of Storm Runoff Characteristics From Small Urban Basins Author: DRCOG Agency: DRCOG Date: June 1983	Rooney Gulch at Rooney Ranch, Morrison Asbury Park Storm Drain at Tejon Street, Denver Asbury Park Storm Drain at Asbury Avenue, Denver Upper North Avenue Storm Drain at Denver Federal Center, Lakewood Lower North Avenue Storm Drain at Denver Federal Center, Lakewood Cherry Knolls Storm Drain, Lakewood Villa Italia Shopping Center Storm Drain, Lakewood	See Gibbs (1981) and Gibbs and Doerfer (1982).	water quality data consists of nutrients--total phosphorus, dissolved phosphorus, ortho-phosphate, total nitrogen, total kjeldahl nitrogen, ammonia (dissolved), nitrite-nitrate nitrogen; Metals--total lead, total zinc, total copper, total manganese; Oxygen demanding substances and solids--total suspended solids, total organic carbon, dissolved organic carbon, and chemical oxygen demand.a This is an interpretive report based on data collected in Denver NURP. Relationships of runoff to rainfall and loading to area investigated for application as a planning tool.
Results of the Nationwide Urban Runoff Program, Volume 1--Final Report, EPA, December 1983 Author: EPA Agency: EPA Date: 1983	See Report	See Report	This report summarizes the quality characteristics of urban runoff, and similarities or differences at different urban locations. It presents the extent to which urban runoff is a significant contributor to water quality problems across the nation and performance characteristics and the overall effectiveness and utility of management practices for the control of pollutant loads from urban runoff.[b]
Hydrologic Data for the Drainage Basins of Chatfield and Cherry Creek Lakes, Denver Metropolitan Area, Colorado (OF 83-057) Author: J. W. Gibbs L. M. Arnold and R. L. Reed Agency: USGS Date 1983	South Platte above Chatfield Lake Deer Creek Massey Draw Plum Creek South Platte below Chatfield Lake Cherry Creek Happy Canyon Creek Piney Creek Lone Tree Creek Cottonwood Creek Shop Creek	See report and Gibbs (1981).	First year of inflow and inlake monitoring for the Chatfield and Cherry Creek Clean Lake studies. Rainfall, runoff, and water quality for nutrients, solids, oxygen-demanding substances, bacteria, and selected metals.
Analysis of Urban Storm-Runoff Data and the Effects of the South Platte River, Denver Metropolitan Area, Colorado (WRI 84-4159) Author: S. R. Ellis, J. T. Doerfer M. H. Mustard S. R. Blakely, and J. W. Gibbs Agency: USGS (with Date: 1984	See DRURP data	See Gibbs (1981) and Gibbs and Doerfer (1982)	Regression analyses are presented for selected small basins and selected combined small and tributary basins, as well as the effects of urban storm runoff on the South Platte River. This is the final report of the Denver NURP by USGS and includes interpretations based on data collection in the program.

Appendix A. Historic Studies Identified in MS4 Phase 1 Permit Application

Water Quality Report	Outfall(s) Studied	Sampling Procedures Used	Comments
Calibration and Verification of a Rainfall-Runoff Model and a Runoff-Quality Model for Several Urban Basins in the Denver Metropolitan Area, Colorado (WRI 83-4286) Author: Juli B. Lindner-Lundsford and Sherman Agency: USGS (with Date: 1984	North Avenue Basin Southglenn Basin Northglenn Basin Cherry Knolls Basin Villa Italia Basin	See Gibbs 19(1981) and Gibbs and Doerfer (1982).	DR3M-II was calibrated and verified for five urban basins. The model is a multievent urban runoff-quality model.
Cherry Creek Reservoir Clean Lakes Study: Denver, Colorado Author: DRCOG Agency: DRCOG Date: 1984	Shop Creek Piney Creek Lone Tree Creek Cottonwood Creek Happy Canyon Creek	Staff gage and recorder, two automatic sampling stations. Analysis by Metro District Lab.	Both wet and dry weather sampling.
Chatfield Reservoir Clean Lakes Study Author: DRCOG Agency: DRCOG Date: 1984	South Platte, Waterton Deer Creek above Chatfield Lake Massey Draw above Chatfield Lake Plum Creek near Louviers South Platte below Chatfield Lake	Automatic runoff samplers for 3 tributaries, ambient samples for South Platte stations.	Storm runoff, ambient and in-lake samples collected for nutrients, solids, oxygen-demanding substances and selected trace elements
Runoff Characteristics and Washoff Loads From Rainfall-Simulation Experiments on a Street Surface and Native Pasture in the Denver Metropolitan Area, Colorado (OF 84-820) Author: Martha H. Mustard, Sherman R. Ellis, and Johnnie W. Agency: USGS and Date: 1985	East bound lane of North Avenue on the Denver Federal Center, Lakewood Rooney Ranch	Rainfall simulation described by Lusby (1977), constituent deposition was measured by collection buckets and by vacuum strip sampling. Runoff samples collected at small flume.	Selected water quality constituents; suspended solids, total lead, total zinc, total manganese, total nitrogen, total phosphorus, total organic carbon.a
A Summary of Urban Runoff Studies in the Denver Metropolitan Area, Colorado (WRI 84-4072) Author: Sherman R. Ellis and Martha H. Mustard Agency: USGS (with Date: 1985	See DRURP Data	See Gibbs (1981) and Gibbs and Doerfer (1982)	This report presents the major conclusions of the pre-Denver Regional Urban Runoff Program studies and a summary of the various elements of the DRURP. The report summarizes and references urban runoff studies in the Denver area and is a guide for planners and other persons interested in urban runoff.
USGS Urban-Stormwater Data Base for 22 Metropolitan Areas Throughout the United States. (OF 85-337) Author: Nancy E. Driver, Martha H. Mustard, R. Bret Rhinesmith, and Robert F. Middleburg Agency: USGS Date: 1985	See Report	Not Reported	This report and associated data tape provide a comprehensive compilation of national urban stormwater data, references to pertinent published reports, and contacts for further information, including information from the Denver area.

Water Quality Report	Outfall(s) Studied	Sampling Procedures Used	Comments
Comparison of Conceptually Based and Regression Rainfall-Runoff Models, Denver Metropolitan Area, Colorado, and Potential Applications in Urban Areas (WRI 87-4104) Author: Juli B. Lindner-Lunsford and Sherman R. Ellis Agency: USGS Date: 1987	North Avenue Storm Drain at Denver Federal Center, Lakewood 116th Avenue and Claude Court, Northglenn Cherry Knolls Storm Drain, Denver Villa Italia Storm Drain, Lakewood	See Gibbs (1981).	Data includes, storm runoff volume, peak flow, chemical oxygen demand, total suspended solids, total nitrogen, total phosphorus, total lead, total manganese, total zinc.[a] This is an interpretive report based on data collected in the Denver NURP program.
USGS Urban Stormwater Data Base of Constituent Storm Loads: Characteristics of Rainfall, Runoff, and Antecedent Conditions; and Basin Characteristics (WRI 87-4036) Author: Martha H. Mustard, Nancy E. Driver, John Chyr, and Agency: USGS Date: 1987	See Report	Not Reported	The purpose of the report is to present storm loads and characteristics data for 22 metropolitan areas in the U.S., including Denver.[a]
Clean Water Plan Volume I Author: DRCOG Agency: DRCOG Date: February 18, 1987	DRURP data was used in the report	Not Reported.	The report updates the CWP previously adopted by DRCOG and extends the planning horizon through the year 2010.
Lower South Platte Water Quality and Wastewater Management Study Author: DRCOG Agency: DRCOG Date: January 1989	None	Phosphorus loading was estimated using DRURP models.	The study developed information on long-range water quality trends, anticipated development forecasts, and wastewater service planning for northern metropolitan Denver.
Chatfield Basin Water Quality Study Author: DRCOG Agency: DRCOG Date: October 1988	East Plum Creek at Larkspur East Plum Creek at Sedalia West Plum Creek at Sedalia	See DRCOG, 1984.	The report defines a point and nonpoint phosphorus control strategy and comprehensive wastewater plan through 2010. This plan was a result of development of a pollutant load forecast and main water quality assessment.
1989 Annual Report of the Chatfield Basin Authority to the Water Quality Control Commission Author: Chatfield Basin Authority Agency: Chatfield Basin Authority Date: 1989	Chatfield Reservoir Plum Creek South Platte River	See Report.	The report updates point source data, point source phosphorus loadings, nonpoint source data, water quality data (see report).
Bear Creek Reservoir Clean Lakes Study Author: DRCOG Agency: DRCOG, Colorado Department of Health, Jefferson County Mountain Water Quality Association, and City of Date: December 1990	Bear Creek Turkey Creek	Manual sampling of 3 storm events. Streamflow measured by current meter.	The objectives of the study were to characterize the water quality data and identify potential water quality problems in Bear Creek Reservoir and the associated watershed. Data reported includes wastewater treatment facility discharge data, public user survey data, hydrologic data, and water quality data (see report).
Bear Creek Reservoir Clean Lake Study Technical Appendices Author: DRCOG Agency: DRCOG Date: December 1990	Bear Creek Turkey Creek	See DRCOG, 1990.	Technical supplement containing summaries of water quality data, checklists of biological resources and trend plots of selected water quality parameters.

Source: Phase 1 MS4 Permit Application, Appendix C-2, Summary of Existing Quantitative Data for Stormwater Discharge Characterization for the Denver Metropolitan Area.

[a]Analytical Method not reported.

[b]See report for Analytical Method.

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Appendix B

Statistical Summaries for Individual Colorado Monitoring Studies with EMC Data

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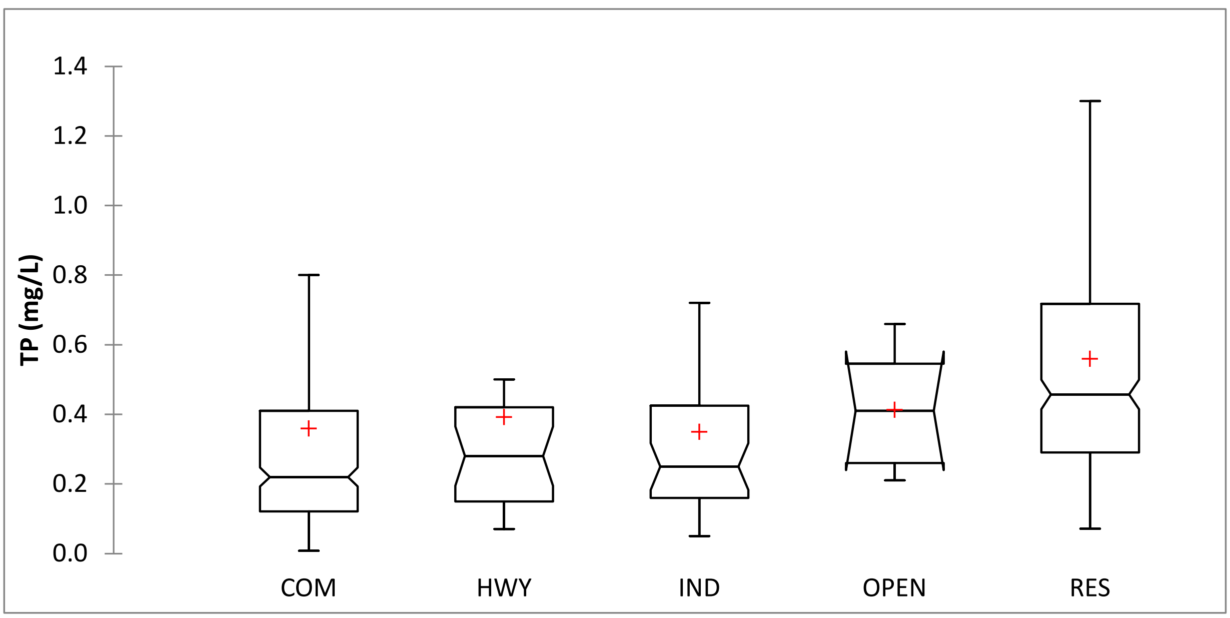
Colorado EMC Data for Total Phosphorus (mg/L)
Descriptive statistics (Quantitative data):

Statistic	COM	HWY	IND	OPEN	RES
No. of observations	277	25	39	7	254
No. of missing values	0	0	0	0	0
Minimum	0.01	0.07	0.05	0.21	0.07
Maximum	6.30	2.60	1.30	0.66	2.71
1st Quartile	0.12	0.15	0.16	0.26	0.29
Median	0.22	0.28	0.25	0.41	0.46
3rd Quartile	0.41	0.42	0.43	0.54	0.72
Mean	0.36	0.39	0.35	0.41	0.56
Variance (n)	0.28	0.24	0.08	0.03	0.15
Standard deviation (n)	0.53	0.49	0.28	0.16	0.39
Variation coefficient	1.47	1.25	0.81	0.39	0.69
Lower bound on mean (95%)	0.30	0.18	0.26	0.25	0.51
Upper bound on mean (95%)	0.42	0.60	0.44	0.58	0.61

Box plots:



Kruskal-Wallis Test and Dunn's Procedure for Colorado Total Phosphorus EMC Data

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
TP (mg/L) | COM	277	0	277	0.008	6.300	0.359	0.528
TP (mg/L) | IND	39	0	39	0.050	1.300	0.350	0.286
TP (mg/L) | HWY	25	0	25	0.070	2.600	0.392	0.502
TP (mg/L) | OPEN	7	0	7	0.210	0.660	0.413	0.175
TP (mg/L) | RES	254	0	254	0.071	2.710	0.559	0.387

Kruskal-Wallis test (TP (mg/L)):

K	95.730
p-value (Two-tailed)	< 0.0001
alpha	0.05

The p-value has been computed using 10000 Monte Carlo simulations. Time elapsed: 1s.
99% confidence interval on the p-value:
] 0.000, 0.000 [

Test interpretation:
H0: The samples come from the same population.
Ha: The samples do not come from the same population.
As the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha.
The risk to reject the null hypothesis H0 while it is true is lower than 0.01%.

Ties have been detected in the data and the appropriate corrections have been applied.

Multiple pairwise comparisons using Dunn's procedure / Two-tailed test:

Sample	Frequency	Sum of ranks	Mean of ranks	Groups	
TP (mg/L) | COM	277	65552.500	236.652	A	
TP (mg/L) | HWY	25	6473.000	258.920	A	
TP (mg/L) | IND	39	10239.500	262.551	A	
TP (mg/L) | OPEN	7	2414.500	344.929	A	B
TP (mg/L) | RES	254	96823.500	381.195		B

Table of pairwise differences:

	TP (mg/L) | COM	TP (mg/L) | IND	TP (mg/L) | HWY	TP (mg/L) | OPEN	TP (mg/L) | RES
TP (mg/L) | COM	0	-25.900	-22.268	-108.277	-144.543
TP (mg/L) | IND	25.900	0	3.631	-82.377	-118.644
TP (mg/L) | HWY	22.268	-3.631	0	-86.009	-122.275
TP (mg/L) | OPEN	108.277	82.377	86.009	0	-36.266
TP (mg/L) | RES	144.543	118.644	122.275	36.266	0

p-values:

	COM	**IND**	**HWY**	**OPEN**	**RES**
COM	1	0.384	0.540	0.104	**< 0.0001**
IND	0.384	1	0.935	0.249	**< 0.0001**
HWY	0.540	0.935	1	0.247	**0.001**
OPEN	0.104	0.249	0.247	1	0.586
RES	**< 0.0001**	**< 0.0001**	**0.001**	0.586	1

Significant differences:

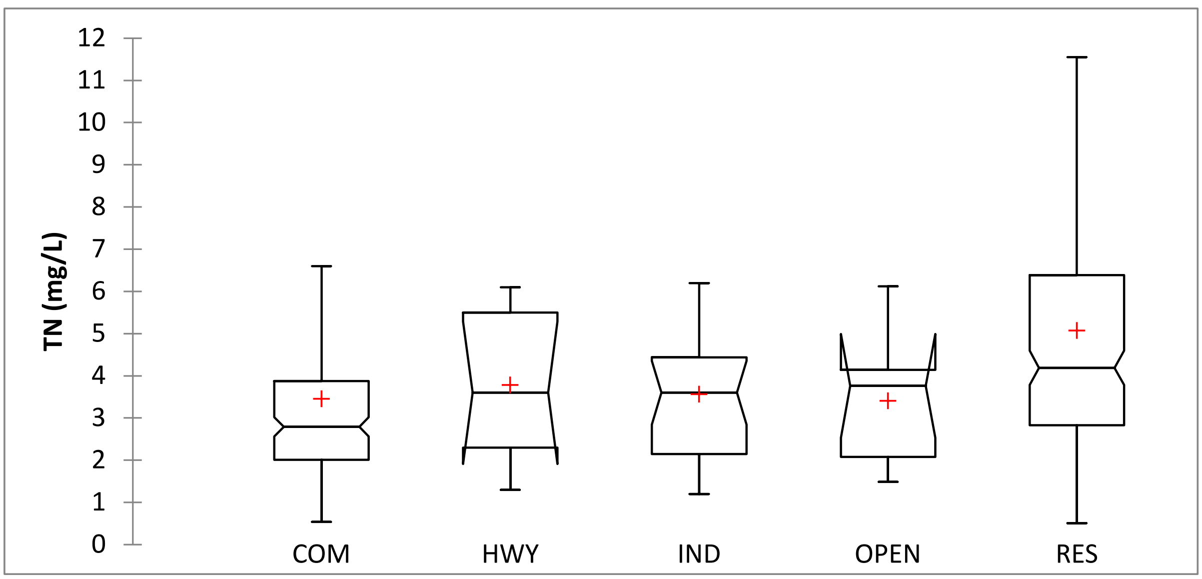
	TP (mg/L) | COM	TP (mg/L) | IND	TP (mg/L) | HWY	TP (mg/L) | OPEN	TP (mg/L) | RES
TP (mg/L) | COM	No	No	No	No	**Yes**
TP (mg/L) | IND	No	No	No	No	**Yes**
TP (mg/L) | HWY	No	No	No	No	**Yes**
TP (mg/L) | OPEN	No	No	No	No	No
TP (mg/L) | RES	**Yes**	**Yes**	**Yes**	No	No

Colorado EMC Data for Total Nitrogen (mg/L)

Descriptive statistics (Quantitative data):

Statistic	TN (mg/L) | COM	TN (mg/L) | HWY	TN (mg/L) | IND	TN (mg/L) | OPEN	TN (mg/L) | RES
No. of observations	168	9	23	7	191
Minimum	0.54	1.30	1.20	1.49	0.51
Maximum	16.63	6.10	8.70	6.12	22.77
1st Quartile	2.01	2.30	2.15	2.08	2.83
Median	2.79	3.60	3.60	3.76	4.19
3rd Quartile	3.88	5.50	4.44	4.14	6.38
Mean	3.45	3.78	3.56	3.40	5.06
Variance (n)	6.07	2.92	3.10	2.25	10.42
Standard deviation (n)	2.46	1.71	1.76	1.50	3.23
Variation coefficient	0.71	0.45	0.49	0.44	0.64
Lower bound on mean (95%)	3.08	2.39	2.78	1.90	4.60
Upper bound on mean (95%)	3.83	5.17	4.34	4.90	5.53

Box plots:



Kruskal-Wallis Test and Dunn's Procedure for Colorado Total Nitrogen EMC Data

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
TN (mg/L) | COM	168	0	168	0.540	16.630	3.452	2.472
TN (mg/L) | HWY	9	0	9	1.300	6.100	3.780	1.814
TN (mg/L) | IND	23	0	23	1.200	8.700	3.560	1.800
TN (mg/L) | OPEN	7	0	7	1.490	6.120	3.401	1.621
TN (mg/L) | RES	191	0	191	0.510	22.770	5.064	3.237

Kruskal-Wallis test (TN (mg/L)):

K	38.950
p-value (Two-tailed)	< 0.0001
alpha	0.05

The p-value has been computed using 10000 Monte Carlo simulations. Time elapsed: 0s.
99% confidence interval on the p-value:
] 0.000, 0.000 [

Test interpretation:
H0: The samples come from the same population.
Ha: The samples do not come from the same population.
As the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha.
The risk to reject the null hypothesis H0 while it is true is lower than 0.01%.

Ties have been detected in the data and the appropriate corrections have been applied.

Multiple pairwise comparisons using Dunn's procedure / Two-tailed test:

Sample	Frequency	Sum of ranks	Mean of ranks	Groups	
TN (mg/L) | COM	168	27066.000	161.107	A	
TN (mg/L) | OPEN	7	1244.000	177.714	A	
TN (mg/L) | IND	23	4195.500	182.413	A	
TN (mg/L) | HWY	9	1775.000	197.222	A	B
TN (mg/L) | RES	191	45120.500	236.233		B

Table of pairwise differences:

	TN (mg/L) | COM	TN (mg/L) | HWY	TN (mg/L) | IND	TN (mg/L) | OPEN	TN (mg/L) | RES
TN (mg/L) | COM	0	-36.115	-21.306	-16.607	-75.126
TN (mg/L) | HWY	36.115	0	14.809	19.508	-39.011
TN (mg/L) | IND	21.306	-14.809	0	4.699	-53.820
TN (mg/L) | OPEN	16.607	-19.508	-4.699	0	-58.519
TN (mg/L) | RES	75.126	39.011	53.820	58.519	0

p-values:

	COM	HWY	IND	OPEN	RES
COM	1	0.359	0.405	0.708	**< 0.0001**
HWY	0.359	1	0.743	0.736	0.320
IND	0.405	0.743	1	0.925	**0.034**
OPEN	0.708	0.736	0.925	1	0.186
RES	**< 0.0001**	0.320	**0.034**	0.186	1

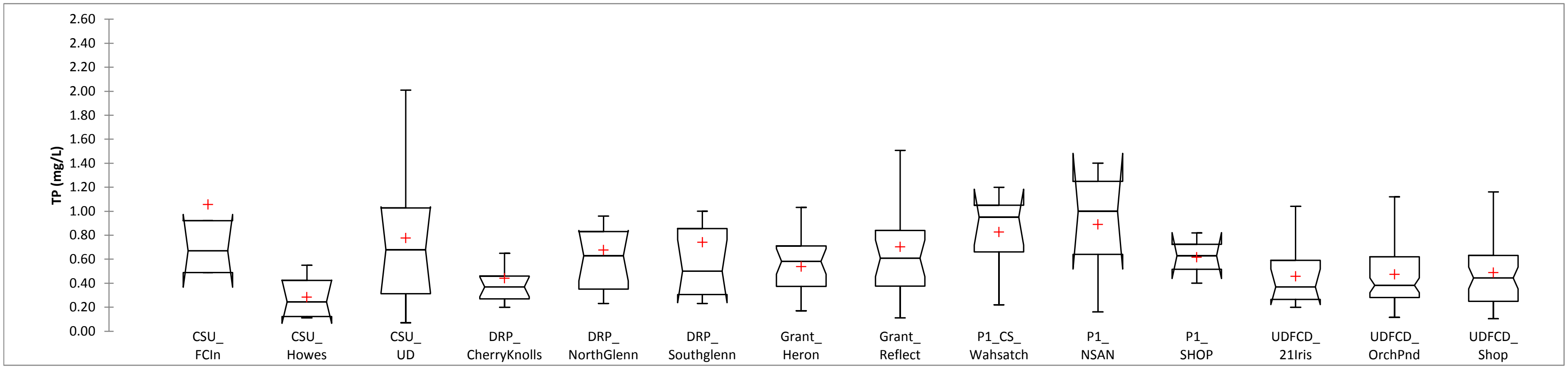
Significant differences:

	TN (mg/L) | COM	TN (mg/L) | HWY	TN (mg/L) | IND	TN (mg/L) | OPEN	TN (mg/L) | RES
TN (mg/L) | COM	No	No	No	No	**Yes**
TN (mg/L) | HWY	No	No	No	No	No
TN (mg/L) | IND	No	No	No	No	**Yes**
TN (mg/L) | OPEN	No	No	No	No	No
TN (mg/L) | RES	**Yes**	No	**Yes**	No	No

Colorado Total Phosphorus EMCs for Residential Sites
Descriptive statistics (Quantitative data)

Statistic	CSU_FCIn	CSU_Howes	CSU_UD	DRP_ CherryKnolls	DRP_ NorthGlenn	DRP_ Southglenn	Grant_ Heron	Grant_ Reflect	P1_CS_W ahsatch	P1_NSAN	P1_SHOP	UDFCD_ 21Iris	UDFCD_ OrchPnd	UDFCD_ Shop
No. of observations	5	7	10	13	13	11	25	23	7	4	3	12	77	44
Minimum	0.49	0.11	0.07	0.20	0.23	0.23	0.17	0.11	0.22	0.16	0.40	0.20	0.12	0.10
Maximum	2.71	0.55	2.01	1.05	1.69	2.10	1.03	1.79	1.20	1.40	0.82	1.04	1.73	1.16
1st Quartile	0.49	0.12	0.31	0.27	0.35	0.30	0.37	0.38	0.66	0.64	0.52	0.27	0.28	0.25
Median	0.67	0.25	0.68	0.37	0.63	0.50	0.58	0.61	0.95	1.00	0.63	0.37	0.38	0.44
3rd Quartile	0.92	0.42	1.03	0.46	0.83	0.85	0.71	0.84	1.05	1.25	0.73	0.59	0.62	0.63
Mean	1.06	0.28	0.78	0.44	0.68	0.74	0.54	0.70	0.83	0.89	0.62	0.46	0.47	0.49
Variation coefficient	0.80	0.59	0.75	0.56	0.55	0.85	0.43	0.66	0.38	0.53	0.28	0.54	0.60	0.58
Lower bound on mean (95%)	-0.11	0.12	0.34	0.29	0.44	0.30	0.44	0.50	0.51	0.02	0.09	0.29	0.41	0.40
Upper bound on mean (95%)	2.22	0.45	1.21	0.60	0.91	1.18	0.63	0.91	1.14	1.76	1.14	0.62	0.54	0.58

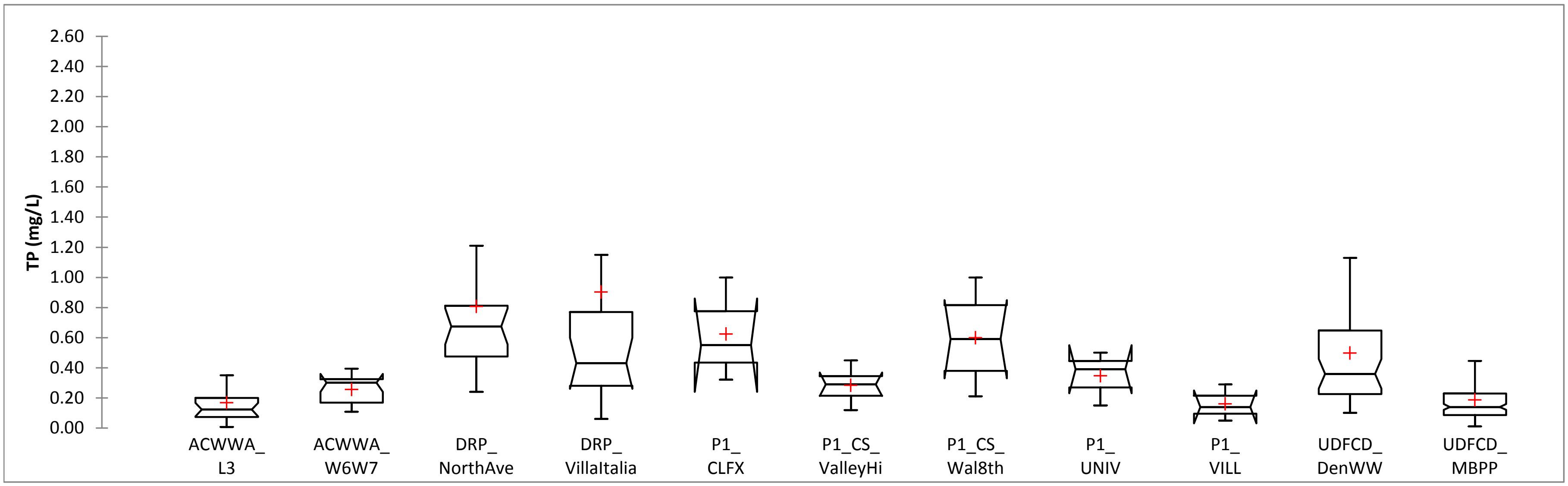
Box plots:



Colorado Total Phosphorus EMCs for Commercial Sites
Descriptive statistics (Quantitative data)

Statistic	ACWWA_L3	ACWWA_ W6W7	DRP_ NorthAve	DRP_ VillaItalia	P1_CLFX	P1_CS_ ValleyHi	P1_CS_ Wal8th	P1_UNIV	P1_VILL	UDFCD_ DenWW	UDFCD_M BPP
No. of observations	19	17	20	21	3	7	7	3	3	46	131
Minimum	0.01	0.11	0.24	0.06	0.32	0.12	0.21	0.15	0.05	0.10	0.01
Maximum	0.54	0.40	3.06	6.30	1.00	0.45	1.00	0.50	0.29	2.31	0.93
1st Quartile	0.07	0.17	0.48	0.28	0.44	0.22	0.38	0.27	0.10	0.22	0.09
Median	0.12	0.30	0.68	0.43	0.55	0.29	0.59	0.39	0.14	0.36	0.14
3rd Quartile	0.20	0.32	0.81	0.77	0.78	0.35	0.82	0.45	0.22	0.65	0.23
Mean	0.17	0.26	0.81	0.90	0.62	0.28	0.60	0.35	0.16	0.50	0.19
Variation coefficient	0.87	0.38	0.77	1.52	0.45	0.39	0.48	0.42	0.62	0.84	0.84
Lower bound on mean (95%)	0.10	0.20	0.51	0.26	-0.24	0.17	0.31	-0.10	-0.14	0.37	0.16
Upper bound on mean (95%)	0.24	0.31	1.11	1.54	1.48	0.39	0.88	0.79	0.46	0.62	0.21

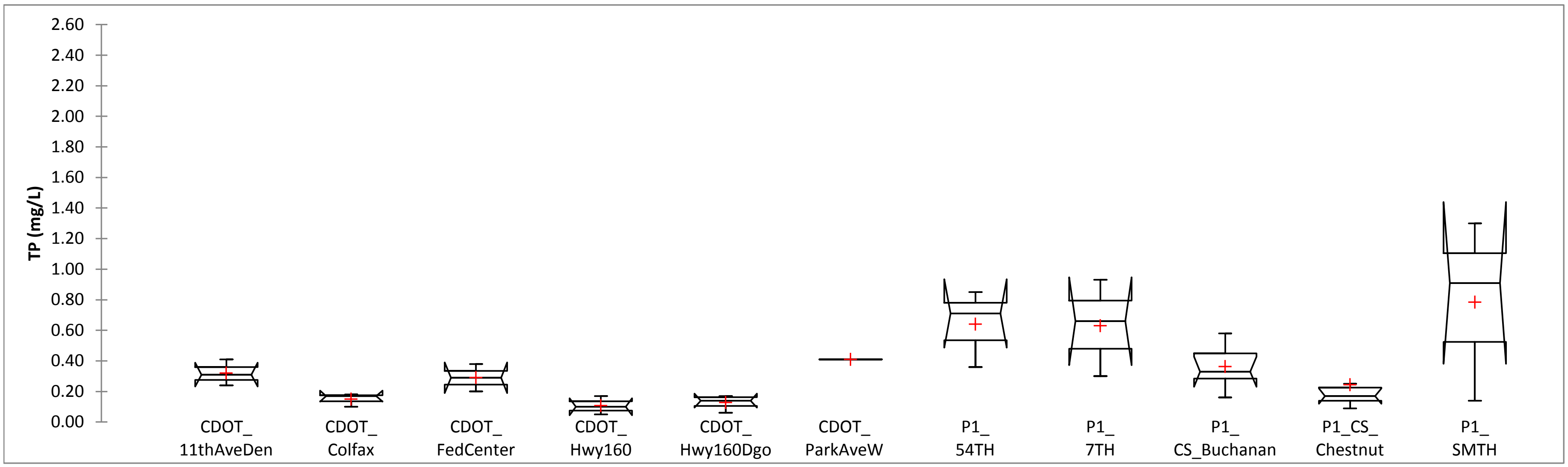
Box plots:



Colorado Total Phosphorus EMCs for Industrial Sites
Descriptive statistics (Quantitative data)

Statistic	CDOT_ 11thAveDen	CDOT_ Colfax	CDOT_ FedCenter	CDOT_H wy160	CDOT_Hwy 160Dgo	CDOT_ ParkAveW	P1_54TH	P1_7TH	P1_CS_ Buchanan	P1_CS_ Chestnut	P1_SMTH
No. of observations	3	3	2	3	4	1	3	3	7	7	3
Minimum	0.24	0.10	0.20	0.05	0.06	0.41	0.36	0.30	0.16	0.09	0.14
Maximum	0.41	0.18	0.38	0.17	0.17	0.41	0.85	0.93	0.58	0.72	1.30
1st Quartile	0.28	0.14	0.25	0.08	0.11	0.41	0.54	0.48	0.29	0.14	0.53
Median	0.31	0.17	0.29	0.10	0.14	0.41	0.71	0.66	0.33	0.17	0.91
3rd Quartile	0.36	0.18	0.34	0.14	0.16	0.41	0.78	0.80	0.45	0.23	1.11
Mean	0.32	0.15	0.29	0.11	0.13	0.41	0.64	0.63	0.36	0.24	0.78
Variation coefficient	0.22	0.24	0.31	0.46	0.34	0.11	0.32	0.41	0.36	0.82	0.62
Lower bound on mean (95%)	0.11	0.04	-0.85	-0.04	0.05		0.01	-0.16	0.23	0.04	-0.68
Upper bound on mean (95%)	0.53	0.26	1.43	0.26	0.21		1.27	1.42	0.49	0.44	2.25

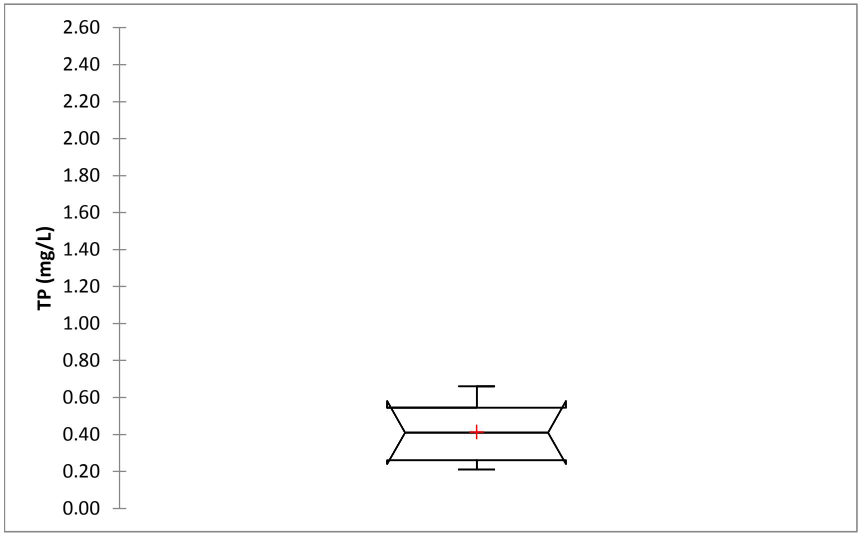
Box plots:



Colorado Total Phosphorus EMCs for Natural Open Space
Descriptive statistics (Quantitative data)

Statistic	DRP_Rooney
No. of observations	7
Minimum	0.21
Maximum	0.66
1st Quartile	0.26
Median	0.41
3rd Quartile	0.54
Mean	0.41
Variation coefficient	0.39
Lower bound on mean (95%)	0.25
Upper bound on mean (95%)	0.58

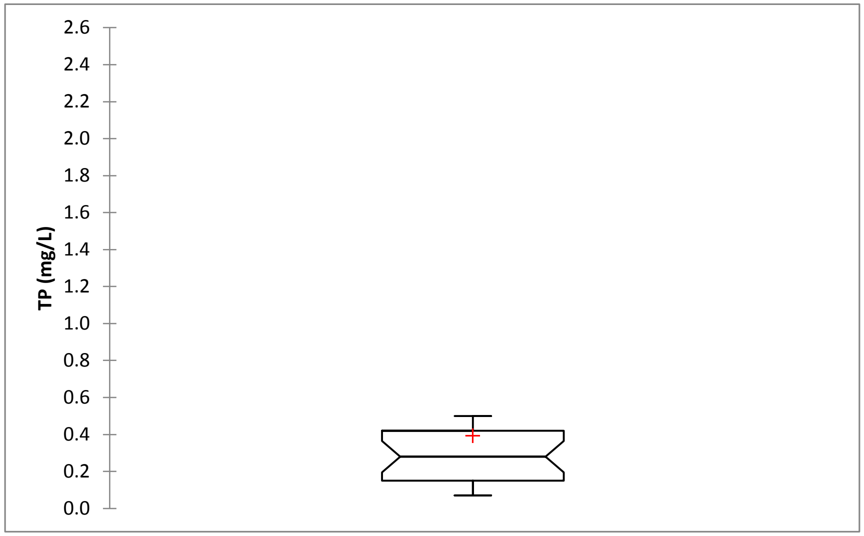
Box plots:



Colorado Total Phosphorus EMCs for Highways
Descriptive statistics (Quantitative data)

Statistic	HWY (all sites combined)
No. of observations	25
Minimum	0.07
Maximum	2.60
1st Quartile	0.15
Median	0.28
3rd Quartile	0.42
Mean	0.39
Variation coefficient	1.25
Lower bound on mean (95%)	0.18
Upper bound on mean (95%)	0.60

Box plots:

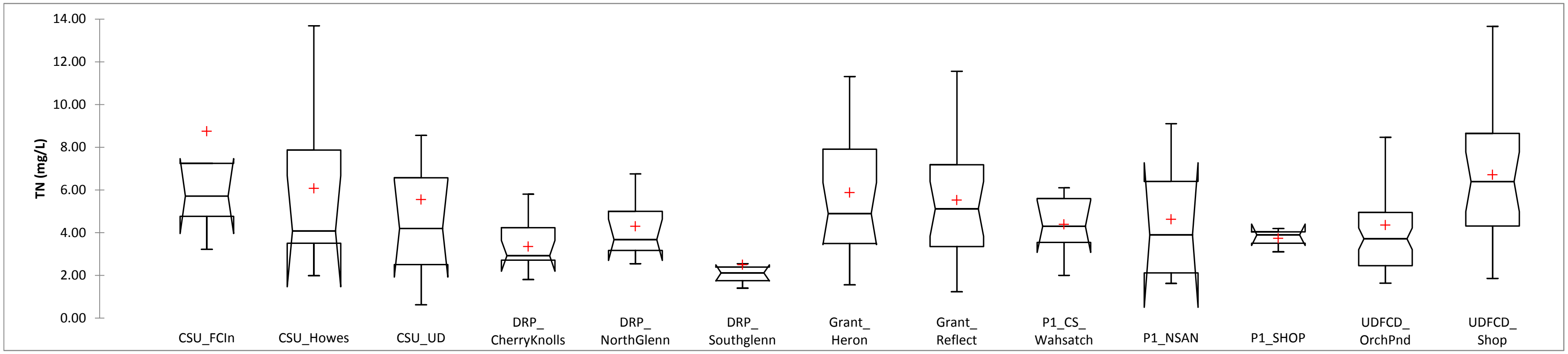


Colorado Total Nitrogen EMCs for Residential Sites

Descriptive statistics (Quantitative data)

Statistic	CSU_ FCIn	CSU_ Howes	CSU_UD	DRP_ CherryKnolls	DRP_ NorthGlenn	DRP_ Southglenn	Grant_ Heron	Grant_ Reflect	P1_CS_ Wahsatch	P1_NSAN	P1_SHOP	UDFCD_ OrchPnd	UDFCD_ Shop
No. of observations	5	7	8	11	9	7	23	22	7	4	3	61	24
No. of missing values	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum	3.22	1.99	0.63	1.81	2.54	0.51	1.55	1.24	2.00	1.62	3.10	1.64	1.86
Maximum	22.77	13.68	16.04	5.80	6.75	6.54	11.31	11.55	6.10	9.10	4.19	15.23	13.66
1st Quartile	4.77	3.50	2.50	2.71	3.17	1.76	3.49	3.35	3.55	2.12	3.50	2.45	4.32
Median	5.71	4.08	4.20	2.92	3.67	2.12	4.90	5.12	4.30	3.89	3.90	3.71	6.38
3rd Quartile	7.25	7.86	6.57	4.23	5.00	2.39	7.91	7.18	5.60	6.40	4.05	4.95	8.64
Mean	8.74	6.07	5.55	3.35	4.30	2.50	5.87	5.52	4.39	4.63	3.73	4.35	6.71
Variation coefficient	0.82	0.66	0.82	0.36	0.35	0.71	0.47	0.53	0.31	0.64	0.12	0.60	0.52
Lower bound on mean (95%)	-1.16	2.08	1.46	2.51	3.08	0.73	4.65	4.20	3.02	-0.83	2.33	3.68	5.22
Upper bound on mean (95%)	18.65	10.06	9.64	4.19	5.51	4.26	7.10	6.85	5.75	10.08	5.13	5.02	8.21

Box plots:

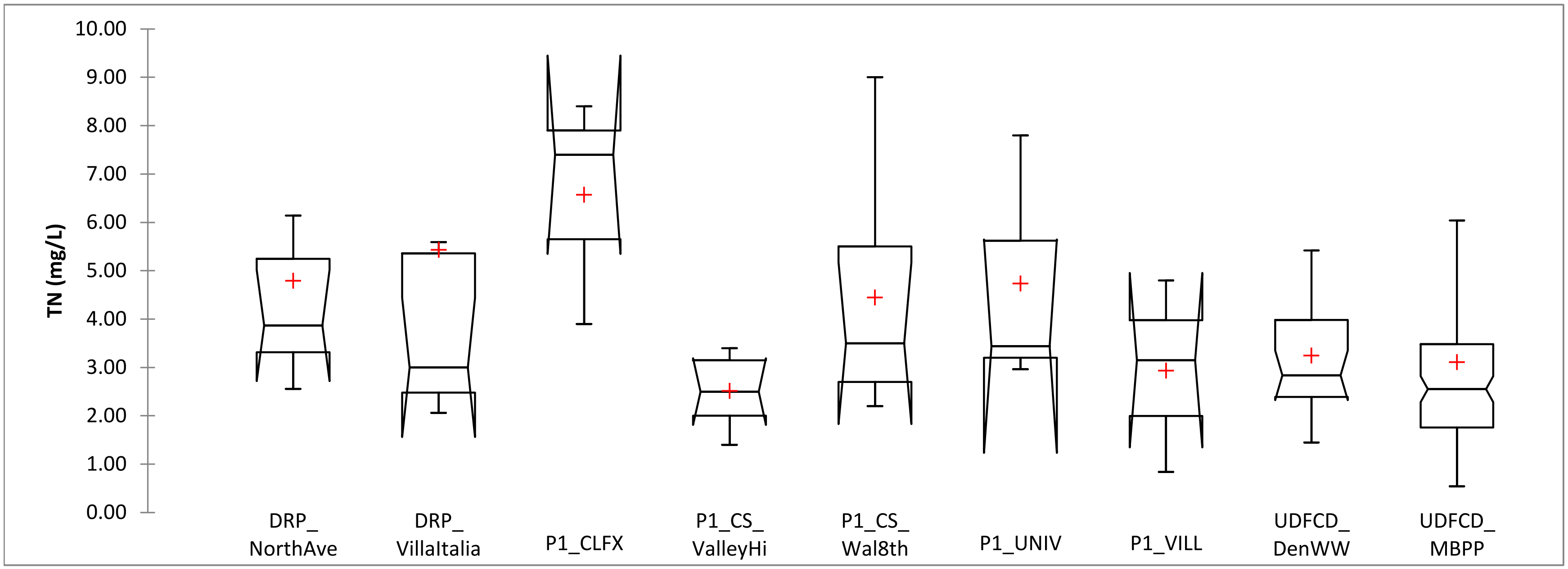


Colorado Total Nitrogen EMCs for Commercial Sites

Descriptive statistics (Quantitative data):

Statistic	DRP_ NorthAve	DRP_ VillaItalia	P1_CLFX	P1_CS_ ValleyHi	P1_CS_ Wal8th	P1_UNIV	P1_VILL	UDFCD_ DenWW	UDFCD_ MBPP
No. of observations	7	10	3	7	7	3	3	24	104
No. of missing values	0	0	0	0	0	0	0	0	0
Minimum	2.56	2.06	3.90	1.40	2.20	2.96	0.84	1.45	0.54
Maximum	9.97	16.63	8.40	3.40	9.00	7.80	4.80	6.78	13.49
1st Quartile	3.31	2.48	5.65	2.00	2.70	3.20	2.00	2.39	1.76
Median	3.87	3.00	7.40	2.50	3.50	3.44	3.15	2.84	2.55
3rd Quartile	5.24	5.36	7.90	3.15	5.50	5.62	3.98	3.98	3.48
Mean	4.79	5.43	6.57	2.51	4.44	4.73	2.93	3.24	3.10
Variation coefficient	0.50	0.86	0.29	0.28	0.51	0.46	0.55	0.38	0.74
Lower bound on mean (95%)	2.41	1.92	0.70	1.82	2.19	-1.89	-2.01	2.72	2.66
Upper bound on mean (95%)	7.16	8.94	12.44	3.21	6.70	11.36	7.87	3.77	3.55

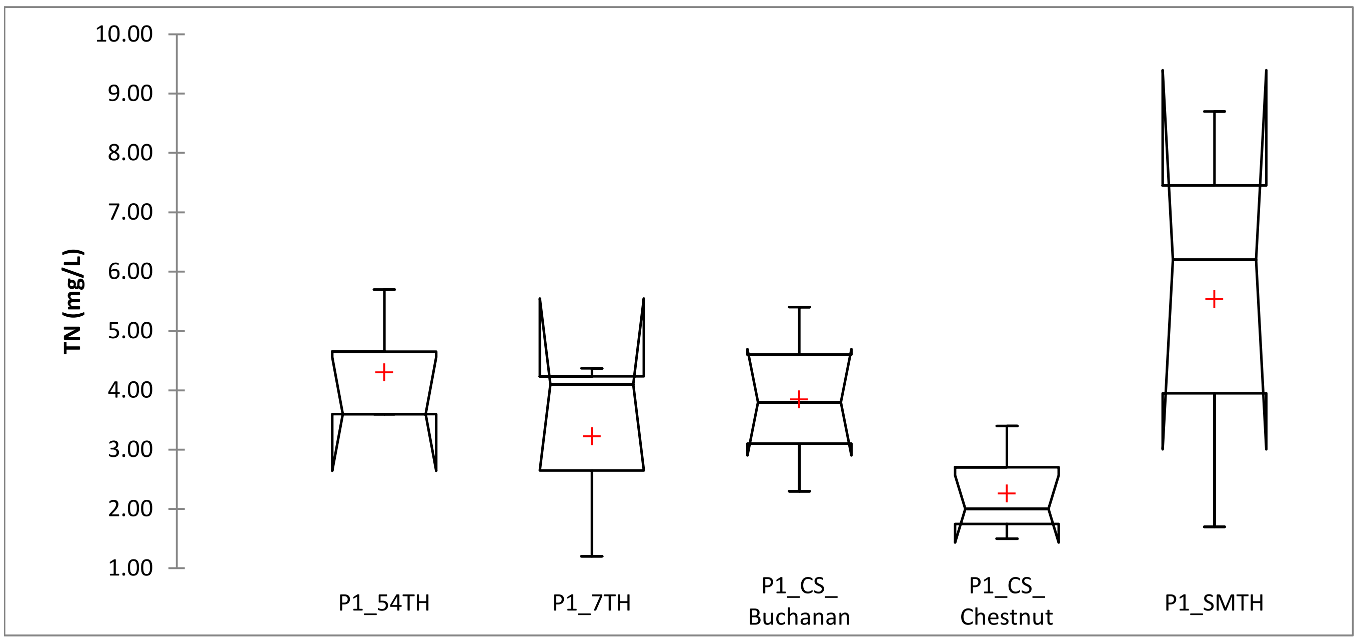
Box plots:



Colorado Total Nitrogen EMCs for Industrial Sites
Descriptive statistics (Quantitative data)

Statistic	P1_54TH	P1_7TH	P1_CS_ Buchanan	P1_CS_ Chestnut	P1_SMTH
No. of observations	3	3	7	7	3
No. of missing values	0	0	0	0	0
Minimum	3.60	1.20	2.30	1.50	1.70
Maximum	5.70	4.37	5.40	3.40	8.70
1st Quartile	3.60	2.65	3.10	1.75	3.95
Median	3.60	4.10	3.80	2.00	6.20
3rd Quartile	4.65	4.24	4.60	2.70	7.45
Mean	4.30	3.22	3.84	2.26	5.53
Variation coefficient	0.23	0.45	0.27	0.29	0.52
Lower bound on mean (95%)	1.29	-1.14	2.79	1.59	-3.28
Upper bound on mean (95%)	7.31	7.59	4.90	2.92	14.35

Box plots:

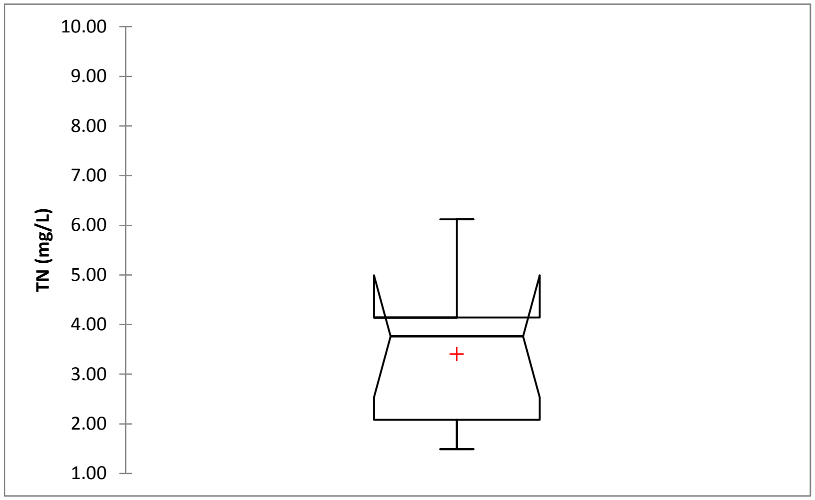


Colorado Total Nitrogen EMCs for Natural Open Space

Descriptive statistics (Quantitative data):

Statistic	OPEN
No. of observations	7
No. of missing values	0
Minimum	1.49
Maximum	6.12
1st Quartile	2.08
Median	3.76
3rd Quartile	4.14
Mean	3.40
Variation coefficient	0.44
Lower bound on mean (95%)	1.90
Upper bound on mean (95%)	4.90

Box plots:

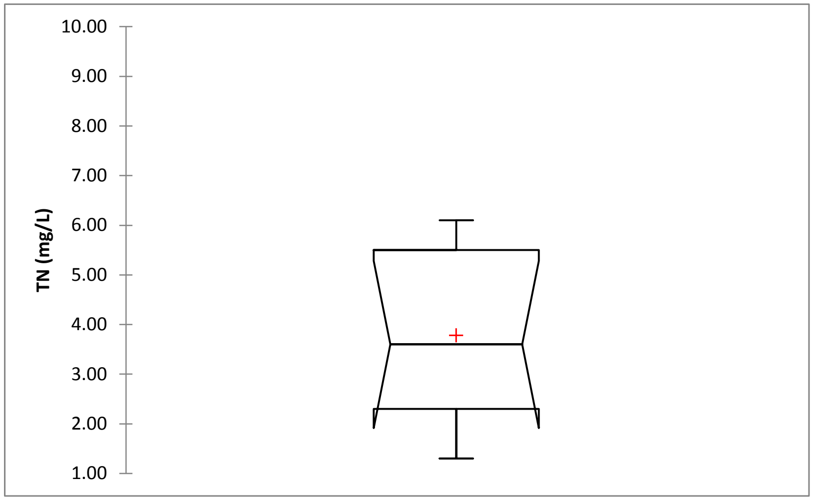


Colorado Total Nitrogen EMCs for Highways

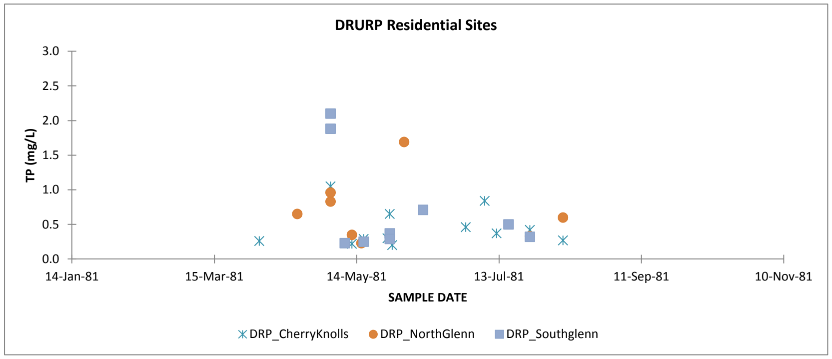
Descriptive statistics (Quantitative data):

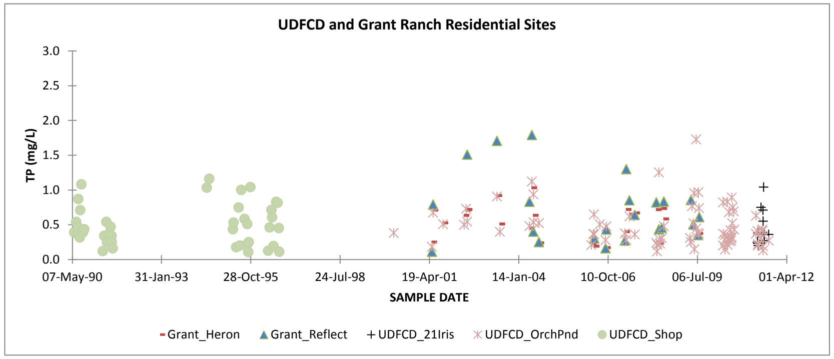
Statistic	HWY
No. of observations	9
No. of missing values	0
Minimum	1.30
Maximum	6.10
1st Quartile	2.30
Median	3.60
3rd Quartile	5.50
Mean	3.78
Variation coefficient	0.45
Lower bound on mean (95%)	2.39
Upper bound on mean (95%)	5.17

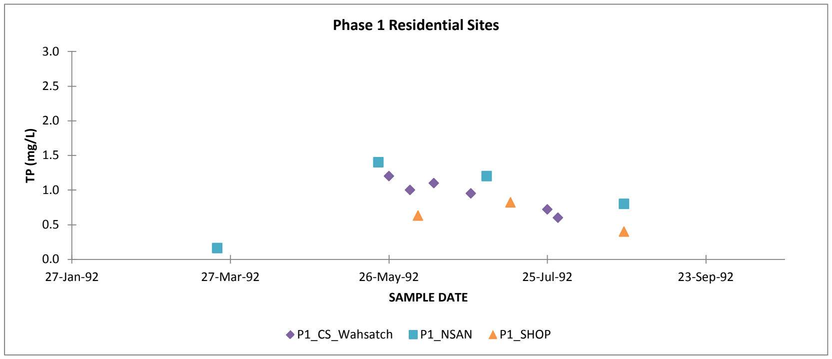
Box plots:

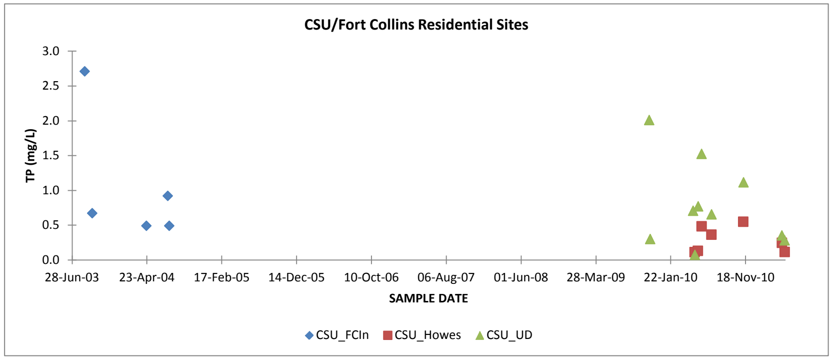


Colorado Total Phosphorus EMCs for Residential Sites by Data Source Groups
Scatter plots:

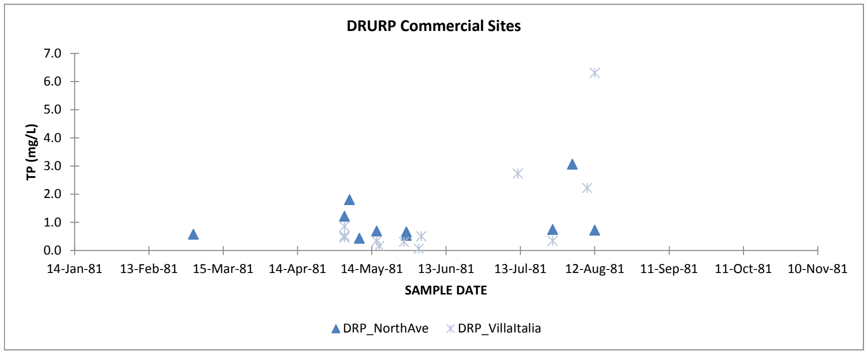


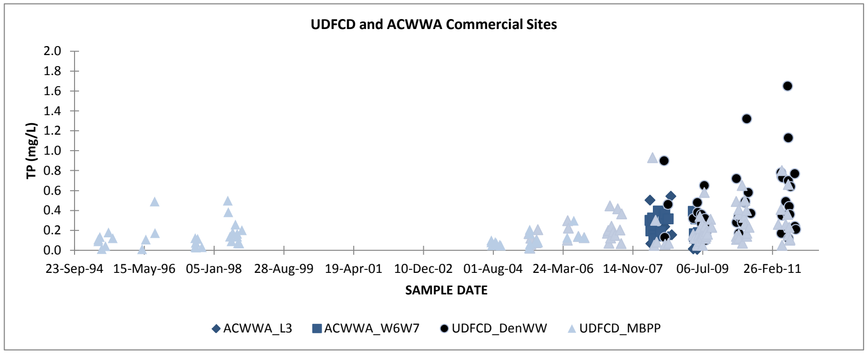


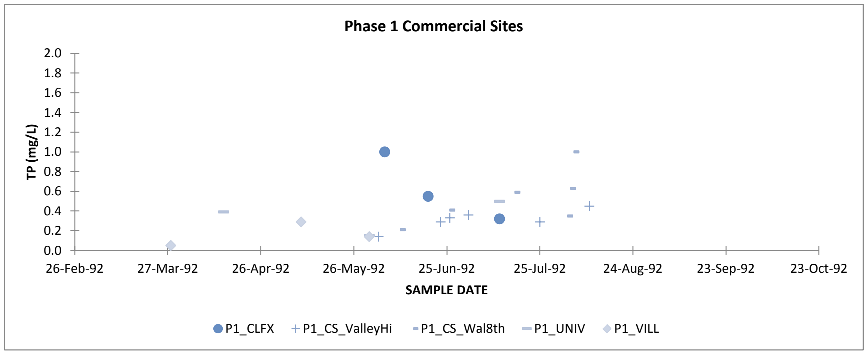




Colorado Total Phosphorus EMCs for Commercial Sites by Data Source Groups
Scatter plots:

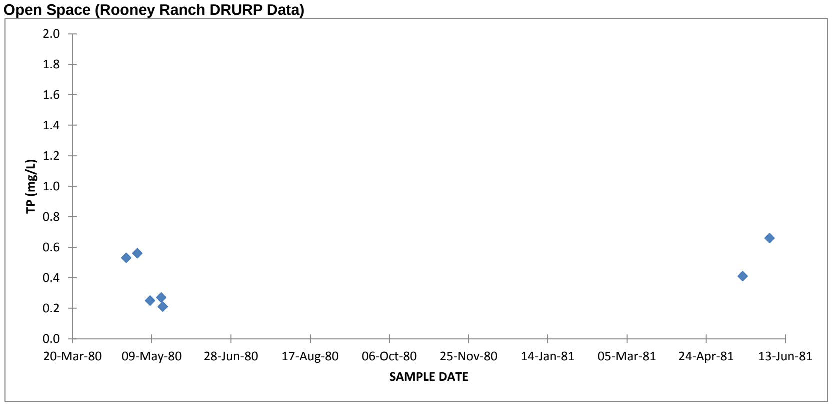




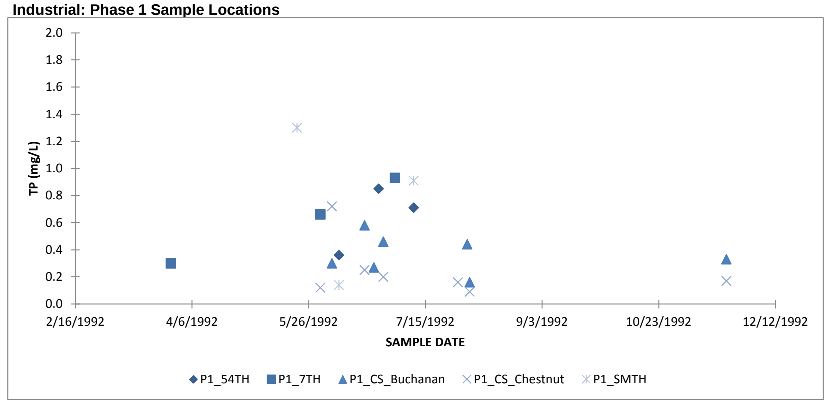


Colorado Total Phosphorus EMCs for Open Space, Highways and Industrial Sites
Scatter plots:

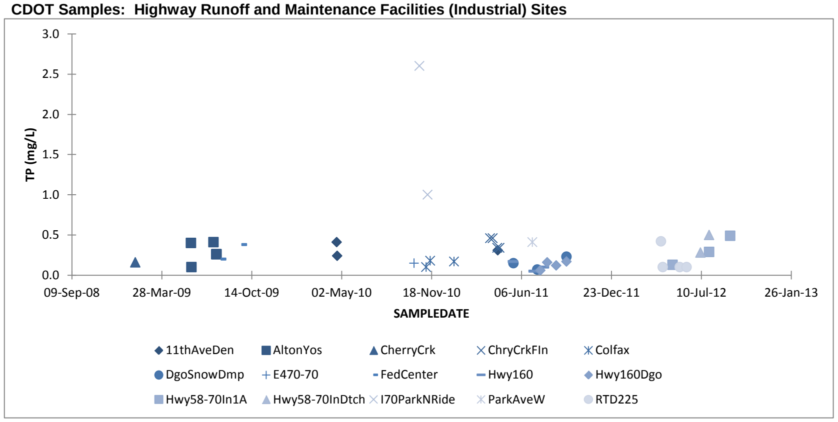
Open Space (Rooney Ranch DRURP Data)



Industrial: Phase 1 Sample Locations



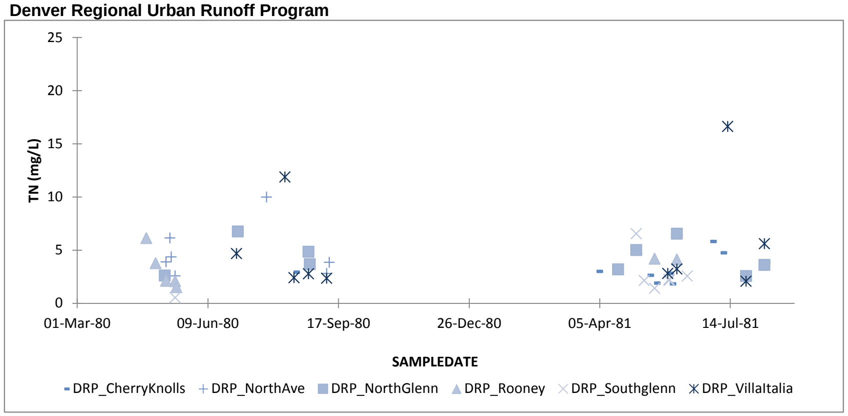
CDOT Samples: Highway Runoff and Maintenance Facilities (Industrial) Sites



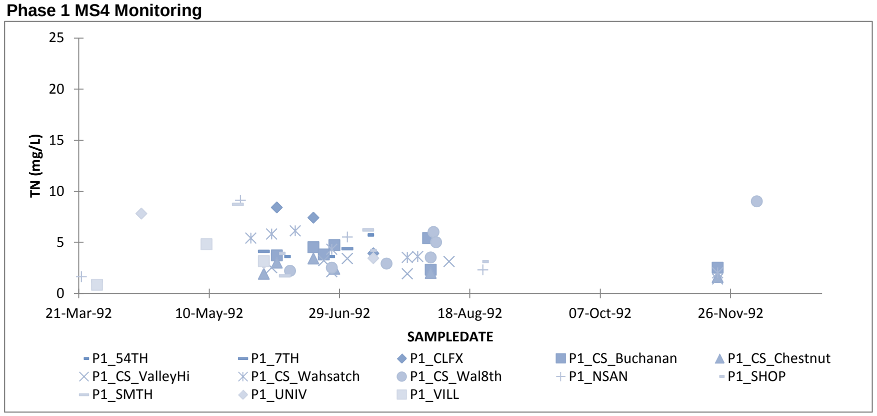
Colorado EMC Data for Total Nitrogen by Sampling Source

Scatter plots:

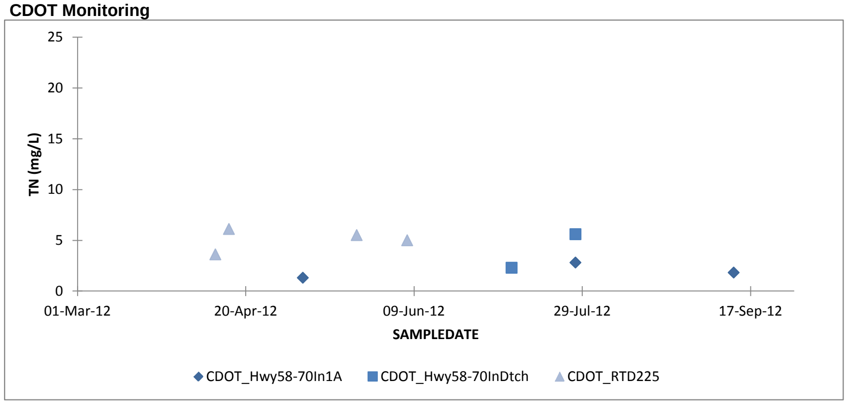
Denver Regional Urban Runoff Program



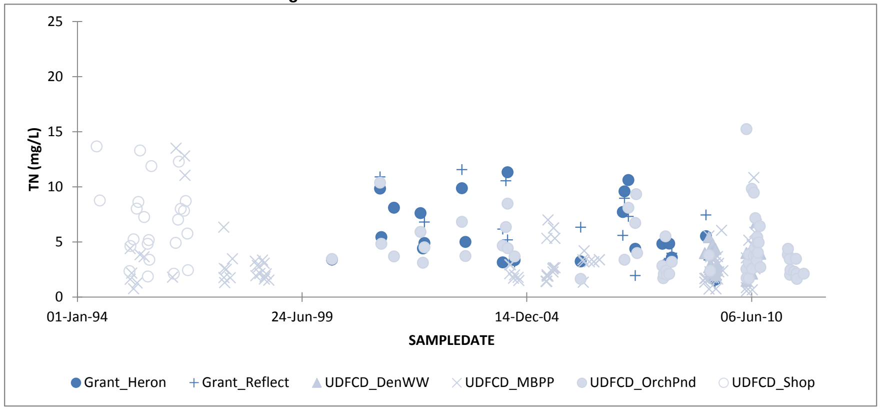
Phase 1 MS4 Monitoring



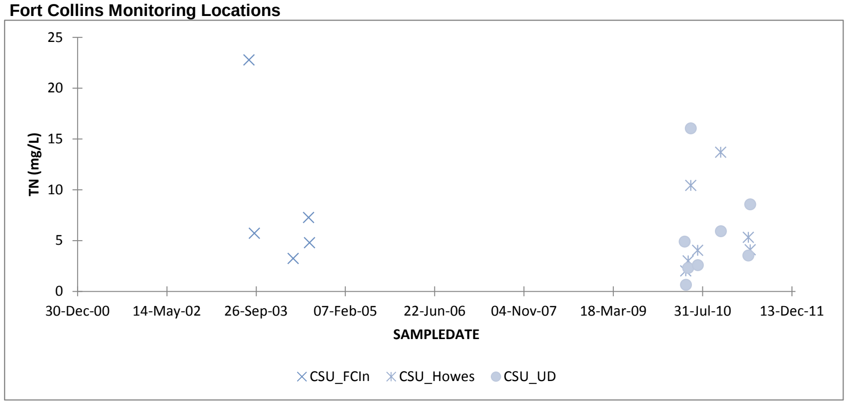
CDOT Monitoring



UDFCD and Grant Ranch Monitoring



Fort Collins Monitoring Locations



Appendix C

Statistical Results for Kruskal-Wallis and Dunn's Procedure Comparisons of Nutrients by Land Use and EPA Rain Zone

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Colorado Total Phosphorus EMC Data and NSQD Data by Land Use

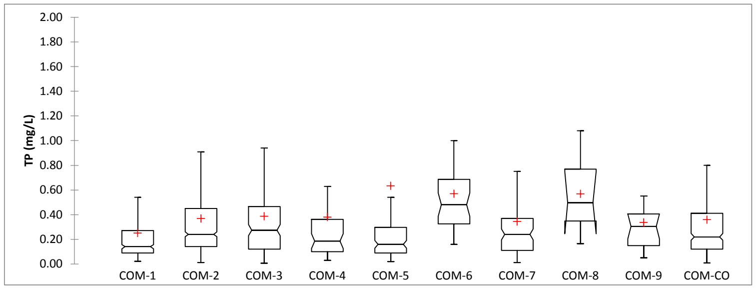
Descriptive statistics (Quantitative data):

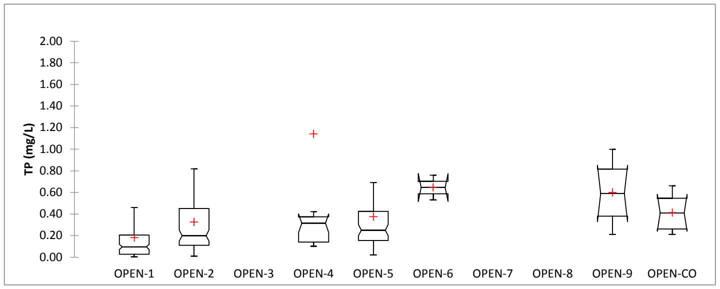
Statistic	COM-1	COM-2	COM-3	COM-4	COM-5	COM-6	COM-7	COM-8	COM-9	COM-CO	HWY-1	HWY-2	HWY-3	HWY-5	HWY-6	HWY-7	HWY-CO
No.	263	621	141	50	112	35	84	7	16	277	3	177	14	245	135	24	25
Minimum	0.02	0.01	0.01	0.03	0.02	0.16	0.01	0.16	0.05	0.01	0.35	0.04	0.07	0.01	0.03	0.11	0.07
Maximum	8.60	6.72	2.86	3.55	15.60	2.00	3.30	1.08	1.00	6.30	0.54	11.56	0.46	0.97	7.19	0.90	2.60
1st Quartile	0.09	0.14	0.12	0.10	0.09	0.33	0.11	0.35	0.15	0.12	0.38	0.21	0.11	0.12	0.18	0.22	0.15
Median	0.14	0.24	0.27	0.19	0.16	0.48	0.24	0.50	0.31	0.22	0.41	0.44	0.13	0.18	0.27	0.28	0.28
3rd Quartile	0.27	0.45	0.47	0.36	0.30	0.69	0.37	0.77	0.41	0.41	0.47	1.34	0.14	0.30	0.42	0.42	0.42
Mean	0.25	0.37	0.39	0.38	0.63	0.57	0.34	0.57	0.34	0.36	0.43	0.96	0.16	0.22	0.48	0.35	0.39
Variation coefficient	2.24	1.29	1.10	1.56	2.98	0.71	1.32	0.57	0.66	1.47	0.18	1.31	0.71	0.71	1.65	0.56	1.25
Lower bound on mean (95%)	0.18	0.33	0.32	0.21	0.28	0.43	0.24	0.24	0.21	0.30	0.20	0.78	0.09	0.20	0.35	0.26	0.18
Upper bound on mean (95%)	0.32	0.41	0.46	0.55	0.99	0.71	0.44	0.89	0.46	0.42	0.67	1.15	0.24	0.24	0.62	0.43	0.60

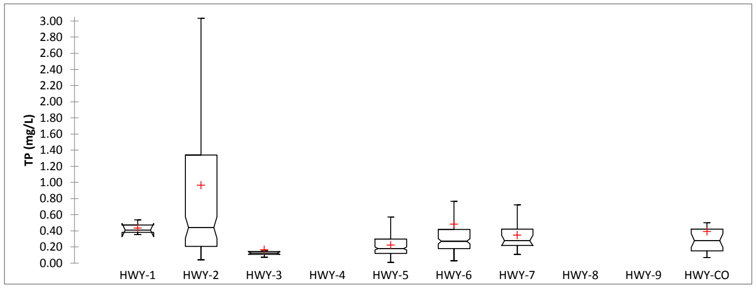
Statistic	IND-1	IND-2	IND-3	IND-4	IND-5	IND-6	IND-7	IND-8	IND-9	IND-CO
No.	74	360	108	49	108	61	76	1	23	39
Minimum	0.03	0.02	0.02	0.02	0.02	0.14	0.05	0.31	0.09	0.05
Maximum	1.50	4.88	1.00	2.50	2.64	7.90	1.40	0.31	1.30	1.30
1st Quartile	0.14	0.12	0.09	0.15	0.12	0.66	0.10	0.31	0.19	0.16
Median	0.24	0.23	0.13	0.26	0.19	1.10	0.25	0.31	0.33	0.25
3rd Quartile	0.40	0.38	0.25	0.37	0.28	1.60	0.46	0.31	0.69	0.43
Mean	0.33	0.33	0.20	0.35	0.26	1.31	0.33	0.31	0.45	0.35
Variation coefficient	0.86	1.42	0.94	1.18	1.18	0.92	0.88	0.94	0.70	0.81
Lower bound on mean (95%)	0.26	0.28	0.16	0.23	0.20	1.00	0.27		0.31	0.26
Upper bound on mean (95%)	0.39	0.38	0.24	0.47	0.31	1.62	0.40		0.59	0.44

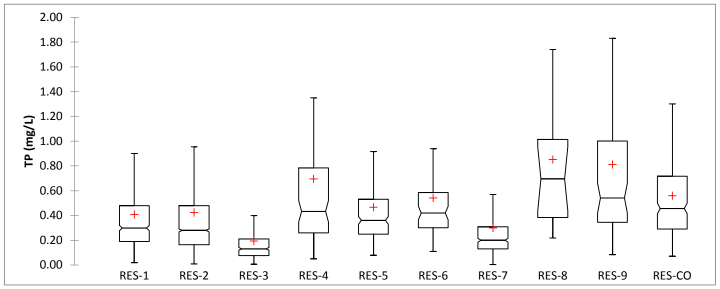
Statistic	OPEN-1	OPEN-2	OPEN-4	OPEN-5	OPEN-6	OPEN-9	OPEN-CO	RES-1	RES-2	RES-3	RES-4	RES-5	RES-6	RES-7	RES-8	RES-9	RES-CO
No.	139	106	18	67	2	7	7	498	1923	410	91	206	67	331	15	75	254
Minimum	0.00	0.01	0.10	0.02	0.53	0.21	0.21	0.02	0.01	0.01	0.05	0.08	0.11	0.01	0.22	0.08	0.07
Maximum	2.50	2.50	15.40	2.29	0.76	1.00	0.66	6.69	19.90	3.40	5.33	4.19	4.96	3.61	2.95	6.42	2.71
1st Quartile	0.03	0.11	0.14	0.16	0.59	0.38	0.26	0.19	0.16	0.08	0.26	0.25	0.30	0.13	0.38	0.35	0.29
Median	0.10	0.20	0.32	0.25	0.65	0.59	0.41	0.30	0.28	0.13	0.43	0.36	0.42	0.20	0.70	0.54	0.46
3rd Quartile	0.21	0.45	0.37	0.43	0.70	0.82	0.54	0.48	0.48	0.21	0.79	0.53	0.59	0.31	1.02	1.00	0.72
Mean	0.18	0.33	1.14	0.37	0.65	0.60	0.41	0.41	0.42	0.19	0.69	0.47	0.54	0.30	0.85	0.81	0.56
Variation coefficient	1.65	1.09	3.04	1.09	0.18	0.48	0.39	1.08	1.74	1.45	1.21	0.89	1.11	1.20	0.81	1.13	0.69
Lower bound on mean (95%)	0.13	0.26	-0.63	0.27	-0.82	0.31	0.25	0.37	0.39	0.17	0.52	0.41	0.39	0.26	0.46	0.60	0.51
Upper bound on mean (95%)	0.23	0.39	2.91	0.47	2.11	0.88	0.58	0.45	0.46	0.22	0.87	0.52	0.69	0.34	1.25	1.02	0.61

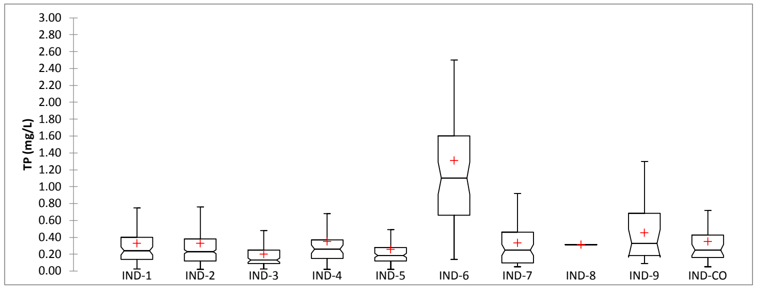
Colorado Total Phosphorus EMC Data and NSQD Data by Land Use











Kruskal-Wallis and Dunn's Procedure Results Comparing Colorado Total Phosphorus EMCs to the NSQD Rain Zones

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
COM-CO	277	0	277	0.01	6.30	0.36	0.53
IND-CO	39	0	39	0.05	1.30	0.35	0.29
HWY-CO	25	0	25	0.07	2.60	0.39	0.50
OPEN-CO	7	0	7	0.21	0.66	0.41	0.18
RES-CO	254	0	254	0.07	2.71	0.56	0.39
OPEN-1	139	0	139	0.00	2.50	0.18	0.30
COM-3	141	0	141	0.01	2.86	0.39	0.42
RES-7	331	0	331	0.01	3.61	0.30	0.36
RES-3	410	0	410	0.01	3.40	0.19	0.28
RES-2	1923	0	1923	0.01	19.90	0.42	0.74
HWY-5	246	1	245	0.01	0.97	0.22	0.16
OPEN-2	106	0	106	0.01	2.50	0.33	0.36
COM-2	621	0	621	0.01	6.72	0.37	0.48
COM-7	84	0	84	0.01	3.30	0.34	0.46
RES-1	498	0	498	0.02	6.69	0.41	0.44
COM-5	112	0	112	0.02	15.60	0.63	1.90
IND-5	108	0	108	0.02	2.64	0.26	0.30
IND-2	360	0	360	0.02	4.88	0.33	0.47
OPEN-5	67	0	67	0.02	2.29	0.37	0.41
IND-4	49	0	49	0.02	2.50	0.35	0.42
COM-1	263	0	263	0.02	8.60	0.25	0.56
IND-3	108	0	108	0.02	1.00	0.20	0.19
IND-1	74	0	74	0.03	1.50	0.33	0.28
HWY-6	135	0	135	0.03	7.19	0.48	0.80
COM-4	50	0	50	0.03	3.55	0.38	0.60
HWY-2	177	0	177	0.04	11.56	0.96	1.27
RES-4	91	0	91	0.05	5.33	0.69	0.84
COM-9	16	0	16	0.05	1.00	0.34	0.23
IND-7	76	0	76	0.05	1.40	0.33	0.30
HWY-3	14	0	14	0.07	0.46	0.16	0.12
RES-5	206	0	206	0.08	4.19	0.47	0.42
RES-9	75	0	75	0.08	6.42	0.81	0.92
IND-9	23	0	23	0.09	1.30	0.45	0.32
OPEN-4	18	0	18	0.10	15.40	1.14	3.56
HWY-7	24	0	24	0.11	0.90	0.35	0.20
RES-6	67	0	67	0.11	4.96	0.54	0.60
IND-6	61	0	61	0.14	7.90	1.31	1.21
COM-6	35	0	35	0.16	2.00	0.57	0.41
COM-8	7	0	7	0.16	1.08	0.57	0.35
OPEN-9	7	0	7	0.21	1.00	0.60	0.31
RES-8	15	0	15	0.22	2.95	0.85	0.71
IND-8	1	0	1	0.31	0.31	0.31	
HWY-1	3	0	3	0.35	0.54	0.43	0.09
OPEN-6	2	0	2	0.53	0.76	0.65	0.16

Kruskal-Wallis test (TP (mg/L)):

K	1180.783
p-value (Two-tailed)	< 0.0001
alpha	0.05

The p-value has been computed using 10000 Monte Carlo simulations. Time elapsed: 10s.

99% confidence interval on the p-value:

] 0.000, 0.000 [

Test interpretation:

H0: The samples come from the same population.

Ha: The samples do not come from the same population.

As the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha.

The risk to reject the null hypothesis H0 while it is true is lower than 0.01%.

Ties have been detected in the data and the appropriate corrections have been applied.

Kruskal-Wallis and Dunn's Procedure Results Comparing Colorado Total Phosphorus EMCs to the NSQD Rain Zones

Multiple pairwise comparisons using Dunn's procedure / Two-tailed test:

Sample	Frequency	Sum of ranks	Mean of ranks	Groups							
OPEN-1	139	255532	1838.360	A							
HWY-3	14	28411	2029.357	A							
RES-3	410	872680	2128.488	A							
IND-3	108	254008	2351.926	A	B						
COM-1	263	661225	2514.162		B	C					
COM-5	112	315730	2819.018		B	C	D				
HWY-5	245	702101	2865.718			C	D				
IND-5	108	313589	2903.602			C	D				
COM-4	50	156812	3136.240			C	D				
RES-7	331	1054921	3187.071				D				
COM-7	84	281587	3352.226				D	E			
IND-2	360	1208705	3357.513				D	E			
OPEN-2	106	357928	3376.675				D	E			
COM-CO	277	948798	3425.264				D	E			
IND-7	76	264476	3479.941				D	E			
IND-1	74	266848	3606.054				D	E			
IND-4	49	176788	3607.918				D	E			
COM-2	621	2257731	3635.637				D	E			
OPEN-5	67	245805	3668.731				D	E	F		
COM-3	141	527043	3737.894					E	F		
IND-CO	39	147603	3784.692					E	F		
HWY-CO	25	94799	3791.940					E	F		
OPEN-4	18	69774	3876.306					E	F		
COM-9	16	63777	3986.031					E	F		
RES-2	1923	7685127	3996.426						F		
HWY-6	135	543386	4025.078						F		
RES-1	498	2085374	4187.497						F		
HWY-7	24	101305	4221.042						F	G	
IND-8	1	4474	4473.500						F	G	
IND-9	23	104299	4534.717						F	G	
RES-5	206	985454	4783.755							G	
OPEN-CO	7	34643	4948.929							G	H
HWY-2	177	878869	4965.362							G	H
RES-4	91	467975	5142.582							G	H
RES-6	67	345471	5156.284							G	H
RES-CO	254	1332941	5247.797								H
COM-8	7	37167	5309.500								H
COM-6	35	187727	5363.629								H
HWY-1	3	16237	5412.167								H
RES-9	75	410975	5479.660								H
OPEN-9	7	39768	5681.071								H
RES-8	15	89455	5963.667								H
OPEN-6	2	12640	6320.000								H
IND-6	61	391161	6412.475								H

Kruskal-Wallis and Dunn's Procedure Results Comparing Colorado Total Phosphorus EMCs to the NSQD Rain Zones

Table of pairwise differences:

	COM-CO	IND-CO	HWY-CO	OPEN-CC	RES-CO	OPEN-1	COM-3	RES-7	RES-3	RES-2	HWY-5	OPEN-2	COM-2	COM-7	RES-1	COM-5	IND-5	IND-2	OPEN-5	IND-4	COM-1	IND-3	IND-1	HWY-6	COM-4	HWY-2	RES-4	COM-9	IND-7	HWY-3	RES-5	RES-9	IND-9	OPEN-4	HWY-7	RES-6	IND-6	COM-6	COM-8	OPEN-9	RES-8	IND-8	HWY-1	OPEN-6
COM-CO	0	-359.429	-366.676	-1523.665	-1822.534	1586.904	-312.630	238.193	1296.776	-571.162	559.545	48.589	-210.373	73.037	-762.233	606.246	521.662	67.751	-243.468	-182.655	911.102	1073.338	-180.791	-599.814	289.024	-1540.098	-1717.319	-560.768	-54.677	1395.906	-1358.491	-2054.396	-1109.454	-451.042	-795.778	-1731.020	-2987.212	-1938.365	-1884.236	-2255.808	-2538.403	-1048.236	-1986.903	-2894.736
IND-CO	359.429	0	-7.248	-1164.236	-1463.105	1946.333	46.799	597.621	1656.205	-211.733	918.974	408.018	149.055	432.466	-402.805	965.674	881.090	427.180	115.961	176.774	1270.531	1432.766	178.638	-240.385	648.452	-1180.669	-1357.890	-201.339	304.752	1755.335	-999.063	-1694.968	-750.025	-91.613	-436.349	-1371.591	-2627.783	-1578.936	-1524.808	-1896.379	-2178.974	-688.808	-1627.474	-2535.308
HWY-CO	366.676	7.248	0	-1156.989	-1455.857	1953.580	54.046	604.869	1663.452	-204.486	926.222	415.265	156.303	439.714	-395.557	972.922	888.338	434.428	123.209	184.022	1277.778	1440.014	185.886	-233.138	655.700	-1173.422	-1350.642	-194.091	311.999	1762.583	-991.815	-1687.720	-742.777	-84.366	-429.102	-1364.344	-2620.535	-1571.689	-1517.560	-1889.131	-2171.727	-681.560	-1620.227	-2528.060
OPEN-CO	1523.665	1164.236	1156.989	0	-298.869	3110.569	1211.035	1761.858	2820.441	952.503	2083.210	1572.254	1313.292	1596.702	761.432	2129.911	2045.327	1591.416	1280.197	1341.010	2434.767	2597.003	1342.875	923.851	1812.689	-16.433	-193.654	962.897	1468.988	2919.571	165.174	-530.731	414.211	1072.623	727.887	-207.355	-1463.547	-414.700	-360.571	-732.143	-1014.738	475.429	-463.238	-1371.071
RES-CO	1822.534	1463.105	1455.857	298.869	0	3409.438	1509.904	2060.726	3119.309	1251.372	2382.079	1871.123	1612.160	1895.571	1060.300	2428.779	2344.195	1890.285	1579.066	1639.879	2733.636	2895.871	1641.743	1222.719	2111.557	282.436	105.215	1261.766	1767.856	3218.440	464.042	-231.863	713.080	1371.492	1026.756	91.514	-1164.678	-115.831	-61.703	-433.274	-715.869	774.297	-164.369	-1072.203
OPEN-1	-1586.904	-1946.333	-1953.580	-3110.569	-3409.438	0	-1899.534	-1348.711	-290.128	-2158.066	-1027.359	-1538.315	-1797.277	-1513.866	-2349.137	-980.658	-1065.242	-1519.153	-1830.372	-1769.559	-675.802	-513.566	-1767.694	-2186.718	-1297.880	-3127.002	-3304.223	-2147.672	-1641.581	-190.997	-2945.395	-3641.300	-2696.358	-2037.946	-2382.682	-3317.924	-4574.116	-3525.269	-3471.140	-3842.712	-4125.307	-2635.140	-3573.807	-4481.640
COM-3	312.630	-46.799	-54.046	-1211.035	-1509.904	1899.534	0	550.823	1609.406	-258.532	872.175	361.219	102.257	385.667	-449.603	918.876	834.292	380.381	69.162	129.975	1223.732	1385.968	131.840	-287.184	601.654	-1227.468	-1404.689	-248.138	257.953	1708.536	-1045.861	-1741.766	-796.824	-138.412	-483.148	-1418.390	-2674.582	-1625.735	-1571.606	-1943.178	-2225.773	-735.606	-1674.273	-2582.106
RES-7	-238.193	-597.621	-604.869	-1761.858	-2060.726	1348.711	-550.823	0	1058.583	-809.355	321.353	-189.604	-448.566	-165.155	-1000.426	368.053	283.469	-170.442	-481.660	-420.847	672.909	835.145	-418.983	-838.007	50.831	-1778.291	-1955.511	-798.960	-292.870	1157.714	-1596.684	-2292.589	-1347.646	-689.235	-1033.971	-1969.213	-3225.404	-2176.558	-2122.429	-2494.000	-2776.596	-1286.429	-2225.096	-3132.929
RES-3	-1296.776	-1656.205	-1663.452	-2820.441	-3119.309	290.128	-1609.406	-1058.583	0	-1867.938	-737.231	-1248.187	-1507.149	-1223.738	-2059.009	-690.530	-775.114	-1229.025	-1540.244	-1479.431	-385.674	-223.438	-1477.566	-1896.590	-1007.752	-2836.874	-3014.095	-1857.543	-1351.453	99.131	-2655.267	-3351.172	-2406.230	-1747.818	-2092.554	-3027.796	-4283.988	-3235.141	-3181.012	-3552.584	-3835.179	-2345.012	-3283.679	-4191.512
RES-2	571.162	211.733	204.486	-952.503	-1251.372	2158.066	258.532	809.355	1867.938	0	1130.707	619.751	360.789	644.199	-191.071	1177.408	1092.824	638.913	327.694	388.507	1482.264	1644.500	390.372	-28.652	860.186	-968.936	-1146.157	10.394	516.485	1967.068	-787.329	-1483.234	-538.292	120.120	-224.616	-1159.858	-2416.050	-1367.203	-1313.074	-1684.646	-1967.241	-477.074	-1415.741	-2323.574
HWY-5	-559.545	-918.974	-926.222	-2083.210	-2382.079	1027.359	-872.175	-321.353	737.231	-1130.707	0	-510.956	-769.919	-486.508	-1321.779	46.701	-37.883	-491.794	-803.013	-742.200	351.557	513.792	-740.336	-1159.359	-270.522	-2099.643	-2276.864	-1120.313	-614.222	836.361	-1918.036	-2613.942	-1668.999	-1010.587	-1355.323	-2290.565	-3546.757	-2497.910	-2443.782	-2815.353	-3097.948	-1607.782	-2546.448	-3454.282
OPEN-2	-48.589	-408.018	-415.265	-1572.254	-1871.123	1538.315	-361.219	189.604	1248.187	-619.751	510.956	0	-258.962	24.448	-810.822	557.657	473.073	19.162	-292.057	-231.244	862.513	1024.749	-229.380	-648.403	240.435	-1588.687	-1765.908	-609.357	-103.266	1347.317	-1407.080	-2102.985	-1158.043	-499.631	-844.367	-1779.609	-3035.801	-1986.954	-1932.825	-2304.397	-2586.992	-1096.825	-2035.492	-2943.325
COM-2	210.373	-149.055	-156.303	-1313.292	-1612.160	1797.277	-102.257	448.566	1507.149	-360.789	769.919	258.962	0	283.411	-551.860	816.619	732.035	278.124	-33.094	27.719	1121.475	1283.711	29.583	-389.441	499.397	-1329.725	-1506.946	-350.394	155.696	1606.280	-1148.118	-1844.023	-899.081	-240.669	-585.405	-1520.647	-2776.839	-1727.992	-1673.863	-2045.435	-2328.030	-837.863	-1776.530	-2684.363
COM-7	-73.037	-432.466	-439.714	-1596.702	-1895.571	1513.866	-385.667	165.155	1223.738	-644.199	486.508	-24.448	-283.411	0	-835.271	533.208	448.624	-5.286	-316.505	-255.692	838.065	1000.300	-253.828	-672.852	215.986	-1613.135	-1790.356	-633.805	-127.715	1322.869	-1431.529	-2127.434	-1182.491	-524.079	-868.815	-1804.057	-3060.249	-2011.402	-1957.274	-2328.845	-2611.440	-1121.274	-2059.940	-2967.774
RES-1	762.233	402.805	395.557	-761.432	-1060.300	2349.137	449.603	1000.426	2059.009	191.071	1321.779	810.822	551.860	835.271	0	1368.479	1283.895	829.984	518.766	579.579	1673.335	1835.571	581.443	162.419	1051.257	-777.865	-955.085	201.466	707.556	2158.140	-596.258	-1292.163	-347.220	311.191	-33.545	-968.787	-2224.978	-1176.132	-1122.003	-1493.574	-1776.170	-286.003	-1224.670	-2132.503
COM-5	-606.246	-965.674	-972.922	-2129.911	-2428.779	980.658	-918.876	-368.053	690.530	-1177.408	-46.701	-557.657	-816.619	-533.208	-1368.479	0	-84.584	-538.495	-849.713	-788.901	304.856	467.092	-787.036	-1206.060	-317.222	-2146.344	-2323.565	-1167.013	-660.923	789.661	-1964.737	-2660.642	-1715.700	-1057.288	-1402.024	-2337.266	-3593.458	-2544.611	-2490.482	-2862.054	-3144.649	-1654.482	-2593.149	-3500.982
IND-5	-521.662	-881.090	-888.338	-2045.327	-2344.195	1065.242	-834.292	-283.469	775.114	-1092.824	37.883	-473.073	-732.035	-448.624	-1283.895	84.584	0	-453.911	-765.129	-704.317	389.440	551.676	-702.452	-1121.476	-232.638	-2061.760	-2238.981	-1082.429	-576.339	874.245	-1880.153	-2576.058	-1631.116	-972.704	-1317.440	-2252.682	-3508.874	-2460.027	-2405.898	-2777.470	-3060.065	-1569.898	-2508.565	-3416.398
IND-2	-67.751	-427.180	-434.428	-1591.416	-1890.285	1519.153	-380.381	170.442	1229.025	-638.913	491.794	-19.162	-278.124	5.286	-829.984	538.495	453.911	0	-311.219	-250.406	843.351	1005.587	-248.542	-667.565	221.273	-1607.849	-1785.070	-628.519	-122.428	1328.155	-1426.242	-2122.148	-1177.205	-518.793	-863.529	-1798.771	-3054.963	-2006.116	-1951.988	-2323.559	-2606.154	-1115.988	-2054.654	-2962.488
OPEN-5	243.468	-115.961	-123.209	-1280.197	-1579.066	1830.372	-69.162	481.660	1540.244	-327.694	803.013	292.057	33.094	316.505	-518.766	849.713	765.129	311.219	0	60.813	1154.570	1316.805	62.677	-356.346	532.491	-1296.630	-1473.851	-317.300	188.791	1639.374	-1115.024	-1810.929	-865.986	-207.574	-552.310	-1487.552	-2743.744	-1694.897	-1640.769	-2012.340	-2294.935	-804.769	-1743.435	-2651.269
IND-4	182.655	-176.774	-184.022	-1341.010	-1639.879	1769.559	-129.975	420.847	1479.431	-388.507	742.200	231.244	-27.719	255.692	-579.579	788.901	704.317	250.406	-60.813	0	1093.757	1255.992	1.864	-417.159	471.678	-1357.443	-1534.664	-378.113	127.978	1578.561	-1175.836	-1871.742	-926.799	-268.387	-613.123	-1548.365	-2804.557	-1755.710	-1701.582	-2073.153	-2355.748	-865.582	-1804.248	-2712.082
COM-1	-911.102	-1270.531	-1277.778	-2434.767	-2733.636	675.802	-1223.732	-672.909	385.674	-1482.264	-351.557	-862.513	-1121.475	-838.065	-1673.335	-304.856	-389.440	-843.351	-1154.570	-1093.757	0	162.236	-1091.892	-1510.916	-622.078	-2451.200	-2628.421	-1471.870	-965.779	484.804	-2269.593	-2965.498	-2020.556	-1362.144	-1706.880	-2642.122	-3898.314	-2849.467	-2795.338	-3166.910	-3449.505	-1959.338	-2898.005	-3805.838
IND-3	-1073.338	-1432.766	-1440.014	-2597.003	-2895.871	513.566	-1385.968	-835.145	223.438	-1644.500	-513.792	-1024.749	-1283.711	-1000.300	-1835.571	-467.092	-551.676	-1005.587	-1316.805	-1255.992	-162.236	0	-1254.128	-1673.152	-784.314	-2613.436	-2790.656	-1634.105	-1128.015	322.569	-2431.829	-3127.734	-2182.791	-1524.380	-1869.116	-2804.358	-4060.549	-3011.703	-2957.574	-3329.146	-3611.741	-2121.574	-3060.241	-3968.074
IND-1	180.791	-178.638	-185.886	-1342.875	-1641.743	1767.694	-131.840	418.983	1477.566	-390.372	740.336	229.380	-29.583	253.828	-581.443	787.036	702.452	248.542	-62.677	-1.864	1091.892	1254.128	0	-419.024	469.814	-1359.308	-1536.528	-379.977	126.113	1576.697	-1177.701	-1873.606	-928.663	-270.252	-614.988	-1550.230	-2806.421	-1757.575	-1703.446	-2075.017	-2357.613	-867.446	-1806.113	-2713.946
HWY-6	599.814	240.385	233.138	-923.851	-1222.719	2186.718	287.184	838.007	1896.590	28.652	1159.359	648.403	389.441	672.852	-162.419	1206.060	1121.476	667.565	356.346	417.159	1510.916	1673.152	419.024	0	888.838	-940.284	-1117.505	39.047	545.137	1995.721	-758.677	-1454.582	-509.640	148.772	-195.964	-1131.206	-2387.398	-1338.551	-1284.422	-1655.994	-1938.589	-448.422	-1387.089	-2294.922
COM-4	-289.024	-648.452	-655.700	-1812.689	-2111.557	1297.880	-601.654	-50.831	1007.752	-860.186	270.522	-240.435	-499.397	-215.986	-1051.257	317.222	232.638	-221.273	-532.491	-471.678	622.078	784.314	-469.814	-888.838	0	-1829.122	-2006.342	-849.791	-343.701	1106.883	-1647.515	-2343.420	-1398.477	-740.066	-1084.802	-2020.044	-3276.235	-2227.389	-2173.260	-2544.831	-2827.427	-1337.260	-2275.927	-3183.760
HWY-2	1540.098	1180.669	1173.422	16.433	-282.436	3127.002	1227.468	1778.291	2836.874	968.936	2099.643	1588.687	1329.725	1613.135	777.865	2146.344	2061.760	1607.849	1296.630	1357.443	2451.200	2613.436	1359.308	940.284	1829.122	0	-177.221	979.330	1485.421	2936.004	181.607	-514.298	430.644	1089.056	744.320	-190.922	-1447.114	-398.267	-344.138	-715.710	-998.305	491.862	-446.805	-1354.638
RES-4	1717.319	1357.890	1350.642	193.654	-105.215	3304.223	1404.689	1955.511	3014.095	1146.157	2276.864	1765.908	1506.946	1790.356	955.085	2323.565	2238.981	1785.070	1473.851	1534.664	2628.421	2790.656	1536.528	1117.505	2006.342	177.221	0	1156.551	1662.642	3113.225	358.828	-337.078	607.865	1266.277	921.541	-13.701	-1269.893	-221.046	-166.918	-538.489	-821.084	669.082	-269.584	-1177.418
COM-9	560.768	201.339	194.091	-962.897	-1261.766	2147.672	248.138	798.960	1857.543	-10.394	1120.313	609.357	350.394	633.805	-201.466	1167.013	1082.429	628.519	317.300	378.113	1471.870	1634.105	379.977	-39.047	849.791	-979.330	-1156.551	0	506.090	1956.674	-797.724	-1493.629	-548.686	109.726	-235.010	-1170.252	-2426.444	-1377.597	-1323.469	-1695.040	-1977.635	-487.469	-1426.135	-2333.969
IND-7	54.677	-304.752	-311.999	-1468.988	-1767.856	1641.581	-257.953	292.870	1351.453	-516.485	614.222	103.266	-155.696	127.715	-707.556	660.923	576.339	122.428	-188.791	-127.978	965.779	1128.015	-126.113	-545.137	343.701	-1485.421	-1662.642	-506.090	0	1450.584	-1303.814	-1999.719	-1054.777	-396.365	-741.101	-1676.343	-2932.535	-1883.688	-1829.559	-2201.131	-2483.726	-993.559	-1932.226	-2840.059
HWY-3	-1395.906	-1755.335	-1762.583	-2919.571	-3218.440	190.997	-1708.536	-1157.714	-99.131	-1967.068	-836.361	-1347.317	-1606.280	-1322.869	-2158.140	-789.661	-874.245	-1328.155	-1639.374	-1578.561	-484.804	-322.569	-1576.697	-1995.721	-1106.883	-2936.004	-3113.225	-1956.674	-1450.584	0	-2754.398	-3450.303	-2505.360	-1846.948	-2191.685	-3126.926	-4383.118	-3334.271	-3280.143	-3651.714	-3934.310	-2444.143	-3382.810	-4290.643
RES-5	1358.491	999.063	991.815	-165.174	-464.042	2945.395	1045.861	1596.684	2655.267	787.329	1918.036	1407.080	1148.118	1431.529	596.258	1964.737	1880.153	1426.242	1115.024	1175.836	2269.593	2431.829	1177.701	758.677	1647.515	-181.607	-358.828	797.724	1303.814	2754.398	0	-695.905	249.037	907.449	562.713	-372.529	-1628.721	-579.874	-525.745	-897.317	-1179.912	310.255	-628.412	-1536.245
RES-9	2054.396	1694.968	1687.720	530.731	231.863	3641.300	1741.766	2292.589	3351.172	1483.234	2613.942	2102.985	1844.023	2127.434	1292.163	2660.642	2576.058	2122.148	1810.929	1871.742	2965.498	3127.734	1873.606	1454.582	2343.420	514.298	337.078	1493.629	1999.719	3450.303	695.905	0	944.943	1603.354	1258.618	323.376	-932.815	116.031	170.160	-201.411	-484.007	1006.160	67.493	-840.340
IND-9	1109.454	750.025	742.777	-414.211	-713.080	2696.358	796.824	1347.646	2406.230	538.292	1668.999	1158.043	899.081	1182.491	347.220	1715.700	1631.116	1177.205	865.986	926.799	2020.556	2182.791	928.663	509.640	1398.477	-430.644	-607.865	548.686	1054.777	2505.360	-249.037	-944.943	0	658.412	313.676	-621.566	-1877.758	-828.911	-774.783	-1146.354	-1428.949	61.217	-877.449	-1785.283
OPEN-4	451.042	91.613	84.366	-1072.623	-1371.492	2037.946	138.412	689.235	1747.818	-120.120	1010.587	499.631	240.669	524.079	-311.191	1057.288	972.704	518.793	207.574	268.387	1362.144	1524.380	270.252	-148.772	740.066	-1089.056	-1266.277	-109.726	396.365	1846.948	-907.449	-1603.354	-658.412	0	-344.736	-1279.978	-2535.170	-1487.323	-1433.194	-1804.766	-2087.361	-597.194	-1535.861	-2443.694
HWY-7	795.778	436.349	429.102	-727.887	-1026.756	2382.682	483.148	1033.971	2092.554	224.616	1355.323	844.367	585.405	868.815	33.545	1402.024	1317.440	863.529	552.310	613.123	1706.880	1869.116	614.988	195.964	1084.802	-744.320	-921.541	235.010	741.101	2191.685	-562.713	-1258.618	-313.676	344.736	0	-935.242	-2191.434	-1142.587	-1088.458	-1460.030	-1742.625	-252.458	-1191.125	-2098.958
RES-6	1731.020	1371.591	1364.344	207.355	-91.514	3317.924	1418.390	1969.213	3027.796	1159.858	2290.565	1779.609	1520.647	1804.057	968.787	2337.266	2252.682	1798.771	1487.552	1548.365	2642.122	2804.358	1550.230	1131.206	2020.044	190.922	13.701	1170.252	1676.343	3126.926	372.529	-323.376	621.566	1279.978	935.242	0	-1256.192	-207.345	-153.216	-524.788	-807.383	682.784	-255.883	-1163.716
IND-6	2987.212	2627.783	2620.535	1463.547	1164.678	4574.116	2674.582	3225.404	4283.988	2416.050	3546.757	3035.801	2776.839	3060.249	2224.978	3593.458	3508.874	3054.963	2743.744	2804.557	3898.314	4060.549	2806.421	2387.398	3276.235	1447.114	1269.893	2426.444	2932.535	4383.118	1628.721	932.815	1877.758	2535.170	2191.434	1256.192	0	1048.847	1102.975	731.404	448.809	1938.975	1000.309	92.475
COM-6	1938.365	1578.936	1571.689	414.700	115.831	3525.269	1625.735	2176.558	3235.141	1367.203	2497.910	1986.954	1727.992	2011.402	1176.132	2544.611	2460.027	2006.116	1694.897	1755.710	2849.467	3011.703	1757.575	1338.551	2227.389	398.267	221.046	1377.597	1883.688	3334.271	579.874	-116.031	828.911	1487.323	1142.587	207.345	-1048.847	0	54.129	-317.443	-600.038	890.129	-48.538	-956.371
COM-8	1884.236	1524.808	1517.560	360.571	61.703	3471.140	1571.606	2122.429	3181.012	1313.074	2443.782	1932.825	1673.863	1957.274	1122.003	2490.482	2405.898	1951.988	1640.769	1701.582	2795.338	2957.574	1703.446	1284.422	2173.260	344.138	166.918	1323.469	1829.559	3280.143	525.745	-170.160	774.783	1433.194	1088.458	153.216	-1102.975	-54.129	0	-371.571	-654.167	836.000	-102.667	-1010.500
OPEN-9	2255.808	1896.379	1889.131	732.143	433.274	3842.712	1943.178	2494.000	3552.584	1684.646	2815.353	2304.397	2045.435	2328.845	1493.574	2862.054	2777.470	2323.559	2012.340	2073.153	3166.910	3329.146	2075.017	1655.994	2544.831	715.710	538.489	1695.040	2201.131	3651.714	897.317	201.411	1146.354	1804.766	1460.030	524.788	-731.404	317.443	371.571	0	-282.595	1207.571	268.905	-638.929
RES-8	2538.403	2178.974	2171.727	1014.738	715.869	4125.307	2225.773	2776.596	3835.179	1967.241	3097.948	2586.992	2328.030	2611.440	1776.170	3144.649	3060.065	2606.154	2294.935	2355.748	3449.505	3611.741	2357.613	1938.589	2827.427	998.305	821.084	1977.635	2483.726	3934.310	1179.912	484.007	1428.949	2087.361	1742.625	807.383	-448.809	600.038	654.167	282.595	0	1490.167	551.500	-356.333
IND-8	1048.236	688.808	681.560	-475.429	-774.297	2635.140	735.606	1286.429	2345.012	477.074	1607.782	1096.825	837.863	1121.274	286.003	1654.482	1569.898	1115.988	804.769	865.582	1959.338	2121.574	867.446	448.422	1337.260	-491.862	-669.082	487.469	993.559	2444.143	-310.255	-1006.160	-61.217	597.194	252.458	-682.784	-1938.975	-890.129	-836.000	-1207.571	-1490.167	0	-938.667	-1846.500
HWY-1	1986.903	1627.474	1620.227	463.238	164.369	3573.807	1674.273	2225.096	3283.679	1415.741	2546.448	2035.492	1776.530	2059.940	1224.670	2593.149	2508.565	2054.654	1743.435	1804.248	2898.005	3060.241	1806.113	1387.089	2275.927	446.805	269.584	1426.135	1932.226	3382.810	628.412	-67.493	877.449	1535.861	1191.125	255.883	-1000.309	48.538	102.667	-268.905	-551.500	938.667	0	-907.833
OPEN-6	2894.736	2535.308	2528.060	1371.071	1072.203	4481.640	2582.106	3132.929	4191.512	2323.574	3454.282	2943.325	2684.363	2967.774	2132.503	3500.982	3416.398	2962.488	2651.269	2712.082	3805.838	3968.074	2713.946	2294.922	3183.760	1354.638	1177.418	2333.969	2840.059	4290.643	1536.245	840.340	1785.283	2443.694	2098.958	1163.716	-92.475	956.371	1010.500	638.929	356.333	1846.500	907.833	0

p-values:

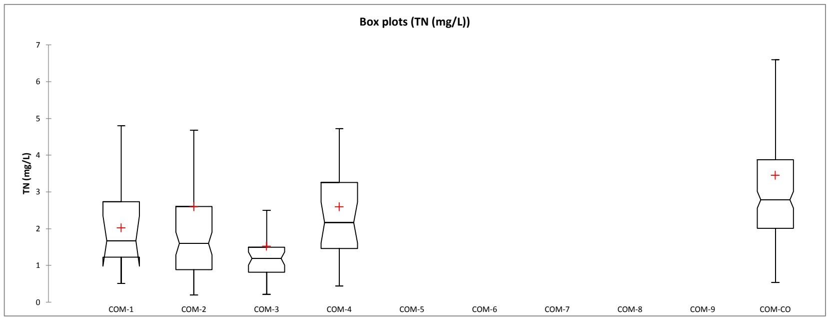
	COM-CO	IND-CO	HWY-CO	OPEN-CC	RES-CO	OPEN-1	COM-3	RES-7	RES-3	RES-2	HWY-5	OPEN-2	COM-2	COM-7	RES-1	COM-5	IND-5	IND-2	OPEN-5	IND-4	COM-1	IND-3	IND-1	HWY-6	COM-4	HWY-2	RES-4	COM-9	IND-7	HWY-3	RES-5	RES-9	IND-9	OPEN-4	HWY-7	RES-6	IND-6	COM-6	COM-8	OPEN-9	RES-8	IND-8	HWY-1	OPEN-6
COM-CO	1	0.326	0.412	0.063	< 0.0001	< 0.0001	0.158	0.172	< 0.0001	< 0.0001	0.003	0.842	0.174	0.784	< 0.0001	0.011	0.032	0.692	0.403	0.582	< 0.0001	< 0.0001	0.518	0.008	0.379	< 0.0001	< 0.0001	0.308	0.844	0.017	< 0.0001	< 0.0001	0.017	0.386	0.080	< 0.0001	< 0.0001	< 0.0001	0.021	0.006	< 0.0001	0.625	0.110	0.057
IND-CO	0.326	1	0.989	0.185	< 0.0001	< 0.0001	0.904	0.099	< 0.0001	0.541	0.013	0.309	0.673	0.297	0.258	0.015	0.028	0.236	0.788	0.700	0.001	0.000	0.673	0.537	0.156	0.002	0.001	0.751	0.470	0.008	0.008	< 0.0001	0.182	0.881	0.432	0.001	< 0.0001	0.002	0.083	0.031	0.001	0.751	0.204	0.102
HWY-CO	0.412	0.989	1	0.206	0.001	< 0.0001	0.907	0.173	0.000	0.635	0.039	0.383	0.720	0.367	0.367	0.040	0.061	0.326	0.806	0.726	0.004	0.002	0.707	0.617	0.211	0.010	0.005	0.777	0.527	0.014	0.029	0.001	0.230	0.899	0.483	0.007	< 0.0001	0.005	0.097	0.039	0.002	0.755	0.215	0.108
OPEN-CO	0.063	0.185	0.206	1	0.715	0.000	0.144	0.031	0.001	0.240	0.011	0.060	0.106	0.058	0.350	0.011	0.014	0.051	0.132	0.121	0.003	0.002	0.112	0.265	0.036	0.984	0.818	0.321	0.082	0.003	0.841	0.530	0.654	0.260	0.428	0.807	0.087	0.640	0.753	0.522	0.300	0.835	0.754	0.424
RES-CO	< 0.0001	< 0.0001	0.001	0.715	1	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.178	0.687	0.022	< 0.0001	< 0.0001	0.021	0.410	0.126	0.009	0.025	0.755	0.000	0.764	0.940	0.597	0.208	0.718	0.895	0.480
OPEN-1	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	1	< 0.0001	< 0.0001	0.167	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.000	0.000	< 0.0001	< 0.0001	< 0.0001	0.003	0.061	< 0.0001	< 0.0001	0.000	< 0.0001	< 0.0001	0.000	< 0.0001	0.750	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.220	0.004	0.003
COM-3	0.158	0.904	0.907	0.144	< 0.0001	< 0.0001	1	0.010	< 0.0001	0.166	0.000	0.189	0.608	0.191	0.028	0.001	0.002	0.074	0.828	0.714	< 0.0001	< 0.0001	0.668	0.265	0.088	< 0.0001	< 0.0001	0.660	0.397	0.004	< 0.0001	< 0.0001	0.098	0.796	0.307	< 0.0001	< 0.0001	< 0.0001	0.058	0.019	0.000	0.732	0.180	0.090
RES-7	0.172	0.099	0.173	0.031	< 0.0001	< 0.0001	0.010	1	< 0.0001	< 0.0001	0.075	0.427	0.002	0.528	< 0.0001	0.116	0.232	0.296	0.093	0.199	0.000	0.000	0.128	0.000	0.876	< 0.0001	< 0.0001	0.145	0.282	0.047	< 0.0001	< 0.0001	0.003	0.183	0.022	< 0.0001	< 0.0001	< 0.0001	0.009	0.002	< 0.0001	0.548	0.073	0.039
RES-3	< 0.0001	< 0.0001	0.000	0.001	< 0.0001	0.167	< 0.0001	< 0.0001	1	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.002	0.001	< 0.0001	< 0.0001	< 0.0001	0.023	0.334	< 0.0001	< 0.0001	0.002	< 0.0001	< 0.0001	0.001	< 0.0001	0.865	< 0.0001	< 0.0001	< 0.0001	0.001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.274	0.008	0.006
RES-2	< 0.0001	0.541	0.635	0.240	< 0.0001	< 0.0001	0.166	< 0.0001	< 0.0001	1	< 0.0001	0.004	0.000	0.007	0.076	< 0.0001	< 0.0001	< 0.0001	0.218	0.209	< 0.0001	< 0.0001	0.124	0.880	0.005	< 0.0001	< 0.0001	0.985	0.039	0.001	< 0.0001	< 0.0001	0.230	0.813	0.609	< 0.0001	< 0.0001	0.000	0.105	0.038	0.000	0.824	0.252	0.125
HWY-5	0.003	0.013	0.039	0.011	< 0.0001	< 0.0001	0.000	0.075	< 0.0001	< 0.0001	1	0.040	< 0.0001	0.072	< 0.0001	0.848	0.878	0.006	0.006	0.027	0.064	0.038	0.009	< 0.0001	0.415	< 0.0001	< 0.0001	0.042	0.029	0.155	< 0.0001	< 0.0001	0.000	0.053	0.003	< 0.0001	< 0.0001	< 0.0001	0.003	0.001	< 0.0001	0.453	0.040	0.023
OPEN-2	0.842	0.309	0.383	0.060	< 0.0001	< 0.0001	0.189	0.427	< 0.0001	0.004	0.040	1	0.249	0.938	0.000	0.054	0.106	0.935	0.382	0.532	0.000	0.000	0.479	0.020	0.512	< 0.0001	< 0.0001	0.288	0.748	0.027	< 0.0001	< 0.0001	0.019	0.360	0.081	< 0.0001	< 0.0001	< 0.0001	0.021	0.006	< 0.0001	0.610	0.104	0.054
COM-2	0.174	0.673	0.720	0.106	< 0.0001	< 0.0001	0.608	0.002	< 0.0001	0.000	< 0.0001	0.249	1	0.255	< 0.0001	0.000	0.001	0.050	0.904	0.930	< 0.0001	< 0.0001	0.910	0.055	0.112	< 0.0001	< 0.0001	0.518	0.549	0.005	< 0.0001	< 0.0001	0.048	0.638	0.188	< 0.0001	< 0.0001	< 0.0001	0.040	0.012	< 0.0001	0.696	0.151	0.077
COM-7	0.784	0.297	0.367	0.058	< 0.0001	< 0.0001	0.191	0.528	< 0.0001	0.007	0.072	0.938	0.255	1	0.001	0.084	0.150	0.984	0.366	0.506	0.002	0.001	0.457	0.024	0.572	< 0.0001	< 0.0001	0.278	0.706	0.032	< 0.0001	< 0.0001	0.019	0.346	0.079	< 0.0001	< 0.0001	< 0.0001	0.020	0.006	< 0.0001	0.602	0.101	0.053
RES-1	< 0.0001	0.258	0.367	0.350	< 0.0001	< 0.0001	0.028	< 0.0001	< 0.0001	0.076	< 0.0001	0.000	< 0.0001	0.001	1	< 0.0001	< 0.0001	< 0.0001	0.062	0.070	< 0.0001	< 0.0001	0.029	0.434	0.001	< 0.0001	< 0.0001	0.711	0.007	0.000	0.001	< 0.0001	0.447	0.544	0.940	0.001	< 0.0001	0.002	0.168	0.067	0.002	0.894	0.323	0.160
COM-5	0.011	0.015	0.040	0.011	< 0.0001	0.000	0.001	0.116	0.002	< 0.0001	0.848	0.054	0.000	0.084	< 0.0001	1	0.769	0.020	0.010	0.031	0.207	0.106	0.014	< 0.0001	0.383	< 0.0001	< 0.0001	0.041	0.038	0.193	< 0.0001	< 0.0001	0.000	0.052	0.004	< 0.0001	< 0.0001	< 0.0001	0.003	0.001	< 0.0001	0.441	0.038	0.022
IND-5	0.032	0.028	0.061	0.014	< 0.0001	0.000	0.002	0.232	0.001	< 0.0001	0.878	0.106	0.001	0.150	< 0.0001	0.769	1	0.053	0.021	0.056	0.111	0.058	0.030	< 0.0001	0.525	< 0.0001	< 0.0001	0.059	0.072	0.150	< 0.0001	< 0.0001	0.001	0.074	0.006	< 0.0001	< 0.0001	< 0.0001	0.004	0.001	< 0.0001	0.465	0.045	0.025
IND-2	0.692	0.236	0.326	0.051	< 0.0001	< 0.0001	0.074	0.296	< 0.0001	< 0.0001	0.006	0.935	0.050	0.984	< 0.0001	0.020	0.053	1	0.274	0.442	< 0.0001	< 0.0001	0.363	0.002	0.493	< 0.0001	< 0.0001	0.250	0.650	0.023	< 0.0001	< 0.0001	0.011	0.315	0.056	< 0.0001	< 0.0001	< 0.0001	0.017	0.004	< 0.0001	0.602	0.098	0.051
OPEN-5	0.403	0.788	0.806	0.132	< 0.0001	< 0.0001	0.828	0.093	< 0.0001	0.218	0.006	0.382	0.904	0.366	0.062	0.010	0.021	0.274	1	0.880	< 0.0001	< 0.0001	0.862	0.265	0.183	< 0.0001	< 0.0001	0.594	0.599	0.009	0.000	< 0.0001	0.094	0.715	0.278	< 0.0001	< 0.0001	0.000	0.054	0.018	0.000	0.709	0.167	0.084
IND-4	0.582	0.700	0.726	0.121	< 0.0001	< 0.0001	0.714	0.199	< 0.0001	0.209	0.027	0.532	0.930	0.506	0.070	0.031	0.056	0.442	0.880	1	0.001	0.001	0.996	0.242	0.273	< 0.0001	< 0.0001	0.539	0.744	0.015	0.001	< 0.0001	0.087	0.649	0.250	0.000	< 0.0001	0.000	0.049	0.016	0.000	0.689	0.156	0.079
COM-1	< 0.0001	0.001	0.004	0.003	< 0.0001	0.003	< 0.0001	0.000	0.023	< 0.0001	0.064	0.000	< 0.0001	0.002	< 0.0001	0.207	0.111	< 0.0001	< 0.0001	0.001	1	0.507	0.000	< 0.0001	0.060	< 0.0001	< 0.0001	0.008	0.001	0.409	< 0.0001	< 0.0001	< 0.0001	0.009	0.000	< 0.0001	< 0.0001	< 0.0001	0.001	0.000	< 0.0001	0.361	0.020	0.012
IND-3	< 0.0001	0.000	0.002	0.002	< 0.0001	0.061	< 0.0001	0.000	0.334	< 0.0001	0.038	0.000	< 0.0001	0.001	< 0.0001	0.106	0.058	< 0.0001	< 0.0001	0.001	0.507	1	0.000	< 0.0001	0.032	< 0.0001	< 0.0001	0.004	0.000	0.596	< 0.0001	< 0.0001	< 0.0001	0.005	0.000	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	< 0.0001	0.324	0.015	0.009
IND-1	0.518	0.673	0.707	0.112	< 0.0001	< 0.0001	0.668	0.128	< 0.0001	0.124	0.009	0.479	0.910	0.457	0.029	0.014	0.030	0.363	0.862	0.996	0.000	0.000	1	0.176	0.230	< 0.0001	< 0.0001	0.520	0.718	0.011	< 0.0001	< 0.0001	0.069	0.631	0.221	< 0.0001	< 0.0001	< 0.0001	0.044	0.014	< 0.0001	0.687	0.152	0.077
HWY-6	0.008	0.537	0.617	0.265	< 0.0001	< 0.0001	0.265	0.000	< 0.0001	0.880	< 0.0001	0.020	0.055	0.024	0.434	< 0.0001	< 0.0001	0.002	0.265	0.242	< 0.0001	< 0.0001	0.176	1	0.012	0.000	0.000	0.945	0.076	0.001	0.001	< 0.0001	0.291	0.782	0.679	0.000	< 0.0001	0.001	0.121	0.046	0.001	0.835	0.267	0.132
COM-4	0.379	0.156	0.211	0.036	< 0.0001	0.000	0.088	0.876	0.002	0.005	0.415	0.512	0.112	0.572	0.001	0.383	0.525	0.493	0.183	0.273	0.060	0.032	0.230	0.012	1	< 0.0001	< 0.0001	0.167	0.378	0.087	< 0.0001	< 0.0001	0.009	0.208	0.041	< 0.0001	< 0.0001	< 0.0001	0.012	0.003	< 0.0001	0.536	0.074	0.039
HWY-2	< 0.0001	0.002	0.010	0.984	0.178	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	1	0.521	0.080	< 0.0001	< 0.0001	0.408	0.081	0.364	0.040	0.110	0.534	< 0.0001	0.314	0.676	0.385	0.083	0.819	0.720	0.373
RES-4	< 0.0001	0.001	0.005	0.818	0.687	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	0.521	1	0.046	< 0.0001	< 0.0001	0.183	0.312	0.224	0.022	0.061	0.968	0.000	0.603	0.842	0.521	0.168	0.756	0.830	0.441
COM-9	0.308	0.751	0.777	0.321	0.022	0.000	0.660	0.145	0.001	0.985	0.042	0.288	0.518	0.278	0.711	0.041	0.059	0.250	0.594	0.539	0.008	0.004	0.520	0.945	0.167	0.080	0.046	1	0.390	0.012	0.151	0.011	0.431	0.881	0.734	0.049	< 0.0001	0.033	0.172	0.080	0.010	0.825	0.289	0.146
IND-7	0.844	0.470	0.527	0.082	< 0.0001	< 0.0001	0.397	0.282	< 0.0001	0.039	0.029	0.748	0.549	0.706	0.007	0.038	0.072	0.650	0.599	0.744	0.001	0.000	0.718	0.076	0.378	< 0.0001	< 0.0001	0.390	1	0.020	< 0.0001	< 0.0001	0.038	0.480	0.139	< 0.0001	< 0.0001	< 0.0001	0.030	0.009	< 0.0001	0.645	0.125	0.064
HWY-3	0.017	0.008	0.014	0.003	< 0.0001	0.750	0.004	0.047	0.865	0.001	0.155	0.027	0.005	0.032	0.000	0.193	0.150	0.023	0.009	0.015	0.409	0.596	0.011	0.001	0.087	< 0.0001	< 0.0001	0.012	0.020	1	< 0.0001	< 0.0001	0.001	0.015	0.002	< 0.0001	< 0.0001	< 0.0001	0.001	0.000	< 0.0001	0.270	0.013	0.008
RES-5	< 0.0001	0.008	0.029	0.841	0.021	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.001	< 0.0001	< 0.0001	< 0.0001	0.000	0.001	< 0.0001	< 0.0001	< 0.0001	0.001	< 0.0001	0.408	0.183	0.151	< 0.0001	< 0.0001	1	0.016	0.597	0.084	0.223	0.216	< 0.0001	0.138	0.523	0.275	0.039	0.885	0.614	0.312
RES-9	< 0.0001	< 0.0001	0.001	0.530	0.410	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.081	0.312	0.011	< 0.0001	< 0.0001	0.016	1	0.064	0.004	0.012	0.369	0.011	0.791	0.841	0.812	0.424	0.640	0.957	0.584
IND-9	0.017	0.182	0.230	0.654	0.126	< 0.0001	0.098	0.003	< 0.0001	0.230	0.000	0.019	0.048	0.019	0.447	0.000	0.001	0.011	0.094	0.087	< 0.0001	< 0.0001	0.069	0.291	0.009	0.364	0.224	0.431	0.038	0.001	0.597	0.064	1	0.328	0.615	0.229	0.000	0.149	0.402	0.215	0.044	0.978	0.504	0.258
OPEN-4	0.386	0.881	0.899	0.260	0.009	0.000	0.796	0.183	0.001	0.813	0.053	0.360	0.638	0.346	0.544	0.052	0.074	0.315	0.715	0.649	0.009	0.005	0.631	0.782	0.208	0.040	0.022	0.881	0.480	0.015	0.084	0.004	0.328	1	0.605	0.024	< 0.0001	0.017	0.133	0.058	0.005	0.786	0.250	0.125
HWY-7	0.080	0.432	0.483	0.428	0.025	< 0.0001	0.307	0.022	< 0.0001	0.609	0.003	0.081	0.188	0.079	0.940	0.004	0.006	0.056	0.278	0.250	0.000	0.000	0.221	0.679	0.041	0.110	0.061	0.734	0.139	0.002	0.223	0.012	0.615	0.605	1	0.066	< 0.0001	0.044	0.236	0.112	0.013	0.908	0.363	0.183
RES-6	< 0.0001	0.001	0.007	0.807	0.755	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	0.534	0.968	0.049	< 0.0001	< 0.0001	0.216	0.369	0.229	0.024	0.066	1	0.001	0.642	0.857	0.537	0.187	0.751	0.839	0.449
IND-6	< 0.0001	< 0.0001	< 0.0001	0.087	0.000	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.011	0.000	< 0.0001	< 0.0001	0.001	1	0.021	0.196	0.392	0.467	0.369	0.429	0.952
COM-6	< 0.0001	0.002	0.005	0.640	0.764	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.000	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.002	< 0.0001	< 0.0001	< 0.0001	0.000	0.000	< 0.0001	< 0.0001	< 0.0001	0.001	< 0.0001	0.314	0.603	0.033	< 0.0001	< 0.0001	0.138	0.791	0.149	0.017	0.044	0.642	0.021	1	0.951	0.720	0.364	0.682	0.970	0.539
COM-8	0.021	0.083	0.097	0.753	0.940	< 0.0001	0.058	0.009	< 0.0001	0.105	0.003	0.021	0.040	0.020	0.168	0.003	0.004	0.017	0.054	0.049	0.001	0.000	0.044	0.121	0.012	0.676	0.842	0.172	0.030	0.001	0.523	0.841	0.402	0.133	0.236	0.857	0.196	0.951	1	0.745	0.504	0.715	0.945	0.556
OPEN-9	0.006	0.031	0.039	0.522	0.597	< 0.0001	0.019	0.002	< 0.0001	0.038	0.001	0.006	0.012	0.006	0.067	0.001	0.001	0.004	0.018	0.016	0.000	< 0.0001	0.014	0.046	0.003	0.385	0.521	0.080	0.009	0.000	0.275	0.812	0.215	0.058	0.112	0.537	0.392	0.720	0.745	1	0.773	0.598	0.855	0.710
RES-8	< 0.0001	0.001	0.002	0.300	0.208	< 0.0001	0.000	< 0.0001	< 0.0001	0.000	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.002	< 0.0001	< 0.0001	< 0.0001	0.000	0.000	< 0.0001	< 0.0001	< 0.0001	0.001	< 0.0001	0.083	0.168	0.010	< 0.0001	< 0.0001	0.039	0.424	0.044	0.005	0.013	0.187	0.467	0.364	0.504	0.773	1	0.500	0.684	0.825
IND-8	0.625	0.751	0.755	0.835	0.718	0.220	0.732	0.548	0.274	0.824	0.453	0.610	0.696	0.602	0.894	0.441	0.465	0.602	0.709	0.689	0.361	0.324	0.687	0.835	0.536	0.819	0.756	0.825	0.645	0.270	0.885	0.640	0.978	0.786	0.908	0.751	0.369	0.682	0.715	0.598	0.500	1	0.704	0.481
HWY-1	0.110	0.204	0.215	0.754	0.895	0.004	0.180	0.073	0.008	0.252	0.040	0.104	0.151	0.101	0.323	0.038	0.045	0.098	0.167	0.156	0.020	0.015	0.152	0.267	0.074	0.720	0.830	0.289	0.125	0.013	0.614	0.957	0.504	0.250	0.363	0.839	0.429	0.970	0.945	0.855	0.684	0.704	1	0.642
OPEN-6	0.057	0.102	0.108	0.424	0.480	0.003	0.090	0.039	0.006	0.125	0.023	0.054	0.077	0.053	0.160	0.022	0.025	0.051	0.084	0.079	0.012	0.009	0.077	0.132	0.039	0.373	0.441	0.146	0.064	0.008	0.312	0.584	0.258	0.125	0.183	0.449	0.952	0.539	0.556	0.710	0.825	0.481	0.642	1

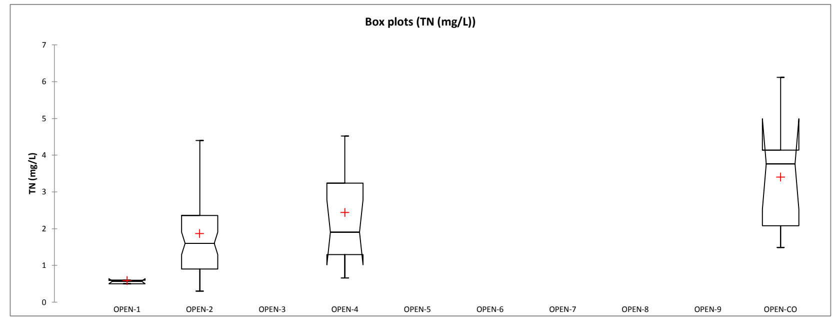
Significant differences:

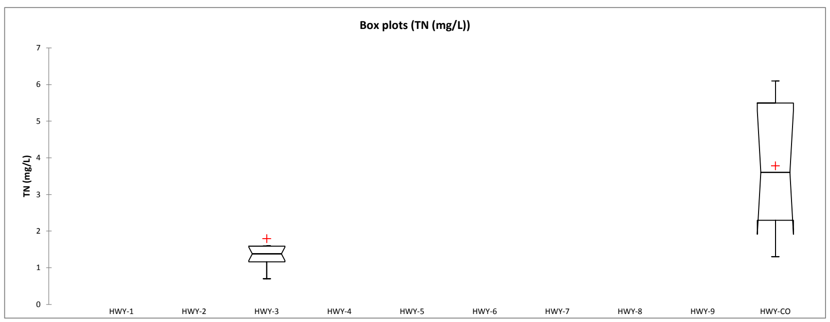
	COM-CO	IND-CO	HWY-CO	OPEN-CC	RES-CO	OPEN-1	COM-3	RES-7	RES-3	RES-2	HWY-5	OPEN-2	COM-2	COM-7	RES-1	COM-5	IND-5	IND-2	OPEN-5	IND-4	COM-1	IND-3	IND-1	HWY-6	COM-4	HWY-2	RES-4	COM-9	IND-7	HWY-3	RES-5	RES-9	IND-9	OPEN-4	HWY-7	RES-6	IND-6	COM-6	COM-8	OPEN-9	RES-8	IND-8	HWY-1	OPEN-6
COM-CO	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
IND-CO	No	No	No	No	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No
HWY-CO	No	No	No	No	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No
OPEN-CO	No	No	No	No	No	Yes	No	Yes	Yes	No	Yes	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	No	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No
RES-CO	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	No	No	No	No	No	No	No
OPEN-1	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
COM-3	No	No	No	No	Yes	Yes	No	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No
RES-7	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	No	Yes	Yes	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
RES-3	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
RES-2	Yes	No	No	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No
HWY-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
OPEN-2	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	No	No	No	No	No	Yes	Yes	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
COM-2	No	No	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
COM-7	No	No	No	No	Yes	Yes	No	No	Yes	Yes	No	No	No	No	Yes	No	No	No	No	No	Yes	Yes	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
RES-1	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	Yes	No	No	No
COM-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
IND-5	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	Yes	No	Yes	No	No	No	Yes	No	No	No	Yes	Yes	No	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
IND-2	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	No	No	No	No	Yes	Yes	No	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
OPEN-5	No	No	No	No	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No
IND-4	No	No	No	No	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
COM-1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
IND-3	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
IND-1	No	No	No	No	Yes	Yes	No	No	Yes	No	Yes	No	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
HWY-6	Yes	No	No	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No
COM-4	No	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	No	No	Yes	No	No	No	No	No	No	Yes	No	Yes	No	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
HWY-2	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	No	No	No	Yes	No	No	Yes	No	No	No	No	No	No	No
RES-4	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	No	No	Yes	No	No	No	No	No	No	No
COM-9	No	No	No	No	Yes	Yes	No	No	Yes	No	Yes	No	No	No	No	Yes	No	No	No	No	Yes	Yes	No	No	No	No	Yes	No	No	Yes	No	Yes	No	No	No	Yes	Yes	Yes	No	No	Yes	No	No	No
IND-7	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
HWY-3	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
RES-5	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	No	Yes	No	No	No	No	Yes	No	No	No	Yes	No	No	No
RES-9	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	No	No	No	No	No	No	No
IND-9	Yes	No	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	No	No	Yes	No	No	No	Yes	Yes	No	No	No	No	No	No	Yes	No	No	No	Yes	No	No	No
OPEN-4	No	No	No	No	Yes	Yes	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	No	Yes	No	No	No	Yes	Yes	Yes	No	No	Yes	No	No	No
HWY-7	No	No	No	No	Yes	Yes	No	Yes	Yes	No	Yes	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	No	No	No	No	Yes	No	Yes	No	No	No	No	Yes	Yes	No	No	Yes	No	No	No
RES-6	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	No	No	Yes	No	No	No	No	No	No	No
IND-6	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No	No
COM-6	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	No	Yes	No	No	No	No	No	No	No
COM-8	Yes	No	No	No	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	No	No	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No
OPEN-9	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No
RES-8	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No
IND-8	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
HWY-1	No	No	No	No	No	Yes	No	No	Yes	No	Yes	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No
OPEN-6	No	No	No	No	No	Yes	No	Yes	Yes	No	Yes	No	No	No	No	Yes	Yes	No	No	No	Yes	Yes	No	No	Yes	No	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No

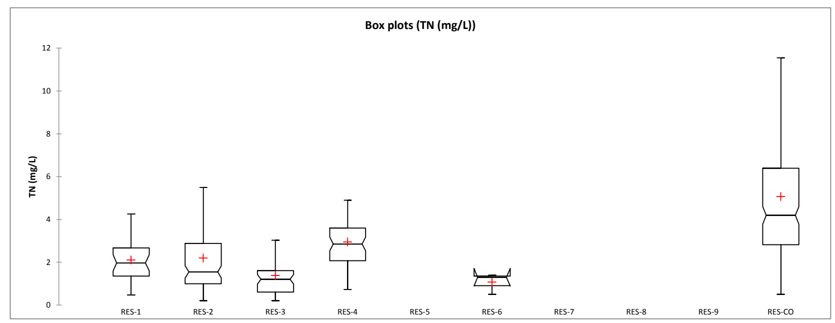
Colorado Total Nitrogen EMC Data and NSQD Data by Land Use
Descriptive statistics (Quantitative data):

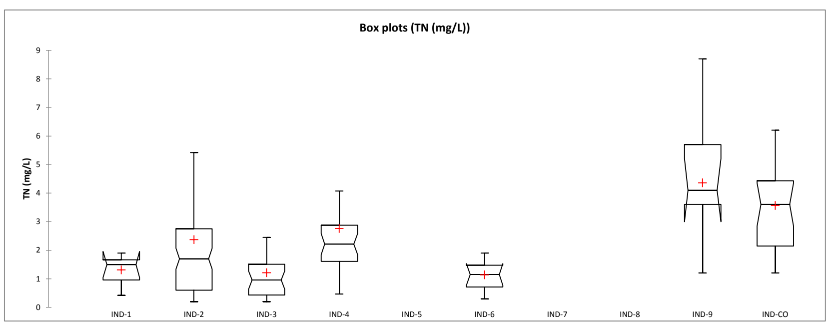
Statistic	COM-1	COM-2	COM-3	COM-4	COM-CO	HWY-3	HWY-CO	IND-1	IND-2	IND-3	IND-4	IND-6	IND-9	IND-CO	OPEN-1	OPEN-2	OPEN-4	OPEN-CO	RES-1	RES-2	RES-3	RES-4	RES-6	RES-CO
No. of observations	12	76	37	26	168	14	9	6	87	28	29	10	9	23	5	57	12	7	30	110	49	56	3	191
Minimum	0.51	0.20	0.22	0.44	0.54	0.70	1.30	0.42	0.20	0.20	0.47	0.30	1.20	1.20	0.28	0.30	0.66	1.49	0.47	0.21	0.20	0.72	0.50	0.51
Maximum	4.80	20.20	8.14	7.20	16.63	3.87	6.10	1.90	16.70	3.83	15.20	1.90	8.70	8.70	0.98	9.40	6.33	6.12	4.25	18.30	8.00	6.31	1.40	22.77
1st Quartile	1.23	0.89	0.82	1.46	2.01	1.16	2.30	0.96	0.61	0.43	1.61	0.71	3.60	2.15	0.50	0.90	1.30	2.08	1.36	1.00	0.61	2.07	0.90	2.83
Median	1.67	1.60	1.19	2.17	2.79	1.38	3.60	1.50	1.70	0.95	2.21	1.15	4.10	3.60	0.57	1.60	1.91	3.76	1.98	1.55	1.20	2.86	1.30	4.19
3rd Quartile	2.73	2.60	1.50	3.26	3.88	1.59	5.50	1.67	2.75	1.51	2.87	1.48	5.70	4.44	0.60	2.36	3.24	4.14	2.67	2.88	1.61	3.60	1.35	6.38
Mean	2.02	2.59	1.52	2.59	3.45	1.79	3.78	1.31	2.36	1.21	2.76	1.13	4.36	3.56	0.59	1.87	2.44	3.40	2.10	2.19	1.38	2.94	1.07	5.06
Variation coefficient	0.60	1.34	0.96	0.66	0.71	0.62	0.45	0.40	1.12	0.82	0.94	0.44	0.50	0.49	0.39	0.81	0.66	0.44	0.48	0.97	0.91	0.43	0.38	0.64
Lower bound on mean (95%)	1.21	1.79	1.03	1.88	3.08	1.13	2.39	0.70	1.79	0.82	1.75	0.76	2.59	2.78	0.27	1.46	1.36	1.90	1.71	1.79	1.01	2.60	-0.16	4.60
Upper bound on mean (95%)	2.82	3.39	2.01	3.30	3.83	2.45	5.17	1.91	2.93	1.59	3.76	1.51	6.12	4.34	0.90	2.27	3.52	4.90	2.48	2.60	1.74	3.28	2.29	5.53











Kruskal-Wallis and Dunn's Procedure Results Comparing Colorado Total Nitrogen EMCs to the NSQD Rain Zones

Summary statistics:

Variable	Observations	Obs. with missing data	Obs. without missing data	Minimum	Maximum	Mean	Std. deviation
COM-CO	168	0	168	0.54	16.63	3.45	2.47
HWY-CO	9	0	9	1.30	6.10	3.78	1.81
IND-CO	23	0	23	1.20	8.70	3.56	1.80
OPEN-CO	7	0	7	1.49	6.12	3.40	1.62
RES-CO	191	0	191	0.51	22.77	5.06	3.24
COM-1	12	0	12	0.51	4.80	2.02	1.27
COM-2	76	0	76	0.20	20.20	2.59	3.49
COM-3	37	0	37	0.22	8.14	1.52	1.47
COM-4	26	0	26	0.44	7.20	2.59	1.76
HWY-3	14	0	14	0.70	3.87	1.79	1.15
IND-1	6	0	6	0.42	1.90	1.31	0.57
IND-2	87	0	87	0.20	16.70	2.36	2.67
IND-3	28	0	28	0.20	3.83	1.21	1.00
IND-4	29	0	29	0.47	15.20	2.76	2.64
IND-6	10	0	10	0.30	1.90	1.13	0.52
IND-9	9	0	9	1.20	8.70	4.36	2.30
OPEN-1	5	0	5	0.28	0.98	0.59	0.25
OPEN-2	57	0	57	0.30	9.40	1.87	1.52
OPEN-4	12	0	12	0.66	6.33	2.44	1.69
RES-1	30	0	30	0.47	4.25	2.10	1.03
RES-2	111	1	110	0.21	18.30	2.19	2.15
RES-3	49	0	49	0.20	8.00	1.38	1.26
RES-4	56	0	56	0.72	6.31	2.94	1.26
RES-6	3	0	3	0.50	1.40	1.07	0.49

Kruskal-Wallis test (TN (mg/L)):

K	350.786
p-value (Two-tailed)	< 0.0001
alpha	0.05

The p-value has been computed using 10000 Monte Carlo simulations. Time elapsed: 1s.
99% confidence interval on the p-value:
] 0.000, 0.000 [

Test interpretation:
H0: The samples come from the same population.
Ha: The samples do not come from the same population.
As the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha.
The risk to reject the null hypothesis H0 while it is true is lower than 0.01%.

Ties have been detected in the data and the appropriate corrections have been applied.

Kruskal-Wallis and Dunn's Procedure Results Comparing Colorado Total Nitrogen EMCs to the NSQD Rain Zones

Multiple pairwise comparisons using Dunn's procedure / Two-tailed test:

Sample	Frequency	Sum of ranks	Mean of ranks	Groups					
OPEN-1	5	410.500	82.100	A					
RES-6	3	614.500	204.833	A					
IND-6	10	2333.500	233.350	A					
IND-3	28	6693.500	239.054	A					
RES-3	49	13243.000	270.265	A	B				
IND-1	6	1676.000	279.333	A	B				
COM-3	37	10675.000	288.514	A	B				
HWY-3	14	5240.500	374.321	A	B	C			
OPEN-2	57	21516.500	377.482		B	C			
IND-2	87	35802.000	411.517			C			
COM-2	76	31879.500	419.467			C			
RES-2	110	46299.000	420.900			C			
COM-1	12	5116.500	426.375			C			
RES-1	30	13837.500	461.250			C			
OPEN-4	12	5865.000	488.750			C	D		
COM-4	26	13426.500	516.404			C	D		
IND-4	29	15136.000	521.931			C	D		
RES-4	56	34645.500	618.670				D	E	
COM-CO	168	107132.500	637.693				D	E	
OPEN-CO	7	4745.000	677.857				D	E	F
IND-CO	23	15794.000	686.696				D	E	F
HWY-CO	9	6391.500	710.167				D	E	F
IND-9	9	6797.000	755.222					E	F
RES-CO	191	150714.500	789.081						F

Kruskal-Wallis and Dunn's Procedure Results Comparing Colorado Total Nitrogen EMCs to the NSQD Rain Zones

Table of pairwise differences:

	COM-CO	HWY-CO	IND-CO	OPEN-CO	RES-CO	COM-1	COM-2	COM-3	COM-4	HWY-3	IND-1	IND-2	IND-3	IND-4	IND-6	IND-9	OPEN-1	OPEN-2	OPEN-4	RES-1	RES-2	RES-3	RES-4	RES-6
COM-CO	0	-72.473	-49.002	-40.164	-151.388	211.318	218.226	349.180	121.290	263.372	358.360	226.176	398.640	115.762	404.343	-117.529	555.593	260.211	148.943	176.443	216.793	367.428	19.024	432.860
HWY-CO	72.473	0	23.471	32.310	-78.914	283.792	290.700	421.653	193.763	335.845	430.833	298.649	471.113	188.236	476.817	-45.056	628.067	332.684	221.417	248.917	289.267	439.901	91.497	505.333
IND-CO	49.002	-23.471	0	8.839	-102.385	260.321	267.229	398.182	170.292	312.374	407.362	275.178	447.642	164.765	453.346	-68.527	604.596	309.213	197.946	225.446	265.796	416.430	68.026	481.862
OPEN-CO	40.164	-32.310	-8.839	0	-111.224	251.482	258.390	389.344	161.453	303.536	398.524	266.340	438.804	155.926	444.507	-77.365	595.757	300.375	189.107	216.607	256.957	407.592	59.188	473.024
RES-CO	151.388	78.914	102.385	111.224	0	362.706	369.614	500.568	272.677	414.760	509.748	377.564	550.028	267.150	555.731	33.859	706.981	411.599	300.331	327.831	368.181	518.816	170.412	584.248
COM-1	-211.318	-283.792	-260.321	-251.482	-362.706	0	6.908	137.861	-90.029	52.054	147.042	14.858	187.321	-95.556	193.025	-328.847	344.275	48.893	-62.375	-34.875	5.475	156.110	-192.295	221.542
COM-2	-218.226	-290.700	-267.229	-258.390	-369.614	-6.908	0	130.954	-96.937	45.146	140.134	7.950	180.414	-102.464	186.117	-335.755	337.367	41.985	-69.283	-41.783	-1.433	149.202	-199.203	214.634
COM-3	-349.180	-421.653	-398.182	-389.344	-500.568	-137.861	-130.954	0	-227.890	-85.808	9.180	-123.004	49.460	-233.418	55.164	-466.709	206.414	-88.969	-200.236	-172.736	-132.386	18.248	-330.156	83.680
COM-4	-121.290	-193.763	-170.292	-161.453	-272.677	90.029	96.937	227.890	0	142.082	237.071	104.887	277.350	-5.527	283.054	-238.818	434.304	138.921	27.654	55.154	95.504	246.139	-102.266	311.571
HWY-3	-263.372	-335.845	-312.374	-303.536	-414.760	-52.054	-45.146	85.808	-142.082	0	94.988	-37.196	135.268	-147.610	140.971	-380.901	292.221	-3.161	-114.429	-86.929	-46.579	104.056	-244.348	169.488
IND-1	-358.360	-430.833	-407.362	-398.524	-509.748	-147.042	-140.134	-9.180	-237.071	-94.988	0	-132.184	40.280	-242.598	45.983	-475.889	197.233	-98.149	-209.417	-181.917	-141.567	9.068	-339.336	74.500
IND-2	-226.176	-298.649	-275.178	-266.340	-377.564	-14.858	-7.950	123.004	-104.887	37.196	132.184	0	172.464	-110.414	178.167	-343.705	329.417	34.035	-77.233	-49.733	-9.383	141.252	-207.152	206.684
IND-3	-398.640	-471.113	-447.642	-438.804	-550.028	-187.321	-180.414	-49.460	-277.350	-135.268	-40.280	-172.464	0	-282.877	5.704	-516.169	156.954	-138.429	-249.696	-222.196	-181.846	-31.212	-379.616	34.220
IND-4	-115.762	-188.236	-164.765	-155.926	-267.150	95.556	102.464	233.418	5.527	147.610	242.598	110.414	282.877	0	288.581	-233.291	439.831	144.449	33.181	60.681	101.031	251.666	-96.739	317.098
IND-6	-404.343	-476.817	-453.346	-444.507	-555.731	-193.025	-186.117	-55.164	-283.054	-140.971	-45.983	-178.167	-5.704	-288.581	0	-521.872	151.250	-144.132	-255.400	-227.900	-187.550	-36.915	-385.320	28.517
IND-9	117.529	45.056	68.527	77.365	-33.859	328.847	335.755	466.709	238.818	380.901	475.889	343.705	516.169	233.291	521.872	0	673.122	377.740	266.472	293.972	334.322	484.957	136.553	550.389
OPEN-1	-555.593	-628.067	-604.596	-595.757	-706.981	-344.275	-337.367	-206.414	-434.304	-292.221	-197.233	-329.417	-156.954	-439.831	-151.250	-673.122	0	-295.382	-406.650	-379.150	-338.800	-188.165	-536.570	-122.733
OPEN-2	-260.211	-332.684	-309.213	-300.375	-411.599	-48.893	-41.985	88.969	-138.921	3.161	98.149	-34.035	138.429	-144.449	144.132	-377.740	295.382	0	-111.268	-83.768	-43.418	107.217	-241.187	172.649
OPEN-4	-148.943	-221.417	-197.946	-189.107	-300.331	62.375	69.283	200.236	-27.654	114.429	209.417	77.233	249.696	-33.181	255.400	-266.472	406.650	111.268	0	27.500	67.850	218.485	-129.920	283.917
RES-1	-176.443	-248.917	-225.446	-216.607	-327.831	34.875	41.783	172.736	-55.154	86.929	181.917	49.733	222.196	-60.681	227.900	-293.972	379.150	83.768	-27.500	0	40.350	190.985	-157.420	256.417
RES-2	-216.793	-289.267	-265.796	-256.957	-368.181	-5.475	1.433	132.386	-95.504	46.579	141.567	9.383	181.846	-101.031	187.550	-334.322	338.800	43.418	-67.850	-40.350	0	150.635	-197.770	216.067
RES-3	-367.428	-439.901	-416.430	-407.592	-518.816	-156.110	-149.202	-18.248	-246.139	-104.056	-9.068	-141.252	31.212	-251.666	36.915	-484.957	188.165	-107.217	-218.485	-190.985	-150.635	0	-348.404	65.432
RES-4	-19.024	-91.497	-68.026	-59.188	-170.412	192.295	199.203	330.156	102.266	244.348	339.336	207.152	379.616	96.739	385.320	-136.553	536.570	241.187	129.920	157.420	197.770	348.404	0	413.836
RES-6	-432.860	-505.333	-481.862	-473.024	-584.248	-221.542	-214.634	-83.680	-311.571	-169.488	-74.500	-206.684	-34.220	-317.098	-28.517	-550.389	122.733	-172.649	-283.917	-256.417	-216.067	-65.432	-413.836	0

p-values:

	COM-CO	HWY-CO	IND-CO	OPEN-CO	RES-CO	COM-1	COM-2	COM-3	COM-4	HWY-3	IND-1	IND-2	IND-3	IND-4	IND-6	IND-9	OPEN-1	OPEN-2	OPEN-4	RES-1	RES-2	RES-3	RES-4	RES-6
COM-CO	1	0.487	0.469	0.732	**< 0.0001**	**0.020**	**< 0.0001**	**< 0.0001**	0.059	**0.002**	**0.005**	**< 0.0001**	**< 0.0001**	0.059	**< 0.0001**	0.259	**< 0.0001**	**< 0.0001**	0.102	**0.003**	**< 0.0001**	**< 0.0001**	0.685	**0.015**
HWY-CO	0.487	1	0.845	0.833	0.447	**0.034**	**0.007**	**0.000**	0.100	**0.010**	**0.007**	**0.005**	**< 0.0001**	0.105	**0.001**	0.754	**0.000**	**0.002**	0.099	**0.031**	**0.006**	**< 0.0001**	0.403	**0.013**
IND-CO	0.469	0.845	1	0.946	0.128	**0.016**	**0.000**	**< 0.0001**	0.051	**0.002**	**0.004**	**0.000**	**< 0.0001**	0.053	**< 0.0001**	0.567	**< 0.0001**	**< 0.0001**	0.068	**0.008**	**0.000**	**< 0.0001**	0.367	**0.010**
OPEN-CO	0.732	0.833	0.946	1	0.342	0.082	**0.032**	**0.002**	0.213	**0.031**	**0.019**	**0.026**	**0.001**	0.224	**0.003**	0.614	**0.001**	**0.014**	0.191	0.090	**0.030**	**0.001**	0.628	**0.024**
RES-CO	**< 0.0001**	0.447	0.128	0.342	1	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	0.744	**< 0.0001**	**< 0.0001**	**0.001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.000**	**0.001**
COM-1	**0.020**	**0.034**	**0.016**	0.082	**< 0.0001**	1	0.942	0.173	0.397	0.664	0.334	0.874	0.074	0.360	0.139	**0.014**	**0.034**	0.613	0.616	0.737	0.953	0.111	**0.047**	0.260
COM-2	**< 0.0001**	**0.007**	**0.000**	**0.032**	**< 0.0001**	0.942	1	**0.032**	0.161	0.610	0.278	0.868	**0.007**	0.123	0.069	**0.002**	**0.016**	0.431	0.464	0.524	0.975	**0.007**	**0.000**	0.231
COM-3	**< 0.0001**	**0.000**	**< 0.0001**	**0.002**	**< 0.0001**	0.173	**0.032**	1	**0.003**	0.369	0.945	**0.040**	0.517	**0.002**	0.611	**< 0.0001**	0.155	0.166	**0.048**	**0.021**	**0.022**	0.783	**< 0.0001**	0.647
COM-4	0.059	0.100	0.051	0.213	**< 0.0001**	0.397	0.161	**0.003**	1	0.159	0.086	0.123	**0.001**	0.946	**0.012**	**0.042**	**0.003**	0.054	0.795	0.499	0.150	**0.001**	0.157	0.093
HWY-3	**0.002**	**0.010**	**0.002**	**0.031**	**< 0.0001**	0.664	0.610	0.369	0.159	1	0.522	0.671	0.175	0.136	0.263	**0.003**	0.065	0.972	0.339	0.378	0.590	0.259	**0.007**	0.381
IND-1	**0.005**	**0.007**	**0.004**	**0.019**	**< 0.0001**	0.334	0.278	0.945	0.086	0.522	1	0.304	0.769	0.076	0.770	**0.003**	0.285	0.452	0.169	0.181	0.267	0.945	**0.009**	0.729
IND-2	**< 0.0001**	**0.005**	**0.000**	**0.026**	**< 0.0001**	0.874	0.868	**0.040**	0.123	0.671	0.304	1	**0.009**	0.091	0.080	**0.001**	**0.019**	0.512	0.410	0.440	0.830	**0.009**	**< 0.0001**	0.248
IND-3	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.001**	**< 0.0001**	0.074	**0.007**	0.517	**0.001**	0.175	0.769	**0.009**	1	**0.000**	0.959	**< 0.0001**	0.288	**0.049**	**0.017**	**0.005**	**0.005**	0.665	**< 0.0001**	0.853
IND-4	0.059	0.105	0.053	0.224	**< 0.0001**	0.360	0.123	**0.002**	0.946	0.136	0.076	0.091	**0.000**	1	**0.010**	**0.045**	**0.003**	**0.037**	0.751	0.444	0.112	**0.000**	0.165	0.086
IND-6	**< 0.0001**	**0.001**	**< 0.0001**	**0.003**	**< 0.0001**	0.139	0.069	0.611	**0.012**	0.263	0.770	0.080	0.959	**0.010**	1	**0.000**	0.364	0.167	0.050	**0.040**	0.062	0.727	**0.000**	0.887
IND-9	0.259	0.754	0.567	0.614	0.744	**0.014**	**0.002**	**< 0.0001**	**0.042**	**0.003**	**0.003**	**0.001**	**< 0.0001**	**0.045**	**0.000**	1	**< 0.0001**	**0.001**	**0.047**	**0.011**	**0.002**	**< 0.0001**	0.212	**0.007**
OPEN-1	**< 0.0001**	**0.000**	**< 0.0001**	**0.001**	**< 0.0001**	**0.034**	**0.016**	0.155	**0.003**	0.065	0.285	**0.019**	0.288	**0.003**	0.364	**< 0.0001**	1	**0.037**	**0.012**	**0.010**	**0.015**	0.188	**0.000**	0.581
OPEN-2	**< 0.0001**	**0.002**	**< 0.0001**	**0.014**	**< 0.0001**	0.613	0.431	0.166	0.054	0.972	0.452	0.512	**0.049**	**0.037**	0.167	**0.001**	**0.037**	1	0.250	0.222	0.382	0.071	**< 0.0001**	0.338
OPEN-4	0.102	0.099	0.068	0.191	**0.001**	0.616	0.464	**0.048**	0.795	0.339	0.169	0.410	**0.017**	0.751	0.050	**0.047**	**0.012**	0.250	1	0.791	0.463	**0.026**	0.180	0.148
RES-1	**0.003**	**0.031**	**0.008**	0.090	**< 0.0001**	0.737	0.524	**0.021**	0.499	0.378	0.181	0.440	**0.005**	0.444	**0.040**	**0.011**	**0.010**	0.222	0.791	1	0.520	**0.007**	**0.022**	0.164
RES-2	**< 0.0001**	**0.006**	**0.000**	**0.030**	**< 0.0001**	0.953	0.975	**0.022**	0.150	0.590	0.267	0.830	**0.005**	0.112	0.062	**0.002**	**0.015**	0.382	0.463	0.520	1	**0.004**	**< 0.0001**	0.225
RES-3	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.001**	**< 0.0001**	0.111	**0.007**	0.783	**0.001**	0.259	0.945	**0.009**	0.665	**0.000**	0.727	**< 0.0001**	0.188	0.071	**0.026**	**0.007**	**0.004**	1	**< 0.0001**	0.718
RES-4	0.685	0.403	0.367	0.628	**0.000**	**0.047**	**0.000**	**< 0.0001**	0.157	**0.007**	**0.009**	**< 0.0001**	**< 0.0001**	0.165	**0.000**	0.212	**0.000**	**< 0.0001**	0.180	**0.022**	**< 0.0001**	**< 0.0001**	1	**0.022**
RES-6	**0.015**	**0.013**	**0.010**	**0.024**	**0.001**	0.260	0.231	0.647	0.093	0.381	0.729	0.248	0.853	0.086	0.887	**0.007**	0.581	0.338	0.148	0.164	0.225	0.718	**0.022**	1

Significant differences:

	COM-CO	HWY-CO	IND-CO	OPEN-CO	RES-CO	COM-1	COM-2	COM-3	COM-4	HWY-3	IND-1	IND-2	IND-3	IND-4	IND-6	IND-9	OPEN-1	OPEN-2	OPEN-4	RES-1	RES-2	RES-3	RES-4	RES-6
COM-CO	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	No	**Yes**
HWY-CO	No	No	No	No	No	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	No	**Yes**
IND-CO	No	No	No	No	No	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	No	**Yes**
OPEN-CO	No	No	No	No	No	No	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No	**Yes**	**Yes**	No	No	**Yes**	**Yes**	No	**Yes**
RES-CO	**Yes**	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
COM-1	**Yes**	**Yes**	**Yes**	No	**Yes**	No	No	No	No	No	No	No	No	No	No	**Yes**	**Yes**	No	No	No	No	No	**Yes**	No
COM-2	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	No	**Yes**	No	No	No	No	**Yes**	No	No	**Yes**	**Yes**	No	No	No	No	**Yes**	**Yes**	No
COM-3	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No	**Yes**	No	No	**Yes**	No	**Yes**	No	**Yes**	No	No	**Yes**	**Yes**	**Yes**	No	**Yes**	No
COM-4	No	No	No	No	**Yes**	No	No	**Yes**	No	No	No	No	**Yes**	No	**Yes**	**Yes**	**Yes**	No	No	No	No	**Yes**	No	No
HWY-3	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	No	No	No	No	No	No	No	No	No	**Yes**	No	No	No	No	No	No	**Yes**	No
IND-1	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	No	No	No	No	No	No	No	No	No	**Yes**	No	No	No	No	No	No	**Yes**	No
IND-2	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	No	**Yes**	No	No	No	No	**Yes**	No	No	**Yes**	**Yes**	No	No	No	No	**Yes**	**Yes**	No
IND-3	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No	**Yes**	No	No	**Yes**	No	**Yes**	No	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No
IND-4	No	No	No	No	**Yes**	No	No	**Yes**	No	No	No	No	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	No	No	**Yes**	No	No
IND-6	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	No	No	**Yes**	No	No	No	No	**Yes**	No	**Yes**	No	No	No	**Yes**	No	No	**Yes**	No
IND-9	No	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**
OPEN-1	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No	No	**Yes**	No	**Yes**	No	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No
OPEN-2	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	No	No	No	No	No	No	**Yes**	**Yes**	No	**Yes**	**Yes**	No	No	No	No	No	**Yes**	No
OPEN-4	No	No	No	No	**Yes**	No	No	**Yes**	No	No	No	No	**Yes**	No	No	**Yes**	**Yes**	No	No	No	No	**Yes**	No	No
RES-1	**Yes**	**Yes**	**Yes**	No	**Yes**	No	No	**Yes**	No	No	No	No	**Yes**	No	**Yes**	**Yes**	**Yes**	No	No	No	No	**Yes**	**Yes**	No
RES-2	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	No	**Yes**	No	No	No	No	**Yes**	No	No	**Yes**	**Yes**	No	No	No	No	**Yes**	**Yes**	No
RES-3	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No	**Yes**	No	No	**Yes**	No	**Yes**	No	**Yes**	No	No	**Yes**	**Yes**	**Yes**	No	**Yes**	No
RES-4	No	No	No	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	**Yes**	No	**Yes**	No	**Yes**	**Yes**	No	**Yes**	**Yes**	**Yes**	No	**Yes**
RES-6	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	No	No	No	No	No	No	No	No	No	No	**Yes**	No	No	No	No	No	No	**Yes**	No